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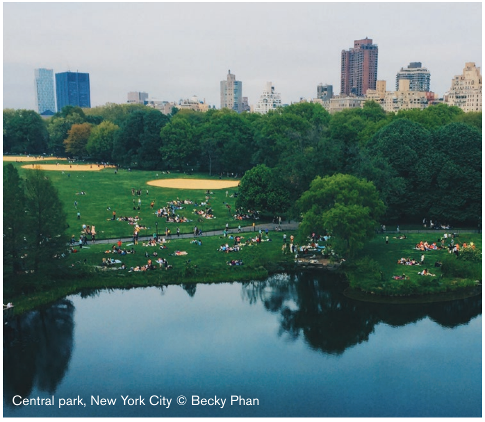
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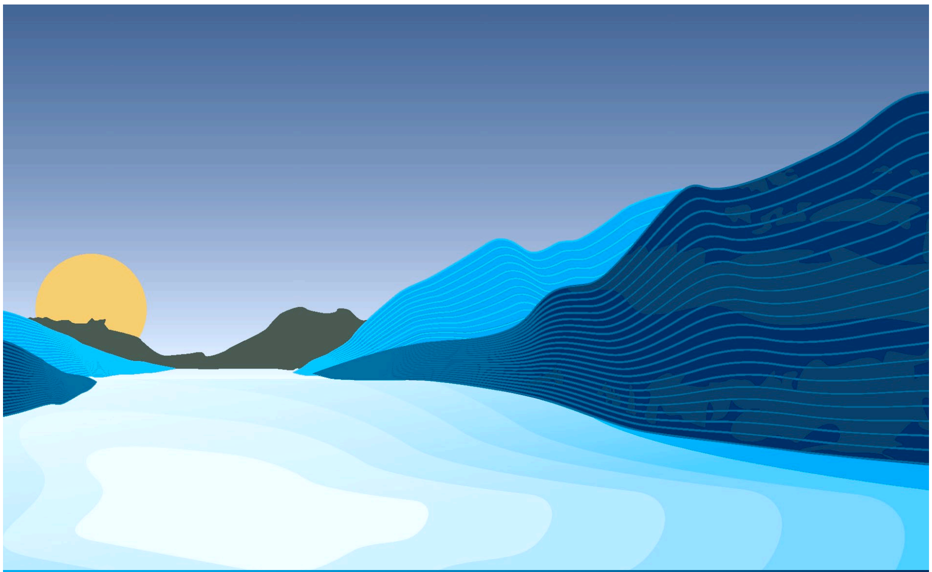

HANDBOOK ON BASIN-CONNECTED CITIES

WHY AND HOW URBAN STAKEHOLDERS CAN BE ACTIVE WATER STEWARDS IN THEIR BASINS

September 2022

HANDBOOK ON BASIN-CONNECTED CITIES

Why and how urban stakeholders can be active water stewards in their basins

This report was produced in collaboration between the International Water Association (IWA) and International Network of Basin Organizations (INBO).

The primary author for this report is Katharine Cross. François-Xavier Imbert provided inputs from INBO.

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EXECUTIVE SUMMARY

Many of the global challenges, such as urbanization, climate change, increased resource demand and competition between different water users, impact the cities where most of us live. These create water risks for cities, including flooding, water scarcity and pollution. Flooding can cause loss of life, homes and infrastructure, and negatively affect economic activities within cities. Floods also disrupt and limit access to resources that cities rely on, not only water, but also food and energy. Water scarcity and drought often lead to costly investment in capital intensive approaches to secure supply, and potentially use of unsafe alternative sources. Declining water quality can affect water supply and sustainability. According to a 2019 World Bank report when rivers become very heavily polluted, regions downstream see reductions in economic growth, losing between 0.8 and 2.0 percent of economic growth (Desbureaux et al., 2019).

These pressures and challenges highlight the need for more sustainable urban planning and public services. At the same time, linkages between urban and rural areas can be strengthened by building on their existing economic, social and environmental ties. By proactively taking part in basin management, the city secures water, food and energy resources, protects water quality and increases resilience to extreme events. It is an opportune time to encourage collaborative action to improve connectivity between urban and wider basin stakeholders to optimize costs, resilience and biodiversity. Implementing appropriate and sustainable solutions in line with governance in cities and their basins means working towards public policy coherence and efficient water management across administrative boundaries and sectors. This includes stakeholder engagement across catchments involving institutional actors, representatives of the civil sphere and citizens.

ABOUT THE BASIN-CONNECTED CITIES HANDBOOK

The Handbook on Basin-Connected Cities aims to support decision making in strengthening the city's connection and integration with its river basin. It expands on the **International Water Association (IWA) Action Agenda for Basin-Connected Cities**, which provides a framework to influence and activate utilities, cities and their industries to become water stewards working with basin stakeholders. The Action Agenda and the Handbook have three main parts:

- **Drivers for Action** outlining how basin-wide risks are impacting urban areas from economic, environmental and social perspectives;
- **Pathways for Action** demonstrating how cities and their basins can actively cooperate; and
- **Foundations for Action** which are the elements needed to create an enabling environment to implement.

The Action Agenda for Basin-Connected Cities builds on **IWA's Principles for Water-Wise Cities**, which aim to integrate water in planning across scales. The Principles support city leaders planning a future-proof access to safe water and sanitation for everyone in their cities, while delivering enhanced liveability for people and nature. Basin-Connected Cities is the third level of action in the Principles Framework (1. Regenerative Water Services; 2. Water Sensitive Urban Design; 3. Basin-Connected Cities; and 4. Building Water-Wise Communities).

The Handbook also draws on the International Network of Basin Organizations' (INBO) principles and objective to:

- Promote the exchange of experiences between organizations in charge of river basin management; and
- Raise the awareness of the general public on water resources management.

The Handbook is a comprehensive and detailed resource for practitioners, structured for quick reference. It provides more depth and understanding of the framework, including:

- Why and how urban stakeholders can lead the way in realizing their role as water stewards; and
- Real examples of the different pathways and activities towards improving dialogue between cities and basin organizations and stakeholders to achieve sustainable water management.

The purpose is to inform, influence and encourage urban stakeholders to take an active role in protecting and investing in water resources, together with basin and catchment organizations.

The target audience includes multiple stakeholders with different roles in taking action in improving their water sources and watersheds. This includes political or technical decision makers in water and sanitation services, local governments, industries, developers, inter-municipal structures, basin organizations and water management agencies. Engagement with civil society and environmental groups is also important to convey the key concepts and messages to a broader audience.

A key reference for the Handbook is a series of case studies or "basin stories'' that have been developed over several years by IWA and more recently through INBO. The basin stories document some of the best practices and approaches that demonstrate how stakeholders, especially those in urban areas (e.g., city government, water and wastewater utilities, industries) are taking part or contributing to sustainable management of water resources. Greater basin level collaboration from catchment to consumer is essential for sustainable water management in the face of growing demand on water resources and global change. The stories aim to inspire urban stakeholders to be aware and respond to what is happening in their watersheds. Excerpts from the basin stories are incorporated throughout the Handbook, and full versions will be available online through the IWA and INBO websites.

DRIVERS FOR ACTION

The Drivers for Action reflect the top risks impacting cities today including: floods due to extreme events, decline in water quality, and water scarcity and droughts (CDP, 2017).

Part A examines the Drivers for Action which reflect the top risks impacting cities today including:

- Floods due to extreme events;
- Decline in water quality; and
- Water scarcity and droughts.

Insights into how these basin-wide risks are impacting urban areas from economic, environmental and social perspectives are examined using existing literature and case studies.

Addressing the root problems of these risks can be supported by urban stakeholders including city governments, utilities and industry, to actively engage and contribute to watershed management by working with basin level organizations, their networks and other basin level stakeholders, such as agriculture, mining, environment, and indigenous and local communities.

Flooding

Civilizations have adapted to natural flooding by constructing cities around lands that are subjected to periodic floods to have access to water and fertile farmland (Queensland Chief Scientist, 2011). However, human activities including urbanization, upstream land uses (forest, agricultural practices) and construction of dams are influencing the magnitude and impact of floods. Furthermore, climate impacts on the hydrological cycle are changing the timing and intensity of rainfall, directly affecting the quantity and quality of water resources for different users (WHO, 2017). Projections show that more people will be at risk from floods by 2050 (from 1.2 billion today to 1.6 billion), especially in coastal cities (OECD, 2012).

Severe floods can result in physical damage and loss of life, as well as indirect damage such as waterborne diseases (Hammond et al., 2015). If drinking-water sources become contaminated and there is no available alternative treatment of water supplies, then flood victims are increasingly at risk of infection and disease. Flooding also disrupts economic and supply chain activities. Economic losses are mounting as exposure increases due to climate change impacts that are leading to more intense rainfall events and greater likelihood of severe floods. For example, severe flooding that hit Copenhagen in 2011 caused about EUR 700 million of damages; and hurricane Sandy in New York City generated USD 19 billion of economic losses in 2012 (OECD, 2012).

Severe degradation of watersheds can diminish their ability to be a natural buffer against water-related hazards, such as floods, leading to even greater damage to urban life and infrastructure. In addition, flooding in dense urban areas can cause further damage to the surrounding ecosystems due to overflow of sewage systems resulting in raw sewage being carried into waterways.

Declining water quality

Just as important as access to water is for water to be clean and safe for drinking. Urban water quality is impacted by both localized pollution and activities in the wider basin. Although many countries have increasingly strict management of point source pollution, dumping untreated wastewater into rivers and oceans, especially in developing countries, is still a common practice. This has resulted in about 25% of urban residents in developing countries being unable to obtain adequate water (McGrane, 2016). Poor water quality affects human health leading to a decline in livelihood and social well-being. Furthermore, reduced access to safe water can impact hygiene making it challenging to control water- and vectorborne diseases.

Declining water quality due to watershed degradation, as well as from point and non-point sources, has a direct impact on aquatic ecosystems and drinking water, and the economy in downstream urban areas. Economic impacts include the direct increase of costs for water treatment for different users and the loss of production revenue due to disruption in supply to industry. It is estimated that the total cost of watershed degradation to water utilities is about USD 5.4 billion annually (McDonald et al., 2016). Poor water quality can also lead to a decline in property values, loss of recreational revenue, effects on human health which in turn affect economic productivity, and loss of livelihoods. Water quality can also influence food supplies to urban areas. Contaminated water can impact soil productivity and reduce the production and quality of crops leading to negative implications for the food sector.

Water pollution poses serious threats to the environment in cities and their wider basins, leading to the loss of key ecosystems, and impact fisheries and agricultural productivity. Discharge of pollution into water bodies can influence dissolved oxygen availability and temperature of the water leading to changes in nutrient and contaminant concentrations, which result in aquatic species' deaths or eutrophication. Furthermore, algal blooms from increased nutrient loads can produce toxins which contaminate water resources.

Water scarcity and droughts

Water scarcity is a result of human activities that have led to low availability compared to demand. On the other hand, drought refers to the state of the system and is a natural hazard, caused by large-scale climatic variability. The severity and frequency of droughts can lead to water scarcity situations, while overexploitation of available water resources can exacerbate the consequences of droughts (Wanders, 2017).

Currently, 2.3 billion people live in water-stressed countries, of which 733 million live in high and critically water-stressed countries (UN-Water, 2021). Cities face unprecedented hydrological changes due to global climate change and land use change, and when combined with increasing water demand can exacerbate water scarcity and drought. There are currently 150 million people in urban areas that do not have sufficient water, meaning less than 100 litres per day which is needed to maintain the basic living standards of residents (McDonald et al., 2011). The water supply in cities for drinking, sanitation and other household purposes can be severely impacted as demand for water in the food and energy sectors increases.

Water scarcity can lead to inequitable allocation and distribution of available water among different sectors. Reduced water availability in cities is more likely to affect low-income groups and can increase social stratification in urban settings. It can lead to increased dependence on potentially less safe alternative water sources that might otherwise be avoided. On a city-wide scale, water scarcity can increase the rate of over-abstraction of groundwater leading to depletion, land subsidence and deteriorating water quality, making it unsuitable for human consumption. Consequently, water scarcity can mean that there needs to be costly investments such as basin transfers to secure supply.

Economic activity is water dependent and shrinking availability of water is endangers urban as well as the global economy. In fact, droughts are the costliest natural hazards on a year-to-year basis and are significant and widespread, affecting many economic sectors and people at any one time. There are direct impacts such as decreased agricultural outputs, disruption in industrial operations, and indirect such as rising costs of food in cites. Drought in the USA has an average cost of USD 9.7 billion per event, and the most fatal when accompanied by heat waves (NOAA, 2018).

PATHWAYS FOR ACTION

The Pathways for Action describe various approaches that inspire stakeholders to take action and deal with water challenges in the wider catchment and play an essential role in ensuring water quality and quantity.

Part B outlines the Pathways for Action, which are categorized into assessment, planning and implementation. The approaches listed provide a wide range of options but can further expanded with new ideas and experiences.

Assessment

Assessment looks into approaches for evaluating a problem and the measures that can be taken. This includes:

- Identifying values and principles which provide the roadmaps to achieve common objectives;
- Investing in data and information systems as it is only feasible to manage what can be measured (and analysed) ; and
- Integrating local and traditional water knowledge to complement what is being scientifically measured and analysed.

An agreed set of values can provide motivation and guidance towards action on achieving basin-connected cities. These values can be defined and then systemized into a written set of principles, that can provide the roadmap on how to deliver on mutual objectives for using water within the city and the whole basin. Developing common principles can bring together local governments, urban professionals and individuals to actively participate in solving and finding solutions to water problems in their cities. Developing a strategy or plan can also provide an opportunity to agree on a set of values and principles for the future.

Decision makers at all levels from city to basin to transboundary need to be able to access and use reliable, up-to-date and relevant information for regulatory purposes, planning, risk management and public awareness. How an organization uses and manages its data is just as important as the process of gathering the information. Consequently, holistic information systems that integrate data and information from across a basin provide a sound basis for cooperation as well as decision making.

In addition to scientific data and information, water management needs to traditional and local knowledge. Citizen science can be used to improve management practices by providing more frequent monitoring and data collection. This approach can improve participants' knowledge and awareness which can increase confidence in both the quality of water and the water company. Water management can also benefit from the knowledge around traditional and indigenous water conservation systems.

Planning

Improving planning focuses on approaches where cities and their basins have an opportunity to cooperate to ensure sustainable water management. This includes:

- Having a risk-based approach to planning from catchment to consumer;
- Water allocation mechanisms which balance downstream and upstream needs but also explore alternative sources;
- Alignment of urban development with basin resources and management; and
- The active involvement of diverse stakeholders in developing plans for water resource management.

Prevention and preparedness actions are effective ways to build resilience when managing water resources for cities and their basins. This can be achieved through risk-based planning, which promotes a proactive approach to identifying, controlling and monitoring critical risks. Risk-based planning approaches, such as water safety planning as well as flood and drought planning, involve stakeholders across the water value chain in the management of drinking water quality and flows, actively linking urban stakeholders (e.g., water utilities, industries) with the catchment they rely on for water sources.

Increased pressure and risks due to urbanization, competing demands and climate change can create tensions over water allocation regimes, highlighting the need for long-term strategies of sharing water between urban and rural areas. Water allocation mechanisms to share water resources between different users in rural and urban areas should be based on Integrated Water Resources Management (IWRM) principles, which recognize the interconnection between upstream and downstream regions, urban and rural areas, and how changes in water quality and quantity in one area will affect the availability of resources in another.

Aligning urban development with basin management is a step towards sustainable economic, social and environmental relations. The urban–rural interface can contribute a great deal to protecting cities against water risks such as floods now and in the future, through cooperation between upstream and downstream stakeholders.

Stakeholder participation in planning and management can create a dialogue between those that impact and are impacted by the quality and availability of water supplies to cities and other users. Stakeholder collaboration is not only among scientists and policy makers but also the public. Such processes improve decisions, as communities have more in-depth knowledge of the local conditions, increase effectiveness, increase public awareness and provide platforms for the public to express their concerns.

Implementation

Tools to implement connectivity between cities and their basins include:

- The use of financing mechanisms such as where downstream users compensate upstream stakeholders for activities that sustain water quality and quantity;
- The integration of nature-based solutions (NbS) within the catchment and urban areas to improve water quality and reduce the impact of extreme events;

- Creating partnerships that build trust and cooperation to effectively share and manage water; and
- The use of digital technologies to improve monitoring and management.

Payments for watershed services (PWS) are schemes that use funds from water users (including governments) as an incentive for landholders to improve their land management practices and connect basins and cities to protect water resources. They have been regarded as a promising approach to coordinating the interests of upstream and downstream ecosystem services stakeholders, as they create structures to implement activities to protect the catchment, monitor investments upstream and measure their impacts.

PWS and equivalent financing schemes invest in upstream NbS to help reduce the costs of operation and maintenance of urban water utilities, improve service quality and delay the need for expensive capital investment to improve or expand services. Integration of NbS within cities and their basins can reduce nutrient leaching and erosion/sediment runoff and improve the health of watersheds to provide better water quality and flows.

The management of NbS for improved water management can assist in formalizing and activating partnerships across a catchment, including national and local government, local stakeholders and community-based organizations, the private sector and donor agencies. Building such partnerships from catchment to tap across sectors and scales can catalyse action in sustaining and improving water quality and flows to and from cities. Partnerships also provide a foundation for building trust across organizations in urban areas and their wider basins and be used to solve local water challenges, pool expertise and resources, and leverage financial resources.

While partnerships are a demonstration of collaboration between cities and their basins, the digital water economy, which includes the technologies and processes to support their implementation, is a key tool for these partnerships to manage urban water (Sarni et al, 2019). This includes using digital technologies to support availability and access of information (e.g., real time data and forecasting) across the water sector from upstream water management to urban consumers.

FOUNDATIONS FOR ACTION

The Foundations for Action are derived from the building blocks of the Principles for Water Wise Cities and include vision, governance, knowledge and capacity, planning tools, and implementation tools.

Part C is structured around the Foundations for Action which are what is needed to enable delivery of sustainable urban water management. Along with case studies, this section includes reflections from various thought leaders on the essential components for sustainable water management. These perspectives are showcased in boxes to provide views and examples of how the foundations are being put in place in different geographies and scales.

Vision

A vision motivates stakeholders to define a common set of objectives for the greater benefit of both the city and the basin and is the stepping stone to ensure implementation of policies and strategies. A vision needs to be agreed and owned by multiple stakeholders. Collaborative processes can support this, by navigating the understanding of being more than a water user, but a water steward that contributes to defining long-term ambitions for the whole basin and its beneficiaries. For a vision to be established it needs to be translated into local policies and adequate governance. It also needs the right tools, such as masterplans and financing mechanisms, and improved knowledge and capacity to guide action.

Governance

There can be spatial-scale misalignment between implementation of urban water governance with that of the wider hydrological and natural water system which a city depends on for water, food and energy, as well as other resources. Improving water governance can be undertaken through different approaches that places a city in the context of their water catchment to better understand and address the upstream and downstream influences from, for example, water, sediment and pollutant flows.

Good governance is key to coordinate policy and implementation between local, regional and national governments. This includes agreement on the roles and responsibilities of urban stakeholders in taking action to improve their water sources and watersheds (water and wastewater utilities, city governments, industry, policy makers and regulators). These urban stakeholders work with basin organizations, water resources agencies, civil society and environmental groups to ensure equitable and effective water management. There are also stakeholders that use water in basins which cities rely on for their water security such as agriculture, energy, natural resource extraction and other business interests. All parties need to actively work together to ensure sustainable and equitable water allocation across sectors from catchment to consumer.

Knowledge and Capacity

Capacity building is crucial for better water management, including training, data management, expertise, and support to water stakeholders and information systems. Knowledge exchange and learning from other cities and basins about solutions to common challenges can introduce new ideas and approaches that can be tailored to the local context. For example, "peer-to-peer learning" which encourages continuous knowledge exchange between organizations, cities, basins, etc can be a way to lessen the knowledge gap and help develop relationships that can provide continuous support.

Planning tools

Planning tools, such as decision support systems, integrated water resource management plans, as well as risk-based planning can support the alignment of urban development with basin management. Planning can also be framed around a key issue, such as floods or droughts. These can be used to raise awareness of flood (or drought) risk and promote protective measures among the population, improve land planning especially in urban areas, improve predictive capacity, strengthen coordination among public administrations, reduce vulnerability, reduce flood hazards and improve the environmental condition of water bodies. There is a need for coherent planning documents and strategies between the city and basin levels.

Implementation Tools (Policy, Regulation and Financing)

Policies can establish clear guidelines, with appropriate thresholds and limits based on the best available science. Policies and the resultant laws provide the foundation for a course of action, and regulations provide the directions for implementation. Then regulations create incentives that drive improved water management by urban stakeholders. This could be in the form of financing mechanisms which, for example, can help source funds to resource upstream catchment restoration activities to improve drinking water quality. Implementation of such funding mechanisms needs enablers and leaders to create awareness, a business plan and an implementation structure.

WAY FORWARD

SUSTAINABLE DEVELOPMENT GOALS

The Handbook provides a practical reference on how to respond to the call to action for urban stakeholders to play a greater role in engaging in their watersheds and drainage basins. It can be used as a source for policy recommendations, and as a reference for best practice for more active awareness and involvement from across urban areas to ensure water quality, flows and preparedness for extreme events. It also provides approaches for taking action which can contribute to the 2030 Sustainable Development Goals (SDGs).

The basin stories interwoven throughout the narrative throughout of this handbook can provide initial ideas on actions which can be shaped to local context. INBO and IWA will continue to collect and highlight basin stories and encourage organizations to document and showcase their experiences. The aim is for this Handbook to evolve and integrate these new stories along with approaches and best practices.

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from the International Water Association

Cities today face increasing pressures on their water resources from climate change, increasing urbanisation, land use change, and economic shifts. Urban areas are already experiencing difficulties in efficiently managing scarcer and less reliable water resources, along with the impacts of extreme events such as flooding and droughts. As urban water demand increases in the coming decades, it is essential to have a holistic approach to urban water management which connects cities with their surrounding basins.

It is recognised that water is a "system within systems" that is inextricably linked across sectors including energy, agriculture, transport, public health, and the economy, among others. The actions in one part of the water system will impact another. Shaping our water future today means actively making intersections with these other systems within and beyond city boundaries. Cities are influential nodes with the water system and their management approaches to water can reverberate across a basin, impacting different sectors. For example, ineffective treatment of wastewater can impact downstream water quality and affect agricultural production. On the other hand, as water demand increases, there may be less water available for both agricultural and energy production in upstream catchments, meaning trade-offs need to be negotiated across sectors including with urban stakeholders.

The International Water Association (IWA) promotes a holistic systems approach to assessing the sustainability of water management within and beyond cities. These are outlined in the IWA Principles for Water Wise Cities which provide a framework for collaborative action across interconnected scales: water services, urban design, basin management, and people working together. This is further developed in the IWA Action Agenda for Basin-Connected Cities through drivers, pathways and foundations for action that urban stakeholders can consider to improve the resilience of their surrounding watersheds.

The Action Agenda provides a basis to encourage city-basin dialogue and has been expanded with the development of this Handbook on Basin-Connected Cities in collaboration with the International Network of Basin Organisations (INBO). Together IWA and INBO are well placed to facilitate this connection and encourage their members and partners to take on the perspectives, lessons learned, and best practices outlined in the Handbook.

Kalanithy Vairavamoorthy
Executive Director of the International Water Association

FOREWORD

from the International Network of Basin Organizations

From a watershed perspective, urban areas significantly impact hydrology, because they massively concentrate populations and consequently concentrate major problems in terms of water resources. They are a major source of pollution, have significant needs in terms of water supply security, and are highly exposed to risks related to floods. From the point of view of these urban areas, these water-related issues are perceived with increasing intensity, in a context of continuous growth of urban populations.

Despite the increasing pressures, the necessary dialogue between cities and basins for the management of water resources is ill-equipped in terms of governance. In particular, the integration of economic costs between cities and their basins is insufficient, for example in terms of agricultural and food security, risk allocation, management of industrial pollution, payment for environmental services, or calculation of drinking water and sanitation tariffs.

A similar observation can be made concerning the insufficient integration of planning and management scales, in the case of urban planning, design of water and sanitation services, but also in the matter of land use and land planning.

The collaboration between the International Water Association (IWA) and the International Network of Basin Organizations (INBO) highlights the city-basin approach connecting urban areas with their watersheds. Urban areas and their rural hinterlands must improve coordination and connectivity at the technical, economic and political levels. This is why it is crucial to work on collecting experiences, producing recommendations and documenting the debate. The objective is to facilitate the dialogue between cities and organisations that deal with managing water resource across basins, drawing on best practices between cities (e.g., municipal water management services) and basin stakeholders, surveyed across the world.

Among INBO's overall objectives includes developing relationships between organizations interested in comprehensive water resource management at the river basin level and enable exchanges of experiences and expertise. The Handbook on Basin-Connected Cities is a tool that can support this exchange. It is an essential addition to the INBO Handbook series providing best practices, case studies and a broad spectrum of perspectives that can inspire and influence basin organisations to integrate and encourage active involvement of urban stakeholders in improving water resource management across scales.

Eric Tardieu
Executive Director of OiEau; General Secretary of the International Network of Basin Organizations

LIST OF ABBREVIATIONS AND ACRONYMS

AHIS	Automatic Hydrological Information System
ANA	National Water and Sanitation Agency
AWS	Alliance for Water Stewardship
BCAS	Bangladesh Centre of Advanced Studies
CABA	Catchment Based Approach
CHJ	Confederación Hidrográfica del Júcar // Júcar River Basin Authority
CFF	Cities Finance Facility
COAG	Council of Australian Governments
CRCWSC	Cooperative Research Centre for Water Sensitive Cities
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Combined sewer overflows
CWRA	City Water Resilience Approach
CWRF	City Water Resilience Framework
DBB	Densu Basin Board
DEP	Derwent Estuary Program
DKH	Delta Knowledge Hub
DPR	Direct Potable Reuse
EWSETA	Energy & Water Sector Education Training Authority
FONAG	Fondo Ambiental para la Protección de las Cuencas y Agua // Environmental fund for the protection of wáter and watersheds
GDP	Gross Domestic Product
GM&B	Greater Miami & the Beaches
GWCL	Ghana Water Company Limited
HU	Hydrologic units
INBO	International Network of Basin Organizations
INRAE	Institut national de la recherche agronomique // National institute for agronomy research
IOT	Internet of things
IPCC	Intergovernmental Panel on Climate Change
IUWM	Integrated Urban Water Management
IWA	International Water Association
IWM	Integrated Water Management
IWRM	Integrated Water Resources Management
KENGEN	Kenya Electricity Generating Company
LABOCEA	Laboratoire d'analyse en Bretagne // Analysis laboratory of Breton
LDAI	Learning Delta Asia Initiative
MAWaC	Megacities Alliance for Water and Climate
MRSE	Mechanisms of Rewards for Ecosystem Services
MWRRA	Maharashtra Water Resources Regulatory Authority
MVCS	Ministerio de Vivienda, Construcción y Saneamiento // Ministry of Housing, Construction and Sanitation
NbS	Nature-based solutions
NCWSC	Nairobi City Water & Sewerage Company
NGO	Non-governmental organization

NRM	Natural Resource Management
NOAA	National Oceanic and Atmospheric Administration
NWRM	Natural Water Retention Measures
O&M	Operations and maintenance
OBEPINE	Observatoire Épidémiologique des Eaux Usées // Epidemiological Observatory of Wastewater
PAPI	Programme d'Action de Prévention des Inondations // Flood Action Prevention Programme
PDAIRE	Plan directeur d'aménagement intégré des ressources en eau du bassin hydraulique du Sebou// integrated water resources development master plan for the Sebou
PROSE	Environmental biOtechnology PRoceSses
PTGE	Projets de territoire pour la gestion de l'eau // Territorial Plan for water management
PWS	Payments for watershed services
RMA	Risk management authorities
S2S	Source-to-Sea
SAGE	Schéma d'aménagement et de gestion des eaux // Local water development and management plan
SCADA	Supervisory control and data acquisition
SDAGE	Schéma directeur d'aménagement et de gestion des eaux // Water development and management master plan
SDGS	Sustainable Development Goals
SFPUC	San Francisco Public Utilities Commission
SIAAP	Syndicat interdépartemental pour l'assainissement de l'agglomération Parisienne // the greater Paris Sanitation Authority
SIWI	Stockholm International Water Institute
SMABB	Syndicat Mixte d'Aménagement du Bassin de la Bourbre
SPV	Special purpose vehicles
SUDS	Sustainable drainage systems
SUNASS	Superintendencia Nacional de Servicios de Saneamiento
TNC	The Nature Conservancy
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNESCO	The United Nations Educational, Scientific and Cultural Organization
WBCSD	World Business Council for Sustainable Development
WEIP	Watershed and Environmental Improvement Program
WFD	Water Framework Directive
WIS	Water information systems
WRC	Water reuse certificates
WSP	Water safety planning
WSUD	Water sensitive urban design
WWTP	Wastewater treatment plant

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1 - INTRODUCTION

1.1 – CONTEXT

Water is often viewed as a resource that users can appropriate, own and exploit according to their needs. However, over the past few decades, the value of water as a "resource" has been reinforced by the emergence of the principles of "sustainable development" which recognizes the multiple users of water. Concepts such as Integrated Water Resources Management (IWRM)[1] have been implemented, crossing institutional and operational frameworks across basin areas. In addition, the model of governance of hydrologic units is becoming more widespread, providing opportunities to engage all stakeholders across a catchment including urban areas and involve them in implementation of actions to sustainably manage the resource.

Involvement of urban stakeholders in basin management is critical as urbanization is expected to increase over the next decade from 56.2% today to 60.2% in 2030 (UN Habitat, 2020). With growing pressure on natural resources, cities and towns face challenges around water quality, quantity and resilience to extreme events. A disruption in water supply can have significant socio-economic, environmental and health impacts. Protecting basins and conserving basins that are already degraded are priorities for urban stakeholders who play a critical role in preserving water resources. Such challenges are expected to grow with continuous population growth, demographic shifts and climate change (IWA, 2018a).

With growing cities and increasing pressures on available water resources, it is an opportune time to encourage collaborative action to improve connectivity between urban and wider basin stakeholders to optimize costs, resilience and biodiversity. Implementing appropriate and sustainable solutions in line with governance in cities and their basins means working towards public policy coherence and efficient water management across administrative boundaries and sectors. This includes stakeholder engagement at a local level allowing involvement of institutional actors, representatives of the civil sphere and citizens.

IWA and INBO developed this Handbook to support decision making in strengthening the city's connection and integration with its river basin. Through reviewing literature, practical cases, testimonies and recommendations, this guide illustrates how "urban actors" can and should play an active role in protecting the resource.

1.2 – ABOUT THE HANDBOOK

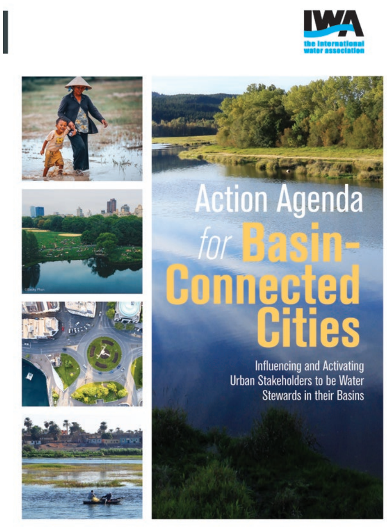

Figure 1. Cover of the Action Agenda for Basin-Connected Cities

A **handbook** is usually defined as a concise reference book covering a particular subject. It is a comprehensive and detailed resource on a particular topic for practitioners, structured for quick reference and often used as a supplement to a textbook.

The concept of a handbook comes from INBO which has developed a handbook series including publications on topics ranging from water information systems to participation of stakeholders and civil society to management and restoration of aquatic systems. The handbooks focusing on these various issues across basins include problem identification, analysis, recommendations and good practices, as well as illustrative case studies from across the INBO network.

The focus of this Handbook is on how cities and their urban stakeholders can take an active role in protecting and investing in water resources, together with basin and catchment organizations. The purpose is to inform, influence and encourage urban stakeholders (across administrative boundaries) to engage in collaborative action, allowing for inclusive participation, public policy coherence and efficient water management across administrative boundaries, to attain sustainable water management.

The Handbook expands on the **IWA Action Agenda for Basin-Connected Cities** (Figure 1) with case studies and best practices, recommendations, as well as insights from water experts. The Action Agenda for Basin-Connected Cities builds on **IWA's Principles for Water-Wise Cities**, which aim to integrate water in planning across scales (see Figure 2). The Principles support city leaders planning a future-proof access to safe water and sanitation for everyone in their cities, while delivering enhanced liveability for people and nature (IWA, 2018b).

1 IWRM promotes coordinated development and management of water, land and related resources in river basins to maximize the economic benefits and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2018a).

The Principles include four levels of action:

1. Regenerative Water Services
2. Water Sensitive Urban Design
3. Basin-Connected Cities
4. Building Water-Wise Communities

Figure 2. The "Principles for Water-Wise Cities" Framework: four Levels of Action and five Building Blocks for urban stakeholders to deliver "Sustainable Urban Water" in their cities

The Action Agenda for Basin-Connected Cities acknowledges that the city is intrinsically connected to – and dependent on its surrounding basin(s) (Figure 3). Proactive engagement in managing water resources in the basin aims to secure water, food and energy resources, reduce flood and drought risk and enhance activities contributing to the economic and environmental health of the basin (IWA, 2018a).

This Handbook provides more depth and understanding of this framework, including: 1) why and how urban stakeholders can lead the way in realizing their role as water stewards and 2) the different pathways and activities towards improving dialogue between cities and basin organizations and stakeholders to achieve sustainable water management. The Handbook is designed as a reference, where readers can delve into a specific section to learn more about an area of interest, without having to read the previous section. Consequently, there is a degree of repetition as the same set of basin stories or case studies are referenced throughout the publication. The assumption is that the reader will not have necessarily read the previous section.

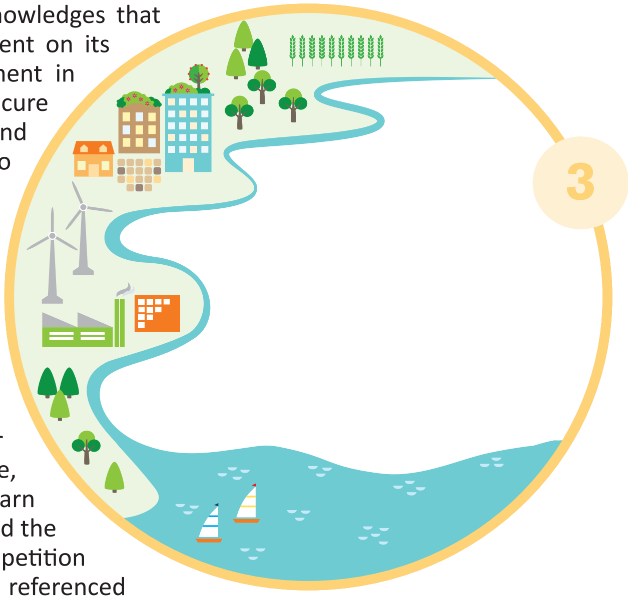

Figure 3. Third level of action – Basin-Connected Cities – from the IWA Principles for Water Wise Cities

- **Part A examines the Drivers for Action** – why urban actors are driven to reconnect to their catchment areas? What are the links, dynamics and trends? This section is based on existing literature as well as case studies, and structured around flooding due to extreme events, declining water quality and water scarcity.
- **Part B follows the Pathways for Action** integrating best practices and case studies. This includes how to assess the problem and evaluate measures being taken (e.g., defining common principles, through data management, water information systems, research and expertise, integration of traditional and local knowledge); how to improve planning (e.g., risk-based approach, allocation mechanisms for water sharing, urban development and basin management, public participation); and how and what to implement concrete actions (e.g., economic and financial mechanisms, integration of nature-based solutions (NbS), building partnerships, use of digital technologies).
- **Part C is structured around the Foundations for Action** which includes developing a vision, improving governance, building capacity, planning and implementation. This section includes testimonials or reflections from various thought leaders on the essential components for sustainable water management. These perspectives from experts are showcased in boxes to provide views and examples of how the foundations are being put in place in different geographies and scales.

1.3 – BASIN STORIES

A key reference for the Handbook is a series of case studies or "basin stories'' that have been developed over several years by IWA and more recently through INBO. The basin stories document some of the best practices and approaches that demonstrate how stakeholders, especially those in urban areas (e.g., city government, water and wastewater utilities, industries) are taking part or contributing to sustainable management of water resources. Greater basin level collaboration from catchment to consumer is essential for sustainable water management in the face of growing demand on water resources and global change. The stories aim to inspire urban stakeholders to be aware and respond to what is happening in their watershed. A list of basin stories referred to in the Handbook appears in Annex 1.

Excerpts from the basin stories are incorporated throughout the Handbook, and full versions are available online through IWA and INBO websites. The basin stories cover a variety of geographies and scales ranging from small population areas to megacities which refer to metropolitan areas with a total population of more than 10 million people.

Megacities highlight how the risks associated with water are amplified. For instance, there were 22 large cities between 5 and 10 million inhabitants in 1995 and 14 megacities with more than 10 million people around the world. By 2015, the numbers had doubled to 44 large cities and 29 megacities, most located in the developing world (UN, 2019). There are 31 megacities today. Still according to the UN, the general migration from rural to urban areas, combined with overall population growth, will lead to the planet having 43 megacities by 2030, each home to more than 10 million people. Despite the challenges, these cities are also major innovation centres and economic leverages that can offer the world solutions to the challenges of today and tomorrow.

1.4 – TARGET AUDIENCE

The target audience of this Handbook includes multiple stakeholders with different roles in taking action in improving their water sources and watersheds. This includes political or technical decision makers in water and sanitation services, local governments, industries, developers, inter-municipal structures, basin organizations and water management agencies. Engagement with civil society and environmental groups is also important to convey the key concepts and messages to a broader audience.

The Handbook can be used as a source for policy recommendations, and as a reference for best practice for more active awareness and involvement from across urban areas to ensure water quality, flows and preparedness for extreme events. The cases presented provide a starting point to show how the pathways for action and foundations for action (as defined in the Action Agenda) are being implemented in practice.

1.5 – KEY CONCEPTS AND DEFINITIONS

1.5.1 Basin

The Global Water Partnership defines a basin thus: “A river or lake basin is the area bounded by the watersheds of a system of streams and rivers that flow towards the same outlet. In the case of rivers this is generally the sea, but may be an inland water body, such as a lake or swamp” (GWP, 2021). All uses, including the needs of ecosystems and wildlife, must be “compatible and interdependent”. The basin (and its sub watersheds) is the most relevant scale for sustainable natural resources management, as it is the geographical area within which all water flows into a given aquatic ecosystem: a river, a lake, aquifer or the ocean (INBO, 2021).

The European Water Framework Directive (WFD) defines the river basin as: “the area of land from which all surface run-off flows through a series of streams, rivers and possibly lakes, to a particular point into the sea at a single river mouth, estuary or delta” (European Commission, 2000). The definitions from Global Water Partnership (GWP) and the WFD indicates that river basin management goes beyond political, social or cultural boundaries (in Europe there are 20 transboundary basins). Watersheds and river basins, referred to as hydrologic units (HUs) are independent of territorial boundaries, and therefore compel stakeholders representing all the nations or other administrative units within a HU to adopt a holistic approach to resource management. Although basins can span large areas across borders, much of the day to day action and implementation takes place at the sub-basin level and informs overall management of the larger HU.

Several countries have set up river basin organizations to manage water within integrated basin governance systems. River basin organizations are official organizations set up by political authorities or in response to stakeholders’ demands or legal requirements. As administrative and hydrologic perimeters do not always match, a diversity of situations can be observed in terms of how many river basin organizations operate within a city’s perimeter. There often needs to be a “functional” approach which takes into account water demand (urban areas where most people live) and water supply (the surrounding environments where point sources are located). According to a 2016 OECD survey across 48 cities, river basin organizations carry out different water-related tasks such as monitoring (85%) and data collection (81%), as well as coordination, planning and stakeholder engagement (above 60%) (OECD, 2016).

1.5.2 Dialogues between cities and basins

Over 1.4 billion people currently live in river basins where the use of water exceeds minimum recharge levels, leading to the desiccation of rivers and depletion of groundwater (UNDP, 2006). Urban areas concentrate water management problems: pollution, water consumption, floods, scarcity of the resource, etc. This creates a challenge for cities to become sustainable and requires collective intelligence and action to be put at the service of water security and the environment. Urban growth is therefore both an opportunity for economic development and a threat to quality of life.

Urban stakeholders across a basin play a critical role in preserving the freshwater resources on which they depend. A disruption in the supply of freshwater resources to cities can have significant socio-economic, environmental and health consequences. The challenges are expected to grow in the future, as global projections show a continued increase in urban populations thus improving water security and protecting water resources on which cities rely must be an urgent priority.

It is crucial for urban stakeholders to lead the way in realizing their role as water stewards and the different pathways and activities towards achieving IWRM. It is therefore essential that dialogue between basin management institutions and cities is initiated and strengthened. Basin level dialogues can be participatory involving several different categories of local stakeholder groups including associations, non-governmental organizations (NGOs), municipal authorities, trade unions, schoolteachers, representatives state/provincial representatives, academics, etc (Secretariat of the 3rd World Water Forum, 2003).

Good governance is key to coordinate policy and implementation between local, regional and national governments. This includes agreement on the roles and responsibilities of urban stakeholders in taking action to improve their water sources and watersheds (water and wastewater utilities, city governments, industry, policy makers and regulators). These urban stakeholders work with basin organizations, water resources agencies, civil society and environmental groups to ensure equitable and effective water management. There are also stakeholders that use water in basins which cities rely on for their water security such as agriculture, energy, natural resource extraction and other business interests. All parties need to actively work together to ensure sustainable and equitable water allocation across sectors from catchment to consumer.

Better connecting urban stakeholders and their city to their basin requires:

- Defining community aspirations and trajectories to support water and sanitation improvements that move towards universal coverage in cities in an equitable manner.
- Interrogating the plans and planning assumptions of water organizations to improve water and sanitation provision, based on the water resources available.
- Building a consensus across a range of public authorities and stakeholders that can help identify innovative, effective and efficient ways forward to better manage too much, too little and too polluted water now and in the future.

PART A – DRIVERS FOR ACTION

Three of the top risks impacting cities today include: 1) floods due to extreme events, 2) decline in water quality and 3) water scarcity and droughts (CDP, 2017). The recent IPCC (2021) report specifically mentions how urbanization intensifies heatwaves, as well as how it can increase mean and heavy precipitation over and/or downwind of cities, resulting in runoff intensity. It also shows how coastal cities are dealing with a combination of sea level rise and storm surge, and extreme rainfall/river flow events leading to higher probability of flooding.

Solving the root problems of these risks can be supported by urban stakeholders including city governments, utilities and industry, to actively engage and contribute to watershed management by working with basin level organizations, their networks and other basin stakeholders, such as agriculture, mining, environment, and indigenous and local communities (IWA, 2018a). This section provides insights into how these basin-wide risks are impacting urban areas from economic, environmental and social perspectives.

Flooding in China © Jean Beller

Toxic green algae in Copco Reservoir, northern California © Aurora Photos Alamy

2007-2008 Australian drought. Rawnsley park station , South Australia © Peripitus

2 - FLOODING DUE TO EXTREME EVENTS

Box 1. Key points on how flooding due to extreme events impacts cities

- The phenomenon of flooding is a natural event; however, building on floodplains and channelization of rivers can lead to loss of life, livelihoods and disrupt economic and supply chain activities during these events.
- There are different types of flooding which all can have adverse impacts on cities from flash floods to large riverine floods from upstream, to coastal floods due to storm surges.
- Economic losses are mounting as exposure increases due to climate change impacts that are leading to more intense rainfall events and greater likelihood of severe floods.
- Severe degradation of watersheds can diminish their ability to be a natural buffer against water-related hazards, such as floods, leading to even greater damage to urban life and infrastructure. Human activities, including urbanization, upstream land uses (forest, agricultural practices) and construction of dams, are influencing the magnitude and impact of floods.
- Physically, floods can endanger human life by drowning or causing injuries, biologically by spreading of waterborne and vectorborne disease and chemically by exposure to hazardous chemicals like heavy metals.
- If drinking-water sources become contaminated and there is no available alternative treatment of water supplies, then flood victims are increasingly at risk of infection and disease.

Extreme events arising from climatic and environmental issues include floods, heavy rainfall, sea level rise as well as droughts and increased temperature, all pose a real challenge for watershed management (IWA, 2018a). This section focuses on flooding and its economic, environmental and social impacts.

Civilizations have adapted to natural flooding by constructing cities around lands that are subjected to periodic floods to have access to water and fertile farmland (Queensland Chief Scientist, 2011). However, human activities including urbanization and construction of dams, as well as the channelization of rivers are influencing the magnitude and impact of floods. Furthermore, climate impacts on the hydrological cycle are changing the timing and intensity of rainfall, directly affecting the quantity and quality of water resources for different users (WHO, 2017). Severe floods can result in physical damage and loss of life, as well as indirect damage such as waterborne diseases (Hammond et al., 2015). Projections show that more people will be at risk from floods by 2050 (from 1.2 billion today to 1.6 billion), especially in coastal cities (OECD, 2012).

Many types of floods are described in the literature. In this handbook, three different types are considered:

- Fluvial or river flooding;
- Pluvial flooding which includes surface water and flash floods; and
- Coastal floods including storm surges and tidal floods.

A fluvial, or river flood, occurs when water levels rise in a river, lake or stream and overflow. This is due to persistent rainfall and storms sometimes over an extended period, and in some cases combined with excessive springtime snowmelt runoff (Zurich, 2020; USGS, 2021; NOAA, 2021a; Esri, 2021).

In many areas, building continues in floodplains, exacerbating the potential damage from natural floods as it puts populations in vulnerable areas and reduces the ability of land to absorb flood water (Hammond et al., 2015). An example of this is in the middle stretch of the **Ebro River Basin**, in Spain, where the population is the most concentrated. Urban areas are located along its banks, and following a severe flooding event in 1960, the river began to be channelled by means of protective dykes that reduced the mobility of the riverbed, while economic and urban activities occupied the river area. However, at the beginning of the 21st century, damage from floods continued to increase, in part due to channelization and greater occupation of the flood area, both by urbanized and agricultural areas. The compensation to those affected by both insurers and administrations has been steadily increasing in recent years. These impacts are expected to increase with a higher frequency in the number and intensity of floods due to climate change.

Pluvial flooding or rain-related flooding can occur in both urban and rural areas and is not necessarily related to a specific water body. Surface water floods take place when the urban drainage system is overwhelmed, and the lack of natural drainage can flood streets and buildings. For example, the city of **San Francisco**, in the USA, experiences intense storms that overwhelm the sewer system. Other types of surface water floods are when high groundwater level combined with heavy rain and permeable land surface can lead to oversaturated soils that cannot absorb water and sometimes sinkholes form. Pluvial flooding includes flash floods which are caused by heavy or excessive rainfall in a short period of time, although they can also occur with no rain, for example due to the failure of a levee or dam, or after a sudden release of water by a debris or ice jam. Flash floods are usually characterized by raging torrents through riverbeds, urban streets or mountain canyons. They are often dangerous and destructive due to the high flow and debris that is swept along (Zurich, 2020; USGS, 2021; NOAA, 2021a; Esri, 2021).

Coastal flooding is the inundation of land areas along the coast by seawater caused by storm surges and/or tidal floods. Storm surges are when there is intense rain and windstorms which can be especially devastating at high tide. The severity of a coastal flood depends on several factors, including the strength, size, speed and direction of the windstorm as well as topography (Zurich, 2020; USGS, 2021; NOAA, 2021a; Esri, 2021). When there are storm surges, large areas of low-lying land can be flooded causing loss of life and property. Tidal floods occur due to encroaching seas and when there are exceptionally high tides (Zurich, 2020; USGS, 2021; NOAA, 2021a; Esri, 2021).

This type of flooding is becoming more common with sea level rise due to climate change as well as coastal erosion and land subsidence increasing the vulnerability of infrastructure (Karegar et al., 2017). Such floods can have a major impact as nearly two-thirds of cities with populations greater than five million are located in areas at risk of sea level rise (WEF, 2019). Consequently, coastal cities and communities are facing the threat of direct inundation as well as greatly magnified risks from storm surges, tidal flooding, extreme rain, erosion of coastal landforms, and saltwater intrusion within coastal rivers and aquifers (IPCC, 2019; USGCRP, 2017). These impacts can severely affect water systems that cities rely on for their drinking water as well as for other uses (Moore, 2019).

2.1 – ECONOMIC IMPACTS

Flooding can lead to a loss of life, livelihoods, and disrupt and limit access to resources that cities rely on, not only water, but also food and energy (IWA, 2018a). Severe degradation of local watersheds can diminish their ability to be a natural buffer against water-related hazards such as floods, leading to even greater damage to urban life and infrastructure.

An example is the tropical storm Ondoy and typhoon Pepeng of 2009 that resulted in widespread devastation in the Philippines, leaving thousands homeless, causing nearly a thousand deaths and an economic loss of approximately USD 4.38 billion (PEDRR, 2011). It was assessed that almost 90% of the damage caused by Typhoon Pepeng was due to massive urbanization of a landslide-prone area of Baguio City in Philippines (Nakasu et al., 2011). Separately, the degradation of the Marikina Watershed in the Province of Rizal combined with the intensive rainfall episodes from Ondoy surpassed the watershed's carrying capacity and generated a high flood in the Marikina River (World Bank, 2011). Other examples include the severe flooding that hit Copenhagen in 2011 causing about EUR 700 million of damages, and hurricane Sandy in New York City which generated USD 19 billion of economic losses in 2012. In October 2018, hurricane Michael in Florida may have caused USD 25 billion in economic losses. Overall, between 2010 and 2050 the economic value of assets at risk of flood is projected to grow by 340%, reaching USD 45 trillion (OECD, 2012).

Floods are often the most expensive type of natural disaster because damage to infrastructure can be extensive; it can include damages and disruptions to communication links, power plants, roads and bridges. These can lead to long-term impacts, such as disruption of electricity, transport, communication and water supply, all of which can affect the livelihoods of people in the affected areas. The damage to infrastructure and public properties when translated into monetary terms are more likely to be costly than that to private properties (Hammond et al., 2015; Unterberger, 2018). In 2020, the global cost of flooding was USD 51.3 billion which was greater than the annual average between 1970 and 2018 of USD 33.2 billion (CRED & UNDRR, 2021). Flooding in the USA has an average cost of USD 4.3 billion per event (NOAA, 2018). In Australia, direct costs were estimated over the period 1967–2005 to average at AUD 377 million per year (calculated in 2008 Australian dollars) (Queensland Chief Scientist, 2011).

In addition to direct immediate destruction of infrastructure, floods can cause economic activities to come to a standstill due to factors such as (temporary) relocation of people, reduction in purchasing power, loss of land value and inflation. The relocation costs induced by flooding events and rehabilitation costs can divert the capital required for maintaining production. Floods also impact energy and food sectors induced by the disruption of electricity, destruction of crops and loss of livestock. The loss of resources and the high cost of goods and services delay economic development in the affected area and the country as a whole (IWA, 2018a).

For example, following the severe flood disaster of 2011, Thailand's Gross Domestic Product (GDP) grew by only 0.8%, compared to 7.5% in 2010, and 7.2% in 2012 (CEIC Data, 2021). Between 1998 and 2002, Europe suffered over 100 major damaging floods, including the catastrophic floods along the Danube and Elbe rivers in 2002. Between 1998 and 2004, floods caused some 700 fatalities, the displacement of about half a million people and at least EUR 25 billion in insured economic losses (EEA, 2003).

Collège Pré Bénit in the Bourbre Basin in France © SMABB

The basin stories used in this handbook cite various instances of the economic damage caused by flooding. For example, in the **Melbourne Basin**, in Australia, the annual average damage caused by flooding is estimated to be AUD 399 million. In addition, the ongoing population growth and urbanization is expected to generate more storm water (due to increasing built infrastructure) and sewage, resulting in more potential flooding. Another example is the **Bourbre Basin** in France which has 73 municipalities and 211,000 inhabitants. Continuous urbanization and development within the Bourbre basin over the past years has led to an increased risk of flooding. The cost of serious flood events in 1993 and 1998 impacts was estimated to be about EUR 63 million over the entire watershed, out of this EUR 54 million affected businesses alone. At a larger scale is the case of **Mexico City**, where half of the city is classified as inundation prone (from medium to high risk). Climate change is expected increase damages due to hydrometeorological and sanitary events. Between 1980 and 2013, these events affected almost 50,000 people and amounted to USD 32 million in Mexico City, including damages by inundations, wind, hail and sewage overflow.

The basin stories also provide several examples of how flooding has already and has the potential to damage infrastructure. For example, due to the low-lying nature of the **City of Kunshan (China)** and its poor drainage system, there is a high risk of frequent inundation which can cause damage to infrastructure. Similarly, in **Cuenca (Spain)**, there are areas that have a high probability of flooding which can cause considerable damage to buildings and infrastructure. In 2007, **Hull and the East Riding of Yorkshire, in the United Kingdom**, were severely impacted by a flood event that damaged approximately 8,600 residential properties, 1,300 businesses and 91 out of 99 schools. In December 2013, a storm surge on the North Sea moved into the Humber Estuary which flooded over 400 properties. Climate change further increases the threat of flooding, as intense storms become more frequent and sea levels are rising.

In coastal areas, such as the example from Hull, flooding combined with sea-level rise can lead to saltwater intrusion into groundwater drinking supplies, especially in low-lying, gently sloping coastal areas (Chang et al., 2011). The impact of sea level rise is further exacerbated by groundwater pumping rates. The amount of saltwater that goes into freshwater aquifers has an economic impact by increasing the treatment costs of water utilities to remove salt (WHO, 2017).

2.2 – ENVIRONMENTAL IMPACTS

Natural systems are resilient to the effects of all but the largest floods. In fact, floods are essential to sustain ecosystem function and biodiversity (WMO, 2015). Floods can help redistribute minerals from riverbeds to agricultural land, thus restoring the fertile topsoil needed for effective growth. This sediment can also help keep land above sea level, by replenishing the top layer of soil and preventing subsidence. In addition, for many species, floods are an important trigger for breeding events, migration and dispersal (Queensland Chief Scientist, 2011).

Although there are benefits to flooding, large floods can be devastating to the environment and ecosystems in the affected region. In such cases, flood water carries a vast quantity of sediments leaving behind deposits after the water recedes. The sedimentation can clog rivers and reduce the storage capacity for wetlands and dams (European Commission, 2007). Flood water can contain debris, pollutants and nutrients. These can degrade aquatic habitats, lower water quality, reduce inland and coastal production, and contaminate food resources (Queensland Chief Scientist, 2011). Sedimentation and turbidity can result in the growth of algae and phytoplankton blooms that jeopardize water quality (Alberta Water Portal Society, 2014). Other negative effects include loss of habitat, dispersal of weed species, the release of pollutants, lower fish production, loss of wetlands function and loss of recreational areas (Queensland Chief Scientist, 2011).

Areas that have been highly modified by human activity tend to suffer more significant and negative effects from flooding (Queensland Chief Scientist, 2011; European Commission, 2007). For example, the urban environments of riverside cities, rivers have been subjected to different pressures that have led to their degradation. In the **Jucar Basin (Spain)**, water pollution problems and dense urbanization have led to rivers being modified to become drainage channels. The original ecosystems have been reduced due to increasing deterioration resulting in a greater risk of flooding as there is no longer any buffer zone. Communities in the basin have found that the high degree of degradation and the complexity of these natural systems require technical capacities beyond the local administration.

Flooding in dense urban areas can cause further damage to the surrounding ecosystems due to overflow of sewage systems resulting in raw sewage being carried into waterways. This can lead to increased levels of bacteria and pollution that will become present in lakes and other natural ecosystems (Pollution Solutions, 2014).

Chemicals and other hazardous substances can end up water bodies and can increase when there are flooding events. In 2011, a big tsunami hit Japan, and seawater flooded a part of the coastline. The flooding caused massive leakage in nuclear plants and has since caused high radiation in that area. Authorities in Japan fear that Fukushima radiation levels are 18 times higher than expected (McCurry, 2013).

2.3 – SOCIAL IMPACTS

There are a variety of negative socio-economic impacts from flooding including loss of lives and property, loss of livelihoods, decreased purchasing power, mass migration, hindering economic growth and development, psychosocial effects and political implications (WMO, 2006). Food security in urban and rural areas can be threatened due to soil erosion and greater runoff rates from farmland during floods. This affects agricultural productivity and can result in potential contamination of downstream water and food supplies by heavy chemicals, metals, pesticides and animal waste carried by runoff (WMO, 2015).

Physically, floods can endanger human life by drowning or causing injuries, biologically by spreading of waterborne and vectorborne disease, and chemically by exposure to hazardous chemicals like heavy metals (PEDRR, 2011). Health impacts from flooding can vary depending on many factors including flood characteristics (severity, duration and frequency), population, exposure and vulnerability. Local impacts of flooding in high-density urban slums can have devastating effects on the population, for example due to water contamination, loss of access to water supply as well as the threat of waterborne diseases (WMO, 2015).

Such impacts are highlighted in one of the basin stories, where regular flooding of **Dakar's (Senegal)** outlying districts poses a problem of extreme vulnerability for the city and will further worsen with increased rainfall frequency due to climate change. Due to this ongoing threat, the Grand Yoff stormwater retention basin is in one of the 19 districts of Dakar, and has issues of flooding, water quality and drainage. Rapid urbanization, land use change, poor upstream management, sedimentation, aquatic weeds, unmanaged wastewater discharge and dumping of solid waste have degraded the area. This means that during heavy rains, the retention basin overflows and floods the surrounding catchment area with contaminated water impacting health, the local economy, livelihoods and environment.

Wastewater treatment systems and water supply networks are at risk of contamination and physical damage during severe flooding events (PEDRR, 2011). Infrastructure systems that are in poor repair may further exacerbate potential health threats, for example, corroded pipes that are impacted by flood will be more susceptible to allowing contaminated water into the network (Bell et al., 2018). If drinking-water sources become contaminated and there is no available alternative treatment of water supplies then flood victims are increasingly at risk of infection and disease (WMO, 2015).

3 - DECLINING WATER QUALITY

Box 2. Key points on how declining water quality is impacting cities

- Declining water quality due to watershed degradation, as well as from point and non-point sources, has a direct impact on aquatic ecosystems and drinking water, water treatment costs and the economy in downstream urban areas.
- Urban landscapes are host to a suite of contaminants that impact on water quality, including from atmospheric deposition, anthropogenic activities (industry, construction, vehicles, etc.), drainage surfaces and poorly connected urban drainage systems.
- Higher temperatures can create conditions for increased waterborne pathogens in the supply system. Such temperatures combined with increased nutrient loads can result in algal blooms that can produce toxins which contaminate water resources.
- Declining water quality can impact the economy in numerous ways including the direct increase of costs for water treatment for different users and the loss of production revenue due to disruption in supply to industry. Poor water quality can also lead to a decline in property values, loss of recreational revenue, effects on human health which in turn affect economic productivity and loss of livelihoods.
- Water pollution poses serious threats to the environment in cities and their wider basins. This can lead to the loss of key ecosystems, and impact fisheries and agricultural productivity.
- Poor water quality has a direct impact on human health leading to a decline in livelihood and social well-being. Reduced access to safe water can impact hygiene, making it challenging to control water- and vectorborne diseases.
- Water quality can also impact food supplies to urban areas. Contaminated water can impact soil productivity and reduce the production and quality of crops, leading to negative implications on the food sector as a whole.

Just as important as access to water is for water to be clean and safe for drinking. The physical, biological and chemical characteristics of water, as well as aesthetic (in terms of appearance and smell) define water quality. Although many countries have increasingly strict management of point source pollution, dumping untreated wastewater into rivers and oceans, especially in developing countries, is still a common practice. This has resulted in about 25% of urban residents in developing countries unable to obtain adequate water (McGrane, 2016). Urban water quality is impacted by localized pollution as well as activities in the wider basin

Seventy-eight percent of large cities rely on upstream surface water and source watersheds (McDonald et al., 2016). However, land is being converted for a variety of uses across watersheds, including housing, industry and agriculture. This is leading to degradation of the source watershed, including sediment and nutrient pollution problems with pollutant yields that are estimated to increase by 40% for sediment, 47% for phosphorus and 119% for nitrogen (McDonald et al., 2016). The case study of the **Densu River Basin in Ghana** which provides the majority of drinking water to Accra illustrates a wide variety of activities impacting downstream water quality. This includes agrochemicals in farming and harmful chemicals in fishing, encroachment and expansion of farming and urban settlements within the riparian buffer of the river; inappropriate disposal of solid and liquid waste from local government authorities, and sand mining and quarrying in and around the riparian buffer.

Declining water quality due to watershed degradation, as well as from point and non-point sources has a direct impact on aquatic ecosystems and drinking water, water treatment costs and the economy in downstream urban areas (McDonald et al., 2016; World Bank, 2014; NPR, 2013). Examples of pollution sources across a basin are illustrated in the case of the **Büyük Menderes River basin in Turkey**. The major economic activities are industries based on textile, cotton and other food products. There are also many agro-industrial activities which supply cities across the basin including animal husbandry for dairy, meat production and cultivating fodder crops with high productivity also exists. These activities make the basin highly vulnerable to both point and diffuse forms of pollution.

Agriculture and animal husbandry production is a significant source of non-point source water pollution (McGrane, 2016). Agricultural utilization in an upstream source watershed can produce a large amount of agricultural runoff during rainfall events leading to impaired water quality because pesticides and nutrients used in farming can trigger algal growth in rivers and lakes resulting in eutrophication (NPR, 2013). For example, in the **Guandu Basin in Brazil**, there is a high level of erosion due to topography combined with loss of vegetation cover, degradation of soils and high-impact livestock production resulting in pollution and silting which affects water source quality.

Chemicals and heavy metals in industrial and municipal wastewater also pollute waterways. These pollutants are toxic to aquatic organisms, usually shortening the lifespan and reproductive capacity of organisms, and entering the food chain (Denchak, 2018). In some cases, excessive nutrients can trigger harmful algal blooms (HABs) most frequently caused by cyanobacteria, which can produce toxins that can harm human health. CyanoHABs can threaten both human and aquatic ecosystem health.

Urban landscapes are host to a suite of contaminants that impact on water quality, where novel contaminants continue to pose new challenges to monitoring and treatment regimes (McGrane, 2016). Urban run-off pollution sources within the urban environment include atmospheric deposition, anthropogenic activities (industry, construction, vehicles, etc), drainage surfaces and poorly connected urban drainage systems (Müller et al. 2020). Impermeable surfaces accelerate the migration of pollutants through increased surface runoff and hydraulic efficiency (Denchak, 2018). The important infrastructure below the surface of the city changes the compactness of the soil and affects the water permeability of the soil (McGrane, 2016). This results in leakage from water supply and sewerage pipes, impacting the groundwater aquifers. To compound this contamination, in many developing countries, massive exploitation of groundwater resources reduces the rate of groundwater recharge, which leads to further groundwater pollution (McGrane, 2016).

Another cause of declining water quality is associated with higher temperatures, which can create conditions for increased waterborne pathogens in the supply system. Such temperatures combined with increased nutrient loads can result in algal blooms (WHO, 2017). An increase in algae in water is a problem because they can produce toxins which contaminate water resources (e.g., cyanobacteria produce a group of harmful algal toxins known as microcystins), as well as the water treatment facilities supplying drinking water. Warmer, less oxygenated water may also result in higher levels of metals, including phosphorus and phytoplankton. Water treatment plants face a difficult task of not only removing the toxins and contaminants but doing so in a safe and cost-effective way (WHO, 2017).

3.1 – ECONOMIC IMPACTS

Desbureaux et al. (2019) estimated that when rivers become very heavily polluted, regions downstream see reductions in economic growth, losing between 0.8 and 2.0 percent of economic growth. Declining water quality can impact the economy in various ways. Impacts on health can affect labour productivity; the quality and quantity of food produced can be reduced; and sectors that rely on environmental quality and ecosystem services, such as tourism, real estate and aquaculture/fisheries, can lose business (Desbureaux et al., 2019). The economic impacts of declining water quality on cities can also be directly seen in the increase of costs for water treatment for different users. Inadequate water quality can decrease the quality of some industrial products (Yongguan et al., 2001; Yao et al., 2016). Furthermore, poor water quality can disrupt supply to many industries which cannot use the polluted water, consequently industrial production may shut down.

Other economic impacts on urban areas include decline in property values, loss of recreational revenue, effects on human health which in turn affect economic productivity, and loss of livelihoods. For example, the **Trancão River, a tributary of the Tagus near Lisbon**, was the most polluted river in Europe at the turn of the 20th century. Prior to its clean-up, economic activities, such as fishing or nature tourism, were practically non-existent. Another example of widespread economic impact is in Vietnam where untreated industrial wastewater can have a significant impact on the downstream economy. Rice paddy yields downstream of industrial parks in the Mekong Delta and Red River Delta, were reduced by 12 percent due to poor water quality, impacting the national GDP (World Bank, 2014). The discharge of untreated wastewater from upstream can harm the health of people living in downstream urban areas which in turn affects the economy through reduced worker productivity and increased health costs (World Bank, 2014).

A further example is in **Shaoxing, China**, where textile, printing and dyeing industries experienced rapid development in the 1980s. Wastewater from these industries was discharged directly into rivers resulting in increased siltation and pollution. Rivers within and around Shaoxing city had reduced ability to self-purify and the overall environment deteriorated. By the end of the 1990s, water quality of Shaoxing city was extremely poor, the aquatic ecosystem was out of balance, the water was black and emitted foul odours. Residents preferred to not live close to the river, and the state of the rivers impacted liveability and investment in the city. The credibility and trust of the city management also became severely eroded.

Decline in water quality due to an increased sediment loading or chemical contamination requires additional treatment to meet regulations and standards. McDonald et al. (2016) estimated that the total cost of watershed degradation to water utilities is about USD 5.4 billion annually. Higher water treatment costs include capital investment during construction, and O&M costs due to the need to adopt expensive methods to further treat the water (McDonald et al., 2016). For example, an advanced filtration plant, such as one using membrane filtration, would have 2.1-fold greater annualized costs than a conventional filtration plant which uses sand or gravel filtration (McDonald et al., 2016). There are also increased operational costs, including higher chemicals and energy consumption, to treat water with increased pollutant loads. For example, in the USA, large amounts of powdered activated carbon are used to remove atrazine, an herbicide widely applied to cornfields in the spring, from untreated water. In northeast Missouri, the Clarence Cannon Wholesale Water Commission treats 1.5 billion gallons of water each year with a 900-pound bag of powdered activated carbon that costs roughly USD 130,000 a year. The plant passes that bill on to customers (NPR, 2013). The deterioration of water quality can force cities to look to unconventional water resources such as tapping into deep aquifers and desalination of seawater that are high-cost options for cities (IWA, 2018a).

Additional examples from the basin stories show various economic impacts due to deteriorating water quality. In **Peru**, the use of fertilizers and chemicals in rural and mining areas, illegal waste dumping and infrastructure deterioration are contributing to the degradation of basins. As a consequence, water quantity and quality are compromised, resulting in utilities needing to invest more in treatment techniques, chemicals and the expansion of treatment plants. The water quality issue in **Mexico City** is more localized as the drainage systems are not separated, so rainwater and residual waters are combined, and this limits reuse and increases treatment costs. In **Fez, Morocco**, industrial pollution from industries such as tanneries, copper workshops and oil mills has seriously inhibited the functioning and efficiency of the wastewater treatment plant (WWTP) as there is little treatment prior to discharge. This has led to pollution of the Sebou River and affected downstream users, including disruption on drinking water treatment and increased costs.

3.2 – ENVIRONMENTAL IMPACTS

Water pollution poses serious threats to the environment and has a cascading effect on downstream water resources. Discharge of pollution into water bodies can influence dissolved oxygen availability and temperature of the water leading to changes in nutrient and contaminant concentrations which can cause water quality, taste and odour problems (Yao et al., 2016; Keiser et al., 2019). These changes can influence flora and fauna leading to aquatic species deaths or eutrophication, thereby altering the balance of bacteria, zooplankton, and insect and fish populations (Yao et al., 2016; Keiser et al., 2019; Beck et al., 2018).

Declining water quality can also affect ecosystem services within cities themselves. The poor water quality in rivers and lakes can limit activities including swimming, boating, angling, bird watching and other recreational interests, such as walking along the riverbank, landscape appreciation etc. (Keiser et al., 2019). For example, in the urban area around the **Tagus estuary**, there have been numerous problems, such as unreliable wastewater treatment facilities, the functional failure of the sewage network during storm events, constant and devastating floods in some areas, the discharge of untreated domestic and industrial wastewater in the river, and growing environmental degradation, with polluted beaches and important ecosystems at risk. Prior to extensive investments to improve water quality, the cities in the area (Lisbon and Almada) did not see their riverside areas as spaces for enjoyment and leisure.

Water quality is a common issue in estuaries near cities and at the mouth of rivers subject to industrial activity. The estuarine habitat of the **Derwent River** is a prized ecosystem for the residents of Tasmania's capital city, Hobart. Pollution entering the estuary originates from both point and diffuse pollution sources. Point sources of pollution have been identified as industrial effluent and treated sewage (with high nutrient content) which are contributing to poor water quality. Diffuse pollution sources include urban storm water runoff and runoff from the wider catchment and from landfills and contaminated sites. Pollution from aquaculture operations and marina and shipping activities are also negatively contributing to poor water quality in the estuary ecosystem.

Another example of the impacts of water quality on ecosystems is in **Mexico City**. As the city grew, urban and peri-urban rivers were used to discharge waste and were becoming a nuisance and health hazard. These rivers were channelled or piped to join the sewage system (as is the case of the lower Magdalena River in the eastern part of the city). In the remaining open water bodies, the decline of water quality directly impacts local communities. An illustration of this issue is in the Channels of Xochimilco, well-known for its chinampas, a unique pre-Hispanic agriculture system built on the lake. Increasing local discharge of wastewater and growing use of agrochemical products, contributed to eutrophication of the system, causing the deterioration of this UNESCO World Heritage Site and loss of its traditional agricultural practices. Such deterioration of the surface water not only affects the health and well-being of the population but also leads to the loss of key ecosystems and the possible contamination of groundwater resources. At the same time, the disappearance of the local rivers and water bodies reinforces the disconnection of the city with its basin, erasing with them the cultural remnants of the city's lake basin.

The pollution from local industries in **Fez, Morocco** cannot always be effectively treated by the WWTP resulting in discharge of polluted effluent to the Sebou river. This in turn has led to the degradation of flora and fauna downstream, and as well as reduced quality of water used for irrigation which is extracted from the Sebou River. Water releases from upstream dams are sometimes needed to dilute the level of pollution in the river.

A further example of the impacts on ecosystems is in the Recife Metropolitan Region (Pernambuco state, Brazil), where the Pirapama River has been one of the main sources of resources for the water supply. During the 1960s and 1970s there was accelerated and often unplanned urbanization, along with establishment of an industrial district in Cabo municipality (within the Recife Metropolitan Region) and the Port of Suape. A lack of domestic wastewater treatment, release of untreated industrial effluents, lack of solid waste treatment and the use of pesticides and chemical fertilizers, resulting from the temporary cultivation of sugarcane and polyculture, have all contributed to degradation of water quality. In addition, intensive soil use within and outside of the city has modified biogeochemical and hydrological cycles, reducing the availability and quality of water in the basin (Bacalhau et al., 2016; Menezes et al., 2016; Montenegro et al., 2009; Dias and Barros, 2008).

Water quality is also an issue in less dense population centres and can impact wider ecosystem processes. Rapid global climate change, urban development, land cover changes and pollution from industrial development are affecting the water quality and ecosystem health in the **Mackenzie River Basin** in the Northwest Territories and Yukon, Canada. Communities that rely on its water seek protection for these water resources. The basin has a population of about 400,000 people living primarily in remote, Indigenous communities, mainly accessible by air or water. The Mackenzie River Basin sustains not only communities, but also ecosystems that contribute to the Arctic Ocean circulation.

3.3 – SOCIAL IMPACTS

Declining water quality can affect water supply quality and sustainability which impacts the urban economy and living conditions. Poor water quality has a direct impact on human health leading to a decline in livelihood and social well-being. It can lead to the spread of waterborne diseases, such as cholera and other diarrheal diseases, which are contagious, and their cost implications affect wider society.

When water quality is not safe, urban residents in the cities need to buy household water purification instruments to purify tap water if water quality keeps declining. But many residents may not have access to such technology. Water pollution can contribute to non-infectious diseases including skin diseases, birth defects, spontaneous abortions, and some forms of cancer, such as cervical cancer, liver cancer and stomach cancer (Yongguan et al., 2001). If people consume polluted drinking water with microbial contamination, it can increase the risk of some diseases such as typhoid, dysentery, diarrhoea, hepatitis A and hepatitis B for humans (Hasan et al., 2019). In addition, the impact on public health increases the pressure on health services cities' departments and increases costs for many citizens that need to pay for medical treatment. Decreased work labour force and increased risk of early death due to illness has long-term effects on the human per capita GDP.

Examples of health impacts of poor water quality in urban areas are illustrated in the basin stories from the Congo and Manila. The significant pollution of the **Congo basin** is caused by discharge of wastewater and solid waste directly into the river from Kinshasa (DRC) and Brazzaville (Republic of Congo). In Kinshasa, 40% of waste and wastewater is dumped into the river, and in Brazzaville this increases to 45%. The remaining waste is dispersed in wells, groundwater or directly on the street. The lack of treatment and management of solid waste and wastewater has created a breeding ground for various infectious diseases, including cholera, which particularly affects vulnerable populations, especially children. Nearly 88% of diseases in the area are linked to the absence of water and wastewater treatment.

In **Manila, Philippines**, the severe water degradation due to industrialization of the city combined with population growth has resulted in significant pollution of the Pasig River. Untreated wastewater is directly discharged into the river resulting in destruction of fisheries which were a local income source, and a drop in the standard of living for families who relied on natural resources of the area. In addition, the direct discharge of waste into the river has led to outbreaks of various diseases, particularly cholera, which contributes to increasing mortality, especially children who are most susceptible to this type of disease.

Declining water quality can also impact the quality of life and liveability of a city. In the **Guandu Basin** in Brazil, although there is a high level of water treatment, only 34% of the sewage produced is collected. Of this, only 2.3% is treated, which directly affects water quality, creating difficulties for the proper operation of Guandu Water Treatment Plant and, consequently, generating insecurity and a lack of trust in the water supply for the

View of the historic city of Porto, Portugal © Shutterstock

inhabitants whose daily activities depend on the Guandu river. In the case of **Porto in Portugal**, there has been rapid urban growth that has led to significant pressures on water resources. More than 75% of the streams in Porto were piped and buried to allow construction of new buildings, leading to degradation of water quality which has persisted for decades, compromising the quality of life of the people living there. Another example is in **Kunshan**, China, where rapid urbanization and economic growth in the past few decades have seriously degraded its waterways. Catchment pollution, poor circulation and an inadequate sanitation system, has resulted in the degradation of the water quality in the network of constructed canals. The water environment that once defined the liveability of the city is now under threat.

Water quality can also impact food supplies to urban areas. For example, farmers may use sewage for irrigation due to a lack of water, but this can reduce the production and quality of crops. In the Taohua Stream basin in China, sewage irrigation led to toxic heavy metals in the soil which damaged the quality of crops (Yongguan et al., 2001). Declining water quality also damages fisheries and stock husbandry due to poor water quality of the environment. Water pollution has caused livestock, such as cows, horses, and poultry, to decline gradually because fodder for livestock is of poor quality along rivers (Yongguan et al., 2001).

4 - WATER SCARCITY AND DROUGHT

Box 3. Key points on how water scarcity is impacting cities

- Severity and frequency of droughts can lead to water scarcity situations, while overexploitation of available water resources can worsen the consequences of droughts
- Water scarcity can lead to inequitable allocation and distribution of available water among different sectors. The water supply in cities for drinking, sanitation and other household purposes can be severely impacted as demand for water in the food and energy sectors increases.
- The onset of droughts is slower than floods but the hazard footprint for droughts is larger.
- Droughts can disrupt water supply and reduce water availability leading to environmental, health, social and economic impacts. Vulnerable populations often suffer the brunt of these impacts as they may not have the resources to prepare and adapt.
- Droughts are the costliest natural hazards on a year-to-year basis and are significant and widespread, affecting many economic sectors and people at any one time. There are direct impacts such as decreased agricultural outputs, disruption in industrial operations and indirect, such as rising costs of food in cites.
- Water scarcity can increase the rate of over-abstraction of groundwater leading to depletion, land subsidence and deteriorating water quality making it unsuitable for human consumption.
- Water scarcity can mean that there needs to be costly investments such as basin transfers to secure supply.
- Water scarcity and drought are also often associated with longer-term poorer water quality as low flows and reduced water levels tend to increase the concentration of pollutants and nutrients. This has an indirect effect on drinking water supply as it can lead to increased dependence on potentially less safe alternative water sources that might otherwise be avoided.
- Water is essential for social stability and the deficiency of potable water can disrupt the daily activities of a society. Reduced water availability in cities is more likely to affect low-income groups and can increase social stratification in urban settings.

Water scarcity is when there is insufficient water resources for long-term average requirements. There is a long-term water imbalance where there may be low water availability and a level of demand exceeding supply. Water scarcity is due to human activities that have resulted in low availability compared to demand (European Commission, 2022; Wanders, 2017; Van Loon and Van Lanen, 2013). On the other hand, drought refers to the state of the system and is a natural hazard, caused by large-scale climatic variability. Droughts can be considered as a temporary decrease of the average water availability due to a lack of rainfall (European Commission, 2022; Wanders, 2017; Van Loon and Van Lanen, 2013). The two phenomena influence and exacerbate each other. The severity and frequency of droughts (which are exacerbated by climate change) can lead to water scarcity situations, while overexploitation of available water resources can worsen the consequences of droughts (European Commission, 2022).

Accessibility of water resources for human consumption and ecosystems largely depends on the spatio-temporal distribution of both precipitation and evaporation. Urbanization and economic growth are increasing the number of urban residents living in water-scarce areas. There are currently 150 million people in urban areas that do not have sufficient water, meaning less than 100 litres per day which is needed to maintain the basic living standards of residents (McDonald et al., 2011). According to the UN, in 2025 nearly 2 billion people will live in conditions of absolute water scarcity, and two thirds of the world in areas of water stress. Water scarcity affects different stakeholders in different ways and can lead to tensions among them. It will become more difficult to provide access to water to all, particularly to vulnerable groups (Huntjens and De Man, 2017). There is further pressure on available water resources for competing sectoral demands including industry and energy expansion of irrigated agriculture, as well as the added complication of reduced availability due to water pollution (Chen et al., 2015). Effects of water scarcity are amplified when the region has high population density and is an economic hub such as the Recife Metropolitan Region (Pernambuco State, Brazil), whose population is 3.8 million inhabitants, corresponding to 51% of the urban population in Pernambuco State (Bacalhau et al., 2016). With a water demand of around 14 m^3/s, the population of the Recife Metropolitan Region, has faced serious problems around shortage of public supply (Montenegro et al., 2009).

In addition to the aforementioned pressures, cities also face unprecedented hydrological changes due to global climate change and land use change (McDonald, et al., 2011; Yigzaw and Hossain, 2016). These hydrological changes combined with increasing water demand can exacerbate drought which impacts cities and their watersheds.

There are several different types of droughts including meteorological, hydrological, agricultural and socio-economic drought (WMO and GWP, 2016; National Weather Services, 2021). Meteorological drought happens when there is less rainfall than usual in an area. Hydrological drought usually occurs after a meteorological drought where there is low rainfall which later affects the amount of water in streams, reservoirs and groundwater levels. For example, it is projected that a reduction in annual precipitation by 10% in 2050 and increased evapotranspiration will reduce the flow rate in Büyük Menderes River in Turkey by 20% in 2050. This indicates how vulnerability of water resources is highly influenced by the climate variability of the region.

Agricultural drought is when hydrological and meteorological drought affects crops. This impacts food supply which is part of socioeconomic drought and relates to the supply and demand of various commodities due to drought (NOAA, 2021b). In the case of the **Büyük Menderes Basin**, decreasing flows will result in increased competition for available water between agriculture, industries and cities.

The onset of droughts is slower than floods but the hazard footprint for droughts is larger. Droughts can disrupt water supply, and reduce water availability leading to environmental, health, social and economic impacts. Droughts are also often associated with longer-term poorer water quality as low flows and reduced water levels tend to increase the concentration of pollutants and nutrients (WHO, 2017). Frequent and severe droughts in **California** threaten the stability of existing water supplies. **Melbourne, Australia**, also has been challenged with extreme climatic events which have impacted their water resources. In 2006, water storages received the lowest annual inflows on record, with storages dropping from 58.4% in January to 39.0% in December. In 2009, the region experienced devastating bushfires which damaged about 30% of Melbourne's water supply catchments, reducing water storage levels of the Thomson Dam to 25.6%, the lowest level recorded since the dam began filling in 1984.

Other natural disasters can also lead to water scarcity and can wreak havoc on entire cities and related infrastructures. For example, in the **San Francisco area**, catastrophic events such as earthquakes or wildfires in the surrounding watersheds means it is necessary to plan for disruptions in service that may occur due to these disasters. During such events, there can be a decline in water quality and increased demand for limited water resources.

Water scarcity can lead to inequitable allocation and distribution of available water among different sectors. Water-intensive energy and food sectors have the potential to further elevate the risks of water scarcity in already water-stressed areas. The water supply in cities for drinking, sanitation and other household purposes can be severely impacted as demand for water in the food and energy sectors increases (Leahy, 2018). Electricity generation from biomass, and fossil fuels such as oil, gas and coal, includes the use of thermal plants which require large amounts of water (Faeth, 2012). Hydropower can divert and change flows, reducing availability of water.

Water used for many high-value crops ends up getting exported. For example, studies show that it takes approximately 100–200 litres of water to grow the grapes and process one glass (125 ml) of wine (Leahy, 2018). In 2016, Cape Town exported 428.5 million litres of wine to the USA and Europe. This means that the wine trade exports an even larger amount of water which is no longer available for the people of the area (Leahy, 2018). This example demonstrates the concept of virtual water introduced by Tony Allan, which calculates the hidden flow of water in food or other commodities that are traded from one place to another.

4.1 – ECONOMIC IMPACTS

Watersheds are a source of economic goods that are not only essential for local livelihoods but also for the economies of urban areas. The reduced availability of water affects provision of these products and services to cities, resulting in decreased production in urban areas and hindering economic growth. The World Bank has estimated that by 2050, the growth rate in some regions can decline by approximately 6% of the GDP (World Bank, 2016). According to estimates by McDonald et al. (2014), approximately 22% of the total global economic activity is in one-quarter of severely water stressed large cities. A total of USD 4.8 trillion of economic activity in these cities depends on 167 billion litres per day of water supply. This large amount of water dependent economic activity indicates that the shrinking availability of water is not only endangering urban economies but also the global economy as a whole.

Droughts are the costliest natural hazards on a year-to-year basis and are significant and widespread, affecting many economic sectors and people at any one time. According to NOAA, drought in the USA has an average cost of USD 9.7 billion per event, and the most fatal when accompanied by heat waves (NOAA, 2018). Economic impacts of drought can be both direct, such as decreases in agricultural outputs, and indirect, as seen by increases in food prices which can impact those living in cities (NOAA, 2021c; Desbureaux and Rodella, 2019). Droughts also impact the energy sector, for example reducing hydropower generation and impacting thermal plants as there needs to be sufficient water for cooling (FAO, 2019).

Industries rely on water for production, diluting, cooling, material processing, facility sanitation and the transportation of products. Reduction in water availability poses a significant risk to companies with the potential to disrupt their operations and supply chains (Hoekstra, 2014). Businesses need to divert more of their resources to ensuring water access rather than production, as the water security risks increase. A survey of the world's largest 1,200 companies, conducted in 2016, highlighted that water risks are becoming visible for business as a USD 14 billion loss was observed due to water-related impacts in one year (CDP, 2016). Furthermore, water shortages are likely to erode business confidence and Foreign Direct Investment (FDI) in water-scarce cities which would not only reduce the economic output but also adds stress to the lives of residents (Mpakati Gama and Mkandawire, 2015).

Macroeconomic ramifications of water scarcity can have far-ranging consequences on an individual level as well. With the slowing of business operations leading to reduced profits, businesses are likely to be forced into laying off some of their workforces, leading to reduced consumer spending power among vulnerable communities. Desbureaux and Rodella (2019) looked at the economic impacts on water scarcity in Latin American metropolitan areas. They found that severe droughts decrease the general level of employment (~1%), the number of hours worked (~4.5%) and labour incomes (~6.5%). Furthermore, it is workers in the informal sector that are most impacted. Power outages and deterioration of health are the reasons behind these economic impacts.


Tana River in Kenya © Sgt R.A. Ward

Another example of disruption in supply not only due to water shortage but also water quality is in the **Tana River Basin in Kenya** which supplies 95 percent of Nairobi's water and 50 percent of the country's electricity. The Upper Tana River Basin is one of the nation's most productive agricultural areas; however, it has become increasingly polluted by sedimentation and the water levels have been reduced due to unsustainable abstraction. This has disrupted water supply and caused power outages in Nairobi city as well as other parts of the country, due to sedimentation clogging the Masinga reservoir.

Water scarcity can increase the use of unregulated water resources, such as groundwater. Over-abstraction of groundwater can reach a point where aquifers are depleted, or it becomes no longer economically feasible as the costs of pumping energy can become prohibitively expensive. Depletion of aquifers can also lead to deterioration of water quality making it unsuitable for human consumption (Richey et al., 2015; World Bank, 2018). In **Mexico City**, the depletion of groundwater increased abstraction costs as water needed to be pumped from greater depths and caused the city to sink as the underlying soil structure was compacted, generating damage to infrastructure and in particular to the drainage system. To cope with the city expansion and increased water demand, an extensive investment was made in infrastructure in the 1940s bringing water from the basins of Cutzamala and Lerma across the mountains, over a one-kilometre altitude variation.

As illustrated in Mexico City, water scarcity can also mean that there needs to be costly investments such as basin transfers to secure supply. For example, the Central Region of Namibia where **Windhoek** is located is characterized by low average precipitation of 250–400 mm/year, high potential evaporation of up to 3000 mm/year and no natural perennial surface water bodies. During prolonged droughts, the city on a number of occasions has faced a complete breakdown of freshwater supply which could only be narrowly avoided through the establishment of certain innovative counter measures, such as Direct Potable Reuse (DPR). Today, even the average demand outstrips available supply from the current conventional and unconventional water resources. The long-term solution for sustaining further water supply and development in Windhoek is to import fresh water from other basins which will involve huge capital investments and operational costs.

4.2 – ENVIRONMENTAL IMPACTS

Droughts and water scarcity have both increased the vulnerability of aquatic ecosystems as less water is available to sustain them and reduced the capacity of these same ecosystems to provide and protect water resources (Yigzaw and Hossain, 2016). The availability of freshwater in watersheds and large river basins is declining drastically, which in turn leads to water stress in cities which rely on these watersheds.

Water stress from over-allocation of surface or groundwater resources by different water users is a current or emerging problem across most of the world. High water consumption compared to water availability can decrease river flows or even deplete them before reaching the end of their course, mostly during the dry period, such as the case in Colorado River in the western USA (Mekonnen and Hoekstra, 2016). Over exploitation can also lead to decline in water levels in lakes, rivers and groundwater, as well as the destruction of wetlands. This has significant effects as wetlands support some of the most productive habitats on the planet, including vertebrates, invertebrates, fish and mammals, as well as the cultivation of rice which makes staple food for a large portion of the world population (WWF, 2021).

As in many places, basin managers in **British Columbia, Canada** are faced with increased problems of how basin's water resources can be proportionally allocated to all water users while maintaining flows for the environment. Environmental flows are needed to maintain healthy rivers with diverse fish habitat, sediment transport and instream water quality that meets guidelines for the protection of aquatic life (Koning et al., 2016). When basic information on the availability and use of the resource at a catchment scale is unavailable, it can make it difficult to manage withdrawals within sustainable limits for all water users and ensure there is sufficient for ecosystems. Neglecting environmental water requirements can lead to biodiversity losses, land subsidence and salinization of soils and groundwater resources (Mekonnen and Hoekstra, 2016). Such ecological impacts can affect the food chain, resulting in severe food shortages, particularly in urban areas which in turn can decrease life expectancy (WWF, 2021).

An example of drought affecting a large urban area is in the basin where **Mexico City** is located. The area is one of the most vulnerable in the country according to a drought vulnerability analysis conducted by the Secretariat of Environment and Natural Resources in 2011. Contributors to drought susceptibility include a high concentration of population, combined with limited resources and difficulties in managing increasing water demand. Directly linked with the droughts occurring in the dry season, forest fires occur frequently in conservation areas surrounding the city. In 2019, there were 445 forest fires affected over 3,200 hectares, causing significant air pollution. Forest fires also contribute to degradation and reduction of forest cover across the metropolitan area.

The reliance on groundwater due to water scarcity can also impact the environment. For example, there are hydro-morphological challenges in the **Büyük Menderes River basin in Turkey** due to over-abstraction of groundwater for various uses (e.g., agriculture and human consumption). In **Mexico City**, over-abstraction of groundwater has led to ground subsidence resulting in damages to the pipe system, as well as creating fractures and sinkholes.

4.3 – SOCIAL IMPACTS

Reduced water availability causes inconvenience, even crisis, and social instability (Koop & van Leeuwen, 2017). Over time, shortages of water will induce a higher cost of living and increase conflicts over water resources. Inefficient response to such a challenge has a negative impact on the political, economic and social welfare of countries as water, energy and food supply will all be affected (IWA, 2018a; Tarrass and Benjelloun, 2012).

The more immediate effects of drought are usually reduced freshwater supply and longer-term poorer water quality as low flows and reduced water levels tend to increase the concentration of pollutants and nutrients (WHO, 2017). The decrease in freshwater supply particularly affects households, businesses and communities directly involved in agriculture and production. Water scarcity also increases food prices, which again disproportionally affects the most vulnerable members of society (Vaal University of Technology, 2020).

Drought has an indirect effect on drinking water supply as it often leads to increased dependence on potentially less safe alternative water sources that might otherwise be avoided (WHO, 2017; NOAA, 2018). For example, the use of water from unprotected rivers and wells will aggravate the chances of waterborne diseases in urban areas (Mpakati Gama and Mkandawire., 2015). Storing water in buckets can also have negative impacts on health as there is an increased probability of contamination in stagnant water. Unfortunately, most of these methods are unhygienic and unsafe and can have short- and long-term health-related implications (Mpakati Gama and Mkandawire, 2015).

Groundwater can be an alternative water supply; however, resource sustainability can be an issue due to localized aquifer depletion combined with groundwater quality deterioration due to inadequately controlled urban sanitation, including disposal and re-use with underlying shallow groundwater (Foster, 2020). In **Fez, Morocco**, drinking water is primarily from the Saiss aquifer. However, the overexploitation of this aquifer, which is already in deficit, threatens the security of the drinking water supply in Fez. Therefore, alternative solutions must be put in place such as surface water from the Sebou River, although this can be highly polluted from local industries.

As clean water is important for hygiene which in turn is crucial for human health, water scarcity has detrimental impacts on human health (Vaal University of Technology, 2020). A large number of adverse health consequences are related to insufficient safe water, including infectious diseases, diseases related to chemicals and pollutants found in water sources, skin diseases and algae-related diseases (Yusa et al., 2015).

Water is also essential for social stability and the deficiency of potable water can disrupt the daily activities of a society. Societies stop without water because the imperative turns to survival (Stuckenburg and Contento, 2018). Reduced water availability in cities is more likely to affect low-income groups and can increase social stratification in urban settings (Stuckenburg and Contento, 2018). People from higher income groups can adopt better coping mechanisms during the event of water deficiency, such as transportation of water from neighbouring areas and installation of high-capacity water storage tanks. Water shortages can also potentially increase the food prices which disproportionately affects vulnerable groups. Food shortages in cities resulting from reduced water availability is also likely to cause developmental and growth issues especially in infants (Damania et al., 2017).

PART B – PATHWAYS FOR ACTION

Urban stakeholders need to recognize their reliance on the upstream watershed and their role in maintaining ecosystem services from both upstream and downstream areas such as estuaries, deltas and coastal receiving waters (PEDDR, 2011). What actions need to be taken by cities today to address the drivers for action? How can cities play a role in achieving sustainable management of basins in the future? How can utilities participate more actively in water governance?

The Action Agenda for Basin-Connected Cities is intended as a starting point for urban stakeholders to answer these questions and tailor the suggested approaches to their context (i.e., not just in developed countries but also developing countries; small and large basins, etc.) while identifying available resources. The following pathways for action through assessment, planning and implementation respond to the impacts outlined in the drivers for action to connect cities and their basins. The pathways have been adjusted from the original Action Agenda to reflect evolving approaches to linking cities and their basins. This section will expand on each pathway to action highlighting best practices extracted from the basin stories.

With all pathways, customization of solutions is important to highlight since there is no one size fits all solution. Planners and basin managers need to learn from best practices across different basins. Approaches for connecting cities with their basins need to be customized for not only physical characteristics, but also socio-political and cultural issues.

Wetland park in Guiyan, China © lin2015

Aerial view of the urban area of Shaoxing city

Fishing in Vietnam © Quang Nguyen Vinh

5 - ASSESSMENT

The pathways outlined in this section, are approaches to improve understanding of water resources and the dynamics between cities and their basins. They include:

- Identifying values and principles which provide the roadmaps to achieve common objectives;
- Investing in data and information systems as it is only feasible to manage what can be measured (and analysed); and
- Integrating local and traditional water knowledge to complement what is being scientifically measured and analysed.

Box 4. Key points outlining assessment focused pathways for action to achieve basin-connected cities

- An agreed set of values can provide motivation and guidance towards action on achieving basin-connected cities. Principles can provide the roadmap on how to deliver on mutual objectives for using water within the city and the whole basin. Developing agreed principles can bring together local governments, urban professionals and individuals to actively participate in solving and finding solutions to water problems in their cities.
- Developing a strategy or plan can be an approach to agree on a set of values and principles for the future.
- Data is the "life blood" of an organization, for as it flows between systems, databases, processes and departments, it carries with it the ability to make the organization smarter and more effective. How an organization uses and manages its data is just as important as the process of gathering the information. Holistic information systems that integrate data and information from across a basin provide a sound basis for cooperation as well as decision making.
- Water management needs to use both traditional and local knowledge as well as scientific information. Citizen science can be used to improve management practices by providing more frequent monitoring and data collection. This approach can improve participants' knowledge and awareness which can increase confidence in both the quality of water and the water company
- Water management can also learn a lot from traditional water conservation systems. This can be through combining traditional technologies for rainwater harvesting with modern methods, or through traditional administration systems.

5.1 – SETTING VALUES AND PRINCIPLES

Box 5. Definitions of vision, values and principles

- **Vision** – what an organization wishes to be like in a few years' time
- **Values** – describe the desired culture or the "compass" to achieve the vision
- **Principles** – a set of directions to reach the vision and implement the values

Extracted from the Harvard Business Review (Kenny 2014).

Values can help provide guidance on how to achieve a common vision for cities and their basins (as outlined in the "Vision" section under "Foundations for Action"), help stakeholders at different levels to get better involved and motivate decision making within a basin. Values can provide guidance to decision makers on efficient investment and construction within the basin. These values can be agreed and then systemized into a written set of principles. A negotiated set of principles can clarify mutual objectives for using water within the city and the whole basin (Box 5).

The Council of Australian Governments (COAG) took action in 2008 to adopt national urban water planning principles (Allan, 2018). The seven principles defined are based on economy, information acquisition, cooperative relationships, multiple schemes, sustainability, efficiency and monitoring. The water supply services and urban water safety planning of each state in Australia are designed to deal with the different conditions of each state, and the system formulation and planning arrangements of each state must meet the above principles.

Similarly, in New Zealand, the urban water working group developed a set of urban water principles in 2018, also known as NgāWai Manga. The team developed 10 high-level urban water use principles and values (Urban Water Working Group New Zealand, 2018) based on the relationships between man and nature, water and life, community and water, and between human beings and the environment in the future. The implementation of these principles aims to build sustainable urban water management. As the impact of applying these principles is still to be seen, the working group developed and recommended a suite of policies and practices for the Central Government, local government and the water sector to adopt (Urban Water Working Group New Zealand, 2018).

The goal of such principles provided in these two examples is to encourage collaborative actions, so that water utilities, local governments, urban professionals and individuals can actively participate in finding solutions to and solving water problems in their cities. At the same time, the aim is to advocate high efficiency and the use of limited resources to achieve long- and short-term water management goals.

Developing a strategy or plan can also provide an opportunity to agree on a set of values and principles for the future. In the **Ebro Basin in Spain**, a Resilience Strategy has been developed for the middle stretch of the river. The strategy is a framework for collaboration between the different administrations, including the cities and other stakeholders, to work in solidarity and coordination to manage the flood risk of the middle stretch of the Ebro River. It articulates goals for the future in which economic activities and towns coexist with an Ebro River in a good state of conservation, without the inevitable floods causing significant damage. This strategy provides an agreed framework for the various actors to come together to achieve these goals.

Similarly, in **Kunshan, China** stakeholders developed a city-wide strategy to not only reduce the urban pollution in regional waterways and improve the quality of water, but also mitigate the risk of floods in downstream cities. This was important for a sustainable water future so as to ensure safe and uninterrupted water supply in the context of increased urbanization and burgeoning population while reducing the level of dependency on external water resources.

In the case of **Guandu Basin in Rio De Janeiro State, Brazil**, the basin committee and water agency has developed a Strategic Water Resources Plan which is divided into eight Thematic Agendas and several lines of action. The actions have short-, medium- and long-term horizons and are in accordance with priority needs to guarantee the basin's water availability and quality. These thematic agendas can provide a roadmap to how stakeholders can implement the agreed objectives for the future.

Another example of using a plan to set agreed values and principles is the master plan for integrated water resources development of the Sebou basin where **Fez, Morocco** is located to address water security, flooding and pollution issues within the city and the wider catchment. The plan was developed with a participatory and concerted approach with all concerned stakeholders and has initiated projects to protect and preserve water resources while supporting the city's socio-economic development.

5.2 – INVESTMENT IN DATA AND INFORMATION SYSTEMS WITHIN AND BEYOND CITY LIMITS

Decision makers at all levels from city to basin to transboundary need data, as it sustains the continuous management of water resources. Water resource managers need to be able to access and use reliable, up-to-date and relevant information for regulatory purposes, planning, risk management and public awareness. The necessary data and information can be fragmented, incomplete, dispersed and heterogeneous, and access is often difficult for numerous reasons (e.g., multiplicity of data producers, inconsistency of data and information) (INBO, 2018).

Even when data is available it can often be underutilized due to limited capacity for analysis and interpretation. Crucial planning decisions may be taken with partial, insufficient and imprecise data and information. However, it can be improved with a minimum of political will, and planning to use existing information, fill the biggest gaps in data collection, and enable ease of access to data and its interpretation. Furthermore, data assets need to be accessible to the processes and individuals who require them, and be of sufficient quality and timeliness (INBO, 2018).

An example of the effective use of data to guide decision making is through the **Derwent Estuary Program (DEP) in Tasmania, Australia** which was established in 1999 to protect and promote the estuarine environment.

The programme uses data and information as a basis to foster collaboration with key stakeholders negatively impacting the health of the estuary and the wider catchment. Transparent environmental reporting supported by data identifies a stakeholder as negatively contributing to the health of the estuary and river. This information is then used to collaboratively craft solutions to limit sources of pollution.

Another example of data being used to help with decision making was demonstrated in **British Columbia (BC), Canada**. As in many places, basin managers are faced with how to allocate water to all water users including the environment while maintaining environmental flows including in times of water stress. The BC Water Tools were developed to provide information on water supply and demand to be considered in decisions regarding water allocation. The system combined monitoring data from a variety of public and private sector databases, which was then fed into analytical hydrology models, and calibrated to characterize surface water and groundwater resources, the connection between these resources and sustainable environmental thresholds for use. This information is then visualized in an accessible, user-friendly platform to allow users to find out information on the timing and amount of natural water supply, existing water allocations and the needs of the environment. Providing science-based information in a publicly accessible manner for decision makers, proponents and stakeholders is a building block in sustainable water management.

How an organization uses and manages its data is just as important as the process of gathering the information. Investing in data monitoring, water information systems (WIS), and modelling can provide a common platform for cooperation. Such systems must be complemented with knowledge and expertise to interpret and apply the data in decision making.

Holistic information systems that integrate data and information from across a basin provide a sound basis for cooperation as well as decision making. The **Guandu Basin (Brazil)** which includes Rio de Janeiro State has an Integrated Water Management System which assists in decision making through a set of tools that support the monitoring of the basin's geographic information, such as meteorological data and quality/quantity data of water bodies. Information is accessible so as to support the coordination process between the basin's actors. In addition to geographic and environmental information, the system relies on the availability of studies carried out by the basin committee and water agency so as to provide a complete picture of what is happening across the basin.

A key aspect of a WIS is the ability to bring together data from across the water cycle into a common platform that is accessible to those that need the information. Management of the different stages of the water cycle for **Porto (Portugal)** was originally spread through various entities, resulting in significant inefficiencies in the way water was managed. In 2016, Águas do Porto launched the design and development of an innovative real-time management platform for the full water cycle, the H2PORTO. This platform incorporates all data gathered in-house from meters, sensors, operations and Supervisory Control and Data Acquisition (SCADA) systems as well as external sources, such as weather stations. The development of this integrated management system improved Águas do Porto's efficiency around operation and maintenance activities in their water networks, changing the asset management approach to proactive rather than reactive thereby, preventing pollution events in the urban streams to protect the watersheds and their ecosystems. Such tools demonstrate how effective use of such systems can improve the health of the overall catchment.

Practical tools can also reinforce the connections between cities and their citizens and ensure preparedness and action in the case of extreme events such as flooding. The Flood Risk Management Plan of the **Ebro River Basin District in Spain** supports the prevention, protection, preparedness and recovery in the event of floods, and promotes self-protection of the population, as well as the coordination between all the administrations involved, including the cities. The Automatic Hydrological Information System (AHIS) was developed to support implementation of the plan and increase awareness and co-responsibility around flooding. The AHIS provides real-time data, every 15 minutes, on rainfall and levels or flows; and a Decision Support System offers hydrological forecasts based on weather forecasts. This information, which is available online to all, supports better decision making, activation of civil protection services and general warnings for the population.

5.3 – LINKING LOCAL AND TRADITIONAL WATER KNOWLEDGE

Water management benefits from using problem-solving processes that draws on vernacular knowledge, which integrates expert science and local knowledge (or indigenous practices) with community beliefs and values (Nguyen and Ross, 2017). For example, ecosystem management which includes water systems, requires connecting different forms of knowledge between scientists and citizens. This includes a variety of local information to have a holistic understanding of the environment including traditional knowledge, recent situated understandings of water management practices and insights from individual experiences (Damman et al., 2019).


River in British Columbia © FoundrySpatial

Citizen science can be used to improve management practices by providing more frequent monitoring and data collection (Minkman et al., 2017). In addition, technologies such as robust, inexpensive and low-maintenance sensors or applications to instantly share and receive data provides more opportunities for engaging citizens in the field of complex water management. (Minkman et al., 2017). An example of this is in the **Northwest Territories in Canada**, where an open access tool, Mackenzie DataStream, was set up to support Indigenous communities to keep track of water quality issues to reduce further damage in the basin. Partner communities are actively monitoring the Basin's waters and contribute massive amounts of data that is used to understand the quality and health of the freshwater bodies in the Mackenzie River Basin. The tool brings together large amounts of monitoring information collected from various sampling points allowing users and communities to prepare reports and use the information to create protection plans and avoid the degradation of water resources in the Basin.

Citizen science can improve participants' knowledge and awareness which can increase confidence in both the quality of water and the water company (Brouwer et al., 2018). In a demonstration case in Oslo, citizens took part in long-term monitoring and evaluation of two solutions for treatment of combined sewer overflows (CSO). The citizens were involved in the different stages from design to observation to final evaluation and workshops. The process improved understanding of the potential benefits and social value associated with local CSO treatment on the river system (Damman et al., 2019).

The Source to Tap project in Ireland is another example of increasing awareness. The project cooperates with local residents through citizen science and volunteering which encourages participation in the protection and improvement of rivers and lakes. This is through providing training and establishing a community-led water quality monitoring initiative to protect their freshwater environment (The Rivers Trust, 2020).

In addition to current local knowledge, modern water management can learn a lot from traditional water conservation systems. Although, it is important to understand that practices are dependent on the local situations (Behailu et al., 2016). In **Mexico City**, there are ongoing activities to rehabilitate key ecosystem functions of the natural water cycle: this includes projects which promote chinampas, a pre-Hispanic farming system. These are plots of land surrounded by several channels for drainage: they are also known as floating gardens and are now used for floriculture and vegetable planting. This not only contributes to local food security but also provides green and blue infrastructure adapted to the metropolitan area of Mexico City.

A further example of integrating traditional knowledge into current water management is in India, where the government is making use of the traditional systems of water harvesting to adapt to changing rainfall patterns (Sanchari, 2016). Combining the traditional method of tank irrigation structures with modern rainwater-saving techniques, such as percolation tanks, injection wells and subsurface barriers, has the potential for providing water during dry periods (Sanchari, 2016). An example from a basin story is **Huzhou, China**, which is an important commercial centre with close ties to the wider landscape which is included in the greater metropolitan area. This includes the ancient Lougang irrigation and drainage system in the plains of Taihu Lake, China which was initially constructed 2500 years ago. The Lougang system is made up of canals, culvert gates and dykes which have been and are still used to control water drainage, irrigation and provide waterway transportation. Urban construction has increased siltation reducing the lake area and the function of the historic Lougang system. Since 2011, there have been efforts to restore the traditional landscape through dredging, riverbank restoration and land zoning which protects the traditional irrigation system. Further to these efforts, there has been promotion of the historical and cultural values of the irrigation landscape through tourism.

In Southern Ethiopia, Borana and Konso communities have well-structured traditional institutions that have sustained their water systems for more than five centuries (Behailu et al., 2016). In the Borana community, the traditional administration system which includes water management in is known as "Gedaa". The general assembly of the Gedaa meets every 8 years, and during this meeting every rule adopted in previous years is evaluated from the perspective of current community challenges. Water management is part of the agenda of the Gedaa general assembly and evaluates water management rules in general, and well management in particular as this is where the community gets their water (Behailu et al., 2016). Through this process, rules can be modified to adapt and deal with new issues.

6 - PLANNING

The pathways outlined in this section focus on approaches to planning where cities and their basins have an opportunity to cooperate to ensure sustainable water management. This includes:

- Having a risk-based approach to planning from catchment to consumer;
- Water allocation mechanisms which balance downstream and upstream needs, but also explore alternative sources;
- Alignment of urban development with basin resources and management; and
- The active involvement of diverse stakeholders in developing plans for water resource management.

Box 6. Key points outlining planning focused pathways for action to achieve basin-connected cities

- Prevention and preparedness actions are effective ways to build resilience when managing water resources for cities and their basins. This can be achieved through risk-based planning, which promotes a proactive approach to identifying, controlling and monitoring critical risks.
- Risk-based planning approaches, such as water safety planning as well as flood and drought planning, involves stakeholders across the water value chain in the management of drinking water quality and flows, actively linking urban stakeholders (e.g., water utilities, industries) with the catchment they rely on for water sources.
- Increased pressure due to urbanization, competing demands and climate change will create tensions over water allocation regimes and highlights the need for long-term strategies of sharing water between urban and rural areas.
- Water allocation mechanisms to share water resources between different users in rural and urban areas should be based on IWRM principles, which recognize the interconnection between upstream and downstream regions, and how changes in water quality and quantity in one area will affect the availability of resources in another. Municipalities and environmental protection agencies may need to play a role in resolving conflicts caused by water distribution or pollution.
- Aligning urban development with basin management is a step towards sustainable economic, social and environmental relations. The urban–rural interface can contribute a great deal to protecting cities against water risks such as floods, and enabling water security now and in the future, through cooperation between upstream and downstream users.
- Stakeholder participation in planning and management can create a dialogue between those that impact and are impacted by the quality and availability of water supplies to cities and other users.
- Water management requires not only stakeholder collaboration among scientists and policy makers but also the public. Such processes improve decisions as communities have more in-depth knowledge of the local conditions, increase effectiveness, increase public awareness, and provide platforms for the public to express their concerns.

6.1 – RISK-BASED APPROACH TO PLANNING

Prevention and preparedness actions are effective ways to build resilience when managing water resources in basin-connected cities, and the necessary steps to do this can include implementing a risk-based approach to planning (European Commission, 2014). Resilience “is the ability of a person, household, community, region, or country to resist, adapt, and recover quickly from stresses and shocks such as violence, conflict, drought, or other natural disasters”, without compromising its long-term development (European Commission, 2014).

Risk-based planning promotes a proactive approach to identifying, controlling and monitoring critical risks (Van Den Berg et al, 2019) and aims to reduce vulnerability and increase resilience through various measures. The approach helps authorities focus on key areas of importance, including public health, livelihoods, environment and the economy, and maximize the benefits that can accrue from limited resources (Van Den Berg et al, 2019; WHO and IWA, 2009).

Managing risks from catchment to consumer has several advantages including: development of more robust plans that can achieve their objectives; plan outcomes that are better defined and more effectively achieved; clearer understanding of risk and uncertainty, and their implications in water resources planning; and reduction in unforeseen circumstances and any consequent disruptions and costs (Black et al., 2015). Despite the importance for risk management, water companies do not always engage in their catchment areas, and control measures are often concentrated at the water intake points (Cross, 2015) as this may be where they have administrative jurisdiction.

Water safety planning (WSP) looks beyond administrative boundaries and responsibilities and provides a comprehensive risk assessment and risk management approach that encompasses all steps in a drinking-water supply chain, from the source to the end user (WHO and IWA, 2009). WSP involves stakeholders across the water value chain in the management of drinking water quality and flows, and can actively link urban stakeholders (e.g., water utilities, industries) with the catchment they rely on for water sources. Since the development of WSP, there has been a significant shift from mainly focusing on drinking water quality surveillance to ensure drinking water quality, to the additional inclusion of proactive, preventative risk management through the adoption of WSP (Hasan et al., 2021). For instance, 93 countries have implemented WSP, and 46 countries have incorporated WSP into policy or regulatory instruments, with 23 other countries having formal tools under development (WHO and IWA, 2017).

WSP can enable various stakeholders to jointly develop and implement relevant plans including drought response plans to reduce impact during extreme events. For example, Melbourne Water worked with Melbourne's three water retailers to jointly develop drought response plans to coordinate water supply system management. The basis of the Drought Response Plans included monitoring of storage levels, stream flow into reservoirs, catchment conditions and climate outlooks, and managing supply and demand actions (Cross, 2015). Another example is in Portugal, where Águas do Noroeste used WSP as a mechanism to work across the catchment, where a water intake point was adjusted to ensure continuity of supply. Awareness and communication with basin stakeholders were also necessary during spills or periods of eutrophication upstream. This allowed treatment control measures to be put in place before there was contamination at the intake (Cross, 2015).

Risk-based planning often focuses on dealing with the impact of extreme events such as flooding. An example of this is the Flood Action Prevention Programme known as the Programme d'Action de Prévention des Inondations (PAPI) established by the Syndicat Mixte d'Aménagement du Bassin de la Bourbre (SMABB), which is the organization responsible for the **Bourbre Basin, in France**. Urbanization is increasing the risk of flooding in downstream cities of the basin, and the PAPI outlined a set of actions to prevent, anticipate and manage the flood risk. This involved a wide variety of stakeholders to connect urban areas with their basin and also promote knowledge exchange amongst different services (e.g., urban planning with water services) and different sectors (environment, water, agriculture). The partnership with stakeholders paved the way for the development of a five-year land use planning programme (Flood Risk Prevention Plan), which gained the acceptance of the local community, to reduce risk of flooding in the downstream areas of the basin. These long-term strategies and plans to address risk and reduce vulnerability of the basin as well as increasing the awareness among different parties, has been the foundation to improve resilience.

As demonstrated in the Boubre Basin, it is essential that stakeholders work together across a basin to manage and plan for risks such as floods. **The Living Water Partnership in Yorkshire, UK** is an illustration of this type of cooperation. In 2007 and 2013, Hull and the East Riding of Yorkshire were severely impacted by flood events. These flood events served as a warning to put measures into place to manage the water risks of the area, including the essential need for risk management authorities to work together. As a response, the Living with Water Partnership was founded in which key stakeholders are working together to develop and deliver a master plan for the city which puts water resilience at its centre. The long-term ambition of the partnership is to work collaboratively with the public sector, private sector and communities to co-design and develop water sensitive urban regeneration which manages flood risk and enhances the environment and well-being of the region alongside flooding.

Risk-based planning can be supported by modelling scenarios. For example, in the Thames basin in the UK, a system simulation models estimates of the frequency, duration and severity of water shortages at present and in the context of future plans and scenarios. The proposed method provides evidence with which to develop water resource management plans that balance the risks of water shortages, costs to water users and environmental constraints in an uncertain future (Hall et al., 2020).

6.2 – WATER ALLOCATION MECHANISMS TO SHARE WATER RESOURCES

Sharing water is a major challenge in the 21st Century. Water resources are allocated to ensure that water is available for human consumption, sanitation, energy and food production as well as the environment. Societies have invested in infrastructure to maintain this allocation, but due to various global changes these allocations need to be adjusted (Lasserre, 2006). The main issue is that water allocation mechanisms need to account for high variability of the resource and that water sharing tools must integrate risk management mechanisms. As water becomes increasingly scarce, it is essential to consider it as an economic asset for better allocation, since its use or consumption by competing sectors or groups is also growing (Fondation 2iE, 2010).

Water allocation mechanisms to share water resources between different users in rural and urban areas should be based on IWRM principles, which consider how changes in water quality and quantity in one area will affect the availability and quality of resources in another. For example, abstraction for energy and agricultural purposes can impact the available drinking water supply in urban areas. Climate change creates additional uncertainty, thus allocation of water across multiple sectors should follow a flexible strategy and where feasible identify alternative water sources (Raschid-Sally et al., 2013).

San Francisco (USA) is facing such uncertainty with natural disasters and climate variabilities, including severe floods and droughts. To respond to these challenges, OneWaterSF was established by the San Francisco Public Utilities Commission (SFPUC) as an integrated planning and implementation approach to manage water resources for long-term resiliency and reliability, meeting both community and ecosystem needs. This is essential as 85% of San Francisco's water supply is located over 250 km away in the upstream catchment. Part of the OneWaterSF approach is to recognize the value of both local water supplies and high-quality groundwater located within San Francisco. The San Francisco Groundwater Supply Project reduces dependence on the regional water system and supplements surface water supply. A second highlight from OneWaterSF has been rainwater harvesting from small rain barrels to large cisterns, which reduces the use of potable water for irrigation and helps reduce runoff from entering the combined sewer system during storm events. A third area has been in reducing potable water consumption by collecting wastewater and greywater for non-potable applications, such as toilet flushing and irrigation. Furthermore, with growing scarcity of water, and wet years interspersed with extended periods of drought, the SFPUC is advancing the science of purified water with a pilot project that takes treated wastewater from within the SFPUC headquarters and further treats it to meet drinking water standards with advanced technologies.

As in San Francisco, **Windhoek, Namibia** has numerous measures and stakeholders involved to plan and prepare for future water crises in the arid city, which has a growing population that is facing more frequent droughts. Surface water supply is currently augmented by direct reclamation, and groundwater use under a managed aquifer recharge scheme. However, the only long-term solution to sustainably ensuring supply to Windhoek is to import freshwater supplies from other basins. One option is abstracting water from the Okavango River; however, the risk with this is that: 1) the upstream neighbour Angola is pushing agricultural development in the relatively unused area around the river's headwaters, decreasing the amount of water flowing towards the downstream riparian states; 2) a reduced flow into the world heritage site of the Okavango delta might negatively affect this precious ecosystem, which could bear the risk of a potential conflict with Botswana. Due to these issues, the import of water from other basins must be kept to a minimum in order to keep water affordable; and all locally available water resources must be used as efficiently and optimally as possible. Water demand management is necessary to achieve this especially during drought periods. During a drought in 2016, consumption was reduced by 35% and highlighted the need for permanent demand reduction to a level suitable for an arid environment.

Agricultural and rural regions are often prime sources of water for cities once local and lower cost sources are no longer available (Garrick et al., 2019). Increased pressure due to urbanization, competing demands and climate change will create tensions over water allocation regimes and highlights the need for long-term strategies of sharing water between urban and rural areas (Newborne, 2016; Civitelli and Gruère, 2017). In many river basins, allocation plans have to deal with historical water provisions as well as the future changes that are likely to modify water availability due to climate change. To provide for this, water is often reallocated away from existing agricultural users to supply water for growing urban and industrial uses with a higher economic value (Speed et al., 2013).

To effectively carry out allocation or reallocation, there needs to be clear, accessible and transparent information. The **British Colombia Water Tools, in Canada**, provide information on water supply and demand to be considered in decisions regarding water allocation. The tools provide information that would be extremely time-consuming to assemble and compile. People can become informed more quickly on water use pressures and proceed with more detailed data collection or analysis where needed to. The outcome of the tools is that to increase transparency and democratize knowledge from catchment to tap allowing all parties to engage in discussions around allocation and water use from a more informed perspective.

6.3 – ALIGNING URBAN DEVELOPMENT WITH BASIN MANAGEMENT

"Urban water management is now on the verge of a revolution in response to rapidly escalating urban demands for water, as well as the need to make urban water systems more resilient to climate change. Growing competition, conflicts, shortages, waste and degradation of water resources make it imperative to rethink conventional concepts – to shift from an approach that attempts to manage different aspects of the urban water cycle in isolation to an integrated approach supported by all stakeholders."

Dr Mohamed Ait Kadi, Chair, GWP Technical Committee (Bahri, 2012)

As cities grow so does the demand for food, energy and water from their surrounding areas, thus urban water management should be clearly articulated within basin management planning and implementation (Van den Brandeler et al., 2019). Furthermore, an efficient and environmentally sensible urban water management system needs to consider the interaction and coordination of urban and rural water uses (Civitelli and Gruère, 2017). For example, the water used by downstream users can be impacted by upstream activities, and municipalities and/or regional governments may need to play a role in resolving conflicts caused by water distribution or pollution. Approaches such as Integrated Urban Water Management (IUWM) have the objective of aligning urban development with basin management to ensure sustainable economic, social, and environmental relations along the urban-rural continuum (GWP, 2013).

Water supply, sanitation, stormwater and wastewater are managed by isolated entities, and all four are separated from land-use planning and economic development. IUWM calls for the alignment of urban development and basin management to achieve sustainable economic, social, and environmental goals (Bahri, 2012).

Metropolitan regions especially megacities are extremely complex as there are numerous mayors concerned with the interests of constituents in their jurisdictions; however, actions across the region impact the wider basin. Improved coordination is needed between local governments to protect catchments, allocate water, and manage drainage in urban and surrounding rural areas (Van den Brandeler et al., 2019). Cities can target their policies in a way that national or regional schemes may not be able to, for example using sustainable urban drainage at the local level to reduce localized flooding. At the same time, the urban–rural interface can contribute a great deal to protecting cities against water risks such as floods now and in the future, at least cost to society (Civitelli and Gruère, 2017).

This is demonstrated in the **Boubre Basin**, located in the Rhone Basin in France, where continuous urbanization and development within the basin over the past years has led to an increased risk of flooding. Dealing with the problem of floods needed integrated water management and a holistic approach that can look beyond one municipality. The Flood Prevention Action Programme (PAPI) led by Syndicat Mixte d'Aménagement du Bassin de la Bourbre (SMABB) and involving municipalities, connected both urban and rural stakeholders across the basin. PAPI has succeeded in increasing the farmers' awareness and acceptance for constructing flood protection measure on their lands that protect the downstream cities.

Large-scale projects at the basin level are often put in place in part to protect and restore water quality in cities. To restore the natural hydrology and hydrodynamics of the river network within and around **Shaoxing, China**, an urban and rural four-level river-network was developed. More than 20 billion yuan was invested in the comprehensive improvement of Cao'e River's main and branch rivers, such as the Huancheng River, the ancient canal, the inland river of the city. The aquatic environment was improved through river desilting, constructing retaining walls, sewage retention, removing sand mining and creating green areas. Clean water from Cao'e River was diverted in 2007 into the urban river network, thus improving the Huancheng River's hydrology, hydrodynamic condition and water quality. In 2008, the Cao'e River Sluice (the biggest estuary sluice in Asia) was completed to control flooding and tidal bores.

In Dakar, Lisbon, Kinshasa and Brazzaville, and Fez there are various initiatives to address pollution from urban and industrial areas to improve water quality in these cities and the surrounding catchment areas. In the case of **Dakar, Senegal**, an important storm-water retention basin inside one of the city's 19 districts has become a cesspool where untreated wastewater and solid waste were disposed due to continual urbanization around the basin and poor upstream management. A partnership with the Cities Finance Facility (CFF) is supporting the reintegration of infrastructure into the natural and historical hydrological functioning of the watershed. Flagship actions include redirecting wastewater to be treated with nature-based infrastructure on site; reshaping of the retention basin topography in order to enhance its hydraulic performances (volume) and allow water to flow freely out of the basin; and creation of a functional recreational space.

The city of **Fez, Morocco** has similar issues with urban and industrial pollution affecting receiving waters and the surrounding catchment. Most industries in the city, some of which are very polluting (oil mills, tanneries, etc.), do not have treatment or pre-treatment systems meaning that that are fluctuating pollutant loads, and serious pollutants such as heavy metals entering the environment. Effluents from the city drain into the Sebou Wadi which impacts water use downstream including: disruption of drinking water production; generation of additional treatment costs; impacts on the quality of irrigation water along the Sebou River; the need for water releases from upstream dams to dilute and absorb pollution peaks; and the degradation of the fauna and flora. An industrial pollution control programme was established by the partners concerned, including the Basin Agency, leather industry, local, regional and national government. The involvement of industry was essential for the success of this programme in recognizing the impact of urban industry on the wider catchment.

Addressing pollution at catchment scale is also being explored in **Kinshasa (DRC) and Brazzaville (Republic of Congo)**. The cities are separated by the Congo River which is heavily polluted due to a lack of sanitation infrastructure as well as regulation of discharges impacting the water quality and health of both people and environment within the urban areas and downstream. A series of initiatives supported by Alliance of Megacities for Water and Climate (MAWaC) are underway to install sewage sludge treatment in the province of Kinshasa and the city of Brazzaville along with training for its operation, as well as a legal framework in order to put in place standards for discharges and user fees. Ultimately, this project will reduce pollutants and promote the circular economy by reinjecting money from resource recovery into the economy.

An example of aligning urban and basin management at a larger scale is in the **Tagus estuary near Lisbon, Portugal** which has been greatly impacted by the concentration of densely urbanized areas and industrial clusters. The Águas de Portugal Group led the Tagus Estuary Clean-up Project over 15 years, benefiting more than 3.8 million inhabitants, and gathering together three wastewater companies and 19 municipalities surrounding the estuary. The project incorporated an integrated supra-municipal governance model that considered the physical reality prevailing in the river basin. The governance approach included convening skills, shared management of assets, reorganization of these assets, construction of multi-municipal infrastructure (serving more than one municipality) and enabling economies of scale.

Part of the urban–rural alignment is around the effective management of water resources locally and in the wider catchment. Circular economy approaches may be easier to design and implement through this multi-scale vision. The reuse of wastewater and nutrient capture included in city water management can reduce costs of wastewater discharge and capture economic potential of nutrient re-use. Wastewater can be regarded as a resource providing reuse opportunities for urban irrigation and groundwater replenishment, and the integration of infrastructure and institutions should link wastewater to the urban water cycle (Schussel and Nascimento Neto, 2015). It does not need to be simply discharged outside the city boundary.

An example of this approach is being implemented by the **San Francisco Public Utilities Commission (SFPUC), in the USA**, through "OneWaterSF" which is moving away from operating within traditional water, wastewater and energy boundaries to more holistic resource management. Some highlights include taking advantage of local water supply through groundwater projects, rainwater harvesting and water recycling. The scope for sustainable water management, however, exceeds the city boundaries. Both upstream and downstream catchment areas are included in the strategic planning and management of water supply and nature conservation through the "Watershed and Environmental Improvement Program" (WEIP). The programme is permanently protecting watershed lands, which includes enhancing public awareness of watershed resources, their protection, and restoration. In line with the OneWaterSF, SFPUC is also feeding nutrient-rich bio-solids from wastewater processing into surrounding farmland which not only acts as a fertilizer but also is a way to combat climate change by making California more resilient to droughts.

Another example of local urban water management aligning with basin management is in **Windhoek, Namibia**'s capital. Located in the dry and hot central highland, the city's water demand outstrips both conventional (rivers and dams, groundwater) and unconventional (desalination, managed groundwater recharge, water reclamation) water resources. Inter-basin transfers are being considered including from the bordering perennial rivers or desalinated seawater but involve huge capital investments and operational costs, as well a high level of risk impacting the environment. Other more locally focused measures include direct reclamation of wastewater which makes up 25% of supply, along with managed aquifer recharge. Storing excess water in aquifers during times of high rainfalls underground where losses are minimal is a way to improve urban resilience during droughts.

6.4 – STAKEHOLDER PARTICIPATION IN PLANNING AND MANAGEMENT

Multi-stakeholder dialogues provide opportunities for a wide range of actors across a basin to participate in identifying and in promoting policies and coping strategies to reduce the impacts of global change and change from the regional through to the community level (Huntjens et al., 2016). This includes enabling stakeholder participation in planning and management with those that impact and are impacted by the quality and availability of water supplies to cities and other users. Involving stakeholders is an important step to ensure that catchment management plans take into consideration local needs, experiences and interests (Sabina and Stanghellini, 2010).

Water management and planning needs multiple experts with knowledge of ecological, social, business, education, construction, community, and political perspectives (Woldesenbet, 2020). Engaging all sectors in understanding and translating the basin status and involving them in the decision-making process creates an enabling environment for changing people's behaviour, while shedding light on economic opportunities.

An example of multi-sectoral engagement is the **Büyük Menderes River Basin (in Turkey)**, where a management committee was established to prepare river basin action plans and flood and drought management plans, as well as monitoring plans. This committee is a multi-stakeholder committee from different sectors such as water utilities, municipalities, representatives of the Ministry of Environment and Urbanization, universities and the organized industrial zone management. These diverse water stewards are close to the actual problems and also aware of the status of polluters. Their core functions are to prepare river basin action plans, flood and drought management plans, monitor prepared plans and also prepare further plans and actions if needed.

In the case of the clean-up of the **Tagus River and its estuary near Lisbon, Portugal**, the process involved 19 municipalities and required active engagement of all stakeholders at each step, from strategy and planning to infrastructures construction and asset management, as well as the public and industries awareness. Led by the Águas de Portugal Group, the Tagus Estuary clean-up project addressed the high level of pollution and environmental degradation. The project included an expansion of the wastewater treatment plant incorporating green infrastructure; construction of a wastewater drainage system along Lisbon's waterfront area; and construction of several new WWTPs near some of the most important industrial districts, nature reserves and tourist areas.

In the **Densu River Basin in Ghana**, a basin board plays a key role in coordinating stakeholder interests. The Densu River Basin serves as a source of drinking water for 74% of the population in Greater Accra, however, the water quality is adversely affected by inappropriate waste disposal, agrochemicals, and degradation of the riparian zone (among others). The Water Resources Commission, established the Densu Basin Board (DBB) to facilitate joint efforts for better water management and improve capacity of stakeholders in the basin, thereby improving the quality of water in the river to benefit consumers. The basin traverses about 13 local authority boundaries, and the members of the public were chosen through a consultative process. The DBB plays an advisory and consultative role in the management of the Densu River with implementation through a secretariat under the Water Resources Commission. In general, the presence of the DBB and its monitoring activities within the basin has increased awareness in various communities on the need to sustain environmental conservation practices.

Water management requires not only stakeholder collaboration among scientists and policy makers but also the public who may not have any specific water-related knowledge (Woldesenbet, 2020). By working in collaboration, research design by scientists can meet policy/community needs, and communities and policy people learn the value of scientific research (Fenemor et al., 2011). The United Nations Economic Commission for Europe (UNECE) Aarhus Convention which establishes the right for everyone to receive environmental information and participate in environmental decision making, outlines four key benefits of public participation. Firstly, public engagement processes improve decisions as communities have more in-depth knowledge of the local conditions. Secondly, inclusion of those interested or affected by decisions in the actual implementation helps in it being more effective. Thirdly, participation increases public awareness. Fourthly, providing platforms for the public to express their concerns and having them addressed is empowering and increases trust and confidence in participatory processes. It is also important to ensure participatory approaches are not dominated by one group and take into account heterogeneity (Jiménez et al., 2019). On the final point, online platforms developed as a result of COVID-19 have enabled far greater participation from a range of stakeholders and numbers of people able to be engaged. The positive aspect is that this has allowed a wider range of actors to access and engage with public platforms, but this interaction can lack the depth and connection of face to face meetings.

Yarra River in Melbourne, Australia
© Denise Jan

Solutions that are developed with stakeholders are more likely to lead to appropriate actions, to promote flexible and adaptive working practices, and to foster and strengthen the development capacity of local organizations and communities (UN, 2010). In the case of **Melbourne in Australia**, Melbourne Water manages water resources on behalf of the community and has led a series of strategic conversations with stakeholders and the community across the region to identify the best ways to respond to these complex challenges and associated opportunities, in order to keep Melbourne a liveable, water sensitive city. As the city faces several climate risks from drought to intense rainfall to sea level rise, several strategies have been co-developed with the community on (a) Flood Management, (b) the Water System, (c) Drinking Water Quality and (d) Healthy Waterways. Their development and implementation are supported by place-based "Integrated Water Management Forums" which brings stakeholders together to discuss challenges and collective solutions.

Similarly, Barwon Water in the state of Victoria's south-west and including Geelong, Victoria's second largest city, has established community conversations to have a broader understanding of community attitudes to water management. More broadly the Victorian State Government sets the water resource allocation framework through the development of Sustainable Water Strategies (Victoria State Government, 2021).

In **Dakar, Senegal** public participation allowed more active involvement in understanding issues related to the Grand Yoff storm-water retention basin, and future involvement in rehabilitation of this basin. The Grand Yoff storm-water retention basin in one of the districts of Dakar has had issues of flooding water quality and drainage. In the process of rehabilitation of the retention basin, the needs and concerns of different stakeholder groups, such as private sector, government and civil society, were collected by the City of Dakar and discussed in participatory dialogue workshops, and consequently included in the redesign of the basin. Participatory engagement allows stakeholders to have a better grasp of the wider issues across the basin and increases their involvement in the preparation and implementation of the project. For example, stakeholder groups are defining and contributing to actions, such as establishment of a monitoring committee, awareness campaigns and clean-up of the basin area.

7 - IMPLEMENTATION

This section outlines implementation approaches that support cities and their basins to become better connected. This can be through:

- The use of financing mechanisms such as where downstream users compensate upstream stakeholders for activities that sustain water quality and quantity;
- The integration of nature-based solutions (NbS) within the catchment and urban areas to improve water quality and reduce the impact of extreme events;
- Creating partnerships that build trust and cooperation to effectively share and manage water; and
- The use of digital technologies to improve monitoring and management.

Box 7. Key points outlining implementation focused pathways for action to achieve basin-connected cities

- Financing mechanisms which support payment for watershed services can also create governance structures that allow downstream stakeholders to support and incentivize source watershed protection on lands owned and managed by those living upstream.
- Payments for watershed services (PWS) are schemes that use funds from water users (including governments) as an incentive for landholders to improve their land management practices and connect basins and cities to protect water resources. They have been regarded as a promising approach to coordinating the interests of upstream and downstream ecosystem services stakeholders. There need to be processes in place to implement activities to protect the catchment, monitor investments upstream and measure their impacts.
- Integration of NbS within cities and their basins can reduce nutrient leaching and erosion/sediment runoff and improve the health of watersheds to provide better water quality and flows.
- Investments in upstream NbS can reduce the costs of operation and maintenance of urban water utilities, improve service quality and delay the need for expensive capital investment to improve or expand services.
- NbS can assist in formalizing and activating partnerships across a catchment including national and local government, local stakeholders and community-based organizations, the private sector and donor agencies.
- Partnerships can provide a foundation for building trust across organizations in urban areas and their wider basins, and be used to solve local water challenges, pool expertise and resources, and leverage financial resources.
- Digital technologies support availability and access to information (e.g., real time data and forecasting) across the water sector from upstream water management to urban consumers.

7.1 – APPLICATION OF FINANCING MECHANISMS

Urban water security relies on external water resources for urban water supply and food imports for urban food supply (Hoekstra et al., 2018). These external water resources are usually from the surrounding basins and need investment to secure quality and supply. Firstly, water service fees to cover financial costs and ensure minimum water security provide the user with information on the cost-of-service provision, indicating the value of the resource. Secondly, revenues from tariffs provide financing for measures to provide water security, including water resources protection, maintenance of infrastructure and ensuring service delivery (Aboelnga et al., 2019). Water funds, eco-compensation and other similar investments in watershed services programmes, not only provide finances but also create governance mechanisms that allow downstream stakeholders to support and incentivize source watershed protection on lands owned and managed by those living upstream (Michell, 2018).

For example, eco-compensation, which is being implemented in China, is a package of different mechanisms, including monetary subsidies and project support. Governments use these mechanisms to compensate those who invest money or suffer economic losses in protecting ecosystems (often landowners or resource managers in the upper watershed) by transferring resources from those who benefit from or damage them (such as consumers of potable water and industries or agriculture using water downstream) (ADB, 2016; IWA, 2019). This approach effectively connects basins and cities to protect water resources. However, there are several challenges to promote and disseminate eco-compensation mechanisms. These include putting in place systems to monitor restoration of degraded ecosystems; and incentives for local governments to put a high priority on effective implementation of eco-compensation, such as policies and guidelines. (ADB, 2016; IWA, 2019).

An approach that is driven partly by the regulators is in **Peru**, where Superintendencia Nacional de Servicios de Saneamiento (SUNASS), the national water regulator, together with water utilities and other stakeholders are working to introduce principles and practices to create water wise basins. The main source of water resources in Peru are river and lake basins which start in the Andes. In Lima, for example, more than 50% of the water comes from the Mantaro River through a transfer that crosses the mountain range, and the rest comes from Chillon, Rimac and Lurin river basins. The ecosystems located upstream of these river basins are a source of the services that generate water but are being degraded by land change use, like agriculture and cattle, especially in large cities where the population is rapidly growing. The use of fertilizers and chemicals in rural and mining areas, illegal waste dumping and infrastructure deterioration are also contributing to the degradation of basins. The Mechanisms of Rewards for Ecosystem Services (MRSE) is helping to address the issues around deteriorating water quantity and quality.

SUNASS in cooperation with the Ministry of Environment and water utilities has implemented a series of norms as part of the MRSE at basin and national level to mobilize funds from downstream users, through a percentage of the water tariff, to upstream providers for the conservation of water resources and the basins where they come from. Stakeholders work through a voluntary agreement (Acuerdo voluntario) where those receiving benefits of ecosystems services (beneficio) provide rewards (retribucion) to stakeholders who contribute to ecosystem services. With these rewards the contributors to ecosystem services are able to conserve, recover and promote the sustainable use of natural resources. These rewards can be (but are not limited to): 1) community capacity building in agriculture, raising cattle livestock or other sustainable activities which do not impact ecosystem health; 2) building basic sanitation services with the condition that the degraded ecosystem is protected/restored 3) environmental education and 4) providing technical capacity in sustainable tourism.

Since the introduction of the MRSE, utilities have been collecting fees for water use and allocating them to different projects for the recovery and rehabilitation of the basin. An example of the MRSE in action is at Piuray Lake in Cusco. During the first phase of the programme, fees and investments were allocated for projects focused to increase the water quality at the lake and at the same time the quality of life for people in the community of Piuray – Ccorimarca, by implementing sanitation and water supply networks. In the second phase of the programme, fees are being used in land conservation projects, land and water use, and design and use of hydrological monitoring systems.

An example of a well-established Water Fund is in Quito, Ecuador where the city’s water supply is derived from the Andean mountain systems, including protected grasslands known as páramos. The fund is known as Fondo Ambiental para la Protección de las Cuencas y Agua (FONAG) and was initiated in 1997, when the Nature Conservancy (TNC) and partners began negotiations with the Municipality of Quito and the water utility to evaluate sources of sustainable financing for natural infrastructure investments surrounding the city. It has been designed as an endowment fund that receives money from public utilities, private companies and non-government organizations. It is “non-depleting” meaning the original endowment is not invested in green infrastructure. Rather, the financial returns made upon this endowment are used to finance water conservation activities in the water supply catchment. In 2006, a Metropolitan Ordinance was passed, requiring the water utility to provide a permanent contribution of 2% of their annual budget to the fund. By 2013, financial contributions increased to approximately USD 1 million per year, and as of 2019 FONAG now has an endowment of nearly USD 18.7 million and an annual budget of USD $2.5 million (Ertel et al., 2019).

A more recently developed Water Fund is the **Upper Tana-Nairobi Water Fund (UTNWF)** set up in 2015 by TNC, in collaboration with the government and other partners to finance and educate the farmers upstream on sustainable farming practices. Ninety-five percent of Nairobi’s freshwater supply comes from the Tana River, which originates in the highlands above Nairobi. The highlands are home to more than 100,000 smallholder farmers who rely on the river for irrigation water. Since the 1970s, due to agricultural activities on the upper reaches of the river, there has been increased abstraction and siltation, which inevitably impacted downstream communities, ecosystems and activities, including reduced water supply to Nairobi, hydropower generation and water quality. In an effort to reverse the deteriorating condition of the river, the Upper Tana-Nairobi Water Fund was established. The premise behind the water funds is that it is cheaper to invest in protecting water at the source (upstream) than it is to address water problems when they occur downstream.

Using state-of-the art planning and watershed modelling tools, the business case outlined the return on investment that funders can expect. It lay the groundwork for how benefits will be realized, specified timeframes and guided the implementation process. In planning for the UTNWF, the economic impact of different land conservation interventions was modelled for three key basin stakeholders: smallholder farmers; Nairobi City

Water & Sewerage Company (NCWSC) and Kenya Electricity Generating Company (KenGen). Land conservation measures further upstream in collaboration with smallholder farmers were deemed to hold mutual benefits. For example, reduced soil erosion is projected to increase agricultural yields and to increase water quality further downstream towards Nairobi. Scientists estimate that several million more litres of water are available for Nairobi each day as a result of on-farm activities to retain soil and to reduce water extraction from the river.

Another example of using water tariffs to secure water supply is in the **Guandu Basin in Rio de Janeiro State in Brazil**. The Strategic Water Resources Plan developed by the Guandu Committee includes a Green Infrastructure Agenda with a range of actions including the Water and Forest Producers project. The project adopted a payment system for environmental services which provided financial compensation to rural producers who were actively conserving forest remnants of the Atlantic Forest on their properties. Their conservation practices contribute to the provision of ecosystem services, bringing benefits to the hydrographic basin and to its population, reducing the pressure on the water sources. To determine the amount to be paid per hectare of conserved forest, indicators that reflect the condition of conservation of the forest remnants are considered. In addition, the conservation practices applied in consideration of the property management characteristics, give greater value to properties with a greater potential for the provision of environmental services.

The Water and Forest Producers Water Fund has been supported by the Green-Blue Water Coalition, a TNC initiative in collaboration with key Brazilian companies from different sectors, and civil society and the Latin American Water Funds Partnership. Today, the financial resources for payment for environmental services providers and forest restoration actions come from the billing system for the use of water in the Guandu river basin, with the Guandu Committee as the intermediary. In addition to compensating producers who dedicate themselves to providing environmental services, the project contributes to the socioeconomic and environmental development of the region.

Annually, the Guandu Committee allocates approximately BRL 360,000 to the payment of producers in the project. Since its creation, approximately BRL 2.8 million have been invested by the Guandu Committee for implementation and monitoring activities. Currently, the project has the participation of 74 rural properties, which has led to the conservation of 4,098 hectares of the Atlantic Forest and the restoration of 507 hectares of deforested areas.

An approach that further illustrates the use of water fees or environmental taxes for improving water quality and quantity is in France. Water Agencies oversee collection of fees from economic sectors (industry, household, agriculture) who abstract water or discharge polluted water. They also provide subsidies or soft loans to municipalities and industrial or agriculture units who invest in pollution reduction. Over time, the use of fees has shifted from a sole focus on building treatment infrastructure to one that incorporates natural and urban ecosystems. Water agencies use financial resources collected to both modernize the drinking water networks but also to combat diffuse pollution and protect the aquatic environment. For example, support is provided to local authorities for restoring and protecting aquatic environments, in particular waterways – revegetation, ecological continuity – and wetlands. This assistance reduces the pressure on local finances, and by extension the price of water (French Ministry for the Ecological and Solidary Transition, International Office for Water, French Water Partnership, 2020).

A final example from Calgary, Alberta in Canada, involves monetizing existing and new licences for water abstraction. It was found that the provincial government had over-allocated water over decades of development, and there was not enough water to sustain the ecosystem health of rivers. The solution was to no longer approve any new licence applications to abstract volumes/flows of water for human use (potable, industrial, irrigation etc) from the South Saskatchewan River (includes the Bow River which runs through Calgary). New requests for water required purchasing a licence or part of a licence from a person or party (e.g., a city, or irrigation district) who already held a licence. To further ensure that there was sufficient water for the environment, the provincial government has the option to invoke a 10% holdback. This means that 10% of the total volume of a licence can be claimed by the province and returned to the river to help move towards more sustainable environmental flows (Clipperton et al., 2003; W. Koning, personal communication, February 2nd, 2022).

7.2 – INTEGRATION OF NATURE-BASED SOLUTIONS

There is a growing interest for a range of solutions inspired by nature, under different terminologies. The overarching term nature-based solutions (NbS) is defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016). There are various approaches (and terminology) for integrating NbS such as eco-engineering, use of green or natural infrastructure, ecological rehabilitation, Sustainable Drainage Systems (SuDS), Natural Water Retention Measures (NWRM), etc. (FWP, 2017; Browder et al., 2019).

Many of the basin stories mentioned in this handbook include investment and application of NbS as part of linking cities with their catchment areas. These solutions should be part of a global, participative and integrated approach and can be combined with institutional and technical solutions, to respond to the specific needs and constraints of various localities. Approaches include integration of NbS to improve the health of watersheds, reduce nutrient leaching and erosion/sediment runoff is a fundamental part of creating a basin-connected city. Furthermore, links to climate forecasting and economic modelling can drive management changes at farm and landscape level. It is important to have monitoring mechanisms in place to continually assess and validate the benefits of these solutions.

There is increasing interest of urban stakeholders including the water supply and sanitation sector authorities, local governments and water utilities in the application of NbS through watershed management, for the protection of urban water supply sources. Water quality and quantity can be improved and secured for cities through approaches, such as land protection, reforestation and riparian restoration (UN-Water, 2018). Such investments in upstream NbS can reduce the costs of operation and maintenance of urban water utilities, improve service quality and delay the need for expensive capital investment to improve or expand services (Echavarria et al., 2015).

In the famous case from the Catskills areas upstream of New York City initiated in 1997, the costs of investing in watersheds to maintain and restore natural filtration were much lower than building new treatment plants (Smith et al., 2006). There are now three protected areas which saves New York City more than USD 300 million per year on water treatment operation and maintenance costs and has saved an estimated USD 8 and 10 billion in the cost of building a water treatment plant (Abell et al., 2017).

An example from the basin stories of investment in NbS upstream is in **Peru** which was outlined in the Pathway on "Application of financing mechanisms", here the focus is on how the NbS are put into practice. Since the regulator SUNASS introduced the Mechanisms of Rewards for Ecosystem Services (MRSE) across Peru, utilities have been collecting fees for water use and allocating them to different projects for the recovery and rehabilitation of the basin. Fees are being used to improve sanitation and water supply networks in the upstream communities and in land conservation projects, land and water use, and design and use of hydrological monitoring systems.

In Moyobamba, the MRSE has been implemented from 2008, and since then 153 hectares of forest have been restored in the Mishquiyacu, Rumiyacu and Almendra basins (which provides 80% of water for the population in the city). The success in Moyobamba is such that fees have planned to be collected over 5 years to continue with the reforestation and conservation projects of basins.

In larger urban areas as in Lima, SUNASS and utilities have recognized threats to the water quality and quantity in their catchments (Chillon, Rimac, Lurin and high Mantaro Basins), including soil erosion, overuse of water resources, high water treatment costs, etc. To reduce the threats and their impacts, the water utilities have introduced for the first time an optimized plan that is running from 2015 to 2020 which seeks to create reserves to protect basins and at the same time to guarantee the availability of the water resources.

The **Upper Tana-Nairobi Water Fund (UTNWF)** was also mentioned in the Pathway on "Application of financing mechanisms" and is a driver for the city of Nairobi to shift from solely investing in grey infrastructure (water treatment plants and reservoirs) at the urban level to investing in green infrastructure. A restored watershed yields enhanced water storage capacity and improved water quality through natural filtration and retention of sediment. To help meet conservation and restoration goals, the UTNWF identified vulnerable farmland (e.g., established on steep slopes or in riparian buffers) in the sub-watersheds from which much of Nairobi's drinking water is derived and that contribute to Kenya's main hydroelectric dams.

Through the work of the Water Fund, thousands of farmers are engaging in soil and water-saving methods and sediment/pollutant reduction techniques such as rainwater harvesting, drip irrigation, terracing, planting permanent grass buffers along streams and agroforestry. The UTNWF partners have been providing the farmers with the skills, training and resources needed to conserve water, reduce soil runoff and improve productivity.

The Water Fund has been able to help 8,500 coffee farmers earn Rainforest Alliance Certification for conservation measures. These efforts have translated to increased yields of over 40% for the farmers. Along this timeline, 80 km of riverine vegetation has been restored, and over one million trees have been planted in the watershed, with 65 schools actively engaged in conservation activities locally.

Another example of upstream connectivity to urban areas through NbS is in the **Guandu Basin in Rio de Janeiro State, Brazil**. As mentioned in previous pathways, the Guandu Basin has a Strategic Water Resources Plan divided into eight Thematic Agendas. Among the Thematic Agendas, the Green Infrastructure Agenda has had significant investment by the Guandu committee. The Water and Forest Producers project is part of the Green Infrastructure Agenda and has a payment system for environmental services outlined in the Pathway on "Application of financing mechanisms". The project also includes forest restoration actions, recovering and protecting water sources, springs, riparian forests and other priority areas, promoting the gradual alteration of the soil cover, mitigating erosion processes and recovering the native forest.

Forest restoration is being used as a strategy for the provision of environmental services, such as erosion control, increasing soil infiltration rates, mitigating the effects of floods and regulating water flows. As the water present in the water bodies is the result of soil use conditions across the basin, water quality and flows can be impacted by deforestation and conversion to agricultural land. For this reason, there is a prospect of expanding the Water and Forest Producers project to areas for crop production, where farmers would be encouraged to adopt conservationist practices in order to improve the provision of ecosystem services and also the productivity and profitability of their property.

Forest restoration efforts are not just about planting trees but also need to consider the use of native species. On the island of Madeira, Portugal, sudden flash floods in 2010 left the city of Funchal devastated with significant damage to infrastructure and loss of life. In the recovery efforts funded by the EU, pine trees on the mountain tops are being replaced by nearly two million endemic species, which are more resistant to forest fires and better at storing water (Cebrián, 2018).

As well as large-scale NbS, the implementation of localized NbS within cities themselves offer additional opportunities for meeting multiple water management objectives. Urban green infrastructure, from the revegetation of impermeable surfaces to green roofs and constructed wetlands, can improve water availability, water quality and flood reduction (UN-Water, 2018).

In **Porto, Portugal**, rapid urban growth has led to significant pressures on water resources. More than 75% of the streams in Porto were piped and buried to allow construction of new buildings, leading to degradation of water resources. A strategy to rehabilitate these streams was designed to complement the water sensitive urban design (WSUD) and improve the citizens´ quality of life. The NbS put in place included stabilization of stream beds and banks to enable geomorphological processes to reduce erosion and improve flow control; retention of stormwater in the landscape to reduce flooding; planting new trees along the streams banks and creating new riparian zones with native species; make the riparian corridors accessible to the public for recreation and well-being. The uncovering of three urban stream sections and the rehabilitation of the green corridors adjacent to these streams brought back the connection between water bodies and citizens. With one of the interventions, the stream daylighting allowed the creation of a large retention basin to accommodate the excessive flow and therefore contributed to minimize frequent flooding problems.

Local NbS solutions can also support improved water management of downstream environments. For example, the flood management potential of the Grand Yoff storm-water retention basin in one of the districts of the city of **Dakar in Senegal** has significantly been reduced due to a lack of maintenance, sedimentation and uncontrolled vegetation. During heavy rains, the basin often overflows which results in flooding around the catchment area with contaminated water. To address these challenges, the City of Dakar is developing a multi-tiered retention basin which will fill up incrementally improving its function, reducing flood risks in Grand Yoff as well as integrating it within the urban fabric. It is planned for a section of the basin to be transformed into a park that can be used for recreational purposes during dry months and will be submerged – partially or entirely depending on intensity of precipitation – during the rainy season.

NbS implementation within a city to reduce downstream flooding is also exemplified in the city of **Cuenca in Spain**. The Júcar and Moscas rivers pass through Cuenca (which is a World Heritage Site), which has a high risk of flooding. Collaboration between the Cuenca City Council and the Confederación Hidrográfica del Júcar (CHJ) is implementing a project which includes NbS to reduce the flooding risk in the area and to contribute to environmental improvement.

To reduce flood risk, the project aims to improve the general ecological status of water bodies, improve and restore the native riverside vegetation and associated habitat, provide space by the river for recreational and public use, as well as better land-use planning. The project is recovering the natural floodplains of the Júcar and Moscas rivers at their confluence and, at the same time, building protection through restoring slopes with natural vegetation. The restoration of natural river floodplains is an NbS that is highly effective in mitigating the risk of flooding in urban environments, while at the same time enabling the recovery of the riverside forest and the enhancement of the river environment for citizens.

An example of integration of NbS at catchment and local scale is in **Kunshan, China**. Increased urbanization and rapid economic growth in recent decades present a great threat to the water environment of the city that has historically underpinned the liveability of the city. Poor drainage and catchment pollution have resulted in a deterioration of water quality in its extensive network of constructed canals. Kunshan has also had to deal with frequent flooding which is likely to be exacerbated by climate change. The city has adapted to these risks with more than 100 polders and over 1,000 km of waterways connected via pumps and gates.

A city-wide strategy incorporating NbS was developed to mitigate the risk of flood and to reduce the urban pollution into regional waterways. NbS support treatment of wastewater and stormwater from Kunshan's canals which are then returned to the city. The basic strategy that has been adopted is the collection of wastewater to the centralized water-treatment and proper management of stormwater pollution at source with the help of biofilters. The treated stormwater is then recycled for non-potable use, thus transforming Kunshan into a water supply catchment. This is coupled with canal water recirculation through precinct scale wetlands in the open spaces making Kunshan a sponge city.

The waterways and canals are also being protected by improving the natural drainage systems in urban areas and ensuring through the biofilters that the peak flows are detained and safely transferred to waterways. This idea has been carried out at macro- and micro-levels with multi-functional areas combining grey, green and blue infrastructure as integral parts of the urban ecosystem. The ecosystem services embedded into Kushan's landscape have improved the connectivity of landscape, increased biodiversity and improved water quality. It has allowed the city to self-repair by influencing the micro-climate. This city-wide strategy has also saved downstream cities, for example, Shanghai from the risk of floods and has reduced pollution into regional waterways.

Another example of NbS across scales is being implemented in **Mexico City**, which is an emblematic case of city development that has become disconnected from its wider water basin. The city was founded by the Aztec Empire in 1324 and was built across an extensive lake system embedded in a volcanic chain. As the city grew, construction of dykes helped control floods. Following Spanish colonization, artificial outlets were constructed to drain the lakes and remove the threat of flooding while increasing cultivable land area. As the lakes disappeared, groundwater became the main source of water for the city's development, leading inevitably to its overexploitation and subsidence of the city's foundations. The reduction of green and blue permeable areas has deleteriously affected many neighbourhoods of Mexico City's metropolitan area, with little or no access to green public spaces for well-being, as well as flooding events and a lack of basic water supply and drainage services.

To redirect the city development trajectory towards a more sustainable path, green and blue infrastructure provided an opportunity to recreate some of the benefits of the lake basin including sufficient water resources for all, local food production opportunities, better health and well-being of the population and biodiversity support and conservation. Green infrastructure has now become an institutionalized planning tool in Mexico City and the intent is for it to become a regional planning framework to reconnect Mexico City's metropolitan area with its lake basin.

The strategies implemented to reduce water scarcity, control water pollution and floods are across the water cycle and areas of Mexico City. The city has a portfolio of projects that are being implemented and also showcase NbS. For example, to prevent the rainwater falling on the impermeable city streets from flowing directly to the drainage system and out of the basin, there has been construction of rain gardens and permeable pavements focused on restoring the infiltration capacity of streets and public spaces. These systems operate at different scales, from a series of rain gardens with a capacity of a few hundred cubic meters to larger infiltration ponds in urban parks. With different layers of filtration material and appropriate vegetation, these systems also reduce the contamination in the runoff to avoid polluting groundwater. A second initiative is reforestation and protection of natural spaces in the metropolitan area to increase the recharge capacity of the aquifer due to the infiltration capacity of the soil. In deteriorated areas, green infrastructure features also contribute to erosion control through water retention practices and fostering the infiltration, also reducing the flood in lower constructed areas. Finally, there is a strategy to develop green corridors to link the different elements of green infrastructure, which will ensure the maximization of the environmental services each provides. Organizing the different existing and potential components as a connected network is what will create a green and blue infrastructure adapted to the metropolitan area of Mexico City.

7.3 – BUILDING PARTNERSHIPS FROM CATCHMENT TO TAP

Building partnerships from catchment to tap across sectors and scales can catalyse action in sustaining and improving water quality and flows to and from cities. Investment and implementation of NbS can assist in formalizing and activating partnerships across a catchment including national and local government, local stakeholders and community-based organizations, the private sector and donor agencies (UN-Water, 2018). The circular economy is another area which thrives on partnerships between cities and their basins, for example through the reuse of water and waste products.

There are a variety of water-related organizations across a basin such as water supply companies, local authorities, landowners, agricultural organizations, academia and local enterprises. The cooperation of these organizations can achieve environmental, social and economic benefits. For example, the Source to Tap project in Ireland includes a water utility, government, a research institute, a local authority and an NGO. The project is developing cooperation programmes with schools and local communities to provide education and awareness on the importance and connection of water bodies, such as rivers and lakes. There is ongoing cooperation with forestry departments, to reduce soil erosion and run off to rivers from forestry activities by building settlement ponds or sediment traps of different sizes and filtering run-off from forestry operations through various media

(The Rivers Trust, 2020). The project is also working with farmers by providing incentives to adopt sustainable land management practices that help reduce herbicide residue and soil escaping from the land into rivers.

An example of how partnerships developed in catchments can be shaped to undertake integrated management of land and water and deliver crosscutting practical interventions is through the Catchment Based Approach (CaBA), which is a framework used in the UK to support implementation of the Government's Environment Plan. CaBA is an inclusive, civil society-led initiative that works in partnership with government, local authorities, water companies and businesses to maximize the natural value of the environment. Establishing a partnership requires time and a lot of energy, but when the partners initiate a joint bid and get the support of the local community, the trust established here leads to positive results in improving water quality, enhanced biodiversity, reduced flood risk, resilience to climate change, more resource efficient and sustainable businesses, and health. The partnership approach also absorbs local knowledge and expertise and encourages individuals, organizations and communities to take responsibility for problems (CaBA, 2020).

CaBA outlines how achieving and sustaining a healthy waterway requires partnerships across the catchment. This was also the case in the **Derwent River and estuary, in Australia**, which have been contaminated from industrial and agricultural activities and the urban areas of Hobart. The Derwent Estuary Program (DEP) demonstrates how collaboration across the catchment mediated through transparent environmental monitoring can restore and promote the health of an estuary and, hopefully, an entire catchment. Over the years, the DEP has worked hard to build a strong reputation with partners based on credibility and transparency. Partners include city councils, industry, the state government, water and energy utilities, the Tasmanian Ports Corporation, as well as the Australian Government, University of Tasmania, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Natural Resource Management (NRM) South, local businesses and community groups. Alongside a commitment to building a programme based on science, the DEP has been effective through collaboration. It is through financial partnerships, especially with industry that heavy metal pollution entering the Derwent estuary has been reduced by over 50%. Partners that work with the DEP also benefit from enhanced credibility and improved public image.

A further example of partnership between public and private sectors and civil society across urban areas and their watersheds is through the Comitê do Itajaí, established in 1996 in the Santa Catarina state of Brazil. The committee has 50 members: 10 representing federal and state agencies, 20 representing water users, 10 representing the municipalities and 10 representing non-governmental organizations. Local institutions, including municipalities, industrial and commercial organizations, and universities, came together initially to solve flood problems. This led to the set up of a Water Resources Management Committee for the basin, which is formally recognized by the state government as a partner of the State Water Resources Council. It is charged with management of the water resources of the Itajaí basin, coordinating the actions of responsible agencies in the basin and supervising implementation to meet the planned goals. In addition, it has been given the authority to set charges for water use. A governance system has evolved with a General Assembly that appoints senior management and approves the water management and flood management plans. Public participation has built support and cooperation from the population in the basin as well as developing consensus among those involved in the public and the private sectors (INBO, 2009).

Another example of basin-wide cooperation is **The Living with Water partnership in the UK**, which is a collaboration between Yorkshire Water, Hull City Council, East Riding of Yorkshire Council and the Environment Agency. The aim is to reduce vulnerability to flooding and increase resilience through infrastructural projects and activities working with the public sector, private sector and communities. Extensive public engagement has been undertaken by the partnership and continues to underpin the broader programme, supported by the development and dissemination of a suite of creative materials including chatterbox games for children, literature and interactive workshop-based tools. There is also an effort to partner with universities including Hull, Northumbria and Sheffield, specifically focussing on research areas, such as telemetry integration between risk management authorities, customer interaction with rainwater harvesting for multiple benefits, a baseline study of current awareness of flood risk, and resilience and flood training protocols for first responders.

Research partnerships are essential to improving how water is managed and monitored. In **France**, the Epidemiological Observatory of Wastewater - Observatoire Épidémiologique des Eaux Usées (OBEPINE) system is a partnership working together on epidemiological monitoring of COVID-19 in wastewater. The partnership includes the Mocopée research program, Laboratoire d'analyse en Bretagne (LABOCEA) laboratory, the Environmental biOtechnology PRoceSses (PROSE) unit, Institut national de la recherche agronomique (INRAE), and the Greater Paris Sanitation Authority known as Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne (SIAAP). The partnership makes it possible to pool the skills of the various institutions to monitor and produce frequent analytical data and will eventually be able to adapt to all viral diseases. The monitoring not only serves to improve knowledge about COVID-19 and other viruses, but also evaluates the efficiency of wastewater treatment. To build partnerships it is essential to ensure that a clear engagement mechanism is in place, including defined roles and responsibilities across institutions that link the urban areas with their basins.

Partnerships are also relevant in the Júcar Basin, in Spain, where conservation of rivers in urban environments is the responsibility of the local administration; however, cooperating with different stakeholders is the only real way to achieve this. The growth of cities around rivers in this basin and others has meant a progressive occupation of river space which, together with the deterioration of water quality, has led to the degradation of the environment. The restoration of rivers as they pass through cities has becomes an opportunity for dialogue and collaboration between the basin organization and the local councils to tackle joint actions within the framework of their competences, contributing to achieving environmental objectives, as well as development of green spaces of high ecological value in cities.

The **Júcar River Basin Authority known as Confederación Hidrográfica del Júcar (CHJ)** allocates water resources to urban (Valencia, Albacete and Sagunto cities), agricultural (farmers associations) and industrial (Iberdrola power company) users. For many years, the CHJ has been promoting a cooperation programme with local councils for river restoration in urban or peri urban areas, which is put into practice through collaboration agreements. An example has been the need to remove invasive species (e.g., Arundo donax) from riverbank areas. Working with Ondara town council (in Alicante, Spain), the CHJ is removing the invasive species and replanting with native riverside species. The council is then responsible for maintenance. A similar approach is being undertaken to reduce the risk of flooding, with CHJ undertaking the works to recover the floodplain in Cuenca, and the city council carrying out maintenance.

As demonstrated in the previous examples, partnerships are essential to deal with water-related risks such as flooding. **Fez, Morocco** is at the confluence of several rivers and has experienced excessively violent floods in the past that have caused significant damage. The risk of flooding is amplified by the effects of climate change. Measures and arrangements for the protection of the population and their property have been set up in partnership between the stakeholders concerned (Ministry of the Interior, Ministry of Public Works, Regions, Local Authorities, Basin Agency, etc.). These measures have benefited from the financial support of the FLCN (Fund for Fighting against Natural Disasters) managed by the Ministry of the Interior.

Partnerships to address water management across a catchment can have multiple benefits beyond securing water resources. In **Johannesburg**, the War on Leaks (WOL) programme is simultaneously addressing both problems of non-revenue water (NRW) and unemployment in the City of Johannesburg and various provincial regions across the country. Through the implementation of the WOL programme, unemployed youth will be qualified in different artisan and water-related disciplines which will improve the socio-economic conditions within your local communities. The programme is a tripartite initiative by the South African Department of Human Water and Sanitation, Rand Water Board (a government-appointed implementing agent) and the Energy & Water Sector Education Training Authority (EWSETA, South Africa). The City of Johannesburg is actively involved in the WOL programme, since Johannesburg Water entered into a Service Level Agreement with Rand Water for the WOL programme for a period of five years (2015 - 2020). Unemployed learners who are part of this programme have been deployed at various Johannesburg Water worksites to gain the necessary workplace exposure.

7.4 – USING DIGITAL TECHNOLOGIES

Digital tools have shifted who can access and provide data and information, increasing transparency and accountability. Digital technologies offer hardware, software and equipment infrastructure to enable more connected, intelligent, efficient and responsive water systems and services. The digital water economy, which includes the technologies and processes to support their implementation, is a key tool for the water industry and its customers to manage urban water (Sarni et al, 2019). This includes using digital technologies to support availability and access of information (e.g., real time data and forecasting) across the water sector from upstream water management to urban consumers. Digital tools create opportunities for increased awareness and engagement from the Internet of Things (IoT) to crowd sourcing of information from citizens.

Sampling in the Mackenzie Basin, Canada © GordonFoundation

An example of harnessing information from citizens, is the **Mackenzie DataStream**, which supports water quality monitoring in the basin by housing data inputs collected by communities throughout the Mackenzie River Basin in the Northwest Territories in Canada. DataStream is an open access application that contains high quality data and allows users to explore and share water data relevant to the Mackenzie River Basin. DataStream's design is based on past experiences and applications created by the developer together with inputs from end-users and partners. It also seeks to present data in ways that can be easily understood by community users who may not have technical knowledge or a scientific background.

To ensure that the platform functions smoothly and without errors, the developer made use of "Frictionless Data", a system created by Open-Knowledge International. This system allows users to work around information and data (upload and download) without friction, making the process more dynamic and productive. The added value has been both the access to data free of charge and allowing users to monitor and upload information to be shared. An improvement underway at the time of writing the case study is a systematic and standardized way to control the quality of uploaded data.

Urban water utilities are now dealing with large volumes of data for a variety of sources that needs to be accessed and integrated. Maximizing the use of big data means accessing the right data when it is needed (Sarni et al., 2019). **Águas do Porto** found that integrating data with the digital H2PORTO platform provided the utility with a useful tool that has improved and made water service provision more reliable while also achieving a more structured and effective communication and collaboration process, both internally and externally. The H2PORTO platform relies on organizing data spread in several databases, providing communication amongst other technological platforms, business intelligence tools and decision making through the analysis of data, modelling tools, and predictive analysis and strives to provide information to its citizens.

Digital tools can also allow employees to input information allowing more rapid response and efficiencies. The H2PORTO platform has also allowed the introduction of mobile devices for operational employees to register the details of their interventions and to expedite communications. This has helped to eliminate redundancies. The design and development stages of this tool are promoting improvements and changes in internal processes of operation and maintenance and encouraging the improvement of tasks that were hindered by obsolete habits and routines. The inputs and involvement of operational employees were fundamental to create an application that better serves their daily work.

The relevant data can better prepare water resources management for heavy rains, indicate when protective measures should be taken during droughts, and ensure that all treated water is delivered to customers (Sarni et al., 2019). The **Ebro basin in Spain** has three million inhabitants, approximately one third of whom live in cities and towns along the banks of the middle Ebro. The Ebro River Basin Authority have put in place several measures which reinforces the connection with the cities and citizens to share the flood management strategy in the middle stretch of the Ebro River, increasing awareness and co-responsibility. This includes the use of a digital tool in the form of a web application "check your risk" which allows every citizen to check the risk of flooding of their property, simply by indicating the name of the town and their property's cadastral number. High risk areas are shown in red, medium in orange and low in yellow. The same application shows information on the flow associated with each zone. These data come from the flood hazard maps drawn up in the Ebro basin for the second phase of the development of the Floods Directive. Apart from this application, towns and citizens have access to the entire zoning and therefore to the activities and uses that can be carried out in each of the areas according to flood regulations.

PART C – FOUNDATIONS FOR ACTION

This section lays out the foundations for the pathways to action to deliver sustainable urban water management. The foundations include:

- How to develop a common vision across cities and their basins;
- Agreed governance arrangement on managing water;
- Building knowledge and capacity for urban stakeholders to effectively contribute to basin management;
- Planning tools to support the alignment of urban development with basin management; and
- Implementation tools specifically policy, regulations and financing to support the connection between urban stakeholders and their catchments.

Throughout this section, views of water experts are showcased in boxes to provide views and examples of how the foundations are being put in place in different geographies and scales.

River Ganga in India © Rajesh Balouria

Seine River in Paris, France © Bidyut Das

Valley of Scalve, Italy © Pascuii

8 - BUILDING BLOCKS FOR A BASIN-CONNECTED CITY

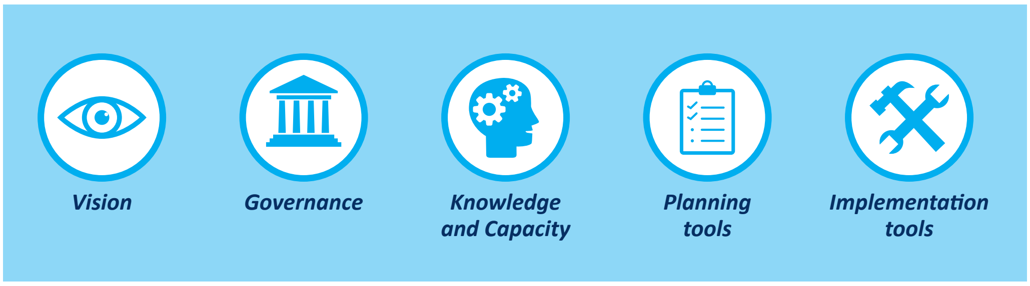

Figure 4. Principles for Water Wise Cities building blocks.

These foundations are derived from the building blocks of the Principles for Water Wise Cities (IWA, 2018b) and include vision, governance, knowledge and capacity, planning tools and implementation tools (see Figure 4). Cities and their stakeholders will be at different stages, from creating a joint vision to showcasing how they are implementing the connection between cities and basins.

Box 8. Key points on the foundations for a basin-connected city

Vision

- A vision motivates stakeholders to define a common set of objectives for the greater benefit of both the city and the basin and is the stepping stone to ensure implementation of policies and strategies.
- A vision needs to be agreed and owned by multiple stakeholders. Collaborative processes can support this, by navigating the understanding of being more than a water user, but a water steward that contributes to defining long-term ambitions for the whole basin and its beneficiaries.
- For a vision to be established it needs to be translated into local policies and adequate governance. It also needs the right tools, such as masterplans and financing mechanisms, and improved knowledge and capacity to guide action.

Governance

- Water governance “determines who can have what water, when and how” (Tropp, 2005).
- Governance arrangements are important for addressing issues in the many administrative regions which a basin may cover. When connecting basins with cities, there needs to be an understanding of multi-level governance and how different sectors, and administrative levels share authority for policy making, accountability, development and implementation
- There can be spatial-scale misalignment between implementation of urban water governance to that of the wider hydrological and natural water system which a city depends on for water, food and energy, as well as other resources. Improving urban water governance can be undertaken through different approaches that places city in the context of their hinterland to better understand and address the upstream and downstream influences from, e.g., water, sediment and pollutant flows.

Knowledge and Capacity

- An understanding of what are the current competencies and capacities of both urban and rural stakeholders is needed to effectively contribute to integrated water resource management (IWRM) across a basin. Capacity building is crucial for better water management, including training, data management, expertise, and support to water stakeholders and information systems.
- Knowledge exchange and learning from other cities and basins about solutions to common challenges can introduce new ideas and approaches that can be tailored to the local context.
- “Peer-to-peer learning” which encourages continuous knowledge exchange between organizations, cities, basins, etc can be a way to lessen the knowledge gap and help develop relationships that can provide continuous support.

Planning Tools

- Planning tools such as decision support systems, IWRM plans, as well as risk-based planning can support the alignment of urban development with basin management.
- Planning can also be framed around a key issue, such as floods or droughts. These can be used to raise awareness of flood (or drought) risk and promote protective measures among the population, improve land planning especially in urban areas, improve predictive capacity; strengthen coordination among public administrations; reduce vulnerability; reduce flood hazards and improve the environmental condition of water bodies.
- There are a variety of urban stakeholders that play a role in planning, and their engagement is important to create a shared sense of responsibility as well as integration of local knowledge.
- There is a need for coherent planning documents and strategies between the city and basin levels.

Implementation Tools (Policy, Regulation and Financing)

- Policies can establish clear guidelines, with appropriate thresholds and limits based on the best available science.
- Policies and the resultant laws provide the foundation for a course of action, and regulations provide the directions for implementation. Then regulations create incentives that drive improved water management by urban stakeholders. This could be in the form of financing mechanisms which, for example, can help source funds to resource upstream catchment restoration activities to improve drinking water quality.
- Implementation of funding mechanisms needs enablers and leaders including the mobilization of a champion to create awareness, a business plan, an implementation structure and funding.
- Policy, regulation and finance can also drive innovation and create new business models for the management of wastewater discharged by urban users back into the catchment areas. This can be through recycling of water by industry and the trading of reused water between industry and municipal authorities.

8.1 – VISION

A vision defines an agreed future among stakeholders with long-term ambitions, values and aspirations. It motivates stakeholders to define a common set of objectives for the greater benefit of both the city and the basin and is the stepping stone to ensure implementation of policies and strategies. Setting principles and values can guide cities and their basins to achieve a common vision that bridges the individual silos across organizations and sectors.

A resilient city vision which includes the connection to the surrounding basin enables people to work together at different scales and across disciplines. It supports the political will needed to invest in long-term measures, and it provides consistency beyond political cycles. The example in Box 9 from Water-Cities provides an overview of how a vision can be developed and examples of how this is being applied at basin scale with urban stakeholders.

Box 9. Developing a water wise vision

By Corinne Trommsdorff, Founder and CEO, Water-Cities

Most people only do things that are beneficial for them. That's why a vision that connects urban stakeholders together with the upstream and downstream water users is essential. Vision underlies action. It's the route to drive actions by stakeholders who have adopted the joint vision as their own, and therefore made it their own interest to achieve it.

The crux is to grow the ownership of the vision by the multiple stakeholders. An effective way to achieve this is to use a collaborative process that supports the mental switch from water users to water stewards and that leads to defining a joint long-term ambition for the whole basin and its beneficiaries. Through this collaborative process, each stakeholder realizes the dependencies it has with the others, and how, through meeting the needs of others it protects these dependencies and ultimately its own activities. This process takes time, but it's well invested time if the result is a shared vision and shared ambitions to improve water management through the work done at many levels: water supply and sanitation utilities, city drainage, urbanization planning, agriculture, tourism, forests and landscapes. After this first step of developing ownership on the vision through a collaborative process, the vision needs to be formalized into powerful communication materials to anchor the ambition, values and aspirations, and keep that vision as the north star as each stakeholder goes back to its daily work. In summary the 3 success factors of developing a vision are:

1. Using a collaborative process to define the joint vision and grow the stewardship mentality;
2. A high level of ownership on the vision, so that it becomes in each stakeholders' interest to achieve the vision;
3. Strong communication around the vision.

Once the vision is well anchored, the risk is for it to remain a wishful thought. The implementation of actions relies on translating it to local policies and adequate governance. It also needs the right tools, such as masterplans and financing mechanisms, and in some cases, it requires to grow knowledge and capacities in order to take the right actions.

Basin-scale vision is currently supporting actions in many parts of the world. For example, in France the basin-connected cities vision is carried by 5 Basin Agencies, which structure action plans though various tools: Wider Basin Masterplan for water management (SDAGE), Local Basin Masterplan for water management (SAGE), or a lighter weight Territorial Plan for water management known as projets de territoire pour la gestion de l'eau (PTGE). The initial phase of these tools is always to define a joint local ambition, in line with the Basin Agency's vision, which itself is in line with the European Community's directive on water management. Successfully guiding local stakeholders through developing their own vision and ambitions based on these macro-level directives is the main success factor to enable the local action plans. Other examples are how the One-Water vision supported San Francisco in driving actions towards reducing water consumption from the basin, or how the IWA Principles for Water-Wise cities adopted in Paris, Lyon, Berlin, Brisbane or Kampala sparks the collaboration between urban and basin stakeholders.

The cases cited in the "Setting values and principles" section already illustrate different mechanisms such as defining principles or developing a strategy or plan for an area, which create a basis for a common vision. For example, the city of **Kunshan, China** has developed the "Kunshan Sponge City Special Plan". The plan was jointly approved by several urban stakeholders, aligning the urban water vision across the city. This has led to 22.9 km2 being designated as a Sponge City demonstration area. This plan has created a common vision across departments that Kunshan will deliver government wide responses, involve public and private sectors to protect and enhance its canals and waterways, and progressively transform into a water-wise city. Furthermore, as a designated "sponge city", Kunshan is a hub for technologies and techniques that promote infiltration, greening, and integrated water management. This designation gives focus to opportunities in the city and has been supported by the input from various researchers (IWA, 2021).

In the case of **San Francisco, USA, SFPUC** developed the OneWaterSF Vision which states "With our OneWaterSF approach, San Francisco will optimize the use of our finite water and energy resources to balance community and ecosystem needs, creating a more resilient and reliable future". This Vision and its accompanying Guiding Principles have been tested by supporting different initiatives. In this way, the OneWaterSF approach grew organically and relied on cultural commitment from within SFPUC and partner using the Guiding Principles (SFPUC, 2020). An example of how the vision helped a project which connects basins and urban areas become more impactful than its initial scope is in the Alameda Watershed which contains two important drinking water reservoirs for the San Francisco area. The primary watershed management goal for SFPUC in the Alameda Watershed is to maintain and improve source water quality to protect public health and safety. The OneWaterSF vision and guiding principles helped SFPUC to consider complementary opportunities to improve watershed management by including programmes for the community and businesses. This led to the establishment of Sunol AgPark as a collaborative farm which is supporting local farmers in sustainable farming practices, and providing awareness and education on how these practices can benefit watershed health (SFPUC, 2020). The goal is for the OneWaterSF Vision and Guiding Principles to be considered in all SFPUC efforts, fostering a culture of collaboration to implement innovative projects and programmes that help manage water and energy resources in more sustainable ways (SFPUC, 2020).

Fez River (Oued Fes) in Fez, Morocco © Bureau EAST

In **Fez, Morocco**, A common vision has been agreed through the development of a basin plan (for the Sebou Basin covering 100 km2) to adopt an inclusive and sustainable water management strategy to strengthen the links between the city's stakeholders and those of the watershed. This agreed vision within the plan has provided the foundation for projects to protect and preserve water resources without hindering the socio-economic development of the city.

8.2 – GOVERNANCE

Water governance is a set of systems both formal and informal, that direct decision-making processes around management of water resources. In other words, how decisions are made, and the roles and responsibilities in the design, regulation and implementation of these decisions (Moench et al., 2003). Water governance "determines who can have what water, when and how" (Tropp, 2005). Exchange and sharing of governance approaches is the best way to learn from past successes and failures and to develop locally appropriate solutions.

Governance and institutions provide the framework for stakeholders to work together from catchment to tap to achieve a joint vision. Policies can frame how water is managed and provide incentives for urban stakeholders to invest and be active water stewards in their catchment. Effective integration of multiple needs and interests at the basin level requires appropriate institutional setup and stakeholder engagement, for example, through multi-stakeholder platforms.

The basin stories from Kenya and Peru demonstrate the use of financial instruments coupled with governance arrangements which unite public, private and civil society stakeholders around a common goal to contribute to water security through nature-based solutions (NbS) and sustainable watershed management.

In **Peru**, the successful implementation of Mechanisms of Rewards for Ecosystem Services (MRSE) depended on the governance arrangements between utilities, stakeholders, water organizations, communities, citizens and government agencies. Each stakeholder had clear roles and responsibility. For example, the regulator (SUNASS) has control over tariffs and utilities, meaning they regulate fees for water supply and sanitation services, supervise and audit the quality of services and the correct execution of laws. The Ministry of Housing, Construction and Sanitation known as the Ministerio de Vivienda, Construcción y Saneamiento (MVCS) designs, monitors and regulates policies at basin and national level. They work in cooperation with municipalities and approve policies and oriented plans to achieve objectives. Utilities collect fees and provide water and sanitation services; local governments and municipalities finance the technical programmes; citizens support the protection of the environment services and basins by monthly paying their fees for water supply; and NGOs provide support, funding and advice during the implementation process of the law in the pilot basins and in a later stage in major cities.

Tana River in Kenya © Sgt R.A. Ward

In the case of Kenya, the **Upper Tana-Nairobi Water Fund** required a governance structure to manage the fund. This was in the form of strong trustee and management boards for 3-year renewable terms and helped to maintain a steady and consistent management system. The board is empowered in decision-making and legally establishing the water fund as an independent non-profit entity.

When connecting basins with cities, there needs to be an understanding of multi-level governance and how different sectors, and administrative levels share authority for policy making, accountability, development and implementation (OECD, 2011). This can be between different ministries and/or public agencies at the central government level (horizontal coordination at the top level); between different levels of local, regional, provincial/state, national and supranational authorities (vertical coordination); and between different actors at the sub-national level (horizontal coordination at the lower level) (OECD 2011).

Governance arrangements are important for addressing issues in many jurisdictions which a basin may cover. In **Ghana**, the Water Resources Commission has set up Basin Boards to manage water resources. The basin story from Ghana focuses on the Densu Basin which traverses about 13 local authority boundaries. Members of the Densu Basin Board (DBB) were chosen through a consultative process. The DBB plays an advisory and consultative role in the management of the Densu River. The work of the board is mainly facilitated by a secretariat as a decentralized entity of the national level Water Resources Commission. In general, the presence of the DBB and its monitoring activities within the basin has increased awareness in various communities on the need to sustain environmental conservation practices. Before the establishment of the Commission and hence the board, the national water utility - Ghana Water Company Limited – was faced with the challenge of eutrophication in Weija Lake, which heavily affected water treatment activities. Initial actions supported by the Water Resources Commission were to set up a water quality monitoring programme and develop a water quality index to interpret measurements of ambient water quality parameters. This provided an indication the degree to which the natural water quality is affected by human activity and allowed identification of actions to improve quality in the lake.

The example from the city of **Shaoxing, China**, demonstrates how an integrated governance approach across sectors was used to improve the health and cultural value of the river network and the urban landscape. The Huancheng River, which includes the moat encircling the ancient city, has a history of more than 2,500 years and connects with East Zhejiang Canal and Jianhu Lake. With increasing economic development, rivers became polluted and silted. In 1999, the government launched a project called the "Comprehensive governance of Huancheng River" with the aim to improve flood control and drainage. The approach by the Shaoxing City Government has been to bring together different sectors responsible for urban flood control and urban construction, environmental protection, tourism and culture as the foundation for the comprehensive governance of the Huancheng River. Within the Shaoxing City Government, a group led by the water conservancy department and joined by the departments of urban construction, land, planning, finance, transportation, electric power, and environmental protection was established. The group gathered scientific and technological knowledge from across the city administration and invited experts and scholars to conduct in-depth research and discussions on the state of Huancheng River. The opinions and advice of stakeholders, such as industry and citizens, were also an important source of information in implementing the project.

The approach of undertaking comprehensive governance of the Huancheng river was an opportunity to not only improve the river within the city, but also the ecology of the wider Cao 'e River basin (of which the Huancheng is a tributary).

Box 10 provides further examples of governance arrangements across scales which connect cities and their basins. These include the City Water Resilience Approach (CWRA) and the Source-to-Sea (S2S) system approach which provide a framework for cities to make linkages to their catchments.

Box 10. Water governance approaches for action in basin-connected cities

By Panchali Saikia, Alejandro Jiménez, Ruth Mathews and Maggie White, Stockholm International Water Institute (SIWI), Sweden

A city draws upon a wider catchment/basin area, extending beyond the urban administrative boundaries, and at times even national borders. This leads to a spatial-scale misalignment between implementation of urban water governance to that of the wider hydrological and natural water system within which a city depends. Urban systems are complex, with overlapping, interconnected and often poorly coordinated sectors (e.g., water, energy, forest, food supply, land, transport). In addition, the actions taken at the city level may lead to major downstream implications, ultimately putting pressure on connected rivers/lakes/wetlands/ocean systems. This is often not taken fully into account in urban water planning. These urban complexities, governance gaps and lack of understanding on the interconnectedness between the city and the basin bring additional challenges for cities, when it is confronted with climate disasters or other water-related shocks and stresses.

The solution often lies in improving urban water governance; however, cities often face hurdles of how to address this, and implementing tangible water governance actions. In an article '**Unpacking Water Governance: A Framework for Practitioners**', an operational framework on water governance is presented that guides practitioners on understanding how to apply water governance in practice. It describes water governance *as a combination of functions, performed with certain attributes, to achieve one or more desired outcomes, shaped by the values and aspirations of individuals and organisations*. Reflecting on this concept, **the City Water Resilience Approach (CWRA)** and the **Source-to-sea (S2S) approach**, provides practical guidance for cities to use a multi-stakeholder approach to understanding the links within their wider catchment, improve governance and build a sustainable and resilient water system.

CWRA, a five-step approach enables cities to develop water resilience at an urban scale, supported by a set of tools and resources. Through it application, cities are able to understand their water system and its stakeholders in the context of a broader catchment through a digital tool (**OurWater**), measure and monitor water resilience capacity by using **a governance based planning tool, City Water Resilience Framework (CWRF)** and develop water resilience actions. CWRF is implemented through a multi-stakeholder workshop, where city stakeholders assess gaps and opportunities in the current governance situation **using a set of qualitative and quantitative water resilience indicators**. Based on the assessment results, stakeholders are guided through a methodology to identify actions to address those gaps, and define an implementation plan with a Monitoring, Evaluation and Leaning (ME&L) mechanism in place. The implementation of CWRA in **City of Cape Town**, the **Greater Miami & the Beaches (GM&B)**, **Addis Ababa** and **Hull**, helped the cities develop a holistic urban water resilience strategy and further improve their governance capacity to respond, cope and adapt to water related shocks and stresses.

The S2S approach places city in context of the source-to-sea system, which is the land that is drained by a river system, connected lakes, aquifers, and downstream deltas, estuary, coasts, and ocean. The S2S approach offers a methodology to address the upstream and downstream influences from alterations in e.g., water, sediment, biota and pollutant flows. By addressing the linkages between land, freshwater, coasts and the ocean, it calls for coordinated resources management. The approach has been piloted in the **Vu Gia Thu Bon River Basin in Viet Nam** to address plastic leakage into the sea, and in the **Lake Hawassa Sub Basin of Ethiopia** to strengthen management of sediment and plastic flows into the lake. It outlines a **step-wise methodology** to guide analysis and planning through a collaborative and cross-sectoral approach. Through its application, the government authorities in these basins were able to understand the upstream-downstream context, identify and engage upstream and downstream stakeholders to engage and assess the governance baseline to pinpoint the governance gaps and needed changes in the enabling conditions. This provided the foundation for designing priority actions to be taken to reach the desired long-term outcome. From this, a financing strategy and implementation and monitoring plan can be developed to take these actions forward.

8.3 – KNOWLEDGE AND CAPACITY

Knowledge and capacity building are one of the building blocks in achieving basin-connected cities. It is important to consider knowledge not only as a product of scientific research but also as information shared by multiple stakeholders. It includes the application of methods and tools for managing, monitoring, planning and implementation, and the documentation of studies, guidelines and practices. Knowledge is used by a large number of target groups across cities and their basins including decision makers, managers of water services, user associations, NGO representatives and citizens. Knowledge is also produced and used at all levels, from the international and national to the local level.

A lack of knowledge on how to obtain information for IWRM is considered as a limiting factor to making sound decisions for basins and their cities. Therefore, capacity building is crucial for better water management, including training, data management, expertise, and support to water stakeholders and information systems. An understanding of what are the current competencies and capacities of both urban and rural stakeholders is needed to effectively contribute to IWRM across a basin. This can be through knowledge exchange and learning from other cities and basins about solutions to common challenges, such as low river flows due to water scarcity, flooding, sea level rise, tidal events, waste management and water quality. Approaches include learning to work differently with new tools, pooling resources, and being open to other sectors' approaches and methods (International Office of Water, 2021).

An example of peer-to-peer knowledge exchange which accounts for the role of cities in the wider basin is the **Megacities Alliance for Water and Climate (MAWaC)** which is mentioned in several of the basin stories. MAWaC is an international collaboration forum that facilitates dialogue on water, through which megacities will learn from each other's experience, exchange best practices, partner with appropriate technical, academic and financial institutions, as well as design and implement their individual responses to the challenges of climate change. Specifically, the Alliance focuses on improving the dialogue on adapting to or mitigating the effects of climate change related to water in megacities which presently includes 32 local activities. The initiative aims to help keep the global average temperature rise to below 1.5°C/ 2°C (UNESCO, 2021).

MAWaC offers its members the pooling of experiences and best practices, support for the design of technical tools and models of urban water governance, the sharing of strategies and scientific studies, partnerships between operators to improve the adaptation capacities of each megalopolis to the impacts of climate change. The project to address wastewater discharges into the Congo River between **Kinshasa, DRC and Brazzaville, Republic of Congo** is supported by the MAWaC. In addition, the rehabilitation of the basin is an important step in the relationship between these two countries since the river represents most of the border between the DRC and the Republic of Congo.

An additional example of knowledge and capacity building at a global scale, is the **LWW Partnership** which is successfully sharing and learning from experiences in other cities around the world. For example, Hull participates in the development of City Water Resilience Assessment (CWRA) alongside Mexico City, Cape Town, and Miami, that outlines a process for developing urban water resilience and provides a suite of tools to help cities manage and build their capacity to survive and thrive in the face of water-related shocks and stresses.

Through such partnerships the approach to building skills and knowledge can be targeted as outlined in Box 11 which showcases the Learning Delta Asia Initiative (LDAI) which enables south-south cooperation and knowledge exchange on adaptation to climate change in urban deltas.

River systems in Kunshan, China © ken-qcl

Another example of successful knowledge exchange and capacity development is from the Cooperative Research Centre for Water Sensitive Cities (CRCWSC), based in Australia, working with the local government in **Kunshan, China** to mainstream water sensitive principles through demonstrating proof-of-concept approaches, providing a testing ground for translating discovery research into concrete products and creating a market for water sensitive urban design expertise. A similar approach is now being explored in Vietnam and Thailand, where Australian partners are working in close cooperation with national government agencies to demonstrate the integrated urban flood management process and support the application of the Investment Framework for Economics of Water Sensitive Cities and supporting tools. The tools were successfully trialled by CRCWSC throughout Australia and in several cities in China and are being applied to four case study sites in Vietnam and Thailand (AWP, 2021).

Box 11. Knowledge for governance in building resilient cities: learning from climate change and health connections in the coastal cities in Bangladesh

By Indika Gunawardana formerly with Cap-Net and Fany Wedahuditama, GWP South-East Asia

GWP and Cap-Net are actively supporting the Learning Delta Asia Initiative (LDAI) which aims to enable south-south cooperation and knowledge exchange on adaptation to climate change in urban deltas. A case study focusing on the coastal zone of Bangladesh, provides an example of how the initiative is supporting knowledge and capacity development.

Developing knowledge and overcoming capacity gaps among rural and urban communities, and among cities in delta areas, is critically important in seeking action pathways towards achieving integrated water resources management. Realizing urban and rural stakeholders' roles as water stewards, LDAI recognized "peer-to-peer learning" as a way to lessen the knowledge gap. The LDAI aims to actively share the knowledge that has been developed in Asia Pacific deltaic countries to facilitate tailor-made learnings and knowledge exchanges. In 2018, the partners of LDAI recognized the Delta Knowledge Hub (DKH) as a timely initiative to bridge the knowledge gap in the region. In moving towards developing and sharing knowledge, the identification of ground-level issues; recognition of technology needs; and understanding prevailing bottlenecks in governance structures are significant in the foundation for action.

The adverse health impact of poorly managed sanitation aggravated by climate change is a significant issue among both rural and urban communities in deltaic areas. To understand the depth of this issue and the connections between various hazards, in 2019, the Bangladesh Centre of Advanced Studies (BCAS), the host of Cap-Net Bangladesh, carried out a case study on the impacts of climate change on sanitation, and the resulting health risks in coastal deltaic areas in Bangladesh, considering two communities as study samples: Shyamnagar in Satkhira district, and Mongla in Bagerhatas district, both located in the Bengal Delta.

In summary, this case study demonstrated that salinity, cyclones, tidal surges, floods, waterlogging, riverbank erosion and rising temperatures are the most frequent disasters that negatively impact people's health in the coastal belt of Bangladesh. The knowledge and understanding of these connections are important in the governance of deltaic areas, as is finding pathways to preventative actions for resilient cities.

Learning through case studies such as this is a good way of recognizing the real issues and helps peer-to-peer learning in moving towards adaptive delta management. The proposed knowledge hub of LDAI aims to fulfil this need and to lessen the knowledge and capacity gaps in Delta areas in the Pan-Asia region, which will be a useful tool in the Action Agenda for Basin-Connected Cities.

A final example that illustrates the importance of strengthening knowledge and capacity is the War on Leaks (WOL) programme in South Africa which is simultaneously addressing both problems of NRW and unemployment in the **City of Johannesburg** and various provincial regions across the country. Through the implementation of the WOL programme, unemployed youth become qualified in different artisan and water-related disciplines which will improve the socio-economic conditions within local communities. In addition, the WOL programme aims to have a positive impact on water conservation and water demand management in basin-connected cities, by reducing the leakage rate of underground invisible leaks; repairing old plumbing infrastructure and installing meters; reducing high burst frequencies; and the implementation of educational campaigns aimed at educating citizens on water demand management. Reducing NRW allows utilities to expand and improve service, enhance financial performance, make cities more attractive, increase climate resilience and reduce energy consumption (Kingdom et al., 2016).

8.4 – PLANNING TOOLS

Planning tools such as decision support systems, integrated water resource management plans, as well as risk-based planning can support the alignment of urban development with basin management. These tools, developed and used by cross-sectoral teams from catchment to consumer, allow for assessing and monitoring of risks, identifying benefits and co-benefits of projects, defining levels of service and ownership by stakeholders.

Many of the basin stories refer to various types of plans which provide a basis for management of water resources within a catchment including for urban areas. Furthermore, as touched on in the "Vision" section, a plan can provide a roadmap on how a common vision can be achieved. For example, in the **Guandu Basin in Rio de Janeiro State in Brazil**, the Strategic Water Resources Plan sets out the socioeconomic, institutional and environmental status of the basin, as well as the water balance, and this information is used to formulate sectoral programmes and actions to guarantee the basin's water availability and quality now and for the future. The actions in the plan are financed by users who carry out water derivations and extractions or discharge into water bodies. Box 12 provides more details from National Water and Sanitation Agency (ANA) of Brazil on river basin planning in Brazil and the importance of this planning for cities.

Box 12. Integration urban areas into river basin planning in Brazil

By Sérgio Ayrimoraes, National Water Agency, Brazil

Brazil is a country with more than 180 million inhabitants living in cities (more than 80% of the population); 25% of the urban population depend on large transfers between river basins. Basin transfers are needed in the two main metropolitan regions of São Paulo and Rio de Janeiro to sustain the cities. In the case of wastewater treatment, the capacity of a receiving body to assimilate the polluting load is often affected by the discharge of wastewater from cities located upstream. There needs to be an approach which considers water resources from a basin perspective to control and reduce pollution from and between urban areas.

Data from studies by National Water and Sanitation Agency (ANA) of Brazil, including the Atlas Brazil - Urban Water Supply; and the Sanitation Atlas on urban wastewater treatment have been used in the preparation of River Basin Plans, one of the formal instruments of our National Water Resources Policy. The River Basin Plans in Brazil are developed based on a participatory process and approved by the River Basin Committees. A River Basin Committee is a forum for discussions and decisions taken on water resource management issues in a specific river basin. These committees are structured in ways that encourage participatory and decentralized water resource management, supporting the implementation of management tools and negotiated solutions to disputes over water users. Therefore, they are known as "water parliaments", with their composition including representatives of governments, water sectors and civil society.

River Basin Plans coordinated by ANA that were drawn up and approved more recently have adopted a new approach that shortens plan preparation lead-time and ensures plan conceptualization with more realistic action budgets. Focused on the governability of water resource management systems, it provides step-by-step instructions on implementing strategic actions through an Operating Handbook. This approach has brought concrete elements to the shared vision of cities and the river basin in the planning of water resources.


Densu Basin, Ghana © WRC

In **Ghana, the Densu Basin** which supplies drinking water to Accra, has issues of land degradation, water quality degradation and water shortage. Following the Accra city implementation plan for "Managing Water for African Cities Project" (sponsored by UN-Habitat / UNEP), the Densu River Basin was chosen as the focal point for the environmental component of the Accra city plan, to focus on the mitigation of environmental impacts of urbanization in the basin. The Densu River Basin needed a wider basin planning approach that involved stakeholder participation, awareness raising, public meetings, capacity building and training, as well as environmental engineering. A basin board was established with representatives from across sectors and local authorities including from Greater Accra and the Ghana Water Company Limited. The basin board developed an Integrated Water Resources Management Plan for the Densu Basin informing the annual work plan. The plan is a "blueprint" for further water resource management activities in the basin (Agyenim and Gupta, 2012). This has included for example, a systematic water quality monitoring programme in 2005 and 2006 in the Densu Basin to determine trends in water quality, as well as riparian Buffer Zone Policy, which seeks to protect and maintain the native vegetation within these zones to improve water quality.

In **Morocco**, in accordance with Law 36/15, the integrated water resources development master plan known as Plan Directeur d'Aménagement Intégré des Ressources en Eau du bassin hydraulique (PDAIRE) for the Sebou is drawn up for each basin or group of basins, taking into consideration the strategic guidelines and prescriptions of the national water plan. The PDAIRE is an important tool for the planning and management of water resources in the Sebou basin. It is established for a period of at least 30 years, by the Sebou Water Basin agency in consultation with the administrations and public institutions involved in the water sector. Within the framework of the PDAIRE of the Sebou basin, an action plan has been elaborated to face the challenges of water resources management in the city of Fez. This includes securing drinking water supply from the Sebou River, pollution control and flood protection.

As urbanization increases, the planning of water resources in basins and cities are interconnected. An example is from **Huzhou**, a prefecture-level city in China, which encompasses the surrounding densely populated area that has been intensely farmed since at least the 7th century. The farming landscape includes the Lougang drainage and irrigation system that interacts with Taihu Lake. Even today, the Lougang system still serves as the backbone for irrigation, flood control and drainage in the Huzhou area. Urbanization and economic development have affected the traditional Lougang irrigation system. Huzhou City developed a comprehensive management plan to protect the Lougang system, as well as value the historical and cultural landscape, conserve the environment and provide shipping routes among other functions. Huzhou has adopted a plan that combines integrated management of Lougang and spatial planning of its urban area.

In the case of France, water resource planning is based on the European Water Framework Directive (WFD), the national legislation, the use of appropriate tools and the involvement of relevant stakeholders (institutional and local). The pre-existing French institutional, economic, and planning tools have been modified and the roles of water stakeholders have changed in order to fully meet the WFD expectations (Nion, 2009). What this means in practice is that planning at the basin level consists of developing a Water Development and Management Master Plan known as Schéma Directeur d'Aménagement et de Gestion des Eaux (SDAGE), and the actions to be implemented (Programme of Interventions/Programme of Measures). Plans cover a six year period and are based on governance that considers the various different uses and users, regional issues and promote cooperation across sectors. The SDAGE sets the general targets to be met over a six-year period in terms of water quality and quantity, preserving aquatic eco-systems, and the economic value of water. For example, the SDAGE for the Rhone-Mediterranean SDAGE (2015–2021) has three main area of focus including: 1) restoration of 300 km of waterways including flood prevention; 2) wetland restoration and protection and 3) restoration of water quality of 269 drinking water catchments to protect human health (French Ministry for the Ecological and Solidary Transition, International Office for Water, French Water Partnership, 2020).

At the sub-basin level, there is a local version of the SDAGE called the Local Water Development and Management Plan known as Schéma d'Aménagement & Gestion des Eaux Bassin (SAGE), which is led by the Local Water Commission made up of representatives of the various stakeholders, including municipalities. There is a push at this level to foster greater consistency between land use planning, environmental management and flood prevention (e.g., inclusion in town planning documents, zoning, etc.) (French Ministry for the Ecological and Solidary Transition, International Office for Water, French Water Partnership, 2020).

Planning can also be framed around a key issue such as floods or droughts. The Syndicat Mixte d'Aménagement du Bassin de la Bourbre (SMABB), which is the organization responsible for the **Bourbre Basin** developed a Flood Risk Prevention Plan which is a regulatory document for urban planning to ensure that the development in urban areas considers mitigating measures against flooding. Similarly, a Flood Risk Management Plan was developed by the **Ebro River Basin Authority in Spain** as a framework instrument that covers a whole range of measures for government to implement including urban development, territorial planning, the natural environment, forest management, insurance, hydrology, hydraulics, etc (Tomás et al., 2020). The plan is intended to raise awareness of flood risk and promote protective measures among the population and both social and economic actors; improve land planning especially in urban areas; improve predictive capacity; strengthen coordination among public administrations; reduce vulnerability; reduce flood hazards and improve the environmental condition of water bodies (Tomás et al., 2020).

As mentioned in the section on "Stakeholder participation in planning and management", engagement of water users is important to create a shared sense of responsibility as well as integration of local knowledge. Across the state of Victoria in Australia, there has been establishment of Integrated Water Management (IWM) Forums which bring together organizations with an interest in water issues. In Melbourne, the IWM Forums are aligned with catchment boundaries to contribute to better stormwater management and progressively improve the ecology of urban and peri-urban waterways (Victoria State Government, 2017). The IWM forums coordinate, prioritize and oversee place-based IWM Plans. This can identify preferred servicing options and implementation arrangements in growth or urban renewal areas (Victoria State Government, 2017). They may also be community-driven projects to enhance an established area such as transformation of a concrete drain into a naturalized waterway and wetland, creating a revegetated recreational corridor (Victoria State Government, 2017). Such an approach ensures IWM planning, and implementation involves government, civil society and the private sector at a local level where actions take place. At the same time, these actions need to be coordinated at scale to benefit the wider city and its catchment area.

As demonstrated in the example from Victoria, there are a variety of urban stakeholders that play a role in planning, some with more impacts on water resources than others. Box 13 provides an example of a tool, The

Alliance for Water Stewardship (AWS) Standard, that might be used by urban stakeholders such as industry to support their role in water resources planning and management. The AWS Standard is a globally applicable framework for major water users to understand their water use and impacts, and to work collaboratively and transparently for sustainable water management within a catchment context. The Standard facilitates connections between stakeholders across basins and supports water related planning as well as risk and performance assessment.

Box 13. AWS Standard as a planning tool for basin-connected cities

By Dr. Mark Dent, Senior Advisor, Alliance for Water Stewardship

Water is a key element in all 17 of the SDGs and has no substitute nor peer, besides air, as an essential connector for all forms of life and business activity. All organisations in a city and the basins in which it is located are impacted by and in turn impact others beyond their own fence-line, through their connections to water. In such a complex, dynamic realm the mission of the Alliance for Water Stewardship is to ignite and nurture global and local leadership in credible water stewardship that recognizes and secures the social, cultural, environmental, and economic value of freshwater, is a valuable contribution to the growing global effort to connect cities to the basins which sustain them.

To match the scale and urgency of the need, the AWS Standard System provides global consistency of approach; drives transparency; enables diverse stakeholder engagement; provides credible recognition; drives innovation; creates coherence and provides a framework for locally-appropriate actions that delivers globally-consistent outcomes.

Through the multiple dimensions of supply and customer chains and other inter-dependencies, AWS members, from business, public and civil society sectors at global, national, and local levels, help to connect cities and basins. They do this inter alia through their commitment to supporting the furtherance of the entire AWS System which has at its pragmatic core a Standard framework of water stewardship actions, which focus on the use of water that is socially equitable, environmentally sustainable and economically beneficial achieved through a stakeholder-inclusive process, that involves site and catchment-based actions.

The 5 Steps that make up the AWS Standard are: Gather and Understand; Commit and Plan; Implement ; Evaluate; Communicate and Disclose. Sites are required to engage constructively in existing local, basin and national, water related multi-stakeholder engagement spaces, where appropriate. In these governance space the sites are required to play a constructive role in facilitating transparent and inclusive multi-stakeholder engagement designed to co-generate wise options and enable the co-consideration of consequences of options.

The Standard does not need to be implemented beginning at Step 1 and proceeding through Step 5. Rather it should be implemented as suitable for the site's purpose and may indeed require adaptive, iterative, and non-sequential use of the steps and criteria en route to 5 Outcomes, namely:- good water governance; sustainable water balance (site & basin); good water quality; conservation of important water related areas; safe water, sanitation and hygiene for all (WASH).

Stripped to its generic essentials this is akin to the framework of actions which led business, government and civil society organisations in the City of Cape Town, South Africa to connect strongly and wisely to the basins, which feed it. The basins feed the city, not only with water, but all of its agriculture related economic activity, which includes processing, transporting, financing, insuring, and servicing outputs and inputs. The economic multipliers from rainfall and wise water-related management were starkly revealed. In so doing Cape Town avoided the spectre of being the first major city in the world to completely run out of water.

In Peru's Ica basin, courageous leadership by major agricultural export growers and the National Sanitation Services, inspired by the systems, networks and knowledge of the AWS, has created a strong commitment to a program of work, to reduce the basin's water related risk. The municipality of Pueblo Nuevo in Ica district, which depends heavily on agricultural exports for its economic and social wellbeing, is pioneering the application of the AWS Standard in a municipal setting. In doing so, Pueblo Nuevo is drawing on the experiences of farmers who are in the process of certification to the AWS Standard and, as such, align with the opportunities that this process generates.

8.5 – IMPLEMENTATION TOOLS (POLICY, REGULATION AND FINANCING)

The previous building blocks are vital, but concrete change depends on implementation tools are what is used to move from concept to reality to put planning into action, to improve water quantity and quality, as well as food and energy security. This section focuses on policy, regulations and financing as key tools for implementation which support the connection between urban stakeholders and their catchments.

Water policies are goals that are set for water use, protection and conservation (GWP, 2018b). This includes what a country or organization intends, which could be in the form of a water policy or forest policy, as well as also other types of intervention, such as the use of economic instruments, market creation, subsidies, etc (GWP, 2021). Policies and the resultant laws (when a policy is written into legal language and passed by the government) provide the foundation for a course of action, and regulations provide the directions for implementation.

Regulations refer to 1) the rules that emanate from governments and public administration and are enforceable by regulatory authorities or regulators – that is, "regulations"; and 2) the act of applying and enforcing standards, criteria, rules or requirements, which have been legally or contractually adopted to regulate (IWA, 2016). Based on quality assurance, equity, transparency, accountability and sound financing, regulations provide a solid frame for stakeholders to invest in sustainable urban water. Regulations create incentives that drive improved water management by urban stakeholders and can be combined with financing mechanisms (which can help source funds) that value adaptive approaches and build resilience to changes and extreme events (IWA, 2018a; IWA, 2018b).

An example of regulations that support financing mechanisms is in **Peru**. The Peruvian Framework Law for the Management and Supply of Sanitation Services seeks to regulate water supply, sanitation services and infrastructure, and the protection of basins from further degradation. The Law provides a reference point for utilities on fees for water services. With these fees, utilities can maintain their infrastructure and their source basins can be rehabilitated and sustainable management programmes can be introduced. Consumers are paying for the water services which include hydrological ecosystem services and are directly involved in the catchment management process. Water tariffs are fixed by SUNASS (the national regulator), considering the needs of water supply companies to operate and maintain the water and sanitation infrastructure. A percentage of these tariffs are invested to restore, protect, and conserve the sources of water. This part of the tariff is under the Mechanisms of Rewards for Ecosystems Services (MRSE). The MRSE are instruments and incentives to generate, channel, transfer and invest economic, financial and non-financial resources, through a voluntary agreement between the stakeholders contributing to ecosystem services (e.g., upstream farmers), and the beneficiaries (e.g., water utilities).

In 2016, the Peruvian government approved regulations of Law No. 30215 – which includes the MRSE, providing specific guidelines for the design and implementation of the mechanisms, and defining roles and responsibilities of different stakeholders that are involved (Quintero, 2016). The MRSE finances conservation, rehabilitation activities and promotes the sustainable use of ecosystems. The regulations determine how public entities can participate in the MRSE and establish the registry system for reward initiatives, which supports monitoring and learning from their implementation (Quintero, 2016).

To implement the MRSE, SUNASS works together with water utilities, companies, stakeholders and communities across basins. SUNASS with water utilities review and update the water tariff structure every five years. The water tariff will consider new investments and conventional/grey infrastructure, operation and maintenance of current grey infrastructure and also the implementation of MRSE.

Another example of policy and regulation supporting financing mechanisms is in the municipality of Skanderborg, located in Eastern Denmark. The municipality developed a climate change action plan to identify vulnerable areas and address flooding. Within the municipality's action plan, the utility – Skanderborg Forsyning – is involved in several climate adaptation projects. For example, the utility transformed a former industrial site into a community park that could accommodate excess rainwater and protect 2,000 residents against increasing flood risks. The municipality finances climate adaptation projects through taxes, and the municipality and utility apply for co-financing from the Secretariat for Water Supply or "Forsyningssekretariatet", which is the Danish economic regulator for water utilities. If the request for funding is approved, then funds from the water tariff can also be used to finance the climate change adaptation project, enabling a co-financing model supported by utility and consumer (Ertel et al., 2019).

The examples from Peru and Denmark, have similarities with several Water Funds set-up across Latin America by the Nature Conservancy (TNC), the InterAmerican Development Bank and partners which connect urban and rural stakeholders. Water Funds which are well established are often supported by a regulatory mechanism which secures regular investment from water tariffs into the fund. An example of a successful Water Fund is the Quito Water Fund which is described in the "Application of financing mechanisms" section. Across Latin America, the Water Fund initiatives provide a steady source of funding for the conservation of more than 7 million acres of watersheds and secure drinking water for nearly 50 million people (Calvache, 2021). Water users including water utilities, municipalities and industries pay into the funds to secure a safe and reliable water supply. The funds, in turn, provide resources for forest conservation in water catchment areas, to improve water quality and quantity downstream (Calvache, 2021).

Implementation of mechanisms such as Water Funds needs enablers including the mobilization of a champion, a business plan, an implementation structure and funding. In Box 14, TNC outlines how such approaches can support integration of NbS within water infrastructure projects which supply water, energy and food to cities.

Box 14. Using nature-based solutions to bridge the urban-rural divide

By Andrea Erickson Quiroz, Global Lead, Water Security, The Nature Conservancy

In a world with increasingly too much or too little water depending on where you look, nature has an important role to play in addressing a variety of water security challenges. Nature-based solutions (NbS), when properly designed, can help regulate the timing and flow of water, provide nutrient and sediment reduction, facilitate aquifer recharge, and offer important co-benefits for biodiversity, rural livelihoods and carbon storage.

Despite these many contributions, we know NbS are often undervalued, or entirely ignored, as cities and authorities develop water infrastructure projects. But this isn't simply a matter of indifference or the result of a lack of understanding. Often, we find water managers do understand the potential benefits of an integrated approach that links grey and green infrastructure, but lack the tools to design, deliver and pay for NbS effectively.

So, what exactly is needed to create the optimal integration of catchment management in the water sector? Each city is unique, but several building blocks are uniformly critical to success: a champion, a business plan, an implementation structure and funding.

First, a champion, like a utility, political leader or leading business, needs to articulate why change is needed and put their energy toward creating a new pathway. Our experience at The Nature Conservancy has been clear: a committed champion is paramount. We have also learned that to be successful, champions need a clear business plan that uses science to understand how changes in the catchment, including climate change, may be impacting current and future water management challenges and how NbS can help improve resilience and reduce costs. A plan should articulate a clear return on investment expected for major water users and society based on a plan that will share value and benefits with multiple stakeholders. We estimate that one out of four large cities today could be saving money on water supply combined operating and capital expenditures if they were to deploy NbS effectively.

The business plan should also reflect different perspectives and incorporate diverse stakeholders. New skills are needed beyond traditional engineering approaches to both integrate ecological functions and social participation. Collective action platforms can help foster dialogue among stakeholders, ultimately aligning vision, incentives and resources.

One example comes from Nairobi, Kenya, where the Upper Tana Water Fund has brought together public and private water users, upper catchment land stewards and local government agencies to address water security challenges along the Tana River, which supplies 95% of Nairobi's water. With coordinated action through the Water Fund, farmers in the middle and upper catchments are now learning sustainable farming practices that can help address downstream water challenges. These practices are both contributing to the resilience of farmers and their livelihoods and reducing treatment costs for Nairobi Water and Sewerage Company. In this example, success has been fuelled by the leadership of an active board of champions who are supported by a solid business case.

Finally, for nature to be considered an investable infrastructure asset on par with grey infrastructure, enabling polices to create dependable cash flow and specific mechanisms to finance projects are needed. Regulators in Ecuador, Peru and Colombia, for example, have provided for tariff reform that allow utilities to invest in NbS, and emerging approaches in the Brazilian states of Santa Catarina and São Paulo are also helping create a new pathway for water utility companies to consider nature as an asset to their water delivery mandates. Cities in the USA, like San Antonio, have similarly found multiple ways to finance investments in aquifers and watershed protection. Policy support is central to all these approaches.

From Europe to South America and beyond, cities across the globe are considering integrated solutions that bridge grey infrastructure with nature as a means to solve their unique water security challenges. No matter the local context, leveraging the right tools to design, deliver and pay for NbS are key to connecting to a city's catchment, bridging the urban-rural divide, creating value for rural communities and ultimately, sustaining water for all. The Nature Conservancy is working to connect stakeholders with the technical assistance they need to invest in their watersheds through the new **Nature for Water Facility** and additional resources that can be found at **www.resilientwatersheds.nature.org**.

Hobart - Tasmania, Australia © Derwent Estuary Program

Environmental regulations are a pathway for dialogue between multiple stakeholders within a basin, however, waiting for these to be put in place to trigger integrated water management is not always an option. The case of **Derwent Estuary in Tasmania, Australia**, demonstrated action can be taken through partnership and cooperation despite the lack of clear regulations, as the state of Tasmania has no regulatory framework that allows for an integrated catchment approach for environmental regulation. Consequently, to manage the increasing pollution from industrial and municipal wastewater discharge as well as non-point sources, the Derwent Estuary Program (DEP) was established and now aims to coordinate initiatives to reduce pollution; conserve habitats and species; monitor river health; and promote greater use and enjoyment of the foreshore. Data and environmental monitoring in partnership with various urban and industry stakeholders is the basis for improving the health of the estuary. As the Program is expanded to the wider catchment the solutions for pollution control will continue to be crafted on sound data, financial partnerships and working with communities to streamline initiatives.

Finance tools as well as policy and regulation can incentivize the management of wastewater discharged by urban users back into the catchment areas. These three interdependent factors can transform how we manage wastewater, leading to outcomes that improve freshwater biodiversity, climate action and water security. Box 15 from the World Business Council for Sustainable Development (WBCSD) outlines regulatory and financing mechanisms which industry are using to improve water resources in their wider basins.

Box 15. Regulatory and financing mechanisms for managing wastewater

By Tom Williams, Director, Nature Action & Nature Based Solutions, WBCSD

Material used in this text is taken from: Wastewater Zero - A call to action for business to raise ambition for SDG 6.3, download here: **https://www.wbcsd.org/Programs/Food-and-Nature/Water/Resources/Wastewater-Zero-Raising-business-ambition-for-SDG-6.3**

There is an important untapped nexus between cities, basins and industry in water management. **A 2019 report by the World Bank** suggests that in regions downstream from heavily polluted rivers, GDP growth is lower by a third. Such pollution comes from diffuse (e.g., agricultural run-off) and point (e.g., municipal and industrial wastewater) sources. Eighty percent of all wastewater is discharged directly into the environment without treatment, embedded within it are water and nutrients that could be used and hazardous substances that are easily removed.

For industry – as a wastewater producer and solution provider – policies that establish clear guidelines, with appropriate thresholds and limits based on the best available science (for industrial effluent discharges and wastewater reuse) in industry and agriculture provide clear and transparent performance targets to reach. Regulations that incentivize the recycling of water by industry and the trading of reused water between industry and municipal authorities will drive innovation and create new business models.

For example, to drive adequate wastewater treatment in the Indian state of Maharashtra, 2030 Water Resource Group has proposed water reuse certificates (WRCs) – an innovative market-based mechanism – to promote the trading of recycled wastewater. The team and the Maharashtra Water Resources Regulatory Authority (MWRRA) have collaborated to:

- Design two separate tradable permit mechanisms to promote the trade of WRCs among large municipal corporations and among leading private industrial sector water users, wherein WRC equals 100 m3/day of recycled wastewater;
- Create specific targets based on the assets deployed/planned in the urban sector and the number of water-use closed loops possible in the industrial sector;
- Roll out guidelines and an MWRRA-led regulation to galvanize the use of WRCs; and
- Develop a blockchain and an Internet of Things (IoT) backbone to operationalize WRC harnessing of cloud computing possibilities.

Through the right fiscal and institutional incentives, the 2030 Water Resource Group expects the tradable permit mechanism to maximize the use of wastewater treatment assets, mobilize financing for water infrastructure and disruptive technologies through private sector participation, and build institutional resilience through information technology-based innovations.

The significant potential for public–private partnerships to manage wastewater requires a mix of financing models that can meet local conditions. One example is special purpose vehicles (SPVs), a form of off-balance sheet financing. Such partnerships jointly commit or raise funds to build and operate infrastructure. The benefits of SPVs are that partners can share the risks and access blended finance from private and public sources. For wastewater management, which is both a public and private sector issue, SPVs provide a formal mechanism creating accountability for financing, building, operating and maintaining infrastructure that benefits the public and private sector.

An example of an SPV is in Rustenburg Municipality, a water-stressed area in South Africa, which faced the dual challenge of increased water demand from domestic and industrial sources and reaching wastewater treatment capacity. Public finances could not meet investment needs, which led to an engagement with local mining companies. The municipality and mining companies established an SPV – the Rustenburg Water Services Trust – to finance and operate new water infrastructure: 50% of the SPV's revenue comes from mining companies who have a 25-year agreement to off-take non-potable treated wastewater. After seven years of operation, the Rustenburg Water Services Trust had cash reserves of USD$12 million. The SPV has realized several benefits: secured supplies for mining, reduced dependence on freshwater sources for industry that is increasing freshwater availability for other purposes and improvements in downstream water quality through better wastewater treatment.

Pollution prevention and reduction at the source is the most effective response in terms of minimizing health and environmental impacts and intervention costs. Industry should proactively engage in developing public policies and regulations to find solutions that protect public health and the environment in a cost-effective way.

9 - CONCLUSION AND NEXT STEPS

This Handbook provides a practical reference on how to respond to the call to action for urban stakeholders to play a greater role in engaging in their hydrological basins. It can be used as a source for policy recommendations, and as a reference for best practice for more active awareness and involvement from across urban areas to ensure water quality, flows and preparedness for extreme events. It also provides approaches for taking action which can contribute to the 2030 Sustainable Development Goals (SDGs).

9.1 – CITY-BASIN DIALOGUE AND THE SDGS

SDG indicators have a global focus, but decisions around SDG 6 ("Clean water and sanitation for all") are happening locally, across neighbourhoods, cities, aquifers and basins. Cities are crucial agents to deliver action on the SDGs which can secure health and well-being of citizens and the environment. Holistic approaches and cross-sectorial partnerships are important to develop water for smart liveable cities. At least 105 of the 169 SDG targets will not be reached without proper engagement and coordination with local and regional governments (OECD, 2020). Furthermore, cities and regions are increasingly using the SDGs as a foundation to shape the design and implementation of urban strategies, policies, and plans.

Cities need to engage and have active dialogue with stakeholders in their surrounding watersheds to achieve SDG targets across the different goals including SDG 6. In most countries, local governments are providers of water and sanitation facilities, or they oversee the provision of services through private sector partnerships. However, the responsibilities of the local government can include ensuring equitable distribution of water resources, identifying alternative sources, and supporting coordination with surrounding regions to secure supply and protect quality (Freyling, 2015).

As cities use the SDGs to shape their policy and planning, interactions and trade-offs between different SDG targets need to be recognized, meaning there should be promotion of synergies across sectors. Actions to achieve SDGs can be designed to consider linkages – for example urban wastewater utilities can be operated to not only improve water quality, but also produce energy (SDG7 – Affordable and clean energy), as well as contribute to SDG 11 – Sustainable cities and communities. At a city-basin scale, local governments can contribute to SDG 6 through water-use efficiency by ensuring sustainable withdrawals and supply of freshwater within their source watersheds. This can be through implementing IWRM policies and initiatives which can contribute towards conservation practices and restoration of ecosystem (Goal 15 – Life on Land) (Urban SDG Knowledge Platform, 2022). SDGs provide the drive and direction for cities to use a systems approach in planning and implementation.

Interconnectedness is the essence of a basin-connected city, only by having a systemic approach can cities work in conjunction with their wider basins to effectively respond to different pressures. Understanding the linkages and the impacts of different actions means active cooperation and communication among stakeholders from catchment to tap. The Handbook on Basin-Connected Cities provides an insight into how this is happening in practice, and demonstrates how different actors navigate amongst complexities to ensure sustainable basin management for upstream and downstream users.

9.2 – NEXT STEPS

INBO and IWA will use the Handbook to encourage connectivity between basins and urban areas including the relationships around biodiversity, communities, business, government and infrastructure (e.g., river cities and ports). The aim is to promote coherence among public policies and efficient management of water which has a holistic approach beyond administrative borders and sectoral approaches in silos.

Planners and basin managers can learn from best practices across different basins. Sharing knowledge, data, ideas and technology is essential. However, approaches for connecting cities with their basins need to be customized for not only physical characteristics, but also socio-political and cultural issues. Water planning and management can take place at different scales, nonetheless it is important to remember that water is local in that how it is managed within a country or region, or town will reflect culture, history, religion, geography, geology, soil characteristics, economy and climatic patterns along with hydrological realities (rainfall patterns, rivers, lakes, groundwater and weather events) (Catley-Carlson, 2012).

The basin stories interwoven throughout the narrative throughout of this handbook can provide initial ideas on actions which can be shaped to local context. They demonstrate that water solutions can usually not be adopted without being adapted locally (Catley-Carlson, 2012). They provide the inspiration and demonstration on how urban stakeholders can play an active role in their basins. Moving forwards IWA and INBO will continue to collect and highlight basin stories and encourage organizations to document and showcase their experiences. Each city is unique but by sharing challenges and successes their experiences can add value, and be used as a stepping stone to develop context specific approaches for other urban centres. The aim is for this Handbook to evolve and integrate these new stories along with approaches and best practices.

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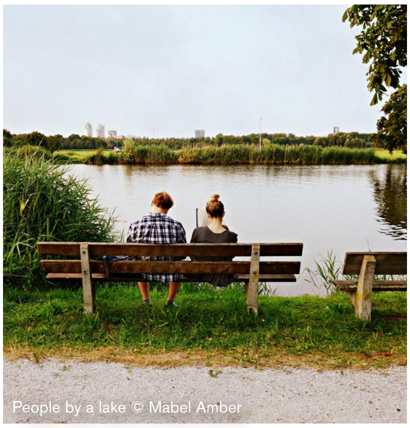
ANNEX 1 – BASIN STORIES

Title	City/Basin/Country	Further information
Mechanisms of Reward for Ecosystem Services (MRSE)	Peru	https://iwa-network.org/mechanisms-of-rewards-for-ecosystem-services-mrse/
Upper Tana-Nairobi Water Fund	Nairobi, Kenya	https://iwa-network.org/upper-tana-nairobi-water-fund/
Fundamentals to Enhance Büyük Menderes River Basin	Büyük Menderes River Basin, Turkey	https://iwa-network.org/buyuk-menderes-river-basin/
Densu Basin Board	Densu Basin, Ghana	https://iwa-network.org/densu-basin-board-story/
Derwent Estuary Program	Derwent Estuary, Tasmania, Australia	https://iwa-network.org/derwent-estuary-program/
Towards a liveable water sensitive city	Melbourne, Australia	https://iwa-network.org/melbourne-basin/
A vision for San Francisco	San Francisco, USA	https://iwa-network.org/a-vision-for-san-francisco/
The Upper Swakop River Basin	Windhoek, Namibia	https://iwa-network.org/the-upper-swakop-river-basin-2/
Bourbre's Flood Risk Management Programme	Boubre Basin, France	https://iwa-network.org/bourbre-basin/
Urban Water Cycle Integrated Management	Porto, Portugal	https://iwa-network.org/aguas-do-porto/
Living with Water Partnership	Yorkshire, UK	https://iwa-network.org/yorkshire-water/
City of Kushan – A sponge city vision	Kushan, China	https://iwa-network.org/city-of-kunshan/
Mackenzie DataStream	Northwest Territories, Canada	https://iwa-network.org/mackenzie-datastream/
'One stop shop' for water management	British Colombia, Alberta, Canada	https://iwa-network.org/one-stop-shop-for-water-management/
Middle Ebro River. Flood risk management and resilience for cities and citizens	Zaragoza, Spain	https://iwa-network.org/ebro-river-basin-spain/
Green infrastructure as a conceptual framework to reconnect Mexico City metropolitan area with its lake basin	Mexico City, Mexico	https://iwa-network.org/mexico-city-mexico/
Rehabilitating an urban river	Manila, Philippines	https://iwa-network.org/manila-philippines/
Improving water quality using infrastructure and legal mechanisms	Congo Basin - Kinshasa and Brazzaville	https://iwa-network.org/kinshasa-and-brazzaville-congo/
Environmental surveillance during a pandemic	Paris, France	https://iwa-network.org/paris-france/
Holistic regeneration of the Grand Yoff storm-water retention basin in the heart of Dakar's Peninsula	Dakar, Senegal	https://iwa-network.org/dakar-senegal/
Bringing Life Back to the Tagus River – The Tagus Estuary Clean-Up Project	Lisbon, Portugal	https://iwa-network.org/city-of-lisbon/

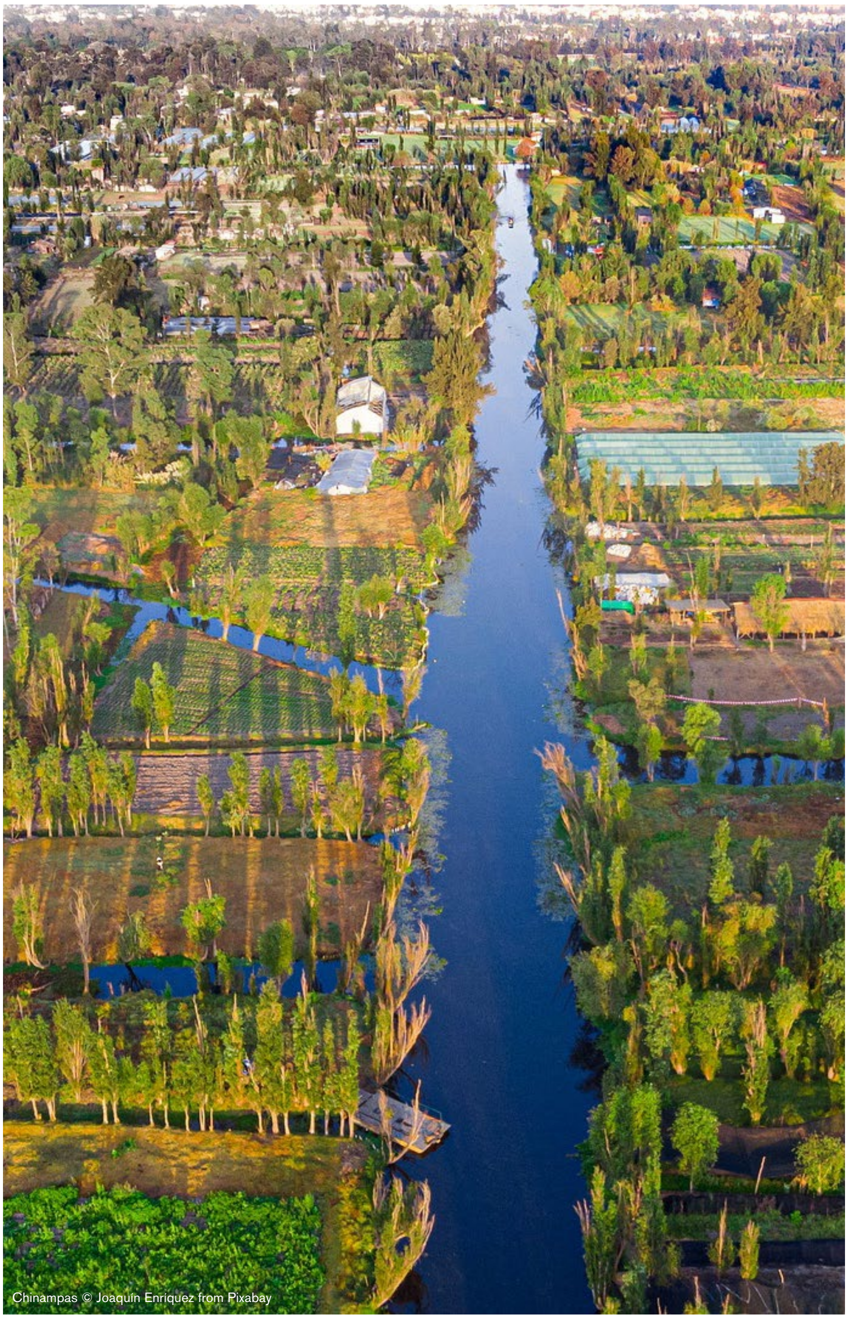
Title	City/Basin/Country	Further information
Water supply of Rio de Janeiro's Metropolitan Area and Integrated Management of the Guandu basin	Rio de Janeiro, Brazil	https://iwa-network.org/rio-de-janeiro-brazil/
War on Leaks	Johannesburg, South Africa	https://iwa-network.org/city-of-johannesburg-south-africa/
Recovery of the river habitat in urban environments	Alicante, Spain	https://iwa-network.org/jucar-basin-alicante/
Reduce the Risk of Flooding and Improving the Ecological Status of the Júcar and Moscas Rivers	Cuenca, Spain	https://iwa-network.org/jucar-basin-cuenca-spain/
City of Fez: Technical and institutional strengthening for sustainable management of water resources	Fez, Morocco	https://iwa-network.org/fez-morocco/
Comprehensive Governance of Huancheng River of Shaoxing City	Shaoxing, China	https://iwa-network.org/shaoxing-city-china/
Protection and Utilization of Taihu Lake Lougang Irrigation and Drainage System in Huzhou City	Huzhou, China	https://iwa-network.org/huzhou-city-china/

Fishing boats along an estuary in Thailand © woren76



People by a lake © Mabel Amber

Piruay Lake © poon sandy



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