Deltares

Strategic Water Systems Planning
- A Framework for Achieving Sustainable, Resilient and Adaptive Management

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Preface

This document outlines the framework which Deltares uses to guide their planning and analyses of water systems. It is based on knowledge gained from many years of experience that Deltares and collaborating partners have had in carrying out strategic planning studies. 'Water system' is a broad term which can be applied to many different types of water resources, including river basins, coastal zones, urban water systems, groundwater systems, etc. Each water system is different and has its own specific physical, socio-economic and institutional characteristics and challenges. Consequently, strategic planning studies for any particular water system will be unique and will require its own approach. But even in recognizing this uniqueness, the approach should be systematic and should follow a logical process of sequential steps. This systematic approach is the basis of the Strategic Water Systems Planning Framework (in short the Analysis Framework). The Analysis Framework is described in chapter C. Although water systems and their respective challenges show considerable variety and variability, the underlying principles for an integrated planning process are always the same. The Analysis Framework presents these underlying principles in a generic manner that can be easily adapted and tailored to fit the needs of a specific project. This is often done in the Inception Phase of a planning study. As such, the Analysis Framework is not meant to be a rigid checklist of steps that must be followed, but rather a guide for planners of specific systems as they develop their own approach to planning and analysis.

The **objective** of this document is to describe the background of strategic planning of water systems and to illustrate how a strategic planning study can be carried out. It emphasizes the need for an integrated, comprehensive and inclusive approach. The step-by-step and systems-based framework defines the integrated approach that needs to be followed in the planning exercise. It also facilitates communication with and among stakeholders during the study.

The **target audience** of the document are researchers and/or consultants who carry out planning activities. Similarly, the document might also be useful for the clients of strategic planning studies, who initially may need background information to produce an appropriate Terms-of-Reference and subsequently may wish to use the information in order to supervise the work carried out by the consultants. The document can also serve as lecture material in professional and academic classes or as training material in capacity building activities during the execution of a planning study. A PowerPoint version of this document is available for these education and training purposes.

We recognize that the Analysis Framework is a simplification of a real planning process. The Framework is presented as a straightforward step-by-step process that results in a strategic plan (see Figure C1). The reality is that there are many other activities that need to be carried out and feed-back loops in which previous steps will need to be revisited. Clarifying the general structure of the planning process and identifying the different roles required help the multi-disciplinary project team to communicate with each other and with stakeholders. It also specifies early on in the process which assumptions must be made and which activities must be undertaken, and in doing so lowers the need to have a large number of feed-back loops.

The Analysis Framework presented in the document defines a comprehensive planning process, from inception to implementation. If parts of the planning process have already been performed, the Analysis Framework can be used as an integrating tool to complete the planning process or to provide additional information needed for decision-making.

Acknowledgments

This document has been compiled by a working group of experts in Deltares, led by Eelco van Beek. This working group consisted of specialists in the various fields mentioned in the document: Arno Nolte (coastal zone and marine), Hans Gehrels (urban), Judith ter Maat (river basin management, drought), Marta Faneca Sanchez (groundwater) and Nathalie Asselman (flood). This team made use of the experience of many other Deltares colleagues, including the scientific work carried out by Laura Basco Carrera (stakeholder engagement and collaborative modeling), Monica Altamirano (financing framework), Reinaldo Penailillo Burgos (inclusiveness) and Marjolijn Haasnoot (adaptive planning). The document is also based on the expertise and knowledge which Deltares gained when previously carrying out planning projects, such as the Delta program in the Netherlands, developing Integrated Water Resource Management guidelines for the Philippines, producing Integrated Coastal Zone Management guidelines in Kuwait and the Manila Bay Project Sustainable Development Master Plan, as well as incorporating information from training projects on Integrated Water Resource Management and Water Security (used in Mongolia, the Philippines, Kosovo and at several universities). Deltares experts involved in those projects were Tjitte Nauta, Laura Basco Carrera, JanJaap Brinkman, Judith ter Maat, Monica Altamirano, Eelco van Beek, Judith Blaauw, Arno Nolte and Ana Nunez Sanchez. Ana Nunez Sanchez reviewed earlier versions of this document.

Part of the text in this document is a further elaboration of earlier work on the subject, as presented in the book 'Water Resource Systems Planning and Management' by Pete Loucks and Eelco van Beek. Prof. Loucks provided comments and suggestions in an earlier draft of this document which is highly acknowledged. Editing of the document was done by Eliana Harrigan (Water Science Policy). Roel Savert took care of graphic design and lay-outing of the document.

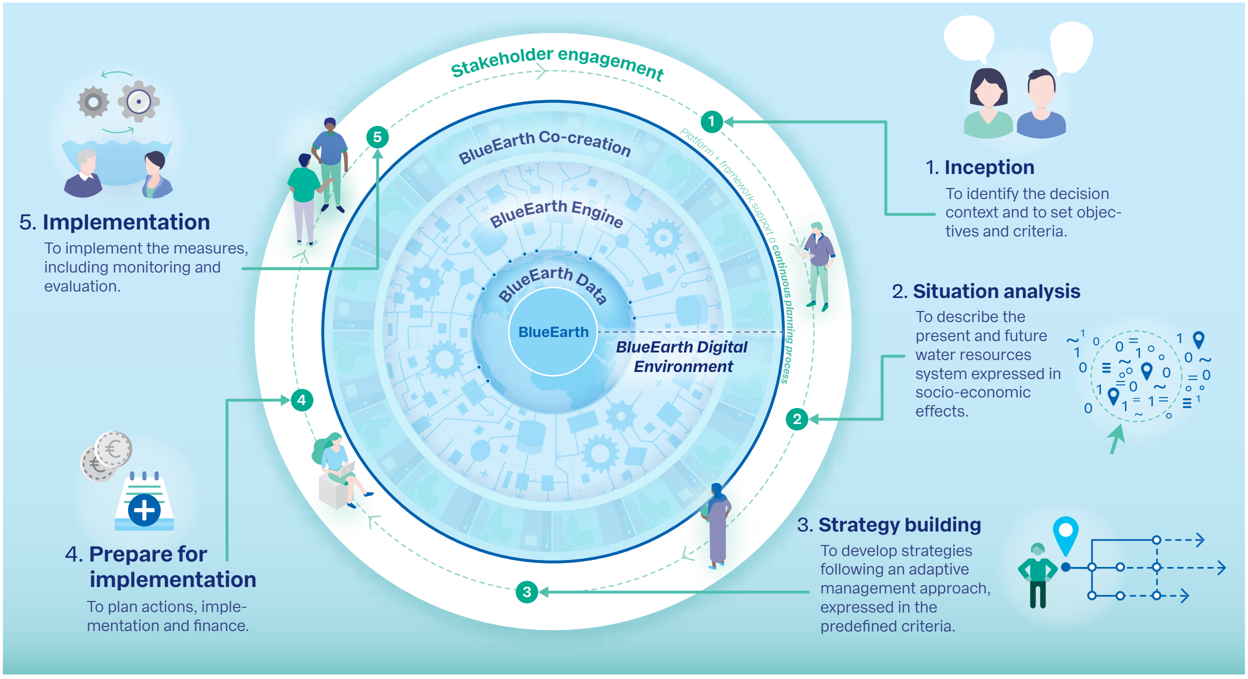
BlueEarth

The Analysis Framework is an integral part of Deltares' BlueEarth initiative, which aims to facilitate stakeholder collaboration in decision-making. The underlying concept of BlueEarth is that the use of open global data, open model tools and user-oriented dashboards, in combination with the client's own data and models, will help to enable informed and interactive decision-making about how to develop and manage water systems. BlueEarth uses the five phases of the Analysis Framework to develop and apply the analytical tools that are used in specific planning studies. This is shown in the figure below.

BlueEarth has a strong focus on engaging stakeholders in the planning process, as well as making the analytical tools fit the particular planning project's needs in each of the five phases of the Analysis Framework. The three layers of the core of BlueEarth (the BlueEarth Digital Environment) are:

- BlueEarth Co-creation: supporting collaboration with stakeholders by using tools like user-oriented dashboards and group model building approaches.
- BlueEarth Engine: running and processing data to build water system models, perform smooth transparent data-model workflows, and analyze and visualize the results.
- BlueEarth Data: facilitating access to online and open-access (global) input and output datasets, combined with local datasets.

For more information on BlueEarth, refer to https://www.deltares.nl/en/blueearth.



Executive Summary

1. Need for Integrated Planning of our Water Systems

Water is essential for all life on Earth. For millennia humans have been managing water systems to satisfy drinking and sanitation needs, irrigate crops, support industrial activity and commercial navigation, produce energy and provide recreational opportunities. At the same time, water systems are also used for protection against floods, to prevent water pollution and to maintain healthy aquatic environments. Exponential population growth and enhanced economic activity have increased demand for freshwater whilst drastically lowering supply, simultaneously causing many water systems around the world to become seriously stressed and increasing the total amount of area and assets that need to be protected. Climate change is exacerbating these challenges. Socio-economic growth and climate change are also affecting the coastal zone and marine systems. Coastal zones are some of the most densely populated areas where many economic activities take place and converge. Sea-level rise is an additional challenge for coastal zones. Coastal seas are often also filled with economic activities that compete with space and must be managed well in order to maintain their highly diverse and complex ecosystems.

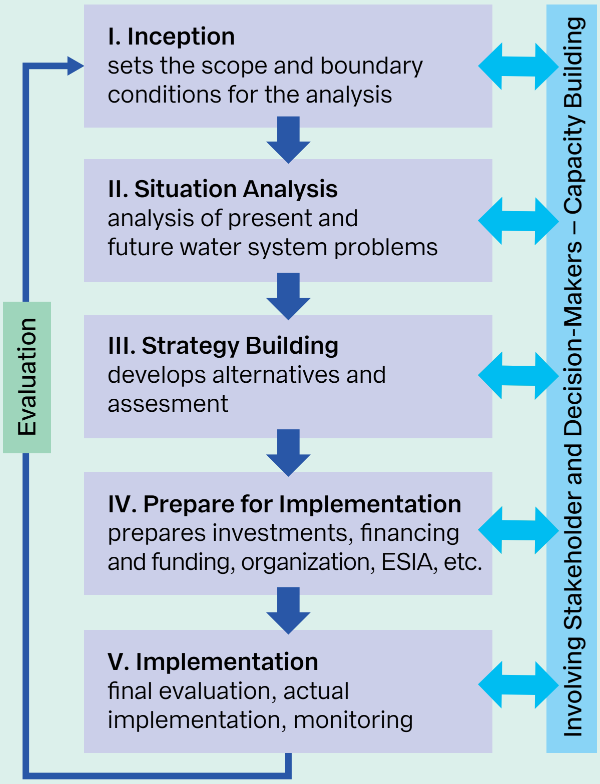
The ultimate aim of water management efforts is to achieve water security. The many dimensions of water security (for example human, economic and environmental use, protection against floods, droughts and pollution) are reflected in the Sustainable Development Goals (SDG). Strategic plans are needed to develop a long-term vision to achieve water security and the SDGs, and to set medium-term goals, clear targets and roadmaps for policy-makers and organizations.

Governments develop strategic plans for distinctive geographic water systems such as river basins, coastal zones, urban areas, aquifers, and seas. Strategic plans are also developed on how to deal with floods, droughts, aquatic pollution and ecological degradation. Common to all of these plans is an integrated approach that considers the interactions between the natural resource system (NRS), the socio-economic system (SES), and administrative and institutional system (AIS). They promote the coordinated development and management of water, land and related resources as formulated in the principles of integrated water resources management (IWRM). This systems approach must contain two main elements: i) a conceptual framework of steps to be followed in the analysis phase and, ii) a computational framework (such as models and data) to quantify the impacts of possible decisions relating to the development and management of the water system.

One of the principles of IWRM is that the planning, development, and management of water systems should be based on a participatory approach, involving users, planners and policy-makers at all levels (Dublin Principle II). When involving stakeholders, special attention needs to be given to inclusiveness to ensure equal opportunities so that everyone, regardless of their background, will benefit from the planned developments and management.

2. From Inception to Implementation in 5 Phases

The Analysis Framework described in this document identifies five phases in the continuous strategic planning cycle for managing water systems. Phases I, II, and III focus on the development of a strategic plan, phase IV defines the actions needed for implementation and phase V is the actual implementation of the strategy (see figure). While this framework is presented as a simple one-directional flow of activities, in reality there might be many feed-back loops involved in the process. Reviewing previous phases may be useful when there is increased knowledge about the system and its issues, especially considering that both can change during the planning process. The application of the Analysis Framework must be flexible enough to allow such feedbacks.



Analysis Framework for Strategic Planning of Water Systems (see Figure C1 for details)

The first *inception phase* (Phase I) of the process identifies the subject of the analysis (what is to be analyzed and under what conditions), the objectives (the desired results of the analysis) and constraints (its limitations). Based on this analysis, during which intensive communication with decision-makers is essential, an agreement on the approach which will be used for the remainder of the analysis needs to be achieved. The results of the Inception phase can be presented in an inception report, which includes the work plan for the remaining phases of the analysis.

In the *situational analysis phase* (Phase II), the analytical tools for the analysis of the water resource system are selected or developed. Major activities in this phase typically include data collection and modeling. The models will be used to quantify present and future system performance. This performance can be based on multiple economic, environmental, and/or social criteria, to name a few. Scenarios will be developed that describe the future boundary conditions for the system. Identifying and screening alternative decisions can occur in this phase. If possible, no-regret measures will be identified for immediate implementation.

The level of understanding of the water system's various characteristics generally improves as the study progresses from limited data sets and simple tools to more detailed data and models. Interaction with decision-makers will be greatly enhanced if they trust and communicate with the analysis team, or, even better, are directly involved as part of the analysis team. More formal interactions can be structured through presentations of results in meetings and in interim progress reports.

In the *strategy building phase* (Phase III), alternative strategies will be developed and discussed with decision-makers and relevant stakeholders. This will include adaptive management elements to ensure that the preferred strategy is sufficiently robust and flexible in case the future develops differently than expected. This phase ends with the formulation of a mutually accepted integrated strategic plan for the development and management of the water system.

In the *preparation of implementation phase* (Phase IV), the selected strategy will be prepared for implementation. An implementation plan will be developed which provides the details necessary for implementing the project, such as what will be done, by who, how it will be financed, etc. Additional work may need to be undertaken before decisions are made, including conducting feasibility and design studies and social and environmental impact assessments (SEIA). Institutional arrangements may have to be made to ensure a smooth implementation of all activities.

Finally, during the *implementation phase* (Phase V) the actual implementation will take place. Continuous monitoring and evaluation are needed to determine if and when adjustments to the plan should be made, for instance, as a result of changing conditions (e.g., finances, social pressures, political mood and objectives).

3. Applying the Analysis Framework

The Analysis Framework presented above is generic in nature. It can be applied to strategic planning studies of different types of water systems such as aquifers, river basins, coastal zones, and urban areas. The same principles apply, and the same approach can be followed. However, the focus on particular aspects of these water systems will vary. These differences of focus can be at spatial or temporal scales or on certain components of the water system.

Integrated river basin plans present a comprehensive picture of all water-related activities and supply and demand components in a river basin. The concept of IWRM is fully implemented in integrated river basin plans, incorporating data on the quantity and quality of surface- and groundwaters into its models, policies and processes.

Integrated coastal zone plans specifically address the issues and activities in the coastal zone. The focus of a coastal zone plan tends to be on spatial planning of the functions and activities in coastal zones. In most plans much attention is given to coastline development, including protection against flooding and prevention of erosion.

Integrated urban management plans cover densely populated areas where the essential function of water is to sustain life, the economy and the environment. These urban plans include the water chain (drinking water and wastewater) as well the urban drainage system. The many actors involved and the role of water to improve the livability in the city (including dealing with heat stress) make stakeholder involvement an important factor when developing urban management plans.

Groundwater management plans are developed to ensure the sustainable use of and protection against pollution in groundwater resources. They also set boundary conditions for the use and protection of groundwater in other plans, in particular river basins, coastal zones and urban areas. Groundwater management plans address important processes and solutions which are relevant for other plans, such as salinity intrusion, land subsidence issues and conjunctive surface- and groundwater use in droughts.

Marine spatial plans allocate the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process. A marine spatial plan creates and establishes a more rational use of marine space and the interaction between uses, to balance demands for development, with the need to protect the environment, and to deliver social and economic outcomes in an open and planned way.

Drought management plans describe what measures can be put in place to prevent droughts and what action should be taken when a drought event occurs. As such, their purpose is both strategic and operational. The latter are often called drought mitigation plans. The strategic section of a drought plan should have strong links and references to relevant river basin plans.

Flood management plans also often have a strategic and operational character. Their main objective is to prevent floods, but they also explain what should be done when flood events take place, i.e., how to mitigate the impacts of floods. Flood management plans are associated with river basin management (watershed management and fluvial flooding), coastal zone management (coastal flooding) and urban water management (pluvial flooding and urban drainage).

Water quality and ecosystem management plans aim to achieve healthy water systems that are fit-for-purpose to the assigned functions of the water system. The plan describe the measures to be taken to prevent point and diffuse pollution of the water systems and to restore conditions in which ecosystems can flourish. This might include the determination of environmental flows that describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

Despite their different areas of focus, all of these plans need to be based on the principles of integrated management and will benefit from following the Analysis Framework.

4. How to ensure that the strategic plan gets implemented

Many water system plans never reach the implementation phase. Clarifying certain details when carrying out strategic planning studies during phases I, II, III and IV will increase the likelihood that the plan will be implemented by the responsible authorities and organizations. The main points of attention in these phases are: i) stakeholder involvement and ownership, ii) ensuring that enabling conditions are in place, iii) confirming that the plan is realistic and can be translated into implementable projects that are financially feasible.

The first condition necessary for plan implementation is to involve relevant stakeholders in developing the plan. Such involvement is more than just informing and discussing with them about the proposed idea. They should be intensively involved in identifying problems, objectives and possible solutions. Additionally, as argued in the Analysis Framework, stakeholders should be involved in the analytical work, especially in discussions concerning data and analysis, to make best use of their knowledge about the system. The ultimate goal of this involvement is that stakeholders should consider the plan to be their own. Ensuring such ownership is important for governmental authorities and non-governmental organizations who will be the key players in implementing the plan.

The second condition needed for effective plan implementation is the presence of enabling conditions, specifically the existence of clear policies and laws, a well-developed institutional setting with defined responsibilities, and management instruments to assess information based upon which operational decisions can be taken. If there is an absence of these conditions, the strategic plan should include measures which allow for their creation, i.e., the development of new policies, laws and institutions, as well as capacity building of responsible organizations.

The third condition is that the plan is realistic in terms of its ability to be implemented. The plan should not just be a simple wish-list of everything that has been proposed by stakeholders. The total project cost and/or investment should be reflective of the usual budgets of the implementing organizations. Next, the strategy should be developed into an action plan with concrete (investment) projects for which economically, financially and politically acceptable implementation arrangements have been established.

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Acronyms

ADB	Asian Development Bank
AIS	Administrative and Institutional System
APFM	Associated Programme on Flood Management (of WMO and GWP)
AWDO	Asian Water Development Outlook
BAU	Business-as-Usual
B/C	Benefits/Costs
CAPEX	Capital Expenses (investment)
CC	Climate Change
CRIDA	Climate Risk Informed Decision-Making Analysis
CV	Climate Variability
DAPP	Dynamic Adaptive Policy Pathways
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DSS	Decision Support System
EBM	Ecosystem-Based Management
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
FFWS	Financial Framework for Water Security
GCF	Green Climate Fund
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GWP	Global Water Partnership
HM	His Majesty
ICZM	Integrated Coastal Zone Management
IDRM	Integrated Drought Risk Management
IDMP	Integrated Drought Management Programme (of WMO and GWP)
IDP	Integrated Drought Plan
IDRP	Integrated Drought Risk Plan
IFC	International Finance Corporation
IFI	International Financing Institutions
IFRM	Integrated Flood Risk Management
IGM	Integrated Groundwater Management
IIC	Inter-American Investment Corporation
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
IUWM	Integrated Urban Water Management
IWRM	Integrated Water Resource Management
JICA	Japanese International Cooperation Agency
KD	Key Dimension (of AWDO)
MCEM	Multi Criteria Evaluation Methods
MIS	Management Information System
MSP	Marine/Maritime Spatial Plan
MoV	Means of Verification
MWh	Megawatt hour
NbS	Nature-based Solutions
NGO	Non-Governmental Organization
NRS	Natural Resource System
O&M	Operation and Maintenance
OECD	Organization for Economic Cooperation and Development
OPEX	Operation Expenses (O&M)
OVI	Objectively Verifiable Indicators
PFD	Project Formulation Document
PPP	Public Private Partnership
RBM	River Basin Management
RBMP	River Basin Management Plans
RBO	River Basin Organization
SA	Sustainability Appraisal
SDG	Sustainable Development Goal
SEA	Strategic Environmental Assessments
SES	Socio-Economic System
SLR	Sea Level Rise
TA	Technical Assistance
S2S	Source-to-Sea
TOR	Terms-of-Reference
TS	Technical Secretariat
WASH	Water Sanitation and Hygiene
WFD	Water Framework Directive (of EU)
WMO	World Meteorological Organization
WRS	Water Resource System (= NRS-SES-AIS)
WWF	World Wildlife Fund

A. Water systems and the need for strategic planning

Managing water is important. The effectiveness of strategies for dealing with water availability and variability, water quality, and spatial planning is a major determinant for biodiversity, the functioning and resilience of ecosystems, and the economic and social vitality of communities. Managing water aims to maximize the beneficial uses of water as a commodity, e.g., for agricultural, commercial, domestic, industrial, public heath, and recreational uses, to sustain the role of water for ecology and biodiversity and to minimize the detrimental impacts of water, e.g., from flooding, droughts or water pollution. However, it also includes allocating spatial zones for water-based human activities, e.g., fishery catchment areas, park grounds or shipping lanes. This chapter outlines the functions of water systems, the objectives of water management policies, and the general principles and need for strategic planning of these water systems.

A.1 Functions of Water Systems

Water is essential for life. The many functions that water has for human beings can be tangible or intangible, as presented in Table A1. Tangible functions can be described quantitatively. For instance, hydropower generation or municipal water supply may be assigned a monetary value. Intangible functions are difficult to quantify in monetary terms. An example of an intangible function is the sense of peace and happiness that one feels when looking at a lake, waterfall or ocean. In between are environmental functions, some of which may be given quantitative values and others valued only indirectly, such as by using the opportunity cost associated with meeting a particular target. The natural self-purification process of a river, for example, may be assigned a value by comparing this 'work done by nature' with the costs of the least-cost alternative that accomplishes the same results, such as constructing, maintaining and operating a wastewater collection and treatment system. The spiritual and cultural significance of water and its uses for all people, including disadvantaged groups, are non-transactional values of water and can be described quantitatively, although not always in monetary terms.

Subsistence Functions
Communities are largely dependent on water for household uses and for irrigating home gardens. They may also use streams, paddy fields, ponds, and lakes for fishing. These uses are often neglected in national economic accounts, as they are not marketed or otherwise assigned a monetary value. However, if the Water Resource System (WRS) becomes unable to provide these products or services, this may well be considered an economic loss.

Commercial Functions
Commercial uses of water resources are reflected in national economic accounts because they are marketed or otherwise given a monetary value, e.g., the price paid for domestic water supplies or the

Functions	Description	Examples
Subsistence function	Local communities making use of water and water-based products which are not marketed	- Local drinking water supply - Traditional fishing - Subsistence irrigation
Commercial functions	Public or private enterprises that are making use of water or water-based products which are marketed or otherwise given a monetary value	- Urban drinking water supply - Industrial water supply - Irrigation - Hydro-power generation - Commercial fishing - Transportation
Environmental functions	Regulation functions Non-consumptive use	- Purification capacity - Prevention of salt intrusion - Recreation and tourism
Ecological values	Value as an ecosystem	- Biodiversity - Gene pool - Nature conservation value
Non-transactional value of water	Regards the symbolic value of water for people beyond its value as a resource	- Cultural value of water - Emotional value of water - Spiritual value of water

Table A1 Functions of a water system

profit individuals or enterprises make by selling fish. These uses have a commercial value, and most are consumptive. The concept of 'non-consumptive use', i.e., when water is used but is still available for other users, should be regarded with certain reservations. Non-consumptive water use may alter the performance of the WRS in various ways. Consider reservoirs built for hydropower. Reduced sediment and fish passage and increased evaporation losses may adversely impact downstream ecosystems and users. Second, the reservoirs operations aiming to produce 'peak power' may alter the flow regimes downstream, which can also negatively affect downstream ecological habitats and users. Finally, the impacts and operations of the reservoir may decrease water quality, leading to potential human and environmental health issues. Another example of partly non-consumptive use is inland water transportation. Oil and chemical pollution caused by water transport activities can affect other users and ecosystems that depend on the water resources. Moreover, inland water transportation may involve a consumptive demand for water. If water depths are to be maintained at a certain level for navigational purposes, releases from reservoirs may be required, which provide no value to other water users. An example is the Lower Nile system, where water is released from Lake Nasser to enable navigation and energy generation during the so-called winter closure. This water could otherwise remain stored for (consumptive) use in agriculture during the growing season.

Environmental Functions
Environmental functions refer to the benefits and contributions that the physical environment provides for human and ecosystem well-being. This can include purifying air and water, climate regulation and waste decomposition. The drainage basin of a river fulfills a series of environmental functions that require no human intervention, and thus have no need of regulatory systems. It is sometimes difficult to assign values to environmental functions. They may be assessed by using opportunity costs, calculated as the costs of providing similar functions in other ways, e.g., the cost of additional wastewater treatment. Tourism and recreational activities can also be environmental functions. Lower bounds on recreational and tourism values may be estimated by assessing the economic benefits accruing from the use of tourist facilities including hotels, and/or the revenue obtained from the sale of fishing licenses. Unlike the more natural environmental functions, tourism and recreation activities may require some form of regulation to ensure that they are sustainable.

Ecological Functions
Water systems are essential for many different types of flora, fauna and habitats to live and thrive. For example, rivers, streams and lakes and their associated wetlands, floodplains and marshes offer habitats for a variety of aquatic species. Land–water ecotones (transition areas between adjacent ecological communities) are known to harbor a rich assemblage of species and are important for the biodiversity of adjacent ecological communities. These ecological entities have an intrinsic ecological value irrespective of actual or potential human use. There are many concepts and expressions that describe this ecological value: 'heritage value', 'aesthetic value', 'nature value', 'option value', 'existence value', among others.

Non-transactional value of water
Non-transactional values of water are subjective and change over time. They reflect what is meaningful for individuals and societies, including its symbolic meaning to different social groups and traditions of various communities in the world. The commensuration of such value depends on how and why people attribute cultural meaning to the certain physical status of water bodies. Non-transactional values can be described quantitatively even though they may not be able to be expressed in monetary or productive terms. In some cases, surveys may be used to ask people to indicate their valuation of water. The valuing water initiative brings into light values attributed to water beyond simply being a natural resource for people to access[1].

A.2 Water Security and Sustainable Development Goals

The ultimate goal of water management is to enable humans to live in harmony with nature. Water is needed to support life and socio-economic activities, and if managed well the impacts of water-related disasters can be minimized. In other words, the aim is to become 'water-secure'. Water security elements are included in various Sustainable Development Goals (SDG).

Water Security
The concept of water security emerged in recent years in line with other important resource securities such as food security and energy security. A definition of the term is provided in Box 1. The World Economic Forum has identified water insecurity as one of the biggest global economic development issues. It contains the same elements and conditions of Integrated Water Resource Management (IWRM, see section B.2),

1 https://www.government.nl/documents/reports/2020/01/31/valuing-water-a-conceptual-framework-for-making-better-decisions-impacting-water

although water security focuses purely on outcomes, i.e., the capacity to provide the water-related services to the population, while IWRM focuses on processes.

Box 1 Definition of Water Security

"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."

UN-Water, 2013

Water security has many dimensions: ensuring the availability of adequate and reliable water resources, mitigating water-related risks and addressing the conflicts that may arise from disputes over shared waters. By specifying the dimensions of water security, decision-makers and stakeholders are able to form clear objectives within their plans. Recently, approaches have become available that aim to quantify Water Security and its various dimensions (Van Beek et al, 2013; ADB, 2020). This is a multiple-step process. Depending on local conditions and problems, key-dimensions (objectives) are identified. Indicators are selected that reflect the main characteristics of these key-dimensions. Monitoring and analysis results provide the scoring of these indicators and key-dimensions. An excellent example of this approach is given in AWDO-2020 (Asian Water Development Outlook) in which 5 key-dimensions were identified, as demonstrated in Figure A1. The approach is used to measure the level of water security in the 48 countries in the Asia and Pacific Region and scores the countries at a scale of 1 (extremely poor) to 100 (perfect). Based on the results, countries are able to identify gaps and solutions and ultimately increase their water security.

The World Bank has developed a Water Security Diagnostic Framework, as shown in Figure A2. At its core is water endowment, which is determined by the water sector architecture of infrastructure and institutions in the inner circle (including financing and governance). The outer circle represents the different outcomes that people, the economy and environment receive as a result of the activities within the inner circles. Evaluating water sector architecture and performance - and how these can determine outcomes – can lead to recommendations for improving aspects of sector performance and adjusting sector architecture to achieve higher levels of water security.

Figure A1 Approach to water security in AWDO 2020 • Source: ADB (2020)

Figure A-2 Water Security Diagnostic Framework of World Bank • Source: World Bank, 2021a

The analysis of sector performance considers i) management of the water resource, ii)delivery of water services, and iii) mitigation of water-related risks[2].

Sustainable Development Goals

In 2015, the UN adopted the Sustainable Development Goals 2015-2030. These are a set of 17 interrelated goals, of which SDG 6 specifically addresses water-related challenges, illustrated in Figure A3. Within each SDG, targets were defined, and indicators were developed to enable monitoring and measuring the extent to which the Goal had been achieved. While SDG 6 is considered to be the central goal for water, due to its interdisciplinary nature water management will also contribute to the realization of other SDGs, for example SDG 2 on Agriculture, SDG 7 on Energy, SDG 8 on Sustainable Growth and SDG 11 on Cities. It is envisioned that governments, the private sector and international institutions use the SDGs as objectives in water resources planning. This means that planning and management should quantify the impacts of possible plans and policies in terms of the SDG's targets.

A.3 The need for strategic planning of water systems

Humans have been managing water and adapting to its surpluses and shortfalls since the dawn of civilization. There is evidence across the globe of thousands of years of dam-building and canal construction to direct water towards various types of crops. More recent is the increasing competition for space and the rising awareness that there are limits to what water systems can provide and cope with. Though the tools and infrastructure which water users utilize and operate in the modern day are dramatically more sophisticated than those used in the past, and the spatial scale on which water users work is much more extensive in almost all cases, the activities undertaken are still very much the same: managing floods and droughts through harvesting and storing water above or underground, delivering and distributing water across long distances through pipelines and canals to where it is needed, collecting and treating wastewaters, and allowing certain activities in some areas while restricting or

Figure A3 The 17 Sustainable Development Goals of Agenda 2030

2 https://www.worldbank.org/en/topic/water/publication/water-security-diagnostic-initiative#2

even prohibiting them in others. These activities are all designed to meet a variety of economic, public health, environmental and social objectives and they must all be performed simultaneously.

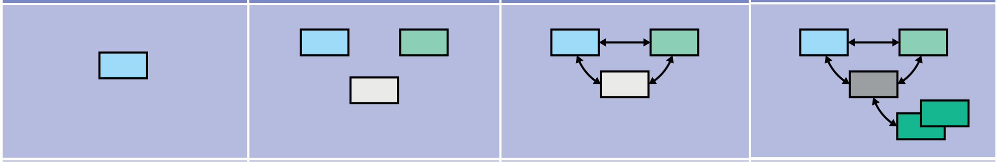
Regions which are experiencing population growth need access to more energy, more food, and more space for living and working together. The combination of this vast demographic growth and a more uncertain climate has led to a complex, dynamic and interconnected web of physical, economic, and social components with many opportunities for intelligent adaptive management interventions. These interventions can change the distribution of water quantities and qualities over time and space and/or the allocation of space for human activities, and may consequently lead to substantial economic, environmental, and social benefits. However, they can also introduce unexpected costs and risks. The constraints are physical (for example, the large inputs of energy required for desalination), geographical (depending on the available suitable locations for infrastructure), financial (building, operating, and maintaining infrastructure can be expensive), political (there are many vested interest involved in the distribution of water, particularly when it is scarce), and ethical (what uses deserve to be prioritized, how do they relate to the needs of the environment, and who has the authority to make such decisions).

Trade-offs are almost inevitable when allocating water or space to various sectors of society. Water is linked to the production of goods such as energy, food and industrial products, as well as to human health and the condition of the broader environment. For many kinds of water uses, allocating water to one use usually means that less water is available for others. Consumptive use in agriculture, industry or urban areas almost always involves trade-offs, as do mandates for instream flows to protect ecosystems or fisheries. However, even consumptive uses do not diminish the total amount of global water. Consumption simply shifts water to a different part of the hydrological cycle: for example, from liquid to vapor, from clean to contaminated, or from fresh to salty. There are also spatial trade-offs to consider. Allocating space to one activity may reduce the space of another. For example, intense fishing is typically not allowed in (marine) protected areas. The use of agricultural biocides is generally not allowed near groundwater wells for drinking water. Conversely, uses are able to coexist such as recreation activities taking place in dune areas which also provide protection against flooding and are havens for biodiversity.

Choices about managing water trade-offs involve more than hydrology and economics. They involve integrating people's values, ethics, and priorities that have evolved and been embedded in societies over thousands of years into decision-making. The juxtaposition of hydrology, economics, and values is at the crux of the water-climate-food-energy-environmental-society nexus. While it is perhaps unreasonable to assume that models of water systems will include each component of this interconnected, interdependent nexus within its calculations, analysts must be cognizant that the part of the system which they analyze is interacting with and being influenced by those components which initially appear to be exogenous. One fundamental principle for addressing values, ethics and priorities is inclusiveness. It calls for improving the ability, opportunity, and dignity of all people – especially disadvantaged populations - to take part in decisions relating to water resources planning and management.

Water system planning and management issues are rarely simple. Projects focused on addressing and finding solutions to water-related issues are also rarely simple. These projects need to be planned and executed in ways that will maximize their likelihood of success, i.e., will lead to useful results. When decision-makers and other stakeholders disagree on the desired outcomes of the project or which processes would be most useful to achieve these outcomes, or if certain stakeholder groups and their perspectives are not adequately included, the challenge facing project planners and managers is even more demanding.

The development of planning approaches for water systems is shown in Figure A4. When there is a great amount of interaction and interdependence among projects, the singular project-based approach should be replaced by the grouping together, or packaging, of related projects. Long-term thinking and taking the future into account leads to the development of master plans. Realizing that the future is uncertain has motivated Deltares to introduce an adaptive planning and management approach to water management. The figure explains that:



	Stand-alone projects	Compilation of projects	Traditional master planning	Adaptive management
	Project-based	Package of individual projects	Strategy as a blue print for the future	Dynamic strategy
Interaction between projects			Integrated	Taking uncertain future into accent
Levels of regret	Low regret?	Low regret?	Future regret?	No future regret
Implementation period	Immediate Implementation	Immediate Implementation	Implementation during planning period (±25 years)	Implementation during planning period (±100 years)
Time horizon	Short term	Short to medium term	Short to longer term	Short to long term

Figure A4 Development in planning approaches in water management (source: Nauta et al., 2013)

- The project-based approach is straightforward and easy to implement. This approach does not consider the (positive and negative) interaction of the project with other projects.
- Interactions are considered when related projects are grouped into a package of projects. However, the overall system is not yet integrated nor optimized.
- Traditional master planning tries to optimize the performance of the overall system. The projects are implemented as components of an integrated system. The implementation of the planning strategy attempts to optimize system performance over the planning period, which is usually between 15 and 30 years, for which a cost-benefit analysis usually applies. Such a master planning approach should consider the long-term uncertainties that are involved in socio-economic developments and climate change. If the system cannot adapt to changes in socio-economic conditions and climate, this might lead to 'future regret'.
- To reduce future regret, a planning period of up to 50 or even 100 years needs to be considered. As the life-time of most structural measures (dikes, floodways, reservoirs, etc.) are designed for a period of 50 to 100 years, it is wise to incorporate future uncertainties in boundary conditions into their designs and make them a part of a dynamic strategy. The adaptive approach not only informs what action should be taken in the present, but also gives directions on what to do when the conditions develop differently than expected.

Each water resources system is unique, and the specific application of any planning and analysis approach needs to address the particular issues of concern, as well as adapt to the political and societal environment in which decisions are made.

Box 2 Is an adaptive approach always required?

When developing strategies and designing measures, uncertainties in boundary conditions should always be taken into account, for instance the potential effects of climate change. This may lead to a dynamic strategy or adaptive approach, indicating when and how a strategy or a design should be adapted to deal with these new and unexpected conditions. This adaptive approach ensures a certain level of flexibility and will minimise possible regrets in the future. However, an adaptive approach is not always required. Sometimes, strategies or designs of measures can be very robust, meaning that they are effective under a wide range of possible future scenarios. In these cases, an adaptive approach may not be necessary.

What is important in all cases is that such planning and analyses are comprehensive, systematic, transparent and inclusive and are performed in full and constant collaboration with the region's planners, decision-makers and the interested and affected public.

A.4 General principles for successful strategic planning

To develop a comprehensive strategic plan that has a high chance of being implemented, several drivers of success must be addressed. This section highlights these drivers of success and indicates where these are embedded in the Analysis Framework.

A.4.1 Stakeholder involvement and inclusiveness

Participation is one of the main drivers of success in a strategic planning process. Participation enriches the understanding of the natural, socio-economic and institutional context, helps to create a common vision of development amongst stakeholders, enables ownership of the outcome and increases the effectiveness of the implementation of the plan. One of the main challenges of participation is making sure that the process is socially inclusive, i.e., that all groups in society that are or would be affected by the plan and/or its outcome are meaningfully included in the process. In this context, social inclusion is the process by which efforts are made to ensure equal opportunities for all to participate in the decision-making processes which affect them, regardless of background. People may be excluded from decision-making for various reasons including personal characteristics (e.g., ethnicity, gender, age, region, political orientation, disabilities), unawareness of the process or not being recognized as a stakeholder.

Social inclusiveness considerations are strong drivers behind organizing and facilitating effective stakeholder involvement during the planning process. As an outcome, inclusiveness refers to the situation in which everyone is able to experience the full enjoyment of

well-being considered normal in the society in which they live. As a process, inclusiveness uses decision-making to improve the ability, opportunity, and dignity of people to take part in and be integrated into society. Both the outcome and the process of inclusiveness must be taken into account in strategic planning exercises. Hence, an inclusive process of water resources planning and management is one where all people feel valued, their differences are acknowledged and fairly addressed, their basic water rights are all equally met, and they can live in dignity.
Inclusiveness also implies an awareness of unintended consequences of water security measures that might cause or contribute to adverse human rights impacts on certain groups. Consequently, an inclusive process purposively defines mechanisms for preventing and mitigating adverse impacts via open dialogues with public authorities and in consultation with potentially affected groups. Ideally, water users, authorities and communities should agree on mechanisms for preventing grievances and – if they occur – have a transparent process for their resolution. Experience shows that failing to adequately include the interests and perspectives of disadvantaged groups into initiatives leads to technical solutions which are more prone to social criticism, therefore compromising implementability. An illustrative case is given in Box 3.

Box 3 Project failure due to insufficient inclusiveness in project preparation

In 2018, a flood protection project in Jakarta, Indonesia was cancelled for failing to address the impacts it would have on the livelihoods of fishers. Even though the project would have effectively provided flood protection to more than three million inhabitants, overlooking adverse impacts on fishers contributed to the widespread perception that the project mainly favoured real estate development investments over the livelihoods of local communities. The bottom line is that the planning process should have made a concerted effort to understand and address the consequences of decisions which may have impacted the rights of specific populations, rather than neglecting them. Combining different measures and perspectives into strategies allows beneficiaries and non-beneficiaries to be aware of impacts and of compensation options. This is not a minor challenge for water authorities, although can be effectively addressed by establishing an inclusive and fair stakeholder management process.

Effective water governance underpins water security by sustainably, equitably, and transparently determining “who gets what” and “who does what” in terms of water resources and services, and mitigating water-related risks which may disproportionately affect disadvantaged groups. Specific social outcomes of water security which are linked to inclusive processes include:

- Protecting children affected by water-related disasters, and those stunting or experiencing health issues due to poor water supply and hygiene.
- Protecting women and girls in urban and rural areas who may be disproportionately impacted by water scarcity, floods and other water-related disasters – particularly adolescent girls - and reducing water-gender gaps.
- Reducing inequitable and unequal access to municipal and rural water services and/or access to irrigation water in the context of asymmetric power relations.
- Protecting vulnerable groups affected by water-related disasters, and inadequate access to water supply and hygiene services.

Section C.3.2 describes in Step I.2 of the Analysis Framework the setting-up of the stakeholder process. More details on stakeholder engagement are given in Appendix 2. In this appendix, special attention is given to how to ensure social inclusiveness in the five phases of the Analysis Framework.

A.4.2 From a sector approach to IWRM

The growing pressure on water systems has forced governments to reconsider their policies with respect to water management. In a situation where water resources were abundant and water quality was good, each sector could address their own needs without impacting others. The present situation's water shortages and poor water quality make it necessary to coordinate developments at different sectoral and spatial scales. This has led to the concept of Integrated Water Resources Development (IWRM). While IWRM is often pictured at river basin scale, the principles of IWRM apply at other spatial scales such as coastal zones and urban areas.

The Analysis Framework has been purposefully designed to ensure an integrated approach to developing and managing water systems. The Framework coordinates the activities that have to be carried out to enable integrated development and management processes. It also specifies the conditions that have to be in place for an integrated approach to be successful, including the above-mentioned stakeholder involvement.

The integrated approach of IWRM and its necessary enabling conditions are described in section B.2. The application of IWRM to various water systems is given in section B.3 for river basins, coastal zones, urban areas, groundwater systems, marine systems, and drought and flood risk systems.

A.4.3 Institutions and governance for implementation of the plan

An important enabling condition for IWRM is having a strong institutional framework in place with efficient water institutions at national and regional levels, both of which should have qualified staff. An integrated approach by its very nature means that the development and management of the water systems is not separated into silos and that coordination takes place among sectoral institutions and among institutions in different regions (e.g., upstream-downstream). Where appropriate, a specific water institution might be required (such as a river basin organization) to coordinate and lead the planning effort. Strong institutions require clear mandates and requirements (e.g., as set in laws or regulations), and sufficient funds to carry out their tasks.

Institutional analysis goes hand-in-hand with setting-up of stakeholder processes, as described in Step I.2 of the Analysis Framework (Section C.3.2). Institutional analysis will be addressed in Phase IV, where in Step IV.3 the implementation arrangements must be determined for the recommended interventions. Reference is also made to the 12 OECD principles of water governance (OECD, 2015). Reference is also made to the OECD principles of water governance (OECD, 2015). The 12 principles are grouped in 3 mutual reinforcing and complementary dimensions: effectiveness, efficiency and trust and engagement.

Figure A5 OECD Principles on Water Governance

A.4.4 Dealing with an uncertain future

Plans must not only address present problems, but should also prevent future problems from occurring. Socio-economic developments and climate change will put more pressure on water systems. Changes in the trajectory of water supply and demand must be anticipated, while recognizing that these changes are characterized by a high degree of uncertainty. The Analysis Framework takes these uncertainties into account.

A general description of the potential uncertainties involved and how to deal with these is given in section B.5. In the Analysis Framework, uncertainty is addressed in Step II.2, in which scenarios for future developments are defined. These scenarios are used in the problem definition in Step II.4 and in the development of alternative strategies Step III. 1. Evaluations are undertaken in the adaptation pathways analysis of Step III.2 and the ranking of alternatives in Step III.3.

A.5 Objective and structure of this document

The objective of this document is to provide guidance for the planning of water systems. Following this introductory chapter A, chapter B describes the components of water systems and the need for an integrated approach. Chapter B also provides an overview of the various water systems for which strategic plans need to be developed.

Chapter C is the core chapter of this document. In this chapter, the generic Analysis Framework is presented. This Analysis Framework outlines a logical sequence of steps that should be followed in planning and implementation of water resources interventions.

In chapter D, recommendations are given on how to apply this generic Framework for river basins, coastal zones, and urban, groundwater and marine systems planning as well as for more thematic-oriented plans such as flood and drought management. Figure A6 illustrates the strusture of the document.

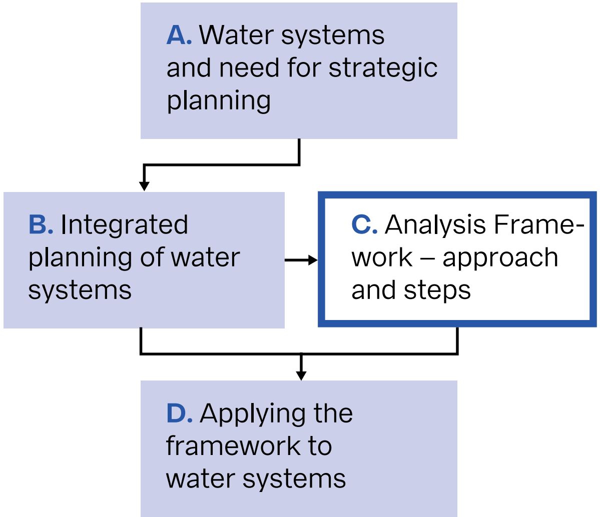
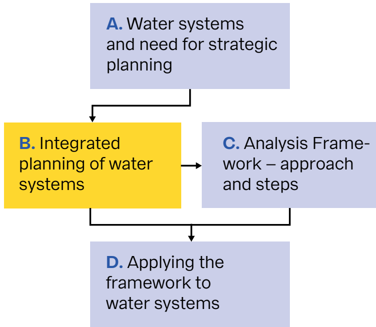


Figure A6 Structure of the document

The Annexes to this report provide more detailed information on several important elements of the Framework such as social inclusiveness, stakeholder participation and the use of models in the planning process.

B. Integrated planning of water systems



The previous chapter explained that water systems have many functions and that they need to be effectively managed to achieve water security for people and to contribute to the SDGs. This chapter describes the various components of water systems and the need to apply the principles of IWRM within their development and management. In these water systems, a distinction can be made at a spatial scale (river basin, coastal zone, urban, aquifer, etc.) or at a thematic scale (floods, droughts, etc.). The chapter concludes with a description on how to deal with the uncertainties involved in strategic planning.

B.1 Water system components and the need for strategic planning

B.1.1 Thinking in systems

Distinguishing between different system components and their interactions is an effective way of dealing with the high levels of complexity involved in water management. A water system can be viewed as consisting of three sub-systems: the Natural Resource System (NRS), the Socio-Economic System (SES) and the Administrative and Institutional System (AIS). These sub-systems all constantly interact with each other and thus an integrated approach is needed to develop and manage the overall water system. This is shown in Figure B1. These sub-systems can be distinguished in all of the water systems which are addressed in this document: river basins, coastal zones, marine areas, urban settings and aquifers.

The ***natural resource system*** **(NRS)** component consists of streams, rivers, lakes, estuaries, coastal zones, coastal seas and oceans and their embankments and bottoms, groundwater and the rocks and soil which contain the groundwater (aquifers). This includes the abiotic or physical, biological, and chemical ('ABC') components of and in the water and sediment. It also includes the infrastructure needed to collect, store, treat and transport water such as canals, reservoirs, dams, weirs, sluices, wells, boreholes, pumping stations, pipes, sewers, and water and wastewater treatment plants, the infrastructure needed to protect people and assets against disasters (dikes, barriers, etc.). See section B.1.2 for a more detailed description of the NRS.

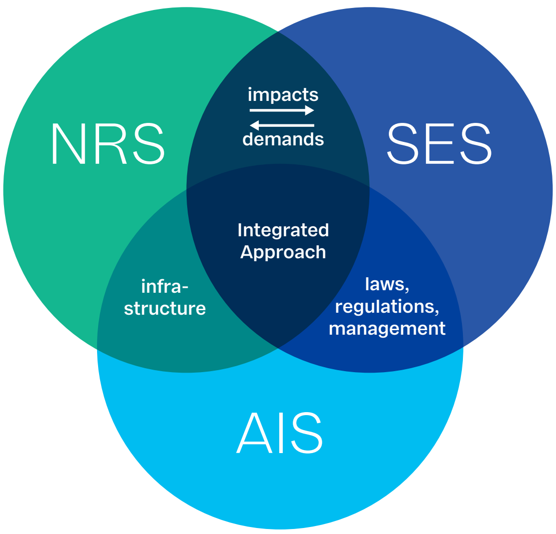


Figure B1 The 3 sub-systems NRS, SES and AIS and their interactions

The **socio-economic system (SES)** component relates to water-using and water-related human activities such as fishing, tourism and navigation., The SES also encompasses the various desires, needs and challenges of stakeholders, including vulnerable societal groups such as women, the poor and disadvantaged. The benefit (or value) that people receive from water and all of its uses, beyond just monetary or commercial, are a part of the SES component, as are the power relations that possibly influence or affect the outcomes of received benefits. See section B.1.3 for a more detailed description of the SES.

The ***administrative and institutional system*** **(AIS)** are the institutions that are responsible for the administration, legislation, and regulation of the supply (NRS) and the demand (SES) components of the water system and their respective rules, roles and responsibilities. The AIS includes institutions that plan, build and operate the infrastructure required to ensure that that water is in the right place, at the right time and in the right condition so that it is beneficial to society, as well as the decision-making processes these institutions use to define what is 'right' or 'beneficial'. See section B.1.4 for a more detailed description of the AIS.

The spatial dimension – Multi-Layer model
An important element in water management is the human-environment interaction, i.e., the interaction between the NRS and the SES. This is illustrated by the Multi-Layer model of Figure B2, which also adds a spatial dimension to this interaction. At the top is the Occupation layer (zoning of land use functions) and at the bottom is the Base layer (consisting of water, soil and ecosystems). The Network connects the two. Human interventions take place in the top two layers and these impact the Base layer, but the Base layer sets limits ('boundary conditions') for the other two layers.

The model indicates a physical hierarchy in the sense that the Base layer influences the other layers through both enabling and constraining factors. For instance, the soil type determines the type of agriculture that can be performed in the Occupation layer. Unfavorable conditions (constraints) posed by the Base layer can, to a certain extent, be mitigated through adaptations in the Network layer or Occupation layer. For example, farmers can use agrochemicals to improve soil conditions, or dikes can be constructed to protect land from flooding. However. these adaptations to the original physical geography of an area require investments, have an impact on the Base layer, and need to be managed.

The essence of the Multi-Layer model is to highlight the difference in dynamics and vulnerability between the layers, which results in a logical order in planning and managing the various layers. The layers enable and/or constrain activities in other layers. Besides the physical interactions between the layers, the model is also useful in positioning the roles of different actors, such as government agencies, private entrepreneurs, and other stakeholders. For instance, the development and maintenance of infrastructure in the Network layer is traditionally the responsibility of the government. The government also has a legal responsibility to protect and manage their jurisdiction's Base Layer. Moving towards the Occupation layer, the role and influence of the government becomes more restricted, and the influences of private parties and citizens' interests become more dominant.

Water management differentiation in spatial scales
Water is everywhere, found in various states and conditions. Depending on the specific use and governmental management focus, it is possible to distinguish between different 'water systems' and 'water management domains.'. While a water system encompasses the NRS, SES and AIS, a water management domain is the management of water-related supply and demand according to specific catchment area. For instance, River Basin Management (RBM) will oversee all of the water resources within a certain river basin, including the allocation of the basin's water amongst different stakeholders. The specific problems of coastal areas require a focus on the interaction between the sea and the coastal land, and in that case, Integrated Coastal Zone Management (ICZM) is needed. Urban water problems ask for Integrated Urban Water Management (IUWM). These different approaches will be described in the next chapter.

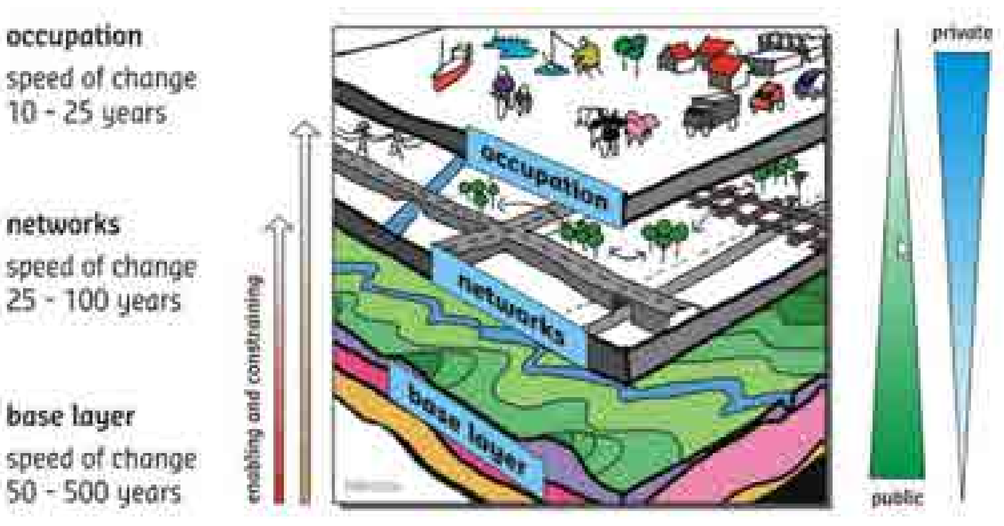


Figure B2 Multi-Layer Model

B.1.2 Characteristics of the Natural Resources System

System Boundaries
The study area of a planning project will usually coincide with an administrative boundary (state, county, district, province, etc.). However, a WRS is typically defined by its hydrologic boundary. These political and hydrologic boundaries can differ. Clearly, any planning project for a WRS must focus on the larger of these boundaries, but not necessarily everything within them need be included depending on the purpose of the study and the particular WRS. For the purposes of modeling, it has proven useful to subdivide the NRS into smaller units with suitable boundaries. Examples are subdivisions into a groundwater and a surface water system, subdivision of a surface water system into catchments and sub-catchments, and subdivision of a groundwater system into different aquifers or aquifer components. The definition of (sub) systems and their boundaries should be done in such a way that the transport of water across area boundaries can be reasonably determined and modeled.

Physical, Chemical and Biological Characteristics
The physical processes in a NRS are transport and storage within and among its sub-systems. For the surface water system, a distinction is usually made between the infrastructure of rivers, canals, reservoirs and regulating structures (such as the open channel network) and the catchments draining into the open channel network. The biological and chemical characteristics define the biological and chemical composition of groundwater and surface water and the transport, degradation and adsorption processes that may influence this composition. The level of detail to which these characteristics are considered will depend on the requirements of the study and threats they pose to water-using and water-based activities.

Control Measures
The design and operating policy options of the NRS are defined by the values of its parameters, and so changing the parameters can change the state of the system. An example is the rule curve of a reservoir which dictates how much water to release, when and for what purpose. Another example is the flow capacity of irrigation feeder canals, where increasing the capacity of these canals permits a greater allocation of water to farmers. An example of non-physical control that changes the state of the biotic system is the release of predator fish in reservoirs to reach a desired balance of species in the ecosystem.

B.1.3 Characteristics of the Socio-Economic System

System Boundaries
The SES generally does not have a physical boundary like that of the NRS. Economic and social activities in a river basin, for example, are connected to regions geographically far from the basin boundary through the exchange of goods, people, and services. The factors that determine which socio-economic activities should be included in a project planning exercise will depend on the context of the problems and the development opportunities being considered. Outside the boundary of the SES are factors or conditions that are beyond the control of the WRS decision-makers. Developments outside these boundaries have to be included as scenarios in the analysis process.

System Elements and Parameters
The socio-economic component of the WRS can be defined by identifying the main uses of water, tangible and intangible values of water, expected changes and developments in the study area, and the parameters whose values define these changes and developments.

To appropriately describe the SES within the study, the type of information that must be obtained includes:

- Agriculture and fisheries: present practice, location and area of irrigated agriculture and/or fisheries, desired and potential developments, water-use efficiency.
- Power production: existing and planned reservoirs and power stations, operation and capacity, future demands for electric energy.
- Public water supply: location of population and industrial activities, expected growth, alternative raw water sources.
- Recreation: types of biodiversity and location, expected and desired development, water quality conditions.
- Navigation: water depths in relevant parts of the open channel system.
- Nature conservation: location of valuable and vulnerable areas and their dependence on water quality and quantity regimes.
- Non-transactional values: the symbolic values of water for people beyond its value as a resource, including the cultural value of water, the emotional value of water and the spiritual value of water.

Some examples of important system parameters of the SES are labor force and wage rates, price levels in relation to national and international markets, subsidies, efficiency of production and water use, and income distribution. When identifying and analyzing activities in the study area, it is important to consider possible discrepancies between the opinions and

perspectives of individual actors and stakeholders, as well as between different societal groups. For example, individual farmers' needs may not reflect those suggested by official agricultural organizations or the interests of women may differ from the interests expressed by men in patriarchal contexts.

Control Measures

The functioning of the SES can be influenced by legislative and regulatory measures, and the price of water may be a particularly important factor in understanding levels of demand. This price can be influenced by water resource authorities and used as a control variable. When the cost of water use represents only a small portion of the total cost of an activity, an increase in its price may have little to no impact on water use. In some cases, water may be an essential function of the SES beyond fulfilling human biological necessities, for example if the economy is highly dependent on water-intensive activities, and so will be used no matter what the price. In these situations, the price of water (or taxation for wastewater discharges) may not be an acceptable control variable (except perhaps to inform stakeholders on the consequences of possible cost reduction measures).

B.1.4 Characteristics of the Administrative and Institutional System

System Boundaries

The AIS, like the NRS and SES, has its own system boundaries based on the jurisdiction area(s) of the relevant authorities.

System Elements

AISs can vary with scale and scope, and the way in which they function and operate. In many countries, but certainly not all, the institutional framework generally consists of:

- central government, divided into sectors such as public works, irrigation, agriculture, forestry, environment, housing, industry, mining, public health, and transport, amongst others.
- a coordinating body, for example a national water board, to coordinate actions involving water by various sectors of the national government.
- regional bodies based on spatial subdivisions of government, for example provinces, districts, cities, tribes, and villages.
- regional bodies based on a division according to the physical characteristics of the area, such as river basin authorities.
- water-user organizations, representing the interests of directly involved stakeholders, for example in irrigation districts.

When initiating broad comprehensive water planning projects, having knowledge on the following points is useful:

- the ministries and coordinating bodies which have authority and responsibilities related to water resources management.
- the agencies involved in the preparation of water resources development plans.
- existing national and regional water resources development plans and the authorities responsible for implementing these plans, establishing, and enforcing regulations and overseeing infrastructure construction and operation.

- the existing legislation (laws and regulations) concerning water rights, allocation of water resources, water quality control and the financial aspects of water resources management.
- existing social groups that are disproportionately impacted by water management decisions.
- the influence of existing power relations in decision-making related to water resources management.
- water-gender relationships (or gaps) in relation to representation in institutions and water management arrangements.

Other useful information includes the policies and plans of various water-related sectors, such as environment, agriculture, economy, transportation, urban development, and energy.

Control Measures
From a systems' perspective, the decision or control variables that can be changed in the AIS are less clear than in the case of the NRS and SES. Measures can be taken to improve the functioning of the system, for example by establishing coordinating bodies when these are absent or by decentralizing and shifting responsibilities towards lower levels of government. If the AIS cannot be changed, possible beneficial changes can be identified and presented to those responsible for making decisions.

B.2 The need for an integrated approach in strategic planning for water systems

The management actions between the NRS and SES components of a water system are depicted by the arrows shown in Figure B1. The arrows only represent actions, not information flows. There must be information feedbacks between all of the components of a WRS, otherwise effective management would be impossible. Each of the three systems is embedded within its own environment: the NRS is bounded by climate and physical conditions; the SES is formed by the demographic, social and economic conditions of communities and the surrounding economies; and the AIS is shaped by the constitutional, legal, and political system and its procedures. Boundary conditions are usually considered fixed, but in some cases, they may not be. For example, climatic conditions are now fluctuating as a result of climate change, and laws and regulations may be adapted to reflect this. Whether and, if so, when to consider the possibility of changes in this 'external' environment should be decided at the start of any planning project.

Consider for example regional economic growth. This predicted growth is often treated as given. If the water resources available cannot sustain this projected growth (or are able to but only at very high costs), it may be appropriate to reconsider this assumed growth. By understanding the consequences of unrestricted growth at the regional level, planners can assess the desirability of other options that might be considered at higher (usually national) planning levels.

Over the past several decades, the need for an integrated approach for developing and managing our water systems has emerged. This need led to the concept of IWRM, and has been incorporated into different water systems' management plans such as IRBM in river basins, ICZM along coastal zones and IUWM for urban areas. IRBM, ICZM and IUWM are all responses to the growing pressure on their respective water systems. Water shortages and deteriorating water quality have forced many nations to reconsider their development policies with respect to the management of their water resources. As a result, water management has been undergoing a change worldwide, moving from a mainly supply-oriented, engineering-biased approach towards a supply-and-demand-oriented, multi-sectoral approach. This integrated approach addresses not only the NRS but also the SES and AIS as was depicted in Figure B1.

Box 4 The many dimensions of integration in water management

Natural system integration: surface water and groundwater, quantity and quality, upstream and downstream, land and water management, blue and green water, freshwater and coastal water, etc.
Integration with sector plans: agriculture, rural and urban development, hydropower, industry, etc.
Integration with national policies: food security, energy security, poverty alleviation, public health, climate adaptation, etc.

The concept of IWRM/IRBM/ICZM/IUWM moves away from top-down 'water master planning' which generally focuses on water availability and development, and towards 'comprehensive water policy planning' that addresses the interactions between different sub-sectors, seeks to establish priorities, considers institutional requirements, and promotes building management capacity. The Analysis Framework is based on such an integrated approach. It considers the use of water resources in relation to social and economic activities and functions. These determine the need for laws and regulations pertaining to the sustainable and beneficial use of the water resources. Combining efficient infrastructures with sustainable regulatory measures allows for more effective use of the resource, including meeting ecosystem needs.

Box 5 Definition of IWRM

IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

(GWP, 2000)

IWRM, IRBM, ICZM and IUWM are described in many handbooks. The basics of the IWRM concept were first mentioned in Technical Background Paper No. 4. Of the Global Water Partnership (GWP, 2000), which also contains the widely accepted definition of IWRM as given in Box 5, as well as a description of the Dublin Principles on which IWRM is based. These principles include the requirement of stakeholder involvement in management processes and the need to consider water as a scarce economic good. IWRM is a process in which all stakeholders jointly decide on how to develop and manage their water resource system – inclusively and sustainably. This is illustrated in Figure B3.

GWP's definition of IWRM recognizes also the three overriding criteria that should be considered in integrated planning:

- **Economic efficiency in water use**: Due to the increasing scarcity of water, the finite and vulnerable nature of water as a resource, and the increasing demands upon it, water must be used with maximum possible efficiency;
- **Equity:** The basic right for all people to have access to water of adequate quantity and quality for the sustenance of human well-being must be universally recognized; and
- **Environmental and ecological sustainability:** The present use of the resource should be managed in a way that does not undermine the life-support system, thereby compromising the use of future generations of the same resource.

These overriding criteria are sometimes referred to as the 3 E's. These 3 E's are similar to the 3 P's: People (Equity), Planet (Environment), Profit (Economic Efficiency).

An important element for implementing an integrated approach, as described for IWRM in the Technical Background paper, are the enabling conditions, sometimes called the 3 pillars of IWRM. These are displayed in Figure B4 in combination with the 3 E's of IWRM:

- Enabling environment:
  - water legislation and national policies that guide the planning process and enable enforcement in an inclusive manner;
  - clarity and inclusivity of land tenure and water rights.
- Institutional framework:
  - existence of water institutions at national and regional levels with qualified staff;
  - in the case of river basin studies, existence of some type of river basin organization (RBO).
- Management instruments:
  - availability of data, information and tools that enable informed decision making.

These enabling conditions are also considered to be necessary for 'good governance'. OECD has developed 12 principles on water governance (OECD, 2015). These principles are based on three mutually reinforcing and complementary dimensions of water governance: i) effectiveness, ii)

Figure B3 Stakeholders involved in river basin planning, development and management, each having different goals and information needs – examples of the US and Egypt efficiency, and iii) trust and engagement. Reference is made to the OECD publication for a detailed description of these 12 principles.

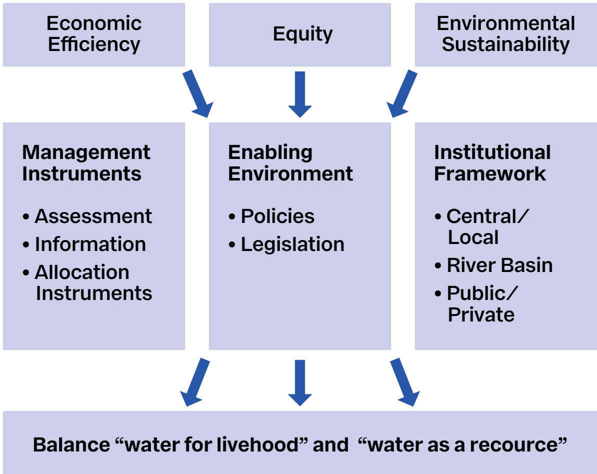


Figure B4 Enabling conditions (the “pillars”) for the integrated management of water systems • Source: GWP (2020)

IWRM should not be perceived as a one-off activity. IWRM planning is done in cycles. Because of budgetary constraints an IWRM plan can cover only the most urgent problems. After the plan is implemented and evaluated the next cycle starts. This cyclic approach is illustrated in the spiral of Figure B5.

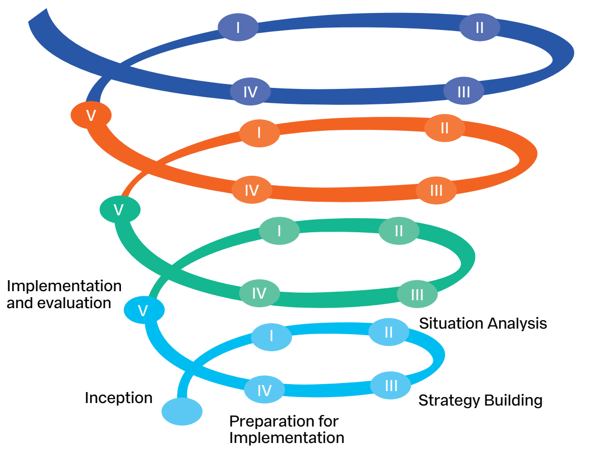


Figure B5 Integrated planning as a spiral process
Adapted from: UNESCO-IHP et al. (2009) – The roman characters I, II, III etc. stand for the phases of the Analysis Framework

A cyclic approach makes it also possible to respond to changing social, economic, and environmental needs and enables practitioners to gradually improve management as they move up the spiral, progressively developing the water resources, building a more integrated institutional framework, and improving environmental sustainability. Presenting IWRM as a spiral model to the stakeholders makes it possible to make realistic and adaptive plans.

IWRM should be seen as a kind of ‘mother’ concept on how to manage water systems. ‘Sustainable water resources management’, ‘Water-Food-Energy Nexus’ and ‘Adaptive water management’ are concepts that are introduced to emphasize certain elements of the approach but basically all these concepts are based on the principles of IWRM.

For further reading on IWRM, refer to the IWRM Action Hub[3] (Toolbox) of GWP.

B.3 Strategic Planning using a Systems Approach

In the following section, a short introduction is offered about the use of systems analysis in water management. This is the core approach behind the Analysis Framework which will be elaborated on in the next chapter.

B.3.1 Strategic planning for water systems

Drastic actions are needed to achieve increased water security and attain the SDGs. However, these actions need to consider the underlying social, economic, and political forces which cause the actions to be necessary in the first place. Moreover, the integrated character of water systems require that these actions are aligned and combined into a comprehensive strategy. Strategic planning should address the causes of problems rather than the symptoms. Understanding the underlying forces that cause water-related problems helps stakeholders to identify which collaborative actions can be taken, which in turn can lead to long-term solutions. Another important feature of strategic planning is the consideration of conflict. The management of water resources is a process characterized by the clash of competing and conflicting interests and viewpoints. An integrated approach to water resources management promotes enhanced dialogue, negotiation, and participation mechanisms. Applying these principles in the planning process brings transparency to decision-making, acknowledgment and resolution of trade-offs, and commitment to implementing the plan (GWP, 2005).

3 https://www.gwptoolbox.org/

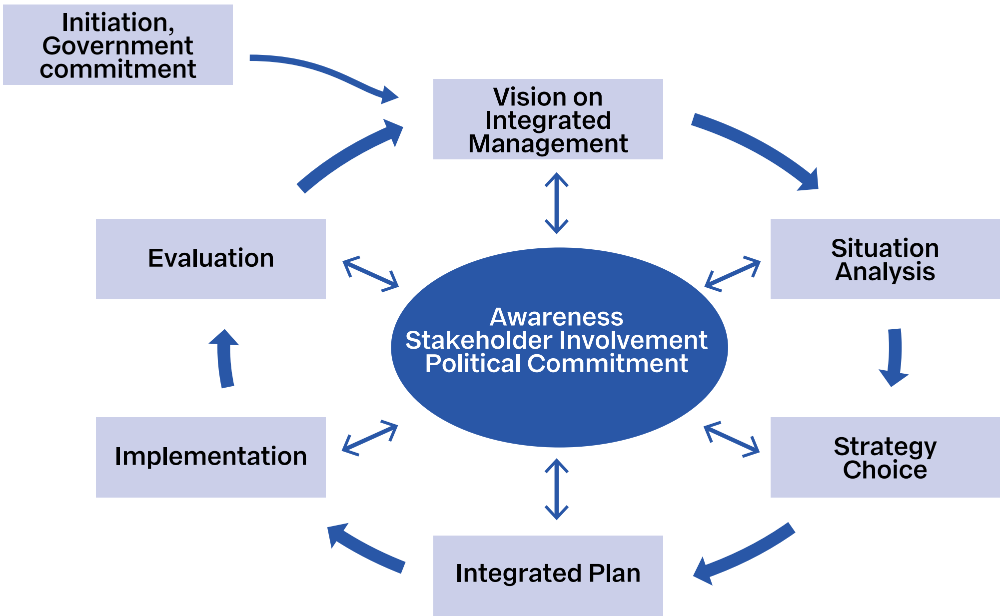


Figure B6 Planning cycle for water management

Strategic planning is a process that follows a cycle of logical steps as indicated in Figure B6.

Plans can differ in how specific they are when formulating actions and defining implementation conditions. From a strategic point of view, plans should contain all of the following key-elements (Browder, et. al, 2021):

- Long-term vision and medium-term goals
- Sector performance reviews and lessons learned
- Proposed adjustments to laws, policies, programs, regulations, collaboration, funding, etc.
- Proposed targets and monitoring indicators
- A roadmap for policy-makers and agencies
- Evidence that planning is mandated by law, periodic (5 - 10 years), and formally adopted by relevant institutions

B.3.2 Systems Approach to Water Management Planning

Effective water management planning requires that the processes within and interactions between the NRS, SES and AIS are considered. Dealing with this complexity requires a systems approach. Literature on systems approaches in planning often emphasizes the mathematical modeling techniques used by practitioners. The use of mathematical tools, however, is only part of what constitutes a systems approach. When there is a complex system compiled of many different components, the approach should include:

- building models to explain and quantify system behavior,
- devising courses of action (strategies) that combine observations with the use of models and informed judgments,
- comparing alternative courses of action available to decision-makers,
- communicating results to the decision-makers in meaningful and accessible ways,
- recommending and making decisions based on the information provided during these exchanges between analysts, planners, decision-makers and stakeholders,
- monitoring and evaluating the results of the strategies implemented, and
- involvement of relevant stakeholders of the system inww all the aforementioned steps, to help assure plan acceptance.

Systems analysis is an approach developed in the 1950s and 1960s for studying and creating systems and procedures that efficiently achieve specified goals and purposes. Systems analysis is also referred to as a problem-solving technique that breaks down a system into its component pieces, and determines how well those parts work and interact to accomplish overall system performance goals. Miser and Quade in their Handbook of Systems Analysis (Miser and Quade, 1984) identify two important components of a systems analysis study:

- Conceptual Framework (the steps to be followed to achieve a specific goal), and
- Computational Framework (the models / quantitative tools necessary for analysis).

The Analysis Framework addresses both components in an integrated way.

When systems analysis is used for preparing or informing policy decisions, it can be referred to as a policy analysis. Systems analysis can indeed also be applied to any system which needs to be analyzed, for whatever reason. As water management plans are used to inform decision making, the water management planning process could also be perceived to be a form of policy analysis.

Conceptual framework - structured analysis process
A water management plan should not only present the specific details of the plan. It should also describe the contextual background of the water resource, the problems it will address, and the plan's objective(s). It should explain why that specific plan is preferred to other possible alternative plans and how to assess the degree of success in meeting the plan's goals over time. Moreover, it should explain how the plan should be implemented.

A common analytical approach for the development of each project or program within a strategic plan is given in Figure B7. It distinguishes 5 phases, each with their own focus. The first 3 phases prepare the project plan. The resulting 'plan' is then translated into an investment package in the 4th phase and actually implemented in the 5th phase. The five phases are spoken about in detail in the next chapter. Evaluation of the results of the implementation should feed into the next cycle of planning, as illustrated in Figure B6 and Figure B7 .

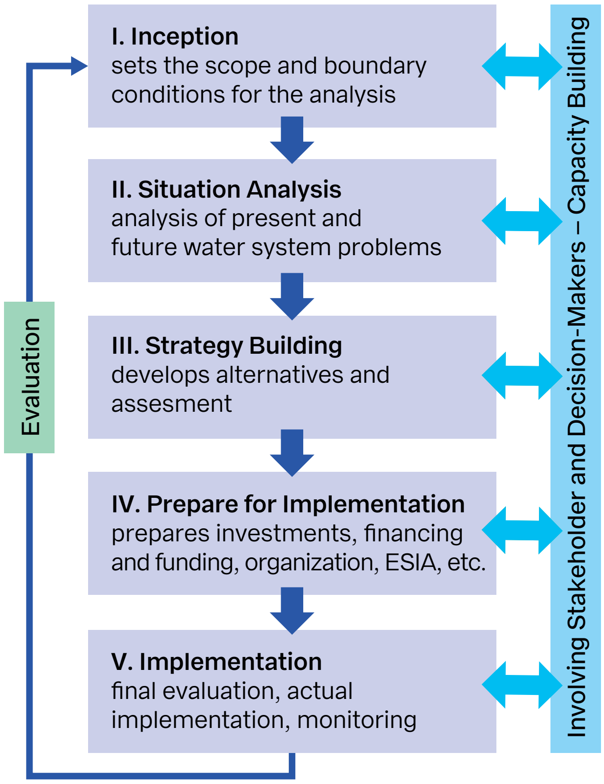


Figure B7 Structured approach for project identification and implementation

Computational framework – the models
The development of a computational framework starts with drawing a system diagram which identifies system components and their linkages. A system diagram represents the cause–effect relations among the components of the overall system. An example of the use of system diagrams in analyzing water resource management (WRM) problems is presented in Figure B8.

Although Figure B8 is a simplified version of a complex process, it highlights the fact that water-using activities may face two problems. First, the quantity demanded may be greater than the supply; second, supply and/or demand may adversely impact the natural system (e.g., generate pollution or alter the water level). The perception of these problems can motivate analysis and planning activities, which in turn can result in management actions. The figure shows that the problems can be addressed in two ways: either by implementing demand-oriented measures within the SES, or by developing infrastructure that impacts the NRS. Demand-oriented measures aim to reduce water use and effluent discharge per unit of output. Supply-oriented measures, on the other hand, are aimed at increasing water supply so that the magnitude and frequency of shortages are reduced or at increasing the assimilative capacity of the receiving water bodies. Which measure or combination of measures is most effective depends on the criteria selected by the implementing authority.

The next step is to translate this system diagram into computer models to be used in the analysis process. How this can be done will be explained in the chapter C.

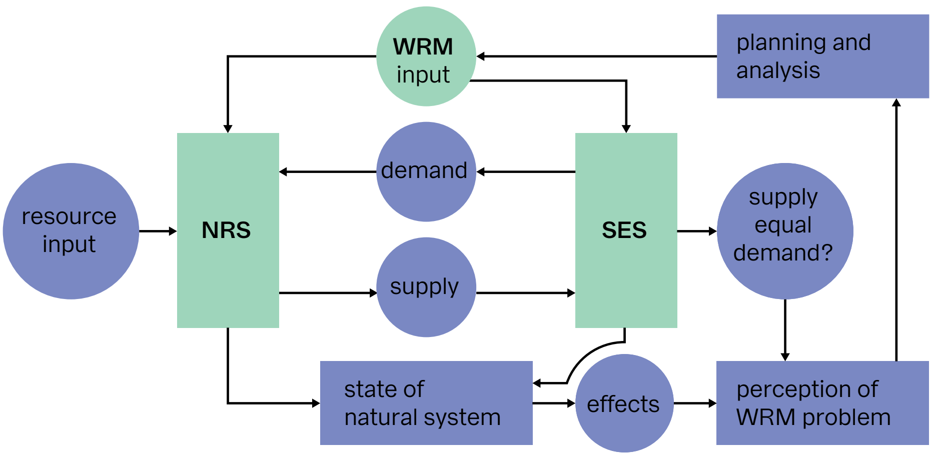


Figure B8 Identification of a WRM problem

B.4 Implementing an integrated approach to the various water systems and their plans

The principles and approach of IWRM and its enabling conditions can be applied to various water systems, as shown in Figure B9. The water systems addressed in this document include river basins, coastal zones, urban systems, groundwater and oceans. The IWRM approach requires that in the plans for these systems due attention is paid to thematic subjects such as drought, floods, water quality, and sediment. Still, depending on the importance and urgency of these themes it may be necessary to make specific plans for these themes. such as a drought mitigation plan, or a water quality plan.

Each of these water systems has their own correlating plan.

Spatial:

- River basins: Integrated River Basin Management (IRBM)
- Coastal zones: Integrated Coastal Zone Management (ICZM)
- Urban systems: Integrated Urban Water Management (IUWM)
- Groundwater: Integrated Groundwater Management (IGM)
- Oceans: Marine Spatial Planning (MSP)

Thematic:

- Droughts: Integrated Drought Risk Management (IDRM)
- Floods: Integrated Flood Risk Management (IFRM)
- Water Quality and Ecosystem Management

A thematic plan can be a stand-alone plan – while still including the principles of integrated management and planning – or one or more thematic plans can be part of a geospatial-focused plan. It is noted that there are many relations and interdependencies between the plans. Figure B10 presents these relations and (partial) overlap of geospatial and thematic plans. Their relations will be described in more detail in section B.4.8. The Analysis Framework's principles and approach are applicable to both types of plan.

In the next sections, a short description is given of these water systems and themes.

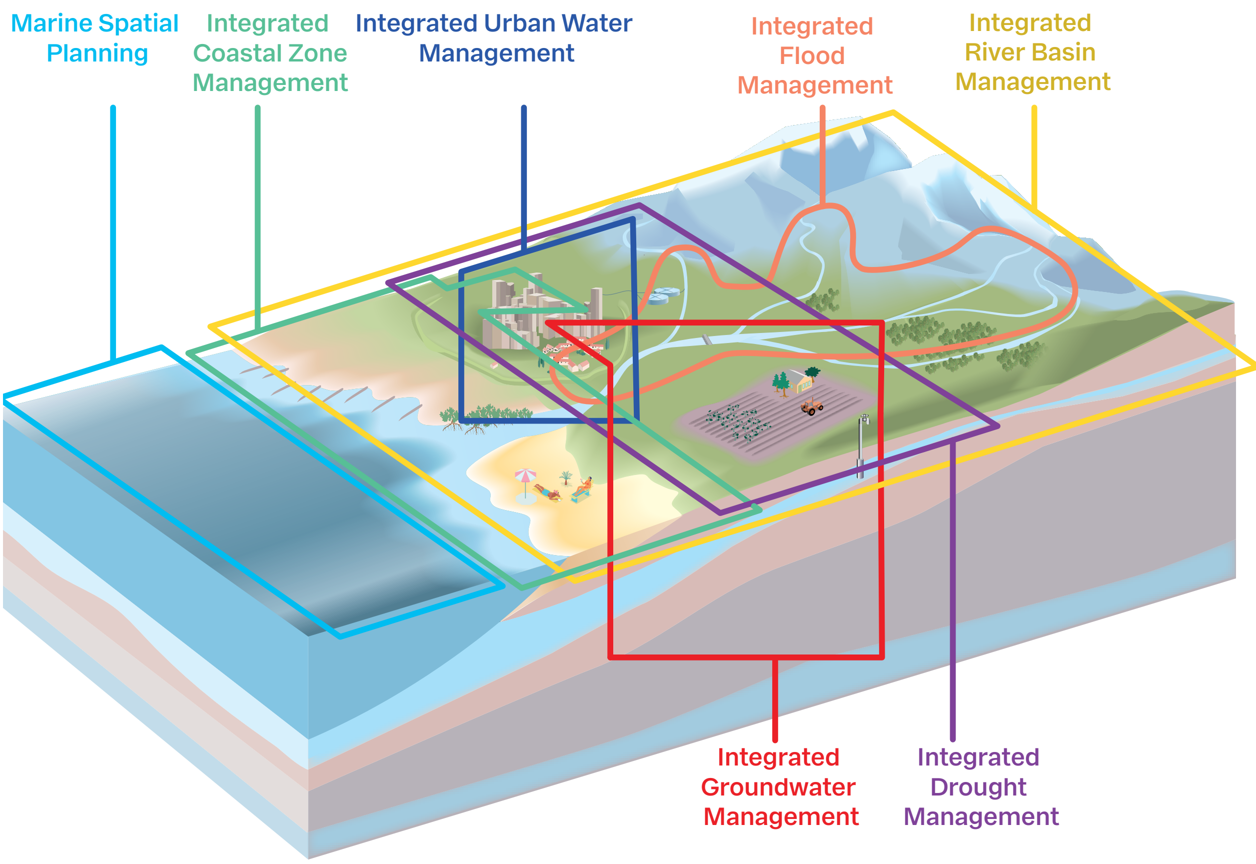


Figure B9 Geospatial coverage of water systems plans

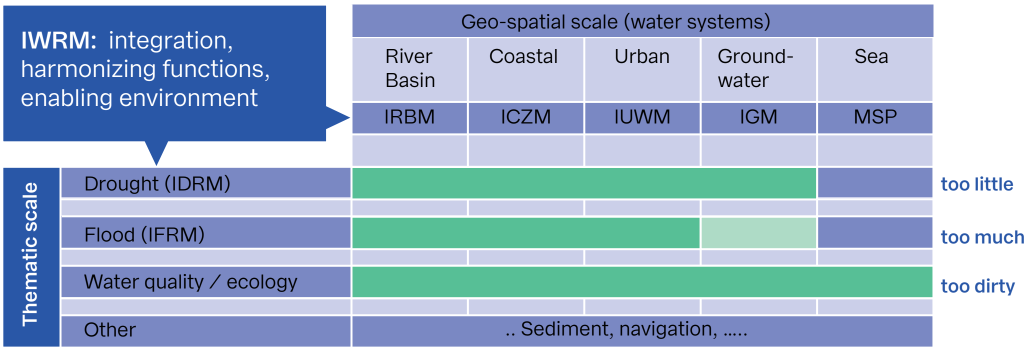


Figure B10 Application of IWRM principles to various water systems and management themes (the green color indicate the overlap between the plans)

B.4.1 Integrated River Basin Management

The world's usable renewable freshwater resources are found in lakes, wetlands, rivers and aquifers. A river basin is the area bounded by the watersheds of a system of streams and rivers that flow towards the same outlet (Figure B11). In the case of rivers this is generally the sea, but may also be an inland water body, such as a lake or swamp. Different disciplines and different countries use various terms for river basin, such as catchment, watershed and drainage basin. In this document, these terms are used inter-changeably.

The river basin is a practical hydro-logical unit for water management as it allows for compre-hensive analysis of supply and demand of water (the water balance) within a specific, well-defined area. A 'whole basin' approach allows for the assessment of impacts of interven-tions at a system level, including intercon-nected upstream-downstream issues. River basin plans usually address all three water management issues: too little, too much and too dirty. Managing water resources at a basin level is most effective when undertaken by 'basin organizations'. In most countries, different types of basin organizations exist, varying in function, purpose, and responsibil-ities. The challenge for these basin organizations is cooperating and coordinating with existing govern-mental structures at national, provincial, and local levels, as the entire area of a river basin can span across several political boundaries.

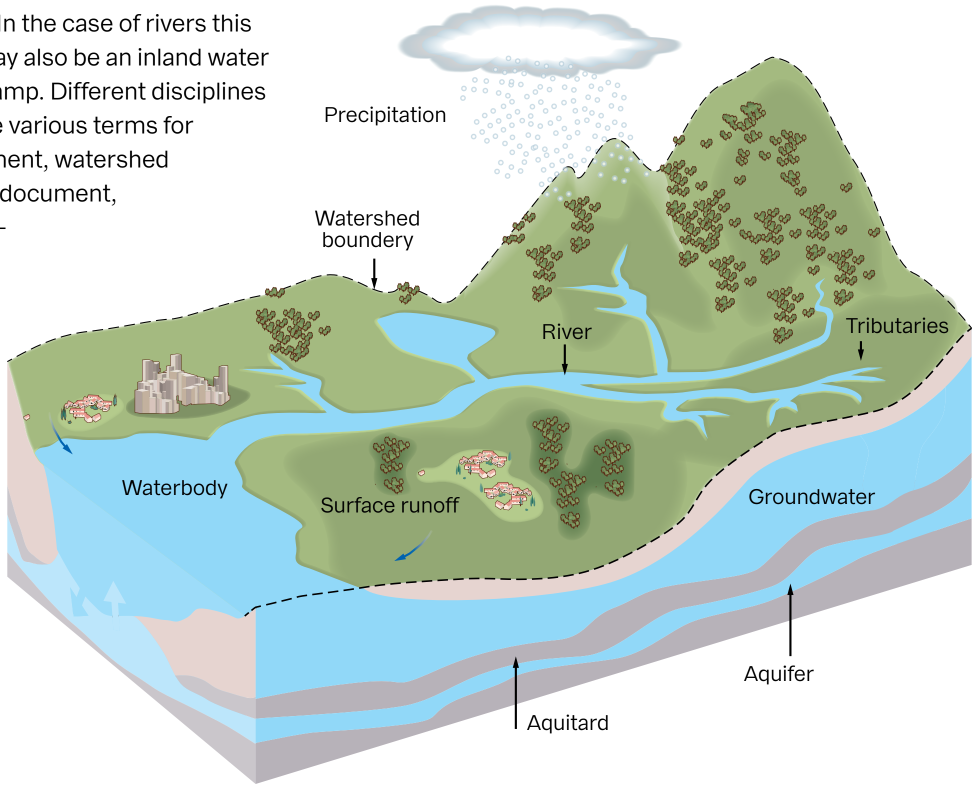


Figure B11 River basins as a management system

Basins which are shared by two or more political jurisdictions – also known as transboundary basins – present particular challenges for water management and planning. Historically, transboundary basins have encouraged regional cooperation but, as resources dwindle and demands grow, the potential for conflict over shared waters also grows. A shared vision approach, based on the principles of IWRM, should be established for such basins to allow for equitable water sharing and conflict resolution.

Integrated river basin planning provides the overarching and coordinating context for more focused plans used for coastal zones, urban areas, groundwater bodies, all of which may involve a river in some way, and addresses thematic areas such as flooding, droughts, and water quality. At the same time, these more detailed plans can provide input to the development of the river basin plan. All of these plans have to take each other into account, and as such river basin plans do not have a specific hierarchical position in terms of importance. In addition, the spatial scale of river basins does not have to coincide with the scales of the other plans.

B.4.2 Integrated Coastal Zone Management

Geospatially, the coast is the area where land and sea meet, as highlighted in Figure B12. Within these coastal zones, land is subject to marine influence and the coastal marine area is subject to terrestrial influences, typically at least several kilometers offshore and onshore of the actual coastline. River basins end at the coast in river deltas and estuaries. Coastal zones are characterized by a high degree of land-sea interaction in all three domains: natural, socio-economic and institutional.

Figure B12 Coastal zone impression

Natural land-sea interactions include those resulting from natural hazards like storms and tsunamis, the effects of rivers discharging fresh water, sediments, nutrients and other substances into the sea, typical coastal dynamics like tides and erosion, and ecological habitats such as dunes, coral reefs, salt marshes and mangrove forests.

Socio-economically, coastal zones are some of the most densely populated areas where many economic activities take place and converge. Ports are the global connectors for goods and commodities both across the sea and to and from the hinterland. Fisheries provide a major food source and contribute to a country's economy. Therefore, coastal areas are typically characterized by economic growth, in which coastal and marine resources serve as drivers for prosperity. Finally, coastal zones provide opportunities for recreation and well-being for the local population and visiting tourists.

Institutionally, due to the many activities taking place in the coastal zone, governmental institutions at all levels play a role and have a responsibility within the area. These roles and responsibilities are sometimes aligned, sometimes conflicting, and sometimes absent. Cooperation of institutions is necessary to sustainably manage the coastal zone.

ICZM is a highly participatory, science-based, principled, and iterative planning approach. There are several definitions for ICZM. This document adopts the slightly adapted version developed by the World Bank in the 1996 Guidelines for Integrated Coastal Zone Management, as given in Box 6.

Box 6 ICZM Definition

Integrated Coastal Zone Management is a process lead by the government consisting of the legal and institutional framework necessary to ensure that development and management plans for coastal zones are integrated with environmental, social and economic goals and are made with the participation of those affected. The purpose of ICZM is to maximize the benefits provided by the coastal zone and to minimize the conflicts and harmful effects of activities upon each other.

(Adapted from World Bank,1996)

ICZM distinguishes itself by its emphasis on sediment resources instead of water resources. The supply, movement and distribution of sediments determine the coastline. In particular the alongshore movement of sediments, i.e., the movement parallel to the coastline, requires careful planning and management of interventions. Structures such as breakwaters, land reclamations and shipping lanes may disrupt the alongshore sediment transport leading to sediment accretion in one location and sediment erosion in another. If there is insufficient sediment available to protect the coast, sea level rise can cause shoreline retreat. The allocation of available sediment resources is therefore a major component in ICZM.

Allocation and distribution of water resources in the coastal zone is almost solely related to spatial planning of competing functions, except for desalination and cooling water for industrial purposes where coastal waters are not extracted or used as a resource. Access to freshwater resources in the coastal zone is more often part of IRBM or IGM, although there are clear links and overlaps that must be considered. At the same time, upstream damming of rivers resulting in blocked sediment flows, sand mining, and excessive groundwater extraction resulting in subsidence can exert major pressures on downstream coastal zones. As the coast supports many major urban areas, IUWM can also overlap with an ICZM approach. Finally, MSP addresses the open sea but also considers the near shore coastal zone, although excludes the spatial planning on land.

B.4.3 Integrated Urban Water Management

Cities face enormous challenges today, and water management is one of their most serious concerns. Climate shifts, environmental degradation, aging infrastructure, energy adaptation and population growth are impacting many cities worldwide and will force changes to the way water is managed in the future for most cities around the world. Urban water systems are complex because of the multiple system components (see Figure 13), different responsible institutional and stakeholders, interactions with the environmental system, numerous buildings and infrastructure, and various land uses.

The urban water system is generally characterized by two sources of water: rainfall and potable water from sources beyond the city's boundaries. Drinking water is typically taken from reservoirs, rivers or aquifers in other parts of the basin or from sources outside of the basin. The city, its residents, and its ecological and economic systems are sensitive to extreme conditions in the water system. Casualties and substantial economic damage may result from flooding, drought and water pollution. Climate change (especially extreme weather events, from prolonged droughts to violent tropical storms) and the continued growth of cities may intensify these effects.

IUWM is a philosophy of varying definitions and interpretations. According to Parkinson et al. (2010), IUWM is described as the practice of managing freshwater, wastewater, and storm water in urban settings and viewing them as components of a basin-wide management plan. It builds on existing water supply and sanitation services considerations within an urban settlement by incorporating urban water management within the scope of the entire river basin. Another way to define IUWM is given in Box 7.

In IUWM, the water sector is integrated with other urban sectors, such as land use, housing, energy, and transportation in order to overcome fragmentation in public policy formulation and decision-making.

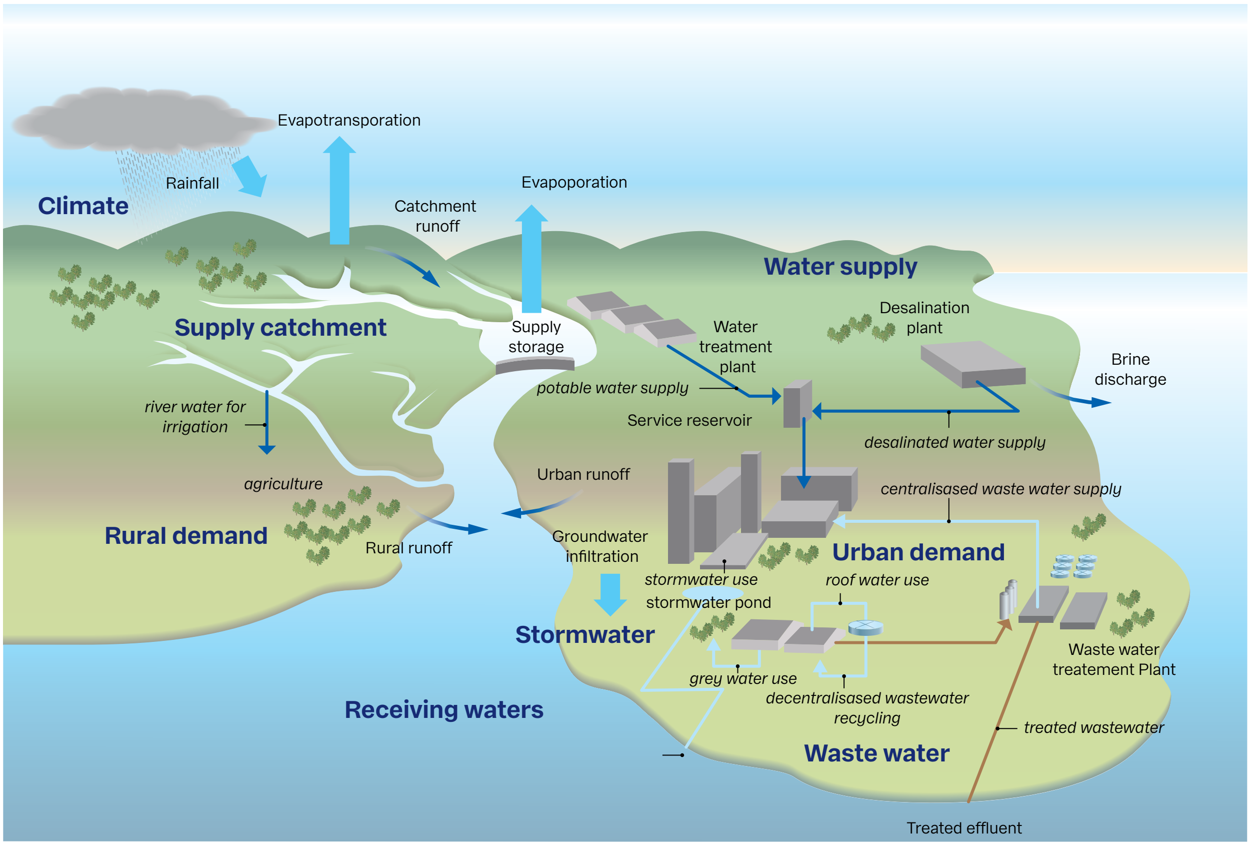


Figure B13 Schematic governance structure of IUWM
Adapted from: Integrated Urban Water Management Planning Manual (CSIRO, 2010)

Box 7 Defining IUWM

IUWM promises a better approach than the traditional system in which water supply, sanitation, stormwater and wastewater are managed by isolated entities, and in which all four are separated from land-use planning and economic development. IUWM, in contrast, calls for the alignment of urban development and basin management to achieve sustainable economic, social, and environmental goals. IUWM encompasses all aspects of water management: environmental, economic, social, technical, and political.

(Bahri, 2012)

integrated water management and urban spatial planning, backed by effective legislation and building regulations, to guide local councils. The informal urban economic sector and perspectives of marginalized populations are specifically included. As indicated in figure B13, a clear link exists with river basin planning. There is also a strong connection with groundwater management and, if the urban conglomerations are located along coastal zones, with ICZM.

B.4.4 Integrated Groundwater Management

Groundwater is an important freshwater resource. It is a major source of drinking water as well as for irrigation across the world. Worldwide, 2.5 billion people depend solely on groundwater resources to satisfy their basic daily water needs (Connor, 2015). Despite groundwater having an estimated 95 times larger volume than all fresh surface waters in the world (Shiklomanov, 1993), it is rather undervalued and overlooked in water resource management. Groundwater management may well be at the core of resolving the global water security crisis and be key to achieving some of the SDGs. Being an invisible resource, the lack of monitoring, information, and expert knowledge in many countries of the world leads to inaction, or indeed detrimental action, with respect to groundwater management.

An aquifer system is a collection of aquifers and aquitards which together constitute the environment in which groundwater is stored or transported. Figure B14 presents the aquifer system as a combination of aquifers, layers of rock or other geological strata of sufficient porosity and permeability to allow a significant flow of groundwater, or the abstraction of significant quantities of groundwater, and the aquitards between these aquifers. Aquitards are layers with low permeability which generally makes it unsuitable for productive wells to be constructed within them. Groundwater flow in aquitards tends to be mainly vertical between the bounding aquifers. Aquitards can act as protective layers against potential pollutants which infiltrate from the surface. Most often the boundaries of an aquifer system do not coincide with the boundaries of a river basin. An aquifer system, when present, is an integral part of the water system and needs to be a part of the water management of that area.

Groundwater frequently interacts with surface water, as well as with nature, people, infrastructure, and plants in river basins, coastal zones, and cities. Rivers traversing the landscape can gain or lose water from and to the subsoil and are thereby connected to shallow aquifers. Coastal aquifers are the connection between the sea and the hinterland. Approximately 70% of the world's population lives in coastal areas, and most of these people depend on coastal aquifers for freshwater. The urban system is usually highly dependent on groundwater resources, and when so, IGWM has strong links with IRBM, ICZM and IUWM.

Due to the characteristics of some aquifer systems (e.g., large storage volumes and capacities, regional flows, broad recharge areas, isolated from surface processes) groundwater is a reliable and resilient resource that becomes indispensable when surface water is scarce. However, dependency on groundwater for households, agriculture and industry, along with increasing droughts, is accelerating its depletion in some areas. Decreasing groundwater levels may cause several adverse effects such as saltwater intrusion in coastal areas, land subsidence, drought damage in nature, decrease in agricultural yields, deterioration of infrastructure and lower well yields. This can result in issues of inequity as increasingly larger investments are required to gain access to groundwater at greater depths. In vulnerable aquifers, the deterioration of the groundwater quality due to overexploitation and contamination by human interferences (pesticides and fertilizers from agriculture, toxic substances from mining sites, and so on) is expected to increase in the coming years. All of these factors need to be a part of an integrated approach to sustainably manage water resources in a given area.

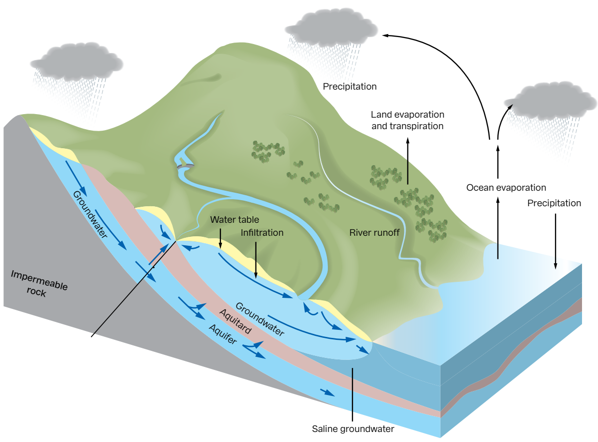


Figure B-14 Groundwater as part of the hydrological cycle

B.4.5 Marine Spatial Planning

A country's territorial sea extends up to 12 nautical miles (22.2 km) offshore and their Exclusive Economic Zone (EEZ) to at most 200 nautical miles (370.4 km). In narrower seas or straights, these boundaries are, in principle, equidistant between the different countries' shorelines. While a country has full sovereign rights in its territorial sea, it only holds sovereign rights to all economic resources in its EEZ, such as fish stocks, minerals, oil, and gas. A coastal state may establish a contiguous zone of up to 24 nautical miles (44.4 km) beyond its territorial sea to exercise specific powers concerning customs, fiscal, immigration and sanitary laws and regulations in protection of its territorial sea. Outside the EEZ, the high seas are international waters which are not 'owned' by any country, i.e., no country can claim sovereign rights over them, and are covered by international jurisdictions and treaties such as the United Nations Convention on the Law of the Sea.

While at a glance the sea may appear to be wide and empty, upon a closer look it is clear that it is filled with abundant activity at the sea surface, in the water column, at the seabed and even below the seabed (Figure B15). These activities all compete for space and must be managed well in order to maintain this highly diverse and complex ecosystem. Marine Spatial Planning– or Maritime Spatial Planning, considered as a synonym in this document – is the integrative approach used to achieve the sustainable management of marine environments. MSP generally covers territorial seas and the EEZ, although (a part of) the territorial sea is typically also included in ICZM. Transboundary marine spatial planning is also a common equivalent to transboundary river basin and/or water resources management.

MSP is a multi-objective planning process which brings together the multiple users and stakeholders of the seas and oceans. There are many definitions of the term. The EU Directive on MSP defines it as "a process by which the relevant [...] authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives" [44]. The concept of Blue Economy has gained traction in the past decade and overlaps with MSP. Although its name may suggest that there is a purely economic focus, the Blue Economy is actually an integrated approach for the sustainable use of coastal and marine resources. This is explained in more detail in section D.5. MSP tends to be incorporated in national legislation and institutional settings, whereas Blue Economy is – so far – used as a strategic and visionary approach. However, both use the steps for planning and management which are outlined in this document.

Figure B15 Impression of the sea at and below the sea surface

B.4.6 Integrated Drought Risk Management

Droughts refers to the period of time when there is a deficit of water compared to 'normal' conditions. By themselves, droughts are the result of natural climate variability and cannot be prevented. Consequently, drought management plans are usually presented as drought mitigation plans. Dealing with droughts is a challenging task for water authorities as the onset and severity of drought events are difficult to predict. Compared to floods, the spatial extent of droughts is usually much wider and there are no easy measures available to mitigate them. They should not be confused with water scarcity, which is a situation in which the demand for water is much higher than available supply. However, the two are interlinked because droughts can lead to water scarcity, as supply drastically drops while demand stays the same or even increases.

Droughts are traditionally classified by type as meteorological (lack of precipitation), agricultural (lack of soil moisture), hydrological (lack of water in reservoirs, rivers and groundwater), and socio-economic. The first three categories deal with ways to measure drought as a physical phenomenon. The last deals with drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socio-economic systems. An additional category known as ecological drought has emerged in recent years, emphasizing the impact of droughts on ecosystems and the associated effects on human communities that rely upon them.

4 *Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Article 20. Available at:
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0089
https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en

Ecological drought occurs when water availability drops below the threshold required to provide ecosystem services (Crausbay and Ramirez, 2017).

Climate change will result in more frequent drought events in many parts of the world. Sea level rise will cause increased salt intrusion in surface and groundwater systems and will increase accompanying water quality issues (such as higher levels of brackish water). Moreover, land and water use changes due to socio-economic developments, soil degradation caused by agricultural malpractices and water mismanagement are some of the other drivers contributing to the increased frequency, duration, spatial extent, and severity of droughts. New typologies of droughts are emerging based on those developments. For example, recognition is now being given to drought categories that focus on the duration and severity, e.g., flash droughts and megadroughts which are pushing countries to re-examine existing drought policies and planning interventions for conditions they were never designed to address, but have exposed to by climate change impacts. Furthermore, more attention is being paid to the vulnerability and impacts of droughts for various water users. A drought can become catastrophic when there is a failure to mitigate and adapt to its impacts, which disproportionately affect marginalized groups, can stunt local economies and have adverse effects on biodiversity.

B.4.7 Integrated Flood Risk Management

Floods are the most common natural disaster and have the largest impacts on society. Devastating (coastal) floods, such as the floods caused by the 2004 tsunami in Asia and Hurricane Katrina in 2005, resulted in hundreds of thousands of people losing their lives and homes. As stated by WMO/GWP and APFM (2017), the number of flood fatalities worldwide is gradually decreasing, partially thanks to improved early warning systems. However, flood damages appear to be increasing due to inadequate levels of investment in prevention and lack of flood-sensitive land use planning. It is expected that climate change will further increase the frequency and severity of floods.

As shown in Figure B10, IFRM planning applies to different water systems, each with their own causes of flooding:

- Coastal floods can be caused by storm surges (such as from a depression or hurricane) or tsunamis. In river delta areas, they often are caused by a combination of storm surges, high tides, and high river discharges.
- Fluvial or riverine floods occur when the river discharge exceeds the capacity of the main river channel, causing it to overflow.
- Pluvial or rainfall flooding occurs when heavy rainfall creates a flood event independent of an overflowing water body. For example, pluvial flooding may occur in urban environments when the local drainage system is not capable of collecting and conveying surface runoff.
- Flash floods are considered separately from pluvial or fluvial floods as they are of very short duration, have a relatively high peak discharge and high flow velocities. Flash floods can occur within a few minutes or hours of excessive rainfall. They can also be related to dam or levee failure, or from a sudden release of water held by an ice jam.
- Groundwater flooding occurs when the underground water table rises and seeps through the ground. This type of flooding is not related to surface water flooding.

IFRM aims to maximize the efficient use of land (e.g., flood plains and coastal zones) while minimizing economic damage and loss of life caused by floods. Flood risk can be reduced by applying protective measures (e.g., construction of embankments) as well as with measures that aim to reduce the consequences of flooding (flood-sensitive land use planning, construction of flood-proof buildings, etc.).

Integrated planning and management for clean water and healthy ecosystems applies as applied by Deltares follows the Source-to -Sea approach (S2S) or the similar Ridge to Reef approach. Both acknowledge the complexity of the hydrological cycle, and so encompass the water's journey through the entire river catchment from its source to estuaries, ground-water systems, coastal zones and eventually the open sea. S2S also identifies and quantifies the sources of harmful substances from upstream and downstream areas. These typically come from urban, agricultural and industrial sources.

As it is impossible to reduce flood risk entirely to zero, part of the discussion in IFRM will include deciding what level of risk is acceptable. This decision can be based on cost-benefit analysis, but also on societal discussions. As explained by WMO (2017), the approach looks for a 'proportionate' response to risk as well as a transparent process of estimating the risk and of assessing the positive and negative impacts of measures. Within this, special attention should be given to social inclusiveness as data of flood events show that women and vulnerable groups are dispro-portionately affected by their impacts.

B.4.8 Water quality and ecosystem management

An ecosystem comprises all biotic and abiotic elements within a certain area, including organisms' interactions with the physical and chemical environment. Examples of natural ecosystems are forests, coral reefs and wetlands. Humans have created their own ecosystems in cities and agricultural lands. Both natural and manmade ecosystems rely on good water quality to survive and thrive.

On a large spatial scale, ecosystems are connected through water flows and the substances carried within these flows. Some are beneficial, such as nutrients, dissolved oxygen and sediments, while others are detrimental, such as pollutants, plastics or even excessive amounts of nutrients. Ecosystems are also connected via migratory organisms. Birds, fish and mammals can travel over thousands of kilometers following their ancient flyways and swimways. These migratory organisms are particu-larly vulnerable to the effects of contaminated water as they move through a range of ecosystems which heightens their exposure.

What is good, or good enough, water quality? The answer depends on the extent to which a system can accommodate a certain load (its carrying capacity) without producing harmful effects to human and ecological functions and well-being. This carrying capacity is substance, system and function specific. However, generally the healthier a natural system, the more effectively it can counter detrimental water quality activities. A substance load that exceeds a system's carrying capacity can cause, amongst others:

- Eutrophication: too high nutrient loadings lead to harmful algal blooms and dissolved oxygen depletion.
- Toxicity: too high loads of chemicals cause toxicity either directly to the WRS or indirectly via bioaccu-mulation in the food chain.
- Prohibiting functions: too high concentrations of pollutants can damage ecological functions, for example chloride causes the purification functions of a river to shut down.

On its pathway from source to sea, water quality changes according to natural and anthropogenic inputs like nutrients, organic matter, toxins, plastics. Water quality is predominantly affected by anthro-pogenic activities, although natural processes may also cause issues with water quality, for example high arsenic background concentrations. Water quality can be improved by reducing input of 'bad' substances, or by artificially or naturally removing substances from the environment. Additionally, water quality may be improved by the purification ability of natural systems (e.g., floodplains, wetlands, soil).

The Water Framework Directive (WFD) of the European Union is an example of integrated planning

and management from source to sea. The WFD requires Member States to work together on trans-boundary water quality issues, using a river basin scale up to and including the coastal zone. The goal is a good chemical status and a good ecological status by 2027 in all water bodies.

B.4.9 Developing plans for different water systems and themes

Water authorities are mandated to develop strategic plans for the water systems and themes described in previous sections. Each of these strategic plans will have their own specific function, but they will also partly overlap. The most comprehensive plan is the river basin plan. In fact, the concept of IWRM is strongly rooted in river basin planning. An integrated river basin plan covers, by definition, all subjects that are also addressed in other plans but will do so in a more integrated, less detailed way.

The main reasons for having specific plans for other spatial areas or themes are institutional. In some cases, the plan may form a part of national policy (mandatory planning). An institution may have the legal responsibility to write and maintain a plan in order to manage a specific water system. This is generally the case for urban water plans, where municipalities are their main drivers. Coastal zone plans can be made at the request of the coastal communities to address the specific issues those communities face. Coastal zones can also include areas that belong to different river basins.

The reason to have specific groundwater, drought and flood plans is that special attention is required to appropriately address these topics. For instance, groundwater is hardly mentioned in the plans of other water systems, despite being an essential part of the hydrological cycle. Flood and drought plans are sometimes made after a flood or drought (near-)event and so contain lessons learnt which can be applied to future events, including the mitigation and adaptation actions to be taken and operational information.

The water management plans that are not addressed directly in this document are national WRM plans. These national plans are high-level and describe the national policies related to the management of water and land resources. As such, they provide directions for the development of other plans. There is no uniform structure on how national, regional and more focus-oriented plans should be made. Each country will have its own objectives and priorities when writing plans, and depending on the context some plans may be more useful than others.

Transboundary issues in planning are also not addressed in this document. If a river basin or groundwater system crosses national (or other political) boundaries, cooperation is required between the riparian countries to develop a strategic plan that covers the whole basin or groundwater system. This is also the case for flood and drought plans, if the water system involved is transboundary. In the case of insufficient cooperation between the riparian countries, assumptions have to be made (in terms of scenarios) on what type of action each country will take. The European Water Framework and Flood Directives address these transboundary issues (see Box 21). Transboundary issues can also manifest themselves within a country's borders when the water legislation of the country places the main responsibility for water at a lower governmental level (e.g., to states or governorates). For water allocation in a transboundary context refer to UN-ECE (2021).

In any case, all of the above-mentioned strategic plans will be based on the principles of IWRM, and their preparation will benefit from following the Analysis Framework.

B.5 Dealing with Uncertainty

B.5.1 Uncertainty analysis: knowing your uncertainties

Water planners, stakeholders and scientists understand that the future is uncertain. However, the multiple dimensions and real and/or perceived meanings of 'uncertainty' are not always fully appreciated. A profound understanding of the role of uncertainties and an appropriate approach to deal with them are crucial for an effective decision-making process. This requires carrying out an uncertainty analysis in the early (Inception and Situation Analysis) phases of a strategic planning study which addresses what is uncertain, why, and what can or should be done about it. The following are typical questions:

- What is meant by uncertainty?
- Which types of uncertainty are there?
- What are the sources of uncertainty?
- Which uncertainties are (most) relevant for planning and decision-making?
- How should these uncertainties be dealt with for decision-making?
- How should the relevant uncertainties be presented to the various actors?

This list is based on an adaptation from Walker and Haasnoot (2011), and references therein, on decision-making under uncertainty for flooding and freshwater resources under climate change.

Uncertainties should be distinguished into four main categories:

- Context or external factors, i.e., factors outside the control of water planners and decision-makers. Typical examples are climate change and population growth.
- Natural and/or socio-economic system response, i.e., how the system changes in response to external factors, autonomous development and/or interventions. This category typically involves predicting system behavior – both current and future evolution. The former relies on the availability of data and the latter on the availability of suitable modeling tools.
- Model outcome uncertainty, i.e., the accuracy and/or reliability of the model prediction which can be shown as a bandwidth around a most likely value. Typically, model input consists of a large number of input parameters and variables, each with its own (probability) value range. The propagation of uncertainty when output from one model is used as input to another model must be carefully considered and controlled in the set-up of a sequence of models in a decision-support system.
- Ambiguity on the outcomes of interest, i.e., differences in the relative importance (weighing) of the current and future situation by stakeholders in the decision-making process. It should be noted that current stakeholders and future stakeholders are not the same and that the weighing of interests may change over time. For example, the occurrence of an extreme weather event, a toxic algae bloom, or the emergence of new technologies can lead to changes in preference values or goals.

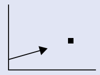
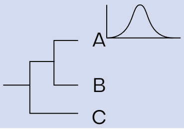
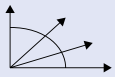
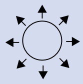
Level of uncertainty		Analysis approach	Type of policy	Result
A clear enough future		Deterministic (optimization, sensitivity)	Forecast and act	Action, implementation
Alternate futures		Probabilistic (sensitivity, most likely value confidence interval)	Predict and act	Strategic plan, work plan
Multiplicity of plausible future		Scenario analysis	Robust, static policy	Policy document with policy options
Unknown future (deep uncertainty)		Exploratory (scenario) analysis, adaptive pathways	Robust, adaptive (dynamic) policy	Policy document with adaptation pathways, triggers and options

Table B1 Levels of uncertainty and associated analysis approaches and types of policy (Walker and Haasnoot, 2011)

Uncertainties are not problematic if they are recognized and dealt with accordingly. Table B1 shows a consistent approach for managing various levels of uncertainty, ranging from minimal uncertainty to maximum, deep uncertainty. The analysis approach must match the level of uncertainty. In a situation with a deep uncertain future, a deterministic model that predicts only one future value is not suitable for decision-making and could lead to ineffective policy decisions.

There are some general characteristics that can be defined for policy analysis models. Policy analysis models are fundamentally different from most other types of models. Scientists and engineers usually build models to try to obtain a better understanding of a portion of the real world. The closer the match between the model and the real world, the better the model is considered to be. Scientific and engineering models can be validated using empirical data. By contrast, policy analysis models are built to provide information to policy-makers who are trying to develop policies intended to solve real world problems, usually for a future situation.

These models are designed to provide policy-makers with data that can help them to develop informed insights of their problem and to create effective policies based on this information. The quality of a policy analysis model is judged not by how accurately it reflects the real world, but by how well it is able to provide information that enables a decision-maker to make knowledgeable choices between different policy options – i.e., how well the model can help to construct and defend an argument about the relative pros and cons of alternative policy options.

B.5.2 Climate Variability and Climate Change

In planning the management of water systems, a clear distinction should be made between Climate Variability (CV) and Climate Change (CC). CV includes all the variations in the climate that last longer than individual weather events. For millennia human beings have addressed and adapted to these variations e.g., by storing water for use during dry periods or by avoiding living in or developing on floodplains. The most important climate variable for water management is rainfall. Rainfall has always been a stochastic variable with annual and inter-annual dry and wet periods. Dealing with this variability is the core of planning for flood and drought management, as well as playing a key role in plans for river basins, coastal zones, and urban areas. For water management in general, attention needs to be given to the variability and the uncertainties of water supply and demand.

CC describes the changes over a longer time period (typically more than 10 years), in particular as a result of global warming. CC is addressed by the Intergovernmental Panel on Climate Change (IPCC), including possible mitigation and adaptation measures. Mitigation has a focus on energy and reducing emissions, and adaptation on water (management). For water management, the change in climate has three main components: the long-term change in averages, the increase in extremes (increase in variability) and accelerated sea level rise. CC is also expected to shift ocean currents which are important for ICZM and MSP. It should be noted that the changes in averages (e.g., of rainfall) are often small compared to normal variability. This means that for short-term decisions, the increase in variability is more important than the change in averages. For long-term decisions, it is important to include the expected CC in project or program design.

B.5.3 Impacts, Vulnerabilities and Risk Assessment

The first step in conducting a risk assessment is to gain insight on possible climate change and climate change-related hazards. The second step is to identify the possible impacts involved. This works both ways, as a risk assessment can also help to recognize potential impacts. The risk involved is determined by the combination of events, exposure and vulnerability, as demonstrated in IPCC's risk-based framework for disaster risk (Figure B16). From an analytical point of view, this framework can be expressed as risk = probability * exposure * vulnerability. Planned interventions in the water system therefore aim to reduce the risk of water-related crises by influencing the probability (of an event occurring) and/or exposure (of the system to the potential impacts of the event) and/or vulnerability (of the overall system, including societies, economies and ecosystems).

In planning, a risk assessment will have to address the acceptable risk level and how to best manage the risk. The acceptable risk level is based on a combination of economic, societal, environmental and political decisions and the additional benefits gained from reducing the risk level. The most effective way of reducing risk will also be a key topic to consider. The impacts can be either defined at full risk level (e.g., the expected damage over the range of return periods) or separately according to the various components of risk, targeting specific vulnerability or exposure reduction objectives (e.g., the number of citizens exposed to hazards).

Risk-informed decision-making on water-related risks
Integrated planning should involve an approach to vulnerability and risk assessments that promotes an understanding of the drivers of risks. After collaboratively identifying the objectives of the plan, stakeholders involved in the analysis should assess the

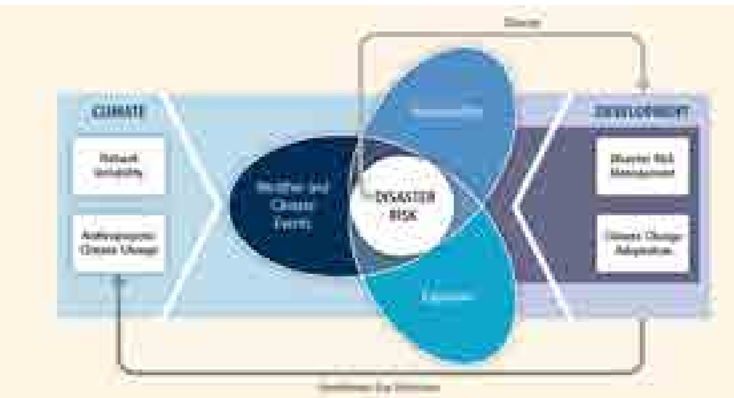


Figure B16 Risk Framework of IPCC • Source: IPCC, 2012

5 Disaster risk management | UNDRR

climatic and non-climatic factors that will pose the highest risk to achieving those goals. The formulation of the objectives is an important step in the structured process (to be further explained in C.3.4).

To enable risk-informed decision-making, the planning process should determine a 'proportionate response' to risk. This entails a transparent process of estimating the overall risk and of assessing the impacts (costs and benefits) of risk reduction and management. Planning for the management of water-related risks should be guided by a number of core principles:

- Achieving absolute protection from disasters (zero risk) is not feasible, hence the need to identify a proportionate response to water-related risk.
- Decisions should be based on a thorough understanding of risk and uncertainty of both current and possible future water-related risks, including the impacts of climate change.
- Risk and uncertainty should be widely communicated amongst stakeholders to ensure mutual understanding.
- Plans should consciously evaluate a wide range of potential responses. Measures selected for implementation should use resources effectively and fairly.
- Plans should reflect the local context and be integrated with other planning processes.
- Responsibilities for governance and action should be clearly defined and communicated.

Disaster Risk Management and Disaster Risk Reduction
The aim of disaster risk reduction (DRR) policies and strategies is to prevent new disaster risk, reduce existing disaster risk, manage residual risk, and to contribute to the strengthening of resilience and reduction of disaster losses. Disaster risk management (DRM) plans set out the goals and specific objectives for reducing disaster risks together along with actions to accomplish these objectives. Both DRM and DRR activities should be guided by the Sendai Framework for Disaster Risk Reduction 2015-2030 (see Box 8) and be considered and coordinated within relevant development plans, resource allocations and program activities. National-level plans need to be specific according to each level of administrative responsibility and adapted to the different social and geographical circumstances that are present (UNDRR[5]).
DRM and DRR policies cover all kinds of hazards such as floods, droughts, earthquakes, volcanic eruptions, and toxic chemical spills. Due to this wider scope, in most countries the institutions which lead on matters related to DRM and DRR are different from the WRM institutions responsible for droughts and floods. This

Box 8 Sendai Framework for Disaster Risk Reduction

On 18 March 2015, after 3 years of consultations, the Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted. The Sendai Framework is the successor instrument to the Hyogo Framework for Action 2000–2015, building on the experiences with the Hyogo Framework and introducing a number of innovations. The most important features of the Sendai Framework are:
- a significant shift from disaster management to disaster risk management;
- seven global targets for 2020 and 2030;
- the reduction of disaster risk as an expected outcome;
- a goal focused on preventing new risk, reducing existing risk, and strengthening resilience; and
- a set of guiding principles, including primary responsibility of states to prevent and reduce disaster risk, all-of-society and all-of-state institutions engagement, and "build back better."

In addition, the scope of disaster risk reduction has been broadened significantly to focus on both natural and human-made hazards and related environmental, technological, and biological hazards and risks. Health resilience is strongly promoted throughout.

Source: United Nations Office for Disaster Risk Reduction,2015

means that when developing policies and plans for droughts and floods, coordination needs to take place between the relevant DRM/DRR and WRM institutions. For a description on the linkages between DRM and WRM, reference is made to the EPIC Response Framework on Innovative Governance for Flood and Drought Risk Management (Browder et al, 2021).

Risk management for droughts and floods
Floods and droughts are arguably the most prominent impacts that climate variability and climate change have on society. It is evident that these extreme events are increasing due to climate change. The assessment of the impacts of droughts and floods will determine the need for risk reduction measures and provide an information base for the selection of appropriate interventions, infrastructure design, and operating criteria.

Such risk assessments can be carried out at various levels of detail. A 'light touch' risk assessment could include semi-quantitative indicator-based assessments and impacts based on globally accessible data and/or the use of simple statistical relationships based on local observations of past events. Detailed assessments would include modeling of the main system components and involve extensive calibration and validation using local climate and hydrology data. The choice for a detailed or light touch analysis will depend on various factors, including the size of the investment, the lifetime of the infrastructure being built, and the level of precaution needed.

B.5.4 Dealing with uncertainty in a strategic planning study

Future uncertainty increases with time. Strategic planning studies will address present problems but are also supposed to prepare for the future, and so should consider a longer time horizon in their analysis processes. As the assessed period of time increases, the range of uncertainty will also increase. Figure B17 displays the development of uncertainty over time for a certain parameter, e.g., rainfall or sea-level rise.

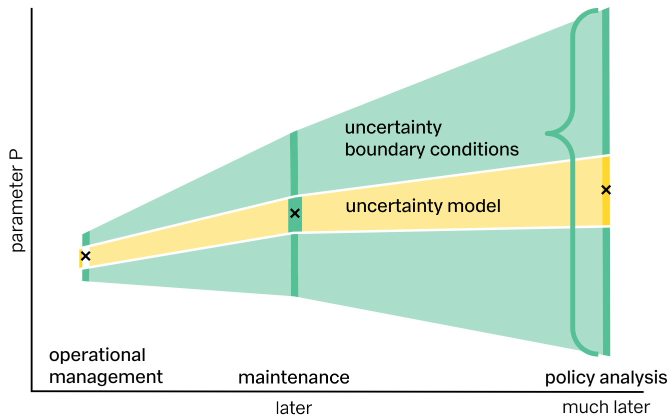


Figure B17 Development of uncertainty over time

Climate change is a slow process, so to appropriately incorporate it into a strategic planning process a longer time horizon will be needed, e.g., at least 50 - 70 years. We first have decide what the system and its possible conditions should look like in the future (the vision), and then move backwards in time and developing actions which will eventually lead to the chosen future (while always taking into account potential uncertainties). This is illustrated in Figure B18. This thinking is also at the heart of the Dynamic Adaptation Policy Pathways (DAPP) approach that will be explained in section C.5.2.

The planning and management of water systems should aim to make them more resilient and able to deal with climate change, water-related disasters, public health emergencies and other shocks. For this, an integrated approach is needed. A good introduction on how to mainstream resilience in water management is given in ADB (2022) with further information on resilience to be found in the Water Resilience Hub[6] of ADB.

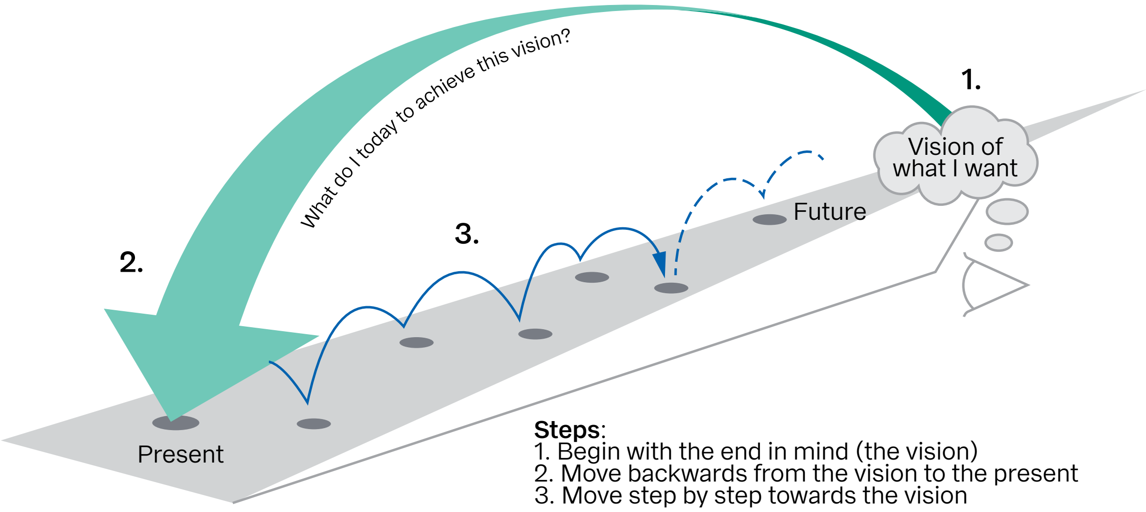
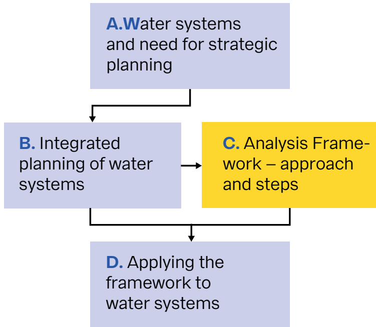


Figure B18 Stepping back from a vision to actions now

1 https://hub4r.adb.org/

C. Analysis Framework – approach and steps



In this chapter, the generic steps of the structured Analysis Framework will be presented. This will start with a description of the function of the Framework, an overview of its five phases, and an explanation of the divergence-convergence processes involved during decision-making in each phase. Next, each phase will be described in detail.

C.1 Function of the Framework and definitions

Before describing the Analysis Framework, it is important to clearly define its key terms. In planning and policy projects many different terms are used and this can be confusing. The main terms used in the Analysis Framework are: objectives, strategies, indicators, measures and scenarios. In this document, they have the following meanings (see also Box 9):

- A development **objective** defines what is to be achieved or how a target is to be met. Objectives identify needs, prioritize issues, define targets and determine constraints. Objectives may also define preferred courses of action. For example, the objective might be to apply user-oriented demand management measures rather than relying on large-scale water supply infrastructure development. Alternative terms sometimes used instead of the term objective: policy, goals, aim.
- A development **strategy** is the logical combination of individual measures and/or decisions that accomplishes the stated objectives and satisfies the constraints imposed on the WRS. For example, constructing of a reservoir, widening a downstream canal and increasing the intakes of irrigation systems are all measures which form a strategy to reduce the risk of damage to the agriculture sector in a drought-prone area, perhaps whilst working in coordination with a public water supply and sanitation project. A strategy at national or river basin scale can include over 100 measures. Alternative terms used for a strategy are: plan and policy. While the word 'scenario' can be used in this context, it could be perceived as being confusing or incorrect. Generally, a scenario (see below) refers to an external situation beyond the control of the decision-maker(s).
- An **assessment indicator** assesses the extent to which an objective has been achieved. As such, it is also a tool for evaluating the levels of success of a strategy or measure.
  Alternative term used for an assessment indicator: criteria.
- A **measure** is a particular course of action. A distinction can be made between:
  - Technical (structural) measures are modifications of the elements of water resources infrastructure such as canals, pumping stations, reservoirs, and fish ladders. Technical measures can include managerial measures such as implementing more effective, sustainable ways of using the infrastructure.
  - Nature-based measures are similar to technical measures in that they work by modifying elements of the water resource system, and make proactive use of natural processes to tackle water security challenges by using natural elements such as wetlands, mangroves, etc. These are referred to as Nature-based Solutions (NbS).

Box 9 Definitions

Development objective: the desired outcome and/or goal of a project.
Strategy: the plan of action which will be implemented to achieve the project's development objective.
Assessment indicator: a variable that measures the extent to which the development objective has been achieved.
Measure: an action that can be taken to meet the development objective.
Project: action (measure) with appropriate implementation arrangement.
Scenario: the external economic, environmental, social and/or political context which may influence the impact of the strategy.

  - Ecological (non-structural) measures improve the functioning of ecosystems, for example by introducing fish fry in spawning areas.
  - Economic measures induce water consumers to alter their use of water by changing the price of the resource use (through charges, taxes or subsidies).
  - Regulatory measures alter the use of water, generally through some form of restriction

(e.g., through land-use zoning, permits, pollution control and other forms of restrictive legislation).
  - Institutional measures specify the roles and responsibilities of government agencies over certain functions or components of the WRS. These measures might also determine the necessary interactions between the public and private sectors involved. Capacity building is an institutional measure.
    Alternative terms used instead of measure: intervention, project, decision, and action.
- A **scenario** is defined as the contextual environment which is exogenous to the water system and which cannot be controlled by the decision-maker involved. Examples of scenario variables include rainfall and other aspects of the climate, demographic trends and changes, production functions (including crop water requirements), and most economic variables relating to benefits and costs. What is considered to be a scenario and what is considered to be a decision variable will depend on the system boundaries that have been defined. Scenarios often relate to climate change and socio-economic development. In areas that depend heavily on external water inflows (e.g., from an upstream country), the transboundary inflow can be defined as a scenario.

C.2 Overview of the Analysis Framework's phases

A water resources planning study generally comprises five general phases, as shown in Figure C1. Although the use of any inflexible rigid framework is not recommended, some distinct phases and activities can be recognized and used to structure planning processes as a logical sequence of steps. The description of these phases, the activities within them and the interactions between them are referred to as the Analysis Framework. The various phases were partly shaped by work previously described by Loucks and van Beek (2017b).

A decision process is not a simple linear sequence of phases as suggested in Figure C1, but involves feedbacks to earlier steps. Part of the process is thus iterative. Feedback loops are needed when:

- proposed solutions fail to meet current objectives,
- new insights change the perception of the problem and its solutions,
- essential system components and links have been overlooked, and
- objectives or the scope of study change (e.g., due to changing political, international, economic, social or environmental developments).

Communication and interaction with decision-makers are essential from the onset and throughout the duration of a planning project, including its implementation. If due importance is not given to stakeholder involvement and communication, there is an increased risk of generating plans and policies that are no longer relevant or of interest to the client. Regular reporting (such as through inception and interim reports) adds a level of accountability and helps in effective communication, but a continuous dialogue is important throughout all phases of the analysis. Stakeholder involvement also brings knowledge and preferences to the planning process – a process that typically will need to find suitable compromises among all decision-makers and stakeholders if a consensus is to be reached.

Figure C1 shows a rather simplified sequence of steps to be followed in a water resource planning and implementation process. The figure shows only the main activities to be taken and the main links between these activities. Besides the above-mentioned feedback loops, there are many more links between the various steps than those indicated by the arrows. Moreover, many of the arrows are actually two-directional while the figure only shows one direction. It was decided not to add all of these details as it would make the figure less clear.

The first inception phase (Phase I) of the process identifies the subject of the analysis (what is to be analyzed and under what conditions), the objectives (the desired results of the analysis) and constraints (its limitations). On the basis of this analysis, during which intensive communication with decision-makers is essential, an agreement on the approach which will be used for the remainder of the analysis needs to be achieved. The results of the inception phase can be presented in an inception report, which includes the work plan for the remaining phases of the analysis.

In the situational analysis phase (Phase II), the tools for the analysis of the water resource system are selected or developed. Major activities in this phase typically include data collection and modeling. The models of the system will be used to quantify present and future problems. Scenarios will be developed to describe the future boundary conditions for the system. Identifying and screening alternative decisions can occur in this phase. If possible, no-regret measures will be identified for immediate implementation. A gradual improvement in the level of understanding of various characteristics of the WRS is generally obtained as the study progresses from limited data sets and simple tools to more detailed data and models. Interaction with the decision-makers will be greatly enhanced if they trust and communicate with the analysis team, or

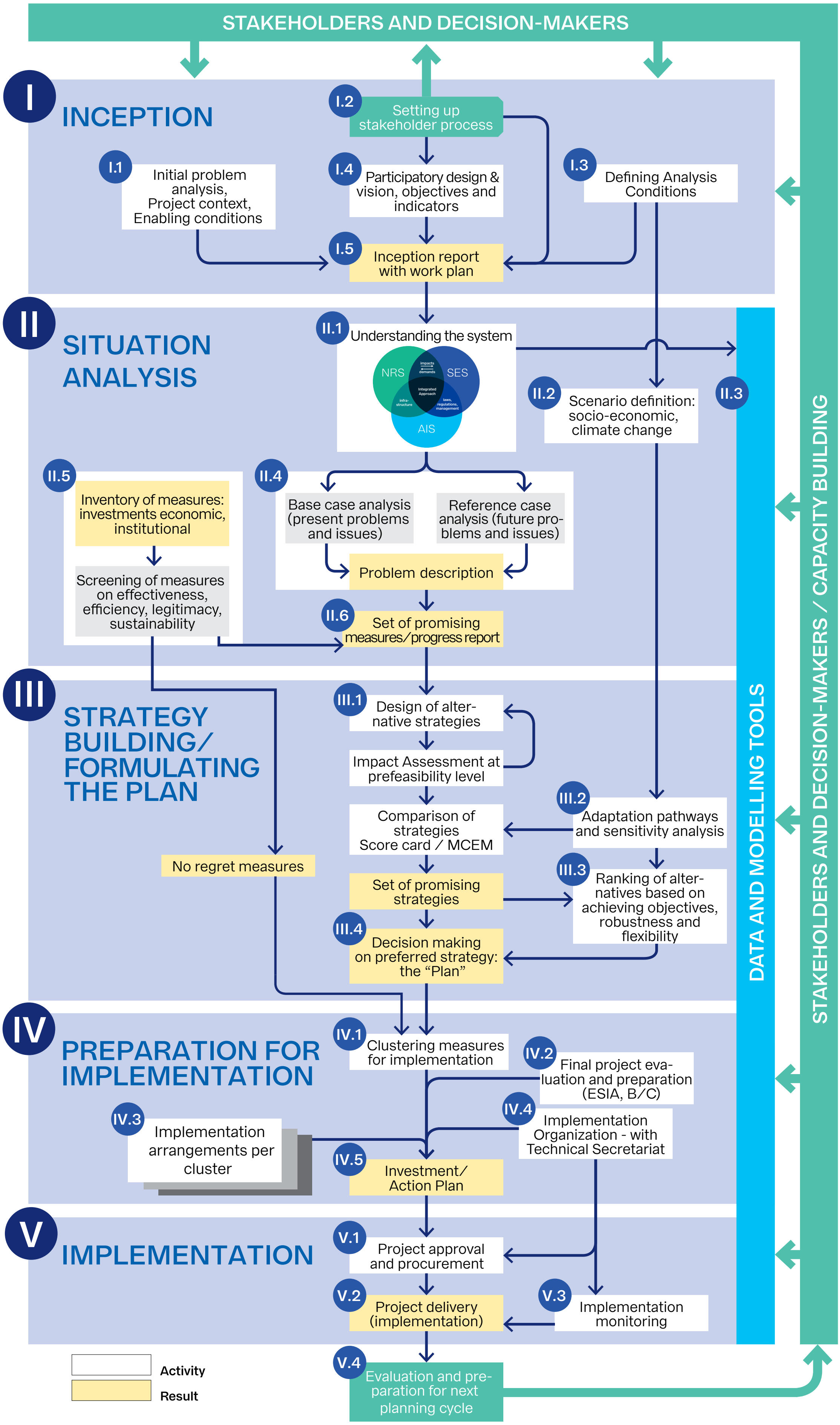


Figure C1 Framework for analysis and implementation of water resources projects even better, are directly involved as part of the analysis team. More formal interactions can be structured through presentations of results in meetings and in interim progress reports.

In the strategy building phase (Phase III) alternative strategies will be developed and discussed with decision-makers and relevant stakeholders. This will include adaptive management elements to ensure that the preferred strategy is sufficiently robust and flexible in case the future develops differently than expected. This phase ends with the formulation of a mutually accepted integrated plan for the development and management of the water resource system.

In the action planning phase (Phase IV), the selected strategy will be prepared for implementation. An implementation plan will be developed which provides details on the measures necessary for implementing the project, such as what will be done, by who, when, and how it will be financed, etc. Additional work may need to be carried out before decisions are made, including conducting feasibility and design studies and environmental and social impact assessments (ESIA). Promotion of the selected strategy is needed to gain public acceptance of the proposed measures. Finally, institutional arrangements will have to be made to ensure a smooth implementation.

Finally, during the implementation phase (Phase V), the actual implementation of the project will take place. Continuous monitoring and evaluation are needed to determine if and when adjustments to the implementation plan should be made, for instance, as a result of changing conditions (e.g., finances, social pressures, political mood and objectives).

It is noted that the planning project needs a preparation of its own. This is usually done by a governmental organization or the organization that finances the planning study. Such preparation can be called Phase 0. This preparation phase might include the development of a Terms-of-Reference for the planning project, the set-up of a steering committee, the tendering process and the selection of the consultant or organization that will be assigned to carry out the planning study.

The first three phases (I, II and III shown in Figure C1) comprise the planning part of the Framework. The ultimate result of these three phases is an integrated plan on the development and management of the chosen water resource system, in which the various proposed measures and/or projects are aligned with each other and care is taken to ensure a comprehensive, inclusive implementation. Integration is the key word in these sections of the Analysis Framework.

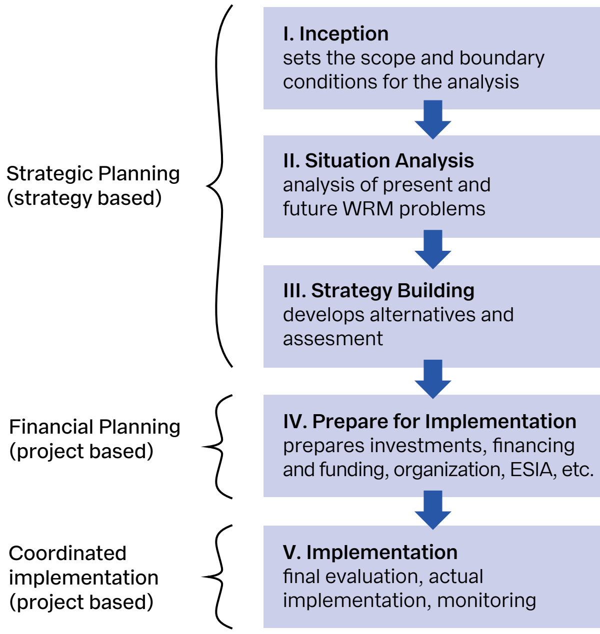


Figure C2 From strategy to 'project' based implementation

The last two phases (IV and V) are about the implementation of the proposed measures. This implementation is mostly undertaken by individual projects as the agencies involved will generally be different. This is illustrated in Figure C2. It is important that the overall integrated development laid out in the plan remains a constant during phases IV and V. This requires a coordination of these developments and effective communication between stakeholders.

Each phase needs to provide information on which actions should be taken and how to best undertake these actions to the governing institutions who will be in charge of decision-making. What these governing institutions need to know to be better informed before making their decisions will vary among different planning projects. However, whatever the knowledge required may be, the purpose of performing analyses is to create and communicate the relevant information. The results of the analyses performed in a planning project should be of no surprise to those reading them in a final project report. Again, communication between the project planners and the requesting institutions, as well as the affected public, is essential throughout the project. This communication may not guarantee a consensus, but it can certainly help the project team with their efforts to gain trust and acceptance.

The Framework involves a series of decisions at the end of each phase. The divergence-convergence process for involving stakeholders in decision-making during the five phases is illustrated in the rhombus approach of Figure C3 and comprises 4 (idealized) sub-phases:

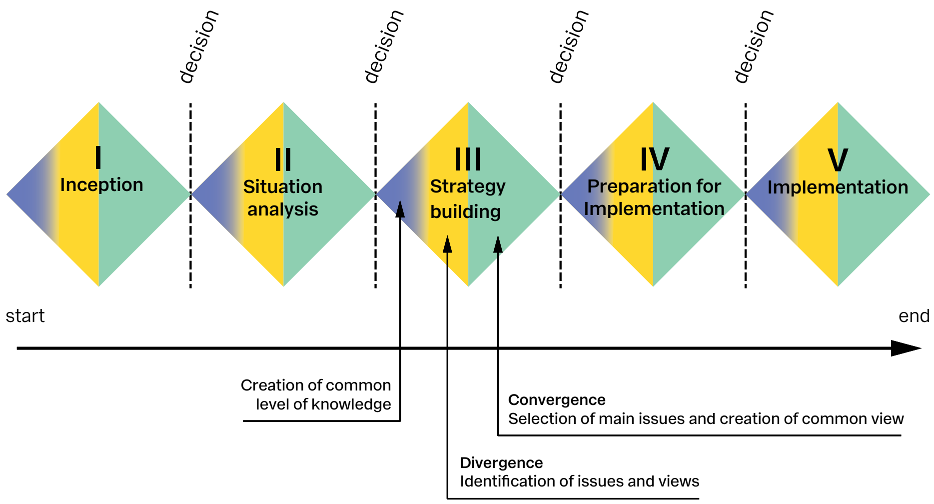


Figure C3 Divergence - convergence process in decision making
Note: this divergence-convergence process takes place in taking place in all phases (somewhat less for phase V); the figure illustrates this only for phase III

- Common knowledge – the phase in which the stakeholders generate a common level of knowledge about the subject.
- Divergence – the phase in which the various views of the stakeholders are expressed.
- Convergence - the phase in which a common view on how to proceed is developed by means of analysis and discussion.
- Decision-making – the phase in which this common view is formalized at the decision-making level.

Note: this divergence-convergence process takes place in taking place in all phases (somewhat less for phase V); the figure illustrates this only for phase III.

The following sections describe the five phases of the Analysis Framework. Within each phase, activities are labeled as 'steps'. The steps are represented as boxes in Figure C1. In some cases, several boxes are combined into one step.

As mentioned above, the Analysis Framework is a simplification of the actual planning process. Depending on the context, special attention might need to be given to certain components. The appendices contain some additional information that can be used in this respect. This includes Appendix 2 on stakeholder involvement and social inclusiveness, Appendix 3 on the use of computer models, and Appendix 4 on financing.

C.3 Phase I - Inception Phase

In Phase I, the structures and foundations are set for a successful planning process in the proceeding phases. Stakeholders will discuss their desired development of the water system with the project planners, and this will be expressed in an agreed-upon objective, a work plan of how to effectively carry out strategies and measures, and an awareness of constraints.
Water resources planning studies are sometimes triggered by specific management problems, such as the need to increase power production or water supply reliability, the occurrence of losses from droughts or floods, or the threat of water quality deterioration. The need for water resources planning in relation to other sectors' planning efforts may also be a trigger. Which parts of the WRS are studied and under what conditions follows primarily from the objectives of the study (and from the available budget, data, and time). The initiators of the study generally will have a rough idea about the objectives and purposes of the analysis. However, these can change during the planning process by stakeholder input and/or progressing insight.

The clients will express which problems and issues they wish to be addressed in a Project Formulation Document (PFD) or Terms-of-Reference (ToR). The very first activity of the project is to review and discuss the contents of these documents. If the subject (what needs analyzing) and objectives (what is to be accomplished) are adequately described in the ToR, the next step of the study is to specify and agree on the approach (how).

However, on many occasions the next task of the project will be to assist decision-makers in further specifying the objectives and scope of the analysis. For this activity, intensive communication is required with the authorities involved in water resources planning, along with other stakeholders. They can provide information on the water-related requirements of various interest groups and on the issues which are to be expected during the course of the project. It is not uncommon to have the stated objectives of a study differ from the actual (often unstated) objectives of the client (which, in some cases, can be stalling for time in the hope that stakeholders

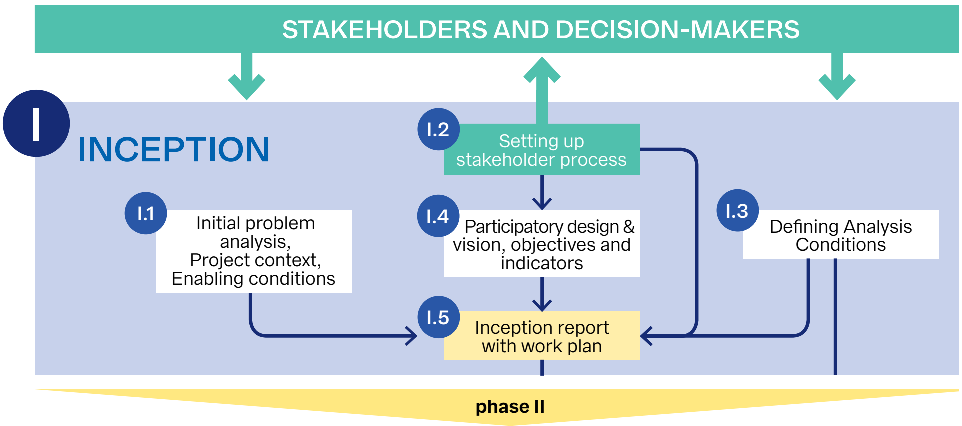


Figure C4 Call-out of the Inception Phase

will lose interest in a particular issue). Furthermore, objectives can change over time. As emphasized above, constant and effective communication between analysts and their clients is absolutely essential to the success of any planning project. This is mentioned frequently in this document as its value cannot be understated, particularly when parties have busy time schedules and may have to learn different terminologies and so do not prioritize coordination.

Figure C4 presents the steps which should be followed in Phase I. These steps are described in the next sections:

- Step I.1: Initial problem analysis, project context and enabling conditions (section C.3.1)
- Step I.2: Setting-up the stakeholder involvement process (section C.3.2)
- Step I.3: Defining the analysis conditions (section C.3.3)
- Step I.4: Participatory design of vision, objectives and assessment indicators (section C.3.4)

Phase I is concluded with decision-making on the next phase, written down in an inception report and/or work plan (section C.3.5)

C.3.1 Step I.1 Initial problem analysis, project context and enabling conditions

The first step of Phase I is to carry out an initial problem analysis, define the context of the envisioned project and conduct an analysis of the conditions that are needed to successfully implement the project.

In the initial problem analysis, a first inventory has to be carried out of the current and expected future problems and possible impacts on the socio-economic system and the environment. This initial problem analysis will determine the problem which the project is trying to address, place this problem in the context of the wider system and identify the stakeholders which will need to be involved in project preparation.
Evaluating the context provides an introduction as to why the envisioned strategy is needed and what institutional settings for the project might be required. In terms of development objectives, links should be made with national laws, policies, strategies and plans. Further details of these items will be developed in next steps of the study, in particular in Phase II on Situation Analysis.

To successfully carry out an effective planning study, certain conditions have to be met. Most of these conditions are external to the project's activities, meaning that they should have been set before the planning exercise starts. A generic description of the enabling conditions for integrated planning is given in Background Paper no. 4 (GWP, 2000). The main categories are: i) enabling environment (policies and laws), ii) institutional framework, and iii) management instruments. These were summarized in section B.3.1 and highlighted in Figure B4.

The conditions which are relevant for the specific planning exercise should be determined in the Inception Phase. This will vary depending on the issues involved. If needed, institutional measures can be a part of the planning project.

C.3.2 Step I.2 Setting-up the stakeholder involvement process – following a whole-of-society approach

Phase I also includes setting-up the stakeholder involvement process. The way in which water systems are developed and managed will influence many people in different ways. Thus, the input of the whole of society is needed to develop effective, inclusive strategic plans for these water systems. Strategic planning typically takes a 'whole-of-society' approach, involving the different levels of government, non-governmental organizations, civil society, citizens, the private sector, academia, and other relevant stakeholder groups. Social inclusiveness should be a priority during this process (see section A.4).
The stakeholders which should be involved and the extent of their roles will depend on the specific basin

and the issues to be addressed. In general, two categories of stakeholders can be identified:

- the people and organizations that will be affected by the plan; and
- the people and organizations that are needed to implement the plan.

Although both categories are very important, from the start of the project special attention has to be given to the organizations that will actually implement the recommended measures. These decisions will play a major role in Phase IV, in which it will be decided which organization will be responsible for the implementation of the various measures. This will include organizations in the private as well as public sectors.

In most cases, it is advised to carry out a stakeholder mapping exercise at the start of a project to determine which stakeholders should be involved. Reference is made to various manuals (e.g., CDI, 2016; World Bank[7]' Schmeer, 1999; ODI[8]) on how to conduct stakeholder mapping and to set-up a stakeholder process. More detail on involving stakeholders is given in Appendix 2. Box 10 offers an example.
Stakeholder involvement is essential in all of the Analysis Framework's steps, as shown in Figure C1.

Box 10 Example stakeholder involvement in ground-water management planning

In 2020, Deltares contributed to the formulation of Aquifer Environmental Management Plans for the city of Santiago de Cali, Colombia (Céspedes et al., 2020). A stakeholder analysis was carried at the start of the project to identify which actors and sectors were involved in the system. This is a tool which allows for a greater understanding of reality, enhances opportunities for action and transforms the environmental context in favor of ecosystems and populations that inhabit them. The following steps were followed during the participatory research process.

1. Review and analysis of secondary information for the identification of actors and sectors.
2. Development of a database of identified sectors and actors.
3. Classification of actors and sectors by category.
4. Characterization of actors by position, power and interest.
5. Elaboration of the map of social actors.
6. Definition of dialogue tools.
7. Days of socialization of the project with the different actors identified.

Stakeholders are depicted as drivers of the planning process (top bar of the chart) as well as the providers of input (right bar of the chart). Stakeholders are also crucial in the decision-making moments of Figure C3, in particular, agreeing on the objectives of the water system's development and management and related evaluation criteria (step I.4) and problem statement (step II.4).

C.3.3 Step I.3 Defining analysis conditions

In addition to the more legal and institutional oriented conditions of section C.3.1, it is necessary to reach an agreement on the analysis conditions for the planning study. This includes:

- The **base year** for the study:
  - The most recent year for which basic data on the present situation is available;
- The **time horizon**(s) for the study:
  - This may include short-term (e.g., 5 years), medium-term (e.g., 20-30 years) and long-term (e.g., 50-100 years);
- The **discount rate** to be applied in the economic analysis:
  - Taken as specified by, for example, the Ministry of Finance or Economic Affairs, or by the financier of the planned investments (e.g., ADB, World Bank and JICA);
- **System boundaries** of NRS, SES and AIS - the components and the level of detail that will be included:
  - Defining the boundaries of the WRS (e.g., will the coastal zone be included in a river basin study?);
  - Assessing what level of detail should be taken, including what terminology should be used, according to the project objectives and stake-holders involved (e.g., are the results to be presented at local government unit level?);
- **Time periods** based on within- and over-year variability of systems processes and inputs;
- **Scenario assumptions** concerning factors external to the WRS, such as climate change, population growth, food and energy consumption and prices, or demand functions (see also section C.4.2.);
- **System assumptions** concerning factors internal to the WRS, such as the response of crop production to improved cultivation practices, or the effectiveness of price incentives on per capita water consumption. These system assumptions can be subject to additional (sensitivity) analyses; and
- **Data, time and budget constraints**, as studies have to be executed within the limitations of available data, time and budget.

7 http://www1.worldbank.org/publicsector/anticorrupt/PoliticalEconomy/stakeholderanalysis.htm
8 https://www.odi.org/publications/5257-planning-tools-stakeholder-analysis

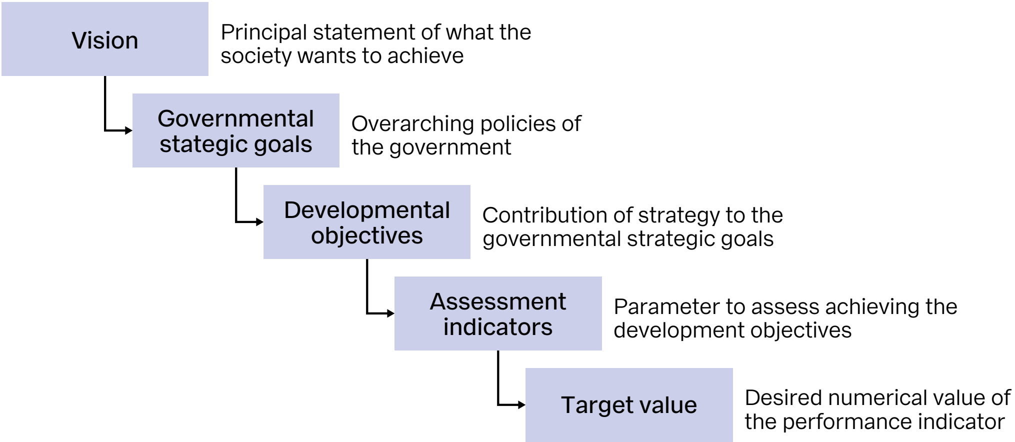


Figure C5 From vision to targets - making development objectives operational

The choice of the **time horizon** is frequently given insufficient attention. Formal planning horizons (e.g., five, ten and twenty-five years) are typically used as time horizons for elements of the analysis. However, one should also consider the time scales of the system and the processes within it. System components will have characteristic time scales. For example:

- Economic activities have life cycles that are usually determined by the amortization period of the investments. Time horizons of planning processes can be based on these conditions.
- Social institutions have time horizons that depend on the pace of legal, institutional and political decision-making.
- Physical–chemical systems have time scales that depend on the response or restoration times of the systems. Restoration of polluted rivers, for example, may be achieved within a few months (depending on their benthal loads), while the restoration of a polluted groundwater aquifer may take decades or even longer.
- Ecosystems may have a time scale of a few weeks (algae blooms) or tens of years (degradation of mangrove forests), depending on the type of process or intervention.

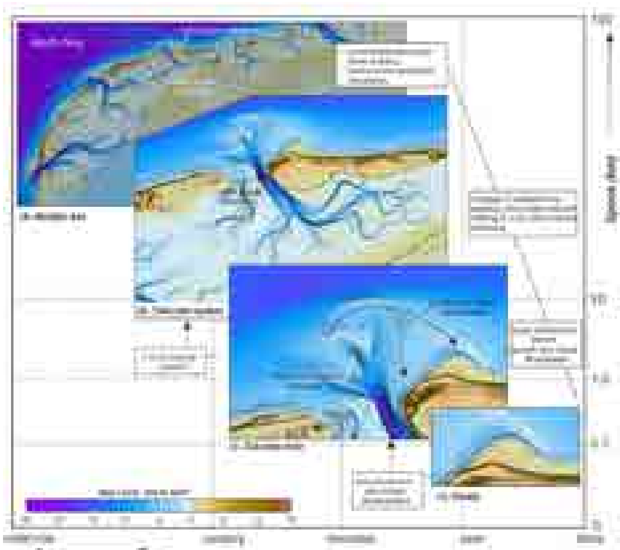
  To appropriately study the sustainability and ecological integrity of the WRS, time horizons should be aligned with the response times of the system rather than the planning horizon of the study. Although more attention is now paid to sustainability, no operational procedure has been generally adopted to properly consider long-term effects in the evaluation process. Decision-makers tend to focus on short-term decisions, even if these create possible risks in the long-term. This is perhaps due to the fact that political time horizons are often limited to (or renewable in) a small number of years, and so aiming for short-term political gains is more advantageous for decision-makers to achieve their own personal goals.

C.3.4 Step I.4 Participatory design of vision, objectives and indicators

An essential activity in the Inception Phase is the translation of general objectives into operational development objectives that can be quantified. Development objectives should be based on higher-level visions and governmental strategic goals, and be made operational by means of assessment indicators and target values, as illustrated in Figure C5.

Box 11 Spatial and time scales of a morphological system

In a system-based approach, space and time are related. The figure shows an example for morphological scales in the Wadden Sea, a tidal lagoon sheltered by barrier islands. The morphological dynamics of the Wadden Sea span hundreds of kilometres and many centuries, while the dynamics of a specific shoal or gully are considered in hundreds of meters and several years. ICZM planning must consider the large scale and long time horizon and address only the relevant local and short time scale developments.



National and regional development objectives
An essential component of an integrated plan is the connection of the plan and its objective to national development goals, as well as to common international goals (e.g., the SDGs). The plan should refer to national policy priorities and indicate how it will contribute to the achievement of set goals and targets. In addition to national policy documents, any existing regional or provincial policy documents need to be considered. Each WRS plan needs to have an agreed-upon objective that not only states the plan's main purpose, but also expresses its relation with national and other sectoral plans and reflects the contribution that the WRS can make in realizing them.

Development objectives, assessment indicators and targets
When translating general objectives to operational objectives, this should be done by specifying them in socio-economic terms which are meaningful to the decision-makers and stakeholders. Assessment indicators should be used to measure the extent to which each objective has been achieved and clear targets should be specified. Monitoring after implementation will indicate whether the project is successful and whether it is effective in the long-term. This process is outlined in Figure C6 and illustrated for a river basin case in Box 12.

General national/regional objectives
(e.g. food security)

↓

Development objectives
(e.g. achieve self-sufficiency in rice)

↓

Assessment indicator
(e.g. self-sufficiency index in %)

↓

Target
(e.g. 100 %)

↓

Monitoring indicator (present situation)
(e.g. 80 %)

Figure C6 Making objectives operational

Having stakeholders, decision-makers and project planners agree on the development objectives and assessment indicators is important for the design of the next phases of the analysis. However, when carrying out the next phases new information may become available. This might lead to an adjustment of the objectives and indicators.

The assessment indicators need to be comprehensive (i.e., sufficiently indicative of the degree to which each objective has been achieved) and measurable. The indicators do not all have to be expressed in a single measurement scale. Indicators can be expressed in monetary and non-monetary terms.

It may be useful to incorporate sustainability as an objective, and if so, this could be related to the SDGs, be it their targets or their monitoring indicators.

The assessment indicators can also be expressed as the levels of service which will be provided by the WRS. This is particularly relevant to Phase IV in which the recommended measures and projects will be prepared for implementation. To get approval for implementation, decision-makers need to know what kind of 'service' they will receive from their investment, e.g., what benefits people will gain from being connected to

Box 12 Objectives and assesment indicators for an illustrative river basin case

Table C2 in section C.5.3 will present a scorecard that summarizes results of an analysis for a river basin case. The results of the study's Inception Phase (i.e., the objectives and indicators) are provided in the first two columns of the table. In this case, there were five overall objectives. For each objective, 2 or 3 assessment indicators were identified which expressed in how far the objective is or will be achieved:

- Objective 1: Provide safe water and sanitation for the people:
  - % people access to safe drinking water;
  - % people access to sanitation facilities;
- Objective 2: Increase food production:
  - Irrigation area (ha);
  - Number of animal water points (#);
- Objective 3: Support economic sectors - industry and energy:
  - Water supplied to mining (% of demand);
  - Water supplied to industry (% of demand);
  - Hydropower generated (MWh);
- Objective 4: Protect the environment:
  - Protected watershed area (km²);
  - Number of springs/sources protected (#);
  - Average class of water quality in rivers (class A to D);
- Objective 5: Decrease risk to floods and droughts:
  - Risk to floods - average damage ($/yr);
  - Risk to droughts - average damage ($/yr).
- In addition, two implementation-related indicators were formulated to assess the case's strategies:
  - Required investments ($);
  - Benefit/Costs ratio of economic categories (</>).

piped water supply or what percentage of a population will be protected from flooding. Undertaking Phase IV will be easier if these ‘service levels’ are considered when determining the assessment indicators to be used in the analysis.

In some cases, the severity and urgency of existing and potential issues might be such that fundamental changes (a paradigm shift) are needed in how the water systems are managed in order to solve these issues.
In these cases, it might be recommended (and sometimes requested by authorities or donors) to develop a Theory of Change (TOC). See Box 13.

Box 13 Developing a ‘Theory of Change’ for achieving a paradigm shift

The Theory of Change (ToC) is a methodology for planning, participation, and evaluation that is used to promote social change. A ToC explains the process of change by outlining causal linkages in an initiative, e.g., its shorter-term, intermediate, and longer-term outcomes. The identified changes are mapped – the “outcomes pathway” – showing the logical relationships between outcomes, as well as chronological flow and feedback loops. The innovation of ToC lies i) in making the distinction between desired and actual outcomes, and ii) in requiring stakeholders to model their desired outcomes before they decide on forms of intervention to achieve those outcomes. An important element of a ToC is also the identification of barriers and risks.

C.3.5 Step I.5 Inception report with work plan and decision-making

Once it is clear what will and will not be analyzed and the reasons for these choices, analysts can specify how this will be undertaken. This includes confirming the conditions and the assumptions under which the analysis will be performed.

All required activities should be combined in a work plan. It is usually advantageous to develop a critical path network of the various analysis tasks. Critical path networks define the sequence of the different tasks which are required to complete an analysis, or indeed the entire planning project, and their planned start and finish times. This will guide the allocation of personnel and other resources and identify the time needed to perform such projects. These networks can be updated as the project proceeds. Such networks are useful for scheduling activities and personnel involved in the project, and for ensuring (or at least increasing the probability) that data and personnel will be available for each task activity when needed. They can also be useful in assessing when decision-makers and stakeholders should be involved in analyses, workshops or meetings.

Data availability
An important boundary condition for studies is the availability of data and other information required for the study. The availability of data determines the level of detail and accuracy that can be achieved in the analysis. If few data are available, a more qualitative analysis may have to be performed. The required level of detail will primarily depend on the problems to be addressed and the objectives to be satisfied.

Level of detail
One of the most common causes of project failure is not using the appropriate level of detail. If the needed level of detail is underestimated at the start of the project, the study will have to obtain the additional detail needed later on to fulfill the analyses’ objectives. Sometimes the right level of detail is chosen, but team members may be tempted to spend too much time addressing more detailed questions which are of interest to them and fail to come up with the all of the desired information within the available time. This is can be the case when specific stakeholders involve external experts who purely focus on their own interests and disregard other components of the WRS. When even more detailed data and models on specific subjects are available (e.g., in academia), this high level of detail may not be necessary to address the plan’s objectives and issues. Analyzing this data will then use up resources (time and money) without adding to the quality of the planning. Maintaining the proper level of detail is one of the main reasons for feedback loops in the analysis process.

Computational requirements
The determination of which computational resources are needed for analysis is essential in Phase I, particularly as this will directly affect the work undertaken in Phase II. This includes mathematical models, databases, GIS, etc. Together, they must be used in a way that appropriately describes the system and permits an evaluation of possible measures and strategies under different scenarios at the level of detail desired. A combination of simulation and optimization models has proven useful.

For the purposes of analysis, the study area is typically subdivided over space and time into smaller units considered to be homogeneous with respect to their characteristic parameters. Each unit can be included in mathematical models. The number of elements required for an analysis depends on the issues being addressed, the complexity of the study area, the measures to be studied and the availability of data. It generally is wise to start with a preliminary schematization using the minimum number of elements. If more spatial or temporal detail is required, model elements can be subdivided. The assumptions and conditions under which analyses are undertaken should be specified in close cooperation with the institutions overseeing and contributing to the study.

Work plan
The results of the Inception Phase are documented in an inception report. This report can serve as a reference during the execution of the study. An essential part of the report is the proposed work plan, in which time, budget and human resource allocations to various activities are specified. This work plan typically includes bar charts (possibly derived from critical path analyses) for activities and staffing, time schedules for deliverables, milestones, reporting procedures and similar features. The report should include a communication plan that describes the interactions among decision-makers, stakeholders and the analysis team.

Inception report
An inception report is a specific and concrete result of the Inception Phase. It should make clear what will be studied, why and how. In many cases, it will also specify what aspects of the system will not be studied and why. It should also highlight which decisions were made and describe any findings. The inception report is an important product because it contains all that has been learned during Phase I and that acts as a record of all that has been agreed upon between the analyst and the client.

Analyst-client interaction
Perhaps one of the most important outcomes of the Inception Phase is the interaction between the analyst and client. By the end of Phase I, the analyst should fully understand the client's concerns, problems and objectives. Clients should feel as though they 'own' the results of the Inception Phase and view the inception report as their own product, not merely a report of the planners, analysts, or consultants. To achieve such ownership, frequent interaction must have taken place among the analysts, decision-makers, and stakeholders, to a much greater extent than is indicated in Figure C1. This communication can take place in specific workshops, such as those devoted to the problem statement or to the specification of objectives and assessment indicators, or in frequent formal and/or informal meetings.

C.4 Phase II - Situation Analysis

In the Situation Analysis phase, the study gains a deeper insight of the WRS. It is steered and confined by the context and boundaries set in Phase I. Its various components will be studied in detail, data will be collected and, where necessary and possible, the system components will be modeled. Ideally, Phase II should be undertaken in close collaboration with stakeholders to ensure that analysts and stakeholders have the same understanding of the system. Once these models are available, a structured analysis can be carried out to quantify the present and future problems and a start can be made with identifying measures to address these problems. Phase II is for joined fact-finding and is neutral. 'Negotiations' start in Phase III.

in Figure C7 presents the steps which should be followed in Phase II. These steps are described in the following sections:

- Step II.1: Understanding the Water Resources System (section C.4.1)
- Step II.2: Defining the external scenarios (section C.4.2)

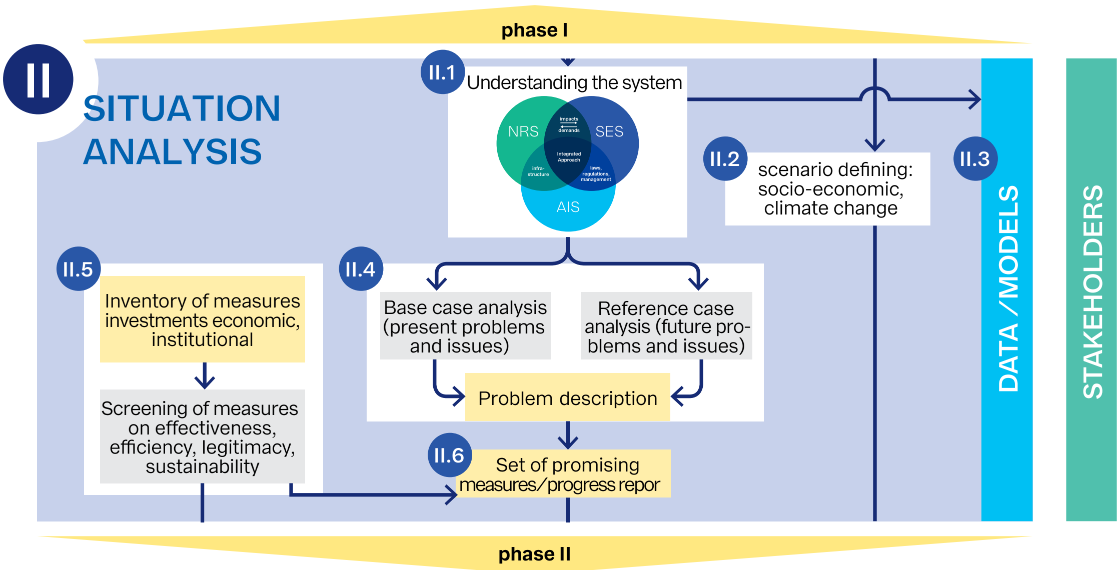


Figure C7 Call-out of the Situation Analysis Phase

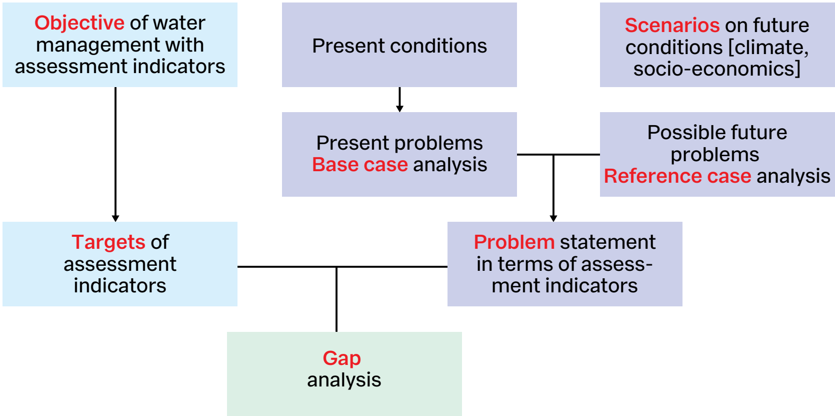


Figure C8 Terminology used in the analysis process

- Step II.3: Collecting data and developing models (section C.4.2)
- Step II.4: Carrying out a quantified problem analysis (section C.4.4)
- Step II.5: Undertaking inventory and screening of measures leading to a set of no-regret and promising measures (section C.4.5)

This phase is concluded with decision-making on the next phase, written in a progress report (section C.4.6) which needs to be discussed with stakeholders.

Decision-making on measures and strategies to improve the performance of the WRS should be based on quantified information about the present problems (e.g., average flood damage), the impacts of proposed measures (e.g., the reduction in flood damage) and the costs of these measures. The analysis process starts with a quantified problem description. The analysis of the present situation is called the base case analysis. To be able to predict possible future problems, scenarios should be defined on how the future might develop. The computational framework will calculate the impacts (the future problems) of these possible external developments. This is called the reference case analysis. The analysis steps and terminology are demonstrated in Figure C8. While the objectives and related assessment indicators were determined in Phase I (Step I.4), these may be reconsidered or made more specific during Phase II as a deeper understanding of the WRS emerges.

Base case

The base case investigates the performance of the WRS according to available infrastructure and current water demands. The base case is based on the base year, which is usually the most recent year for which a complete set of data are available[9]. Thus, the base case exemplifies the performance of the WRS in the present situation. A comparison of the base case with the assessment indicators (and possible targets) specified in the project's objectives will result in a quantified problem statement for the present situation.

Scenario conditions

A good plan should also address the expected water-related problems in the future. The analysis for the future time horizon(s) should include different scenario conditions. The usual scenario conditions for WRM are socio-economic developments (e.g., change in demand and pollution) and climate change (including sea level rise). Depending on the particular case study scenario, conditions might be considered for soil subsidence and autonomous long-term morphological changes (e.g., along coasts, rivers). See step II.2 for more information about developing scenarios.

Reference case

The reference case addresses the future situation by considering the present infrastructure and current water demands together with selected scenario conditions. The reference case analysis may also include institutional data on the WRS, such as what will happen if present policies and regulations are continued and followed by the government and water users.

Problem description – present and future

The problem description should be carried out based on the results obtained from the base and reference case analyses in combination with the problems and issues perceived by decision-makers and stakeholders. As far as possible, the problem analysis should be expressed in terms of the socio-economic and environmental impacts that have a meaning to the decision-makers and stakeholders. An integrated approach is crucial for a solid understanding of the system and its associated problems. This can only be achieved if the plan clearly defines the main problems and issues within the basin and its inter-linkages. Subsequently, it is important that the plan is aligned

9 In cases where the 'present situation' is disputed (e.g., in transboundary conflicts) it may be necessary to define the base case as the situation further back in time or use two base cases, each representing the different views of the disputing actors.

with, as applicable, other related plans such as Watershed Plans (erosion), IFRM, ICZM, IUWM, etc.

Gap analysis
In the gap analysis, the problems, as described in terms of the assessment indicators, are compared with the study's targets. The resulting 'gap' is the challenge that needs to be addressed when formulating interventions in the system.

C.4.1 Step II.1 Understanding and describing the Water Resources System

As explained in section B.1, a WRS comprises the Natural Resources System (NRS), the Socio-Economic System (SES); and the Administrative and Institutional System (AIS). Each of the three systems is embedded within its own environment. The NRS is bounded by climate and (geo)physical conditions. SES is formed by the demographic, social and economic conditions of the surrounding economies. The AIS is shaped by the constitutional, legal and political system and its procedures.

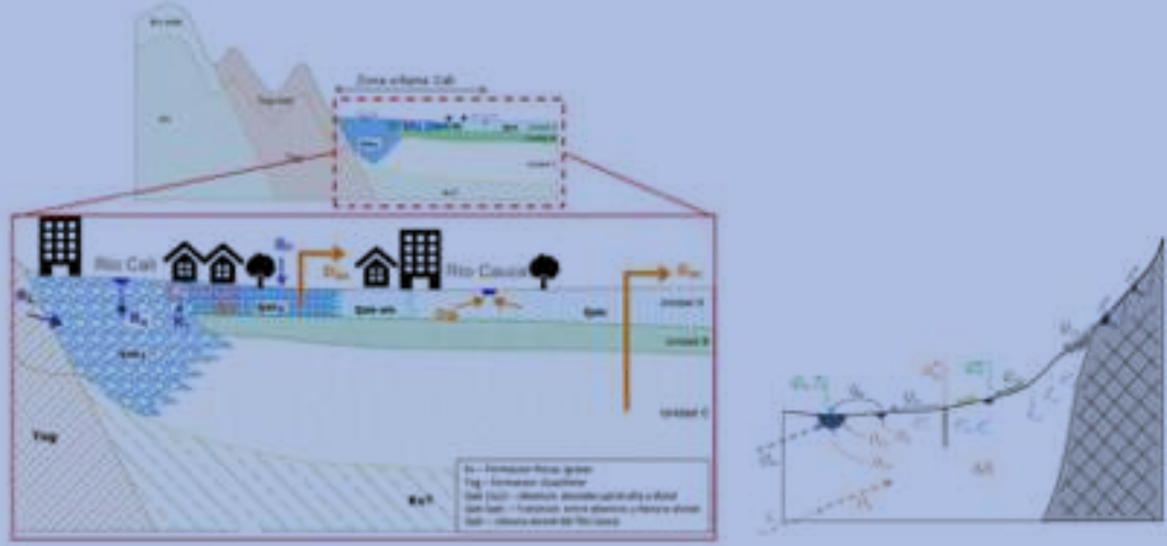
It is important that the plan includes a comprehensive description of all of the integrated elements of the WRS. Most decision-makers and stakeholders will be non-technical or only have knowledge about a limited part of the system. To be able to make balanced decisions, everyone involved should understand how the overall system functions and how interventions in one part of the system will impact other system elements.

The components and processes which are to be considered should have been selected in the Inception Phase. The situational analysis starts with an inventory of the characteristics of the WRS. This requires the reduction of a complex reality into a simplified, comprehensible description of system components and linkages. Choices have to be made about what should be included and what can be ignored, including deciding on what level of detail is necessary for the analysis. Such choices require engineering and economic judgments in combination with an understanding of the problems and possible measures that can be taken to improve system performance. The next step will be an inventory of the activities and ongoing developments that will determine how the system will perform in the future and what kind of additional activities can be expected. This can include autonomous developments (such as population and urban growth) or policy decisions that have been or may be taken which could influence the WRS' characteristics and performance. An inventory of policies and institutions is helpful for identifying who is involved in the management and development of the system (and hence who should be included in the analyses) and their own objectives and opinions. This knowledge will contribute to the development of scenarios for the analyses.

Analysis of the Natural Resources System
The NRS comprises the natural and engineered infrastructure, including hydro-meteorological boundary conditions. Models can be used to simulate the processes of water distribution as influenced by the infrastructure, taking into account water storage and water withdrawals to satisfy the demands of water-using activities. For more information on models that can be used in the analysis, reference is made to Loucks and Van Beek (2017a).

Box 14 Example water resources system study

In 2020, Deltares contributed to the formulation of Aquifer Environmental Management Plans for the city of Santiago de Cali, Colombia (Céspedes et al., 2020). The underground WRS was made visible by using a conceptual hydrogeological model of the Santiago de Cali aquifer. First, the geology of the municipality of Santiago de Cali was mapped in order to find the hydrogeological units of Valle del Cauca, the wider provincial region in which Santiago de Cali is located. Santiago de Cali's hydrogeological units were mapped in a high level of detail, because of the area's socio-economic values. After mapping the hydrogeological units, the groundwater catchments could be pinpointed. By investigating the annual groundwater recharge, groundwater flow systems and groundwater consumption in Santiago de Cali, an underground water balance could be made. The hydrogeochemical characteristics of the system were determined by the analysis of quality indicators relating to pollution in monitoring wells.



Left: Schematic cross-section of the geometry of the hydrogeological units in Santiago de Cali. Right: Diagram of the eastern side of Valle del Cauca with the components of the water balances of the aquifer, Cauca river or tributary rivers.
Source: Céspedes et al. (2020).

The results of the water quantity modeling may be the inputs for water quality models. The analysis of chemical components in the water system can then be used to study the influence which these chemicals have on user functions or the biological system.
The analysis of the biological system aims to assess the response of the ecosystem to water resources management. As there is often a lack of exact information on individual biotic components and their behavior under different hydrologic and chemical regimes, models of ecosystems typically depend on habitat parameters. Box 14 shows an example of a water resources system study in Santiago de Cali that was performed in 2020.

Analysis of the Socio-Economic System
Developments in the SES greatly influence the way in which demands on the NRS may change. Conversely, the development of economic activities within the study area may depend on the availability of water. For example, good supplies of relatively cheap surface water may stimulate the development of irrigated agriculture or attract industrial activities which require high quantities of water for their production processes. Another example is the development of water-based recreation activities adjacent to a reservoir. In turn, these SES developments will increase the demand on water. Economists and planners may be able to estimate future levels of activities based on water discharges and storage levels. These relations can be incorporated into water resource planning models.

The starting point for an analysis of the SES is an assessment of the present economic situation with respect to its water-related activities and the factors that influence these activities. Past trends can help provide information on factors that have been decisive in bringing about the present situation and may give clues about the likely impacts of future developments. Attention should be brought to the most important factors that determine relevant water-related activities rather than on analyses of the total economy. However, the difficulty in forecasting economic development is that there is uncertainty about which factors will play a large role in this development.

In studying the SES, it is recommended to consider the full value chain of economic activities and the value that water has in that chain. This will also provide information about the Willingness to Pay[10] of the economic activities for the services (to be) provided by the water resource system and the desired service level.

Data on the economic activities and their water uses in the SES will be needed to develop accurate planning models. Data are needed to identify the following with respect to each identified activity:

- the amounts of water (quantity and quality) demanded and consumed during periods of the year and in which locations.
- the amounts of water discharged and their pollutant loads during periods of the year and in which locations.
- the benefits to the user if these amounts are made available.
- the damage to the user if these amounts are not available.
- costs that can be recovered by having the user pay for the water and its influence (both at the intake and the discharge sites of the activity) on the water use pattern.

All these data should be able to contribute to the estimates of future water demands, consumption and wastewater discharges per unit of activity. As well as the level of activities and the resulting water demands, knowledge of the geographical location of water-using activities (the pattern of activities) is necessary. If the pattern of activities is not expected to change, the analysis can be focused on the present situation in the study area. If new activities are expected to develop within the study area and their water use characteristics are unknown, it may be necessary to study the water use characteristics of similar activities in other regions.

Water demand data need not always be considered as reflective of the entire truth. Water use coefficients can be changed through measures such as water pricing that aim to reach a socially preferred use pattern. Technological developments may result in less water use and pollutant load per person or unit of product. If supplies and demands are matched before the effects of such incentives are analyzed, needed capacities may be overestimated. Demands may be lower if water users are confronted with the costs as well as the benefits of water use. This type of internal feedback should be considered in the study.

Future water demands are dependent on future scenarios. A water demand scenario includes a logical but assumed combination of basic SES parameters and their effects on water-related activities, including the resulting water demands. An understanding of the SES' functioning developed through the assessment of past and present trends is helpful when formulating a limited number of consistent scenarios. Box 15 is an example of one such scenario.

Box 15 Example demand scenario

The water demand in an agricultural area depends largely on the availability of land, a suitable temperature, and the type of crops being irrigated. The demand for agricultural products, however, will develop in an autonomous way. If the availability of water resources in a region is limited then the autonomous development of the agricultural sector will also be limited., It would not be surprising to see a small increase in agricultural water demand in this situation. If the demand for agricultural products increases considerably and self-sufficiency in food production is an objective, then the political pressure for agricultural development to meet this objective may be considerable. The water demand corresponding to this desired agricultural development could lead to the need for further development of the water resources in the region.

Analysis of the Administrative and Institutional System
An analysis of the AIS is required to identify any legal, regulatory or institutional constraints on water resources management. Attention must be given to the interaction between the various authorities involved in water resources management and to the effectiveness of the AIS. Arrangements made in the past concerning the use of water (particularly water rights and allocations of water) should be identified, since these may significantly constrain the options for water resources development.

Water resources management studies are often limited to the preparation of a specific agency's policies. In this situation, the analysis of the AIS will mainly serve to identify measures that the agency can implement effectively. The responsible agency should be aware of the possible role they may have in solving the management problems. Sometimes, the analysis of the AIS may result in recommendations for institutional and legal changes. In studying the institutional system use can be made of the OECD principles of water governance (see also figure A5) and the OECD Water Governance Indicator Framework (OECD, 2018).

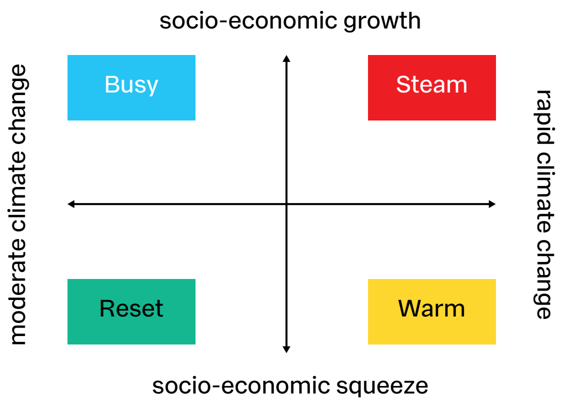
C.4.2 Step II.2 Defining external future scenarios

As defined in section C.1, a scenario is an external development beyond the control of the decision-maker.

10 Willingness To Pay is the maximum price a customer is willing to pay for a product or service

A good plan for development and management should not only address present problems, but should also prepare for problems that might arise in the future. To predict the future, scenario assumptions have to be made. The most usual scenario components for water resources management studies are socio-economic developments (e.g., population growth and economic activities) and climate change (including sea-level rise). For the economic evaluation of a plan, it might be necessary to assume the future prices of energy and food. Changes in diet (e.g., the consumption of more or less meat) can also be important.

Figure C9 Scenario combinations of socio-economic growth and climate change was used in the Delta program is the Netherlands)



The most used combination of scenario elements can be presented in a quadrant of low and high economic growth versus slow and fast climate change. This is illustrated in Figure C9, which was used to define the scenarios in the Delta program. The words 'Reset', 'Busy', 'Steam' and 'Warm' are used to name the scenario combinations. Ideally the analysis should be carried out for all of the scenario combinations, and the selection of which strategy to use should be based on the evaluation of which is best able to cope with all of these possible future developments. In reality most analyses are carried out for the most likely scenario, based on a trend analysis or Business-As-Usual (BAU). The strategy that follows from this is then analyzed in a 'scenario analysis' to test the strategy for its robustness and flexibility in other possible futures. See also section 4.5.2 on adaptive management analysis.

An important activity in scenario development is a spatial planning analysis of expected developments. The expected socio-economic developments have to be translated into changed or changing land use, in particular spatial claims for urban settlements (requiring greater water supply for households, resulting in increased pollution loads, less food production, etc.). Road and rail development plays an important role in expected changes in land-use.

C.4.3 Step II.3 Data and modeling tools

The result of the data collection and modelling activities is a quantitative representation of the WRS at a particular (hopefully appropriate) level of detail. This is called the computational framework. The framework has to be designed to assess the effects of individual measures or combinations of measures, expressed in values of the chosen assessment indicators. If computer programs for running models have to be developed or if existing computer programs have to be adapted in a significant way, a considerable effort may be required to do so which consumes a large part of the available planning budget and time. Careful selection of the phenomena to be represented by the models, aligned with the needs of the project, is important.

During the modeling activity, more information on the study area and the type of measures to be considered may become available. This could lead to changes in model structure. The models should therefore be flexible and adaptable to new information.

Model integration

The various models and components developed for the NRS, SES and AIS describe parts of the total system. Models may produce outputs that are used as inputs for other models. For example, the output of a water quantity model may be the input to a water quality model requiring different spatial and temporal resolutions. Some models may include links to various sub-models and run interactively, others not. Depending on the models and the problem situation, single or multiple linked models may be included within an interactive decision support system. In other cases, a clear description of information flow from one independent model to another may be sufficient.

Figure C10 provides an example in which various simulation models are combined to analyze a river basin under drought conditions. The core of this modeling framework is formed by the 'core models' in the second and third column of the figure. In this models the demand for water is determined, followed by a balancing of supply through water allocation decisions. Data transfer links among these core models are automatic. Other models are linked through file transfer. This applies to the required inputs of macro-economic and hydro-meteorological conditions (generated by scenarios) as well as the side analysis of the sedimentation and water quality in the reservoirs. The last parts of the computational framework are the modules that determine the financial and economic aspects (investments, operation and maintenance, benefit–cost, etc.) and support a multi-criteria analysis.

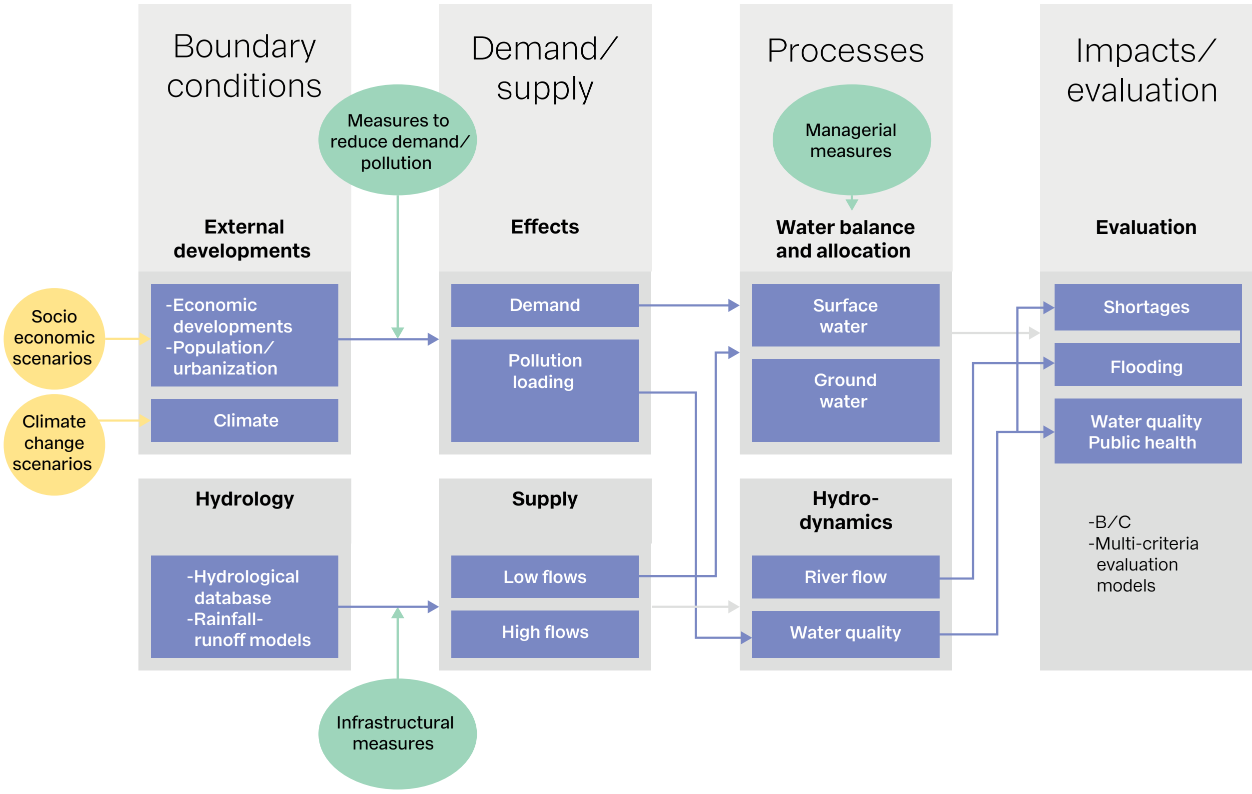


Figure C10 Example of typical computational framework of simulation models

The values of input parameters can be changed in various places within this modeling framework. Various scenarios can be analyzed by changing the socio-economic and hydro-meteorological conditions.

Figure C10 is just an example. Other problem situations may require different modeling frameworks. Box 16 presents another example. Whichever form of modeling framework is used, they should always aim to be as simple and transparent as possible while still adequately addressing the problems to be solved. Sometimes complexity is necessary. In any event, it saves time and money to start as simple as possible and only add more detail if and when necessary.

Developing models for a planning process with stakeholders

Until recently, involving decision-makers and stakeholders in the analysis process has been limited to the more general analysis of problems where quantitative information, such as data from models, was provided by the analysts as input for the discussions. This black-box approach is being increasingly rejected by stakeholders. They want to understand what went into the model, why these inputs were chosen, how the models work and, preferably, they want to 'play' with the models themselves. This is a promising development as it increases the stakeholders' under standing of how the system works and allows them to visualize and explore the opportunities and constraints of that system. Involving stakeholders in the development and running of models requires that these models are more accessible and intuitive, especially their input/output interfaces. It also requires the modelers to have a different, more collective attitude. This collaborative modeling approach is elaborated on in Appendix 3. It includes the development of different kinds of models (such as meta-models), different ways of interacting with the models and accessibly presenting the models' results by means of dashboards.

C.4.4 Step II.4 Quantified problem analysis

In the Inception Phase, the objective (what is to be achieved) and indicators (how success is going to be measured) were defined.

The problem statement should give an overview of the 'scores' of the indicators for typically 3 situations:

- The present situation (the base case)
- The future situations (the reference case – possibly for several scenarios)
- The desired situation (the targets)

Box 16 Integrated impact assessment metamodel for the Vietnam Mekong Delta

The growth of the agricultural sector in the Vietnam Mekong Delta (VMD) has been attributed to the development of water management infrastructure. From a regional perspective, the dike development strategy has successfully improved total rice production by reducing levels of flooding throughout the year. However, at the household level, this strategy has worsened inequality as constantly producing rice overexploits and degrades the soil, therefore requiring smaller farmers to apply more fertilizer to achieve the same level of productivity. This shows how focusing on short-term economic benefits could backfire by hindering long-term sustainability and aggravating inequalities.

Agriculture adaptation planning in the VMD is a complex problem involving many variables: risks of annual flooding, trade-offs between flood safety, natural sedimentation and nutrient replenishment, dilemmas of artificial fertilizer application, changing land use, cropping schedules, crop type preferences, and national-level food security, to name few. Tackling this problem requires a multisectoral approach. Each variable can, in principle, be considered individually using a separate complex model. However, doing so would be costly especially when a large number of uncertainties and policies should be taken into account during the planning process.

Collaborative modelling approaches can be useful to tackle such problems where competing issues need to be prioritized and different types of knowledge need to be integrated. Together with local partners, Deltares began by understanding the key objectives and system indicators to be analyzed. Consultation sessions were arranged with representatives from all levels (national, provincial, district, and commune governments) to understand concerns from the different levels. These sessions helped to identify data availability and gaps, so that the data collection and analysis process did not start from scratch. Most importantly, Deltares learned the social and behavioral side of the system (e.g., how do farmers make decisions?) from local officials, which is very context specific and cannot be simply extrapolated from other studies. All the understanding gained was then reconfirmed and refined with the farmers who were really making decisions and adapting to change on-the-ground. As a result, Deltares developed an integrated impact assessment metamodel that focused more on the social, economics, and behavioral side of the system, while still including the biophysical phenomena by simplifying existing crop yield, hydrodynamic, and sedimentation models.

C.4.4 Step II.4 Quantified problem analysis

In the Inception Phase, the objective (what is to be achieved) and indicators (how success is going to be measured) were defined. The problem statement should give an overview of the 'scores' of the indicators for typically 3 situations:

- The present situation (the base case)
- The future situations (the reference case – possibly for several scenarios)
- The desired situation (the targets)

The presentation of these situations is usually done using a score card. The use of score cards will be explained in Section C.5.3. The problem statement is reflected in the first five columns of the score card presented in Table C2 .

A problem analysis should address and be expressed in terms of the socio-economic and environmental/ ecosystem impacts that are of interest to decision-makers. It is important to use this integrated approach as not all stakeholders may be able to relate to predicted changes in flows, water levels or pollutant concentrations. Some may want to know how much money is involved, the rate of shoreline erosion, the relative change in fish population, or the number of people affected by flooding. Expressing outcomes in terms of socio-economic impacts makes it easier to determine how particular actions or measures impact the (socio-economic) development objectives that decision-makers have formulated for the particular region or system under consideration.

A successful problem analysis will also provide good indications of the measures that can be taken to eliminate, reduce or alleviate the identified problems or to take advantage of new beneficial opportunities. Such information not only helps to clarify the problems and evaluate possible solutions, but also helps in the design of the computational framework

and data collection activities. These activities should be designed in such a way that the measures can be evaluated in the analysis phases of the study.

Barriers and opportunities

In addition to the quantified problem statement as presented above, an overview needs to be given of the barriers that (might) prevent achieving the objectives. These barriers can be:

- Enabling conditions barriers (see Figure B4).
- Financial barriers (financial viability of investments, markets, etc.);
- Environmental barriers (physical, geographical, etc.); or
- Societal barriers (awareness, social norms, political influences, etc.).

Opportunities should be identified to overcome each of these barriers.

C.4.5 Step II.5 Identification and screening of potential measures

Once present and future problems are known, measures (including 'no regrets' that can immediately be implemented) can be identified that will address these problems. An inventory should be made of all the measures that stakeholders are proposing or considering. Based on the quantified problem analysis, additional measures might be formulated. The computational framework can be used to determine the impacts of these measures. The most promising measures are then taken forward for more detailed analysis in the next phase: Strategy Building.

Measures can be divided into different categories: technical (investment), managerial, economic, ecological and institutional. An inventory of all the possible actions that can be taken may result in hundreds of discrete possibilities. In most cases it will not be practicable to analyze all of them in detail. A screening process is needed to select those which are most promising.

This process can be undertaken in several ways, for instance by using the modeling framework developed for the project but limiting the analysis to a few assessment indicators such as economic or environmental impacts. Another kind of screening analysis is to apply expert judgment to effectiveness, efficiency, legitimacy and sustainability.
Box 17 describes these criteria.

Box 17 Criteria for screening

Effectiveness. Measures to be taken are those which solve the most serious problems and have the highest positive impact on the objectives. Measures to prevent problems will be preferred to those that solve them. Similarly, measures that solve problems will be preferred to those that only control them.

Efficiency. Measures to be taken should not meet the explicit objectives at the expense of other implicit objectives. The cost-benefit analysis (at the national level) is one indicator of efficiency. An example is to create a law that makes industrial firms incur the full cost of end-of-pipe wastewater treatment.

Legitimacy. Measures to be included in the strategy should not rely on uncertain legal/institutional changes. Measures should also be as fair and inclusive as is feasible, thus reducing public opposition so that they will be favored by as many stakeholders as possible.**Sustainability.** Measures to be taken are those that improve (or at least do not degrade) the present environmental and socio-economic conditions for future generations.

Services	Gray infrastructure components	Examples of green infrastructure components and their function
Water supply and sanitation	Reservoirs, treatment plants, pipe network	**Watersheds:** Improve source water quality and thereby reduce treatment requirements **Wetlands:** Filter wastewater effluent and thereby reduce wastewater treatment requirements
Hydropower	Reservoirs and power plants	**Watersheds:** Reduce sediment inflows and extend life of reservoirs and power plants
Coastal flood protection	Embankments, groynes, sluice gates	**Mangrove forests:** Decrease wave energy and storm surges and thereby reduce embankment requirements
Urban flood management	Storm drains, pumps, outfalls	**Urban flood retention areas:** Store stormwater and thereby reduce drain and pump requirements
River flood management	Embankments, sluice gates, pump stations	**River floodplains:** Store flood waters and thereby reduce embankment requirements
Agriculture irrigation and drainage	Barrages/dams, irrigation and drainage canals	**Agricultural soils:** Increase soil water storage capacity and reduce irrigation requirements

Table C1 How Green and Gray Infrastructure can work together • Source Browder et all (2019)

The aim of the screening process is to identify the measures which should be analyzed further. The screening of measures is a cyclic process. Assessing the measures will contribute to a better understanding of their effectiveness and new ones may be identified in the process (comprehension loop). Combinations of measures may be considered for specific parts of the WRS, for instance for solving water quality issues in a sub-basin. The result of the screening process is a set of promising measures that can be used for strategy design.

Nature-based and hybrid solutions
Nature-based Solutions (NBS) are a type of measure which should be considered when undergoing screening processes. In the last decades, awareness has grown of the role that ecosystems and/or green infrastructure can have in achieving water security. Accordingly, an alternative "Nature-based" or "Building-with-Nature" engineering approach has emerged. This approach is understood as the enriching of the traditional infrastructure planning process with green and hybrid (green and gray) solutions along with traditional gray infrastructure.

Green infrastructure is defined by the World Bank (2019) as infrastructure that intently and strategically preserves, enhances, or restores elements of a natural system to help produce higher-quality, more resilient and lower-cost infrastructure services. Green infrastructures are multi-functional and adaptive, making them a promising and robust long-term solution.

Due to their characteristics, they can contribute to climate adaptation as well as to climate mitigation. Table C1 presents examples of hybrid water security measures.

Identification of no-regrets measures
A special category of promising measures are the 'no-regrets', although more realistically measures are going to be 'likely no-regrets' and 'low-regrets'. These are measures where there is a very large amount of agreement between decision-makers and stakeholders that they should be implemented, preferably as soon as possible. It should be ascertained that these measures will not have negative impacts on other measures or will not prevent other possible promising measures from being implemented. It is beneficial to identify and define possible no-regret measures in the planning process, as in some situations there is considerable political pressure and/or immediate need to implement measures before other large integrated studies have been completed. Particularly in developing countries there is a need for the implementation of no-regret measures. These measures can proceed immediately to Phase IV on Preparation for Implementation.

C.4.6 Step II.5 Progress report

The Situation Analysis phase should be concluded with drafting a progress report which will be discussed with decision-makers and stakeholders. The progress report should give a clear description of:

- the water resource system, including a breakdown of the relevant components of the NRS, SES and AIS
- the elements that will be addressed in the analysis, the data which will be used and the modeling approach;
- the scenarios that will be considered in the analysis;
- the present and expected future problems and opportunities; and

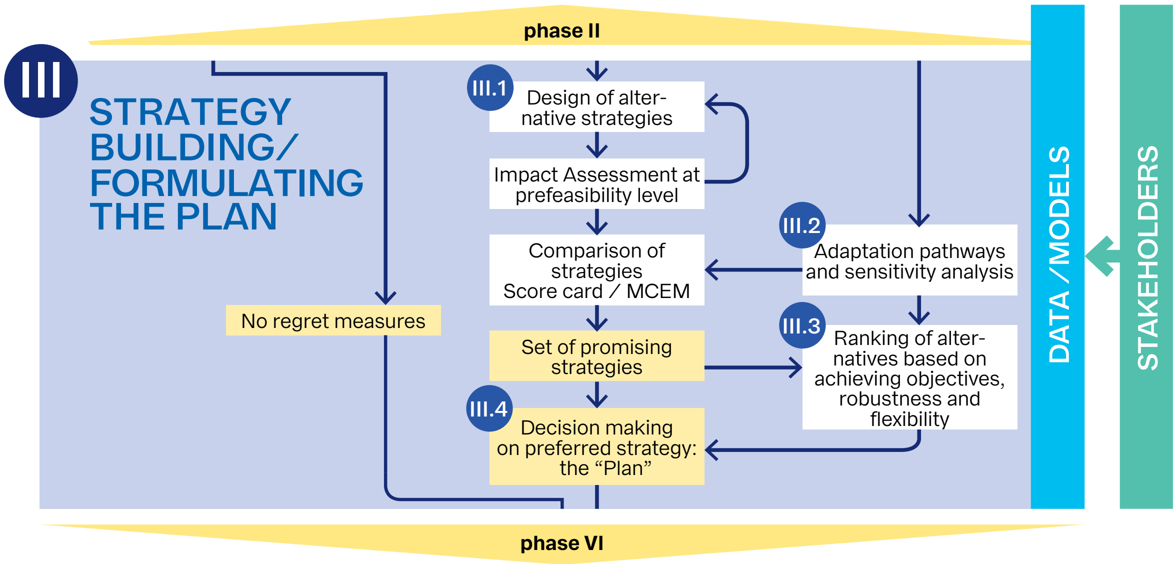


Figure C11 Call-out of the Strategy Building Phase

- the measures that will be considered in the analysis (non-regret and promising).

It is of utmost importance that all stakeholders agree on the content of the progress report as this will be the basis for the next phases.

C.5 Phase III – Strategy Building / Formulating The Plan

In the Strategy Building phase, promising measures are combined into strategies. The effects of various strategies are assessed, and from this a limited set of auspicious strategies is defined and their effects are assessed in more detail. The sensitivity of these effects to the values assigned to the uncertain model parameters is then evaluated. Finally, the results of the selected strategies should be presented to decision-makers.
Figure C11 presents the steps which should be followed in Phase III. These steps are described in the next sections:

- Step III.1: Strategy Design and Impact Assessment (section C.5.1)
- Step III.2: Adaptive management analysis (section C.5.2)
- Step III.3: Ranking of alternatives and selection of strategy to implement (section C.5.3)

The ultimate result of this phase will be the 'Water Resources Plan'. Depending on the subject of the water resources analysis, this can be a national or regional plan or a river basin plan. This plan should be a formal document accepted by decision-makers as the base for implementation and related financial arrangements. Implementation funding and financing will be addressed in phases IV and V. The plan will be referred to in Step III-4: Water Resources plan (section (C.5.4).

C.5.1 Step III.1 Strategy Design and Impact Assessment

Strategy design involves the development of coherent combinations of promising measures which satisfy the management objectives and meet the management targets. As there are generally several assessment indicators related to these objectives, and many are probably expressed in different units, strategy design is not a simple process. Relations among combinations of measures and their scores on the assessment indicators are complex. The optimum combination may depend on who is asked. Trade-offs among the values of different indicators, and disagreements among various stakeholders, are inevitable.

Designing strategies is an iterative process. The process can start by developing strategies based on a single objective, such as increasing the reliability of food and energy production or maximum net economic benefits. These strategies define the boundaries of the solution space. Comparison of the impacts of these strategies can lead to the construction of compromise strategies by changing various elements. A resulting loss with respect to one criterion is then compared with gains in another.

Evaluation of alternative strategies
Strategies can be compared based on their assessment indicators values or scores. To facilitate the comparison, the number of assessment indicators should be limited. Assessment indicators have to be comprehensive (sufficiently indicative of the degree to which the objective is met) and measurable, i.e., it should be possible to assign a value on a relevant measurement scale. Where possible, assessment indicators should be aggregated; for example, some financial indicators might be processed into a single

value. The evaluation of the strategies and the included measures is done at the pre-feasibility level. A more detailed evaluation at feasibility level will be undertaken during implementation in phases IV and V.

It is usually impossible to express all of the assessment indicators in a single measurement scale, such as a monetary value. For example, assessment indicators related to environmental quality, ecosystem vitality, or the beauty of a scenic view can be expressed quantitatively but in non-monetary terms. Whichever measurement scale(s) is used, it should always be designed in such a way that a ranking is possible based on the chosen assessment indicators.

Generally, there will not be a single strategy that is superior to all others and which meets all of the indicators used in the assessment. That means that an evaluation method is required for the ranking of alternative strategies.

Scenario and sensitivity analysis

Before drawing conclusions from planning projects involving uncertain information, and indeed predictions of possible futures, the effects of changes in the uncertain assumptions should be incorporated within analyses to gain an accurate picture of how the future may unfold. If a different scenario significantly changes the attractiveness and effectiveness of a selected strategy, then additional study may be required to reduce the uncertainties in that scenario. The sensitivity of the results to changes in model parameter values and assumptions should be determined and addressed in a similar way.

C.5.2 Step III.2 Dealing with uncertainty - adaptive management analysis

The analysis approach described in the previous section is based on the assumption that it is known what will happen in future. Predictions are made on how population growth, economic growth, spatial developments (e.g., urbanization) and climate change will take place. Some of these developments are quite certain, for example population growth where reasonably accurate projections can be made. Other developments are much more uncertain, such as economic growth and climate change. While it is important to be prepared for a range of future conditions, addressing a large number of uncertainties without a systematic method runs the risk that huge infrastructural investments are made which later appear to have been overdesigned or even unnecessary.
The best way to deal with future uncertainty in the planning process is to follow an adaptive management approach. An adaptive management approach replaces the traditional approach of master planning for the basin. This is illustrated in Figure A4.

Adaptive pathways

The ultimate challenge in water management is to make better informed decisions under future uncertainties. Methods are available to ensure that the decision-making process results in consistent, replicable, and accessible outcomes. The CRIDA (Climate Risk Informed Decision Analysis) approach might be employed to prepare such informed decisions (UNESCO-ICIWaRM, 2018)[11]. CRIDA is an approach that implements decision scaling and bottom-up vulnerability approaches through collaborative stepwise planning procedures and adaptive pathways. The CRIDA approach includes the Decision Tree Framework and Dynamic Adaptation Policy Pathways.

The Decision Tree Framework (Ray and Brown, 2015) is a repeatable process for the evaluation of climate change risks to new development projects. By the end of this process, the project planner will be able to confidently communicate the method in which the vulnerabilities of the project were assessed, and how the adjustments that were made (if any were necessary) improved the project's feasibility and profitability. The framework adopts a bottom-up approach to risk assessment that aims to gain thorough understanding of a project's vulner

abilities to climate change in the context of other non-climate uncertainties (for example, economic, environmental, demographic, or political uncertainties). This helps to identify projects that perform well across a wide range of potential future climate conditions, as opposed to seeking solutions that are optimal for expected conditions but unacceptable in conditions deviating from the expected.

The Dynamic Adaptive Policy Pathways (DAPP) approach identifies tipping points that determine when a certain policy or intervention is no longer acceptable and another intervention is needed.

11 UNESCO and ICIWaRM (2018). Climate Risk Informed Decision Analysis (CRIDA), Collaborative Water Resources for an Uncertain Future.

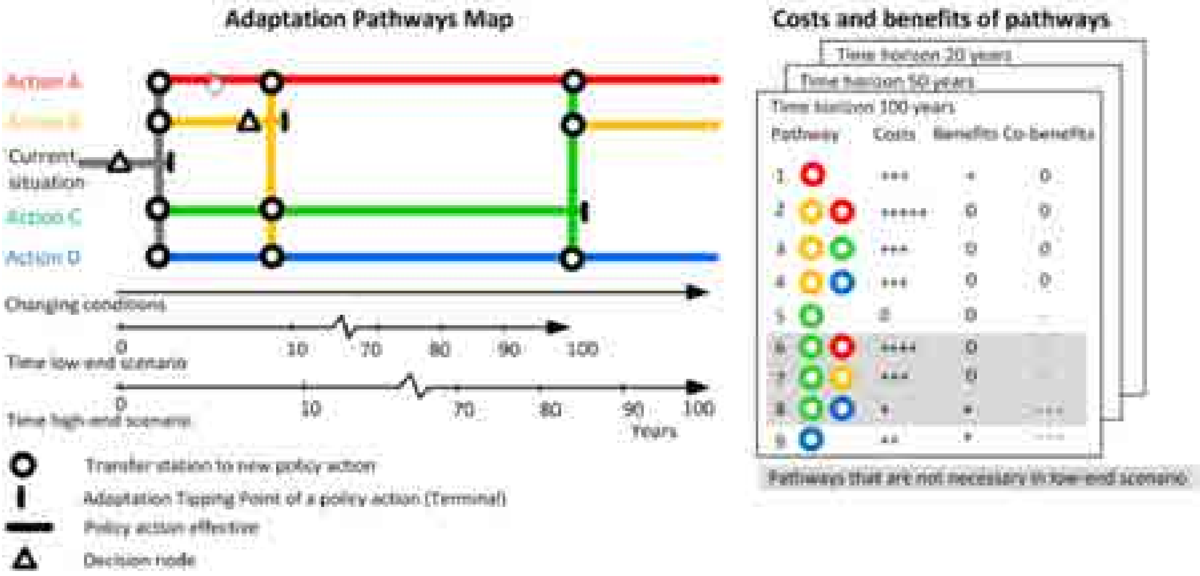


Figure C12 Following an adaptive pathways approach (Haasnoot et al, 2013)

Figure 12 shows that, starting from the current situation, targets begin to be missed after four years: an adaptation tipping point is reached. There are four options available from this point. Actions A and D should be able to achieve the targets for the next 100 years in all scenarios. If Action B is chosen, a tipping point is reached within about five more years; a shift to one of the other three actions (A, C, or D) will then be needed to achieve the targets. If Action C is chosen after the first four years, a shift to Action A, B, or D will be needed after approximately 85 years. The colours in the scorecard refer to the actions: A (red), B (orange), C (green), and D (blue). The point at which the paths start to diverge can be considered as a decision point. Lead times e.g., time for implementation of actions, lie before an adaptation tipping point.

Figure C12 illustrates the DAPP approach. By exploring possible interventions, adaptation pathways can be developed which minimize regret. An adaptive plan distinguishes between actions which can be taken immediately in order to be prepared for the near future and actions which can be taken now that still leave options for future adaptation if necessary. The exploration of adaptation pathways is one of the main features of an adaptive plan. A monitoring system collects information to identify early warning signals (triggers) for implementation of actions or for reassessment of the plan. The left side in Figure C12 gives an overview of possible pathways and the right provides a (very simplified) ‘score-card’ which helps to evaluate the options.

Following an adaptive pathways approach means that two additional assessment indicators should be considered in decision-making:

- **Robustness:** how robust is the existing strategy when the future develops differently than expected? Will the strategy then still achieve the objectives?

- **Flexibility:** how changeable is the strategy when it appears that the future develops differently than expected and will there be a need to change the strategy?

Robustness and flexibility generally have a strong relationship with costs. A robust strategy can be more costly (big reservoirs, high dikes, etc.), although a flexible strategy (e.g., many small reservoirs) can also be expensive over a period of time. These costs need to be considered when deciding on a strategy.

Applying DAPP requires resources in data, time, and expertise. The level of analysis, methods and techniques will depend on the case and actions available. Assessing which type of adaptive pathway approach is most applicable can be determined by answering the following questions:

- Should future uncertainties be included in the analysis?
- Is it beneficial to use the adaptation pathways approach?
- Which economic evaluation method under uncertainty should be used?

These questions are not easy to answer and the methods on how to deal with uncertainty in project evaluation are still developing. The need for these methods is also growing, given the high uncertainty

Objectives and indicators	unit	Base Year 2020	Target 2040	Ref. case no action 2040	Alternative strategies Strategy 1 2040	Strategy 2 2040	Strategy 3 2040
Obj.1: Water and Sanitation							
% people access to safe drinking water	%	50%	73%	63%	65%	67%	73%
% people access to sanitation facilities	%	30%	70%	50%	55%	60%	70%
Obj.2: Food production							
Irrigation area	1000 ha	24	35	26	28	32	35
# animal water points	#	300	900	400	500	700	900
Obj.3: Industry and Energy							
Water supplied to mining	%	30%	90%	40%	50%	60%	90%
Water supplied to industry	%	70%	90%	70%	80%	85%	90%
Hydropower generated	MWh	34	120	34	70	80	120
Obj.4: Environment							
Protected watershed area	km^2	1200	3500	2000	2500	3000	3500
Number of springs/sources protected	#	300	900	400	500	600	850
Average class water quality rivers	I - V	II	IV	II	III	III	IV
Obj.5: Vulnerability							
Vulnerability to floods - average damage	m€/yr	120	< 50	100	100	70	50
Vulnerability to droughts - average damage	m€/yr	200	< 30	160	80	70	30
Implementation information							
Required investments	m€		-		400	700	1200
B/C ratio economic categories (Obj.2, Obj.3)	-		> 1,2		1,3	1,2	1,1

Table C2 Example of a scorecard showing objective values associated with various strategies.

of climate change and the magnitude of the impacts involved. For projects that require huge investments (such as the construction of reservoirs), an adaptive pathway approach is strongly recommended. In particular, these methods are very useful for countries which have advanced management systems and a lot of data. If these are not available, projects should be assessed and prioritized through a multi-criteria assessment that includes assessment indicators such as 'robustness' and 'flexibility'.

C.5.3 Step III.4 Ranking of alternatives and selection of strategy to implement

Presenting the selected promising strategies to decision-makers could be done by means of briefings, presentations, and summary reports. The level of detail and the way in which project results are presented should give a clear and understandable overview of the results at an appropriate level of detail for the audience involved. Visual aids such as score cards and dashboards (interactive computer presentations of study results, see also section 3.2) are helpful for facilitating a discussion about the analysis results.

The results of selected strategies can be presented in matrix form on scorecards. The columns of the scorecard represent the alternative cases used in the analysis. The rows represent the impact of different alternatives with respect to a given criterion. An example is depicted in Table C2. The visualization of scorecards can vary, for instance the scorecard could contain numbers only, or the relative value of the assessment indicators could be expressed by plusses and minuses, or a color-coding could be used. The purpose of a scorecard is to present a visual picture of the relative attractiveness of alternatives based on various assessment indicators. Scorecards can also help to detect clusters of assessment indicators for which alternatives have a consistently better score. The presentation of the results in scorecards allows a decision-maker to give each impact the weight they consider most appropriate.

The scorecard is designed to aid stakeholders and decision-makers when comparing alternative measures or plans. Deciding which is the preferred course of action is not a straightforward process as the various stakeholders and decision-makers involved will have different opinions about what should be prioritized. The ultimate decision is often political and is more intuitive than analytical. Still, the quantified information made available by means of the scorecard can have an influence in such decision-making.

Tools are available that help to 'rank' alternatives. They all depend on assumptions, and assumptions can be disagreed upon. Multi-Criteria Evaluation Methods (MCEM) can be useful in identifying trade-offs among different alternatives based on multiple criteria, but this still leaves the need to determine which alternative is best. An issue of MCEM methods is that the outcome depends on the assumptions made in the selected method. Another issue is that it can be difficult to agree on the weight that should be given to each criterion. Some decision-makers are afraid that they may lose control over the outcome as they do not have a clear understanding of which methods are used and why they are used. For this reason, a negotiated ranking resulting from a joint decision process based on a scorecard is generally the best approach. An MCEM can be integrated in the dashboard (see section 3.3.1) that might be developed to support the evaluation and ranking of alternatives.

C.5.4 Step III.4 Ultimate result: Water System Plan

Phase III finalizes the 'Master Planning' part of the analysis. The results of phases I, II and III and the ultimate result (the chosen strategy) should be stated in a formal document. This document should preferably be authorized by the organizations responsible for the planning process and act as a guidance document for all actors in the field of water resources management. It will be the base document for the next phases: action planning and implementation. The plan should provide a comprehensive picture of the integrated development and management of the water resource system and address all issues at the same time. This can be done at the national level (e.g., a National Water Resources Plan), at the provincial/state level, at the basin level (e.g., a River Basin Plan). or for a specific spatial area (e.g. a coastal zone plan). The thematic plans will focus on their specific theme (e.g. drought, flood, water quality) while taking the interactions with the overall system and the other themes into account. The plan must ensure that individual developments are well coordinated to achieve maximum benefits.

The strategic plan should be accessible to relevant stakeholders. It should be limited to 100 pages and contain a lot of illustrative, visual information (such as infographics). The content of the plan will depend on the specific region or water system, but as a general structure the following is suggested:

1. Introduction (why, how, objectives, participatory approach followed)
2. Description of the WRS (NRS, SES and AIS)
3. The policy context (institutional setting, general goals and policies, legal framework)
4. The analysis carried out (objectives and assessment indicators used, scenarios, problems, measures)
5. Selected strategy (alternatives, adaptive approach, sensitivity analysis)

All technical details can be included in Annexes and separate reports.

While the resulting strategic plan is a major achievement, producing the plan is not a project objective in itself, but rather a necessary step for the actual implementation of interventions. Frequently the plan is seen as an end product, even though the true challenge is turning the plan into a reality. Phase IV describes the activities needed to prepare for implementation. Reference is made to section C.9 on how to ensure that the plan is implemented.

C.6 Phase IV – Preparation of Implementation – towards bankable projects

Once the preferred strategy has been selected, it should be translated into concrete projects and a clear strategic investment program. Careful planning and coordination are required as many authorities may be involved in its implementation. The resulting investment and action plan of this phase will have an 'open' and 'rolling' character, meaning that it is not static or prescriptive, and gives individual decision-makers enough flexibility and freedom to act according to their own knowledge and experience where necessary. On the other hand, the action plan should also be concrete, by assigning clear responsibilities for carrying out the activities involved. It should contain the project's financial implications and set the base for the budgetary requirements for implementation, including capital investments and recurrent costs. The action plan should be based on a long-term commitment of the main actors involved (governments, financiers, etc.) and, as much as possible, not be influenced by changes in political and social viewpoints which might change over time.

Figure C13 presents the steps which should be followed in Phase IV. These steps are described in the next sections:

- Step IV.1: Combining interventions in implementation clusters (section C.6.1)
- Step IV.2: Final project preparation activities (section C.6.2)
- Step IV.3: Implementation arrangements per cluster – developing the business case of projects (section C.6.4)
- Step IV.4: Coordinating implementation organization (section C.6.5)
- Step IV.5: Action plan (section C.6.5)

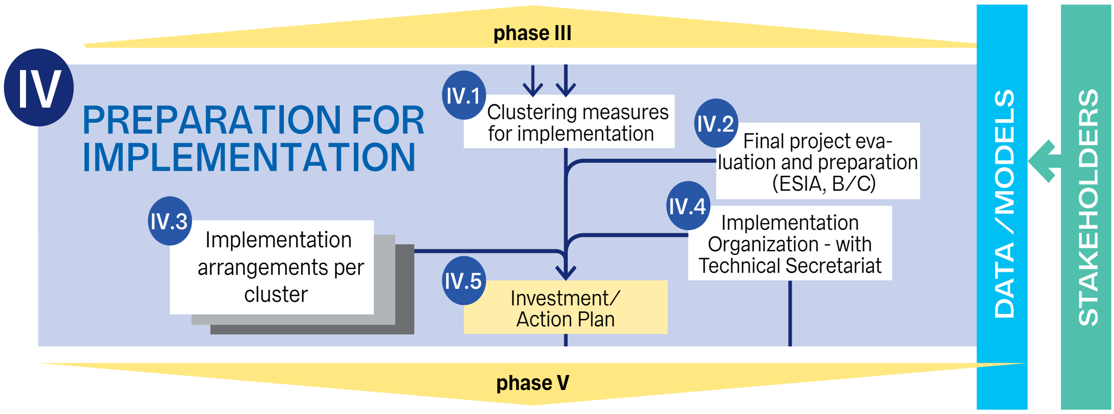


Figure C13 Call-out of the Action Planning Phase

While in most cases the 'planning' phases I II and III will take place in a coordinated setting in which all stakeholders are involved, the actual implementation in Step V will usually be undertaken by specific institutions (ministries, departments, provinces, municipalities, private sector, etc.). Those institutions will be responsible for the implementation of certain components of the agreed upon strategy, i.e., the individual measures, projects, or programs. Although the overall strategy is approved, the acceptance of the individual projects will require a more detailed evaluation. This is called the Business Case development process.

Business Case development
The Business Case development process is essential for spending decisions, in terms of its scoping, options selection, delivery, monitoring and evaluation.
A Business Case is meant to make a project "investable" for a certain actor. Generally, all public sector investments require a Business Case. The "Five Cases Model" of the HM Treasury of the United Kingdom is an example of how this can be done (HM Treasury, 2018) as shown in Figure C14.

Phases I and II address the Strategic Case, and during Phase III the Economic Case of the preferred strategy is developed by showing that a specific set of interventions represent the best public value. The goal of Phase IV is to further develop the Commercial, Financial and Management Cases of the selected measures by drafting suitable implementation arrangements for each measure. Based on these results, a final selection of measures can be made that result in a Strategic Investment Program. This investment plan can be then elaborated on to create an action plan.

The Five Business Cases approach is just one example of how to evaluate projects for public investments. Most countries have their own specific regulations on how to do so, although even country-specific regulations tend to share common elements which must be considered before an actual public investment can be made.

C.6.1 Step IV.1 Combining interventions in implementation project clusters

By definition, an integrated strategy or plan will contain many different components and address various issues in the water system. One strategy can contain multiple projects, for example a project which aims to improve water quality may include projects on drinking water, agricultural development, and ecological protection. The implementation of these projects will usually be done by different institutions. For example, the drinking water project might be implemented by the Ministry of Housing, the agricultural development project by the Ministry of Agriculture and the ecological protection project by the Ministry of Environment. Thus, the first activity of Phase IV

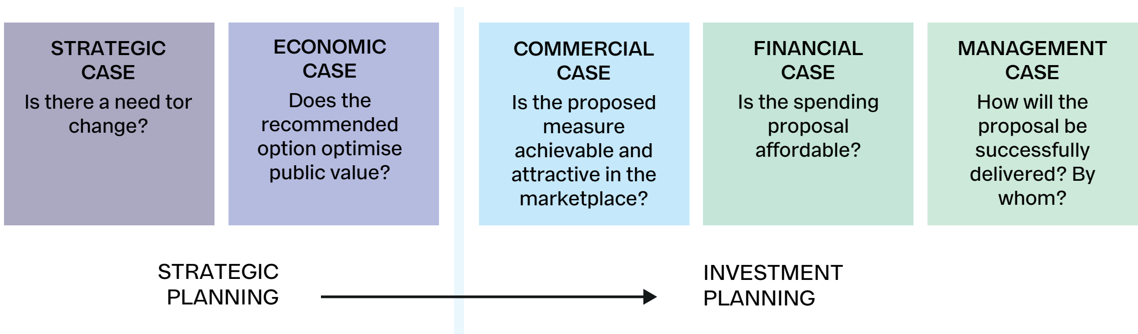


Figure C14 Five Business Cases Model

is to divide the approved (integrated) strategy into consistent project clusters for which the appropriate implementation arrangement can be determined. These project clusters are referred to as 'bankable' projects[12].

The implementation of the approved strategy will be done on an investment project or "transaction" level, where each project cluster is framed and publicized as a service that will be provided to the stakeholders. The main elements to be considered in the development of these project clusters are:

- The characteristics of the transaction: technical and financial characteristics of the project, such as how capital-intensive the project is, how asset-specific is the investment required (e.g., can the assets created be moved and reused for other purposes) and the main functions and services that will be provided through the assets and how these services can be classified according to type of economic good (private, common resource, club or public);
- The service level required over time; and
- The institutional environment (stakeholders involved; strengths and weaknesses of local government, private sector, and community; incentives created by formal and informal institutions).

Based on these three elements, a choice can be made from a wide range of project delivery and finance options that vary from purely public governance up to the creation of markets for private initiatives. Options which are the most effective in ensuring sustainability in service provision are more likely to be chosen due to their longevity advantage. The resulting implementation arrangements for these projects will be developed in Step IV.3 (see section C.6.2).

Once there is a solid understanding of the individual actions, these actions can be combined into project clusters to be picked up by implementing agencies. This clustering process will look at logical combinations of functions of the actions and (sector-oriented) implementation options. Regional clustering will also be an option, in particular when the most likely implementing partner will be a lower governmental organization. A distinction should also be made between short-, medium- and long-term actions.
This clustering process requires sound analysis skills with respect to the technical, financial and institutional aspects involved in the projects.

C.6.2 Step IV.2 Final project evaluation and preparation activities

During Phases II and III, individual investment projects are analyzed at the pre-feasibility level. Before a final decision on budgets can be made and a detailed implementation arrangement can be agreed upon, further preparation might be needed for certain projects. This might include carrying out a full feasibility study. In most cases it also includes carrying out an Environmental and Social Impact Assessment (ESIA) study. This can be done at the level of individual projects or at the level of programs (clusters of projects) as will be defined in Step IV.3.

Feasibility studies
A feasibility study will revisit the analysis carried out in the previous phases, but this time in more detail.
In this process, the five Business Cases for each project or cluster are examined and advanced to the level of detail necessary so that the investment is approved. Commonly a feasibility study includes five areas of feasibility, partly overlapping with the five Business Cases: i) technical, ii) social / environmental, iii) political / legal, iv) financial / economic, and v) operational and scheduling.

Feasibility studies are often carried out by consultants. A Terms-of-Reference for these studies should be developed. The Analysis Framework can be used as a guide of the activities that have to be carried out in each feasibility study.

Carrying out feasibility studies is placed under Phase IV in the Analysis Framework as a last step for final project approval. Such feasibility studies can be performed in earlier phases of the Framework as part of individual project preparations. The results of these studies will provide useful information on the various activities undertaken in their respective phases, and so the results should be integrated into the overall process. For example, problem description in Phase II, impact assessment and ranking in Phase III and determining implementation arrangements in Phase IV.

Environmental and Social Impact Assessments
There are legal requirements in many different countries which call for a mandatory Environmental Impact Assessment (EIA) or Environmental and Social Impacts Assessment (ESIA) for infrastructure projects. Regulations related to EIA laws specify the activities which have to be carried out. Financing agencies such as the World Bank and the ADB have developed detailed Environmental and Social

12 A 'bankable' project is defined as a project or proposal that has sufficient collateral, future cashflow, and high probability of success to be acceptable to institutional lenders for financing.

Frameworks that specify the conditions with which projects must comply to be eligible for their financial support. This includes how to deal with the environmental and social risks, labor and working conditions, resource efficiency, pollution prevention, community health and safety, land acquisition and resettlement, biodiversity, indigenous peoples' rights, cultural heritage, financial intermediaries and stakeholder involvement. An example of such a framework is the Environmental and Social Framework of the World Bank (World Bank, 2017).

It should be noted that Phases I, II and II of the Analysis Framework already pay extensive attention to environmental and social impacts. A formal EIA or ESIA will provide additional detail, complement the information which was gathered in previous phases and place this knowledge in an official legal framework. As such, it is comparable with the feasibility study described above which provides more detailed information on the various components of a project so that it is accepted for financing.

Strategic Environmental Assessments
While EIAs and ESIAs are applied for projects, Strategic Environmental Assessments (SEA) are used for more policy-oriented plans. SEA is also applied to support strategic planning in the water sector. Governmental strategic planning has 3 components: substance (what needs to be decided upon?), process (how does decision-making take place?) and procedure (which legal tools can the institution use to design the process?). SEA focuses on procedure and usually has a legal basis.

The procedures prescribed by SEAs align well with the integrated planning approach used in this document. In the case that the integrated plan (the end result of Phase III) has been developed based on the steps in Phases I, II and III of the Analysis Framework, it can be assumed that the resulting plan is SEA compliant. In countries where SEAs are mandatory for strategic plans, a formal statement has to be made by the relevant authorities explaining that the SEA principles have been fulfilled in the plan.

From a sustainability perspective, sometimes a Sustainability Appraisal (SA) is required. Each type of assessment differs according to the level of integration of environmental, economic, and social considerations. Which one (EIA/ESIA, SEA or SA) should be applied will depend on the type of measure and the country's specific legal requirements.

Box 18 Implementation arrangements – answering the what, who, how and when questions

- What is included in the investment?
- Who should implement, operate and monitor?
- How will it be financed, funded, and procured?
- When will it be implemented?

C.6.3 Step IV.3 Implementation arrangements per cluster

For each of the clusters (programs) developed in step IV.1, implementation arrangements have to be determined. These implementation arrangements (see also Box 18) require defining the:
- mode of governance of the services provided;
- funding strategy;
- financing strategy; and
- procurement strategy.

Box 19 explains the difference between financing and funding.

When determining the best implementation arrangement for each project, it is important to focus on delivering the service that the project is supposed to provide rather than the project itself. Implementing arrangements very much depend on the context, even for the same type of measure or project. Every implementation arrangement is embedded in a specific institutional environment and its effectiveness is highly dependent on the presence or absence of an enabling environment.

Box 19 Difference between funding and financing

- Funding: who will ultimately pay for the investments over their lifecycle?
- Financing: how will the money for up-front costs be made available, and how will this money be repaid?

Define the mode of governance of service provided
The first step in defining the main services that the project will provide is categorizing them by type of economic good. Types of economic goods are: private goods (e.g., industrial water supply), common resources (e.g., lakes, rivers and forests), club goods (e.g., inland water way transport, raw water provision) and public goods (e.g., flood protection). It is important to note that this categorization takes place according to the services that the asset will deliver, not necessarily the asset itself. For example, a forest may provide services that can be considered private (such as reduction of soil erosion), yet the forest itself may be a public good. This categorization enables the identification of which types of funding could be

appropriate to ensure cost recovery. For each type of service specific governance modes can be chosen. The most common in water management are Public Procurement Contracts. Other models are privately driven water Stewardship Investments, Collective Investment Schemes, and Environmental and/or Ecosystem Markets.

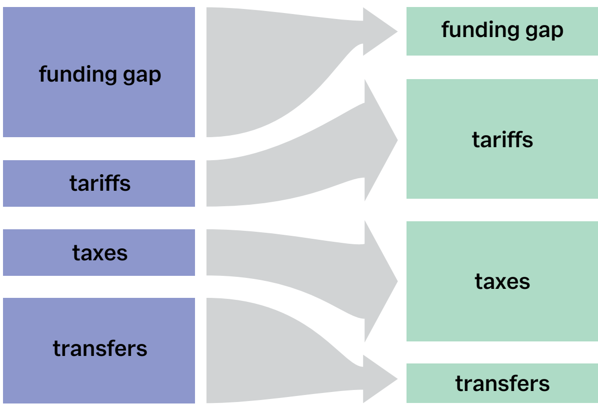


Figure C15 Defining the funding strategy over time

Funding strategy

The main sources of funding are what the OECD calls the 3T's: Taxes, Tariffs or Transfers. The funding strategy is dependent on the economic nature of the services being provided. The objective of the funding strategy is to reduce the funding gap and improve the long-term financial sustainability of the project by reducing transfers (e.g., subsidies and grants from donors or from other government agencies) and increase the funding by means of collecting more taxes (domestic resource mobilization) and tariffs (e.g., user and pollution fees). This is illustrated in Figure C15. The funding of a project could be either public or private. Once the sources of funding are determined, the mechanisms to arrange up-front capital (financing) and how to place the project on the market (procurement) can be selected.

Financing strategy

Depending on the type of project and whether the project sponsor is public or private, a variety of financing instruments could be used to obtain the necessary up-front resources. These up-front resources are usually to be repaid over time. Many options exist for financing the planned investments and will depend on the goods or services that will be delivered. The most commonly used financing mechanisms in the water sector are:

- Governmental sources (from tax income)
- IFI's loans to governments (World Bank, ADB, etc.)
- Concessional loans (IFC, IIC, etc.)
- Tax swaps (e.g., providing tax facilities to investors)
- Institutional investors (e.g., pension funds)
- Bonds (e.g., fixed period loans from public to the government)
- Capital market (e.g., loans from banks)
- Project finance (e.g., by means of Public-Private-Partnerships)

A special, rather new kind of financing is Blended Finance in which 'development' loans from IFI's or other development partners are combined with 'regular' financing from the above-mentioned sources. Other sources for (co-)financing are the specific global funds such as the Green Climate Fund (GCF) and the Global Facility of Disaster Risk Reduction (GFDRR) of the World Bank.

Procurement strategy
The last step is to develop the procurement strategy. Public procurement refers to the process by which public authorities purchase work, goods or services from companies, for example paying for the construction of a municipal wastewater treatment plant. As public procurement accounts for a substantial portion of taxpayers' money, governments are expected to carry it out efficiently and with high standards of conduct to ensure high quality of service delivery and to maintain public approval

To create a level playing field for businesses, many countries have developed laws that set out minimum public procurement rules. These directives on public procurement often apply to the tendering of projects and services which are worth more than a given amount. The core principles of these directives are transparency, equal treatment, open competition, and sound procedural management. They are designed to achieve a procurement market that is competitive, open, and well-regulated. This is essential for putting public funds to good use.

Most water-related services are provided through public procurement where private participation in the delivery may involve the use of Public-Private Partnerships (PPPs). Successful implementation requires that both the public and private partners benefit from the PPP arrangement. To successfully conclude a PPP project has proven to be a challenge.

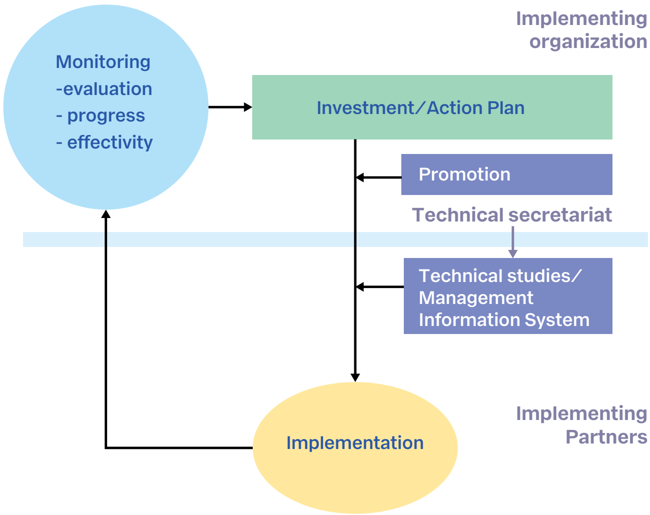


Figure C16 Implementation framework

C.6.4 Step IV.4 Coordinating implementation organization

While the actual implementation will be done on a project or program level and is undertaken by separate institutions (public and private), the integrated character of the Analysis Framework must remain constant and be applied to all phases. Projects might influence each other (positively and negatively) and so implementation needs to be monitored to ensure that these project interactions are beneficial to achieving objectives and that, if necessary, additional actions are taken. For this to occur, an overarching implementation organization at the national, provincial or river basin level is required.

An illustration of this overarching implementation organization is given in Figure C16. The implementation organization will be active in both Phase IV (Action Planning) and Phase V (Implementation) and takes care of monitoring the implementation, as described in Step V.3. The actual implementation will likely be undertaken by decentralized agencies of national ministries or at local governmental levels together with their related utilities, districts and associations as mentioned in Step IV.3.

The overarching implementation organization should include a Technical Secretariat (TS). A monitoring report periodically compiled by the TS can track the progress made in implementing the measures of the action plan and the effectiveness of these measures in meeting their objectives. Often "Log Frames" are used for the monitoring and evaluation (See Box 20). Insufficient progress may lead to an adjustment of the action plan. The TS may also assist the implementing partners by providing available data and/or by carrying out supporting technical studies. This could include the development of a Management Information System (MIS) for the project's implementation.

		Recommended Measures/Actions		Institutions involved																					Implementation info					
																											Phase I only			
			Phase	Province of Cebu	City of Cebu	- MCWD	DENR - VII / NWRB	City of Mandaue	City of Lapu-Lapu	City of Talisay	City of Toledo	City of Danao	Municipality of Naga	Municipality of Minglanilla	Municipality of Liloan	Municipality of Consolacion	Municipality of Balamban	Municipality of Pinamungahan	Municipality of Asturias	Municipality of Carmen	Municipality of Cordova	Municipality of Compostela	Private Sector	Other (NGO, Univ. WRC, etc.)	No. of the measure	Type of measure	Total Investment (in MPesos)	Recurrent costs (MPesos/yr)	Starting year effective operation	Needed lead time (preparation + construction)
Develop more resources	West	Groundwater wells West	I				x				●						●	●	●				●		9	invest.	849	38	2006	-
	Uplands	Spring boxes + level 2 + small impoundments + trucking infrastructure for drought periods	I		●		x			●	●	●	●	●	●	●	●	●	●	●		●	o	o	8	invest.	737	126	2006	-
	East-non MCWD	Groundwater wells East	I				x					●	●	●						●		●	●		9	invest.	639	28	2006	-
	MCWD-East	Groundwater wells MCWD	I		o	●	x	o		o					o	o						o			9	invest.	588	26	2006	-
		Luyang Dam (Carmen)	I	o	x	o	o	x				x			x	x				o		x	●		4	invest.	included in Northern well fields			
		Northern well fields: Liloan, Compostela, Kotkot, Danao, Carmen, Luyang + Luyang dam + pipe	I		o	●	x	o	o			o			o	o				o		o	?		9	invest.	3.169	124	2006	2+2
		Lusaran Dam	I	o	o	●	o										o		x				?		2	invest.	2.536	77	2027	6+2
		Kokot Dam	I	o	o	●	o															x	?		3	invest.	905	59	2022	6+2
		Southern well fields: Napo/Carcar river, Pangdan, Minglanilla + pipeline	I		o	●	x			o			o	o									?		10	invest.	2.490	86	2014	2+2
	MCWD-Mactan	Horizontal wells	I			●	x		o												o				11	invest.	51	5	2006	-
		Shallow fresh water wells	I			●	x		x												x				11	invest.	276	56	2008	-
		Shallow brackish water wells + treatment	I			●	x		x												x				13	invest.	80	42	2006	-
		Desalination by MCWD for industry	I			●	x																?		13	invest.	297	55	2010	2+2
		Desalination by MCWD for domestic use	I			●	x																?		13	invest.	1.393	167	2012	2+2
	Mactan-non MCWD	Desalinaton by industry	I				x																●		13	invest.	297	55	2010	2+2
	Misc.	Rainfall harvesting: urban, rural, industry	I		o			o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	●	o	12	invest.	(515)	-	2006	-
Water demand reduction	Redu-cing losses	Leakage reduction / rehabilitation distribution system MCWD	I		o	●		o	o																14	invest.	820	41	2007	-
		Adequate and differentiated water pricing	I/II			●																	o	o	20	study/policy	pm	pm	2007	1
		Promotion water saving equipment and production	II			●																	o		21	man.	-	-	-	-
	Aware-ness	Awareness raising high demand Cebu neighbourhoods	I		o	●		o	o															o	22	man.	0	2,6	2006	-
		Awareness raising - general	I	●	o	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	23	man.	0	6,9	2006	-
Protecting the resource	Water-shed manage-ment	Land use practices / watershed management	II				●			o	o	o	o	o	o	o	o	o	o	o		o	o	o	30	reg.	-	-	-	-
		Gabion dams	II				●																	o	31	invest.	-	-	-	-
	Water quality improve-ment	Improved solid waste management	II		●		o	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		o	34	man.	-	-	-	-
		Well head protection - spatial planning recharge areas	II	o	o	o	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o			35	reg.	-	-	-	-
		Prevent sand and gravel mining in rivers (enforcement)	II			o	●			o												o	o		36	reg.	-	-	-	-
		Implement strict effluent permitting (EMB)	II		o		●	o	o	o													o		37	reg.	-	-	-	-
		Urban sewage systems in building requirements	I		●			●	●	●													o		38	reg.	0	0	2007	1
		Development of urban sewage systems and treatment	II		●			●	●	●													o		39	invest.	-	-	2010	3
		Sanitary programs in uplands	II				o			●	●	●	●	●	●	●	●	●	●	●		●		o	40	invest.	-	-	-	-
Water governance	Organi-sation improve-ments	Development institutional setting for IWRM (integration and coordination - Board, TS etc.)	I	●	●	o	o																	o	50	instit.	0	0	2006	0
		Capacity development IWRM institutions	I	●	●																				51	capac.	0	xxx	2006	0
		Development monitoring and information system - regional and central	I	●	●	o	o																		53	Cassie	?	?	2006	0
		Family planning and migration control (env. related)	I	●	●																			o	54	man.	pm	pm	-	-
	Regula-tion and control	Development of license system for water withdrawal (NWRB)	II				●																o		52	man.	pm	pm	2007	0
		Implement and enforce spatial planning (urban, industrial, etc.)	I	●	●	o	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		55	man.	pm	pm	-	-
		Priority rules (allocation) during dry periods	I				●																o		56	reg.	pm	pm	-	-
Research and development		Training in good monitoring practises and data analysis	I	o	o	o	o																	●	60	capac.	-	Cassie	2006	-
		Development of efficient (DSS oriented) analysis tools for TS	II	o	o	o	o																	●	61	capac.	xxx	xxx	2007	-
																											15.127	995		

Phase I: part of Action Plan 2006
Phase II: to be developed for Action Plan 2008
Phase III: to be developed for Action Plan 2010

● first responsible for implementation measure/action
o co-operating partner for implementing the measure
x to be consulted for permission or information

Figure C17 Illustration of the Investment / Action Plan for implementing the integrated strategy for Central Cebu
Source: MCWD, 2006

C.6.5 Step IV.5 Overall investment and action plan

The overall investment plan compiles the results of the previous step. For each of the identified projects in the strategy it should become clear:

- **What** will be done? The concrete actions that have to be carried out to implement each of the measures included in the strategy.
- **Who** will do it? The prime decision-maker / stakeholder responsible for carrying out the action and who will take the lead in the implementation.
- **How** will it be done? The steps to be taken and the consultative process involved.
- **When?** The time sequencing of concrete actions.
- **Budget and financing**: where will the money to implement the action come from?

Box 20 Logical Framework Approach for monitoring and evaluation

The Logical Framework Approach takes the form of a four-by-four project table, sometimes referred to as a "Logframe". The rows represent the type of events that take place as a project is implemented: Activities, Outputs, Purpose and Goal. The columns represent the type of information about these events: a Narrative description, Objectively Verifiable Indicators (OVIs) of these events taking place, Means of Verification (MoV) where information will be available on the OVIs, and Assumptions. Assumptions are external factors that could have an influence, whether positive or negative, on the events described in the narrative column. The list of assumptions should include the factors that may impact the project's success but cannot be directly controlled by the project or program managers. In some cases, these include what are known as killer assumptions, which if valid will have major negative consequences for the project. A good project design should be able to substantiate its assumptions, especially those with a high potential to have a negative impact.

The action plan can include a Logical Framework Approach for monitoring the implementation (see Box 20).

The investment and action plan aims to prompt and facilitate the coordinated development and management of the water resources. An illustration is given in Figure C17, which presents an overview of the investment plan for water resource development in Central Cebu in the Philippines. The plan is structured by types of interventions (developing more resources, water demand reduction, etc.) and gives an overview of all the stakeholders involved and implementation information on budget for investment and O&M.

As the measures included in the plan will involve or affect many stakeholders (based on the outcomes of the stakeholder analysis and designed participatory planning process), they should all therefore be included in some way in the implementation process to guarantee a successful implementation and a sustainable benefit of the particular measure. In general, the following roles are distinguished and included in the figure:

- Responsible: the stakeholder has the first responsibility for the implementation of the measure but will cooperate with and/or consult other stakeholders in this process. In Figure C17 this is indicated by the symbol: "●".
- Cooperate: the stakeholder has an important role in the implementation of the measure but is not the first responsible and is expected to work with other stakeholders on this matter. In the figure this is indicated by the symbol: "o".
- Consult: the stakeholder has an interest in the implementation of the measure and will be consulted by the first responsible. In the figure this is indicated by the symbol: "X".

C.7 Phase V – Implementation

The actual implementation of the integrated strategy is generally not part of the strategic planning process, but is added here to complete the planning cycle as presented in Figure B6. Strategic planning is a continuous process. The next cycle will start with an evaluation of the results of the previously implemented project(s), and then the Analysis Framework will revert to Phase I where stakeholders and decision-makers collaboratively assess the new situation, this time considering possible new boundary conditions with respect to socio-economic developments and climate change where necessary.

Figure C18 presents the steps which should be followed in Phase V. These steps are described in the next sections:

- Step V.1: Project approval and procurement (section C.7.1)

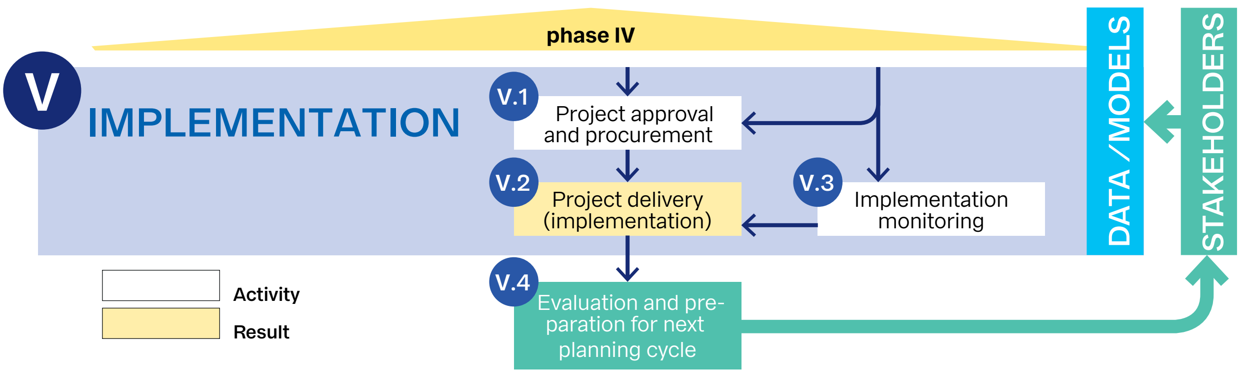


Figure C18 Call-out of the Implementation Phase

- Step V.2: Project delivery – the actual implementation (section C.7.2)
- Step V.3: Monitoring of the implementation (section C.7.3)
- Step V.4: Evaluation and preparation for next planning cycle (section C.7.4).

As this phase is rather straightforward and goes beyond the planning scope of this document, it will only be outlined briefly.

C.7.1 Step V.1 Project approval and procurement

Final approval of the strategy and individual projects strongly depends on the local governmental and political setting. The strong involvement of the stakeholders in all of the previous phases of the Analysis Framework is expected to facilitate and accelerate this final approval process.

As mentioned in section C.6.3, the procurement of projects depends on local laws and governmental spending procedures. In case external financing is involved (e.g., from an investment and/or development bank), the specific regulations of the financing institutions have to be followed.

Final approval will also benefit from taking specific rules and regulations into account in the earlier phases of the strategy preparation process. In studying the AIS during Step II.1, specific attention should be given to these regulations. Required information should be collected and/or developed in the subsequent phases before trying to obtain final approval.

C.7.2 Step V.2 Project delivery – the actual implementation

The actual implementation will also follow local regulations. As these are beyond the remit of the Framework, these will not be mentioned in detail

here. The implementation has to be monitored by the coordinating implementation organization (see Step IV.2), in particular if the implementation deviates from the agreed-upon implementation arrangement. If needed, action has to be taken to ensure that the implementation stays in line with the overall integrated development strategy.

C.7.3 Step V.3. Implementation monitoring

The implementation monitoring is a continuation of the coordinating implementing organization's

lead to a desired increase in the service level. This monitoring is the start of a new cycle of IWRM, as explained in Section B.3.1.

C.8 Summarizing the main results and deliverables of each phase

All of the steps and components in the Analysis Framework are important. Depending on the water resources system and issues involved, some components might need more attention than others. The

Strategic Planning (strategy based)	**I. Inception**	6 - 9 months	Set-up of project organization. Vision – objectives - criteria	Inception report - workplan
	II. Situation Analysis	12 - 18 months	Collection of data and information, set-up of tools Problem statement	Progress report
	III. Strategy Building	6 - 12 months	Development and ranking of alternative strategies. Agreement on preferred strategy	Strategic Plan
Financial Planning ('project' based)	**IV. Prepare for Implementation**	9 - 12 months	Implementation arrangements per 'project'	Investment/ Action Plan
Coordinated implementation ('project' based)	**V. Implementation**	4 - 6 years	Implementation of identified projects and monitoring of progress	Implemented projects

Figure C19 Summary of main activities, deliverables and duration of a typical strategic planning study

activities as described in Section C.6.4 and illustrated in Figure C16. Delays in the implementation of certain strategy components are to be expected due to technical or budgetary difficulties. If this is the case, the coordinating implementation organization should determine whether this will impact other strategy components and/or try to resolve the underlying issues.

C.7.4 Step V.4. Evaluation and preparation for next planning cycle

Once the project has been implemented and put into operation, continuous monitoring is needed to ensure that the agreed-upon service level is being provided. External circumstances might occur which require additional actions to be put in place to achieve this service level. Political and societal developments may

stakeholders and decision-makers need to agree on the results of each phase. These results should be communicated in a clear and transparent way to everyone involved.

As mentioned in the introduction, each water system is unique, and a strategic planning study will have to address this uniqueness. Complex water systems require an extensive study (in both time and money) while more simple water systems might need less effort.

Figure C19 summaries the main activities and deliverables of all 5 phases of the Analysis Framework. It also includes an indication of the duration of a typical strategic planning study for a moderately complex water system.

C.9 How to avoid your strategic plan (just) ending up on the bookshelf

The development of any water system should be based on a strategic integrated plan that presents a comprehensive and cohesive picture of required interventions. The plan itself is not an objective, it is a tool. The challenge is to implement the plan. Still, many plans end up on the bookshelf or in a drawer. This is partly due to the fact that drafting the plan is seen as a project and that once the plan is produced, the project is finished. It is also partly due to the difficulty in translating the plan from a technical paper to a set of bankable projects. The latter reason can be avoided by effectively carrying out Phase IV as described in section C.6.

The Analysis Framework described in this chapter aims to avoid the mistakes that are often made in planning projects. The following gives an overview of the main points of attention to increase the possibility of the plan being implemented.

Align the strategy and its development with the capacity of the stakeholders involved

Each strategy must be aligned with the technical, financial, and institutional capacity of the stakeholders involved. The scope of a strategic plan will depend on the level of development (in terms of water use and threats to the resources) and/or stress on the resource. Measures and strategies vary significantly between a more pristine environment, where a baseline assessment and monitoring can be the focus, and highly stressed systems suffering from irreversible impacts, where a much more comprehensive strategy is required including strong management, regulation, and possibly changes in land use.

Ownership of the plan

Strategic water system plans are usually produced by consultants on behalf of a sectoral governmental organization such as the Ministry of Water or Ministry of Environment. The resulting plan should not be a consultant report (with the logo of the consultant on the cover), but rather a plan which the Ministry views as 'their' plan, and therefore feels a sense of responsibility to ensure its implementation. Seeing as many interventions in a strategic plan will be implemented by other governmental organizations, these implementing organizations should also consider themselves as owners of the plan. If possible, the plan should be jointly signed by all implementing partners. Finally, it is also important that when drafting the plan, the highest possible governmental level is involved such as the Ministry of Planning, or the Office of the Prime Minister. In such cases, it can be preferred that the planning exercise is done under those higher-level Ministries and Offices instead of by sector-oriented Ministries. The involvement of the Ministry of Finance in the early stages of the planning process is also crucial for the successful implementation of the plan.

Stakeholder involvement

The involvement of all stakeholders in all phases of the planning process is an essential element of the Analysis Framework and is described in section C.3.2 and Appendix 2. In this process an inclusive approach should be followed, as defined in section A.4. Appendix 2 lists the points of attention to incorporate inclusiveness in all five phases of the Analysis Framework. Stakeholder involvement should be at the highest practical level (see Figure E3). As much as possible, the stakeholders should also be involved in the supporting analytical work (e.g., data collection, modeling, analysis undertaken in Phase II).

Enabling conditions are not in place

Developing and implementing an integrated strategic plan is only possible if the necessary enabling conditions are present. If these enabling conditions (see Figure B4) are not in place, they should be included in the strategic plan as specific interventions, and be implemented with priority. The EPIC Response Framework (Brower et al, 2021) describes these enabling conditions in detail for drought and flood management, but most of the principles can be applied generally to the planning of water systems.

Make the plan realistic

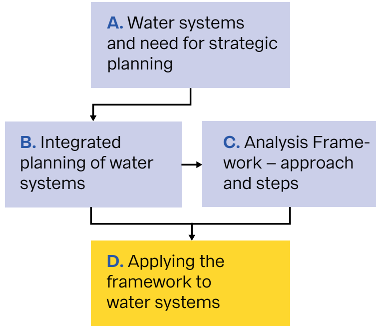
Countries and organizations' capacities to implement interventions are often limited because of financial, organizational and resource constraints. The strategic plan should be realistic in terms of what can be implemented within the time horizons specified in the plan, taking into account the budgets available and the carrying capacity of the implementing organizations. At times, plans can become a simple stakeholder 'wish list' as too much detail is placed on describing all possible interventions without assessing how a certain few could be implemented. The phasing and decision-making of the Analysis Framework (see Figure C3) will help to maintain focus on the most important issues and the most promising interventions.

Risk management

The future is uncertain, and it is likely that this future will bring unexpected surprises. Some of these uncertainties will be acknowledged during analysis in Phase II (section C.4.2) and a sensitivity analysis will be conducted on certain assumptions during the impact assessment step. However, changing conditions may lead to new uncertainties. A significant risk is the political and institutional unwillingness to cooperate in implementation. Other risks are social (e.g., awareness, public support), economic (e.g., creating financial boundary conditions) and environmental calamities (e.g., hurricanes, toxic spills) which cause a shift in political support. Although at times these risks cannot be avoided, it is good to identify possible risks during the planning stages and to give directions on how these risks might impact implementation (i.e., how these risks can be managed).

Carry out Phase IV
Following Phase IV is a solid method of converting the integrated strategy into bankable projects. Each of these bankable projects will be subject to the Business Case analysis as depicted in Figure C14 which helps to establish their legitimacy and highlight their benefits to stakeholders. This analysis will be carried out for projects implemented by both public and private parties. It is important that when developing the plan sufficient attention is given to this Phase IV.

D. Applying the framework for different water systems and thematic areas



The Analysis Framework is generic in nature. It can be applied to different water systems and thematic areas, as presented in Figure B10. However, each water system and thematic area has its own respective characteristics and challenges, and this will require that, when applied, the generic framework is tailored to the specific system. This chapter highlights the specific details which must be considered when planning and managing different water systems: river basins, coastal zones, urban areas, marine and groundwater systems. The chapter also describes how the generic framework can be applied to the thematic areas of floods, droughts and water quality. All plans must deal with uncertainties but in particular the plans for floods and droughts will have a strong risk-based orientation.

D.1 Integrated River Basin Management

A river basin is generally the preferred scale for the implementation of integrated water management as a river basin is the geographic area where demand can be balanced with the supply, and upstream and downstream issues can be addressed simultaneously. The aim of Integrated River Basin Management (IRBM) is to develop and manage the water resources in the basin in a sustainable and balanced way, while taking account of social, economic and environmental needs and interests.

The generic Analysis Framework presented in the previous chapter is largely based on experience gained in river basin planning. Below, a short description is given of the characteristics of river basin management, its challenges and the specific tools that can be used when preparing basin plans. As highlighted in Box 21, national IWRM plans are strongly related with river basin plans and the following text can also apply for national planning exercises.

Box 21 National IWRM plan

Many countries have developed national (IWRM based) water plans. In these national plans, the government outlines the policies for the use and protection of the water resources in the country. These national plans are boundary conditions for developing river basin plans. Conversely, river basin plans can provide the basic information based upon which the national plan is formed. In some cases, river basin plans are included (or summarized) in the national plan. Developing a national plan will follow the same generic steps as described in chapter C.

D.1.1 Specific characteristics of a river basin system

A river basin is the area of land that channels rainfall and groundwater to a common outlet via a system of tributaries and shallow aquifers. In most cases, the outlet of the surface water system will be a sea. When the outlet of a basin is a terminal lake or wetland, this is called an endorheic basin. The water within a river basin usually originates from upstream mountains (the source area). The river's flow is augmented by inflows of tributaries that drain local rainfall of sub-basins and inflows of groundwater from seepage zones and sources. A unique characteristic of river basins is the interaction between surface and groundwater systems. Rainfall and surface water recharge groundwater systems, and groundwater can recharge surface water during dry periods. The boundaries of the surface part of the river basin usually do not coincide with boundaries of the aquifer system.

A river basin plan covers the whole basin and as such should address groundwater systems, coastal zones and urban areas when these fall within the river basin's boundaries. If separate plans are developed for these water systems, the river basin plan could still outline their respective boundary conditions. The same applies for flood and drought plans. The river basin plan (and sometimes the national water resources plan) indicates the context based upon which the other plans can develop their own (often more detailed and operational) strategies. But, as is the case between river basin plans and national plans, these other system and thematic plans can provide input to the development of a river basin plan. An example is the downstream carrying capacity of a coastal system with respect to marine eutrophication that defines the allowed concentration of nutrients in the river.

Box 22 EU Water Framework directive and transboundary basins

The EU Water Framework Directive (WFD), adopted in 2000, has taken a pioneering approach to protecting water according to natural geographical formations: river basins. It requires EU Member States to achieve good status in all bodies of surface water and groundwater by 2027. While the focus of WFD is on the water quality (ecological and chemical status) of surface and groundwater, it also addresses shortages and makes a link to the EU Flood Directive. The WFD requires EU Member States to review and update their river basin management plans every six years. The last round took place in 2016; the next round of reviewing comes up in 2022. Each river basin management plan covers one of the 180 river basins in the EU, and includes the assessment of its water bodies, their pressures and relevant associated plans towards achieving good status. Surface waters includes rivers, lakes, transitional and coastal waters. In the case of transboundary rivers, EU countries are instructed to coordinate the WFD plans for their parts of the transboundary river basin with the other riparian countries.

Transboundary basins (point of attention in steps I.2 (stakeholders), II.2 (scenarios)

A transboundary river is a river that crosses at least one political border, either a border within a country or an international border. Developing a river basin plan for an international transboundary basin requires cooperation between the riparian countries. This can be a challenge due to differences in legal, political and socio-economic settings of the countries and their bilateral relations. Plans for transboundary river basins should take into account the guidelines as laid down in the 1997 UN Convention on the Non-Navigational Uses of International Water Courses. For Europe the EU Water Framework Directive (see Box 22) and the UNECE Convention on the Protection of Transboundary Water Courses and International Lakes provide additional guidelines. The UNECE Convention now applies to all UN Member States.

D.1.2 Main challenges in relation to the SDGs

All basins are different and each basin has its own land and water management challenges. For some basins, the focus can be on balancing supply and demand. For other basins, this focus can be on water quality or floods. River basin plans should address all of these aspects in an integrated way but depending on the severity of the issues, more attention can be given to specific issues. If needed, special strategic plans will be developed for specific (spatial) areas such as urban areas or coastal zones or for specific components such as groundwater, floods, and droughts. These plans will be elaborated on in the next sections of this chapter.

The SDGs include many targets that relate to river basins. SDG 6 specifically addresses water-related challenges, expressed in 6 targets (see Box 23). Within SDG 6, target 6.5 is dedicated to IWRM and trans-boundary issues. While SDG 6 is viewed as the central goal for water, it should be kept in mind that water management will also contribute to the realization of other SDGs, for example SDG 2 on Agriculture, SDG 7 on Energy, SDG 8 on Sustainable Growth and SDG 11 on Cities. Target 11.5 is about reducing the number of people and economic losses caused by disasters, specifically mentioning water-related disasters.

Box 23 The 'Water Goal' and its targets

SDG 6: Ensure availability and sustainable management of water and sanitation for all

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and at least doubling recycling and safe re-use globally.
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity.
6.5 By 2030 implement integrated water resources management (IWRM) at all levels, including through transboundary cooperation as appropriate.
6.6 By 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

Specific point of attention in IRBM is upstream-downstream relations. While most of the supply is generated upstream in the mountains, the demand is much higher downstream in the flatter areas where most of the socio-economic activities of a river basin (population, agriculture, industry, etc.) exist or take place. In many river basins, the economy of upstream areas is much weaker than that of the downstream areas, and specific measures might be considered to improve the socio-economic position of upstream populations. However, increased use of water upstream can harm downstream users by reducing or polluting their supply. At the same time, upstream measures can benefit downstream users. Eco-compensation (from downstream to upstream) can be an effective policy to address these issues. In case of major shortages within the basin, it may be possible to import water from another basin. Such interbasin transfers might also include eco-compensation mechanisms.

D.1.3 Stakeholders and institutional setting

The principles of IRBM state that all stakeholders should be involved in decision-making relating to the development and management of the water and land resources in the basin, including local people that will be directly impacted by any changes. Given the many stakeholders involved in a river basin, careful consideration must be given to finding a balance between who will actually be involved in the process and who will (only) be informed. A balance should also be found between public and private sector stakeholders and national, regional and local interests.

As river basins usually do not coincide with regular governmental borders (such as provinces or states), a basin organization is sometimes needed to manage and coordinate the water-related activities within the basin. A basin organization can refer to any formal or informal entity. They will differ according to their aim, legal and administrative contexts, and human and financial resources. However, their mandate will always be to be the lead in basin water management. Their main functions are: i) monitoring, investigating, coordinating and regulating, ii) planning and financing, and iii) developing and managing. All stakeholders should be well presented in a basin organization. As water is a public good, basin organizations must be public sector organizations.

D.1.4 Models and data for river basin analysis

The focus of river basin management is to find a balanced development of multiple sectors that make use of the same resource. Typical computational tools that are needed in developing a river basin plan are (see also Figure C10):

- Water system models that describe the performance of the water system (surface water and groundwater) in terms of quantity (supply, water levels) and quality.
- Sector models (e.g., for agriculture, drinking water supply) that determine the water demand of the sector depending on socio-economic developments and the impacts that interventions will have in terms of benefits (e.g., increased agricultural production, improved health) and possible negative consequences (e.g., increased pollutant load).
- Water allocation models that help to find the balance between supply and demand of the various sectors.
- Multi-criteria evaluation models that provide insight on the positive and negative impacts of interventions and support decision-making by the stakeholders.

An overview of these types of models is given by Loucks and Van Beek (2017a). Various model systems are available that combine the aforementioned functions. The core of these models is often the water balance and water allocation. Examples of such models are WEAP[13], Mike-Basin[14], RIBASIM[15] and MODSIM[16].

D.1.5 Specific interventions to be considered in river basin management

Possible interventions to be included in an integrated river basin plan can be divided into infrastructural (investment), operational management, observation and monitoring, economic (such as pricing) and institutional measures. A recommended structure to assess possible measures is as follows:

13 WEAP - https://www.weap21.org/index.asp?NewLang=EN
14 Mike Hydro Basin - https://www.mikepoweredbydhi.com/products/mike-hydro-basin
15 RIBASIM - https://www.deltares.nl/en/software/ribasim/
16 MODSIM - http://modsim.engr.colostate.edu/

- Water supply-oriented measures
  - Infrastructure, also known as gray infrastructure (reservoirs, weirs, irrigation systems, managed aquifer recharge systems, etc.)
  - Nature-based solutions, also known as green infrastructure (better watershed management, wetlands and mangroves, etc.)
  - Operational management (allocation, permit systems, environmental flow, etc.)
  - Groundwater management (permit systems, conjunctive use of ground and surface water, etc.)
  - Technological options (e.g., desalinization, recycling)
- Water demand-oriented measures
  - Providing incentives to reduce demand (e.g., subsidies, pricing)
  - Technological options to reduce water demand (drip irrigation, recycling, etc.)
- Water governance measures
  - Introducing licensing and pricing systems (for example for withdrawals, or effluents)
  - Monitoring and information systems
  - Implement and enforce spatial and contingency planning

Depending on the specific situation of a river basin, legal and institutional measures might be considered such as the set-up of a river basin organization. River basin plans can also include research and capacity building activities.

D.1.6 Further reading on IRBM

Considerable literature exists on IRBM and planning for IRBM. The basic principles are well described in the publications of the Global Water Partnership (GWP), UN-Water and OECD. Most of these publications take IWRM as a guiding principle. Reference is in particular made to GWP (2000), GWP (2005), GWP and INBO (2009), OECD (2013), and ADB-GIWP-UNESCO-WWF (2013).

D.2 Integrated Coastal Zone Management

Integrated Coastal Zone Management (ICZM) was first introduced as an integrated approach at the 1992 Earth Summit in Rio de Janeiro. ICZM expanded coastal zone management from coastline protection to the planning and management of the multiple functions of and activities in the coastal zone while still including biophysical elements such as protection against flooding and prevention of erosion. The approach is now embedded in many national legislations as well as in regional co-operations. Although each application of ICZM is unique, the general principles are always the same and are therefore also reflected in the Analysis Framework.

D.2.1 Specific characteristics of a coastal zone system

The coast is the area where the land meets the sea and where river basins discharge into the sea. Whereas the coastline is the physical line where sea ends and land begins or vice versa, such as the high water mark, the coastal zone includes the land area subject to marine influence and the sea area subject to terrestrial influence. Tides, waves, and sedimentation create the physical environment to which coastal ecosystems have adapted.

A broad classification distinguishes between muddy, sandy, and rocky coasts. The sediment composition not only determines the typical geomorphology from very gentle slopes in muddy coasts to steep rock faces, but it also greatly influences the feasible management options and measures available in the area. ICZM therefore focuses more on sediment resources than on water resources. Typical ecosystems in the coastal zone are mangroves, corals, wetlands, and dunes. These ecosystems are among the highest for biodiversity in the world and provide crucial ecosystem services, such as acting as nursery grounds for fish stocks.

In many countries, the coast is the most populated area and hosts significant economic centers which generate a large share of the national GDP. Over the past few decades, migration from the rural hinterland to coastal cities has increased coastal populations five to tenfold and economies have shifted or are shifting from agriculture to industries, manufacturing, and services. Population growth is continuing to increase pressure on limited space, water, energy, and food resources and on the infrastructure which treats and manages wastewater and solid wastes. Climate change is threatening coastal zones through sea level rise and temperature increase (e.g., leading to coral bleaching which lowers levels of natural flood protection). Inland droughts and floods may influence the supply of fresh water, hence impacting the coastal zone.

D.2.2 Main challenges in relation to the SDGs

In general, the major challenges to coastal zones are threefold:

- How to protect the coastal zone from flooding, including coastal erosion, sea level rise and land subsidence?
- How to enable inclusive living for a growing population, including spatial planning for housing, ports and shipping, fisheries, recreation and tourism as major sectors?
- How to maintain a healthy environment and sustainable ecosystem, including biodiversity, clean water and balanced exploitation of resources?

In addition to these coastal challenges, the common institutional challenge of having to appease various stakeholders with different interests is also relevant here (see B.1.4). National, regional, and local governments are all involved in managing coastal economic activities, as are a wide range of private entities, non-governmental agencies, and citizen representations. At times there are overlapping mandates and no clear overarching strategy or integrated decision-making process.

Dealing with relative sea level rise (e.g., steps I.3, II.2, III.2)
Sea level rise is having a significant impact on coastal zones. The 2021 IPCC report states that “coastal areas will see continued sea level rise throughout the 21st century, contributing to more frequent and severe coastal flooding in low-lying areas and coastal erosion. Extreme sea level events that previously occurred once in 100 years could happen every year by the end of this century” (IPCC, 2021). Over the past century, the global sea level rose by 20 cm. IPCC 2021 predicts that the next 20 cm sea level rise will happen within the next 30 years, by 2050. Depending on the success or failure of emissions reduction initiatives, this number could rise to 40 cm higher (zero emissions from 2050) or 80 cm higher (no reductions) by 2100. Regionally, the sea level rise may be higher or lower depending on factors such as the distance to icecaps.

Sea level rise can be expressed as absolute SLR or relative SLR. Absolute SLR does not take land into account and refers to the increased height between the ocean surface and tectonic plates. Relative SLR is the change of the water level relative to the land at a particular location. For ICZM, the relative SLR must be used as land subsidence rates can even exceed the rate of sea level rise. Most importantly, groundwater extraction is known to lead to land subsidence of more than 50 mm per year in extreme cases, e.g., in Jakarta and Manila. This is tenfold higher than the current sea level rise of 2-4 mm/year. Draining of peat areas is also a well-known phenomenon that leads to land subsidence. For example, the Netherlands has lowered certain land areas 2 to 4 m over a period of centuries as a result of peat area draining.

SDG targets in the coastal zone

As an integrated approach, ICZM potentially contributes to many of the SDGs. For the natural system, SDG 14 'Life Under Water' is paramount, taking into account that terrestrial coastal ecosystems such as marshlands, mangroves and dunes are also included in SDG 14. The welfare, well-being and access to inclusive and equal opportunities of the coastal population is embedded in several SDGs: SDG 8 'Decent Work and Economic Growth', SDG 10 'Reduce Inequalities', and SDG 11 'Sustainable Cities and Communities.' The economic development opportunities in the coastal zone are part of SDG 9 'Industry, Innovation and Infrastructure.' A successful ICZM plan will moreover reduce poverty (SDG 1), provide clean water and sanitation (SDG 6) and affordable and clean energy (SDG 7).

D.2.3 Stakeholders and institutional setting

Unlike river basin planning, ICZM has not been fully mainstreamed into national planning processes. Particularly in countries or coastal areas with extensive deltas, ICZM has to be linked with river basin management planning (IRBM, see D.1). The delta represents the terminus of a river basin, where freshwater flows mix with seawater and bring sediments, nutrients, and pollutants to coastal zones which impact coastal ecosystems (both positively and negatively). ICZM is also intertwined with Marine Spatial Planning (MSP, see D.5) due to common geomorphological dynamics and the shared ecosystems which provide services and goods to coastal economies.

ICZM plans provide the overall framework for flood management programs operating in coastal areas and should help to inform local flood management plans for jurisdictions located along the coastline. They also help in establishing priorities for investments related to coastal barrier management, including protection and restoration activities, and offer guidance as to where "hard" coastal defenses such as sea dikes or flood walls may be necessary.

The national framework for ICZM may derive from a specific coastal zone management law, or may be part of a broader environmental law, land use planning law, or ocean governance law. The relevant laws should set out specific requirements for their periodic review to adjust to changing circumstances and to incorporate lessons learned, for example every five years. The laws should nominate a national agency to facilitate the coastal planning process, and to establish regulations and technical guidelines for the preparation of coastal zone management plans. The law may also authorize the creation of Coastal Planning Authorities which are responsible for preparing and/or overseeing the creation of ICZM plans. Coastal Planning Authorities can take on many forms, from an inter-governmental committee established for the purpose of the planning exercise to a localized bottom-up organization with its own budget and staff (Browder et al., 2021).

D.2.4 Models and data for coastal zone analysis

Most decision-makers and stakeholders will be non-technical or have knowledge on a (limited) part of the overall natural, socio-economic, or institutional system. To be able to make balanced decisions, they should understand how the overall system functions and how interventions in one part of the system will impact other elements. Data and models are used to provide decision-makers and stakeholders with the relevant information in an understandable format. Data reflect the historic and current situation, while models are used for future predictions. Data are also needed to set up and feed the models.

For the coastal NRS, a data synthesis is typically required for modeling:

- The hydrodynamic system of water levels, currents, salinity, temperature, and stratification patterns, both daily and seasonal, and in extreme events.
- The morphologic system of sediment composition, sediment movement and transport, coastline change, sedimentation, and erosion patterns.
- The water quality or (bio)chemical system of nutrients, dissolved oxygen, suspended sediments, chlorophyll-a, algae composition and primary production, and pollutants such as plastics, heavy metals, organic micro-pollutants, and oil spills.

- The ecological system of habitats and species, biodiversity, food web from zooplankton, invertebrates and shellfish to fish, birds, and mammals.

The starting point for an analysis of the SES is an assessment of the present economic situation with respect to coastal activities and the factors that determine these activities:
- Economic activities in the coastal zone including their contribution to GDP, employment, etc.
- Population including spatial distribution in gender, age, income, etc.
- Land use coverage and offshore and onshore coastal spatial zoning.

Hydrodynamic data and modeling
Typically, water level data are available from tidal gauge stations. Other hydrodynamic data are often scarcer and models must be used to fill the gaps. Hydrodynamic modeling in 2D is used for water level predictions in normal conditions and in extreme events (See Box 24); the latter can also be used for testing and design of flood protection. 3D hydrodynamic modeling is necessary when transport of heat (temperature), salinity and other substances such as (fine) sediments, nutrients and plastics are relevant.

Morphological data and modeling
As sediment resources are highly relevant in ICZM, morphological data and modeling are key components for understanding the dynamics of the shoreline, of sedimentation and erosion patterns of morphological entities such as sand bars, gullies and mudflats, and of sediment balances.

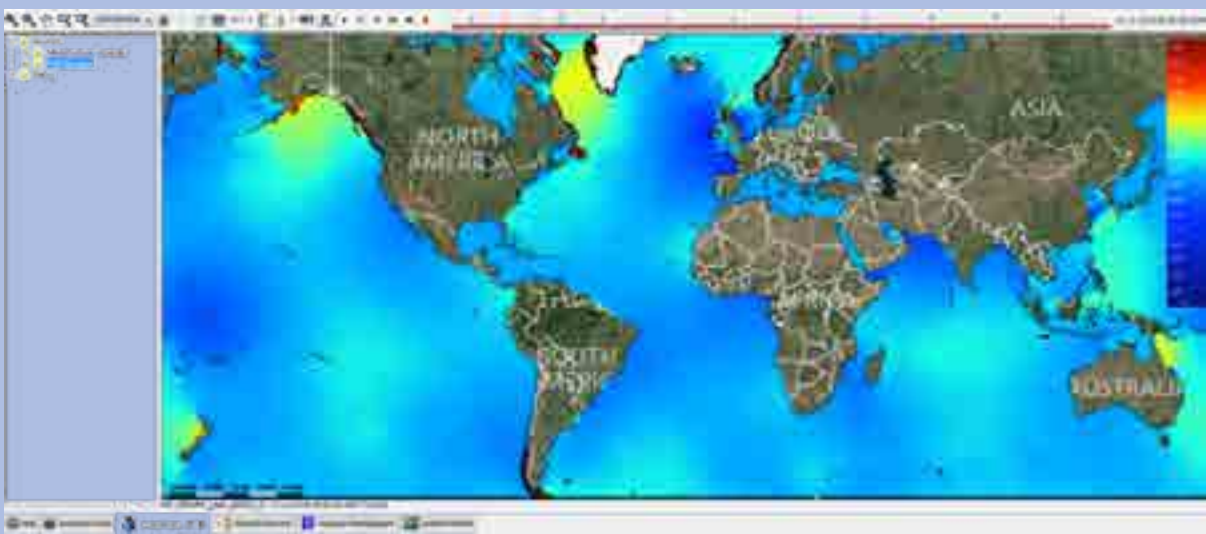
Remote sensing data from satellites is now regularly used for automated shoreline detection, which is particularly helpful in data-scarce environments. Modeling tools for the shoreline and/or the near-shore morphology are for example UNIBEST[17] and XBEACH[18].

Water quality and ecology data and modeling
A key concept in water quality management is that a water body can accommodate a certain load of substances without harmful effects to humans and the ecosystem. A load that exceeds this carrying capacity can cause eutrophication (where levels of nutrients are too high), harmful algal blooms and dissolved oxygen

Box 24 Intermezzo: Global Tide and Surge Model

Coastal inundation by storm surges is one of the main global risks. Risks and impacts are expected to increase due to population growth, sea level rise and land subsidence. To assist with early warning measures, the Global Storm Surge Forecasting and Information System (GLOSSIS, Deltares) provides real-time water level and storm-surge forecasts with global coverage. These forecasts can be used for early warning in areas which currently lack forecasting capabilities, or can provide boundary conditions for more refined local models.

From GLOSSIS, the Global Tide and Surge Model (GTSM) is run four times daily to produce water level and storm-surge forecasts over a ten-day period for about 16,000 coastal segments. GLOSSIS is developed with Delft-FEWS which manages all data flows, such as real-time observations and global meteorological forcing of the model, as well as scheduling model runs and visualizing of the results. The GTSM model is developed with the Delft3D Flexible Mesh Suite (Delft3D FM), and uses an unstructured spherical grid to represent coastal areas in more detail (around 5 km resolution) than open oceans (50 km resolution).



17 https://www.deltares.nl/en/software/unibest-cl/
18 https://oss.deltares.nl/web/xbeach/

depletion. For chemical pollution, an excessive load may cause toxicity either directly or through bioaccumulation in the food chain. In coastal zones, the load of nutrients, organic wastes, chemicals and plastics mainly originates from land, although offshore activities can sometimes contribute significantly, for example oil spills or plastics from fishnets. Emission or waste load modeling identifies the sources and the specific pollutant loadings from each source. In general, sources are the waste loads caused by the population, for example from land uses such as agriculture or industrial waste loads. Wastewater treatment efficiency is applied based on the availability and coverage of primary, secondary and tertiary treatment. Natural purification processes in the river catchment should also be taken into account. Waste load modeling can be applied to both water-born substances and solid wastes. Identification and screening of potential measures to resolve water quality issues are supported by information on the largest sources and on possibilities for reduction at the source (e.g., minimized use of fertilizer), improved wastewater treatment and/or waste collection.

When major interventions which will substantially alter water flows are planned in the coastal zone, the residence time, fate and transport of substances can be changed to the extent that the carrying capacity is (locally) exceeded even with the same loads. For example, the palm islands near the Dubai coast created semi-enclosed lagoons for which water quality modeling demonstrated that (artificial) flushing was needed to ensure good water quality. A coupled hydrodynamic and water quality model such as Delft-FM[19] or MIKE[20] is needed to simultaneously address changes in water flows and the fate and transport of substances.

Ecological assessments for future predictions are typically based on changes in abiotic conditions such as water depth, inundation percentage, salinity range, underwater light penetration, dissolved oxygen concentration, and nutrient concentrations. Of the biotic conditions, primary production by phytoplankton may be used as an indicator for the bottom of the food chain. The higher trophic levels of fish, birds, and mammals are more difficult to predict accurately, although predictions of fish stocks are done regularly. Changes in abiotic conditions can be related to habitat suitability or suitability for certain species or species groups. Typical coastal habitats to be considered by habitat modeling are intertidal areas, salt marshes, mudflats, mangroves, seagrass, corals, and nursery areas for juvenile fish.

D.2.5 Specific interventions to be considered in coastal zones

To prevent coastal erosion and protect the hinterland against flooding, measures for coastal protection are implemented in coastal zones worldwide. Traditionally, coastal protection measures involve hard constructions like groins, seawalls, breakwaters and storm surge barriers. These measures are usually monofunc-

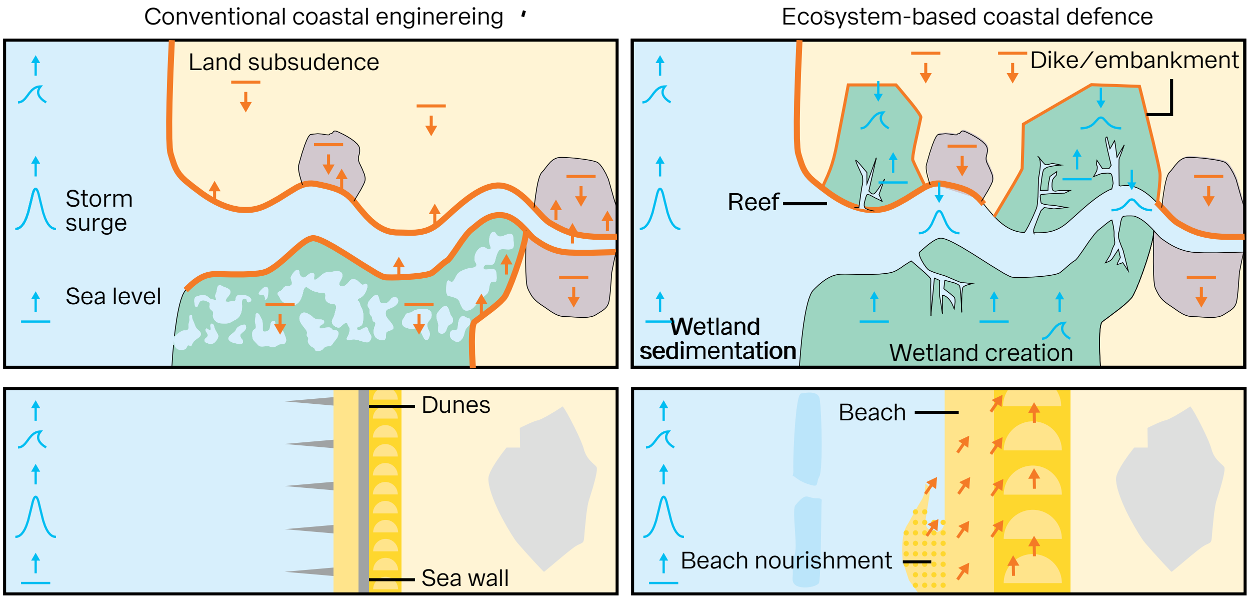


Figure D1 Schematic example of flood risk due to storm waves, storm surges and sea level rise in muddy (top) and sandy coastlines (bottom), protected against erosion and flooding with hard measures (left) or soft measures (right)
Source: Temmerman et al., 2013

19 https://www.deltares.nl/en/software/module/d-flow-flexible-mesh/
20 https://www.mikepoweredbydhi.com/

tional and are made of materials that are alien to the natural coastal environment. Such solutions may be effective on shorter scales of time and space. In contrast to sediment-based solutions, they are not system-based, do not tackle underlying causes like sediment-deficit and may have serious negative side-effects to the natural environment. Coastal zones with sediment deficit tend to become narrower (coastal squeeze). This is the cause of disappearing natural buffer zones.

At sandy or muddy coasts, erosion and flood risk reduction can be established using soft measures, e.g., sediment management based on principles of Building with Nature. Soft measures are system-based and make use of natural elements and processes. These are increasingly applied for coastal protection. Soft measures include actively bringing sediment to the active zone of a coast (sand nourishment), but also restoring coastal ecosystems that can capture sediment (e.g., mangroves). Coastal ecosystems support many functions. From the perspective of coastal safety, attenuation of wave energy and provision of a buffer zone to erosion are the most important. Soft measures, being system-based, aim at supporting all coastal functions, hence also provide benefits to biodiversity, communities and the environment, such as capturing CO_2 and NO_x. Figure D1 shows the application of soft and hard coastal protection measures in shallow coastal areas with fine sediments (e.g., estuaries, deltas or lagoons) and sandy, more exposed coasts.

At muddy coasts, conventional coastal engineering can cause land subsidence and wetland degradation. This increases the risks when storm surges occur. Ecosystem-based, soft measures reduce wave energy and reduce impacts should flooding occur. In tropical regions, mangrove forests play an important role in hazard prevention and mitigation. In sandy coastal systems, hard measures such as groins and seawalls can cause beach erosion and dune degradation. Sand nourishments enhance beach and dune growth as it reduces sediment deficits in the coastal zone. It is known that coasts with sediment deficits erode and coasts with sediment surplus accrete. Providing extra sediment to a coast is a flexible way of adapting to sea level rise.

D.2.6 Further reading on ICZM

The Kuwait Guidelines for ICZM (Nolte et al., 2020) were adapted from an earlier version of the IWRM framework and were applied to the coastal zone and to the specific setting and needs of the State of Kuwait. The Belize ICZM plan is recommended reading as an example of the result of an integrated and inclusive process (Coastal Zone Management Authority and Institute, 2016). For the application of nature-based solutions in ICZM, reference is made to the Blue Guide to Coastal Resilience (The Nature Conservancy, 2021).

D.3 Integrated Urban Water Management

D.3.1 Specific characteristics of the urban water system

Urban water systems are an integral part of the urban space, fabric and overall socio-economic system. Water management can strengthen social, ecological, and economic resilience, for example, by promoting urban blue and green infrastructure that improves livability, health and well-being while at the same time providing safety from flooding and supplying adequate volumes of water of sufficient quality for inhabitants, economic activities and the ecological system. Urban water systems comprise both the water chain (drinking water and wastewater) and the urban drainage system (surface water and groundwater) and involves many actors, as illustrated in Figure D2.

To achieve the many objectives of urban water management, engineering, design and dialogue work together in an integrated manner: engineering aimed at the optimization of solutions and pathways; design aimed at adding value, local cultural identity and preferences; dialogue aimed at engaging and collaborative learning with stakeholders. IUWM is a continuous multidisciplinary activity which takes place in a complex urban environment with shifting demands, requiring flexibility, robustness, reflection and adaptiveness to deal with the dynamic reality.

Typical characteristics of urban water systems are i) the administrative and natural system boundaries are not the same, ii) urban water management is heavily interlinked with urban planning and design, iii) a wide range of stakeholders are involved, all operating in a high-density public space, and iv) projects are undertaken under ongoing political debate. Urban water systems can be sensitive to climate change but also provide good opportunities for applying nature-based solutions.

D.3.2 Main challenges and relation to the SDGs

Due to its high density of population and infrastructure, the built environment is very susceptible to damage from extreme conditions of flooding, drought, and pollution. Consequently, the urban water system requires a stricter water management regime than

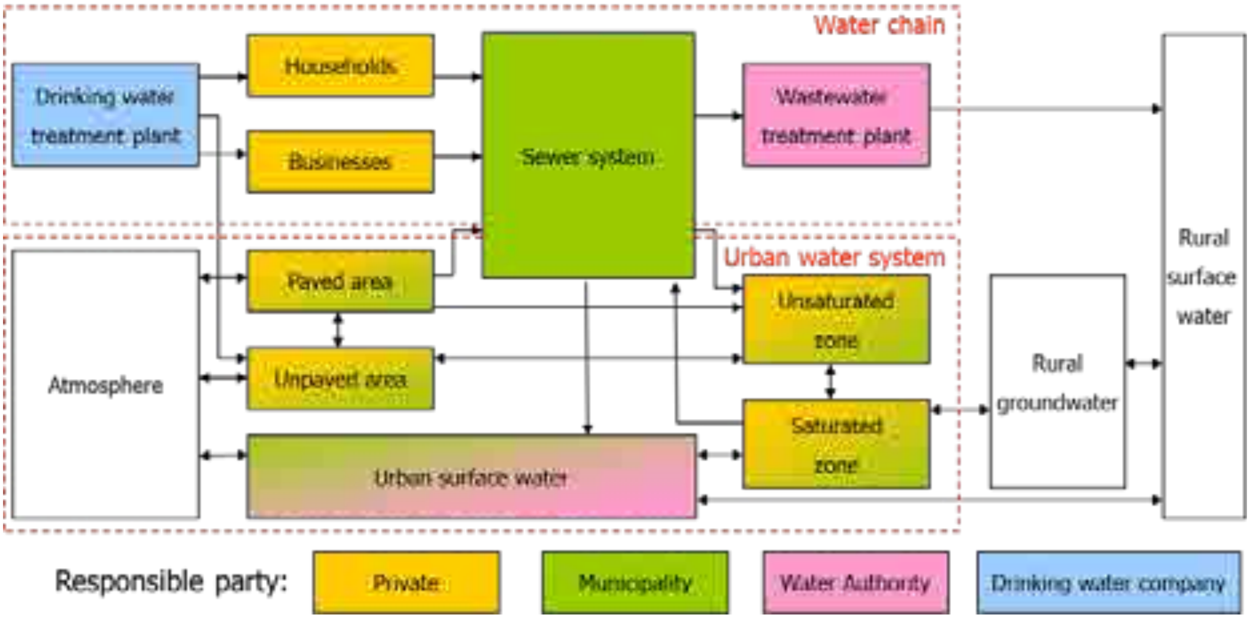


Figure D2 Schematic overview of an urban water system

rural areas and nature reserves. Urban water systems are therefore often partly disconnected from the surrounding water system in the catchment. Many facilities are needed to control the system of ponds, canals, sewage collection networks for wastewater and stormwater, pumping stations, wastewater treatment plants, nature-based solutions to retain, detain and treat water, levees to prevent flooding, subsurface drains to control groundwater levels, the list of how water is involved in urban systems goes on. All of these facilities require space, both on the surface and subsurface, a resource that is usually limited and expensive in urban environments. Such an intricate system needs to be resilient to prevent failure from every shock or stress it encounters.

As mentioned, urban water systems suffer from floods, droughts and water pollution. Flooding can be exacerbated by densification and the increase of paved and impervious surfaces. Insufficient water supply can lead to overextraction of groundwater and consequent soil subsidence. Water quality in the urban environment is important as it is directly related to public health, not only via drinking water but also via urban surface waters to which citizens are exposed. These surface waters may contain pathogens and disease vectors. Urban water systems are also prone to becoming polluted by the continuous production of solid waste, chemicals and wastewater loads.

A particular urban challenge related to water is heat stress. Urban areas are very sensitive to the impacts of heat waves, particularly when considering the urban heat island effect, and can lead to higher numbers of heat-related mortality and morbidity than in rural settings. Water systems can be an instrument in reducing the impacts of these heat waves.

Urban water system management focuses on positively influencing the relationship between water and urban developments and turning challenges into opportunities. Interventions in the urban water system can have a positive impact on the systems of utility networks, infrastructure, urban space, and the citizens themselves. In other words, urban water management must use water as a tool to improve urban resilience for the city and its citizens.

Urban water management contributes to several SDGs, beyond SDG 6. Water can play a major role in SDG 11 ‘Sustainable Cities’ which aims to make cities and human settlements more inclusive, resilient, and sustainable. Target 11.5 is specifically aimed at reducing the number of people affected by disasters. IUWM is also associated with SDG 13 ‘Climate Action’, as water can contribute to making cities more climate resilient generally and more resilient to urban heat stress in particular.

D.3.3 Stakeholders and institutional setting

There are several roles which water plays in urban settings, as mentioned above. Consequently, many organizations are involved in its management, including operation, implementation and adaption to new requirements. The organizations and stakeholders which are involved in IUWM are: i) national and provincial government departments, ii) municipal government departments, iii) water authorities and utilities (drinking water, energy, etc.), iv) emergency services (fire service, hospitals, etc.), v) property and housing owners, and vi) the private sector (industries, contractors, banks, insurance, etc.)
Stakeholders involved in IUWM are: politicians, decision-makers in administrative bodies, funding

agencies, community leaders, commercial companies, individual citizens, constructors, maintenance staff, experts, journalists/media, NGO's, local interest groups. Not all stakeholders need to be involved at the same time and with the same intensity. Involvement could range from 'being informed' and 'being consulted' to 'co-creating' or even 'co-deciding'. Arguments for inviting a specific stakeholder to enter the urban water management arena could be their power (to make, influence or hinder a decision), their money for investments and/or maintenance and preservation of infrastructure, their expertise, skills and local or historical knowledge, or their moral right to participate in planning and decision-making. As a result of the large number of stakeholders and their many conflicting interests, IUWM is a time-consuming process with multiple iterations, especially when planning interventions in existing urban environments.

D.3.4 Specific models and tools in an urban context

When modeling urban water systems, models should generally cover both the city and its upstream catchments. The granularity should be at least at the district level. The availability, quality and resolution of data will determine the level of detail and the modeling approach used. For example, information on the urban drainage network will reveal how the schematization of the network can be best represented in a hydraulic model. There are numerous reasons for modeling urban water systems, for example, to analyze and assess: urban flooding, water supplies and demands, groundwater contamination, soil subsidence and the stability of foundations; but to also quantify the impacts of interventions such as: groundwater abstractions or large underground infrastructure; the impacts of climate change mitigation and adaptation; or the impacts of blue and green infrastructure.

Water balance models are typically used when modeling the hydrological processes in upstream catchments of interest, in which the movement of surface water across the landscape is determined by reservoir or kinematic wave routines. These models generally account for precipitation, interception, snow accumulation and melt, evapotranspiration, soil water, surface water and groundwater recharge, and river discharges entering the city. One example is the model package developed by Deltares called Wflow[21]. Wflow is applied worldwide in studies on flood hazards, drought, climate change impacts, land use changes, and flood warning systems. The urban surface water system is usually modeled as a 1D system of open channels, rivers, waterways, piped systems, urban drainage, including structures, pumps, etc., and a 2D system for predicting overland flow from excess precipitation, river bank overtopping or breaching, and coastal storm surge. Modeling of this urban system, whether using the 1D system, the 2D system or the 1D2D combination and interaction of both systems, requires the modeling of hydraulic processes, for which several widely used physically-based mechanistic software packages exist. Well known examples are: Delft3D FM Suite[22], MIKE FLOOD[23], InfoWorks ICM[24], HEC-RAS[25] and SWMM[26].

A general drawback of these modeling platforms is that they are computationally expensive. Their applications require large numbers of model runs, for example, to adequately simulate the combination of precipitation and river and coastal flooding. To overcome this problem, model codes are developed in which the computational scheme is reduced while still maintaining adequate accuracy. One example is SFINCS[27] (Super-Fast Inundation of CoastS). In SFINCS a set of momentum and continuity equations are solved with a first order explicit scheme. SFINCS neglects the advection term which generally is justified for sub-critical flow conditions. In this way, SFINCS balances a high computational efficiency with adequate accuracy.

The groundwater system in urban areas is generally more complex than in rural (agricultural or natural) areas. The subsurface in a built environment is disturbed with infrastructure, such as basements, foundations, transportation lines, parking garages, cables and pipes. Natural sediments are removed, replaced by building material and/or elevated with sand for site preparation. Depending on the purpose, the modeling of groundwater flow systems either requires examining the entire extent of the city or beyond (e.g., in case of a large groundwater abstraction) or requires including every local detail at a specific location (e.g., when modeling the contamination at an industrial site). Section D.4.4 describes several frequently used software packages for the simulation of groundwater flow.

21 https://www.deltares.nl/en/software/wflow-hydrology/
22 https://www.deltares.nl/en/software/delft3d-flexible-mesh-suite/.g.,
23 https://www.mikepoweredbydhi.com/products/mike-flood
24 http://www.innovyze.com/products/infoworks_icm/
25 http://www.hec.usace.army.mil/software/hec-ras/
26 https://www.epa.gov/water-research/storm-water-management-model-swmm
27 https://sfincs.readthedocs.io/en/latest/index.html

The modeling software mentioned so far is generally rigorous and necessitates a fair amount of effort and expertise in its application. During the stage in the planning process when potential measures are being discussed among stakeholders (Phase II and III of the Analysis Framework), simpler tools can be used to obtain a brief overview of potential options. One example of such a tool is the Climate Resilient City Tool[28] (CRCT). The CRCT is a planning tool for nature-based (blue-green) best management practices in the urban environment, developed to support dialogues with stakeholders on which adaptation measures can be implemented, where, and how. The tool provides estimates on the effects of a proposed package of measures on resilience against extreme rainfall, drought, and heat stress, and on stormwater quality, so that these aspects become an explicit part of the planning process.

D.3.5 Specific interventions to be considered in urban settings

Traditionally, gray solutions were used to manage urban water, with the main aim of rapidly draining any surplus water. Large subsurface stormwater drains, combined sewerage pipes, pumps and, if unavoidable, drainage canals and ponds were used to meet this aim. Water quality was poor, and the water was kept out of sight, hence out of mind. This started to change during the 1970s when priorities shifted to detain water in order to prevent flash-flood runoff peaks and to treat slightly polluted stormwater on-site. Water Sensitive Urban Design (WSUD) frameworks and principles emerged and are now being implemented to retain, detain, treat and reuse urban water in order to minimize the impact of urbanization on the region, the river basin and groundwater system, while maximizing the benefits to citizens and biodiversity, services provided and resilience to extreme climatic conditions. This includes combining a wide variety of nature-based (blue-green), gray, and hybrid measures to find solutions. Value-creation with water in the built environment has become a goal of IUWM.

D.3.6 Further reading on IUWM

Bahri (2012) published a seminal paper under the auspices of the Global Water Partnership defining IUWM. Since then, other holistic concepts have been proposed, such as WSUD. WSUD integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimize environmental degradation and improve aesthetic and recreational appeal; see, for example, Wong and Brown (2008) and Brown et al.

28 https://www.deltares.nl/en/software/adaptation-support-tool-ast/

(2009). Wong and Brown argue that WSUD is based on the integration of two key fields, including ‘Integrated urban water [cycle planning and] management’ – IUWM - and ‘urban design.’ Urban resilience is an even more holistic approach than WSUD, moving beyond the realm of water management and urban design. It involves the threats of climate change and natural disasters, but also poverty reduction, informal settlement and resettlement, environmental sustainability, social inclusion, terrorism and (cyber)crime; see, for example, Jha et al., 2013. Urban resilience has gained prominence over the past decade in the international development discourse and has emerged as one of the core principles of sustainable urban development in global development frameworks and targets, including the Habitat-III new urban agenda[29] , the SDGs, the United Nations Framework Convention on Climate Change, the Sendai Framework, and the Paris Agreement.

D.4 Integrated Groundwater Management

Groundwater is a precious resource which a large proportion of the worlds’ population depend on for their domestic water supply and other needs. Managing groundwater can be a challenge due to the limited amount of data about its availability, current state, and use. In the literature, the term ‘aquifer management’ is sometimes used instead of groundwater management to highlight the resource system and its areal boundaries, although in this document it will be referred to as Integrated Groundwater Management (IGM), simply because it is more accessible to non-groundwater specialists. IGM may be used interchangeably with Integrated Aquifer Management that also includes the specific issues that may arise when aquifers cross administrative borders.

D.4.1 Specific characteristics of a groundwater system

Groundwater is present in the pores and fissures of underground rocks and soft sediments and can be found almost anywhere underneath our feet (Figure D3). This makes it a near omnipresent resource, but that does not necessarily mean that it is easily accessible everywhere. Apart from natural sources through which groundwater seeps, wells or boreholes need to be constructed to access groundwater. Groundwater may be very deep, aquifer permeability may be too low for groundwater to be economically extracted, or natural groundwater quality may make it unsuitable for direct use (e.g., high salinity, arsenic or fluoride concentrations). Similar to surface waters, groundwater occurrence, quality, and flow are determined by a range of factors such as climate, vegetation, and human action. However, to truly understand groundwater it is of paramount importance to have sound knowledge of the geology, lithology and hydraulic properties of the different water bearing layers which make up an aquifer system. Without this knowledge using groundwater can lead to a multitude of unforeseen negative consequences. This is challenging as groundwater users may not have (access to) this type of information, causing the unsustainable management of the resource. Hydrogeological mapping and assessment require specialized techniques and are relatively costly as they require local fieldwork, including the drilling of boreholes to establish aquifer characteristics and for monitoring purposes. Remote sensing and satellite data are only of limited use for hydrogeological mapping as they are unable to provide subsurface data.

Groundwater flow is generally very slow compared to surface water flow. Groundwater in a natural system generally takes place as water moves from recharge areas to discharge areas, such as natural springs, rivers, wetlands and subsurface outflow into the sea. Human activities have impacts on groundwater through groundwater abstraction, as well through changes in land use in recharge areas. Groundwater may be naturally protected against pollution through overlying layers of low permeability, but once groundwater is contaminated aquifer clean-up is complicated and contamination may be irreversible.

The phenomenon of fossil aquifers needs to be mentioned here. These are aquifers in arid regions which are not being recharged under current climate conditions. The groundwater contained in these aquifers is ancient and is a non-renewable resource. Extensive fossil aquifers underlie the Sahara, Arab Peninsula and central Australia with smaller ones found in Southern Africa (Margat and van der Gun, 2013). The use of these aquifers results in groundwater mining, which requires careful consideration between current interests and the needs of future generations.

29 https://urbanresiliencehub.org/

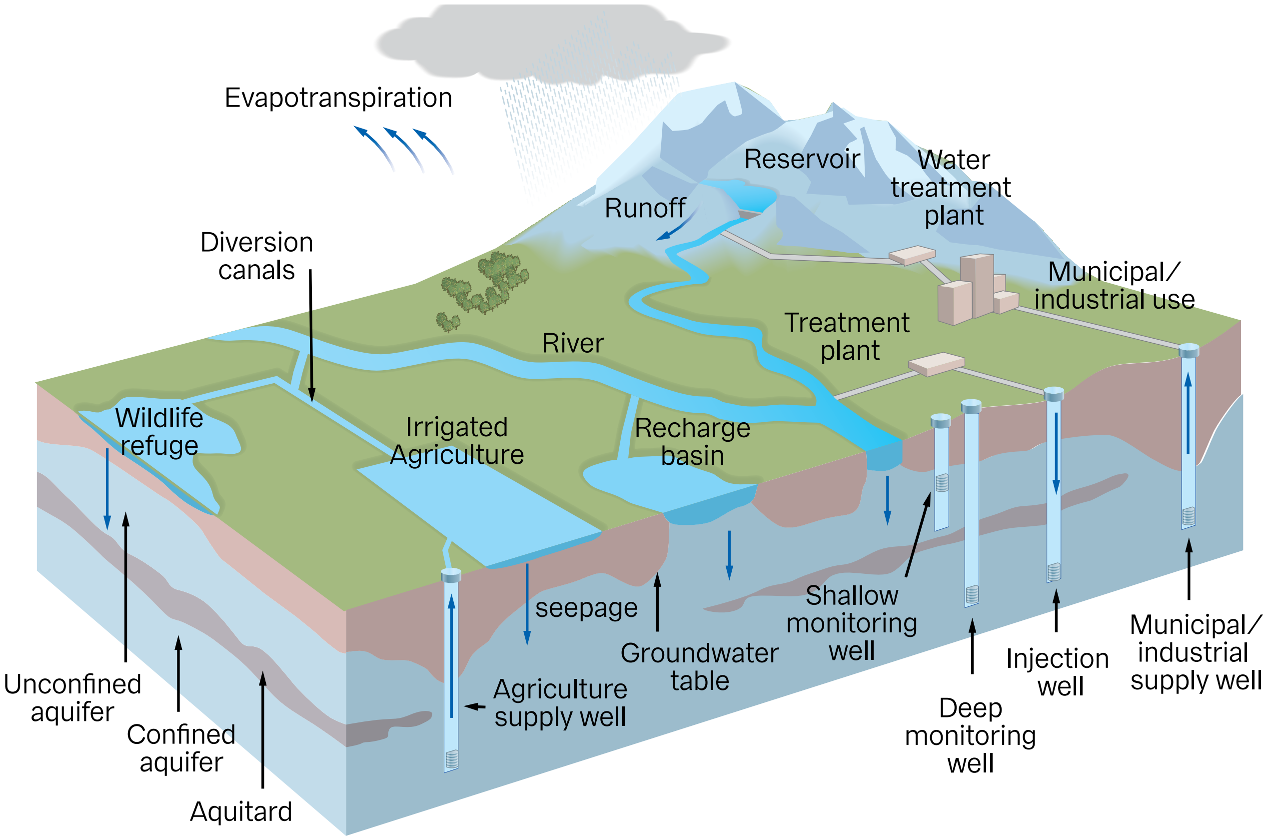


Figure D3 Use of groundwater and surface-groundwater interaction

D.4.2 Main challenges in relation to the SDGs

The main challenges related to IGM are: i) overexploitation of aquifers, ii) land subsidence, iii) contamination of groundwater and aquifers, iv) salinization of groundwater, v) decreasing baseflow in rivers, vi) change in the solidity of soils, vii) negative impacts on groundwater-dependent ecosystems, and viii) issues of inequitable access to groundwater. Addressing these challenges and improving sustainable groundwater management can only be realized by embedding groundwater knowledge and awareness into the broader socio-economic and environmental context.

When preparing an IGM plan, several challenges arise. These can be categorized as i) technical and environmental challenges, ii) socio-economic challenges, and iii) administrative and institutional challenges.

Technical and environmental challenges
The main technical challenge is to understand the various components of an aquifer system, how the groundwater flows, where groundwater can be extracted and how much can be extracted without negatively impacting other interests. Understanding an aquifer system also provides important information about where groundwater is particularly vulnerable to pollution (especially in recharge zones) and where there may be some form of natural protection against pollution. Groundwater can be polluted through, for example, agricultural activities, sewage leaks or industrial practices like (illegal) mining. Aquifers, groundwater flow, and groundwater quality are also all affected by groundwater abstraction and other human activity. The contamination and overextraction of an aquifer system have consequences for other users. Therefore – in addition to understanding the aquifer – it is also crucial to understand who is using groundwater and for what purpose (knowing borehole locations and abstraction volumes is useful here), where activities that may adversely impact groundwater take place and which are the ‘natural dependencies’ on groundwater (e.g., groundwater dependent ecosystems, river base flow, risks of subsidence, etc.).

Socio-economic challenges
Groundwater is widely available and anyone with the capacity to dig a well or drill a borehole is able to access groundwater, at least in theory. This comes with a trade-off: if anyone can access groundwater it is very difficult to manage and regulate groundwater use. Moreover, in many countries the rights to use groundwater are connected to rights of land ownership (i.e., groundwater is ‘privately owned’ rather than ‘collectively owned’), which further limits the extent to which it can be regulated. In addition to issues of resource management, inequitable access to groundwater must be addressed. Poorer communities who

only have the means to access shallow groundwater can quickly lose access when groundwater levels drop as a result of over-exploitation while economically advanced parties can drill ever deeper wells to maintain abstraction rates. An important challenge is also to raise awareness and empower stakeholders with knowledge of groundwater, so that they can put forward communal interests to support sustainable groundwater management and pollution prevention measures. In that way, overexploitation, contamination, conflicts between users and social inequality can be avoided or minimized.

Administrative-institutional challenges

The wide accessibility to groundwater and issues of ownership make it difficult to manage groundwater use. Furthermore, it is crucial to manage potentially polluting activities, especially in recharge zones. This requires cooperation between water management and land use management. The widespread lack of professional groundwater management capacity in water authorities results in the absence of a dedicated governmental authority or department for groundwater management in many countries. Finally, an aquifer system is often a transboundary system that crosses administrative borders. The delineation of appropriate boundaries for a groundwater management plan area is a well-known issue.

Interlinkages with the SDGs

Groundwater has linkages with several targets of the SDGs. Some of these linkages can be reinforcing (good groundwater management helps to achieve the targets) or conflicting (achieving these targets might stress the groundwater system)[30]
. Most linkages are reinforcing such as targets 6.2 through 6.6 of SGD 6 on Water, targets 11.3 and 11.6 of SDG 11 on Sustainable Cities, targets 15.1, 15.2 and 15.8 on SDG 15 on Life on Land. Some targets might be conflicting, in particular the ones that include the increased use of groundwater, for example the food production targets 2.1 and 2.3 of SDG 2 No Hunger. Some other targets might be considered mixed such as target 6.1 (safe and affordable drinking water) and target 11.1 (safe and affordable housing). How much conflict will be involved when attaining the SDGs will depend on how interventions are implemented.

D.4.3 Stakeholders and institutional setting

The stakeholders involved in IGM include groundwater users, possible polluters and those involved in mining or constructing and maintaining underground infrastructure.

Individual groundwater users. Groundwater is often extracted by individuals or small communities. The exact number and locations of groundwater abstraction points are often not known and individual users are often insufficiently aware of the impacts they may have by (over)abstracting groundwater. While there are examples of groundwater user associations, as individuals are often unaware of the importance of groundwater, they may not feel the need to engage with these organizations. This means it is challenging to reach out to individual groundwater users as there may not be formal structures in place to locate them. Consequently, there is a risk of simply overlooking these stakeholders.

Drinking water companies. Drinking water companies extract water from aquifers and, in some cases, use groundwater as an alternative resource for emergency situations. In general, these stakeholders are well-known and their interest in preserving this resource is clear.

Farmers. Farmers use groundwater for irrigating crops and for providing drinking water to their livestock. Groundwater's use is expected to increase as an alternative source of water under changing surface water availability, and changing rainfall patterns due to climate change. Farming practices can also have a negative impact on groundwater quality as fertilizers, pesticides and other chemicals seep through the soil and contaminate the water. Irrigation practices may also be harmful if the water used is of poor quality, as this will also eventually reach the groundwater and/or aquifers.

Industry and mines. Industries abstract large volumes of groundwater for processing and cooling water. Mining is an industry which is particularly harmful for groundwater contamination, especially when exposed chemicals, both those used for mining and those which are a result of the mining process, are left underground. Groundwater is also being increasingly used in the tourism industry, particularly in the hotel industry which uses the water in accommodating its guests. The energy sector has recently started exploring opportunities to use sub-soil for energy extraction and/or storage, which could lead to further challenges.

Nature. Groundwater-dependent ecosystems, including all wetlands, are often the first affected by the impacts of overexploitation or contamination. NGOs like WWF and Greenpeace are striving and advocating for sustainable groundwater management legislation. Their use of social media results in greater awareness of groundwater issues around the globe.

30 Groundwater and Sustainable Development Goals: Analysis of Interlinkages https://inweh.unu.edu/groundwater-and-sustainable-development-goals-analysis-of-interlinkages/

D.4.4 Specific models and data for groundwater

As mentioned above, the lack of adequate knowledge and data on the groundwater system is a major constraint for managing groundwater. To improve this situation, it is important to invest in groundwater monitoring as a pre-condition for modeling the system.

Groundwater monitoring
Groundwater monitoring is vital to assess the state of the groundwater resource and to determine trends in groundwater levels (or piezometric heads) and groundwater quality. Monitoring provides essential information for decision-making processes, which should always be based on sound and validated data. Monitoring should be continued over extended periods of time. This can be done with water level sensors, sampling or passive sampling for water quality, isotopes, tracers, and optic fibers, among others. When monitoring groundwater over extended periods of time, it is possible to:

- Monitor the long-term sustainability of an aquifer as a safe and stable water supply and adopt appropriate policies accordingly.
- Manage groundwater levels and prevent damage by saltwater intrusion, drought or flooding. The groundwater monitoring network provides data on which measures can be designed and provides information about when to adjust the groundwater management plan.
- Identify subsurface contaminants, estimate the speed and direction of the contamination flow and detect the contamination sources.
- Adapt to climate change. The groundwater monitoring network will enable water authorities to timely issue drought or flood warnings and undertake appropriate mitigation measures.
- Understand the ecosystem services provided by groundwater and define strategies to preserve them.

Groundwater modeling
Groundwater models are used to simulate and analyze groundwater flow in and between aquifers. Groundwater flow equations are the foundation for mathematical groundwater models. These differential equations can be solved by approximate methods using a numerical analysis. Examples of numerical codes are MODFLOW[31] and HydroGeoSphere[32] but there are many others. Some groundwater models include quality aspects of the groundwater to analyze seawater intrusion, for example, or to predict the movement of contaminants. Models for predicting variable-density groundwater flows and other features of groundwater systems have been developed such as MT3D, SEAWAT, FEFLOW, and SUTRA. Different tools have been developed to use numerical codes in a graphical user interface. Examples of this are iMOD, GMS, and Visual MODFLOW.

D.4.5 Specific interventions to be considered in groundwater

Groundwater management interventions can be categorized as either technical measures or behavioral measures. Technical measures tend to have a direct impact on the quantity and/or quality of the resource, while behavioral measures are indirect in that they aim to influence human behavior with the purpose of regulating net-groundwater abstraction or preventing groundwater pollution.

Technical measures can be related to groundwater abstraction, groundwater recharge and groundwater remediation. Examples of technical measures are:

- Drilling of wells to provide access to water, for example in a region where many people do not have sufficient access to safe drinking water.
- River-bank infiltration, where abstraction wells are drilled at a short distance from a river and groundwater abstraction induces infiltration of river water. In doing so, use is made of the natural treatment properties of the sediments and so this can bring more advantages than directly using river water. The buffer capacity of the aquifer means that abstractions can continue in periods of low river levels, whilst potential negative effects, such as lowering the groundwater table, are limited due to the infiltration of river water which recharges the aquifer.
- Techniques which augment groundwater resources and thereby decrease net groundwater abstraction and/or increase water availability in the root zone. Relatively simple techniques include the construction of bunds to collect surface water runoff and enhance infiltration, or the construction of subsurface dams to collect groundwater in (dry) river beds. An example of a more advanced technique is large-scale managed aquifer recharge.
- Aquifer and groundwater remediation to clean-up contamination. Examples range from the ‘classic’ physical approach of pump and treat to more advanced approaches that use chemical and/or biological processes to clean contaminated groundwater (e.g., biopharming where oxygen is injected to accelerate the breakdown of pollutants by aerobic bacteria).

31 https://www.usgs.gov/mission-areas/water-resources/science/modflow-and-related-programs
32 https://www.aquanty.com/hydrogeosphere

Behavioral measures include legal, economic, financial and informative instruments (Margat and van der Gun, 2013). Examples of such measures are:

- Registration or licensing of groundwater abstraction, with underlying policies to monitor groundwater usage and regulate groundwater abstractions in order to protect other groundwater-dependent stakeholders (including the environment) from negative impacts. Policies may include delineation of protection zones where no/limited groundwater abstraction is allowed, and requirements to regularly report abstraction volumes and/or monitoring data on groundwater levels.
- Use of groundwater quality protection zones to restrict potentially polluting activities. Groundwater quality protection zones are typically set-up around well-fields for public water supply and in aquifer recharge zones. In addition, more generic rules and regulations can be established to prevent the pollution of aquifers from specific land use practices.
- Taxes on the use of groundwater and fines for non-compliance with regulations can be an effective instrument. Similarly, taxes can be imposed on polluters of groundwater (polluter pays principle) to generate a budget for publicly funded groundwater management interventions.
- Subsidies to enable investments or to (partly) compensate additional costs for alternative, more sustainable techniques e.g., stimulate environmentally friendly practices in agriculture or industry.
- Informative measures can be taken to raise awareness among stakeholders on groundwater quantity and/or quality issues and their own role in how they can or should assist in groundwater management, or to educate stakeholders on new practices that contribute to more sustainable usage and management of groundwater.

Lastly, conjunctive use of groundwater and surface water deserves to be mentioned as this requires a combination of technical and behavioral measures. In this context, groundwater is used to buffer against water supply unavailability when there is high flow variability and drought propensity of many surface watercourses. This measure is especially suitable for the mitigation of climate change impacts, which in many scenarios will lead to increased intensity of droughts.

D.4.6 Further reading on IGM

An excellent overview on groundwater issues and different groundwater management interventions, including examples from case studies, has been compiled by the World Bank's Groundwater Management Advisory Team (GW-MATE) between 2000 and 2010. The publications include a concise Strategic Overview Series, Briefing Notes and Case profiles as well as numerous book contributions. The GW-MATE publications are available from the website of the International Groundwater Resources Assessment Centre (IGRAC)[33].

IGRAC also provides extensive information on the state of the world's groundwater resources and offers access to a number of data sets and documents, including manuals on groundwater monitoring and groundwater assessment and license-free books such as Allan Freeze et al (1979), Margat et al (2013) and Jakemann et al (2016). For more information please see: www.un-igrac.org/downloads. The GWP Toolbox (IWRM Action Hub) provides a good introduction to Groundwater Management Plans (Tool A3.03[34]).

D.5 Marine Spatial Planning

The fully integrated approach of Marine (or Maritime) Spatial Planning (MSP) is a relatively young concept, originating in the mid 2000's. While 'marine' signifies the geographical area and 'maritime' refers to human activities at sea, the scope and objectives are the same. As a term, Maritime Spatial Planning tends to appeal more to economic sectors, while Marine Spatial Planning is perceived to be more inclusive of the environment.

Before the rise of MSP, the planning and management of marine resources and activities had a more sectoral approach, for example fishery management. Multi-sectoral approaches started to appear in the 1990s. Ecosystem-based management (EBM) can be viewed as a predecessor of MSP, taking into account all interactions in an ecosystem including human activity. In fact, EBM is a pillar under MSP. The new concept of Blue Economy (see Box 25), which is not necessarily limited to the marine area, can also be seen as an equivalent to MSP. Although the name 'Blue Economy' may suggest that there is a heavy economic focus, it is actually an integrated approach for the sustainable use of coastal and marine resources.

33 https://www.un-igrac.org/special-project/gw-mate
34 https://www.gwptoolbox.org/learn/iwrm-tools/groundwater-management-plans

D.5,1 Specific characteristics of marine systems

Many coastal seas are located on the continental shelf with gentle slopes of 1:1000 and depths up to 100-200 meters. In other types of coastal sea, the seabed can drop to depths of 500 meters or more at a short distance from the coast. For example, in the Red Sea a narrow coastal fringe of sometimes no more than a few hundred meters wide drops off to a 1000-meter depth a few kilometers from the coastline. The seabed consists of fine sediments originating from continental erosion which has taken place since the last Ice Age. As opposed to a coastal or riverine environment, current velocities in a sea environment are typically (very) low so that there is insufficient energy to keep sediments in suspension and, depending on size, particles settle to the seabed. Wave energy can penetrate the water column to tens of meters during severe storms, but at greater depths sediments are morphologically basically inactive.

Tides do not have a major impact on the seascape. At water depths of tens of meters, a 2 m tide varies the water depth by a few percent and tidal current velocities remain low. For the same reason, sea level rise is not considered a threat to the marine system[35]. However, the residual current is relevant for the net transport and distribution of nutrients, fine sediments, and pollutants. Tidal movements are not symmetrical in ebb and flow stages and therefore the residual current velocity is typically in the order of 1 cm/s. A gyre is an oceanic current system which is formed when a large number of currents work together at a large scale and all move in the same circular direction, although it should be noted that gyres are also influenced by wind patterns and the Earth's rotation. Residual currents in the center of a gyre are near zero which is where pollutants tend to end up. In recent years, much media attention has gone towards oceanic 'plastic garbage patches', most of which are found in gyres.

Marine life depends on organic matter produced by phytoplankton in the photic zone of the water column, i.e., the water depth up to where sufficient sunlight penetrates. Near river mouths, organic matter from river outflow may contribute to organic matter availability. Rivers are an important source of nutrients, particularly nitrogen, phosphorus and silica, necessary for primary production. Far offshore, nutrient concentrations are very low and nutrient availability depends on remineralization and recycling. Upwelling of relatively nutrient rich-waters along oceanic coasts such as Peru results in exceptionally productive fishing grounds.

D.5,2 Main challenges in relation to the SDGs

In general, the main challenges in marine waters are:

- High demand for use of space and resources, especially when bordering densely populated areas.
- Conflicting demands, i.e., different stakeholders or sectors requiring the same space and/or resources which potentially leads to trade-offs in decision-making and, at times, conflicts.
- Increased pressure on the natural system due to high demand by economic sectors. This includes the increased distribution of invasive species as a result of commercial shipping and navigation.
- Climate change pressures such as ocean acidification and temperature rise, impacting natural resources such as fish stocks and natural ecosystems (such as bleaching of coral reefs).

In addition to the natural system perspective, there are institutional challenges:

- There is rarely one leading governmental authority who is solely responsible for a coordinated marine planning process.
- Lack of multisectoral coordination and integration of demands by economic sectors.
- Demands of each nation within its own territorial marine waters impact the resources of neighboring states, potentially leading to transboundary conflicts. MSP therefore also requires cross-border cooperation with neighboring countries since the use of seas and oceans, e.g. fishing and transport, is inherently international.
- Safeguarding the ecosystem is proving to be increasingly challenging. While economic development is the main driver of ecosystem degradation, even sustainably developing and protecting marine habitats and wildlife can pose issues. For example, there is now a new major demand for space in the North Sea as the EU stated in its European Green Deal that a minimum of 30% of

35 Sea level rise impacts shoreline management and shoreline protection and so these are typically included in ICZM, but not MSP.

European sea basins must be marine protected areas by 2030.

The SDG targets are connected through synergistic interdependencies, highlighting the complex interactions between the various social, environmental, and economic dimensions. Given the ocean's central role for coastal livelihoods, biodiversity and climate regulation, meeting SDG 14 'Life Under Water' is essential for the achievement of other environmental (e.g. SDG 12 and 13) and socio-economic SDGs (e.g. SDG 1, 2, 3, 4, 5, 8 and 10).

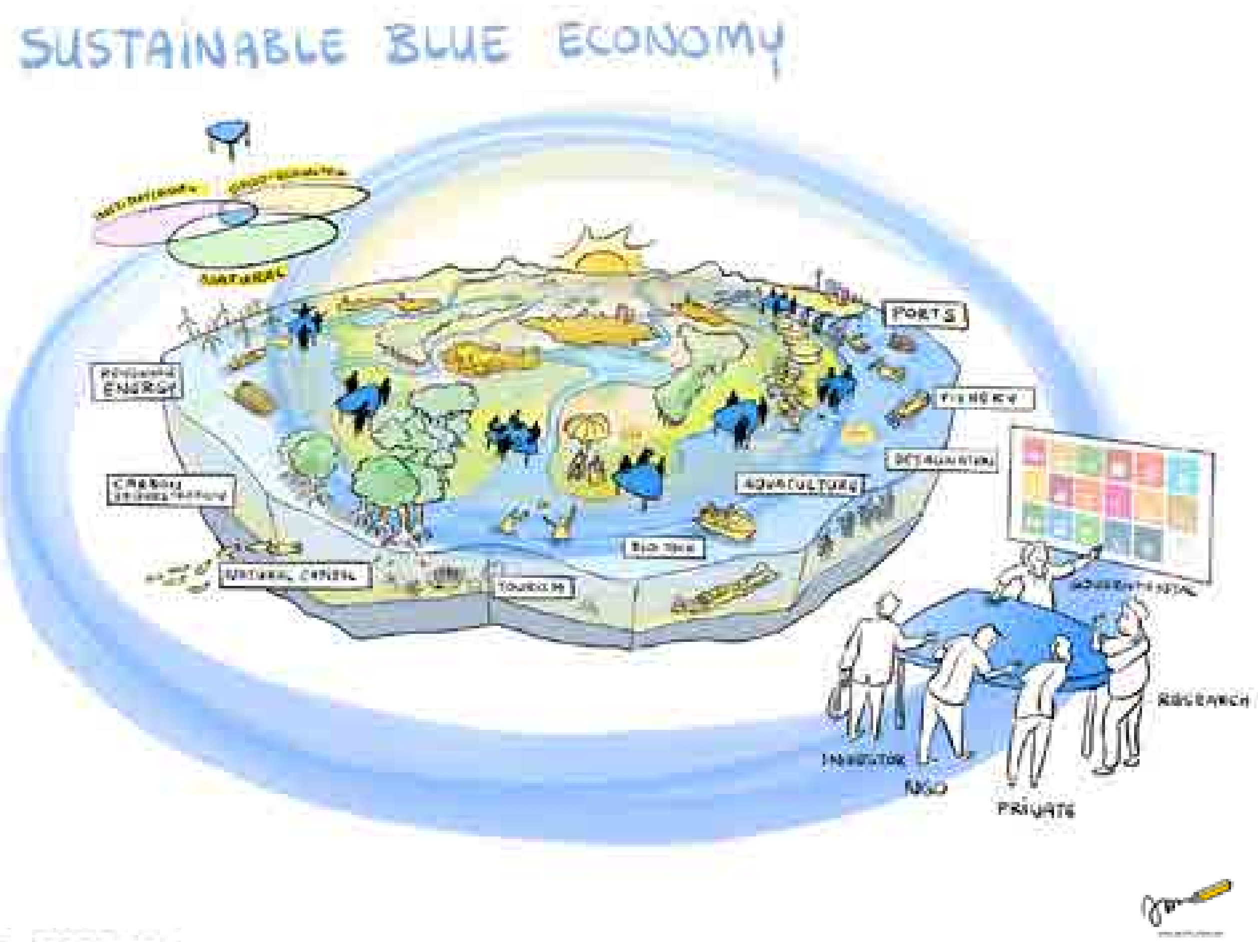
D.5.3 Stakeholder and institutional setting

MSP is now a requirement in the EU for the integrated management of marine resources and space. The principle of ecosystem-based marine spatial planning was introduced with the EU's Marine Strategy Framework Directive (the environmental pillar of EU Maritime Policy) and provides a supportive framework toward marine spatial planning which is designed to improve the environment.

MSP is a holistic process which aims to sustainably address the increased demand for maritime space from different sectors while still safeguarding the functioning and well-being of marine ecosystems. MSP seeks to integrate and balance economic, social, and environmental objectives, moving away from the traditional single sector planning approach. MSP can deliver plans, maps, permits and other policy or management mechanisms that determine the spatial and temporal distribution and co-existence of existing and future activities in marine waters.

Box 25 Blue Economy for sustainable use of coastal and marine resources

The Blue Economy concept was first introduced by Gunter Pauli (2010). In reaction to 2008 financial crisis, Pauli claimed that "the world is in need of a new economic model" (Pauli, 2011). Blue Economy shapes a sustainable economy and society by using nature-inspired technologies, while simultaneously responding to basic needs such as drinking water, food, housing, healthcare and employment. Starting as a predominantly economic-oriented approach, Blue Economy has quickly evolved into a concept in which socio-economic, natural and institutional systems are regarded as equally important. Between 2012 and 2019, many other organizations introduced their vision on the concept, including the World Bank, the Organization for Economic Co-operation and Development, the United Nations, and the European Union.



However, the outcome can also result in non-binding ambitions, visions, strategies, planning concepts, guidelines and governance principles related to the use of the marine space. According to the EU MSP Directive (2014), MSP is a cyclical process that covers the "full cycle of problems and opportunity identification, information collection, planning, decision-making, implementation, revision or updating, and the monitoring of implementation."

Traditionally, key economic sectors are navigation, fisheries and oil and gas exploration. The wind energy sector has emerged as a major player over the past ten years given the transition towards renewable energy. For example, around 10% of the Dutch North Sea may be needed for wind parks. The global shift in dietary practices has triggered a rise in offshore aquaculture, shellfish production and seaweed farms. Non-economic stakeholders include NGOs which advocate for sustainable marine conservation policies and practices.

D.5.4 Specific models and data

Maintaining a knowledge base for managing the sea
An ecosystem is an interdependent collection of individual elements and organisms and the combination of physical, biogeochemical, and ecological processes and interactions. Knowledge about one component provides insight into other components. Therefore, the uncertainty about the entire ecosystem is smaller than the uncertainty about each of the individual components. Quantitatively understanding the ecosystem's processes allows for a comprehensive understanding of the overall picture, and for making predictions about likely future developments. The relative importance of different ecosystem processes will vary according to geographical location and different time scales.

Gaining knowledge about an ecosystem's processes and insight on the problems in a specific area might be a lengthy process. 'Area knowledge' is an important pillar for achieving an integral understanding of ecological dynamics. This knowledge comes from long-term observations, targeted experiments and models, and continuously adjusted interpretations. It should be updated regularly to stay relevant. Monitoring and measuring form an important basis for feeding professional knowledge and area knowledge. In particular, monitoring is needed to obtain continuous time series of standard observations which capture both the current state of the system and the short- and long-term trends. Targeted measurements may be necessary to examine certain aspects in more depth. A monitoring program must not only provide a plan and funding for the sampling, but also for the analysis of the measurements.

Models play an important role in adding to the knowledge base. By means of software and schematizations, ecosystem knowledge is recorded. This can involve simple, conceptual, or statistical relationships, as well as complex ecosystem models. Models capture existing knowledge and formalize hypotheses and therefore interact intensively with area knowledge and measurements. On the one hand, measurements are essential to validate models (i.e., to test hypotheses that are recorded in the models) and for their improvement. On the other hand, models can help to complete measurements, e.g., interpolation routines that supplement holes in satellite images. Models can also play an important role in optimizing measurement programs. Models are also able to deduce which observations best reduce uncertainty in their predictions. Based on this data, models can inform what should be prioritized in a measurement program.

Serious games
A specific kind of tool that can be applied in MSP is a serious game. Serious games are powerful for raising awareness and gaining a common understanding on a topic. The serious game 'Marine Spatial Planning Challenge' is mentioned in Appendix 5.

Blue Economy sector analysis
A Blue Economy sector analysis combines a sectoral approach from the economic perspective with the environmental approach for a sustainable and resilient ecosystem. It relies on an inventory of both the current economic activities and the opportunities for future innovations and/or the need for transition to other sectors. The contribution to the economy is captured in key indicators such as contribution to GDP, employment and income (equality). The use of the DPSIR methodology (Drivers, Pressures, State, Impact & Response) applied to the economic sectors and the natural system to provide an integrated overview for analysis and decision making (Figure D4).

D.5.5 Specific interventions to be considered for marine areas

Multi-use
Multi-use is a solution when two or more users intentionally use scarce space or resources simultaneously. It is a shift from the traditional concept of exclusive resource rights to the inclusive sharing of space and resources. Shared use of marine resources can be spatial, temporal, physical (e.g., infrastructure

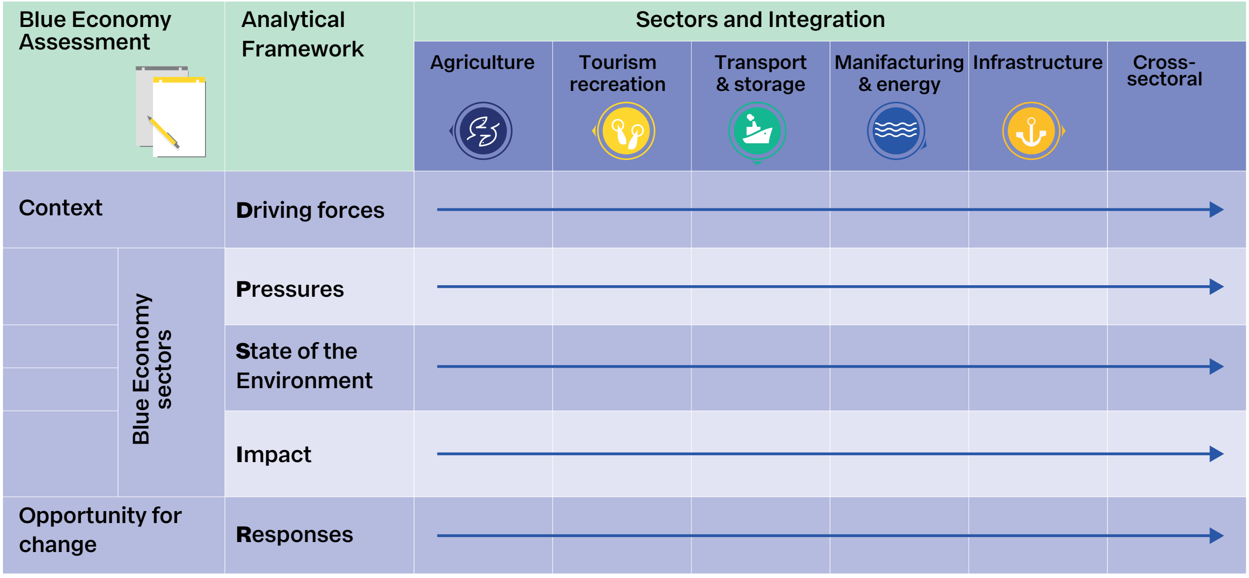


Figure D4 Overview of the steps of the DPSIR assessment framework and Blue Economy sectors

or energy), biological (e.g., sharing of fish stocks) or human (e.g., sharing of personnel)[36]. Multi-use can range from two sectors or users simply sharing the same marine space (co-location), to the sharing of infrastructure, or even sharing their joint activities.

To manage its busy and crowded seas, such as the North Sea, Baltic Sea and Mediterranean Sea, the EU has sought to balance different sectoral interests and marine environment conservation. This is done using its integrated maritime policy, within which one of the principal policies is multiple use. Multi-use approaches are being used at a national level too. The available space in the Dutch North Sea is scarce and in high demand, and so the Dutch government is turning to multi-use to achieve its ambitions of transitioning to renewable energy and food production and conserving nature while solving the country's limited space problem and minimizing the footprint of human activities offshore. To do so, multi-use test sites and pilot studies are being established. The EU's UNITED project[37] is assessing the viability of marine multi-use through the development of multi-use sea farm pilot projects, with the aim of creating a synergy between food, nature and energy[38]. In the Borssele wind farm zone, located 22 km offshore, multi-use has been made possible for aquaculture (including seafood and seaweed), other forms of renewable energy generation and storage (solar and tidal energy), projects promoting nature and biodiversity (e.g., oyster recovery, fish refuges, artificial reefs) and passive fishing (e.g., crab traps and lobster creels).

Reef building and artificial structures
Artificial structures often attract a large variety of biota. Adding artificial reefs (e.g., by the use of reefballs, pipes or even 3D printed reef structures) to the coast is seen as a positive intervention to increase local biodiversity, in particular when these replace or add to natural structures which have been impacted by human interventions. In the North Sea, there are still remnants of stone reefs which were deposited during previous Ice Ages. Many of these stones have been removed to facilitate bottom trawling. Similar activities may be planned in areas where coral reefs have been damaged. In areas with a soft sediment seabed, biodiversity can be enhanced significantly by adding hard substrate with a complex 3D shape. However, adding hard substrate structures in areas where such structures are not naturally present should be considered with care as new organisms will be introduced that could unbalance the ecosystem.

A much less contested addition to habitats is the addition of marine infrastructure, which is generally placed in the sea to serve functions such as energy generation. Offshore wind turbines on sandy sediments tend to be surrounded by stone scour protection to ensure stability. By adding larger stones than necessary for stability and creating large and small holes and crevices, the scour protection can start to attract a diverse ecological community. Such nature inclusive design may locally increase biodiversity, although there is still uncertainty regarding the effects on mobile fish species and the ecosystem as a whole.

36 https://muses-project.com/
37 https://www.h2020united.eu/
38 https://www.northseafarmers.org/

Reef-like structures can be constructed out of stones, concrete or even waste material such as old car tires, but only when there is no risk of leaching of chemicals or shedding of microplastics. Reefs can also consist of biogenic material (e.g., shells and coral). To restore biogenic reefs, some type of initial hard substrate is required to allow larvae to settle. Preferably, suitable settlement substrate should be provided to allow settlement to occur naturally. When species and associated reef structures are functionally extinct in an ecosystem, transferring live organisms can be the only option. In such cases, the risk of introducing exotic or invasive species should be taken into account.

Marine Protected Areas

Marine Protected Areas (MPAs) are considered as an essential and effective tool to protect marine ecosystems and the services they provide. In 2010, the Parties to the Convention on Biological Diversity adopted the 20 Aichi Biodiversity Targets, to be achieved under the Strategic Plan for Biodiversity 2011-2020. Target 11 explicitly mentions MPAs and prescribes that 'at least 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures…'.[39] According to the ETC/ICM Technical Report 2/2017 on Assessing Europe's Marine Protected Area Networks, 'ecological coherence' is a term increasingly used to describe the ultimate goal in the design, establishment and assessment of MPA networks.

The number and status of designated MPA sites varies greatly between countries. Conservation efforts and aims differ between and within countries, and also between individual MPAs. MPAs have a broad range of protection regulations, governance systems and management zoning arrangements (e.g., to control levels of fishing, diving or motorized water sports). At one extreme are 'no-take zones' where no extraction of any kind is allowed and the MPA is well protected from human activity, and at the other extreme are 'paper MPAs' which lack any formal protection measures or enforced management policies, i.e., they are only MPAs on paper and not in practice. The type and variety of protection regulations will influence the overall coherence of the MPA, and the variations in protected species and habitats will impact its representativeness. A comprehensive assessment of the MPA is needed to assess the extent to which it is fulfilling its social, economic and environmental goals and to identify any possible gaps.

39 https://www.cbd.int/sp/targets/rationale/target-11/

D.5.6 Further reading on MSP and Blue Economy

Extensive background on Marine Spatial Planning can be found in the International Guide on Marine/Maritime Spatial Planning (UNESCO-IOC/European Commission. 2021). A framework for Blue Economy with a preliminary set of sustainability criteria and indicators across various sectors can be found in European Climate, Infrastructure and Environment Executive Agency (2021).

D.6 Integrated Drought Risk Management

IDRM aims to mitigate the risk of drought and to build drought resilience by addressing multiple components of drought management, including disaster risk reduction, climate adaptation strategies and national water policies. The Integrated Drought Management Programme (IDMP) of WMO and GWP distinguishes 3 interrelated pillars of Drought Management:

1. Monitoring and Early Warning Systems: It is critical to monitor drought indicators such as precipitation, temperature, soil moisture, vegetation, streamflow and groundwater. Early warning systems analyze these drought indicators and disseminate drought forecasts to key stakeholders in a timely manner.
2. Vulnerability and Impact Assessment: A vulnerability and impact assessment considers social, economic and environmental factors which determine a community's susceptibility to drought hazards. For example, women, children, pastoralists, farmers and marginalized communities could be vulnerable population groups.
3. Mitigation and Response: Drought mitigation includes both structural (i.e., appropriate crops, dams and engineering projects) and non-structural measures (i.e., policies, public awareness, and legal frameworks) necessary to limit the adverse impacts of drought. Drought response refers to the assistance administered during or immediately after the drought to save lives and meet the affected community's basic needs.

An Integrated Drought Plan (IDP) will have to address these 3 pillars in a proactive way. An IDP is mainly produced at national level and can be labeled as the National Drought Management Policy. Compared to the water system plans in previous sections, IDPs have a strong risk orientation and are sometimes called Integrated Drought Risk Plans (IDRP). As a major component of IDPs are the measures taken to mitigate the risks, they can also be referred to drought mitigation plans.

D.6.1 Specific characteristics of IDRM

Droughts are traditionally classified by type as meteorological, agricultural, hydrological and socio-economic. The first three categories measure drought as a physical phenomenon. The last deals with drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socio-economic systems. These types are illustrated in Figure D5.

IDRM planning encourages vulnerable economic sectors and population groups in drought-prone areas to adopt self-reliant interventions that promote risk management and facilitates early recovery from drought through actions consistent with national drought policy objectives (GWP/WMO, 2016). IDRM consists of applying risk-informed decision-making to derive proportionate responses to drought hazards (World Bank, 2019). The IDMP[40] provides a rich source of information (background papers, tools, manuals, etc.) on how to carry out integrated drought management.

Traditionally, integrated drought management is strongly related to DRR. Nevertheless, pro-active approaches are receiving increased attention, including societal transformative approaches aiming at becoming more climate resilient, not only towards climate variability (reconciling water use with its environmental limits or natural endowment) and in dealing with hydroclimatic extreme events (e.g., floods and droughts) but also towards climate change (e.g., resulting in a higher frequency of more extreme drought events).

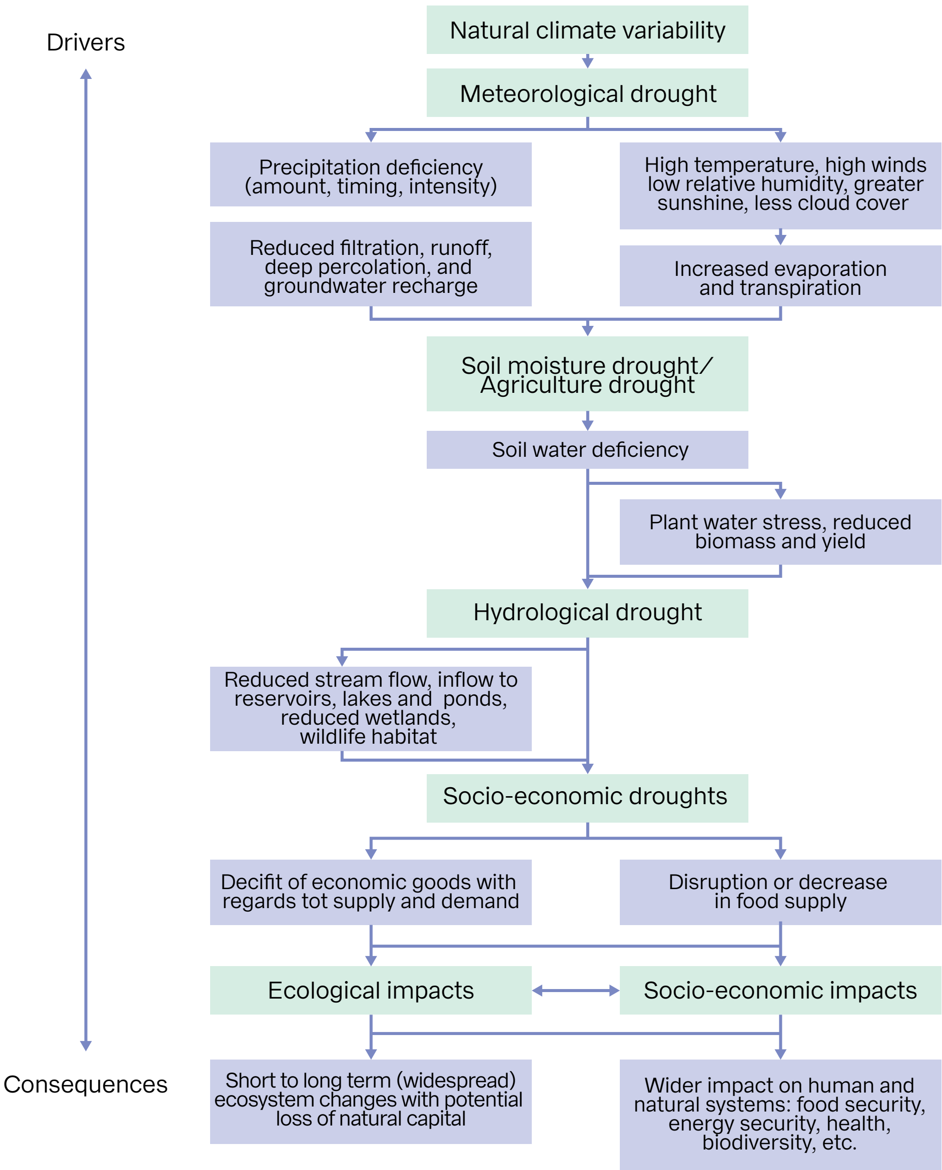


Figure D5 Drought types. • Source: Adapted from Wilhite (2000), HELP Policy briefing paper (2020)

40 https://www.droughtmanagement.info//

Although drought is sometimes perceived to be the 'opposite' of a flood, there is an important difference between IFRM and IDRM. In contrast to floods, drought has a creeping, protracted onset and can persist for up to several years. Generally, it is a period of abnormally dry weather which is sufficiently prolonged by the lack of precipitation, enough to cause a serious hydrological imbalance (WMO 2006). Their timeframes and impacts make the available interventions to mitigate, address, or resolve the two natural phenomena differ. Besides, the way in which drought can impact people, ecology and/or economic sectors varies. Inland shipping, for example, is impacted by low flows while agriculture might overcome dry periods by making use of irrigation, although both will eventually be adversely affected if the drought is prolonged and lasts several months or years. In this instance, priorities will have to be made about water allocation: who gets the water, and when, and how much?

D.6.2 Main challenges and relation to the SDGs

In general, the main challenges in drought planning are:

- High demand for water availability and low supply, especially in densely populated areas.
- Conflicting demands, i.e., different stakeholders or sectors requiring the decreasing water which potentially leads to trade-offs in decision-making and sometimes conflicts.
- Increased pressure on the natural system due to high demand, for example groundwater may be unsustainably extracted to meet people and sectors' water needs.
- Climate change pressures such as increasing rainfall deficit and temperature rise impacting water availability, and subsequently impacting ecology and biodiversity, domestic water use, food security, energy security, navigation and other sectors.

There are also institutional challenges involved:

- Lack of multisectoral coordination and integration of demands by public and economic sectors.
- There is rarely one leading governmental authority solely responsible for a coordinated planning process, even though drought resilience and spatial planning are highly interlinked.
- Drought management is strongly associated with climate adaptation policies which sometimes makes the institutional setting more complicated but also offers opportunities for financing of drought mitigation options.

Drought management contributes to achieving several targets of the SDGs. Drought management will prevent or reduce drought conditions that might constrain achieving SDG 2 (No Hunger), SDG 6 (in particular target 6.1 on providing safe and affordable drinking water), and target 11.5 (reducing the number of people affected by disasters).

D.6.3 Stakeholders and institutional setting

Drought management requires a 'whole-of-society' approach involving a wide range of stakeholders. Stakeholders and their potential roles in drought management include:

- **Governments:** adapt IDRM and water users to the potential impacts of climate change through policies, planning and regulations by following different goals, objectives and requirements, e.g., EU-water related policies or WMO-IHP guidelines.
- **Drought managers and planners** (usually at a river basin or national scale): these are key actors for monitoring, assessments, drought management, and implementation of drought interventions to adopt and/or adapt to drought circumstances.
- **Water utilities:** responsible for the safe and timely distribution of water and other related services, such as wastewater treatment. The utilities can also implement water re-use to close the water cycle and diminish the depletion of water resources.
- **Private sector:** economic sectors, such as the agriculture and hydropower sectors, depend largely on water resource availability and are impacted by water-related extreme events such as droughts. Drought risk management planning could benefit by engaging with economic sectors by creating a wider solution space, leveraging additional capacity and wider support for decisions on interventions like water storage and water efficiency.
- **Civil society and environmental organizations:** ecosystems and communities are vulnerable to changes in magnitude and frequency of drought events. The resilience that ecosystems and communities have to these changes in drought conditions will be enhanced if IWRM principles are followed when the drought management plan is being produced and implemented, as within IWRM the hydrological requirements of ecosystems and communities are considered. As a result, social welfare is promoted in an equitable manner and the sustainability of water-dependent ecosystems and the services they provide is supported.
- **Science and research community:** open data services, model techniques and tools for drought prediction and management will contribute to scientifically credible tools and services that meet stakeholders' needs during the preparation and implementation of drought management plans.

D.6.4 Models and data for IDRM

Historical analysis of drought hazard and impact and predictions on how climate change might influence the probabilities involved are typical datasets that are required for the preparation of the IDRP. Typical activities to derive this information include:

- Hydrological and water balance modeling to determine the probability of drought conditions and water shortages
- Sector or impact modeling that indicate the impact drought conditions have on the users (exposure and vulnerability)
- Drought mapping

For more detailed information, refer to the drought catalog[41] that provides an online catalog of over 200 drought hazard and risk tools that can be used for the main impacted sectors. These tools cover both general overviews and detailed analyses and include:

- Definitions, approaches and data on drought indices
- Models (water balance, impacts)
- Datasets (global, continent)
- Platforms (including early warning systems)

Another major source of information on tools is IDMP[42]. IDMP also provides a HelpDesk on Drought[43] which is supported by the main global knowledge centers on drought. Other valuable sources that have worldwide coverage are the Aquaduct water risk atlas[44] or BlueEarth data[45]. Often, more regional specific data portals exist, e.g., the European Drought Observatory[46], or more sectoral specific data portals, e.g., FAO portal[47].

D.6.5 Specific interventions to be considered for IDRM

Post-disaster actions will always be an important aspect of IDRM, albeit the influence of the Sendai Protocol (see Box 8) means that proactive approaches that prevent drought disasters from happening are receiving more attention. There are two main outputs from the vulnerability and risks assessment that can further inform the identification and selection of risk mitigation or adaptation interventions in IDRM:

- Explore a wide set of options to reduce hazard and/or exposure and/or vulnerability, with the focus on those components that appeared most decisive/sensitive in the risk analysis.
- Depending on the level of confidence in the risk analysis and the potential assessed severity of the impacts, aim for more robust and/or flexible approaches and no-regret options.

It is useful to explore a wide portfolio of options to improve IDRM. Especially for droughts, it is important to focus on building resilience to potential hazards that are likely to occur and realistically cannot be avoided. This is a great challenge for both public and private sectors and requires proactive risk reduction of the exposure and vulnerability to droughts. This can be achieved by:

- Applying the principles of IWRM into related planning, management and implementation processes (see Box 5).
- Prioritizing and balancing different water uses based upon sound drought risk information.
- Establishing flexible governance mechanisms and payment for ecosystem services (e.g., water pricing, public tax) that can be adapted to new realities of uncertain drought increases under climate change.
- Implementing insurance mechanisms that cover residual risks and can improve recovery after droughts for the most vulnerable. These insurance mechanisms should have built-in incentives that stimulate more climate-resilient practices.
- Implementing more and better early warning and response options to weather extremes.

Reference is made to the EPIC Response framework on Floods and Droughts (Browder et al, 2021) for more recommendations on how to improve the governance of droughts.

IDRM strategies should cover a wide range of possible interventions, such as enhancing water supply, improving demand management and establishing fair water allocation mechanisms. Interventions which support the affected population's ability to respond in the short-term and recover in the long-term must also be included. Sayers et al. (2016) suggest the following measures for developing a set of options for drought management:

- Develop a supply surplus and redundancy
  - Use a mix of green and gray infrastructure to enhance renewable supply of water
  - Reduce demand by reducing consumptive use
  - Develop independent water, food, and energy sources to build in redundancy
  - Promote healthy freshwater ecosystems (and hence build resilience)
  - Support the move towards 'drought-ready' communities
  - Support water-sensitive development

41 https://www.droughtcatalogue.com/
42 https://www.droughtmanagement.info/
43 HelpDesk IDMP https://www.droughtmanagement.info/ask/
44 https://www.wri.org/applications/aqueduct/water-risk-atlas
45 https://blueearthdata.org/
46 https://edo.jrc.ec.europa.eu/
47 https://www.fao.org/geospatial/resources/data-portals/en/

- Enable a better response and faster recovery
  - Use short- and medium-term forecasts to take early action so that stakeholders and communities are adequately prepared for the drought
  - Implement prioritization restrictions
  - Provide appropriate compensation and aid through pre-agreed mechanisms
  - Enforce environmental flows and safeguard refugia habitats

Another way to structure the different types of interventions of IDRM is to arrange them from hazard to vulnerability in a risk cascade (see Figure D6). This cascade descends from improved management in the upper ecological catchment down to the individual or household that is impacted. A plan for IDRM will generally include interventions taken from different steps of the cascade.

Low-regret interventions
The drought risk at hand will determine what interventions are most appropriate. Nonetheless, experience has shown that there are a few types of intervention that can generally be qualified as 'low-regret' and offer a good return on investment:

- Establish early warning systems and risk management plans.
- Restore and maintain the functionality of natural freshwater ecosystems and ensure they are safeguarded in local and regional spatial plans and conservation policies
- Regulate and limit "inappropriate" water withdrawals and improve monitoring.

D.6.6 Further reading on IDRM

Considerable literature exists on drought risk management and planning and potential interventions. Reference is made to the following publications:

- On definitions and general approach: Crausbay et al (2017), NDMC (2019), Schmidt et al (2012), UNCDD (2021), UNESCO (2016), Van Loon et al (2016), Vogt et al (2018), World Bank (2019), Aither (2018)
- On governance of drought: Browder et al (2021)
- On regional and specific applications: Europe - EEA (2021), Latin America-Caribbean – UNCDD (2017), drought 2021 - UNDRR (2021)

More information can be found at the website of Integrated Drought Management Planning of the WMO-IHP: see https://www.droughtmanagement.info/ (see also section D.6.4).

D.7 Integrated Flood Risk Management

D.7.1 Specific characteristics of IFRM

The aim of IFRM is for a specific river basin or coastal zone to have a well-balanced, optimal combination of measures available which reduce the risk of flooding to an acceptable level of economic, societal and environmental costs.

IFRM has five key elements:

- Adopting the most effective mix of measures, both structural and non-structural, to reduce flood risk and mitigate the consequences once a flood occurs.
- Managing the water cycle as a whole while considering all types of flooding as well as different flood magnitudes (not just a hypothetical design flood).
- Integrating land and water management, as both have impacts on flood risks.

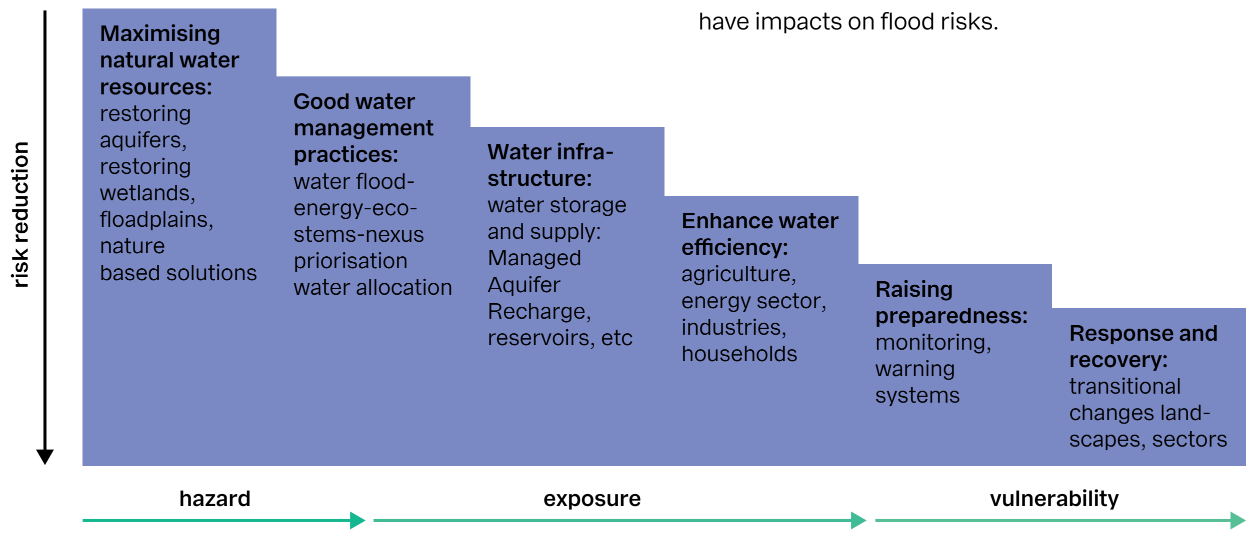


Figure D6 Risk cascade with overview of interventions for risk reduction in drought management

- Adopting integrated hazard management approaches, taking into consideration all flood-related hazards such as landslides, debris flows, mudflows, avalanches, storm surges and tsunamis.
- Ensuring a participatory approach to develop ownership of the strategy and reduce vulnerability.

An IFRM planning study follows the generic phases and steps of the Analysis Framework described in Section C. Due to the risk elements involved in flood planning, certain steps should receive less attention while other steps will require more attention. In countries where the present situation (the base case) is well-known, the emphasis of the study should be on the future situation. As that future situation is unknown, more attention in IFRM studies should be given to the assessment indicators of robustness and flexibility of the alternative interventions and to the development of adaptation pathways.

D 7.2 Main challenges and relation to the SDGs

IFRM is facing several challenges. Notably, climate change is intensifying and will continue to intensify the hydrological cycle. This is expected to result in more extreme rainfall events that will increase the frequency and magnitude of extreme flood events in river basins. Coastal flooding may also become more frequent and more severe due to sea level rise and land subsidence. In other words, climate change is expected to drastically increase flood hazards. Meanwhile, population growth, the need for enhanced economic activity for livelihoods and food security, and the construction of impermeable infrastructure (particularly in urban settings) exert considerable pressure on the natural system and increase the damage potential of flooding, further adding to flood risk.

With arising damage potential, the call for further reduction of flood risk is being increasingly heard. However, absolute protection from flooding is neither technically feasible nor economically and environmentally viable. Even if measures are taken to limit the consequences of flooding, the damage will never be zero. It is therefore vital to be able to deal with residual risk. As such, risk evaluation is one of the key steps in IFRM. It is a societal and policy-making process that addresses the questions of what risk is acceptable and how safe is safe enough. Inputs to this discussion are the results of the risk assessments and the identification of potential measures to reduce risk. The evaluation includes stakeholder views and economic considerations regarding the cost-effectiveness of risk-reducing measures and the acceptability of side effects.

A third challenge is related to social inclusiveness. The poorest and most vulnerable people are generally the most exposed to flooding as they have no other choice but to settle in the flood-prone areas. Yet, the damage to their assets typically only accounts for a small portion of the total damage caused by floods. As a result, measures aiming at reducing the risks for the very poor are less effective when using a cost-benefit perspective. Without adjustments to traditional cost-benefit analyses, there is a risk that IFRM will not contribute to poverty reduction.
Finally, IFRM needs to be part of a truly integrated planning process. Measures aiming to reduce the risk of one hazard should not increase the risk of another. For instance, measures which retain water in dry periods must not increase flood hazards during extreme rainfall events. Conversely, flood measures preferably should not have negative side effects on other functions, such as gray flood protection infrastructure which can lead to erosion or degradation of the natural environment. Decision-making is increas-

ingly becoming multi-dimensional and concerned with resolving multiple, often conflicting, objectives. The challenge thus consists of identifying and exploring innovative multi-purpose solutions.

IFRM contributes to several social SDGs. Flood waters transport bacteria, parasites, and viruses into the clean water system thus leading to outbreaks of waterborne diseases. Flood management may therefore lower the risk of health issues. Controlled flooding can ensure that fertile sediments are deposited on arable fields, while reducing the probability of large-scale uncontrolled flooding which can result in crop loss. Recently, social inclusiveness has received more attention within IFRM. When social inclusiveness is incorporated into IFRM, for example through adapting cost-benefit analyses to be more inclusive, this will contribute to the reduction of poverty as flooding disproportionately affects the vulnerable.

IFRM therefore helps to achieve multiple SDGs: it contributes to good health and well-being (SDG 3), it increases food security (SDG 2) and, when social inclusiveness is accounted for, it reduces poverty and inequality (SDG 1 and 10). To reduce future regret, IFRM not only looks at present flood hazards and risks, but also at future risks, which may increase due to climate change. By considering climate change, IFRM also contributes to SDG 13 'Climate Action'. Finally, by applying nature-based solutions IFRM may also positively affect life on land (SDG 15).

D.7.3 Stakeholders and institutional setting

Stakeholders involved in IFRM include:

- **Governments (national, regional and local):** responsible for flood management planning, including the implementation of international directives such as the EU Floods Directive, and for drafting laws and regulations. In many cases, representatives from different ministries should be involved in IFRM including spatial planning, agriculture, environment and shipping.
- **River managers:** responsible for the day-to-day management of the river and water system (they can be linked to governmental organizations).
- **(International) River basin authorities:** responsible for (international) coordination between stakeholders and preventing different regions of the river (e.g., upstream-downstream) from also suffering from flooding when one area is already being affected.
- **Private sector:** includes all of the economic sectors that can either be affected by floods or can offer measures to reduce flood risk. The hydropower sector can potentially reduce flood hazard by improving reservoir management. Dredgers and companies responsible for sand and gravel mining in and along rivers may contribute to the implementation of nature-based solutions (e.g., supplementation of sand along the coasts or lowering of the flood plains along rivers). However, when implementing measures companies may adversely impact the sustainability of downstream rivers and deltas.
- **Environmental organizations:** this group of stakeholders will all have different individual objectives, but overall they aim to protect and/or restore coastal and river ecosystems.
- **Civil society:** as citizens will be impacted by flooding, they should also be involved in IFRM, especially in discussions about defining socially acceptable risks. Including citizens will also raise awareness so that people are better prepared for a flood, which may reduce the economic damage as well as the number of casualties. Moreover, citizens have specific local knowledge, which can be used to optimize potential measures.
- **Science and research communities:** can contribute to the analyses that are essential in risk-based decision-making, for example by applying data processing and modeling techniques to identify areas which are particularly vulnerable to flood risk, or by developing tools and platforms that help with the dissemination of knowledge and findings, for instance support systems or dash boards.

D.7.4 Specific data and models for IFRM

For managing flood risk, it is important to understand the probability of floods of different magnitudes and their corresponding flood characteristics (e.g., water levels, flood depths, flow velocities), the exposure of different types of assets and the vulnerability of these assets. This means that models, tools and databases applied in IFRM focus on:

- Climate and metrological aspects: what does a 1:10 or 1:100 rainfall event look like (intensity, duration, spatial extent)? What are the probabilities of storms of different magnitudes? What is the probability of a compound event (e.g., extreme rainfall resulting in high river discharge coinciding with a storm surge)? How will the probabilities of extreme rainfall or storm events change due to climate change?
- Rainfall-runoff processes (hydrological models): How does precipitation contribute to increased river discharge? What is the effect of land use changes on runoff? How do urban drainage systems respond to rainfall events of different magnitude? Hydrological models that can

be applied include HEC-HMS[48], SWAT[49] and WFLOW[50].
- Hydraulic processes in rivers and flooding of adjacent flood plains: How will a flood wave travel downstream? What will be the peak attenuation? What areas will be flooded and how deeply will they be flooded? Inundation models often are 2D models, but hydraulic combined 1D2D models are used as well. Well-known modeling software include Delft3D[51], MIKE FLOOD[52] and HEC-RAS[53].
- Coastal water levels and wave heights: How high is the storm surge and how high are the waves that reach the coast? Both will depend on storm magnitude, which may also have to be examined.
- Failure of embankments: What is the probability of failure of embankments and/or other flood protection measures? In what context are these likely to fail?
- Damage to different types of assets: What damage can be expected given the water depths, flow velocities and durations of floods? Several damage models are now being improved to account for combined hazards. In case of coastal flooding, for instance, damage can be caused by both water and wind.

Decision Support Systems (DSS) are frequently used in flood risk management. Originally, their main goal was to support decision-makers. However, in more recent years the goal of DSSs has gradually shifted to enhancing stakeholder engagement for better informed and societally supported decisions. The following types of DSSs can be distinguished in IFRM:
1. Integrated model systems combine data and models into an integrated system in which different models are run in consecutive order.
2. Meta models. A Meta model is a fast and integrated model, intended to mimic the behavior of complex models.
3. Planning Kits for stakeholder interaction (see Box 26).

The main characteristics, potential and limitations of these types of DSSs in IFRM, from both a user and a hydro-informatics perspective, are explained in more detail by Most et al. (2017). See also Appendix 3 for more information on the use of such models in a stakeholder setting.

48 HEC-HMS (army.mil)
49 SWAT | Soil & Water Assessment Tool (tamu.edu)
50 WFLOW - Deltares
51 Delft3D 4 Suite (structured) - Deltares
52 MIKE FLOOD (mikepoweredbydhi.com)
53 HEC-RAS (army.mil)

Box 26 Planning Kits for IFRM

Planning Kits are outcome-based systems which are generally built on the results of numerous simulations with hydrological and hydraulic models. They are used to quantify flood risk and assess the impacts of measures. A Planning Kit enables combining measures into strategies and provides direct feedback on the impacts of these strategies. It typically includes a dashboard from which a user can select measures and learn about the impacts of these measures, including an indication of how well particular targets are being met. The tools do not require any particular knowledge of the flood risk system being studied and can be used by stakeholders and decision-makers who desire different levels of detail.

D.7.5 Specific interventions to be considered for IFRM

Flood risk depends on the flood hazard (flood probability and flood characteristics), but also on the exposure and vulnerability of people and property to flooding. Measures to reduce flood risk may include both reducing the probability of flooding and reducing the adverse impacts of flooding. WMO/GWP (2017) structured the overview of possible measures in a cascade using a source to pathway to receptor approach (see Figure D7). This concept also allows for the distinction between flood hazard (source), pathways resulting in exposure of "receptors" and consequences of flooding to people and property. The cascade does not imply a priority order of taking measures. It only reflects a logical sequence in evaluating them, starting at the source of the flooding.

Flood hazards can be reduced by either lowering runoff (improve infiltration by e.g., afforestation or, in case of urban flooding, by removing impermeable surfaces), or by lowering hydraulic loads, for instance by storing water in reservoirs, restoring wetlands and allowing the river to have plenty of room (see Figure D8). Protection against flooding can be realized by for example, the construction of embankments or storm surge barriers. These are all examples of structural measures. However, non-structural measures should also be considered. Exposure can be reduced by regulating spatial and urban development (i.e., building in areas which are less prone to flood risk), whereas the vulnerability can be reduced by flood proofing buildings. Raising awareness, increasing preparedness and emergency response and the creation of insurance and relief funds may also reduce vulnerability and enhance recovery. A more extensive overview of measures can be found in WMO/GWP (2017).

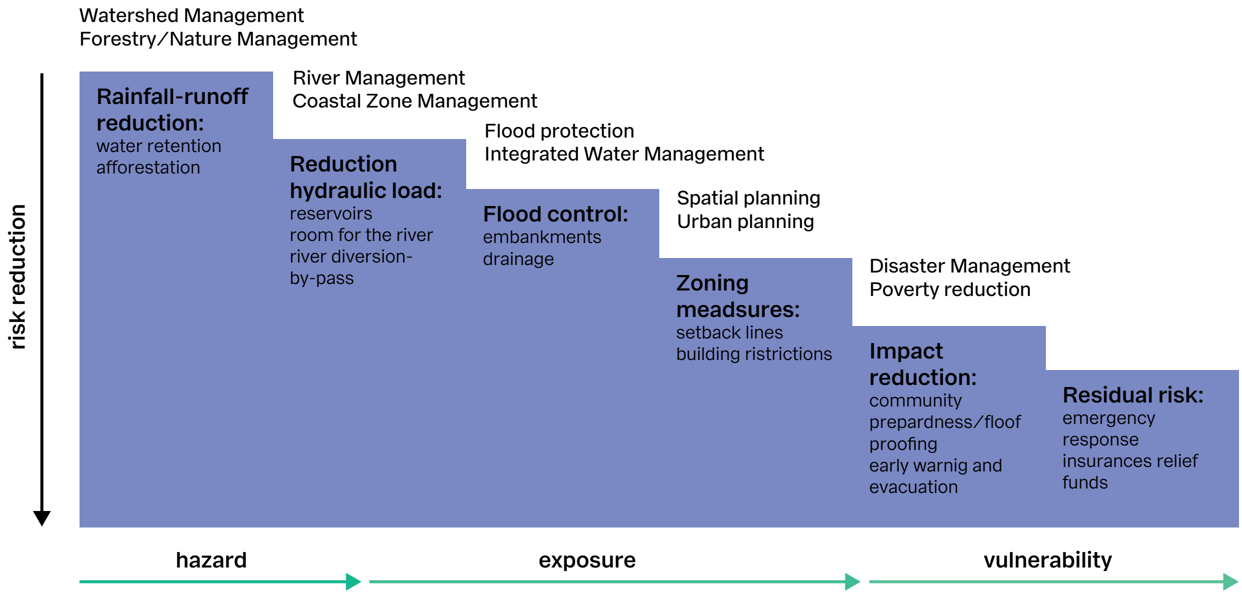


Figure D7 Cascade with potential integrated flood management measures structured using the source to pathway to receptor approach • Adapted from WMO/GWP 2017 and Marchand et al., 2012

Effective measures for reducing flood risk are location specific, as flood behavior and hazard are spatially differentiated due to local geographical conditions. Furthermore, the different magnitudes of flood events will have different impacts on people, property, and infrastructure. For instance, green roofs (moss/sedum roofs and grass/herb roofs) can buffer rainwater up to a point meaning that they are unsuitable for buffering extreme precipitation.

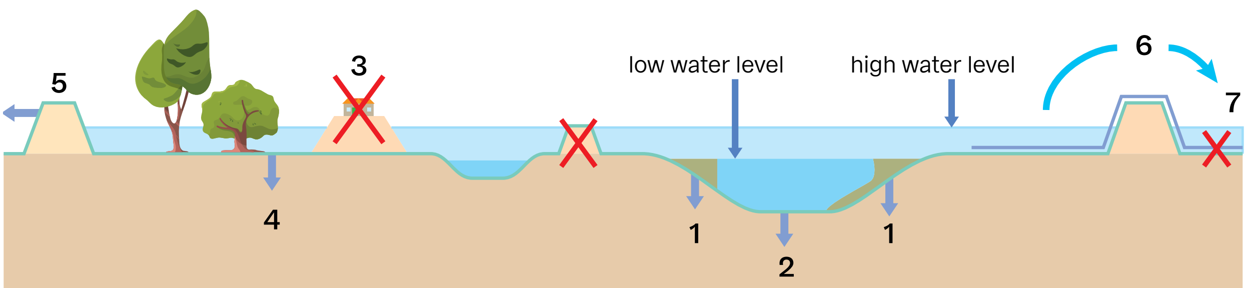
The applicability and success of different types of measures will also be dependent on the socio-economic and cultural context. Hence, there is no single solution to flood risk which can be applied at all locations.

D.7.6 Further reading on IFRM

A major source of information on IFRM is the website of the Associated Program on Flood Management (APFM) of WMO and GWP[54]. APFM aims to support countries in implementing IFRM in order to maximize net benefits from floodplains and minimize loss of life from flooding. The website includes a HelpDesk and contains information on tools, policies, case studies and training manuals. Specific reference is made to the following document:

1. WMO/GWP (2017). Selecting measures and designing strategies for integrated flood management: a guidance document.
2. WMO/GWP (2013). Coastal and delta flood management. Integrated flood management tools series, issue 17.

54 https://www.floodmanagement.info/



1 – lowering of groynes
2 – deepening low flow channel
3 – removing hydraulic obstacles
4 – lowering flood plains
5 – setting back dikes
6 – detention reservoir
7 – reduction lateral inflow

Figure D8 Overview of measures that make room for the river

D.8 Water quality and ecosystem management

D.8.1 Specific characteristics of water quality and ecology

Water quality is not only the result of anthropogenic activities and natural processes, it also affects those activities and processes. In a natural system, water quality is considered good: a healthy water system leads to good water quality and good water quality is a prerequisite for a healthy water system. Anthropogenic activities may alter a healthy water system, by for example straightening and fixating rivers, changing natural water level fluctuations and adding non-natural or excessive natural substances to the water system. Natural water systems have a capacity to purify water, but up to a certain threshold: its carrying capacity. This carrying capacity decreases with a dwindling health of the water system. Water quality does not necessarily have to be like in a pristine condition: it should be fit-for-purpose for the assigned functions. Standards for drinking water are higher than for industrial cooling water. Activities upstream must not cause water quality problems downstream. Industrial discharges upstream may lead to serious water quality problems in the city more downstream.

For water quality and ecosystem management the concept of Source to Sea (S2S) can be applied. S2S, originally coined by the Stockholm International Water Institute, addresses the linkages between land, water, delta, estuary, coast, nearshore and ocean ecosystems in support of holistic natural resources management and economic development. It recognizes the continuum between environmental compartments, which contrasts with often fragmented governance and management of these same domains.
To ensure a sufficient water quality for different activities from Source to Sea, the framework presented can be applied. First the causes of water quality problems and involved stakeholders should be made clear (phase I). Be aware that, depending on the causes of water quality problems and the required water quality, stakeholders could come from different countries. An example of this transboundary cooperation are the Rhine and Danube river commissions. Next, the problem and measures should be described, considering suitable spatial and temporal scales (phase II), like catchment scale and a time horizon of 30 years, including the effects of climate change. In the following step, phase III, different strategies are developed and compared, which result in a strategy like banning of reducing the discharge of certain substances. Next, the full project is evaluated and translated in an investment and action plan (phase IV), like what policies should be adapted to restrict discharge of certain substances or what nature based solutions or more traditional works, like WWTPs, are the be executed. Lastly, the plan is implemented, and effects of the measures are monitored (phase V).

D.8.2 Main challenges ecology and relation to the SDG's

Water quality is facing several challenges: increasing concentrations and number of substances discharged into the environment; growing demand for water as a result of population, agricultural and industrial growth; and decreasing resilience of aquatic ecosystems due harmful anthropogenic activities and climate change. In particular, the increasing concentrations and number of substances are exceeding water systems' carrying capacities, resulting in costly measures to restore water quality to a sufficient level.

The rising demand for water of sufficient quality calls for fewer polluting activities, or conversely that activities find ways to be less polluting. Furthermore, the decreasing area of natural ecosystems means that aquatic WRS are less able to purify water. Climate change may worsen water quality, as higher temperatures and reduced flows lead to lower oxygen concentrations and more phytoplankton blooms.

Good water quality contributes to several SDG goals, as it contributes to good health and well-being (SDG 3 increases food security (SDG 2) and, when social inclusiveness is accounted for, reduces poverty and inequality (SDG 1 and 10). When water quality measures consider the potential impacts of climate change SDG 13 'Climate Action' is also addressed. Finally, by applying nature-based solutions and a S2S approach, good water quality may also positively affect life on land and life underwater (SDG 14 and 15).

D.8.3 Stakeholders and institutional setting

The S2S approach to water quality and ecosystem management should be applied to the work of all authorities involved in the WRS: river basin authorities, groundwater authorities (if they are present, if not this should be incorporated into the work of the river basin authority) coastal zone authorities and finally marine authorities. A challenge in the institutional setting when addressing water quality issues is finding coherence and facilitating cooperation between all of these different agencies. Often, river discharges are a major source of pollutants to the downstream coastal zones and seas, and therefore ICZM and MSP usually rely heavily on measures which take place in the river basin for a good water quality.

Stakeholders include governments (international, national, regional and local) who are involved a river basin authority, such as the Rhine Commission or

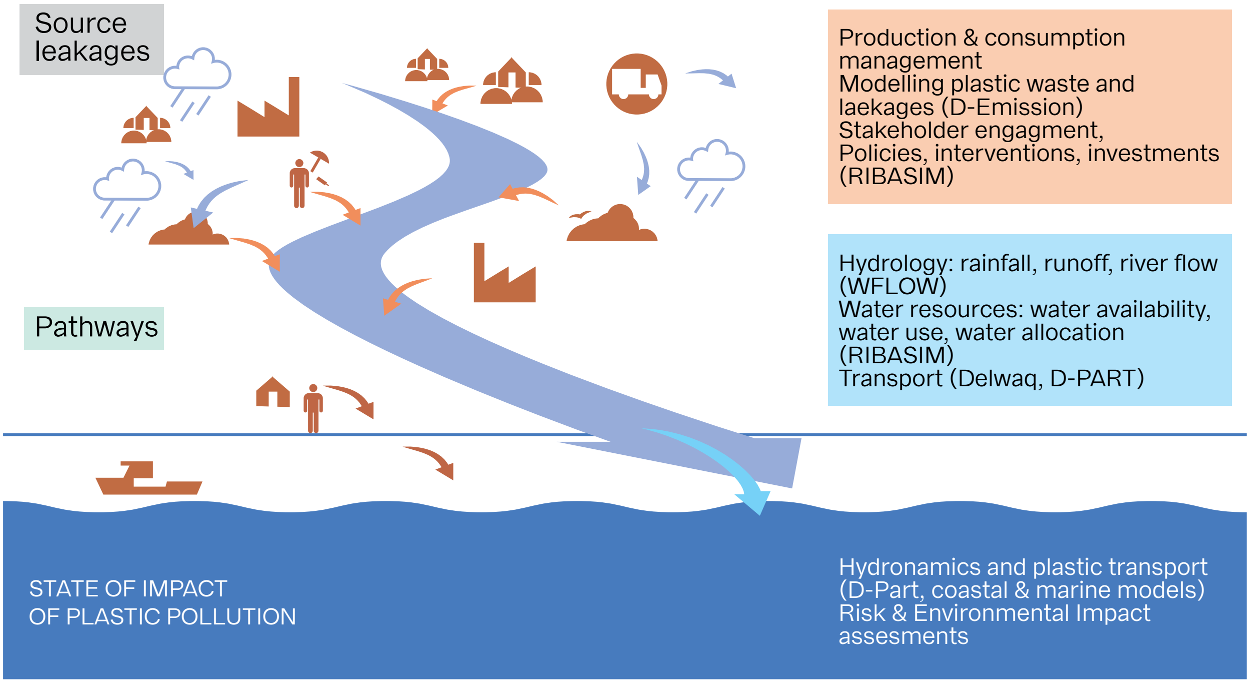


Figure D9 Assessing leakages, hydrological mobilization of plastic litter, state and fate of plastic marine pollution using a "source-to-sea" approach. Methodologies and tools used by Deltares are indicated in the boxes on the right side.

the Danube Commission. The private sector stakeholders include all economic sectors that affect water quality, by either point sources or diffuse sources to the environment, or that rely on water of a quality fit for their use. It depends on the water quality issue at hand which sectors should be included in planning processes. Relevant environmental NGOs aim to conserve biodiversity and habitats which rely on good water quality and social NGOs will focus on lowering the disproportionate impacts of poor water quality (particularly health-related issues) on vulnerable groups. Finally, scientists and researchers provide the data, information and tools necessary for decision-making.

D.8.4 Specific models and tools for water quality

S2S approaches can be applied to assess the how, when and why pollutants enter and affect aquatic WRSs. For instance, plastic pollution can be investigated by encompassing the full journey from its origin (e.g., plastic leakages from land-based sources), to the transport pathways (e.g., via rivers) and finally the inputs and state of pollution in the sea. To model these plastic flows in a holistic and realistic way, a variety of analytical methodologies and tools must be used, such as material flow analysis, and Deltares' hydrological, transport and emission models (Figure D9). The best available data can be used as input for analysis and to validate model outputs.

Knowing the causes of water quality issues and how specific measures may solve these problems is vital. Understanding how different external scenarios (particularly land use and climate change) will affect levels of water quality is also useful here. Therefore, models and tools should (solely or combined) cover some or all of the following aspects, depending on the specific problem:

- A spatial extent to which is large enough to include pathways of substances to and through the water.
- The ability to include emissions of pollutants from land and/or atmosphere and/or water.
- Time dependent water allocation or hydraulics: for example, how is water and its substances being transported through a body of water (surface or groundwater)?
- A water quality module: how are degradable/transformable substances influenced by retention times, other substances, and temperature? In the case of nutrients, phytoplankton should also be simulated.
- An impact tool: how does water quality relate to and affect different aspects in the anthropogenic and natural system?
- A metamodel, touch table or serious game displaying the complexity of the issues and their solutions to engage stakeholders and to support the final plan.

D.8.5 Specific interventions to be considered

Two main categories of interventions can be distinguished: prevention and clean-up. If possible and feasible, prevention is the recommended option. The closer to the source of pollution, the more effectively and efficiently a preventive intervention can be implemented. Prevention measures range from a reduction or change of substance use, such as changing from pesticides to biological pest control, to a complete ban on use. An example of a total ban is the European ban on phosphates in detergents which was implemented in the 1980's.

Clean-up is generally more difficult once the detrimental substances are dispersed in the environment. Wastewater treatment plants can occur as a clean-up measure between the source of wastewater (e.g., households) and the discharge into surface water. Natural purification plays a role in reducing nutrient concentrations and capturing of sediments. However, large areas of water purifying systems will be needed if the pollutant load is high, and generally space is lacking where these high pollutant loads are found (especially in urban areas).

The severity of the impacts of poor water quality depends on the levels of exposure and vulnerability of natural and human systems. For example, when water quality is poor and is used for drinking and hygiene purposes in densely populated areas, this will have different implications from when water quality is poor but is mainly used for navigation. Another example is seepage of water with a poor water quality into a nature reserve vs seepage of water with a poor quality into a highly polluted river.

D.8.6 Further reading on water quality and ecosystem management

Many handbooks exist on water quality and ecosystem management. With respect to environmental flows, reference is made to Arthington et al (2018) and Tharme (2003). For the European Water Framework Directive[55] and their zero pollution approach[56] their websites provide useful information. Eisenberg et all (2019), European Commission (2021) and IUCN (2016) provide a good overview on the use of NbS in water quality management.

D.9 Epilogue

The effectiveness of different water systems' strategic plans has a major impact on the well-being of living species, including on their survival. How well water is managed also impacts the functioning and resilience of ecosystems, the vitality of societies, and the strength and growth of economies. These plans describe the water resources development and management actions that will work best in various situations, both in the immediate future and over a longer period of time. The Analysis Framework and supporting computational framework help to identify and evaluate the effectiveness and adaptability of available water resources development and management alternatives in an economic, ecological, hydrologic and socio-political environment that is constantly changing. The resulting strategies will reflect the concerns and objectives of stakeholders and decision-makers, including local communities which may be the most impacted by water resource mismanagement.

Each water resources system is unique with respect to its management issues and its natural, social-economic, and institutional environments. Project planning and analysis approaches must adapt to these environments. Hence, each project will differ, and will no doubt need to deviate from the suggested guidelines presented in this document. Other approaches are available and may be equally as effective. What remains important in all cases is the establishment of a comprehensive, systematic planning and analysis process combined with constant communication between planners, decision-makers and the interested and affected public. This should result in an improved, more sustainable, and equitable water resources development plan and management policy, appropriate for the region, the environment and its people.

55 https://ec.europa.eu/environment/water/water-framework/info/intro_en.htm
56 https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en

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Apendix 1: Terminology and Definitions

Adaptation: any adjustment made in natural or human systems in response to actual or expected climatic stimuli or their effects that minimizes harm or maximizes beneficial opportunities.

Adaptation pathway: a sequence of measures used to achieve a set of pre-defined objectives under changing external changing conditions, such as climate, socio-economic factors or other developments. Alternative term use: adaptation strategy.

Administrative and Institutional System: composed of the institutions responsible for the administration, legislation and regulation of water systems and who design policies, laws, regulations, procedures and treaties. Also known as AIS.

Base case: the performance of the water system in the base year.

Base year: the most recent year for which a complete set of data is available. The base year is defined as an analysis condition in the Inception Phase.

Civil society: wide array of organizations which are not associated with any level of government or the private sector, including community groups, non-governmental organizations, labor unions, indigenous groups, charitable organizations, faith-based organizations, professional associations, and foundations. Civil society has the power to influence policy-making processes.

Climate change: A shift in the state of the climate that can be identified (e.g., by statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended time period, typically decades or longer. Climate change can be attributed to natural internal processes, external forcings, or anthropogenic changes in the composition of the atmosphere, land use and water system use.

Coastal zone: the area where land and sea meet, including land subject to marine influence and the marine area subject to terrestrial influence. Interactions in this zone come from physical, biological and chemical processes and human activity and interventions.

Cost-Benefit Analysis: a systematic approach weighing all the benefits (from an economic welfare perspective) of a project or policy alternatives against the investment costs

Criteria: A condition or fact used as a standard by which something can be judged or considered. In the Analysis Framework, criteria are sometimes used as an alternative for assessment indicators.

Decision Support System: an integrated suite of tools and impact assessment methodologies designed to understand the physical, environmental, social, and economic implications of the implementation of development scenarios. Decision Support Systems normally include the following: i) a suite of linked numerical simulation models and databases covering flows, floods, water quality, sediments/morphology and saline intrusion, and ii) a set of environmental, social and economic impact assessment methodologies to facilitate the assessment of the wider positive and negative impacts of the implementation of development scenarios, considering external drivers at different time horizons. Also known as DSS.

Development objective: defines what is to be achieved by the planning process and is based on the aspirational development vision of the water system.

Exposure: the presence of people, livelihoods, environmental services and resources, infrastructure, and economic, social, or cultural assets in locations that could be adversely affected by hazards.

Flexible measures: measures that can be adapted (e.g., intensification of the action), abandoned (switch to a different action) or extended (add an action) at low cost and/or with low societal impact. Flexible actions do not result in lock-ins and have little influence on potential future options (i.e., have less path-dependencies). A lock-in is a situation in which a future measure in a pathway can only be implemented at high costs or high societal impact. Path-dependency means a decreased flexibility due to the commitment to certain development trajectories, and limited future alternatives to adapt to unforeseen changes as a result of the infrastructure and the economic and social developments triggered by the investment (e.g., higher costs or limits). Alternative term use: adaptive measures.

Governance: the way society or groups organize to make decisions (e.g., over a resource). Governance encompasses the roles and contributions of the various levels of government (global, international, regional, local), the private sector, nongovernmental actors, civil society, and other relevant stakeholders in decision-making.

Hazard: the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss of property, infrastructure, livelihoods, service provision, and environmental resources.

Impacts: the beneficial or harmful effects of a measure or an event on natural and human systems.

Indicators. Assessment indicators express to what extend the objective has been achieved. As such they are the measuring rods that show how successful a strategy (or measure) is.

Measure: the implementation of a particular action with a clear objective, concrete outcome and output that is narrowly defined in scope, space, and time, and that is measurable, monitorable, and verifiable. Measures can be classified as technical, ecological, economical, regulatory, or institutional interventions. Alternative terms used: intervention, action

Mitigation: the lessening of the potential adverse impacts of physical hazards (including those which are human-induced) through actions that reduce hazard, exposure, and vulnerability. When discussing climate change, mitigation refers mostly to reducing the flow of heat-trapping greenhouse gasses into the atmosphere, either by reducing sources of these gasses or enhancing the "sinks" that accumulate and store these gasses.

Monitoring: systematic and continuous collection of information that enables stakeholders and decision-makers to assess whether an intervention or measure is on target or achieving a set of objectives.

Multi Criteria Evaluation Methods: methods used to identify trade-offs of multiple criteria in a decision-making process with the objective of systematically grading and comparing different development scenarios against defined criteria. Also known as MCEM.

Natural Resource System: the natural system consisting of abiotic or physical, chemical, and biological components, processes and interactions, in both onshore and offshore areas. Also known as NRS.

Nature-based Solutions: measures that make use of natural processes for functional purposes such as the mitigation of floods, droughts and erosion, lowering landslide risk or improving water quality.

Objective: what is to be achieved or how a target is to be met. Objectives identify needs, prioritize issues, and define targets and constraints on possible actions. Objectives may also outline preferred courses of action. Alternative terms used: goals, aims.

Procurement: the purchase of goods or services by a public authority or other organization. This process often involves public tenders.

Project: a measure (or cluster of measures) with the appropriate of implementation arrangements.

Projection: a potential future evolution of a quantity or set of quantities, usually computed using models. Projections are different from predictions, but both involve assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized, and are therefore subject to substantial uncertainty.

Reference case: describes a situation (for a defined time horizon) involving the present infrastructure under the selected scenario conditions and where no new measures are taken. Alternative term used: Business-as-Usual (BAU).

Resilience: the capacity for a socio-ecological system to: i) absorb stresses and maintain function in the face of external stresses imposed upon it (e.g., by climate change), and ii) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future stresses.

Risk: the likelihood of negative alterations in the normal functioning of a community or society due to hazardous physical events interacting with vulnerable social conditions over a specified time period, leading to adverse human, material, economic, or environmental effects (impacts/losses).

Robust measures: measures that result in acceptable indicator values under a wide variety of futures.

Robustness: the ability to remain functioning under a large range of disturbance magnitudes.

Scenario: the environment exogenous to the water system under consideration which cannot be controlled by the decision-maker(s) involved.

Sensitivity analysis: analysis which determines the relationship between variables and uncertainty. It is performed with assumptions that differ from those used in the primary analysis. Sensitivity analysis addresses questions such as "will the results of the study change if other assumptions are used?" and "how sure are we of the assumptions?" Sensitivity analysis is typically performed to check the robustness of the results.

Social inclusiveness: the practice or policy of including people that are affected by the development and management of water systems who might otherwise be excluded or marginalized, such as members of minority groups.

Socio-Economic System: composed of all human economic and social activities that take place in a society or specific area. Also known as SES.

Stakeholder analysis: a planning tool that supports the identification of stakeholders and their engagement. Particularly, this analysis technique supports the task of identifying and, in some occasions, classifying the stakeholders according to their roles, capacities, interests, concerns and needs, as well as their dependencies.

Stakeholders: persons or groups who are directly or indirectly affected by the strategic plan, as well as those who may have interests in the plan and/or the ability to influence its implementation and outcome, either positively or negatively. The term Whole-of-Society is sometimes used to emphasize that stakeholders include not only governmental agencies.

Strategy: a logical combination of individual measures or decisions that accomplishes the stated objectives and satisfies the constraints imposed on the water system. A strategy can be described in terms of (alternative) pathways. Alternative terms used: plans, portfolio plan, portfolio of projects, policy, adaptation pathways. Sometimes the term scenario is used; this should be avoided as scenarios refer to external conditions.

Sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Uncertainty: the degree to which a value or relationship is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty may originate from many sources, such as quantifiable errors in the data, ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgment of a team of experts.

Vision: a clear, high-level aspirational statement about the future based on policy commitments and societal goals. Usually, a vision contains a single clear statement that is easily understandable to a public audience, for example “create and maintain a safe, healthy and sustainable water system for all citizens”.

Vulnerability: the degree to which a system is susceptible to, or unable to cope with, adverse effects of hazards and climate change, including climate variability and extreme weather events.

Water Resource System: the integrated system of the Natural Resource System (NRS), Socio-Economic System (SES) and the Administrative and Institutional System (AIS). Also known as the WRS.

Appendix 2: Stakeholder Engagement – facilitating a Whole-of-Society Approach

Managing water systems is a shared responsibility that requires a 'whole-of-society' effort, involving civil society, the private sector, academia, economic water users such as farmers, and different levels of government. They are all stakeholders, albeit in different ways, and all have an interest in the development and operational management of the water systems, and consequently in the strategic planning for this development and management. Which stakeholders should be involved in a strategic planning process will depend on the specific water system that is being addressed. In general, the stakeholders will be all people and/or organizations that:

- will be affected by the plan; and
- are needed to implement the plan.

An integrated plan and its implementation depend to a large extent on the acceptance and ownership of the plan by decision-makers and stakeholders at national and basin levels. A participatory planning process is therefore indispensable for the sustainable management of water systems. A participatory planning process is the results of a set of steps, as depicted in Figure 1. However, the order of the steps can vary according to the local situation and conditions. The prerequisite for the design of a participatory planning process is a good stakeholder analysis. Stakeholder analysis is a planning tool which identifies stakeholders and considers their levels of interest and influence.

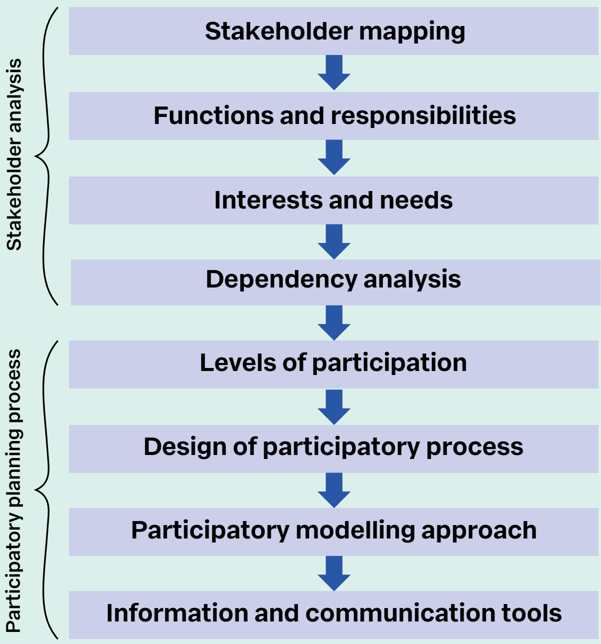

Figure 1 Steps in a stakeholder analysis and participatory planning process

Particularly, this analysis technique supports the task of identifying and, on some occasions, classifying stakeholders according to their functions, capacities, interests, vulnerabilities, concerns and needs, as well as their interdependencies (including the power relations).

2.1 Stakeholder analysis

A stakeholder analysis provides a better understanding of the perceptions, concerns, roles, interests, vulnerabilities and needs of the stakeholders, which in turn allows for the identification of a more effective, long-term solution which addresses causes as well as symptoms. It also helps to reduce the possibility of forgetting important risks, especially those which affect vulnerable groups who may not normally have much political agency. Finally, this technique increases the likelihood and willingness of the various groups of stakeholders to cooperate with each other when solving problems and issues.

A good stakeholder analysis should contain the following steps:

1. Situation analysis as point of departure.
2. Inventory of the stakeholders involved (e.g., primary, secondary and tertiary stakeholders).
3. Mapping of formal relations according to their functions and responsibilities.
4. Inventory of interests, perceptions, vulnerabilities and needs.
5. Mapping of interdependencies and power relations.

The outcome of the stakeholder analysis is the stakeholder interdependency matrix as demonstrated in Figure 2. Based on these results, the participatory planning process can be defined.

2.2 Participatory planning process

Once the stakeholder analysis has been conducted, the first step in the participatory planning process is to determine the levels of participation of the various stakeholders. The level of participation of each stakeholders group will vary depending on the maximum level of participation desired by the study's client. The second step is the design of the participatory process. This will be heavily influenced by the agreed levels of participation and stakeholders involved. The design of the participatory process needs to take into account the modelling approach (informed decision-making) so it is carried out in a participatory manner (step 3).

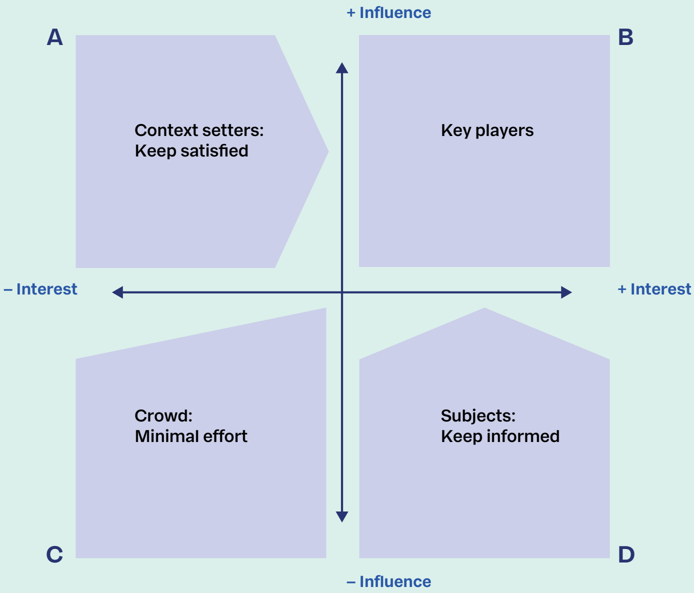

Figure 2 Stakeholders Interdependency Matrix

Finally, as illustrated in Figure 2, the design of the participatory planning process needs to consider the information and communication tools used for disseminating and communicating information to the various stakeholder groups.

Levels of Participation
The various stakeholders are grouped into the different levels of participation according to the outcomes of the stakeholder analysis, as illustrated in Figure 3:

- Ignorance: stakeholders are not aware of what is happening;
- Awareness: stakeholders are aware that something is happening;
- Informed: stakeholders are supplied with one way information, and may be able to act on this on an individual basis but have no formal option to provide feedback, negotiate or participate in the decision-making process;
- Consultation: stakeholders are asked to provide information inputs to the planning process. Information flows are likewise one-way, but in the opposite direction, i.e., information is extracted from these stakeholders but there is no commitment relating to its use;
- Discussion: stakeholders fully participate in two-way dialogues and are asked to give advice and recommendations. Here, information flows in both directions between stakeholders operating with different interests and levels of influence, and also between the stakeholders and the analysis. Since two-way interactions occur, there is room for alternative ideas, solutions and/or strategies to emerge;
- Co-Design: stakeholders are actively involved in problem analysis and problem design, which fosters ownership, although do not have formal decision-making powers;
- Co-Decision-Making: stakeholders have decision-making powers, leading to their empowerment with respect to the policy/planning decision taken. Typically, decisions in these contexts emerge from a process of stakeholder negotiation.

The first few levels (from Ignorance to Consultation) could be thought of as top-down management/planning approaches towards participation, where stakeholders have little control over the decision-making process. The final three levels are more appropriately considered as bottom-up approaches towards participation as stakeholders are much more active and have more control over the decision-making process.

Design of the participatory planning process
The design of the participatory planning process and the data and modeling tools used are important aspects to consider in water systems planning frameworks. Participatory planning tools and techniques enable participants (stakeholders) to influence development initiatives and decisions which affect them. The tools promote knowledge sharing, can enhance stakeholder commitment and empower the groups involved to develop sustainable long-term strategies.

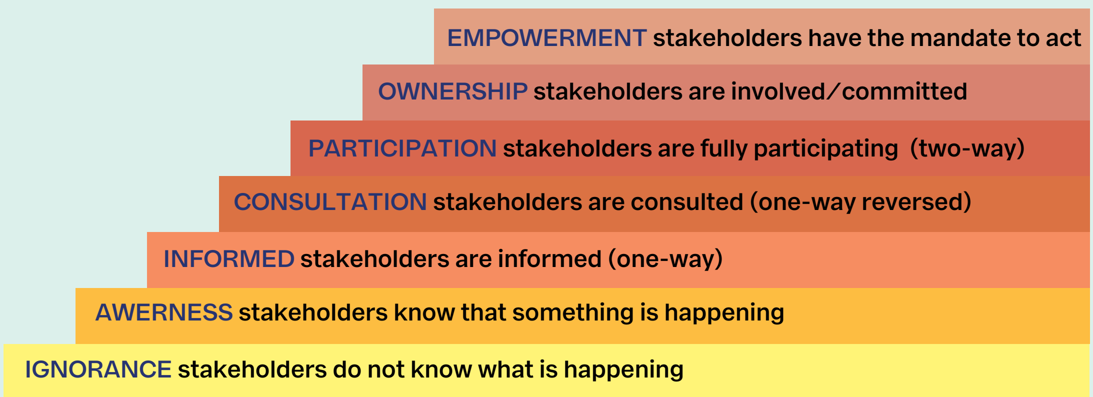

Figure 3 Levels of participation

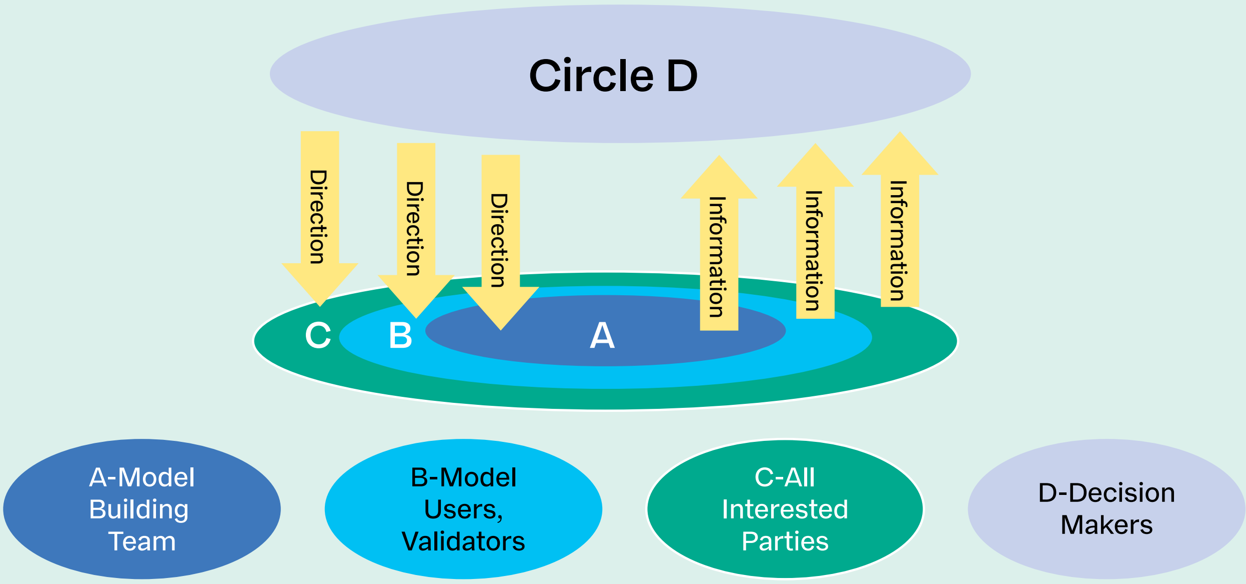

Figure 4 Participatory planning structure based on Circles of Influence • Source: Cardwell et al, 2008

The participatory and informed planning process makes use of the "Circles of Influence" model (Figure 4) which structures participation so that numbers of stakeholders are limited within reason but without taking away the influence of specific groups (Cardwell et al, 2008; Bourget L. (Ed), 2011). Under this model, trust is developed in concentric circles; planners and managers work to develop trust with leaders and organizations which already have the trust of other stakeholders. To elaborate, those most directly involved in policy analysis activities (i.e., planners, managers and modelers, Circle A) communicate with trusted leaders and major stakeholder representatives at the next level (Circle B). These stakeholders provide a trusted link to all other interested parties, who have much less direct involvement (Circle C). Ideally, Circle B participants would be active in professional or issues-oriented organizations and provide connections to others whose interests they represent. Hence, Circle C stakeholders should see their interests represented in Circle B and have formal opportunities to shape the work of Circles A and B via these representatives. The levels of involvement of those stakeholders in Circle C can vary from Awareness to Consultation. The fourth circle (Circle D) includes decision-makers such as agency heads and elected officials who have the authority to accept or reject the recommendations of the policy analysis. For a good participatory and informed planning process, stakeholders should be clearly identified and engaged throughout the planning process with direction and information flows to and from all circles.

Other aspects to be considered for the design of the participatory planning process are:

- Timing of stakeholder involvement. This will be dependent on the Circles of Influence and levels of participation.
- Stakeholder participation in the modeling process (Participatory Modeling). The stakeholders in Circles A and B will be regularly involved in some of the phases of the modeling process. The involvement can be concentrated in i) early and later phases of the modeling process, ii) construction of the model, iii) some of the activities prior to model construction, or iv) once the final model has been built.
- Type of stakeholder involvement. This can be either individually, in homogeneous (stakeholders with similar interests and problem perceptions) or in heterogeneous groups.
- Information and communication tools. Information dissemination (e.g., face-to-face workshops or online platforms) and communication tools need to be adapted so that they are accessible to the various groups of stakeholders. This is particularly important for participatory model construction and use, as well as for the promotion of the plan. The selected marketing options for creating awareness, enthusiasm, and support for projects within the action plan will vary depending on the results of the stakeholder analysis (Figure 2) and levels of stakeholder involvement (Figure 3). For more information about plan promotion, see below.
- Consideration of vulnerable groups. Knowing (im)possibilities of participation of vulnerable groups in the participatory planning process provides insight into possible gaps in outcomes and in evaluation of possible initiatives to obtain relevant input in alternative manners.

Information and Communication Tools

Once a plan has been translated into bankable projects (Phase IV of the Analysis Framework), an important step is to increase the influence of stakeholder groups

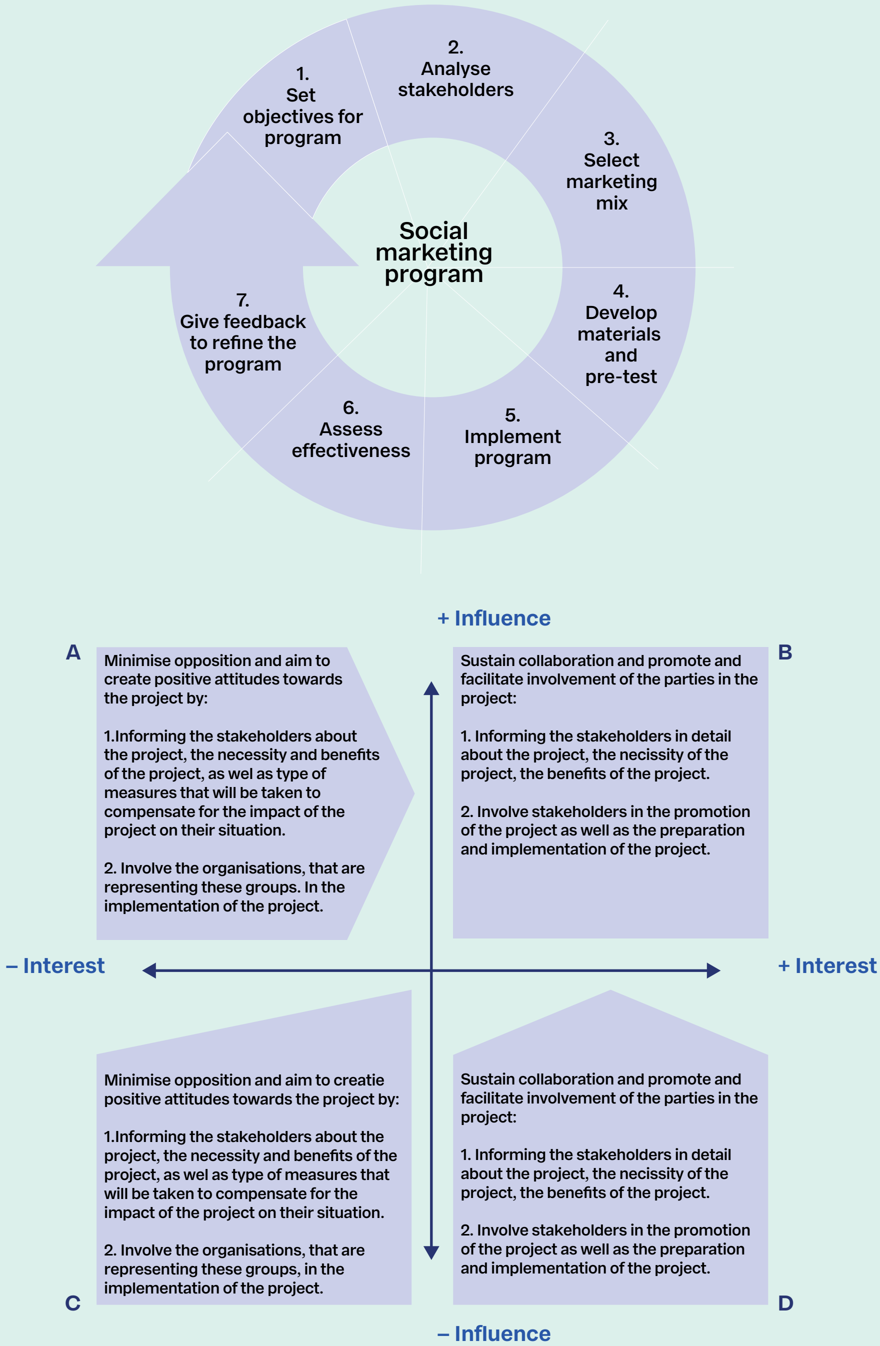

Figure 5 Social marketing program and underlying strategy

which favor its implementation but lack influence, to change the attitude of influential groups which oppose implementation and to use the positive attitude of influential groups which are in favor of implementation. The results of the stakeholder analysis are used for the identification of such stakeholder groups. In Figure 5, the influence-interest matrix is presented. It highlights the strategy used for project acceptability and/or appreciation, and therefore smooth implementation.

To create maximum awareness, enthusiasm and support for selected projects within the plan, selected stakeholder groups need to be provided with the right information. Additionally, involving a selection of stakeholders in project preparation and implementation will assist in boosting their enthusiasm towards the project. To do this effectively, a mix of marketing options can be used. Appropriate marketing options might be:

- Mass one-way communication for the general public (such as newspapers, radio, television and billboards);
- Selective one-way communication for selected stakeholder groups (such as direct mail, brochures with more specific information tailored the selected group); and
- Personal two-way communication between the project promoters and selected stakeholder groups (educational method, outreach methods or more risky word-of- mouth method).

Another communication best practice includes public disclosure (e.g., via a website) of key project documents. A series of public consultations is typically the minimum requirement of many financing institutions.

2.3 Social inclusiveness in water management

Inclusiveness can refer either to a criterion for organizing decision-processes so that all relevant stakeholders are adequately involved, or the universal and substantive realization of rights so that all can live with dignity. In this regard, the World Bank argues for the benefit of differentiating between inclusiveness as a process and inclusiveness as an outcome. As an outcome, inclusiveness refers to the full enjoyment of economic, social, political and cultural rights providing everyone (including and especially disadvantaged and vulnerable people) with a standard of well-being considered normal in the society in which they live. As a process, inclusiveness regards the efforts which are made to ensure equal opportunities for all to participate in the decision-making processes which affect them, particularly those in a disadvantaged position. Therefore, integrated water system management should be arranged as an inclusive planning process that leads to inclusive outcomes. An inclusive integrated process is the one where all people feel valued and their differences and perspectives are respectfully acknowledged and fairly addressed, while their basic water rights are met so they can live in dignity. The result should aim at reducing inequalities in access to water in particular and increasing social welfare in general. Water security should be achieved in an inclusive manner as water insecurity should be perceived as an issue that affects everyone, not just the few.

Integrating social inclusiveness into a project entails considerations that influence how the water system is analyzed as well as on how the stakeholder engagement is executed. Dialogue should address topics such as the position of vulnerable groups, how they perceive the problem and/or project and how they might be affected by its outcomes. Particular attention should be placed on the role of power relations in decision-making processes, and how methodological choices might reduce or reinforce power imbalances between groups with competing interests. Essentially, an inclusive water system planning process is about giving people a voice in decision-making that may otherwise be unavailable to them. Furthermore, inclusiveness leverages diversity as an asset rather than a barrier to development and water security (Talmage & Knopf, 2017).

There are several resources that can guide water managers in articulating how water resource planning can be affected when not everyone's human rights are realized. Those include the Guiding Principles on Business and Human Rights (OHCHR 2011), and the Voluntary Guidelines of the Governance of tenure of land, fisheries and forest (FAO, 2012). The principles of business and human rights call water managers to place an emphasis on human rights due diligence, as well as advocating for the setting up of a process and criteria for dealing with grievances that may arise from proposed measures and strategies. These principles are further developed in the Gender Dimensions of the Guiding Principles on Business and Human Rights (OHCHR, 2019). Voluntary guidelines on tenure governance can clarify the fairness criteria for assessing who can use natural resources, for how long, and under what conditions. This helps with structuring discussions about resource use, including rights, duties and social accountability. Prioritizing and realizing human rights should be understood as a fundamental goal in IWRM.

2.4 Stakeholder involvement and social inclusiveness in the Analysis Framework

The term 'stakeholder participation' also covers the need for inclusiveness in developing and managing water systems. The call to pay more attention to inclusiveness emphasizes the importance involving everyone in these activities – in fact, 'leave no one behind' is the central principle of the SDGs. Social inclusion is defined by the UN[57] as the process by which efforts are made to ensure equal opportunities so that everyone, regardless of their background, can achieve their full potential in life. Social inclusiveness is already mentioned section A.4 as an important element to be taken into account in the planning process and is also included in the Analysis Framework in Section C. A more detailed description on social inclusiveness offered below, beginning with a section on the pre-project phase and then focusing on each of the Analysis Framework's phases (sections 2.4.2 to 2.4.6). Each section includes a checklist of activities which must be undertaken to attain inclusiveness as output and as a process.

2.4.1 Pre-project, Terms-of-Reference and contract negotiation

Before the actual planning activities take place, the potential planning organization or consultant should assess if the conditions specified for the planning

57 Social Inclusion | Poverty Eradication (un.org)

Inclusiveness as an output
• Define with local partners or parties of the consortium what social inclusiveness could mean in the project and how this should best be framed. • How is the project positioned in the broader local context and what are the hot topics around inclusiveness (e.g. livelihoods in risk, women rights, irregular settlements with no access to water)? • How can international policy frameworks such as the SDGs, Sendai Frameworks, European Water Directive, etc., provide an entry point for a stronger socially inclusive • process and outcome? • Analyze if and how you can impact the level of social inclusiveness in the proposed or suggested deliverables. Is there enough budget for an inclusive approach?
Inclusiveness as a process
• Analyze the barriers for carrying out a social inclusive stakeholder engagement. Is the client prone to endorse an inclusive decision-making process? • Assess the possibility of the early involvement of local partners to set the precedent for inclusive stakeholder engagement and social dialogue. • Ask for clarifications of the ToR in the case there is not an explicit ambition on stakeholder engagement or social dialogue. • Upon that clarification, make a statement in the proposal (as methodology or recommendations) about options and limitations with respect to required resources, impact assessment and planning for an inclusive process. An inclusive approach requires that people have access to situations in which they can share their views and perspectives.

Table 1 Inclusiveness checklist in pre-project phase

project (e.g., in a project description or in a ToR) allow for the sufficient integration of inclusiveness. If the conditions are insufficient and are unable to do so, the potential planner might decide to reject the project or discuss the possibility of adjusting the conditions so that inclusiveness is able to be appropriately incorporated into the project during contract negotiations. Table 1 provides a checklist with further points of attention.

2.4.2 Phase I. Inception

The Inception Phase is crucial for creating the space necessary for successful social inclusiveness in the planning project. This might include the revision of the ToR. Intensive communication with the decision-maker and/or client should include how the process will address accountability, transparency and inclusiveness. This should also include open communication on the resources needed for an effective and inclusive stakeholder engagement. Incorporating those impacted by a project within the planning process the long-term legitimacy of the plan for those who ultimately fund water measures – citizens as taxpayers or direct beneficiaries. The discussion on stakeholder engagement should include a definition of the principles for addressing eventual grievances, compensation, trade-offs, and conflicts (especially when there are differing values or beliefs). Early involvement of social groups who will be impacted by the strategy will improve the quality of the operational objectives' benefits.

An important point of attention is that the operational objectives which are defined in this stage should include target disaggregation to explicitly mention inclusiveness outcomes, as well as indicators relating to inclusiveness as a form of monitoring the success of these objectives. Table 2 provides a checklist with further points of attention.

2.4.3 Phase II. Situation Analysis

This Situation Analysis phase will benefit hugely from the feedback of an inclusive stakeholder engagement process. A detailed disaggregation of the indicators will highlight the impacts on the most vulnerable groups. The involvement of the stakeholders and vulnerable social groups in collecting data will make the description of the problem, both present and future, more accurate, comprehensive and meaningful. The task of communicating the information gathered in this stage should be assumed by the planner/analyst, who must strive to make knowledge of the project accessible and understandable to all stakeholders involved. The level of detail will have to be adapted according to who is receiving the information.

An important element of the Situation Analysis phase is the understanding of the system. This requires a detailed inventory of social actors feeding the socio-economic analysis. The socio-economic analysis must include all uses of water in social activities, some of them with economic value and others with non-transaction value. An inclusive SES analysis makes explicit the rights that will be compromised if certain quantities and/or quality of water are not available or regulated. An inclusive AIS analysis comprises two elements: clarifying tenure systems and maps of actors. Knowledge of tenure systems facilitates a greater understanding of the reasoning behind water allocation and use. Actor maps provide an understanding of power asymmetries and dynamics, which should be observed when giving a voice to those

Inclusiveness as an output • Agree on the definition of social inclusiveness for the project with the client in terms of process and outcomes. • Always clarify that the client is the public authority, and they will not lose control of stakeholder engagement nor social negotiation. • Openly discuss the possibility that the final plan and measures might have negative impacts on communities." Also "grievance mechanisms" plural. • Discuss and help the client to be aware that most of the water objectives should contribute to inclusiveness as an outcome. If this has not been considered, define social outcomes as human health, social well-being, improved social dynamics and lower levels of conflict. Ensure the client appreciates the non-transactional values of water (cultural, emotional and spiritual). • Identify indicators that can better illustrate the inclusive approach, such as disaggregating information by social groups or geographical areas.
Inclusiveness as a process • Discuss with the client the benefits and risk of an inclusive engagement of stakeholders, including the early involvement of stakeholders in setting objectives. • Analyze the effects of power relations on decision-making processes and negotiate on resources needed for inclusive data and information collection and inclusive stakeholder engagement • Bring to the client the need to clarify in advance the mechanisms for introducing transparency, accountability and inclusiveness. • Utilize experiences from elsewhere, including examples when there was some resistance to inclusiveness in the early stages but this paid off at the end of the planning process. • After making explicit that current objectives might overlook some unequal access to water and sanitation rights, bring into discussion the consideration of vulnerable groups in the specification. • Insist that an inclusive stakeholder consultation provides a solid basis for testing the relevance of the indicators.

Table 2 Inclusiveness checklist in Phase 1 – Inception

who otherwise may not be able to be heard.

The situational analysis will also benefit from participatory scenario planning, for example to consider the relationships between urban segregation, social equity and economic growth. Quantifying problems should always be made accessible to the most vulnerable, which might require translating numbers into narratives as to how people will experience impacts on their livelihoods.

The screening of potential measures should draw a difference between legality and legitimacy. The main criterion for assessing legitimacy is the extent to which a measure might compromise peoples' livelihoods and rights without fair compensation, essentially asking whether it compromises human rights due diligence). It should be noted here that human rights due diligence always requires an inclusive stakeholder engagement process. When defining low-regrets, the precautionary principle should apply if there is an indication that the measures might negatively impact the livelihoods, well-being and rights of people.
The progress report should include an early warning system of measures that can have unintended consequences on livelihoods, well-being and people's rights.

Inclusiveness as an output • Establish the inclusive stakeholder engagement process as a setting for gaining more insights into the system, while providing an opportunity to give a voice to those who otherwise may not be heard. • Evaluate if findings still align with the defined project objectives.
Inclusiveness as a process • Be aware that your social responsibility is to provide a deep understanding of the role of the water system to stakeholders, including discussing how the water is used by those with conflicting values or interests. • An inclusive situational analysis includes a more detailed social map, a greater understanding of the resource tenure systems and knowledge of how water is valued in the local context beyond its productive/economic dimensions. This is a part of the analysis of the socio-economic system. • Apply stakeholder engagement strategies that reduce the effect of power relations on data recollection (separate groups; create trust; citizen science) • Communicate findings. Making an effort for linking (testing/contrasting) with science. • Apply human rights due diligence when screening projects and ensure low-regret measures which heavily impacts livelihoods, human rights and tenure rights are not included.

Table 3 Inclusiveness checklist in Phase II – Situation Analysis

Table 3 provides a checklist with further points of attention.

2.4.4 Phase III. Strategy Building

The Strategy Building phase should be an open consultive space for reaching a common understanding of the impacts on different groups over different time scales. The identification of trade-offs between stakeholders is critical, as well as communicating these trade-offs in a meaningful and respectful way when evaluating such strategies. The trade-off assessment should formulate the transparency and fairness criteria used for settling conflicts and modulating power asymmetries. The boundaries of the "solution space" should explicitly include inclusiveness-as-an-outcome ambitions.

The mechanisms for addressing conflicts depend on the local context and political will relating to giving a voice to (marginalized) people. There is no standardized way of measuring values, particularly non-transactional values, which may pose challenges when addressing trade-offs.

The final ranking of preferred measures should reflect the outcome of an inclusive and fair negotiation process between social actors. To enable this, quantified information should set the discussion around the limits of water access that the stakeholders are willing to accept, as well as mapping compensation options. The final plan must include the detailed unintended consequences and compensation measures. Table 4 provides a checklist of further points of attentions.

2.4.5 Phase IV. Preparation for Implementation

The stakeholder engagement in previous phases set the basis for stakeholders to feel as though they 'own' the plan and played a major role in the process. In Phase IV, unintended consequences and eventual compensating mechanisms will be linked to financial and budgetary implications. This requires the direct involvement of communities in the project life cycle to increase the implementability of some measures (e.g., ecosystem restoration) as well as the social dividends (employment, human rights promotion, empowerment). Human right due diligence should be considered as the basis of social impact feasibility assessment, and grievance mechanisms should be available from the Inception Phase.

When local communities are engaged in projects and they take responsibility in the delivery of measures, this can trigger new discussions around values to be addressed by dialogue and negotiation. Organizing implementation will require facilitating discussions on legitimacy and the different values behind long-term and social development. The categorization of natural resources as economic assets must be coherent with tenure systems and their implications on ownership and exploitation rights.

An inclusive investment program should consider exploring local financing options and other innovative finance structures, such as grassroots finance. Finance should be made available to support vulnerable groups and to ensure the continuity of an inclusive process towards an inclusive outcome. Table 5 provides a checklist with further points of attention.

Inclusiveness as an output • The boundaries of the "solution space" should inclusive inclusiveness as an outcome. Tools which promote inclusiveness should be explicitly introduced, such as muticriteria analysis. • How do people/groups react to measures? • How are they impacted negatively and positively impacted, including in terms of values of water?
Inclusiveness as a process • Be aware that your social responsibility is to provide a space and basis for enabling a common understanding of trade-offs between public, private and social values when analyzing measures. • Define in advance the criteria for introducing transparency and fairness, ensuring that information is understandable to different groups. • Consider power relations and asymmetries in the stakeholder approach and create ownership in thinking of strategies (citizen science). • Be aware that you must facilitate addressing difficult questions, based on the limits on water access that actors are willing to accept. • Make sure that discussions provide a chance to define compensation mechanisms, always considering physical and financial constraints.

Table 4 Inclusiveness checklist in Phase III – Strategy Building

Inclusiveness as an output • Be aware that the definition of action planning is far from being value-free – organizational and financial arrangements also involve values around public management and social inclusiveness. • Explicitly state trade-offs when including communities as part of implementation arrangements (e.g. increasing risk perception or additional investments in technical assistance), as well as the eventual missing opportunities for locals or social cohesion when organizing implementation based only on efficiency. • Make sure that the classification of natural assets for the implementation arrangements comply with the formal and informal systems of land and other resources tenures. • Make finance available to support vulnerable groups and explore how the plan can rely on grassroots organizing and finance.
Inclusiveness as a process • Be aware that your social responsibility now reflects the social agreements from previous phases in the planning process. • Consider how the timeline of the project relates to other timelines relevant for vulnerable groups, possibly affecting their livelihoods or participatory capacity.

Table 5 Inclusiveness checklist in Phase IV– Preperation for implementation

2.4.6 Phase V. Implementation

The inclusive stakeholder process as developed in previous phases can be further extended as a platform for supporting the implementation process. This platform can be critical for introducing positive changes and dealing with cost overruns and delays in the execution of projects. Participatory monitoring can be suggested to maintain shared ownership of the project and to determine if outcomes are socially inclusive. Table 6 provides a checklist of further points needing attention.

Inclusiveness as an output • Be aware that social feasibility should endorse full human rights due diligence, along with compensation mechanisms, agreed with impacted groups in the implementation of the project.
Inclusiveness as a process • Involve all parties in the implementation of the project', including vulnerable groups. • Participatory monitoring can be suggested to maintain shared ownership of the project and to determine if outcomes are social inclusive.

Table 6 Inclusiveness checklist in Phase V – Implementation

Appendix 3: Role of Models in the Planning Process

Models play an important role in planning projects. Models can range from simple, e.g., based on spreadsheets, to complex DSSs requiring advanced computing skills. Modeling provides a way, perhaps the principal way, of predicting the behavior and performance of proposed system infrastructure designs or management policies. The past 50 years have witnessed major advances in the ability to model the engineering, economic, ecologic, hydrologic, and sometimes even the institutional or political components of large complex water resource systems. Applications of models to real systems have improved overall understanding of such systems, and hence have often contributed to improved system design, management, and operations.

This section does not describe the various modeling tools that are now available. For this, reference is made to textbooks about modeling such as Loucks and Van Beek (2017). This section is about how models should be used in a planning project. First, a description is given on the involvement of stakeholders in the analytical aspect of planning studies (section 3.1). The next section (section 3.2) describes the use of 'dashboards' in planning processes to facilitate this involvement of stakeholders. The final section (section 3.3) describes how to manage the modeling process and how to evaluate the model results.

When talking about , it is important to distinguish the difference between a (computer) 'program' and a 'model'. HEC-RAS, RIBASIM, Delft3D, MIKE etc. are computer programs or program packages. Once these programs/program packages are filled with data and the schematization of a specific situation (e.g., of a river basin) they become a 'model', i.e., they become a computer presentation of that river basin. Having said this, it should be acknowledged that in this document the word model is sometimes used when referring to a computer program. The focus of this document is about developing and using a model for water resource system planning, and not about the development of a computer program. Most computer programs referred to in this document can be accessed easily, as either they are freeware and can be downloaded from the internet or they can be bought from the developer.

3.1 Paradigm shift in modeling in a planning process – towards collaborative modeling

Traditionally, modeling was the work of mathematical and computer experts. The experts collected data on the water system, developed a model based on this data, made the necessary calculations and presented the results to decision-makers. Sometimes this was done using a DSS which combined the results of different models and made the results more accessible to the decision-makers, at times even allowed the decision-maker to change the model parameter values to see how model results changed. This is shown in the left side of Figure E6. Other stakeholders (e.g., the local community) were informed on the outcome and were occasionally offered a list of options at the end of the planning process which were to be discussed This process left decision-makers and stakeholders with little understanding of and no trust in the model or its results. As far as they knew, the modeling process could have been total nonsense.

The last 20 years has seen computing power which was once only available to the best-resourced organizations and institutions become readily available everywhere. An increasing number of people are becoming familiar with computers and modeling systems, and mobile internet has meant that information can be accessed or transmitted from almost anywhere in the world. In addition, technological advances in remote sensing have greatly improved data collection in typically data-poor areas for use in model exercises. These developments have led to a situation in which analytical modeling techniques have become accessible to non-experts, including the community who will be impacted by the project. By using this technology, it has become possible to inject more quantitative information into the decision-making process on water resources development and management, and to enhance stakeholders' ability to comprehend present and future issues and the impacts of possible solutions.

At the same time, there has been a growing recognition of the need to look for truly integrated economic, social, and environmental solutions, solutions which differ from the more traditional approach of maximizing economic benefits while reducing or mitigating social and environmental impacts. Environmental and social interests have become explicit objectives, and not only constraints on possible (economic) solutions. For this approach, new types of models are needed that can

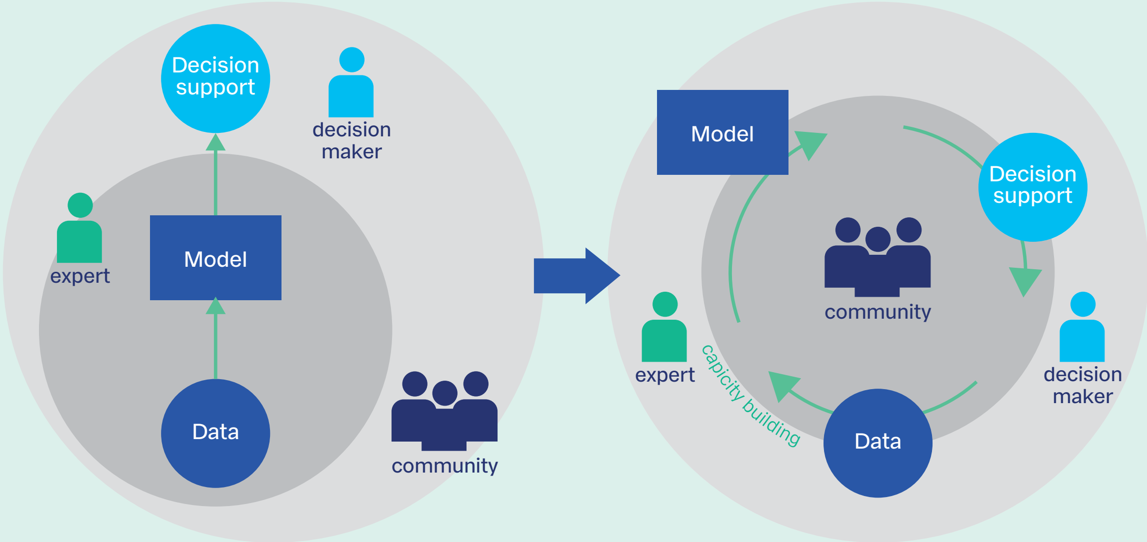

Figure 6 Paradigm shift in working with models in planning projects

integrate and balance multiple objectives, and which reflect the diversity of stakeholder values and perspectives. This requires the involvement of stakeholders throughout the modeling process rather than just at the end. This is the essence of collaborative modeling[58] , which is an approach to help interest-based negotiation in order to avoid sub-optimal outcomes and to promote plan acceptability and completeness.
This approach also offers a means of integrating divergent sources of knowledge and values, building credibility in the information produced, confronting and managing disputes and conflicts, and translating complex scientific information and data into understandable information that can enhance dialogue among stakeholders. The community is now placed at the heart of the modeling process as illustrated in the right part of Figure 6.

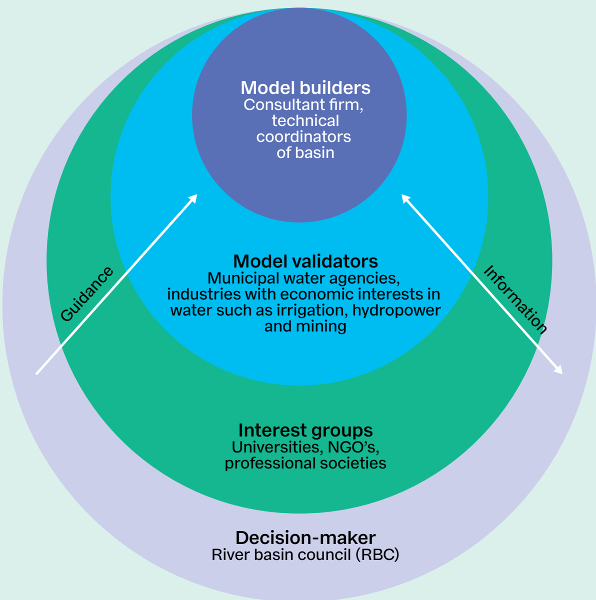

Figure 7 Circles of Influence for Collaborative Modelling
Source: Adapted from Mendoza et al. (2013)

Not everyone is able to participate in the same way in a collaborative modeling process. Collaborating participants should be selected in a stakeholder analysis and be organized into distinct working groups based on Circles of Influence that define the roles, commitments, communication channels, rules of engagement, and the two-way flow of technical information among interest groups, model builders, and analysts. Figure E7 provides more details on this. The Circles of Influence concept enables a change from the traditional approach by putting model builders at the inner/lowest level, who are directed by stakeholders and decision-makers, located at the highest level. Stakeholders and decision-makers therefore become the model and process validators that drive the technical analysis. The Circles of Influence approach is also described in Appendix 2 and illustrated in Figure 4.

Models and data have a prominent place in the Analysis Framework, as shown in Figure C1, and support and influence the activities in several of its phases. A different way of presenting the planning process' analysis activities in relation to collaborative modeling is given in Figure 8. The figure identifies four key pillars of collaborative modeling:
Water resources planning: an iterative decision- or policy-making process commencing with a problem statement that determines activities required to achieve the desired objectives in a timely manner, i.e., the phases of the Analysis Framework.

58 Other terms used for collaborative modelling are: Shared Vision Planning, Interactive Modelling, Group Model Building, Mediated Modelling, Cooperative Modelling; see Basco-Carrera et al. (2017) for an overview of these terms

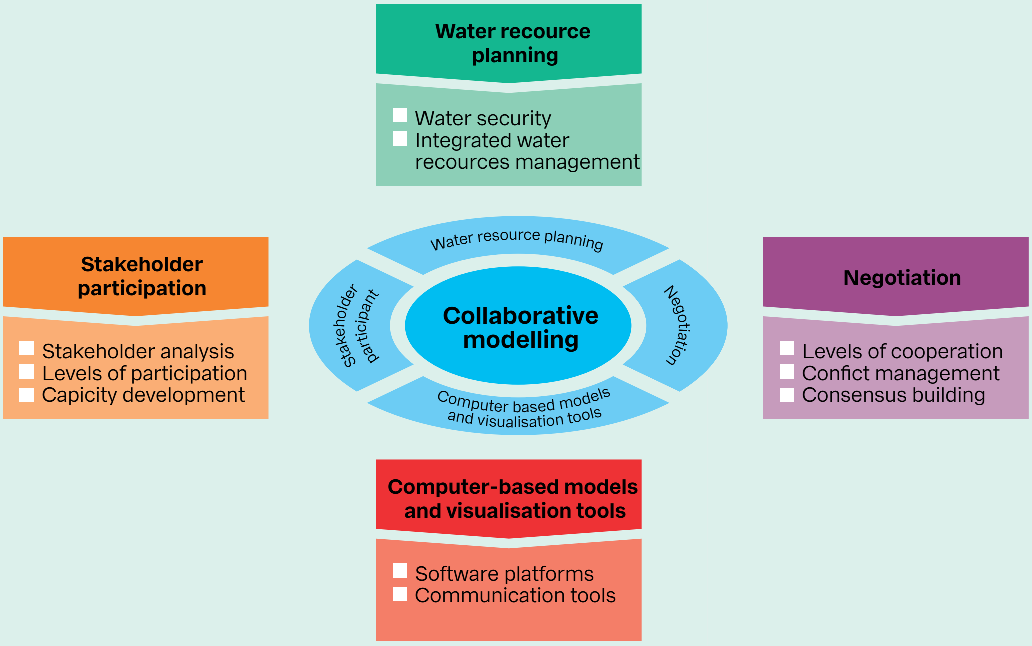

Figure 8 Key components of collaborative modeling for policy analysis

Computer-based models and visualization tools: to provide information on the present and future and to inform the various interest groups which measures would be most effective as they assess the impacts of a decision or policy.

Stakeholder participation: to engage with representatives of different interest groups affected by the decision-making process to capture their needs, challenges, desires, values, perceptions, performance criteria, and objectives, and to validate the process and promote inclusiveness.

Negotiation – the dialogue among stakeholders to achieve acceptable outcomes for everyone.

Collaborative modeling is a two-way process. The stakeholders are involved in the analytical work which builds trust in the tools used to identify and evaluate possible decisions. Their involvement is also important as they can provide localized knowledge on the studied water system which will improve the quality of the tools and data. At the same time, using their knowledge and information will further help to gain their trust in the results as they feel a sense of ownership in the process.

3.2 DSS, Planning Kits, Meta-models and Dashboards

Most models used in water system planning studies are quite complex. Models describing hydraulic, hydrological, groundwater, water quality and morphological processes require a high level of expertise to run and assess the results. Moreover, for an integrated planning study these models need to be coupled with socio-economic models and data to form the computational framework of a planning study. Graphical user-interfaces can be added to such computational frameworks to support their use. Much effort has been spent over the years to develop such DSSs. Despite their intention, most of the 'classical' DSSs stayed in the domain of experts and remained inaccessible to stakeholders. The main reason behind this was DSS' insufficient emphasis on the use of the models in the planning process. In more recent years, the focus of developing a DSSs has gradually shifted to making the systems more suited for engaging with stakeholders, with the ultimate aim to better inform stakeholders and to achieve societally supported decisions. This is also fundamental to collaborative modeling described above. When the systems focus more on decision-making processes, this puts specialized demands on the computational framework:

- The models in the computational framework should cover the full width of the policy area and address the potential physical, economic, environmental and social impacts of the decisions that may be taken (see e.g. Figure C10). The integration of all the components of a system and overall system performance is more important than the scientific depth of each of the components (width over depth).
- The system should enable users to evaluate alternatives by selecting specific interventions and scenarios from a menu of options.
- The models should have short run-times (minutes instead of the hours/days that some complex models require) so that they can be used in decision-making processes (workshops, etc.).
- The system should present the results (data, impacts, etc.) in an accessible and understandable way for the stakeholders.

These requirements have resulted in the increased use of different ways of modeling and expanded how models are used, such as Planning Kits, Meta-models and Dashboards. They are essentially all DSSs, but are designed to be used by stakeholders.

Planning Kits

Planning Kits are outcome-based systems which are generally built on the results of numerous simulations with hydrological, hydraulic, economic, social and political models and are used to quantify the impacts of measures. A Planning Kit combines measures into strategies and provides direct feedback on the impacts of these strategies. It generally includes a user-interface from which a user can select measures and learn about the impacts of these measures, including an indication of how well particular targets are being met. The tools do not require any particular knowledge of the water system being studied and can be used by many stakeholders and decision-makers. An example of such a Planning Kit is presented in Box 25.

Meta models

A Meta model is a fast and integrated model, intended to mimic the behavior of complex models. Meta models often comprise a simplified model, based on more complex models and/or expert judgment. The approach is much faster (i.e., requires less computational time) than that of complex models. A Meta model would also be easier to use, for example, to screen the effectiveness of alternative strategies. A Meta model approach may be adopted for collaborative prototyping to understand the system and from there gradually increase complexity. The Meta model does not replace more complex and detailed models. After screening and ranking strategies, complex detailed models may be used for more in-depth analysis and impact assessment.

Dashboards (to support planning)

A dashboard is a generic term for an interface that monitors and controls functions (similar to a dashboard in a car). Dashboards which are used to support planning are interactive visualization tools that are tailored to address a specific planning issue. The term dashboard is also used for real-time monitoring and for facilitating the setting up and running of complex models[59], but this document purely focuses on dashboards for planning. Planning dashboards:

- Structure, integrate and present information to provide a bridge between information needs and results of detailed planning studies, for which multiple models and data sources are generally used;
- Provide a quick response to user-interaction to facilitate stakeholder learning and understanding of planning objectives, interventions, impacts and trade-offs;
- Are developed in close collaboration with end-users to tailor the interface to the information needs of stakeholders; and
- Offer an add-on or can sometimes even replace reports on strategic planning studies.

Dashboards in water system planning help policy analysts, decision-makers and stakeholders to visualize and communicate system functions and their related risk information, the impacts of external scenarios, the impacts of interventions, and the ongoing performance of any interventions. Information is organized and communicated in a structured way to help actors identify and take the most appropriate decisions.

Dashboards are also used to blend quantitative and qualitative information, depending on the time and information available to populate the underlying models and database. Such information can include:

- Simple semi-quantitative cause-effect relationships. When little data are available, expert judgment can be used to derive these relationships.
- Existing global datasets or results from global models to initially populate the dashboard with quantitative information.
- Outputs from more detailed local models, which may also be partly based on global data, to increase modeling output resolution, and that are used to analyze more localized policy options.

Figure 9 gives an example of a dashboard that has been developed for flood risk assessment. The upper left part of the dashboard contains the input fields where users can select the scenario they want to analyze (climate and economic growth), system assumptions (discount rate), their strategy and what they wish to include in the analysis. The other parts of the dashboard show the risks (the map) and economic information.

The models underlying a certain dashboard are selected based on the information needs of the involved stakeholders, decision-makers and analysts, while taking into consideration any constraints regarding data availability, the required accuracy, and the time and resources available to develop the dashboard.

An advantage of dashboards is that they permit the collation of information from a variety of data sources and models. This allows for flexibility; when improved

59 Delft Dashboard is an example of a dashboard that mainly focuses on the support of modellers in setting up new and existing models and not specifically to be used in a participatory planning exercise

Figure 9 Example of dashboard for a IFRM planning study

data or more accurate models become available, the underlying information in the dashboard can be updated, without having to change the lay-out of the communication medium or update a report.

3.3 Developing and using computational frameworks with dashboards

A computational framework for a planning study consists of: i) the (complex) system of core models and databases, and ii) the dashboard which reduces the complexity for the users and helps them to carry out the analysis and understand the impact of their choices.

These two components are demonstrated in Figure 10. The left side of the figure is the domain of the experts in various disciplines. The dashboard is the visualization of data for the planning analysts and the stakeholders.

Dashboards should be specific to each planning exercise. The exact design of the dashboard is formulated together with its targeted end-users. They should decide which kind of information they wish to include in their decision-making process. This is done in Phase I of the Analysis Framework. The needed information determines which core models and databases need to be included in the computational framework. It also determines the basic elements that should be included in the visualization of modeling and data analysis

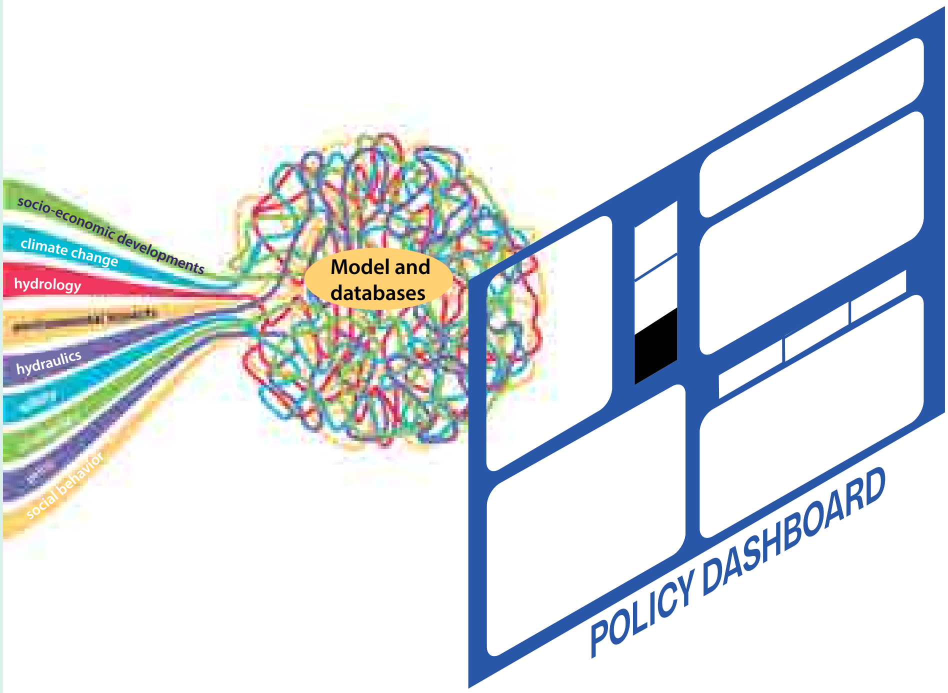

Figure 10 The two components of a computational framework

outcomes that inform the users about the performance of the system. This typically includes both performance under various external scenarios (e.g., climate change, urbanization, economic growth) and when elements of a system are subjected to alternative strategies (packages of interventions). The different scenarios and strategies are selected for display by the end-user through drop-down menus or "buttons". The visualizations communicate how the water system changes as a result of different conditions and interventions.

3.3.1 Participatory development of the dashboard

The development of a dashboard requires a co-creation activity with the stakeholders and follows a number of steps. The key is to ensure that the dashboard is designed to deliver the necessary information and make any analytical insights accessible and understandable to all involved. Following is a description of these steps.

Scoping
Before the dashboard development can start, it is important to identify who will be using it and for what purpose. This means that a stakeholder analysis must be performed before the dashboard development process commences. This is then used to identify how the different stakeholders can best be engaged in each of the different phases. The stakeholders determine the intended use of the policy dashboards and provide input on the main characteristics of the system, the challenges, possible interventions, and the indicators for the objectives and identify specific information gaps/needs.

Design
Based on the information from the Scoping step, designers develop an initial design/mock-up of the dashboard. This can be done before or after collecting specific stakeholder inputs. The initial design can then be discussed with stakeholders to decide on what needs to be added, taken out or amended.

Development
Based on the feedback from stakeholders and inputs from policy documents and other existing information, designers then develop a first version of the dashboard through rapid prototyping.

Application
Stakeholders start to use the dashboard to analyze the current and future situation. This might lead to the identification of possible new policy actions and additional information needs. Where useful, maps and graphs can be added and/or aggregated and visualized in a new map, graph and/or table. Dashboards are flexible and so all information can be generated/visualized/compared with and without scenarios or interventions. With the first or subsequent version(s) of the dashboard, actors can assess and discuss policy options and strategies, prioritize actions, and determine the next steps to implementation and action planning. Dashboard developers expand the dashboard with more detailed information if needed and with impacts of policy actions.

Evaluation
The stakeholders and developers give feedback on the functioning of the dashboard and assess how the dashboard can continue to support their discussion. Above 'co-creation' activities between stakeholders and dashboard will be carried out in parallel with the five phases of the Analysis Framework. Since policy dashboards are intended to support decision-making, their use will focus mainly on the first three of these phases: inception, situation analysis and strategy building.

3.3.2 Points of attention in developing and using core models

The core models and databases behind the dashboard are to be developed, used and analyzed by specialists. Care should be taken to ensure that models and databases provide the intended and needed information. The complexity of the models requires a clear protocol for developing and using models and databases to reduce potential problems and lead to more effective outcomes. These steps are illustrated in Figure 11. Some of the steps of Figure E11 may not be relevant in particular planning projects and if so, these parts of the process can be skipped.

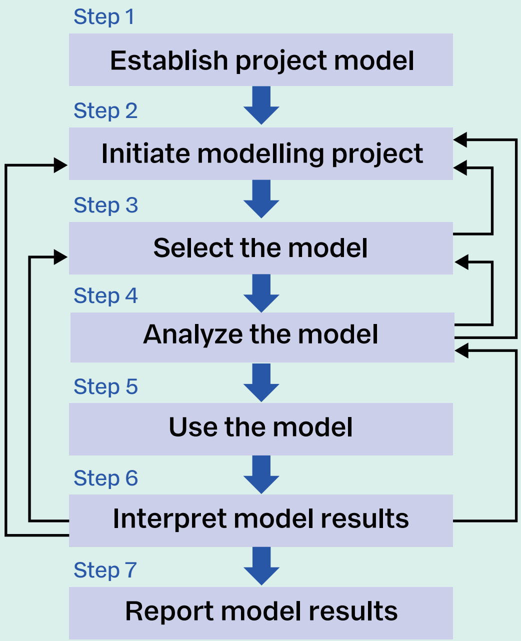

Figure 11 The modeling project process is typically an iterative procedure involving specific steps or tasks.

Creating a project modeling journal

A common problem in modeling projects is that once they are underway, it is fairly difficult to go back over a series of simulation results to see what was changed, why a particular simulation was made or what was learned. It is also difficult, if not impossible, for third parties to continue from the point at which any previous work terminated. These problems are caused by a lack of recorded information on how previous work was carried out. What was the pattern of thought that took place? Which actions and activities were carried out? Who carried out what work and why? What choices were made? How reliable are the end results? These questions should be answerable if a model journal is kept. Project documentation is frequently neglected when there is time pressure, and perhaps because it is not as exciting as running the models themselves.

Initiating the modeling project – problems and possible solutions

This step is carried out during the co-creation process of developing a dashboard described in the previous section. Besides identifying problems and solutions, this step will decide which spatial and time scales are most appropriate in a planning project. The essential natural system processes must be identified and described. The specific elements to be included are placed in a broader context and the interrelations between elements are identified. Proposed modeling activities may have to be justified and agreements made where necessary. The client may also ask for justification of the modeling activities at any stage of the process. In this instance, there should be an agreement on how this justification will take place: are intermediate reports required, have conditions been defined that will indicate an official completion of the modeling project, is verification by third parties required? There are many other options which are available to justify a project to a client. It is particularly important to record beforehand the events or times when the client must approve the simulation results. Finally, it is also sensible to reach agreements with respect to reporting requirements and how they are determined or defined, as well as the format, scope, and contents of modeling project outputs (data files) and reports.

Selecting the components (models) of the computational framework

Whether to select and use pre-existing models or develop new ones depends in part on the processes that will be modeled, the data available and the data required. The available data should include system observations for comparison of the model results. They should also include estimates of the degree of uncertainty associated with each of the model parameters. At a minimum, this might only be estimates of the ranges of all uncertain parameter values. At best, it could include their statistical distributions. In this stage of the process, it is sufficient to know what data are available, their quality and completeness, and how to deal with missing or outlier data. Determining the boundaries of the model is also an essential consideration in model selection and use. These boundaries define what is and is not to be included in the model. Any model selected will contain a number of assumptions. These assumptions should be identified and justified, and later tested. These boundaries and system assumptions will have to be addressed in Phase I of the Analysis Framework. The decision to use a specific model, and which model to use, is an important part of the strategic planning process. Even though there are no clear rules on how to select the right model a few simple guidelines can be followed:

- Use the simplest method that will yield adequate accuracy and provide the answers to the study's questions.
- Select a model that fits the problem rather than trying to fit the problem to a model.
- Question whether increased accuracy is worth the increased effort and increased cost of data collection.
- Consider model and computational cost. Computing costs are rarely an issue, except perhaps for some groundwater management problems.
- Do not forget the assumptions underlying the model and do not read more significance into the simulation results than is actually there.

Analyzing the model

Once a modeling approach or a particular model has been selected, its strengths and limitations should be assessed. The first step is to establish a plan for testing and evaluating the models. These tests can include mass (and energy) balance checks and parameter sensitivity analyses. The model can be run under extreme input data conditions to see if the results are as expected. Once a model is tested satisfactorily, it can be calibrated. Calibration focuses on the comparison between model results and field observations. Generally, a useful principle to follow is the smaller the deviation between the calculated model results and the field observations, the better the model, as the deviations in a perfect model are only due to measurement errors. In practice, however, a good fit is by no means a guarantee of a good model.

The deviations between the model results and the field observations can be due to many factors. These include possible software errors, inappropriate modeling assumptions such as the (conscious) simplification of complex structures, neglect of certain processes, errors in the mathematical description or in the numerical method applied, inappropriate parameter values, errors in input data and boundary conditions, and measurement errors in the field observations. To determine whether or not a calibrated model is 'good,' it should be validated or verified. Calibrated models should be able to reproduce field observations not used in calibration. Validation can be carried out for calibrated models as long as an independent data set has been kept aside for this purpose. If all available data are used in the calibration process in order to arrive at the best possible results, validation will not be possible. The decision to leave out validation is often justifiable, especially when data are limited. Philosophically, it is impossible to know if a model of a complex system is sufficiently 'correct', as there is simply no way to prove it. Experimenting with a model, by carrying out multiple validation tests, can increase the confidence in that model. After a sufficient number of successful tests, it could be stated that the model is 'good enough', based on the modeling project requirements. The model can then be regarded as having been validated, at least for the ranges of input data and field observations used in the validation.

If model predictions are to be made for situations or conditions for which the model has been validated, there should be a degree of confidence in the reliability of these predictions. Nonetheless, it is difficult to be fully certain. Much less confidence can be placed on model predictions for conditions outside the range for which the model was validated. While a model should not be used for extrapolations as commonly applied in predictions and in scenario analyses, this is sometimes the reason behind the modeling project. What is likely to happen given events that have not yet occurred? A model's answer to this question should also include the uncertainties attached to these predictions.

Using the computational framework

Once the models have been judged as 'good enough', they may be used to obtain the desired information. A plan should be developed on how the model will be used, identifying the input to be fed, the time period(s) to be simulated, and the quality of the results to be expected. Again, close communication between the client and the modeler is essential, both while setting up this plan and throughout its implementation, to avoid any unnecessary misunderstandings about what information is desired and the assumptions on which that information is to be based.

Before the end of this model-use step, it should be determined whether all the necessary model runs have been performed and whether they have been performed well. Questions to ask include:

- Did the model fulfill its purpose?
- Are the results valid?
- Are the quality requirements met?
- Was the discretization of space and time chosen well?
- Was the choice of the model restrictions correct?
- Were the correct model and/or model program chosen?
- Was the numerical approach appropriate?
- Was the implementation performed correctly?
- Are the sensitive parameters (and other factors) clearly identified?
- Was an uncertainty analysis performed?

Some of these questions may not apply to certain projects, but if any of the answers to the questions which are relevant is no, then the situation should be corrected. If it cannot be corrected, then there should be a good reason for this.

Interpreting model results

Interpreting the information resulting from simulation models is a crucial step in a modeling project, especially in situations in which the client may only be interested in those results and not in the way in which they were obtained. The model results can be compared to those of other similar studies. Any unanticipated results should be discussed and explained. The results should be judged with respect to the modeling project objectives.

The results of any water resources modeling project typically include large files of time-series data. Only the most dedicated of clients will want to read those files, so the data must be presented in a more concise format. Statistical summaries should explicitly include any restrictions and uncertainties in the results. They should identify any gaps in the domain knowledge, thus generating new research questions or identifying the need for more field observations and measurements.

Reporting model results

Although the results of the model's calculations will not be the sole basis for policy decisions, modelers have a responsibility to report the full results. Decision-makers and participating stakeholders will want simple, clear, and unambiguous answers to complex questions. The executive summary of a report will typically omit much of the scientifically justified discussion, for example, the uncertainties associated with some of the data. This executive summary is often the only part read by those responsible for making decisions. Therefore, the conclusions of the model study must not only be scientifically correct and complete, but also concisely formulated, free of jargon, and fully understandable for decision- and policy-makers. The report should provide a clear indication of the validity, usability, and any restrictions of the model results. The use of visual aids, such as graphs and GIS, can be very helpful. The final report should also include sufficient detail to allow others to reproduce the model study (including its results) and/or to proceed from the point from which this specific study ended.

Evaluating modeling success
There are many ways to judge the extent of success (or failure) in applying models and performing analyses in practice. Goeller (1988) suggested three measures as a basis for judging success:

1. How the analysis was performed and presented (analysis success).
2. How the model and analysis were used or implemented in the planning and management processes (application success).
3. How the information derived from models and their application affected the system design or operation and the lives of those who use the system (outcome success).

It can be hard to judge the degree to which particular models, methods and styles of presentation are appropriate for the problem being addressed, the resources and time available for the study, and the institutional environment of the client (the analysis success). Review panels and publishing in peer-review journals are two ways of judging analysis success. No model or method is without its limitations. Two other obvious indications are how the analysts feel about their own work and, very importantly, the opinions the clients have about the analysts' work. However, client satisfaction may not be an appropriate indicator if, for example, the clients are unhappy only because they learnt something which they do not want to accept. Producing results primarily to reinforce a client's prior position or opinions might result in client satisfaction, but, most would agree, this is not the most useful nor the most appropriate way to use a model.

Application or implementation success implies that the methods and/or results developed in a study were seriously considered by those involved in the planning and management process. Having said this, success or failure should not be judged on the basis of whether or not any of the model results (the computer 'printouts') were directly implemented. Rather, success or failure is more appropriately judged by whether the information and understanding resulting from model application helped to define the important issues and identify possible solutions and their impacts. Did the modeling help to influence the debate among stakeholders and decision-makers about what decisions to make or actions to take? The extent to which this occurs is the extent to which a modeling study will have achieved application or implementation success.

Outcome success is judged according to what happens to the problem situation once a decision which was largely influenced by the results of modeling has been made and implemented. The extent to which the information and understanding resulting from modeling helped to solve the problems or resolve the issues, if it can be determined, is a measure of the extent of outcome success. Success in terms of the second or third criteria (application and outcomes) will depend heavily on the success of the preceding one(s) (analysis and possibly application). Modeling applications may be judged as successful in terms of the first two measures but, perhaps because of unpredicted events, the problems being addressed may become worse rather than improve, or while those particular problems were eliminated, their elimination may have caused other severe problems.

Problem situations and criteria for judging the extent of success will change over time. By the time the results can be evaluated, the system itself may have changed enough for the outcome to be quite different than what was predicted in the analysis. Monitoring the performance of any decision, whether or not based on a successfully analyzed and implemented modeling effort, is often neglected. Monitoring is very important if system design, management and operation are purposefully made to adapt to changing and unforeseen conditions.

If the models, data, computer programs, documentation and knowledge are successfully maintained, updated, and transferred to and used by the client institutions, there is a good chance that this methodology will be able to provide useful information relevant to the changes that are needed in system design, management, or operation. Until relatively recently, the successful transfer of models and their supporting technology has involved a considerable commitment of time and money for both the analysts and the potential users of the tools and techniques. It has been a slow process. Developments in interactive computer-based data-driven DSSs substantially facilitate this technology transfer process, particularly among model users. These technological developments will continue to have a major impact on the use and application of models in support of planning and management of water systems.

Appendix 4: Financing Framework for Water Security

Many potentially successful integrated plans fail to be implemented as it is not clear 'who' is going to do 'what' and 'how' the plan will be funded. By definition, an integrated plan addresses the responsibilities of different agencies, including their role in implementing the (components of) the plan. This is known as the 'implementation gap': how can a strategic plan be translated into a series of investment projects? A strong case for investment has to be made to access funds by justifying how the proposed project will optimize the use of the money.

Based on experiences in closing the implementation gap and linking planning and implementation. Altamirano has developed a Financing Framework for Water Security (FFWS). The FFWS is described in detail in the Handbook for the Implementation of Nature-based Solutions for Water Security (Altamirano, 2021). The FFWS is an integral part of the Analysis Framework and is included in Phase IV, albeit slightly adapted to fit the structure of the Analysis Framework.

4.1 FFWS – from strategic plans to investment planning for water security

Phases I, II and III result in an integrated strategic plan, and FFWS explains how that plan can be implemented. The main activities of FFWS take place in Phase IV, but, as explained in section 4.4, FFWS also includes some activities in the planning stages so that Phase IV is more effective and successful.. The overall objective of phase IV is to close the implementation gap, as described in section C.6.To have a better understanding of some of the steps of Phase IV, the following sections provide some more detailed background information about FFWS:

- The need to develop a business case for the components which are to be implemented (section 4.2).
- Developing 'bankable' projects by clustering components of the integrated strategy (Step 1 - section 4.3)
- Designing the implementation arrangements
- for these projects: mode of governance, funding strategy, financing strategy and procurement strategy (Step 2 - section 4.4)
- The additional point of attention of FFWS in Phases I, II and III (section 4.5).

The essence of FFWS is outlined in Figure 12. An investment has to be accepted by an institution or business in order to be implemented. The overall business case can be split into five specific cases. The Strategic and Economic Cases are addressed in Phases I to III. The FFWS oversees the remaining three cases (Commercial, Financial and Management). The two main steps are: i) breaking up the integrated strategy into potential bankable project clusters and ii) developing the implementation arrangements as shown in Figure 12.

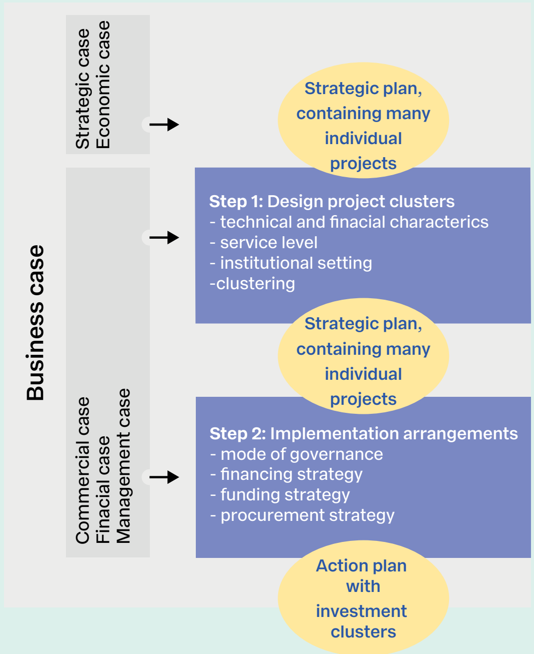

Figure 12 Main approach of FFWS

4.2 Business Case development

The Business Case development process is essential to public value in spending decisions, in terms of its scoping, options selection, delivery, monitoring, and evaluation. A Business Case is meant to make the case that a project is "investable" for a certain actor. All public sector investments usually require a Business Case. The "Five Case Model" (HM Treasury, 2018) includes the following Business Cases:

- Strategic – is there a compelling case for change?
- Economic – does the recommended measure optimize the use of public funding?
- Commercial – is the proposed measure achievable and attractive in the marketplace?
- Financial – is the spending proposed affordable?
- Managerial – how will the proposed measures be successfully delivered and managed?

The **Strategic Case** assesses if the project or strategy aligns with the strategic drivers, policy priorities and enabling conditions at the institutional level. This can include improving the service level in a business-as-usual (BAU) situation or moving to a more transformative direction by implementing a paradigm shift in how to develop and manage water systems. These paradigm shifts are becoming urgent considering the scarcity of water resources along with a growing population, enhanced socio-economic activities, and climate change. If applicable, a key element of the Strategic Case might be the development of a 'Theory of Change' (see Box 13 for a short description). Important elements of the Strategic Case are: i) clarity of solution, ii) paradigm shifting potential, iii) solution impact versus BAU, and iv) strategic fit. The Strategic Case is addressed in Phase I (vision, objectives, etc.) and in Phase II (problem analysis).

The **Economic Case** defines whether it is worth investing in the preferred project or strategy from a societal perspective. The core of the Economic Case is a classical quantitative benefit-versus-cost analysis, but it has to include also defining the winners and losers involved in the project's implementation. If a quantitative CBA is not possible, a good start is a qualitative social cost-benefit analysis.. The Economic Case is the core of the activities undertaken in Phase III of the Analysis Framework.

The **Commercial Case** aims to answer three main questions: i) is the preferred strategy viable?, ii) is there a supplier or private sector market actor who can meet the defined needs and levels of service envisioned?, and iii) can the project be implemented in such a way that value for money can be secured? A key element within this is the outsourcing decision: make-or-buy. This requires an assessment of the envisioned role of the public and private sectors in the delivery of the program. Is the private sector capable and interested in being a part of the project? The Commercial Case requires decisions about the mode of governance and the procurement strategy.

The **Financial Case** evaluates to what extent the project is affordable, fundable, investable, and bankable. To demonstrate that the project is affordable from the public or private sponsor perspective, planners and relevant stakeholders need to provide evidence that the implementation costs and/or lifecycle costs estimated are realistic, and that the required funding is available and supported by future sources or revenue (taxes, tariffs or transfers). Private investors will assess different investments using a risk/reward ratio which allows them to compare the expected returns of an investment with the amount of risk they must undertake to earn these returns.

The **Management Case** determines whether the investment project proposed is achievable. This assessment involves demonstrating that the project sponsor can deliver the projects successfully and professionally and has a robust system and processes in place for project and risk management. It is important that there is enough capacity and expertise in both the public procurement agency and the private or community-based project developer. The Management Case supports the development of robust contractual arrangements to deliver the project and guarantee long term sustainability of service delivery. It explicitly defines the allocation of risks, rewards and responsibilities involved in the delivery of the project and along the entire infrastructure investment cycle. The infrastructure investment cycle includes planning, design, building, maintaining, operation, and monitoring, up to decommission if applicable.

4.3 Step 1: Developing 'bankable' projects

As explained in section C.6.1, an integrated strategy consists of many different measures, ranging from infrastructural projects to institutional capacity building. The first step in the implementation process is to group these strategy components in such a way that the resulting packages (clusters) are attractive to governmental and/or financing agencies. Clusters refer to groups of measures that due to their complementarity in biophysical, social, functional, or financial terms would be best implemented jointly and could therefore be thought of as one transaction, investment project or deal. These resulting 'clusters' can be called 'projects'.

The process of designing bankable projects requires four main stages:

1. Characterize all the components (individual projects, activities, etc.) of the strategy, in terms of the technical and financial characteristics of the project, asset created and the type of economic good provided by the asset.
2. State explicitly the level of service required over time for each component.
3. Analyze the institutional setting for each component.
4. Cluster components into bankable projects and project phasing.

Stage 1 - Determining the technical and financial characteristics of strategy components
The main services provided by the project and made possible by the asset created by the investment and how these services are considered in terms of type of economic good will be determining factors in defining the institution that will be responsible for implementation. For example, freshwater systems (the assets enabling several different ecosystem services) are a common resource which means that generally governmental involvement in projects will be prominent, although this does not necessarily exclude the involvement of the private sector. To allow for diversification in funding sources and identify alternative revenue streams, it is important to make a distinction between the asset enabling service delivery and its ownership and the service provided to specific target groups and its economic nature. Consequently, while a forest required for the provision of erosion management services is a common resource in itself and would require public ownership in some cases, the erosion management services it gives to, for example, hydropower companies could be considered a private economic good and tariffs could be required for that service.

The characteristics of the project often determine the governmental level that will be able to take responsibility for further preparation and procurement (i.e., tendering and oversight) of the project. Relatively small projects can be taken up at municipal or provincial levels while larger projects will require national level involvement. River basin organizations (if existing) can play a role in the coordination of projects.

Stage 2 – Determining the level of service
Each measure has a specific function. All of these functions need to be formulated in terms of their contribution to the delivery of specified levels of service over time. This provides a narrative of the cost generating activities required to deliver the specified service at the level of quality and reliability which beneficiaries would be willing to pay all related costs. Additionally, explicitly specifying the required levels of service over time allows for a thorough identification of risks in terms of circumstances that might compromise the delivery of the service at the expected cost.

Stage 3 – Determining the institutional setting of each component
The next stage is to investigate the institutional setting for each component. This can be done by:

- Carrying out a stakeholder analysis, i.e., an in-depth analysis of the interests, resources and capabilities of stakeholders that could drive or hinder the implementation of the specific measure.
- Institutional analysis where the incentives and disincentives created by different layers of formal and informal institutions are considered.

Stage 4 - Clustering and project phasing
Based on the knowledge gained from the first three stages, the components of the integrated strategy can be grouped into implementation clusters or, in other words, bankable projects. Clustering can be guided by regional or sectoral considerations and the interest of specific investing agencies (such as international financing agencies or private fund managers). The clusters also combine different kinds of measures. Infrastructural projects might be clustered based on institutional measures (e.g., how to operate and maintain the infrastructure) and capacity building. This clustering is an interactive process in which technical, economic, social, and institutional experts closely work together with potential implementing organizations to identify combinations of measures that have a high potential to be picked up for implementation.

4.4 Step 2: Designing the implementation arrangements

The four main phases of analysis used to design an implementation arrangement for each cluster are presented in Figure 13. The clusters identified in Step 1 are called 'projects' in the text below. The four main stages are also described in Phase IV of the Analysis Framework (see section C.6.3). The text below provides some additional information.

Phase 1 - Define mode of governance
The governance mode refers to the organizational design that enables the implementation of the project. Governance modes in the water sector can be: i) public procurements contracts, ii) privately driven water stewardship investments, iii) collective investment schemes, and iv) environmental and/or ecosystem markets. The first mode is the most common in the water sector but given the limited capacity of the public sector, there is a strong push for the other kinds of governance modes.

The governance mode is very much determined by the type of economic good that will be delivered (See box 27). They will generally define the type of governance mode that is best suited to deliver the project and the services which it will provide.

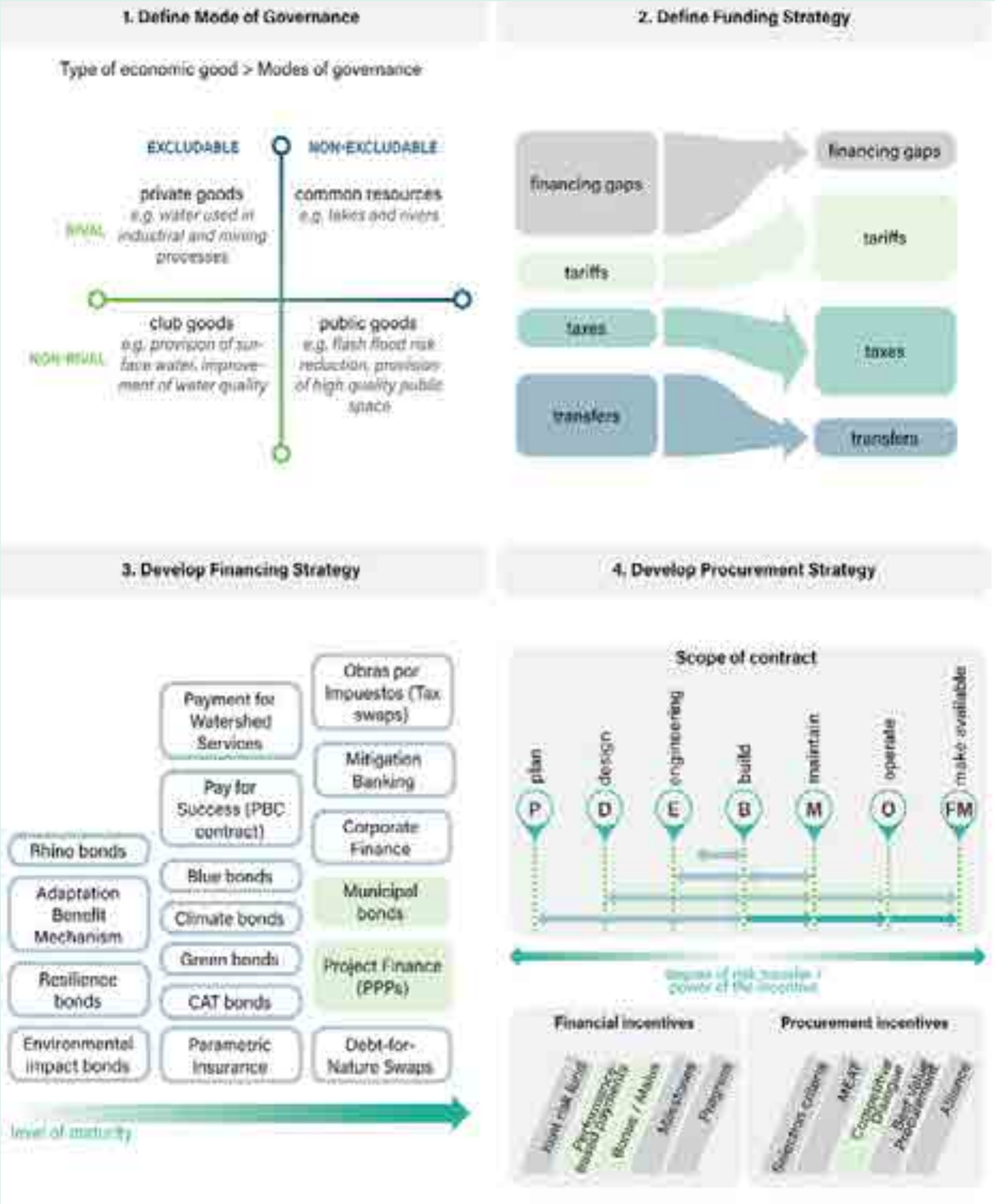

Figure 13 Phases in determining the implementing arrangements • Source: Altamirano et al (2021)\

It should be realized that while the economic nature of an asset itself – e.g., an ecosystem – may be a common good and it would make sense to keep this asset under public ownership, the services which it provides could be considered a private good and it could therefore be decided that the rights to operate this asset will be temporarily given to a private party or community through concession rights.

Phase 2 - Define funding strategy

Funding relates to how the investment will ultimately be paid back. The basic principle is that beneficiaries should pay for the services provided or pay for the pollution they cause. It can be a challenge in the water sector to generate sufficient financial return on investments as beneficiaries are not able or willing to pay for the service.

For example, this is often the case for environmental services (such as sanitation, sewage collection and sewage treatment) and flood protection. Farmers may also be unable to pay for the irrigation water they receive. This results in a funding gap. The funding strategy aims to reduce funding gaps and improve the long-term financial sustainability of the investment. The 3T's concept of OECD states in simple terms that all water funding is based on a cash flow made up by Tariffs (payments from users), Taxes and Transfers (subsidies or grants from public funds, from Official Development Assistance, or philanthropy). These cash flows are used to pay back the capital expenses (CAPEX) as well as the operational expenses (OPEX) involved in the implementation of the project and the continuous provision of water-related and/or other ecosystem services. The use of future cash flows to secure upfront investments is widely employed in the infrastructure world.

Box 27 Four types of economic goods

In economics, a good is anything (good, thing or service) that can be consumed or increases utility and can therefore be sold in a market. A good can be thought of be both a tangible object and/or an intangible service. Further, it is common in economics to divide goods into private, club, common and public goods. The classification responds to considerations of market failures and externalities. The two attributes that set the foundation of this classification are:

- Rivalrousness: whether there is competition involved in obtaining a given good or, in other words, whether this good is finite or infinite, or whether "the marginal cost of providing a good to an additional consumer is zero or not" (Pindyck and Rubinfield, 2001)
- Excludability: Whether it is possible to exclude anyone from the consumption of a given good and how costly it is to do so.
- The classification is illustrated in Figure 13 (top-left)

Phase 3 - Develop financing strategy

A variety of instruments can be used to finance a project such as loans, bonds and others and these instruments can be public, private or both. A rather new approach is 'blended finance', which enables the mixing and blend different sources of public or concessional finance with private or commercial finance. Blended finance, defined by the OECD (2018) as "the strategic use of development finance and philanthropic funds to mobilize private capital flows to emerging and frontier markets," can help to mobilize private financing for water security and climate adaptation projects which have been traditionally be considered little attractive from a commercial lens. The identification of potential financing options depend on the type of project and the envisioned impacts as different financing facilities are available for different kinds of projects (e.g., in the WASH sector, climate change adaptation). Table E9 presents an example of such financing streams for DRR measures. Figure 13 (bottom – left) presents some options for financing instruments structured according to their level of maturity.

Phase 4 - Develop procurement strategy

The last phase is the determination of the best procurement strategy for the project. As explained in section C.7.4, public procurement refers to the process by which public authorities purchase work, goods or services from companies. National regulations apply to ensure high quality of service delivery and safeguard public interest.

The most difficult task in procurement is to arrive at a balanced and acceptable sharing of responsibilities, risks and with the private sector. Despite the variety in formats available, there seem to be a limited number of procurement strategies adopted by public authorities:

- Separately outsourcing pure Operations and Management (O&M),
- Design-Bid-Build (DBB) segmented and publicly financed,

Financial investment	Type of funds available
Public finance / national public investment systems	National public investment system procedures Disaster risk management systems Development cooperation
Climate finance and innovative finance	Public climate funds for climate adaptation projects Private climate funds
Private finance for infrastructure	PPP and private initiative modalities Capital markets and project finance
Infrastructure finance	Project finance
Public funds for disaster risk reduction	National special funds
Conditional financing	Disaster risk financing, insurance
Conservation and biodiversity finance	Conservation and biodiversity funds

Table 7 Public, private and conditional financing streams for DRR measures

- Design-Build (DB) segmented and publicly financed,
- Design-Build-Operate (DBO) integrated and performance-based contract yet publicly financed and
- Design-Build-Finance-Operate (DBFO) fully integrated and performance-based contract, where private sector secured the financing upfront.

Whether public or private, the entity contracting or delegating the implementation of a water systems project or the provision of specific water and/or ecosystem services (designated the "principal" in agency theory terms) can incentivize the implementing party (called the "agent") using several ways that vary in degree of influence. An overview of different potential agents that should be acknowledged when designing a project delivery and finance mechanism is shown in bottom part of Figure 13. The figure also shows the balance that needs to be considered between the degree of risk transfer and power of the incentive. The strongest way to create an incentive is through the contract scope that defines which tasks and risks are transferred to the third party. The second strongest is through the payment mechanisms – which could be based on effort and inputs or results, performance, or even outcomes - and related monitoring systems that are put in place to enforce bonuses or deductions in payments based on the agreed key performance indicators for the services provided.

The transfer of risks and responsibilities to a private agent goes naturally hand in hand with a transfer of more degrees of freedom, so that the private agent can effectively manage this risk and deliver the required performance. The potential of PPPs also brings several challenges with it as the complexity of regulating and managing such contracts increases. Based on this it should be decided (i) whether a specific risk or task should be shared, managed by the public side or transferred to the private agent (ii) whether a specific risk or task should be included or excluded from the scope of procurement.

The authority undertaking the procurement may choose to tender the project as a fully integrated contract (e.g., involving the private sector from design and planning up to long-term operation and maintenance) or choose more traditional separate contracts for each activity and/or lifecycle phase. The main options and sub-options for the procurement of different investment projects and associated services are shown in Figure 14.

4.5 FFWS additions to the Analysis Framework

As well as Phase IV, the FFWS enriches Phases I, II and III of the Analysis Framework with some additional steps. These steps increase the chances of implementation of the preferred strategy by developing investable water security propositions. In doing so, they improve the long-term financial sustainability of the final selection of measures. This can be achieved by involving the private sector and other actors who have crucial knowledge and resources for the successful implementation of the different measures as early as possible. In addition, the stakeholders could be engaged in a two-way and open communication about their needs, wants, and willingness to contribute to implementation. Their contribution could be through their effort or in-kind contribution or through payments for the services to be delivered if the strategy is implemented.

An example of how significant it is to include financing in the early stages of the analysis process can be seen in IFRM and IDRM. In flood and drought risk management studies, reviewing financing options is an important criterion when evaluating alternative interventions. the possibility to finance interventions is considered as an important criterion when evaluating alternative interventions.

Accordingly, FFWS can be applied to Phases I, II and II, with the aim of increasing the implementability success of the ultimate plan:

I. Inception Phase

- When setting-up the stakeholder involvement process (step I.2) ensure that potential implementing partners are included, including the private sector.
- The project's objectives, targets and indicators (step I.3) should be enriched with implementation indicators that consider the multiple values of water. This can include indicators used by the private and the financial sector in their decision to fund and/or implement a measure. Considering the transactional and non-transactional values of water may increase the clarity of the project rationale, strategy and implementation process for potential investors (and other stakeholders). In doing so, there is a greater chance of achieving a shared commitment and support for the project's implementation, making use of all financial means and expertise available.

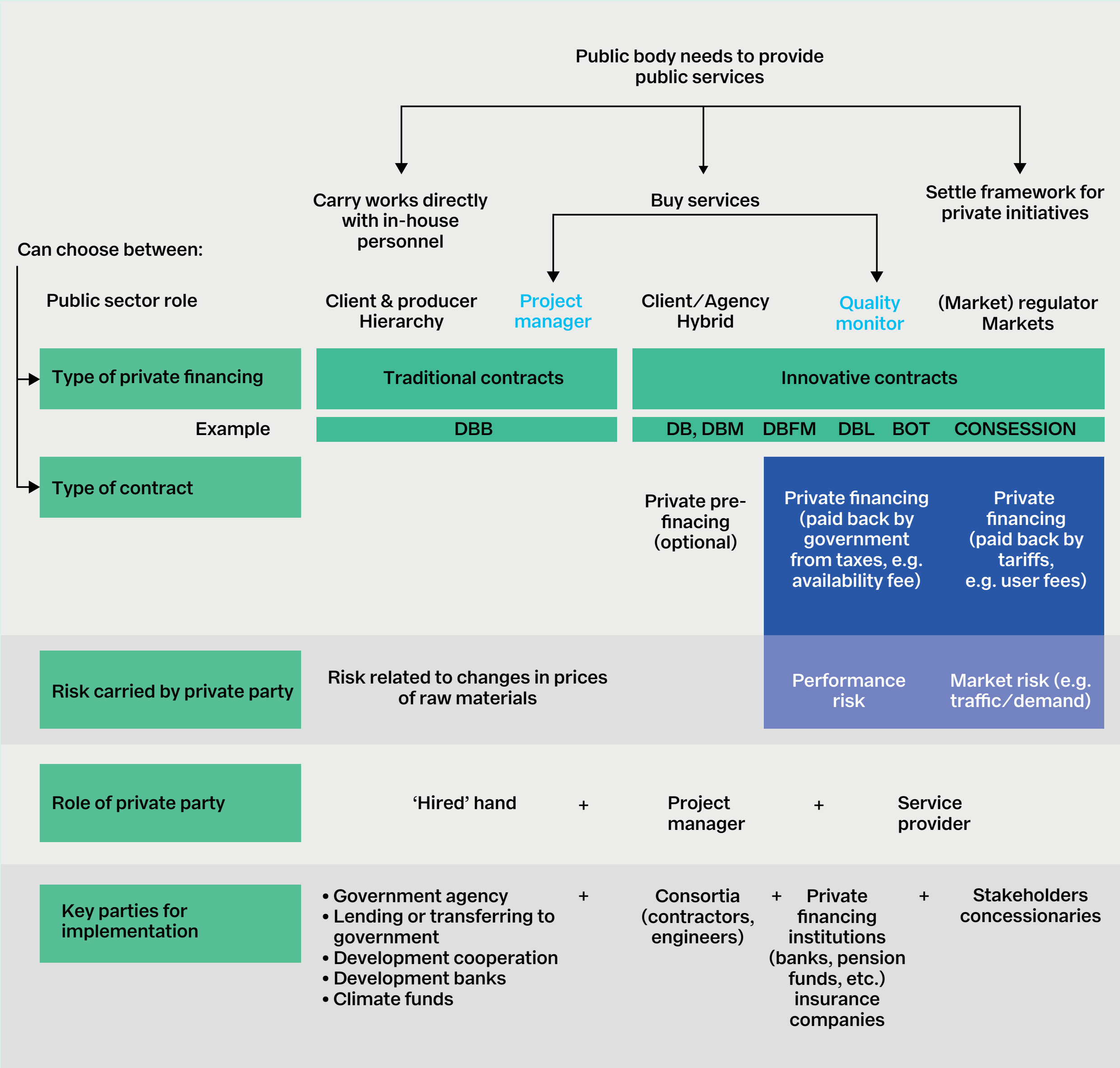

Figure 14 Options for procurement of public services: modes of governance and related project delivery and finance models
Source: Altamirano et al (2021)

II. Situation Analysis Phase

- Identify the different productive value chains and analyze their composition (e.g., many small-scale farmers versus only a few large-scale farmers), the challenges they experience or have experienced in the BUA situation and their willingness to pay for improvements in current levels of services.
- Assess the capacity and levels of trust of the public, private sector and other stakeholders. This requires the analysis of the current role, strengths, weaknesses and future potential of the public sector, the private sector and community agents, as well the enabling conditions for private sector participation and investments in water-related projects.

This also involves building social capital and trust between all the actors which are key for implementation.

III. Strategy Building Phase

- Ensure sufficient attention is given to the sustainability of the service provision, an important precondition for financing the implementation of a measure.
- Where possible, win-win situations should be brought forward which facilitate the clustering of projects in Phase IV.

Appendix 5: Supporting Tools and Serious Games

The planning process can be supported by a wide variety of computer-based tools. These tools are additional to the computational framework that is used in the analysis process. Tools can be oriented at processing data or to support the stakeholder engagement process. Serious games have proven to be powerful tools to explain complex concepts to the stakeholders, and to provide them with a strong understanding of issues and solutions so that they are adequately able to share informed viewpoints on the topic at hand.

Capacity building and the role of serious games
No matter what the type of intervention, capacity is always needed to implement the intended measures and/or to help people become aware of the problems that are supposed to be solved with the intended measures. Often, this capacity needs to be developed. If capacity is already present among stakeholders, it needs to be identified, harnessed, and channeled towards solving the problem in an effective way. This means that the people with capacity need to be involved, connected and motivated. Beyond the more traditional forms of transferring knowledge, serious games can be used to share information and communicate knowledge, and at the same time help to identify problems and potential interventions for which the participants are motivated.

In serious games, participants are confronted with a situation which is not their own but is recognizable and relatable, allowing them to express their ideas more freely than if it were their own situation. Typically, a serious game has certain problems, tasks and options to choose from and multiple roles for people with different interests, thus representing a variety of stakeholders. Participants in a serious game can be from the same organization, but preferably will represent different types of stakeholders. Participants are asked to play a role that does not have to be, or even preferably is not, their natural role. So, governments may play the role of NGOs, NGOs may play the role of industry, and industry may play the role of citizens. In this way, the "role reversal" helps them to understand the position, interests, and reasoning of other stakeholders. Serious games can be simple role plays, board games, computer games, or a mix of these different methods.

The following section gives some examples of such tools developed by Deltares.

Serious Games

Port of the Future Serious Game
- Aims at raising awareness of the current policy-making challenges of ports, so as to support port stakeholders in achieving sustainable development. The game uses a fictional yet realistic environment, autonomous scenarios, a set of measures and a qualitative set of indicators that provide information on the effects on society, natural environment, and economy. By introducing real-world challenges associated with port development and going through a decision-making process for selecting sustainable measures, stakeholders can experience various aspects of sustainable port development.
- Particularly relevant for: ICZM planning studies.
- Website: Port of the Future Serious Game - Deltares

- Marine Spatial Planning Challenge
    - Aims to help decision-makers, stakeholders and students understand and manage the maritime (blue) economy and marine environment. In the interactive simulation, country planners and stakeholders overlook the entire sea region and review many different data layers to assess its current status. They develop plans for future uses of the sea space over a period of several decades. The consequences of decisions for energy, shipping, and the marine environment are simulated and visualized in indicators and on maps.
    - Particularly relevant for: MSP studies.
    - Website: https://www.mspchallenge.info/

- Sustainable Delta Game
    - Aims to inform and enable communities, stakeholders, elected officials, and the general public to better understand water systems and their related restoration and protection measures. It teaches players about the importance of negotiation in decision-making as well as how to make smarter investment decisions given an uncertain future.
    - Particularly relevant for: strategic planning studies for all water systems.
    - Website: Sustainable Delta game - Deltares

Analysis support tools

- Climate App
    - Aims to support city planners, engineers, policy-makers and interest groups who aim to make cities safe against flooding, heavy rainfall, drought, and heat. The game offers an abundance of information and inspiration relevant for any new building, restructuring or renovation project. Based on simple criteria such as scale, land use, and product type, the game selects and ranks possible climate adaptation measures. As a result, the user is provided with a rapid overview of the most relevant measures available.
    - Particularly relevant for: IUWM planning studies.Website: Climate App - Deltares

- CIrcle – Critical Infrastructures
    - Over the past decades, the increasing frequency of extreme climatic events have impacted society in unprecedented ways. Critical infrastructure such as electricity, communication, drinking water and transport systems have been particularly affected. Circle aims to find solutions to the challenge of protecting these critical infrastructures from natural disasters. The touch table application (CIrcle tool) is a key outcome of Deltares' collaborative modeling and workshop concept. A CIrcle workshop helps stakeholders to understand the complex and interdependent relations between critical infrastructure systems. These relations, or causal links, can be investigated and visualized even within the context of a relatively data poor environment.
    - Particularly relevant for: IFRM and ICZM planning studies
    - Website: CIrcle Software Deltares

- Aqueduct Global Flood Analyzer
    - Enables users to estimate current flood risks for a specific geographic unit, taking into account existing local flood protection levels. It also allows users to project future flood risk with three climate and socio-economic change scenarios. These estimates can help decision-makers to quantify and monetize flood damage in cost-benefit analyses when evaluating and financing risk mitigation and climate adaptation projects.
    - Particularly relevant for: IRBM, IUWM, IFRM and ICZM planning studies.
    - Website: Aqueduct Global Flood Analyzer - Deltares

- Climate Resilient City Tool
    - Aims to support stakeholders with different roles, responsibilities and ambitions to work together to find attractive, inclusive, fair, and resilient solutions to climate-related issues in urban settings, both in the public and the private space.
    - Is particularly relevant for IUWM planning studies
    - Website: Adaptation Support Tool for Climate Resilient Cities - Deltares

- Adaptation Pathway Generator
    - Supports the development of adaptation pathways (as explained in section C.5.2). The Pathways Generator helps to explore policy pathways in an interactive way, for example, different stakeholders could work together to examine different scenarios using this serious game. The results are shown in a pathways map.
    - Particularly relevant for: all planning studies.
    - Website: Pathways Generator - Adaptation Pathways - Deltares Public Wiki

- Aqua Monitor
    - Shows at a global scale where water has been transformed into land and vice-versa. It uses freely available satellite data and the Google Earth Engine.
    - Particularly relevant for: IRBM, IFRM and IDRM planning studies
    - Website: Aqua Monitor - Deltares

- BlueEarth Data
    - BlueEarth Data is a community-based open data platform, initiated by Deltares, that provides global data for free. The platform is still under development but is now (October 2022) available as a beta-version.
    - Particularly relevant for: all planning studies.
    - BlueEarth Data - Deltares

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