Main Report

An EPIC Response:

Innovative Governance for Flood and Drought Risk Management

GREG BROWDER, ANA NUÑEZ SANCHEZ, BRENDEN JONGMAN, NATHAN ENGLE, EELCO VAN BEEK, MELISSA CASTERA ERREA, STEPHEN HODGSON

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Deltares

1818 H Street NW, Washington, DC 20433

Telephone: 202-473-1000; Internet: www.worldbank.org

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Foreword

Floods and droughts are some of the most tangible – and devastating – consequences of the climate crisis. They increasingly affect communities across the planet. The toll in human suffering and in economic costs is staggering. It is crucial that societies adapt and that governments prioritize, accelerate, and scale up their response mechanisms in the coming decade.

Societies have long struggled to prepare for and respond to floods and droughts - two hydrological extremes that can happen to the same country and at the same time. Climate change is driving more moisture into the atmosphere, resulting in 'hyper-charged' storms, heavy rains, and more intense dry spells. In many parts of the world, these changes to the hydrological cycle mean stronger and longer flood and drought periods, and in other areas, individuals are experiencing these hazards to a significant degree for the first time in living memory. Worldwide, it is difficult to point to a region or country that will not face more challenges managing these extremes in the years to come.

Countries can harness the power of water for development while avoiding the human suffering, economic losses, and ecological degradation that is associated with the hydrological cycle on overdrive. And societies can learn how to embrace the inevitability of floods and droughts, and the drastic alternations between them. This requires innovative governance and risk management approaches that navigate uncertainty, protect communities, economies, and ecosystems, reduce duplication, and improve efficiency of public resource use.

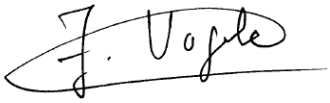
The EPIC Response Framework presented in this report offers a path forward for governments to manage these risks more comprehensively and systematically. It prioritizes the need for a "joined-up" government effort – one that does not rely on a single national lead agency and that does break siloes of single agencies mandated to address isolated parts of the interrelated challenges of floods and droughts.

Critical to the framework is its "whole of society approach", inclusive and representative of the needs of all of society. This means more effective public participation, and greater government effort to absorb citizens' views, especially those who are systematically underrepresented, such as women, minorities, elderly, and the poor. Floods and droughts typically hit groups in vulnerable situations the hardest. Traditionally, loss of assets or reduction in GDP are the measures of impact. But the poor have few assets and are underrepresented in this calculus. The EPIC Framework calls for a broader view that also considers their loss of "well-being" and potential intergenerational consequences.

We hope that governments, along with the countless individuals and organizations working on adaptation and resilience to climate change and disaster risk management, will find the EPIC Framework useful to meet their rising resilience challenges. We also hope that it serves as a rallying cry for governments and other development partners to focus on managing these risks in tandem across the hydrological spectrum and reaping the benefits of this innovative governance approach along the way. This is not to say that implementing the EPIC Response Framework will be easy. Far from it. But the way forward is to invest in strong partnerships and cooperation, at all levels, to stimulate the exchange of knowledge, tools, and resources to systematically prepare for and respond to floods and droughts in the coming decades.

So, while climate change and COVID-19 are compounding many challenges, they also present an unprecedented opportunity. Amid record spending to spur a recovery from the pandemic, we have a chance to leverage these investments towards green, resilient, and inclusive development that reduces rather than further exacerbates our societies' vulnerability to climate risks. Let's seize that opportunity.

Kitty van der Heijden
Director General for International Cooperation
Ministry of Foreign Affairs
The Netherlands



Juergen Voegele
Vice President for Sustainable Development
The World Bank

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About the Authors

Greg Browder, is a Lead Water Resources Management Specialist at the World Bank. During the preparation of the report he served as the Global Lead for Water and Resilience.

Ana Nunez Sanchez, J.D. is a Planning and Institutional Expert at Deltares and leads the Deltares' Adaptation and Implementation Research Program.

Brenden Jongman is a Senior Disaster Risk Management Specialist at the World Bank and leads the World Bank's Community of Practice for Nature Based Solutions.

Nathan Engle is a Senior Climate Specialist at the World Bank and co-leads the World Bank's Drought Resilience Community of Practice.

Eelco van Beek is a Water Resources Management Expert at Deltares and Emeritus Professor at the Delft University of Technology and the University of Twente, in the Netherlands.

Stephen Hodgson, J.D. is an independent environmental lawyer based in Belgium.

Melissa Castera Errea is the Coordinator for the Water Resources Global Solutions Group at the World Bank.

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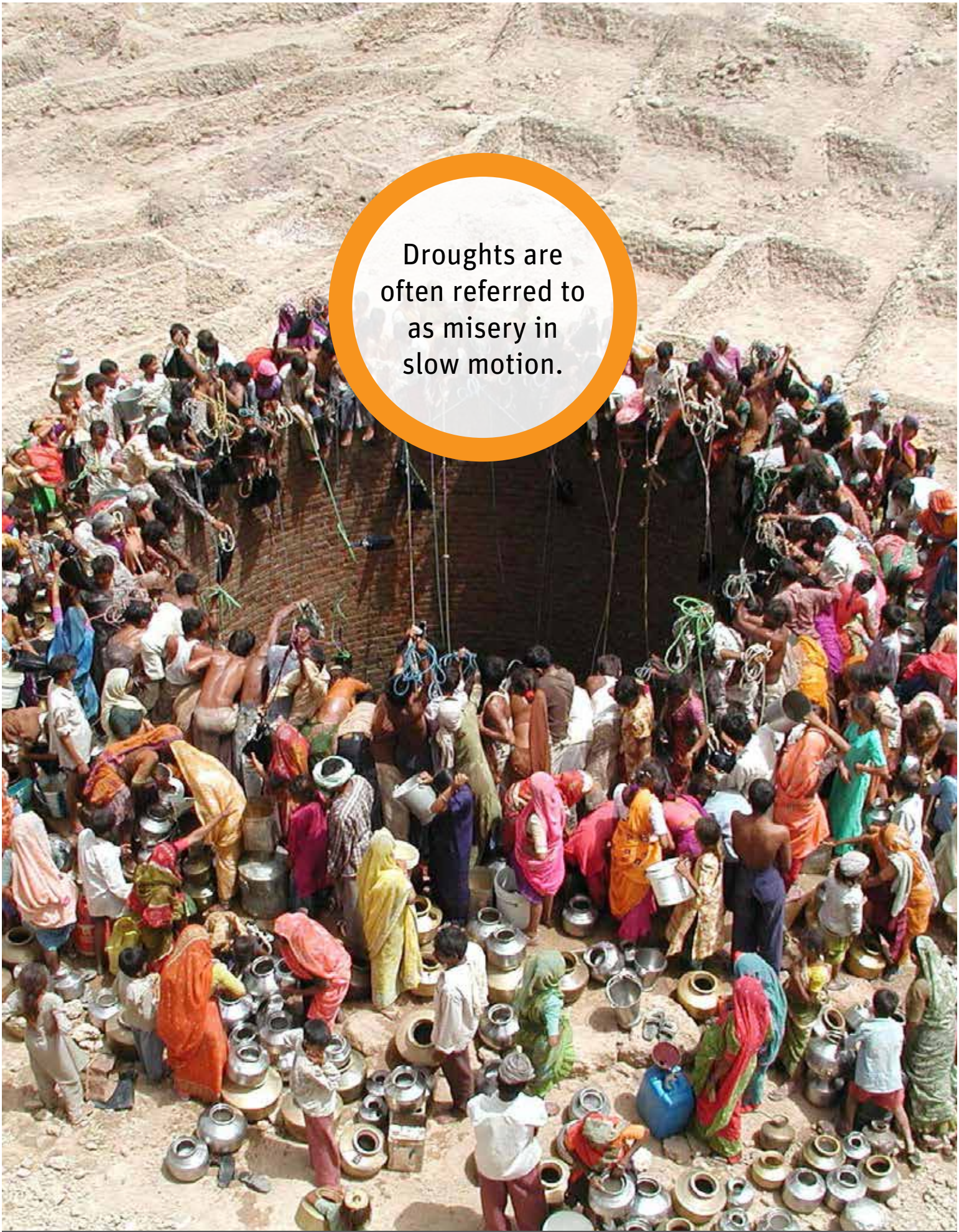
APFM	Associated Program for Flood Management
AWMP	Agricultural Water Management Plan
CDI	Composite Drought Index
CSA	Climate-Smart Agriculture
DMP	Drought Monitoring Program
DRM	Disaster Risk Management
EMS	Emergency Management System
ENSO	El Niño-Southern Oscillation
EOC	Emergency Operations Centre
GEF	Global Environment Facility
GIS	Geographic Information Systems
GTS	Global Telecommunications System
GwMO	Groundwater Management Organization
ICZM	Integrated Coastal Zone Management
IDMP	Integrated Drought Management Programme
IWRM	Integrated Water Resources Management
IWSP	Irrigation Water Supply Plan
NAP	National Adaptation Plan
NCA	National Climate Assessment
NDC	Nationally Determined Contributions
NHS	National Hydrological Service
NMS	National Meteorological Service
PES	Payment for Environmental Services
PDNA	Post Disaster Needs Assessment
RBO	River Basin Organization
UWSP	Urban Water Supply Plan
WaMO	Watershed Management Organization
WMO	World Meteorological Organization
WRI	Water Resources Infrastructure
WRM	Water Resources Management
WSCP	Water Shortage Contingency Plan



People gather to get water from a huge well in the village of Natwarghad in the western Indian state of Gujarat. Photo: REUTERS / Alamy Stock Photo

1 Introduction: Innovative Governance for Accelerating Hydro-Climatic Risks

Floods and droughts take a staggering toll both in human suffering and in economic costs. Over the last decade, these natural disasters have killed tens of thousands of people around the world, affected the lives of billions, and caused damages of more than a trillion dollars (US).

Moreover, the threats from floods and droughts are increasing because of climate change. Storms and rainfall events are becoming more extreme and deadly, while droughts are hotter and more intense. At the same time, more and more people are in harm's way, as populations grow.

Yet the sobering truth is that the world's governments are failing to cope with the increasing risks from extreme events that involve too much or too little water on a warming planet—what this report calls "extreme hydro-climatic events." To cite just one of many current limitations, droughts and floods are typically managed by agencies that rarely collaborate or even communicate. That siloed approach makes it much harder to exploit measures that can protect against both threats, such restoring upstream forests to soak up stormwater flows, thus reducing the threat of flooding, while also recharging groundwater and offering more life- and crop-saving water in times of drought.

A new approach thus is urgently needed to manage the large and growing risks associated with extreme hydro-climatic events. This report offers that new approach. It sets out a vision of how national governments can deal with these challenges through innovative governance, offering a comprehensive path towards a safer, more prosperous future for the world's 7.7 billion people.

This introductory chapter describes the enormity of the challenge and the three overarching governance principles that will make it possible to meet that challenge: (1) engaging all parts of society, from government agencies and universities to the private sector and individuals from marginalized communities in a "whole-of-society" approach, is crucial to managing risks; (2) floods and droughts must be viewed through the same hydro-climatic management lens and addressed together; and (3) national agencies managing key functions like disaster responses or water resources can no longer work alone, exclusively pursuing their own independent mandates, as they are interconnected and complementary to each other. Instead, agencies must coordinate and collaborate through "joined-up" government aimed at presenting a unified face to the citizens they serve by operating as a single unit to manage complex and interrelated problems.

This report presents a new framework for creating a more effective system of managing hydro-climatic risks, a system that has the potential to dramatically reduce the future human and economic toll from these events. The five key elements of that new framework can be represented by the mnemonic term "EPIC Response," and are described as follows:

- *Enabling* environment of policies, laws, agencies, strategic plans, participation, and information.
- *Planning* at multiple and nested geographical levels to ensure that mitigation measures become higher priorities.
- *Investing* in healthy watersheds and water infrastructure to reduce hazards from both floods and droughts.
- *Controlling* water use and floodplain development to reduce exposure and to minimize vulnerabilities.
- *Responding* better to floods and droughts through more effective monitoring, response, and recovery.

An EPIC Response also will require actions taken in eleven different program areas. This introductory chapter provides an overview of those program areas—each organized as single chapter in the report. Each sector agency responsible for program implementation will have its own critical programs that inevitably overlap or interact with those of other agencies; thus, interagency collaboration—and the joined-up government that results—is vital for achieving more effective hydro-climatic risk management.

This report is intended to bring awareness of this enormous challenge and the potential solutions to a broad audience, as well as offering a practical and detailed guide to help governments improve their flood and drought management systems.

1.1 The Wicked Problem of Hydro-climatic Extremes

The wide world of hydro-climatic risks. Hydro-climatology is a rapidly evolving field that looks at the inseparable relationship between climate and hydrology.[1] Driven by the sun, modulated by the Earth's orbit, and influenced by geography, the climate varies around the world. Mediterranean climates enjoy dry summers and suffer through wet winters; tropical monsoon climates have long hot dry periods which are suddenly interrupted with the torrential downpours of the monsoon; and desert climates have long periods of extreme dryness that are occasionally interrupted by brief but intense storms. The well-known Köppen climate classification system has identified more than 30 different climate zones around the world, each with distinct weather and vegetation characteristics. Box 1.1 provides more information on the concepts of climate and climate zones.

Each region has its *average intra-annual* (within a year) weather and hydrological patterns that ecosystems and societies have adapted to over time. However, the Earth's climate system is complex and is influenced by *inter-annual* (weather across multiple years) phenomena that affect global weather patterns. The most notable example is the El Niño-Southern Oscillation (ENSO) in the Pacific Ocean, which changes rainfall patterns and temperatures around the globe. Inter-annual variation can produce hydro-climatic extremes, where precipitation amounts and temperatures are vastly different from what would be expected in an average year, generating potentially dangerous floods and droughts. Every climate zone has its own unique pattern of hydro-climatic hazards, and it is important to remember that humid regions can suffer from major droughts and arid regions can suffer from floods.

With climate change, the patterns and severity of the hydro-climatic extremes are also changing compared to the past record, bringing increasingly frequent and potentially devastating hazards, and requiring a new approach for coping with those hazards, as this report describes.

There are many different types of hydro-climatic extremes and an overview is provided in Annex 1. In the broadest sense, a flood occurs when water unexpectedly pours over the land, potentially inundating homes, roads, and businesses, and putting people and assets at risk. Rivers may spill over their normal banks, for example, or seawater may surge into low-lying coastal areas during storms. Droughts are abnormally dry periods, caused by some combination of low precipitation and high temperature, that may cripple crops or bring water

Box 1.1 Climate and Climate Zones

Climate is the average course of weather conditions for a given location and time of the year, over a period of many years. At the simplest level, the weather is what is happening to the atmosphere at any given time (temperature, humidity, wind, rainfall). Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time (WMO 2020).

Climate zones go beyond weather. Climatic zone classification is often based on rainfall, temperature, crop ecology, humidity, vegetative and geographic criteria or a combination of criteria. The most popular, the Köppen climate classification system, categorizes climate zones throughout the world based on local vegetation, assuming strong interlinkages between vegetation, weather, and hydrology.[a]

[a] For more information about the Köppen Climate Classification System, see National Geographic's website at https://www.nationalgeographic.org/encyclopedia/koppen-climate-classification-system/.

Key issue: Climate zones are a powerful concept for understanding hydro-climatic risks because they are closely correlated with weather, watersheds, and water conditions. Each climate zone will have its own unique flood and drought hazards. Climate change and land degradation are modifying climate zones around the world.

[1] Hydro-climatology was defined by Langbein (1967) as the "study of the influence of climate upon the waters of the land." It includes hydrometeorology as well as the surface and near surface water processes of evaporation, runoff, groundwater recharge, and interception. The total hydrologic cycle, then, is the basis for a discussion of hydro-climatology.

shortages. Floods are generally rapid onset hazards that emerge and disappear quickly. In contrast, droughts are typically slow onset hazards that develop gradually and last longer. This general characterization, however, is not always true: some river floods may take months to fully develop, while short bursts of extreme dryness can cause localized flash droughts that have devastating agricultural impacts. Each region will have its own unique set of hydro-climatic hazards that it must grapple with, and it will need to develop its own fit-for-purpose governance systems to address these risks.

The beneficial and devastating impacts of floods and droughts. Hydro-climatic extremes play important roles in shaping and sustaining the natural environment. Floods deposit rich silt on floodplains, creating fertile soil and productive farmland. Droughts can create the conditions needed for wildfires that reduce forest understory and rangeland brush, and that are required for seeds to germinate, stimulating new growth. But when floods and droughts occur where people live and work, or where strategic assets are placed, natural hazards can be a source of harm—in other words, a natural hazard turns into a potential natural disaster. The overall risks posed by flood and drought hazards will depend not just on their magnitude and frequency, but also on how many people and key assets are exposed to the hazards and on the vulnerability of the exposed populations and assets. Chapter 2 provides more information on disaster risk management terminology.

From a global perspective, countries have generally not managed their hydro-climatic risks well. Between 2000 and 2019, 1.65 billion people were adversely affected by floods and 1.43 billion by droughts, wreaking social and economic havoc across the globe. Droughts and floods caused US$764 billion in recorded damages in the period 2000-2019. Meanwhile, storms alone caused US$1,390 billion in damages, much of it from storm-related flooding (CRED and UNDRR 2020). In addition to these direct costs, floods and droughts can have a wide range of other damaging impacts, such as losses of ecosystem services, disruptions of global supply chains, and increased incidences of disease and other public health costs (He and others 2020).

Moreover, poor and marginalized populations are often disproportionately affected by hydro-climatic extremes (Winsemius and others 2015). Poor people in cities are more likely to live in flood-prone areas that have lower land values; in many developing countries, informal settlements on floodplains or on hillsides vulnerable to landslides offer the only viable housing available to the poor. The urban poor also typically have fewer resources to recover from floods and are unable to access formal flood relief programs. Similarly, the rural poor are often those most severely affected by droughts. Many poor rural households rely upon rain-fed agriculture or small livestock herds which can be devastated by severe droughts. Rural water supplies can run dry. Droughts can also cause a deep and sustained drop in the social capital of poor families, often affecting a family's wealth and health for generations. For example, droughts have been shown to impair the health of children and reduce their educational attainment, helping to perpetuate a cycle of poverty (Damania and others 2017).

The effects of droughts can extend far beyond the specific regions struck by the droughts, with cumulative impacts that only become apparent over time. Often referred to as misery in slow motion, droughts can cause famines that trigger large-scale migrations. In addition, droughts that cut crop yields in one region can lead to global shortages and soaring prices for that crop, causing economic pain and even food riots around the world. The full toll from drought may be much higher than the official figures, because drought monitoring and impact assessment systems are generally weak throughout the world, particularly in developing countries, most probably leading to a systematic underreporting of the economic and social impacts (Mapedza and others 2019).

It is important to add, however, that economic impacts of hydro-climatic extreme events, especially floods, can be both negative and positive as these events ripple through society and the economy, as a closer inspection of the economic dynamics reveals (Damania and others 2017). Flooding obviously can have devastating direct impacts, including loss of life and property damage, and high indirect impacts, such as those associated with lost productivity and impaired public health. On the other hand, building back damaged infrastructure after a flood can provide an economic stimulus. In addition, heavy precipitation can raise agricultural yields and increase generation of hydro-electric power. One study found that after a median flood event, a country's gross domestic product (GDP) rises by around 1 percent. That very same study, however, found that after a median drought event, GDP decreases by -0.6 percent (Loayza 2009).

Global warming is a game changer. A warming world resulting from increased concentrations of atmospheric greenhouse gases is a game changer on multiple fronts. Since the end of the last ice age, around 10,000 years ago, the Earth's climate has been relatively stable, allowing agriculture to flourish and great civilizations to emerge. The global population surged from a few million at the end of the last ice age to 1.2 billion in 1850. Since 1850, emissions from industry and other human activities have increased CO_2 levels from about 280 ppm to 417 ppm in 2021, with the global population approaching 8 billion. The symbolically important milestone of doubling

Rizal, Philippines: Flood inpacts on a community in Rizal, Philippines. Photo: © Leakeem | Dreamstime.com

pre-industrial 1850 CO_2 levels to 560 ppm will most likely be reached sometime in the second half of the 21st century. This will put the Earth at CO_2 levels not seen for 35 million years, the last time that Antarctica was ice-free (Brooke and others 2019). A recent study estimated that there is a 66 percent chance that doubling pre-industrial CO_2 levels (to 560 ppm) will increase global average temperatures between 2.6 and 3.9°C (Sherwood and others 2020).

Increasing global temperatures will have dramatic, but difficult to accurately forecast, impacts on regional climates. From a global perspective, higher temperatures enable the atmosphere to hold more water vapor while also increasing evaporation from oceans and land surfaces, resulting in higher levels of precipitation. More evaporation over land will potentially increase aridity in some regions. Meanwhile, higher temperatures will melt more ice stored in mountain glaciers and polar icecaps and cause seawater to expand, causing sea levels to rise. The global atmospheric and oceanic circulation patterns will most likely be affected by a warming world, resulting in changing regional weather patterns. Finally, the rate of increase of greenhouse gas emissions is uncertain and dependent on how quickly the world acts to reduce those emissions. Climate change may also lead to tipping points in various Earth systems. For example, the rapid release of methane gases from melting permafrost or the collapse of the Antarctic ice sheet could cause irreversible (in the geological near term) jumps in global temperatures or sea levels (Lenton and others 2020).

Climate change means that traditional hydro-climatic risk management no longer works. Under stable climate conditions, annual weather patterns in a specific region are variable but statistically stable over time—a condition known as statistical stationarity. This means that if enough historical information is available, we could predict with a high degree of confidence the magnitude of a storm, flood, or drought that would occur every 100 years on average. With a changing climate, stationarity no longer holds, and the past is no longer a guide to the future. This places a premium on being able to successfully cope with a wide range of potential hydro-climatic extremes, an ability known as climate resilience. Strategies that increase climate resilience include preparing in advance for climate shocks, seeking robust approaches that will work across a range of potential climate futures, and creating enough flexibility to make it possible to adjust quickly as we see which way the wind is blowing. Those strategies will need to be ingrained into our DNA.

As the world warms, the global map of climate zones will be constantly changing. Watersheds throughout the planet also will change as the land adjusts to new conditions, resulting in profound impacts on regions' hydrology and their hydro-climatic extremes. There is evidence that these impacts are already occurring. A survey of recent research concluded that the tropics appear to be expanding at the rate of 50 kilometers per decade, that the Sahara Desert has grown by 10 percent since 1920, and that the permafrost line in Canada has retreated 80 miles north over the last 50 years.

1.2 Innovative Governance: Joined-up Government Leading a Whole-of-Society Approach

Responsibility for managing hydro-climatic risks needs to be shared. Addressing the daunting challenges of flood and drought management is a shared responsibility that requires a whole-of-society effort involving national governments, local governments, businesses, academia, farmers, schools, civil society, and households, including those marginalized. This whole-of-society approach requires vertical integration among different political jurisdictions: international, national, regional, and local. It also requires horizontal coordination among different sectors and groups. It is one of the most important and complex governance challenges that the world faces in the 21st century, particularly with the mounting threats posed by climate change.

A joined-up national government effort is needed to provide leadership. The report is targeted primarily at national governments, working through their sector agencies, as they must provide the leadership to help coordinate a whole-of-society approach. It provides a framework that can help inform decisions regarding laws, institutions, strategic plans, programs, regulations, and critical agency tasks. It highlights what needs to be done and by whom. The report uncovers many of the hidden connections between the mandates and programs of different agencies and shows that a joined-up government approach will result in more effective hydro-climatic risk management.

Looking at floods and droughts as flip sides of the same climatic coin. The report is also about taking a step back and looking at floods and droughts together through the same lens, one that clearly sees the often under-appreciated relationships between the two. Although floods and droughts are at the opposite ends of the hydro-climatic spectrum, it is still the same spectrum. Consequently, the same principles, and many of the same actions, can be applied to reduce risks for both. As shown in Box 1.2, there is increasing understanding of the need to integrate flood and drought risk reduction actions.

Moreover, the same national agencies—WRM, DRM, hydro-met, agriculture, natural resources management, social protection, finance, and others—need to respond to both floods and droughts. This year it may be a drought and next year it may

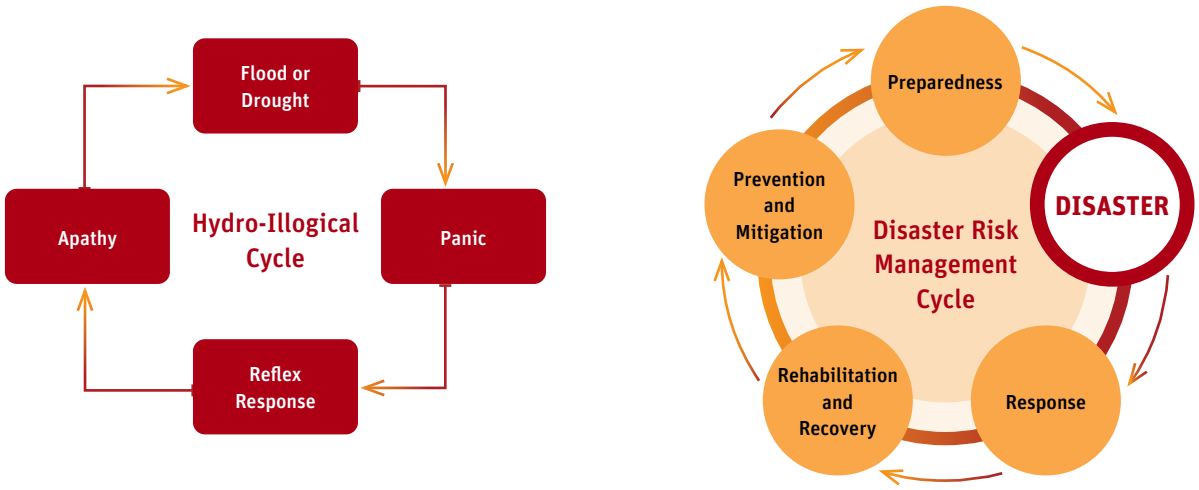
Box 1.2 Integrating Flood and Drought Risk Reduction (DRR) Measures

A recent article (Ward and others 2020) notes that most research on hydrological risks focuses either on flood risk or drought risk, while floods and droughts are actually two extremes of the same hydrological cycle. To better design disaster risk reduction (DRR) measures and strategies, it is important to consider interactions between these closely linked phenomena. The article provides examples of: (a) how flood or drought DRR measures can have (often unintended) positive or negative impacts on the risk of the opposite hazard; and (b) how flood or drought DRR measures can be negatively impacted by the opposite hazard. The article provides examples related to dikes and levees, dams, stormwater control and upstream measures, subsurface storage, migration, agricultural practices, and vulnerability and preparedness.

Consider the example of levees that are primarily constructed for flood risk management along rivers. A levee may reduce groundwater recharge in floodplains, thus reducing the amount of groundwater available to neighboring communities during a drought. Conversely, heat and dryness during droughts may undermine the structural integrity of levees, making them more likely to collapse during flood events. Another example is the need to manage multi-purpose reservoirs in a manner that balances the need for flood control with water storage for drought mitigation.

Key issue: The interlinkage between DRR measures shows that it is best to consider both flood and drought mitigation measures through a single river basin planning approach as highlighted in Chapter 6.

FIGURE 1.1 Hydro-Illogical[2] and Disaster Risk Management Cycles



Source: World Bank; UN-SPIDER 2020.

be a flood, potentially resulting in whiplash and ineffective responses unless the agencies are prepared to deal with either floods or droughts at any given time. There is evidence that climate change will intensify these "seesaw" events of alternating floods and droughts, resulting in feedbacks that intensify the hazards (He and others 2020). An example of this phenomenon is how a drought can reduce vegetation, sometimes by provoking wildfires, which can then increase the impacts of flooding in the subsequent season.

From a reactive to a proactive response. Historically, governments have reacted to hydro-climatic risks by responding to flood or drought emergencies without trying to address the underlying causes of how natural hazards turned into human disasters. This has often led to what is referred to as the "hydro-illogical cycle" as depicted in the left side of Figure 1.1. During a flood or drought, there is typically a flurry of activity as urgent response and relief measures are undertaken—often independently by different government agencies—such as dikes shored up, shelter provided, or food distributed. Typically, reflexive government responses to the public uproar are to rapidly approve new water infrastructure, such as reservoirs or river embankments, to commit to improve forecasting and early warning systems, and to promise to fund the recovery of flood-damaged assets and drought-savaged landscapes. And then, as the memory of the traumatic event fades over time, anxiety subsides and normal life resumes. The promised actions are forgotten as more pressing issues dominate the political agenda.

The shortcomings of falling into the "hydro-illogical cycle" are well known, and a new paradigm has emerged which focuses on proactive risk management as depicted on the right side of Figure 1.1. This modern approach to risk management, which can be applied to any type of natural disaster, was most famously encapsulated in the Sendai Framework for Disaster Risk Reduction 2015-2030 which stresses four principles: (1) understanding disaster risk; (2) strengthening disaster risk governance to manage disaster risk; (3) investing in disaster reduction for resilience; and (4) enhancing disaster preparedness for effective response and to "build back better."

Integrating government agency programs through an EPIC Response Framework. The report builds upon general DRM and WRM concepts and presents a comprehensive framework to help governments lead their societies in addressing flood and drought risks. As described in the introduction to this chapter, the term "EPIC Response" is a mnemonic device that highlights the overarching elements of an effective hydro-climatic risk management system as follows:

- **E**nabling environment consisting of laws, agencies, strategic plans, participation, and information.
- **P**lanning at multiple and nested geographical levels to ensure that mitigation measures become higher priorities.
- **I**nvesting in watersheds and water infrastructure to reduce the hazards from floods and droughts.

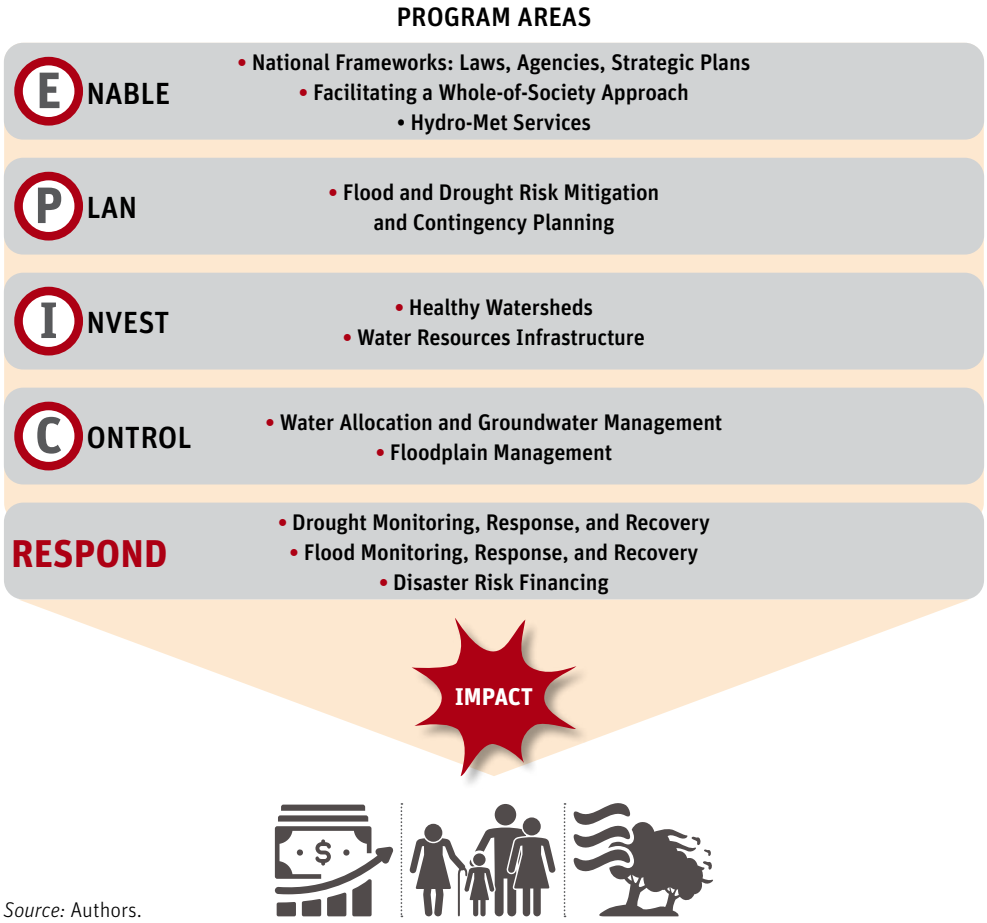
[2] The term hydro-illogical cycle was originally used in Wilhite, D. (2002).

- **C**ontrolling surface and groundwater water use and floodplain development to reduce exposure and minimize vulnerability.
- **R**esponding to floods and droughts through effective early warning, response, and recovery.

A central tenant of the EPIC Response Framework is that there is a *general downward cascading influence* among the main elements, though there sometimes can be influences in both directions. Without an enabling environment it is very difficult to make progress in other elements of hydro-climatic risk management. Planning helps to prioritize investments to mitigate risks and provides a roadmap for managing land and water resources. Managing land and water in turn helps to reduce the exposure and vulnerability of people and assets at risk from floods and droughts. If the EPIC elements are functioning well, a country should be well positioned to handle the risks when an extreme event strikes through effective early warning, response, and recovery programs.

National government agencies need to work collaboratively in a joined-up effort to implement an EPIC Response Framework. Each government agency will have its own sectoral programs, which inevitably overlap or interact with the responsibilities of other agencies. This report defines a program as a continuous set of activities undertaken by a national agency, authorized through national legislation with well-defined objectives, and funded by the national government. The general program areas for managing hydro-climatic risks are highlighted in Figure 1.2, the EPIC Response Framework (sometimes hereafter referred to as the Framework). Box 1.3 describes how the Framework corresponds with other frequently used frameworks in the flood and drought community.

FIGURE 1.2 The EPIC Response Framework



Source: Authors.

Box 1.3 Standing on the Shoulders of Giants: How the EPIC Response Framework Builds Upon Other Frameworks

The World Meteorological Organization (WMO), with support from the Global Water Partnership, houses two programs that deal with hydro-climatic risk management—the Integrated Drought Management Programme (IDMP) and the Associated Programme on Flood Management (APFM).[a]

The EPIC Response Framework is inspired by the APFM's "Integrated Flood Risk Management Cascade" which emphasizes a downward cascading risk reduction impact through the following interventions: (1) reducing flood hazards with watershed interventions; (2) protecting against floods through infrastructure; (3) regulating land use; (4) preparing for floods; and (5) residual risk mitigation through emergency response and recovery. These interventions correlate closely with the investing (I), controlling (C), and responding (R) elements of the EPIC Response Framework.

The IDMP framework revolves around the three pillars of drought management: (1) drought monitoring and early warning systems; (2) vulnerability and impact assessment; and (3) drought preparedness, mitigation, and response. Drought monitoring, impact assessment, and response fall mainly under the responding (R) element in the EPIC Response Framework. Drought preparedness and mitigation cover a broad range of activities which are included in the rest of the EPIC Response Framework.

[a] Information on the IDMP and APFM programs can be found at https://www.droughtmanagement.info/ and https://www.floodmanagement.info/.

Key issue: The EPIC Response Framework combines existing flood and drought approaches into a unified framework that allows hydro-climatic risks to be synergistically managed and promotes collaboration between agencies.

The Framework should be considered a system, with the different program areas interacting and complementing each other in complex ways—with a general downward cascading influence—and ultimately determining how well a country can manage the social, economic, and environmental impacts of floods and droughts. Some of the program areas relate primarily to either floods or droughts, but many of them address both ends of the hydro-climatic spectrum.

1.3 Report Structure

The report chapters are structured around the eleven program areas in the Framework. A general summary of each program area is presented in the paragraphs below. Specific individual programs are discussed in each chapter. Institutional responsibilities will of course vary from country to country, and thus the report uses a generic terminology for national agencies, specifically: WRM, DRM, hydro-met, agriculture, natural resources management, social protection, and finance. Each of these agencies is responsible for the implementation of its own set of programs, yet they must also work together collaboratively in a joined-up government response to lead a whole-of-society approach.

Chapter 2: Navigating the Report. This chapter provides a summary overview of the 43 programs that are presented in the report. Key terminology and guidance on how to use the Framework are provided. The reader is encouraged to read this chapter in its entirety and then utilize the hyperlinks to go to program areas of specific interest. Program descriptions are intended to inform non-experts with the objective of facilitating understanding of how the different programs areas fit together into an EPIC Response Framework for hydro-climatic risk management.

Chapter 3: National Sectoral Frameworks. All the programs in the Framework are rooted in national laws which create the different sector agencies, authorize the programs, and provide the budgets for their implementation. The chapter first examines the national sectoral frameworks for WRM and DRM. The overarching structure for drought and flood risk management, which is composed of many different sectors, is then presented.

Chapter 4: Facilitating a Whole-of-Society Approach. National agencies need to provide leadership in hydro-climatic risk management, but ultimately the decisions and actions of society will determine the effectiveness of government efforts. This report argues that agencies need to equally prioritize technical expertise with social engagement through dedicated programs to promote stakeholder participation, social inclusion, communication, education, research, and ensuring public access to information.

Chapter 5: Meteorological, Hydrological, and Climate Services. These services are the fundamental prerequisite

for hydro-climatic risk management. The chapter looks at the role of meteorological and hydrological agencies in providing information for planning and management, water resources infrastructure design, and flood and drought monitoring. It highlights the changing role of national meteorological services from being sole providers of weather information to facilitators for leveraging the benefits of the global weather enterprise—including international initiatives, the private sector, and academia as well as the importance of co-production.

Chapter 6: Flood and Drought Mitigation and Contingency Planning. Water resources planning at the river basin level is a cornerstone of hydro-climatic risk management. Basin planning also provides the platform for basin-level flood and drought contingency plans. Large water users, such as urban water utilities or irrigation agencies, should also have their own planning processes to improve water use efficiency as well as to prepare for drought contingencies. These plans need to be compatible with, and nested under, the overall basin plan. Coastal zone planning is also touched upon in the chapter, as it can help guide coastal floodplain management. The important issue of local flood mitigation planning is addressed in the floodplain management chapter.

Chapter 7: Healthy Watersheds. This is the first line of defense in reducing hydro-climatic hazards. Forests, wetlands, floodplains, healthy rangeland and cropland, and coastal barriers all have important roles to play in mitigating flood and drought hazards. Sound agricultural policies and climate-smart practices not only contribute to healthy watersheds but also improve the resilience and economic well-being of farmers. The chapter also discusses the importance of establishing local watershed management organizations as well as engaging in periodic watershed assessment and planning.

Chapter 8: Water Resources Infrastructure. The role of infrastructure, such as dams and dikes, in reducing flood and drought risks is well known and clearly understood by policy makers. This chapter calls upon WRM agencies to develop clear policies to guide infrastructure investments to ensure efficiency and sustainability. The chapter also highlights the critical role of WRM agencies in dam and flood infrastructure safety programs.

Chapter 9: Water Allocation and Groundwater Management: While water resources infrastructure can help store water and convey it across long distances, WRM agencies also need to develop programs to allocate available water supplies to promote equity and efficiency, as well as deal with droughts. The chapter presents basic principles that should be incorporated into water allocation programs and stresses the need, as well as the complexities involved, for WRM agencies to develop conjunctive groundwater management programs.

Chapter 10: Floodplain Management. As some degree of flooding in river and coastal flood plains is inevitable, this chapter presents three programs that can help to manage floodplain risks. These are national floodplain mapping, regulating floodplain development, and local flood mitigation planning.

Chapter 11: Drought Monitoring, Response, and Recovery. National governments need to establish multi-sectoral drought monitoring programs that can assess the evolution and risks of droughts as they develop over time. WRM agencies can oversee and help implement drought contingency plans—including conservation and reallocation of water—at the basin, city, and irrigation scheme levels. Agriculture agencies should have programs ready to provide support for farmers and livestock producers to help them respond and recover to droughts. Finally, social protection agencies should have in place scalable programs to help the most vulnerable groups cope with droughts.

Chapter 12: Flood Monitoring, Response, and Recovery. Countries must also be prepared to respond to flooding. The starting point is a flood forecasting program which typically requires close interagency cooperation. Next is the implementation of a flood emergency preparedness and response program that addresses such matters as evacuations and the provision of immediate relief. Then, countries need multi-sectoral flood impact assessments to help inform relief and recovery efforts in the aftermath of a flood emergency and to ensure that flood recovery programs help communities "build back better." Finally, a post-flood assessment should be undertaken to document lessons learned and help prepare the country for the next flood.

Chapter 13: Disaster Risk Financing. The ability of a country to respond to and recover from hydro-climatic emergencies will depend upon its ability to manage the economic and fiscal impacts of natural disasters. A disaster risk financing strategy and related programs that match the country's risk profile and fiscal capacity should be developed. A multi-layered approach should generally be pursued with the impacts of frequent and low-intensity events, such as seasonal floods or droughts, being absorbed through a national disaster fund or budget reallocations while instruments such as contingent disaster loans or sovereign catastrophe (CAT) bonds may be used for less frequent but more severe events. The strategy may also include actions to help create or strengthen natural disaster insurance programs.

Chapter 14: Moving Forward. This chapter summarizes the roles of different national government agencies in

Wildfire affecting a housing development in Santa Clarita, California. Photo: © Wirestock | Dreamstime.com

implementing the EPIC Response Framework programs. It highlights the key areas in which different agencies must collaborate with each other to be effective. The chapter presents recommendations for ensuring that the hydro-climatic risk management system continuously evolves, including constant program evaluation and periodic national strategic planning for water resources management, disaster risk management, and drought management.

1.4 Report Audience and Purpose

The report can be used by a broad audience for a variety of purposes, including as a global knowledge product as well as an assessment framework for flood and drought risk management.

Global Knowledge Product. The report is intended to serve as a global knowledge product for a wide audience. It views floods and drought through the lens of hydro-climatic risk management, helping to bring together two normally disparate communities. The report provides the most comprehensive presentation of flood and drought programs that currently exists in the literature, drawing upon more than 100 key references and four case studies. It hopefully provides new insights and inspiration for national governments, international organizations, civil society, and the research community.

Assessment Framework. The report also provides an ideal framework for engaging in broad policy discussions in a structured manner. This approach was piloted in two of the case studies, the Philippines and Tanzania, with encouraging results. Each country-relevant program in the Framework can be systematically reviewed and categorized into one of the four levels of development: nascent, engaged, capable, and effective. Following this program-by-program assessment, the full Framework can be considered in a holistic manner

and the gaps, constraints, and opportunities for advancing a country's hydro-climatic risk management system can be discussed in a systematic manner with a broad range of stakeholders.

Countries will obviously be at different levels in their capacities to manage flood and drought risks depending on many factors. Using the report as an assessment framework is intended to help structure analysis, generate policy options, and hopefully allow countries to make progress. Certainly, much more detailed analysis at the program level would be required to give country-specific guidance on the necessary policy and institutional reforms. This is particularly true with respect to issues related to agency budgets, capacities, and management—which are often the key constraints to effective program performance. This will be a never-ending process, particularly as the climate changes and countries evolve.

Supporting International Development. The report should be of particular value to national governments in developing countries and their sectoral agencies. International development organizations that support developing countries to enhance their climate resilience will also find the report useful. The report can help guide specific tasks including:

- Informing a country's national climate adaptation plan.
- Structuring discussions for policy loans offered by multi-lateral development banks that focus on climate resilience and disaster risk management.
- Providing a framework for national strategic plans, particularly for water resources, disaster risk management, and drought management.
- Assisting in project appraisal by identifying connections outside a particular sector that can affect the performance of that project.

The different EPIC Response programs, implemented by a variety of agencies, interact together and ultimately determine the final social, economic, and environmental impacts caused by extreme hydro-climatic events.

Aftermath of a flooding event in Lismore, Australia. Photo: Davidf

2 Navigating the Report

2.1 Overview

The EPIC Response Framework. This report presents a new perspective aimed at supporting governments to improve their hydro-climatic risk management systems. This new perspective is operationalized through a practical and detailed framework, the EPIC Response Framework. The Framework identifies the main national government programs with roles in flood and drought risk management and describes how their interaction ultimately determines the final social, economic, and environment impacts.

The report is structured around the EPIC Response Framework as summarized in Table 2.1. There are three levels to the Framework. The first level corresponds to the five basic principles of the Framework: ***Enable*** a whole-of-society effort to manage hydro-climatic risks with policies, laws, agencies, strategic plans, and information; ***Plan*** at all levels to prioritize risk mitigation measures; ***Invest*** in watersheds and water resources infrastructure; ***Control*** water use and floodplain development to reduce exposure and vulnerability; and ***Respond*** better to extreme events. The second level consists of eleven different program areas that correspond to the report chapters. The third level consists of the 43 individual programs that are presented in the report.

This chapter aims to help the reader navigate the extensive content of the report. The goal is to briefly summarize each of the programs presented as part of the Framework, and then allow the reader to hyperlink to the programs of interest. The programs are presented in a general manner aimed at non-experts in a particular field—precisely to facilitate an understanding of how the different programs synergistically interact.

But the key message of this report is that dealing with hydro-climatic risks is not an insurmountable challenge. The hope is that the EPIC Response framework will help government develop more effective responses to the growing risks of floods and droughts

There are hyperlinks embedded in this chapter to help the reader navigate the report.
The hyperlinks are identified by **"orange"** text.
All the programs in Table 2.1 can also be accessed through a hyperlink.

TABLE 2.1 Detailed EPIC Response Framework

Level 1 EPIC Response Principles	Level 2 Chapters/Program Areas	Level 3 Programs
Enable	National Sectoral Frameworks	Water Resources Management
		Disaster Risk Management
		Drought Risk Management
		Flood Risk Management
	Whole-of-Society Approach	Local Government
		Public Participation & Stakeholder Engagement
		Social Inclusion
		Education & Risk Communication
		Scientific Collaboration
		Open Data
	Hydrological and Meteorological Services	National Framework for NMS/NHS Services
		National Water Data Program
		Drought Monitoring and Impact Assessment
		Flood Forecasting and Warning
		Agrometeorological Advisory Services
		National Climate Assessment
Plan	Flood and Drought Risk Mitigation and Contingency Planning	Integrated River Basin Planning
		Coastal Zone Management Planning
		Urban Water Supply Planning
		Irrigation Water Supply Planning
		Local Flood Risk Mitigation Planning
Invest	Healthy Watersheds	Agriculture Policies and Climate-Smart Agriculture
		Forest Management
		Wetlands Management
		Local Watershed Management Organizations
		Watershed Planning
	Water Resources Infrastructure	Water Resources Investment Policy
		Dam Safety
		Flood Infrastructure Safety
Control	Water Allocation and Groundwater Management	Flexible Water Allocation
		Conjunctive Groundwater Management
	Floodplain Management	Floodplain Mapping
		Floodplain Regulation
		Local Flood Mitigation Planning
Respond	Drought Monitoring, Response, and Recovery	Drought Monitoring Program
		WRM Drought Response
		Agriculture Drought Response
		Social Protection Drought Response
	Flood Monitoring, Response, and Recovery	Flood Forecasting and Warning
		Flood Emergency Preparedness, Response, and Relief
		Flood Disaster Recovery
	Disaster Risk Financing	Disaster Risk Financing Instruments
		Disaster Risk Financing National Sector Framework

Source: Authors.

The EPIC Response Framework emphasizes that the whole hydro-climatic risk management system is more important that its component parts, and that for the entire system to deliver optimal results, programs often need to feed into or receive support from another program in the Framework. As will be described in Section 2.3, the different programs in the Framework usually interact together in a general downward cascading influence—although the influences are complex and at times can move in both directions.

The programs contained in the Framework are considered the most relevant for hydro-climatic risk management. There may be other important programs which are not included in the Framework. For example, the Framework programs are discu ssed in the context of a unitary state with a national government and local governments to simplify the presentation and to focus on key principles. The important but complex issues of transnational water management or hydro-climatic risk management in a federal country are not directly addressed. However, the general principles embedded in the unitary government examples can be adapted for federal or transnational situations.

Not all programs will be relevant for all countries—for example, landlocked countries do not require integrated coastal zone management programs. Finally, the agencies tasked with the implementation of a particular program will vary depending on each country. For example, the WRM agency could be a ministry of water resources, a water resources department under another ministry, or a semi-autonomous water resources management agency. Therefore, this report uses the term "agency" in a generic sense, to refer to the institution responsible for the implementation of a program.

Program Presentation. Most of the programs are presented using the following five sections:

- *Program description*. This is a general overview highlighting key elements of an effective program based on global experience. Each program is presented in a stylized manner, generally representing global best practice. Most countries are currently not able to implement fully effective programs as presented in the report. Providing the key elements of a fully effective program, however, allows for a better appreciation of gaps, constraints, and opportunities, which can then be addressed in the context of specific countries.
- *Linkage to sectoral frameworks*. Each program in the Framework is authorized through national legislation, typically tied to a specific sector, such as WRM, DRM, hydro-met, agriculture, natural resources, social protection, and finance. The premise is that a well-developed sectoral framework is necessary but not sufficient condition for an effective program.
- *Key agency actions*. This section provides a list of important functions that the responsible sector agency should undertake to ensure an effective program. Many countries have well-developed national legislation, but implementation may be lacking at the agency level. The list is meant to be illustrative, but also serves as a guide to help assess the status of program implementation.
- *Generic program evolution*. Recognizing that program development is an evolutionary process, four levels are described for each program, using the general categories shown in Table 2.2.[3] This table can be used to help evaluate program status.
- *Key references*. Given the breadth of the report, it is not possible review each program in depth. Thus, each program includes references which provide more detailed information.

Case Studies to Illustrate Program Evolution. The report presents four case studies—Tanzania, Philippines, the Netherlands, and the State of California—illustrating the status of programs at different stages in their evolution to capture some key lessons learned in specific country contexts. The case studies examine the status and evolution of each government's hydro-climatic risk management system, using both a latitudinal (looking across cases) and a longitudinal (looking at the evolution over time) approach. The report includes examples from the cases presented in

TABLE 2.2 Generic Program Development Table

Nascent	Engaged	Capable	Effective
No legal framework or formal program, *ad hoc* approach.	Legal framework authorizes the program, but program not yet operational.	Program is operational but still in early stages of implementation.	Legal framework has been refined based upon experience, with mature program implementation.

Source: Authors.

[3] This terminology is based on the one used in ADB (Asian Development Bank) 2020.

boxes to illustrate specific programs and key lessons. The full background case studies are available as an internet resource at the World Bank Water Practice webpage (https://www.worldbank.org/en/topic/water).

2.2 Key Terminology

This report is about national level governance to manage hydro-climatic risks. The term "governance" is used in a broad sense to include important government actions. The following set of terms are used throughout the report to refer to important governance dimensions:

National sector framework refers to national level laws, agencies, strategic plans, and policies pertaining to a specific sector.

Law is used to mean a set of laws, acts, or codes adopted by the legislature (such as the national assembly or parliament) on a topic (such as WRM, DRM, or drought management). It also refers to a decree or formal decision relating to a program adopted at a high executive level (for example, by the president) above the level of the agency responsible for that program.

Agency is used in a generic sense to mean the government or public entity that is responsible for the implementation of a law or a program. Such an entity could be a ministry, a department within a ministry, or a specialized agency or authority. For example, depending on the country, the WRM agency could be the ministry of water resources, a water resources department in another ministry (such as a ministry of natural resources) or a semi-autonomous water resources management agency.

Program is a continuous set of activities undertaken by a national agency, authorized through national legislation with well-defined objectives, and funded by the national government.

Regulations and technical guidelines are issued by the responsible sector agency to help implement specific programs. Regulations create legal rules that are legally binding while technical guidelines are not. Regulations and technical guidelines address technical issues such as procedures, standards, and incentives. They may apply to local or sub-national governments, businesses, or individuals, and may, in certain circumstances, apply to national other agencies.

National strategic plan helps direct and coordinate the medium-term goals and objectives of a sector. The development of national strategic plans often follows the process of reviewing sector performance and proposing adjustments to the policies, laws, interagency collaboration, programs, regulations, or funding to ensure continuous advancement. A national strategic plan does not necessarily mandate actions or make project-specific recommendations, but rather provides a roadmap for policy makers and agencies to make program adjustments and to appropriate the necessary funds.

Policy is used in a broad sense to refer to important decisions taken by the government in the formulation of laws, agencies, national strategic plans, programs, regulations, and guidelines. In some cases, there may also be standalone policy documents (such as a water policy) which provide overarching sets of principles and establish general plans of action.

The report also uses several terms utilized by the disaster risk management community. These are summarized in Box 2.1.

2.3 Summary EPIC Response Programs

A key insight of the EPIC Response Framework is that the different programs, implemented by a variety of agencies, interact together and ultimately determine the final social, economic, and environmental impacts caused by extreme hydro-climatic events. The following paragraphs summarize the various programs and provide hyperlinks to the specific program sections in the report.

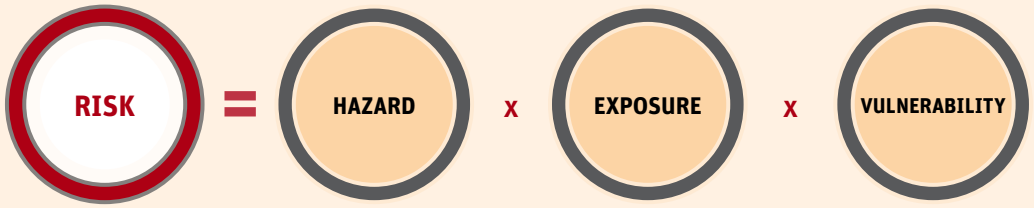
Chapter 3: National Sectoral Frameworks – National sectoral frameworks are composed of laws, agencies, and strategic plans that enable the various programs in the EPIC Response Framework to function effectively. Hydro-climatic risk management does not have a standalone national framework, rather it is a combination of different national sector frameworks—hence the need for close collaboration among different sector agencies. This chapter first presents the national sector frameworks for WRM and DRM, since the majority of the programs are linked to these two frameworks. The overarching structures for drought risk management and flood risk management are then presented. The national sector frameworks for other relevant sector programs are discussed in the relevant chapters.

WRM Sectoral Framework. The legal framework for WRM is typically contained in a water resources law that stresses integrated water management. It typically applies both to surface and groundwater and addresses issues of water allocation, water quality, water-related environmental sustainability, water pollution control, and of course flood and drought risk management. The responsibility for the implementation of the law resides with the WRM agency, which might take many different forms (such as a ministry, a national

Box 2.1 Disaster Risk Management Concepts and Terminology

The United Nations International Strategy for Disaster Reduction (UNISDR) uses the graphic below to indicate the three main elements contributing to disaster risk:[a] (1) hazard magnitude and frequency; (2) number of people or assets exposed to the hazard; and (3) the vulnerability of the people or assets exposed to the hazard. Some other key terms, as used in this report, are described below:

Figure B1.2.1. Understanding Disaster Risk



Source: PreventionWeb.

Mitigation and Disaster Risk Reduction: Mitigation encompasses activities that reduce or eliminate (or prevent) one or more of the three key disaster risk components: hazard, exposure, and vulnerability. The term disaster risk reduction (DRR) is sometimes used instead of mitigation. Once a hazard event takes place or is imminent, subsequent actions are considered response actions and are not called "mitigation." Disaster mitigation is different than climate mitigation, which focuses on reducing greenhouse gas emissions.

Residual Risk: This refers to the risk that remains after all mitigation measures have been implemented. The more effective and comprehensive the mitigation measures, the lower the residual risk. Disaster response and recovery need to deal with the residual risk.

Preparedness: These are activities that build organizational resiliency and/or organizational capacity and capabilities for response to and recovery from hazard events. It includes activities that establish, exercise, refine, and maintain systems used for emergency response and recovery.

Disaster Response: These activities directly address the hazard event, including actions taken in anticipation of an impending event (for example, storm, flood, and drought) and actions during and shortly after an event has occurred.

Recovery: These activities help restore the community to normal after a major event, and hopefully enable the community to be better prepared for future hazards by "building back better." As a recovery progresses, there is a gradual transition back to regular hazard mitigation activities.

Disaster Impact: These are the final social, economic, and environmental impacts of a hazard event and are a product of the combined mitigation, response, and recovery activities.

a. For more information about disaster risk management concepts and terminology, see PreventionWeb's website at https://www.preventionweb.net/disaster-risk/risk/disaster-risk/.

water resources committee, or an authority) depending on the country. Modern water resources laws typically provide for management at the level of river basins (or sub-basins) or individual aquifers, resulting in the creation of specific river basin, sub-basin, or aquifer management organizations, together with stakeholder participation mechanisms. Modern laws typically require the periodic formulation of National Strategic WRM Plans that provide a roadmap for policy makers and agencies to help advance integrated water resources management. Many of the programs identified in the upper part of the EPIC Response Framework fall under the general domain of water resources management, including river basin planning, water resources infrastructure, water allocation, and groundwater management.

DRM Sectoral Framework. A DRM law is a fundamental part of an overall system of risk governance that includes different laws and local government mandates to address a wide spectrum of natural (and sometimes human-induced) hazards such as earthquakes, fires, storms, floods, and droughts. The law typically confers specific powers on a specialized DRM agency that is usually under the direct supervision of the government at a high political level, such as the president or prime minister, due to the need for inter-sectoral cooperation and rapid response during an emergency. DRM laws typically

require the periodic formulation of a National Strategic DRM Plan that lays out a roadmap for managing disaster risks and is an ideal mechanism for helping to foster interagency collaboration and a holistic approach to disaster risk management. Many of the programs identified in the lower part of the EPIC Response Framework fall under the general, but not necessarily exclusive, domain of the DRM sector framework, including floodplain management; flood monitoring, response, and recovery; and disaster risk financing.

Drought Overarching Framework. In most cases, existing laws define some of the roles and responsibilities of sector agencies relating to drought management, particularly for WRM, DRM, hydro-met and agriculture agencies. A drought legal overarching structure, however, goes beyond the sector specific laws and seeks to coordinate and synergize the efforts of several different entities. A law, decree, or decision should typically: (a) set out a general policy on drought risk management, with an overall strategy of moving from crisis management to proactive drought risk management; (b) establish an interagency "Drought Committee" specifying its functions, membership, and secretariat; and (c) require the preparation and periodic revision of a National Drought Strategic Plan. Within the framework of the Drought Committee, it will also be important to include local governments, particularly those relating to affected areas, as well as other stakeholder groups, such as water utilities, farmers, and industry.

Flood Overarching Framework. In most cases, the combination of WRM and DRM sectoral frameworks—if properly synchronized—should address most issues related to flood risk management. The WRM agency typically focuses more on reducing flood hazards, while the DRM agency concentrates on reducing flood exposure and vulnerability, as well as responding to floods. However, some more advanced countries have also found it useful to adopt additional flood management specific laws or national policies to help bind the WRM and DRM frameworks more closely together. To achieve synergy between WRM and DRM agencies, it is important that they work together on almost all dimensions of flood risk management, including preparation of national strategic WRM and DRM plans.

Chapter 4: Whole-of-Society – Programs to reduce flood and drought risks are most effective when they represent the needs of all of society. National sector agencies should strive to develop an organizational culture that puts social expertise on an equal footing with technical knowledge and ensures that agencies are able to work with and respond to the needs of society. A whole-of-society approach will have a cascading influence, helping to better design and implement all programs in the EPIC Response Framework.

Local Governments. Local governments are the indispensable associates of national agencies in hydro-climatic risk management. For every program in the Framework, local governments are key stakeholders, and for many programs, local governments play a critical role in program implementation. National agencies should work in partnership with local governments, and as appropriate, assist them through capacity development, technical assistance, or grant funding. National agencies can also support legal and regulatory reforms that devolve an appropriate level of authority and responsibility to local governments.

Public Participation. The aim is to encourage the public and stakeholders to have meaningful input not only on program design and implementation (such as participation in river basin planning or social protection programs), but also in the overall public policy process to monitor, evaluate, and improve the performance of the program. Agencies should have dedicated public outreach staff who should work closely with technical staff to ensure meaningful participation.

Social Inclusion. Socially excluded individuals or groups—which could consist of women, ethnic or religious minorities, the poor, the elderly, people with disabilities, or other groups—are typically the most vulnerable to hydro-climatic risks. Agencies need to have dedicated social units that are trained and that preferably consist of staff from marginalized groups to help ensure social inclusion. Agencies should also have structured processes for ensuring social inclusion, including undertaking steps to identify and understand who these individuals and groups are, and then targeting efforts to ensure that these individuals or groups can benefit from hydro-climatic risk management programs.

Education and Risk Communication. Ensuring broad understanding of flood and drought risks at all levels of society helps people to make better informed decisions to enhance their climate resilience. That, in turn, helps ensure public safety, protect livelihoods, and safeguard assets. Agencies should have dedicated programs to promote education among the general public, along with targeted campaigns to provide flood and drought risk information to relevant stakeholders.

Scientific Collaboration. In addition to collaborating across national agencies, governments also need to collaborate with the scientific community, tapping into both scientific organizations and private sector technical expertise. The goal should be to have both science-informed policy and policy-informed science. There is also a need for more integrative and transdisciplinary hydro-climatic research that can feed into the policy-making process. Agencies should have a reserved budget for collaboration with the scientific community, including undertaking joint research projects when appropriate.

Open Information. Information that governments produce, collect, or pay for acts as the currency for hydro-climatic risk management. Examples include geographical information, data collected from remote sensing and monitoring networks, or reports from publicly funded research projects. Access to this information will help agencies perform their tasks and collaborate with each other, enhance scientific research, and enable citizens to better engage in the public policy process. National governments can adopt legislation that requires open access to public information, and agencies should develop regulations to ensure the most appropriate manner of making their information available to serve the public interest.

Chapter 5: Hydrological and Meteorological (Hydro-Met) Services – Information related to weather, water, and climate is fundamental to managing hydro-climatic risks. Hydro-met-related programs sit near the top of the EPIC Response Framework as hydro-met information provides the foundation for all forms of water-related planning, water infrastructure design and operation, and water management. Hydro-met information helps to delineate floodplains to better enable floodplain management. Monitoring and forecasting of floods drive emergency management responses. Drought forecasting enables drought managers to zero in on potentially affected areas to better assess impacts and identify vulnerable populations. Hydro-met information also serves to inform flood and drought recovery programs, including the structuring of insurance programs and other disaster risk financing programs. The quality of hydro-met services is of such critical importance to a country's hydro-climatic risk management that it should be featured front and center in each of the strategic plans discussed in Chapter 3: WRM, DRM, and Drought.

In some countries, the national meteorological service (NMS) and the national hydrological service (NHS) are combined, and in other countries they operate as separate agencies; this report therefore adopts the convention "NMS/NHS" to account for both possibilities.

National Framework for NMS/NHS. The legal framework for NMS/NHS should ensure that the agency can serve as a facilitator, as opposed to a monopoly provider, of weather, water, and climate services. The NMS/NHS needs to tap into the global "Weather Enterprise,"[4] a broader network of global and regional centers, the weather industry, other specialized agencies, and research organizations, to deliver the best possible services for the country. If the NMS and NHS are separate agencies, the legal framework also needs to ensure that the two agencies can collaborate in a seamless manner.

National Water Data Program. The NHS usually does not have a monopoly on water data as surface water, groundwater, and water quality data are often collected and stored by different national agencies. The NHS should ensure that all high-quality water data are freely available and accessible to all users, ideally through a single water data platform. Such data will produce value for every program in the EPIC Response Framework.

Co-production of Drought Monitoring and Impact Assessment Services. The NMS/NHS should play a pivotal role in drought monitoring and impact assessment as part of its collaborations with the NMS/NHS, WRM, Agriculture, and DRM agencies. The subject of drought monitoring is covered in detailed in Chapter 11.

Co-production of Flood Forecast and Warning Services. In a similar manner, the NMS/NHS has a critical role to play in flood forecasting and warning as part of its collaborations with the NMS/NHS, WRM, and DRM agencies. The subject of flood forecasting and warning is covered in detailed in Chapter 12.

Co-production of Agrometeorological Advisory Services. Farmers are particularly affected by weather fluctuations and extreme events. The NMS/NHS can team up with the agriculture agency to provide weather and seasonal forecasts in a manner that is accessible and actionable by farmers.

Co-production of the National Climate Assessment (NCA). The NMS/NHS typically plays a key role in periodically producing a NCA, which provides an overview of existing and potential future climate scenarios and their social, economic, and environmental impacts. This assessment helps guide adaptation actions across multiple sectors and reduce hydro-climatic risks.

Chapter 6: Flood and Drought Risk Mitigation and Contingency Planning – Flood and drought planning establish a roadmap for many of the other programs in the lower parts of the EPIC Response Framework. Planning can guide investments in healthy watersheds and water resources infrastructure and help set parameters for water resources management and floodplain management programs. Finally, contingency planning provides a basis for responding to flood and drought events at multiple levels.

This chapter highlights several important relationships in the planning process. First, planning for flood or drought mitigation takes place within a broader planning process, such as a river basin plan, an urban water utility plan, or an

[4] For more information on the weather enterprise, see the following: Thorpe, Alan, and David Rogers. 2018. "The Future of the Global Weather Enterprise: Opportunities and Risks." *Bulletin of the American Meteorological Society* 99 (10). https://doi.org/10.1175/BAMS-D-17-0194.1.

irrigation scheme plan. Second, the plans should be connected at different scales to ensure compatibility; for example, the river basin plan needs to be synchronized with the plans of the water utilities and the irrigation service providers. Third, planning will help to define potential scenarios for contingency planning and thus the two are closely linked. Fourth, like national strategic planning discussed in Chapter 3, the plans should be periodically updated.

Finally, it is important to explicitly integrate climate change, and its inherent uncertainties, into the various plans. Planning for climate change requires a shift from what are usually traditional planning approaches that drive towards one outcome, towards an adaptive approach that considers multiple possible outcomes and allows for the exploration of the robustness and flexibility of various decisions across those multiple futures. The chapter presents five types of plans as summarized below. The relative importance of the plans will depend upon the context of the country.

Integrated River Basin Planning. This is a broad water resources management plan that addresses many different topics in an integrated manner, including both flood and drought risk management. The plan identifies both structural and non-structural approaches to reducing hydro-climatic risks. As part of a river basin plan, or in parallel to the plan, basin flood and drought contingency plans should be developed to help prepare for and respond to a variety of extreme hydro-climatic scenarios. The WRM agency has important role to play in either leading or facilitating the basin planning process.

Coastal Zone Management Planning. This is a broad environmental and land use plan that promotes the sustainable management of fragile coastal areas and addresses many different topics in an integrated manner. Due to the coastal flood risks associated with storm surges, rising sea levels, and more severe storms due to global warming, flood risk management should be an important element of any coastal zone management plan. Typically, but not always, an environment or natural resources agency plays a leading role in facilitating coastal zone planning.

Urban Water Supply Planning. As part of their overall master planning process, urban water utilities should develop both structural and non-structural approaches to drought mitigation, such as developing new supplies, reducing leakage, and promoting water conservation. They also need to develop drought contingency plans in collaboration with local governments, so that when water supplies become scare, they are ready to respond. The water utility drought contingency plans should be consistent with the overall basin drought contingency plan. WRM agencies can help facilitate this process by developing regulations or technical guidelines, providing technical assistance, and in some cases, offering financial assistance to water utilities.

Irrigation Water Supply Planning. Like water utilities and as part of their overall planning process, irrigation service providers need to develop both structural and non-structural approaches to drought mitigation, such as developing new supplies, reducing system losses, and promoting climate-smart agriculture. Of particular importance is the need to measure and control canal flows, as well as to monitor and control groundwater use. The irrigation service providers also need to develop drought contingency plans, so that when water supplies become scarce, they are ready to respond. WRM or agriculture agencies can help facilitate this process by developing regulations or technical guidelines, providing technical assistance, and in some cases, providing financial assistance to water utilities.

Local Flood Risk Mitigation Planning. As part of their overall land use planning process, local governments need to develop plans to help reduce their flood risks, including both structural and non-structural measures. These flood risks can come from overflowing rivers or coastal storm surges and thus local flood risk mitigation plans are closely linked to the broader river basin plans and coastal zone management plans. (Stormwater drainage is considered outside the scope of this report.) The DRM agency, with support from the WRM agency, plays an important role in helping local governments mitigate flood risks. Local flood risk mitigation plans are discussed in detail in Chapter 10: Floodplain Management.

Chapter 7: Healthy Watersheds – Healthy watersheds are the first physical line of defense in the EPIC Response Framework because they can help to reduce flood and drought hazards through natural processes. These "nature-based solutions" in turn can help reduce the demands on water resources infrastructure by providing eco-based services that reduce flood peaks, increase base flows, and improve water quality (UNESCO 2018). Healthy watersheds not only help reduce hydro-climatic hazards, but they often also generate many other benefits, such as improved livelihoods, greater biodiversity, and broader ecosystem services.

On a global basis, agriculture and forests account for most of the habitable land use; even shrub land is often used for marginal livestock grazing activities. The ways we manage forests and wetlands and practice agriculture determine in large measure the health of watersheds. Land degradation is a global challenge that affects everyone through food insecurity, higher food prices, climate change, increased hydro-climatic hazards, and the loss of biodiversity and

ecosystem services. Globally, about 25 percent of the total land area has been degraded, and this percentage is increasing at an alarming rate. This chapter focuses on the role that agriculture and natural resources agencies play in ensuring healthy watersheds and reducing hydro-climatic risks. Natural resources agency is a general term, and can include environmental agencies, forest agencies, and others, depending upon a country's institutional context.

Agriculture Policies and Climate-Smart Agriculture. Agricultural subsidy policies have profound impacts on land and water use, and can reduce sustainability. For example, subsidized irrigation water pricing may result in overuse of water in agriculture, and price supports for certain crops may encourage farmers to overproduce crops ill-suited for a given hydro-ecological zone. Governments thus need to adopt agricultural policies that promote not only food security and nutrition, but also environmental stewardship. Agriculture agencies should also administer programs that help farmers adopt climate-smart practices that reduce soil erosion, increase soil water retention, increase climate resilience, and reduce greenhouse gas emissions. These programs can provide technical assistance and, in some cases, financial incentives. Crop and rangeland management is particularly important in arid or mountainous regions, which are more susceptible to land degradation.

Forest Management. In many countries, the upper elevations of a watershed are covered by forests. Such forests play a critical role in reducing downstream peak flood discharges and sediment flows. Forests along rivers and coastlines also provide important lines of protection against floods. Managing these forests in a sustainable manner is, in many countries, a critical flood risk management activity. The natural resources agency must fashion fit-for-purpose programs that balance competing interests, such as forest conservation and the needs of local communities and timber harvesters.

Wetlands Management. Wetlands also play an important role in both flood and drought management. In periods of high rainfall, wetlands soak up water that could otherwise cause floods elsewhere. They also store water and provide it to aquifers or streams to help reduce drought hazards. Protecting these wetlands from agricultural or urban development is typically a core mandate for the natural resources agency, which can use a variety of instruments such as permitting requirements or working with local governments and communities.

Local Watershed Management Organizations. In large measure, all the programs highlighted in this chapter rely upon active community engagement. Communities are typically most knowledgable about their local challenges and sustainable approaches. Agriculture and natural resources agencies should thus help create and sustain local watershed management organizations that work in partnership in the implementation of the various programs.

Watershed Planning. Natural resources agencies, working in close collaboration with other agencies and a broad group of stakeholders, should periodically prepare an overall assessment and strategic plan for improving watershed health. This includes examining overall watershed quality and the performance of various natural resources management and agricultural programs in that specific watershed. The watershed management planning should be closely linked and serve as input into the river basin plans highlighted in Chapter 5.

Chapter 8: Water Resources Infrastructure – Water resources infrastructure (WRI) broadly refers to assets such as dams and their reservoirs, regional bulk water systems, flood control structures along rivers and coasts, and regional drainage channels and floodways. In broad terms, it is the infrastructure that the WRM agency normally operates or regulates. This infrastructure is used to help control blue water flows through the watershed and is an important tool in the arsenal to reduce hydro-climatic hazards.[5] Chapter 6 reviewed how river basin planning can help define the investment needs for WRI. Investing in green infrastructure through healthy watersheds and nature-based solutions is an important complement to traditional gray infrastructure—resulting in integrated green-gray approaches.

Hydrological processes are dictated by the weather and watersheds. WRI can only temper—and not fully control—hydro-climatic hazards. Degraded watersheds can quickly overwhelm WRI functionality, for example by increasing sedimentation in reservoirs or reducing base flows. This underscores the importance of WRM agencies working with natural resources management and agriculture agencies to prioritize healthy watersheds.

Chapter 8 examines two key elements related to WRI. The first is the idea that WRI investment policy can promote—or distort—good decisions on infrastructure. The second is the important issue of infrastructure safety. WRI can be a dual-edged sword. When it works well, it can reduce flood and drought hazards. But it can also fail, increasing those

[5] This report does not address water infrastructure used to directly delivery water services, such as water supply and sanitation or irrigation and drainage. WRI helps provides the general enabling conditions for this class of infrastructure. Infrastructure needs for water service providers should be defined through the planning processes described in Chapter 5.

hazards. For example, the collapse of a dam constructed to reduce flood hazards and store water for use in dry seasons can result in immediate catastrophic flood damages and increase drought risks.

WRI Investment Policy. Historically, WRI has generally been considered a public good with costs borne almost entirely by national governments. This often distorts investment decisions, resulting in overinvestment and undermaintenance. Thus, WRM agencies should strive to improve their economic analysis, allocate a higher percentage of costs to users, and ensure appropriate cost-sharing by local governments. National government support for WRI investment can also be used as an incentive to encourage non-structural measures to reduce risks, such as improved land management and water conservation.

Dam Safety. Unsafe dams can increase flood and drought risks. These dams are often owned and operated by a wide range of entities, including WRM agencies, local governments, other sector agencies such as agriculture and energy, water utilities, and the private sector for hydropower. Thus, WRM agencies need to ensure comprehensive national programs in which WRI owners are responsible for WRI safety and in which WRM agencies ensure compliance. Dam safety programs are particularly important in the face of climate change and evolving safety criteria.

Flood Infrastructure Safety. Non-dam flood infrastructures such as levees, dikes, flood control gates, and pump stations all play important roles in reducing flood hazards. As in the case of dams, however, the failure of a critical component of flood control infrastructure can increase risks. Flood control infrastructure is also typically owned by a wide range of entities, including local governments, different national agencies, and the private sector. WRM agencies need to ensure comprehensive programs for flood safety.

Chapter 9: Water Allocation and Groundwater Management – This chapter focuses on two key programs for reducing drought risk: adaptable water allocations and conjunctive groundwater management. These programs are influenced by the state of the watersheds as well as by the stock of water resources infrastructure. Healthy watersheds can help store water in soils, aquifers, and wetlands, thereby increasing base flows during dry periods. In a similar manner, WRI such as multi-purpose reservoirs can help store water. Regional water conveyance systems serve to redistribute water supplies to help address variabilities in local water supplies. There are, however, limits on the extent to which WRI can store and redistribute water. When periods of extreme dryness occur, the WRM agency can play a pivotal role in helping to manage drought risks by drawing upon programs for flexible water allocations and conjunctive groundwater management. These programs are closely linked to drought monitoring, response, and recovery as discussed in Chapter 11. However, these programs must be in place and functioning smoothly prior to the onset of a drought.

Flexible Water Allocation. WRM agencies should manage water allocations to ensure that water is not overallocated and there is enough slack in the system to help mitigate drought impacts. When a drought does strike, there should be a formal system for adaptable water allocations whereby water can be transferred from lower value users to higher value users, for example through administrative decisions, negotiated settlements, or water markets.

Conjunctive Groundwater Management. This program involves balancing surface and groundwater use, including managed groundwater recharge where possible, and ensuring that groundwater is available as a strategic reserve to help meet demand during droughts. Where groundwater aquifers exist, they provide an ideal water storage option. Too often, however, aquifers are overexploited, resulting in unsustainable yields and diminishing their effectiveness as strategic sources of water during droughts. WRM agencies should take the lead, working in close collaboration with communities, in developing sustainable groundwater management programs.

Chapter 10: Floodplain Management – River and coastal floodplains are often convenient places for the establishment of cities, farms, and industrial sites. Easily accessible waterways facilitate commerce, rich river floodplain soils increase agricultural production, and rivers offer readily available sources of freshwater. The challenge is that floodplains are also prone to inundation, putting people and assets at risk.

Floodplains are influenced by healthy watersheds and WRI, both of which can help reduce flood hazards and shape floodplain physical characteristics. This chapter focuses on floodplain management, allowing people to live in harmony with river and coastal floods, and making room for the river and the sea while also reaping the benefits of living close to water.

There are four broad strategic options for managing floodplains. These options are “protect, accommodate, retreat, and avoid.” “Protect” implies the use of WRI, such as river embankments and sea dikes. “Accommodate” refers to the practice of reducing the vulnerability of structures and facilities, such as by raising building elevations. “Retreat” involves removing assets at risk, for example by removing structures that are repeatedly flooded. Finally, “Avoid” means not putting assets in floodplains in the first place. Floodplain management is the science and art of us-

ing these strategic options in an appropriate manner given the specific circumstances of a river or coastal area.

Since many floodplains were inappropriately developed before the risks of flooding were fully understood and before climate change increased the risks in some areas, floodplain management is typically a long-term and continuous process of constantly reducing exposure and vulnerability over time. In most cases, it offers an economical and resilient option that is a core pillar for reducing flood risks.

Floodplain Mapping. In order to properly manage river and coastal floodplains, the hazards should be well understood and communicated to local governments and the public. This is an enormously complex and continuous process that the DRM or WRM agency typically manages due to the technical challenges involved. It cannot be done quickly and needs to be constantly updated as flood hazards change over time due to climate change, watershed development, and new water resources infrastructure.

Floodplain Regulation. Floodplain regulation helps to reduce the exposure and vulnerability of people and assets and has two dimensions: (1) a permitting process to authorize development and activities; and (2) standards and codes to reduce the vulnerability of buildings and facilities. Land use management is generally a local government responsibility, and local governments should have their own specific floodplain management units. Some countries have even created multi-jurisdictional floodplain authorities to manage entire river or coastal stretches. The DRM agency has an important role to play in helping local governments by defining permitting guidelines and developing uniform standards. In some cases, the DRM agency may be legally mandated to oversee the implementation of local government floodplain regulations.

Local Food Mitigation Planning. River basin and coastal management planning are the tools generally used to reduce overall flood hazards at the regional level with a focus on watershed health and large-scale water resources infrastructure. Local flood mitigation planning plays an important complementary role to basin planning, and may often be part of a broader multi-hazard local government mitigation plan that includes other potential threats, such as earthquakes, landslides, and fires. Local flood mitigation plans go beyond regulation to proactively manage risks by identifying priority actions, such as refining land use plans and regulations, identifying infrastructure projects, conserving and restoring natural systems, and implementing educational and awareness programs. The DRM agency has an important role in providing guidelines and technical assistance to local governments in the formulation of flood mitigation plans. In some cases, the DRM agency may be legally mandated to oversee local government flood mitigation plans.

Chapter 11: Drought Monitoring, Response, and Recovery – Droughts are an inevitable part of the hydro-climatic cycle and the goal of proactive management is to prepare for a drought, monitor the drought as it evolves, and then help reduce the impact of the drought on people, the economy, and the environment. Actions taken to promote healthy watersheds, develop water resources infrastructure, and manage water better should contribute to reducing drought risks. This chapter focuses on programs to monitor, respond to, and recover from droughts to further reduce impacts.

The distinguishing characteristic of a drought as a hazard is that it typically evolves over time, in some cases years, with each drought event being unique in terms of its geographical scope and social, economic, and environmental impacts. Droughts are driven by meteorological conditions that produce an abnormally high level of dryness in comparison to some "normal" level for that specific region. This period of dryness can impact agriculture by reducing soil moisture, thereby putting stress on plants and reducing their productivity. As the dryness persists, it can have hydrological and eventually ecological impacts, reducing the amount of water available for cities, irrigated agriculture, industry, and the environment.

Chapter 3 highlighted the importance of having a national framework for drought management, consisting primarily of a permanent, multi-sectoral Drought Committee and a periodically updated National Strategic Drought Plan. The National Strategic Drought Plan helps ensure a clear definition of institutional responsibilities and procedures for responding to droughts. Nevertheless, since each drought unfolds in its own unique manner, the Drought Committee needs to be proactive and flexible to tailor the response appropriately. After every significant drought event, the Drought Committee should undertake a *Post-Drought Assessment*. The assessment report should look the evolution, responses, and impacts associated with the drought and distill lessons learned. This will help inform the next iteration of the National Drought Strategic Plan, as well as the specialized programs supporting drought risk management.

Drought Monitoring Program (DMP). This program should ideally be multi-sectoral but anchored in a specialized agency (such as the NHS/NMS or WRM agencies). The program should be constantly providing drought assessments to the Drought Committee, local governments, and the public on drought status throughout the country. As a drought emerges and evolves, the Drought Committee should mobilize a standing or *ad hoc* Impact Assessment Group (IAG) with

the membership and scope adjusted to the circumstances in a specific region. These IAGs should be composed of representatives from specialized national agencies, local governments, the private sector, civil society, and others as appropriate, and provide publicly available situation reports.

The DMP should classify and report on the level of drought for specific regions of the country. The designations often range from 1 to 5, from a low level (1) of "abnormally dry" to the highest level (5) of "an exceptional drought". The designation of a drought level is important because it should help communicate the relative severity of the drought to different parts of the country and trigger actions identified in the National Drought Plan.

WRM Drought Response. Chapter 6 highlighted the importance of having drought contingency plans at the basin, city, and irrigation scheme levels. As different levels of drought are declared, this should help trigger actions outlined in specific river basin plans, urban water supply plans, and irrigation water supply plans. In some cases, it may be necessary to truck in or provide bottled drinking water for communities that are suffering severe water shortages. The WRM agency should help support, monitor, and report on the implementation of these plans as part of its overall responsibility within the Drought Plan and membership in the Drought Committee.

Agriculture Drought Response. Rural populations depend on agriculture for their livelihoods, including both crops and livestock, and are particularly vulnerable to droughts. This is especially true in low-income countries that may not have well-developed water infrastructure to help buffer the impacts of dry periods. Chapter 7 highlighted the importance of climate-smart agriculture programs for helping to mitigate drought hazards. When a severe drought does strike, the agriculture agency should have drought support programs in place to help farmers respond to and recover from droughts. The agriculture agency should administer and report on the implementation of these programs as part of its overall responsibility within the Drought Plan and membership in the Drought Committee.

Social Protection Drought Response. These programs help vulnerable populations, particularly in rural areas, cope with droughts and can include measures such as cash transfers, temporary labor, and in extreme cases, camps for displaced people. It is important that the social protection programs be pre-planned and scalable to help meet the specific needs of the drought. The Drought Committee has an important role in ensuring the effectiveness of social programs, and social protection agencies should be members of the Drought Committee.

Chapter 12: Flood Monitoring, Response and Recovery – Like droughts, floods are an inevitable part of the hydro-climatic cycle, and the goal of proactive management is to prepare for floods, forecast and monitor them, and respond effectively through emergency action and immediate relief for affected communities. Recovering from floods by building back better and smarter is the final step in the process of minimizing the social, environmental, and economic impacts.

Flooding is a natural phenomenon that brings important ecosystem benefits. The delicate balancing act is maintaining these benefits while also minimizing the impact of floods on people and the economy. Actions taken to promote healthy watersheds, develop water resources infrastructure, and manage floodplains all contribute to reducing flood risks. This chapter focuses on programs to monitor, respond to, and recover from floods to further reduce the overall risk.

There are many different types of floods and each flood event has its own unique characteristics in terms of geographical scope, duration, and physical characteristics. Chapter 12 focuses primarily on river and coastal flooding, although many of the same principles apply to other types of floods. In contrast to droughts, floods are relatively short-duration hazards, generally lasting from days to weeks with immediate and often devasting impacts—making emergency response and relief of paramount concern. Floods are often, but not always, driven by other meteorological hazards such as storms or hurricanes, often resulting in multiple-hazard disasters occurring at the same time.

Flood Forecasting and Warning. A multi-agency approach, dependent on the circumstances of the country, is typically required for flood forecasting. As highlighted in Chapter 5, the NMS/NHS plays a key role in facilitating weather forecasts; it generally provides the flood forecasts for coastal and localized flash flooding. For river flooding, the WRM agency typically provides the flood forecasts if there is extensive flood infrastructure; for unregulated rivers, the NHS (which may be embedded in the WRM agency or part of the NMS) typically provides the forecasts.

Ideally, there should be impact-based warnings based on the flood forecasts that provide information on potential impacts. This information is generally derived from the floodplain mapping discussed in Chapter 10. Generally, the DRM agency is best placed to take the flood forecasts issued by the NMS/NHS and provide flood warnings, utilizing its multi-hazard emergency communications system and disseminating the information through various channels.

Flood Emergency Preparedness, Response, and Relief. Emergency response also requires a multi-agency effort under the leadership of the DRM agency, which is responsible for

coordinating overall disaster preparedness, responses, and recovery efforts for natural hazards like floods, storms, and earthquakes. For floods, and in cases where there is extensive flood control infrastructure, the DRM agency needs to work closely with the WRM agency. The WRM agency may operate a flood control center that monitors conditions and coordinates flood infrastructure operations and flood fighting efforts. In parallel, the DRM agency may need to activate its emergency response system to oversee evacuation and relief efforts.

Flood emergency preparedness is critical to an effective response. The DRM agency should have multi-hazard emergency operations plans in place to respond to a variety of natural hazards. These emergency operations can be utilized as a foundation for developing flood emergency plans in collaboration with the WRM agency, particularly for river flooding. The DRM agency will need to work in close collaboration with local governments and civil defense authorities to prepare for local flood emergencies.

A structured post-flood assessment process informs relief and recovery efforts at three critical junctures. In the immediate aftermath of a flood, the DRM agency, in collaboration with local governments, needs to undertake a Rapid Impact Assessment (RIA) to ascertain critical relief needs. The second assessment comes after the emergency has subsided and involves a Post-Disaster Needs Assessment (PDNA) that defines medium- and longer-term recovery efforts with an aim of "building back better". It examines causes of, and responses to, the flood event to inform future policies. The final assessment should come near the end of the recovery period to assess the effectiveness of the recovery program and the final social and economic impacts of the flood event.

Based upon the RIA, the DRM agency should work in collaboration with other agencies and local governments to ensure an effective flood relief effort, including ensuring adequate food and shelter for vulnerable populations, flood aftermath cleanup, and resumption of critical infrastructure and public health services. The DRM agency should have immediate access to disaster relief funds from its national government to provide the necessary support.

Flood Disaster Recovery. Recovery is about ensuring that households, businesses, and communities are at least better off than they were before the flood and that their future flood risk is significantly reduced. The DRM agency should channel disaster relief funds through programs that help local governments and impacted populations make strategic decisions following the principles in Chapter 9 on floodplain management: protect, accommodate, retreat, and avoid.

Chapter 13: Disaster Risk Financing – The programs for flood and drought relief and recovery depend on adequate funding. This chapter explores how national governments can adopt a multi-layered risk financing approach to meet this challenge. Disaster risk financing sits at the bottom of the EPIC Response Framework. If all the programs in the Framework are effectively implemented, then the overall disaster risk financing burden can be significantly reduced, but of course never eliminated. Effective mitigation measures, such as healthy watersheds, water resources infrastructure, watershed management, and floodplain management, all help to reduce the overall risk. When an extreme event occurs, the programs for disaster response, relief, and recovery can help to minimize the final social, economic, and environmental impacts—provided that funding is available to implement these programs.

Disaster Risk Financing Instruments. There are a variety of risk financing instruments, each with specific characteristics that make it well-suited to address certain situations and less effective in others. The optimal mix of instruments depends on the overall fiscal situation of the country as well as its disaster risk profile. The following disaster risk financing instruments are described in the chapter: a national disaster fund, insurance programs, budget allocations, international aid, contingent disaster credit, and sovereign catastrophe (CAT) bonds.

Disaster Risk Financing National Sector Framework. Two sets of laws provide the foundation for the legal and regulatory framework for disaster risk finance: budgetary laws and DRM laws. The budgetary law should explicitly authorize the finance agency to develop and implement a disaster risk financing strategy. The DRM law should mandate the DRM agency to work with the finance agency to develop a disaster risk financing strategy. The role of the DRM agency in administering or overseeing disaster funds should be outlined in the DRM or budget law. The law should require the DRM agency to develop procedures for recommending or declaring a state of national emergency, as this may be used to trigger contingent credit lines or provide access to a national disaster fund.

Chapter 14: Summing Up – This chapter summarizes the roles of different national government agencies in implementing the EPIC Response Framework programs and presents recommendations for ensuring that the hydro-climatic risk management system continuously evolves, including constant program evaluation and periodic national strategic planning for water resources management, disaster risk management, and drought management.

An young boy sits atop a government water supply truck as residents fill water containers in New Delhi, India. Photo: ertyo5

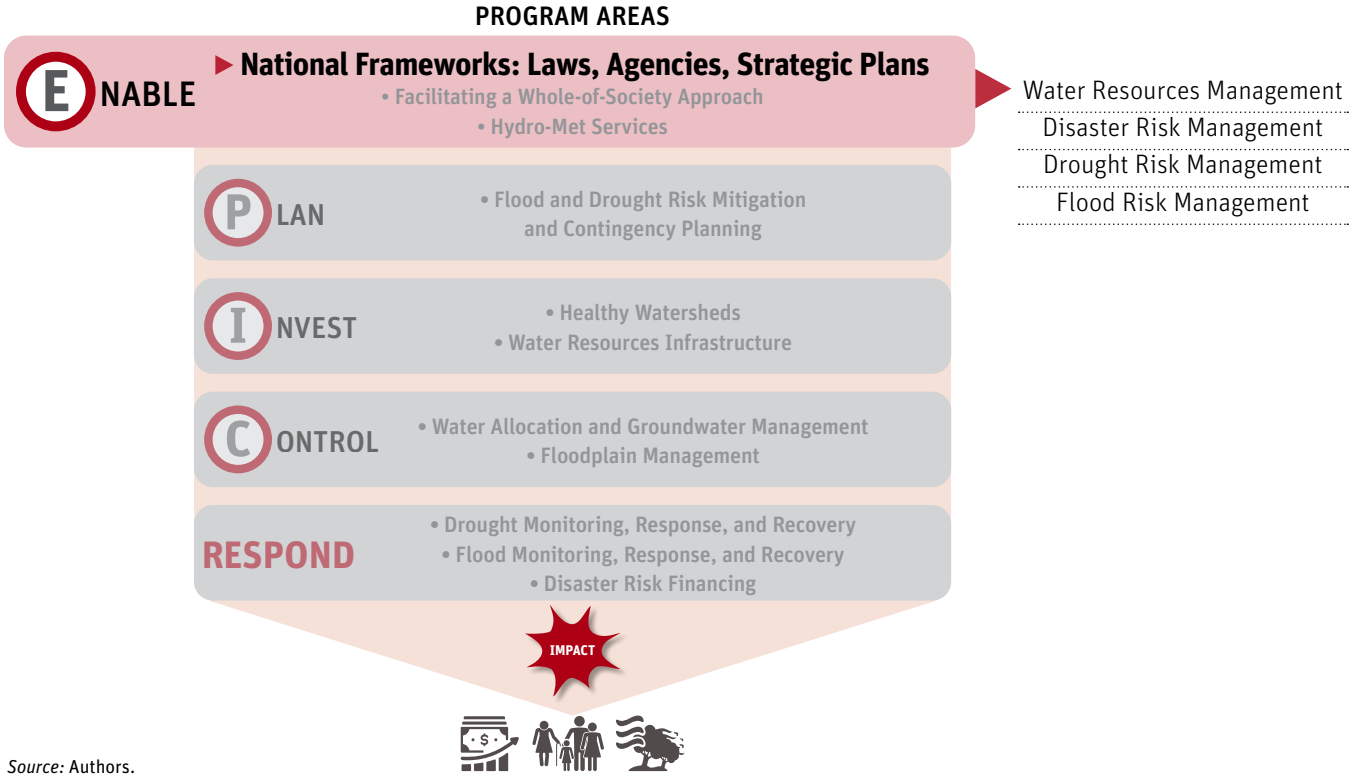
3 National Sector Frameworks

National sector frameworks, which are composed of laws, agencies, and strategic plans, help create the enabling environment for hydro-climatic risk management. Each program in the EPIC Response Framework is authorized through a national law and typically receives its funding through a national budgeting process. National sector agencies are responsible for implementing the programs, and national strategic planning provides an opportunity to assess overall sector performance and opportunities for improvements. As shown in Figure 3.1, national sector frameworks sit atop the EPIC Response Framework.

The four sector frameworks addressed in this chapter are summarized below, and then presented in more detail. Other important sector frameworks, including hydro-met, environment, agricultural, social protection, and finance, are presented in the relevant chapters.

- **WRM Sector Framework.** WRM agencies are responsible for overseeing or implementing the planning, construction, and operation of water resources infrastructure that help to mitigate flood and drought hazards. WRM agencies can also play critical roles in responding to droughts by

FIGURE 3.1 National Sector Frameworks within the EPIC Response Framework



Source: Authors.

promoting water conservation, adaptively allocating water, and conjunctively managing groundwater. They are also instrumental during floods, often acting as the nerve center for flood operations and for actually fighting floods. Hydro-climatic risk management, however, is only one of many functions embedded in an integrated WRM framework, which deals with a broad range of water and water-related environmental issues.

- **DRM Sector Framework.** DRM agencies are responsible for leading a joined-up government effort to prepare for, respond to, and recover from flood, and sometimes drought, disasters. They also play key roles in leading a whole-of-society effort to mitigate flood and drought hazards. Like WRM, flood and drought risk management is only of the many functions embedded in a DRM framework that must deal with the full range of potential natural and human-induced disasters.
- **National Drought Overarching Framework.** This overarching framework requires the collaboration of multiple sector agencies. Each agency must operate within the parameters of its own national sector laws, but it is also indispensable to create an overarching framework of complementary laws, institutions, and national strategic plans to facilitate the collaboration and synergy among the various agencies. This typically includes a national drought law, a National Drought Committee, and a National Drought Strategic Plan.
- **National Flood Overarching Framework.** Flood risk management also requires the collaboration of multiple sector agencies, although the WRM, DRM, and NHS/NMS typically play dominant roles. By following a joined-up government approach, these agencies—working within their own sector frameworks—may be able to naturally collaborate to address flood hazards. It may prove useful, however, to have supplemental laws that ensure a more integrated approach to flood risk management and facilitate interagency cooperation.

3.1 Synchronizing National Sector Frameworks

The Importance of a Joined-Up Government Approach. A key tenet of this report is that a joined-up government effort is necessary for effectively managing hydro-climatic risks. This requires workable linkages between the different sector frameworks, but also raises challenges of policy coherence. This requires that national laws follow the same direction and are clear in assigning agency responsibilities for different programs in order to reduce overlapping and potentially conflicting mandates. There may also be omissions in national laws where there is no agency designated to address a specific issue. Hopefully these inconsistencies and omissions are addressed as the national sector frameworks evolve based upon practice and experience. The role of national strategic planning is critical in helping countries address these issues over time. As discussed in Box 3.1, national climate adaptation planning offers an opportunity to see how the different sectors are interacting to reduce overall hydro-climatic risks.

At a deeper level, it also requires a culture of governance that fosters collaboration between different agencies, even if there are overlaps or gaps. In this regard it is important to

Box 3.1 Climate Adaptation Planning

The importance of climate adaptation was emphasized in the Paris Agreement,[a] which included a call for all countries to engage in national adaptation planning. The goals of these plans are for countries to build resilience to the impacts of climate change through medium- to long-term planning, and to integrate adaptation considerations into all relevant policies and strategies. While a detailed analysis of national adaptation plan (NAP) policies and institutions is beyond the scope of this report, it is important to recognize the close linkages between the NAP process and hydro-climatic risk management. Not only does the NAP process provide an ideal opportunity to examine and propose adjustments to the national sector frameworks for hydro-climate risk management (WRM, DRM, flood and drought risk management) with a specific focus on the impacts of a changing climate, it can also be used to reinforce the concept of a unified framework for hydro-climatic risk management as presented in this report.

[a] For more information about the Paris Agreement, see UNFCC's website at https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

Key Issue: The NAP process is undertaken primarily in response to Paris Agreement requirements and is usually led by a country's environmental agency. In some cases, there may be weak linkages between the NAP and core sector agencies such as WRM, DRM, agriculture, and NMS/NHS. These weak linkages may reduce the usefulness of the NAP.

make the distinction between collaboration and coordination, where collaboration implies a degree of equality among the contributing agencies, while coordination is prone to the domination of more powerful agencies and runs the danger of becoming merely ritualized consultation (Alford and O'Flynn 2012). True collaboration is not easy to achieve, particularly in many developing countries where overall governance may be weak, budgets are scarce, and agencies compete for resources and relevance.

Dealing with Federal and Transnational Situations. As shown in box 3.2, the concept of a "national framework" can be complicated in countries with federal constitutions. In order to simplify the analysis, this report will assume a unitary government system, with only national and local government levels.

While the focus of this study is on national frameworks, it is important not to overlook relevant transnational frameworks. At the international level, the scope for developing and implementing water resources transboundary frameworks will depend on the existence of an international agreement relating to the concerned transboundary river basin, and on the mandate of the relevant river basin organization or commission. Priority program activities will typically focus on the collection and sharing, on a mutual basis, of information in the context of routine hydro-met data as well as flood and drought warning mechanisms. Thereafter, programs will more likely tend to focus on matters that have more evident transboundary implications in terms of planning, risk assessment, infrastructure, and water allocation (including navigation). Depending on the scope of different programs, commitments made at the international level may need to be implemented through the adoption of national laws.

Speeding Up the Public Policy Process. National sector frameworks and their associated programs evolve over time as lessons are learned, the economy grows, and society's priorities change. A warming planet will not only speed up the hydrological cycle, but it should also speed up the public policy cycle as countries grapple with more severe and frequent storms, floods, and droughts.

As defined in Chapter 2, the term "policy" is used in a broad sense to refer to important decisions taken by the government in the formulation of laws, agencies, national strategic plans, programs, regulations, and guidelines. In some cases, there may also be standalone policy documents (such as a water policy) which provide overarching sets of principles and establish general plans of action. This report provides a set of policy considerations that the span the full spectrum of the EPIC Response Framework.

Figure 3.2 presents an overview of the general public policy cycle adapted for flood and drought risk management. The policy cycle helps us understand how national sector frameworks and their associated programs can evolve over time. Each step of the process is discussed below.

Box 3.2 National Frameworks under Federal Systems

The scope and content of national frameworks for flood and drought risk management in a federal context will depend on the constitution of the country. This will determine whether or not legislation on WRM and DRM can be adopted at the federal level or the state or province level, or a combination of both.

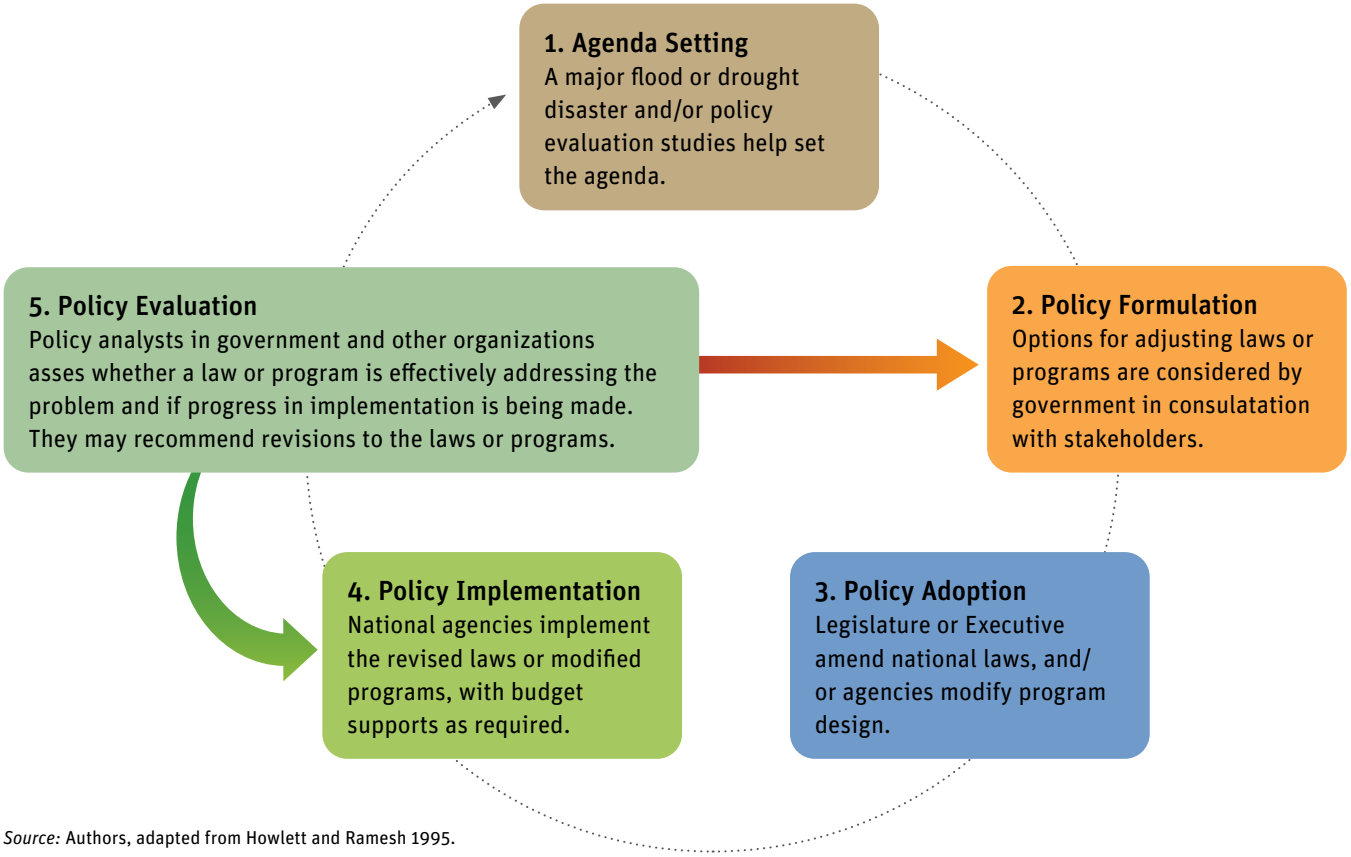
In some federal countries, for example, WRM is entirely a state or province level responsibility. Elsewhere, the reach of the federal legislature may extend to interstate rivers. Alternatively, the constitution may recognize the fact that water resources do not recognize internal boundaries and provide that WRM is a federal responsibility. In some federal countries, the jurisdiction of the federal government over aspects of WRM has emerged from a broader environmental competence or, in a transboundary context, as a result of federal authority over international relations.

However, even if the federal legislature lacks the authority or competence to legislate on WRM or DRM in terms of flood and drought risk management, this does necessarily mean that the federal government is precluded from adopting policies on the topic or of funding programs that may be implemented at a state or province level.

While a federal system is inherently more complex than in a unitary state, the EPIC Response Framework can still be applied, although more analysis will certainly be required.

Key Issue: Federal systems add an additional level of complexity to interagency collaboration as federal agencies need to interact with provincial agencies. In the United States, state governments generally bear primarily responsibility for flood and drought risk management, but state agencies need to collaborate with federal agencies for two reasons. First, the federal government provides substantial funding to help mitigate and respond to hydro-climatic risks. Second, some federal laws influence state water decisions, for example the federal Endangered Species Act.

FIGURE 3.2 An Overview of the Public Policy Process



Source: Authors, adapted from Howlett and Ramesh 1995.

- **Agenda Setting.** A major hydro-climatic event, such as widespread flooding or a devastating drought, can help propel the topic to the top of the political agenda. Public pressure exerted through various interest groups can also compel politicians and national agencies to reevaluate their policies. International agreements can also spur national policy development. National agencies, or other stakeholder groups, can also use this opportunity to shape the agenda based upon their policy evaluations.
- **Policy Formulation.** During this step, there is a search for solutions to address problems that have bubbled to the top of the political agenda. Policy evaluation conducted by national agencies, as well as other organizations, generate different options that are vigorously debated. These options generally revolve around changing national laws to include new or modified hydro-climatic risk management programs. There may be differences of opinion on the efficacy of different solutions, the economic costs, and distributional impacts. This report provides a comprehensive set of programs to address hydro-climatic risks, along with a brief description of an effective program based upon the literature and international experience. The set of programs in the EPIC Response Framework can be considered a menu of options to help inform the policy formulation process.
- **Policy Adoption.** If major changes are required, then the national government may need to modify the legal framework, either through a legislative change or an executive decree; this may involve the creation of a new program or major adjustments to an existing program. In other cases, existing programs may only need to be tweaked, and the responsible national agency can make the necessary regulatory or strategic modifications.
- **Policy Implementation.** During this stage, the national agency gets down to work implementing the policy, including developing detailed procedures, preparing guidelines, and providing funding to program participants. For most of the programs presented in this report, key agency actions for effective implementation are highlighted. Having access to enough budget is critical for successful program implementation.
- **Policy Evaluation.** This is an important step in the policy process and can take place at multiple levels and

feeds into the agenda setting and/or policy formulation steps. Periodic National Strategic Plans for WRM, DRM, and Drought offer an ideal opportunity to holistically evaluate how the flood and drought management systems are operating. In addition, each agency should periodically undertake its own program level evaluation. This evaluation should look at effectiveness, adequacy of budget and human resources, and potential constraints and include recommendations for improvement. In some cases, the national government may also wish to have an independent program evaluation.[6]

The EPIC Response Framework contains many different programs which are mapped to various national sector frameworks. It is important for the responsible agency—and occasionally an independent entity—to periodically evaluate and report on the performance of each program. This evaluation should cover topics such as program achievements and effectiveness, adequacy of budget and human resources, potential constraints, and recommendations for improvement. Programs constantly need to be adjusted to respond to changing circumstances and lessons learned. Some types of program adjustments can be undertaken directly by the agency concerned while others require a change in the relevant law. Program evaluations should be made publicly available and are also useful for informing the National Strategic Plans.

3.2 The National WRM Sector Framework

General Description

The dominant paradigm for WRM is "integrated water resources management (IWRM)". While there is no official definition of IWRM, a commonly used definition is that it is "a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment" (GWP 2000). Recognized at the international level more than 30 years ago at the 1992 Earth Summit in Rio de Janeiro, Target 6.5 of Sustainable Development Goal 6 on Clean Water and Sanitation calls for the implementation of IWRM at all levels by 2030.

The basic objective of WRM is the management of water as a natural resource, the use of which is fundamental to all socioeconomic activities, but which at the same time plays a vital ecological function that needs to be protected. As such, WRM seeks to allocate water among different user sectors (such as water supply, agriculture, industry, and power generation) and water users. It promotes the development of water resources while also seeking to prevent or minimize water pollution and to ensure appropriate water quality. It sets and enforces minimum or environmental flows to enable people to meet basic needs and to protect aquatic ecosystems and the livelihoods of those who depend on those ecosystems. Many of the programs identified in the upper part of the EPIC Response Framework fall under the general, but not necessarily exclusive, domain of the WRM framework, including river basin planning, water resources infrastructure, and adaptable water allocation. It follows that an effective national framework for hydro-climatic risk management system generally requires a functional and comprehensive national framework for WRM.

Legal and Institutional Framework

The legal framework for WRM is typically contained in a water resources law that applies both to surface and groundwater and which addresses issues of water allocation, water quality, water-related environmental sustainability, and water pollution control. Many countries have recently adopted new water resources laws to implement IWRM or are in the process of doing so. However, there are exceptions. In some countries, different aspects of WRM are addressed in separate laws (for example, on groundwater management, irrigation, or water pollution). Moreover, while water resources laws in many countries have long addressed the "harmful" effects of water, it is usually only relatively recently that they have taken a comprehensive approach to floods and droughts. WRM programs, in the sense used in this study, are typically based on the provisions of such a water resources law.

Institutional Arrangements for Water Resources Management. Responsibility for the implementation of a water resources law is usually conferred upon a ministry, such as a water and natural resources ministry or an environment ministry, or on a national water resources management commission or authority which may be established on the basis of the water resources law itself. In this report, irrespective of the approach taken, this entity is referred to as the WRM agency.

Water resources laws often provide for the establishment of a high-level inter-ministerial body, such as a National Water Council or National Water Resources Committee, to ensure inter-sectoral coordination and participation in decision making. Alternatively, they may confer such a role on the government (cabinet) itself.

[6] An example is the Congressional Research Service (CRS), which is a public policy research institute of the United States Congress.

Box 3.3 Tanzania's Water Resources Law

Tanzania's Water Resources Management Act, 2009 was adopted to give effect to the 2002 National Water Policy and provides a good example of a modern water resources law. It sets out several principles and objectives for WRM before reaffirming that water resources belong to the country's citizens with the President acting as the trustee.

The lead WRM agency in Tanzania is the Ministry of Water and Irrigation. The Act next sets out the powers of the Minister, the national level Director of Water Resources, the National Water Board (whose members are appointed by the Minister), and the Basin Water Boards, which have legal personality and which are to be established for each river basin, as well as catchment and sub-catchment water committees.

The Act next requires the preparation of a national IWRM plan which must be based on the IWRM plans prepared by the Basin Water Board and catchment committees. With regard to water resources protection, the Act provides that the Minister may classify water resources for water quality purposes, determine a "reserve" to satisfy basic human needs and protect aquatic ecosystems, establish "Protected Zones" and "Ground Water Controlled Areas". It also provides for the imposition of restrictions on water use in times of drought and natural disasters and contains provisions on the prevention of pollution.

As regards water abstraction and use, the Act provides that this is to take place on the basis of use permits (with transitional provisions for unregistered and customary water rights and an exception for small scale domestic uses), groundwater permits for the construction or enlargement of wells and boreholes, and discharge permits for the discharge of effluents and pollutants to surface or ground water.

Subsequent provisions provide for the establishment of water user associations and public infrastructure for water resources development. The Act also contains extensive provisions on dam safety as well as provisions on flooding that confer powers upon the Minister to prohibit or authorize the construction of dikes and other flood defense structures or if necessary to order their demolition, to cooperate with local governments on the identification of flood plans, and to adopt, in consultation with the minister responsible for local government, regulations providing for the control and management of stormwater within municipal areas. The Act also sets out provisions on water abstraction charges, and how they are to be used, as well as on transboundary water before concluding with provisions on offences, penalties, enforcement, appeals, and miscellaneous and final matters.

Key Issue: The Act sets out a sound legal framework for WRM. As always, implementation is the true challenge.

Because water resources do not respect administrative boundaries, modern water resources laws typically provide for water resources management at the level of river basins (or sub-basins) or individual aquifers, resulting in the creation of specific river basin, sub-basin or aquifer management organizations (hereafter "basin agencies") together with new stakeholder participation mechanisms at basin or sub-basin levels such as "river basin committees". In practice, river basin agencies can take a number of forms depending on a range of factors (including the size and relative development of the river basin). The agencies can be little more than offices or departments in the WRM agency. Or they can be organizations with their own legal authority established on the basis of the water resources law. Or they can be largely self-funding quasi-autonomous river basin organizations in which the river basin committee is effectively also the management board of the basin organization.

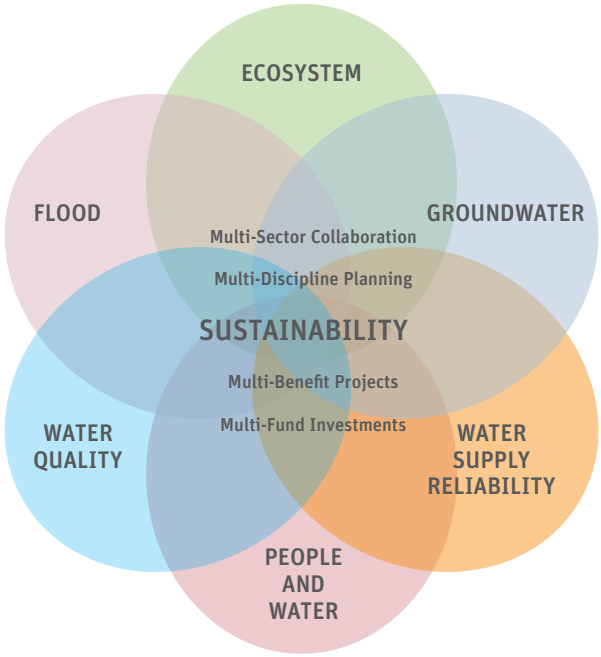
National Strategic WRM Plan

Modern water resources laws typically require the periodic formulation of a National Strategic WRM Plan that lays out a roadmap for future activities. Such a plan can help a country chart a path towards sustainable, equitable, and long-term WRM, and result in a broad and diverse portfolio of recommended actions to address critical, systemic, and institutional challenges. The formulation of the plan is usually led by the WRM agency but should involve the active participation of all other relevant agencies, including DRM, agriculture, natural resources management, and hydro-met. A broad spectrum of other stakeholders should also participate in the process including local governments, the private sector, academia, civil society, and the general public.

The National Strategic WRM Plan provides a roadmap for policy makers and agencies to help the sector advance and is an ideal mechanism to help foster interagency collaboration and a holistic approach to WRM. It provides an opportunity to assess how the country is performing with respect to flood

and drought management, and to propose adjustments to the policies, laws, agencies, programs, and funding to ensure continuous advancement. The National Strategic Plan does not identify measures or make specific investment decisions. Figure 3.3 provides a conceptual vision of strategic water planning in California.

FIGURE 3.3 Strategic Water Planning in the State of California



Source: California Department of Water Resources.

Generic Evolution

Table 3.1 shows the generic evolution of a WRM framework.

At the outset (Nascent), the focus is often on the development of water resources through the construction of infrastructure (for such purposes as irrigation, industry, power generation, and water supply) or specific aspects of WRM (such as water pollution) with such activities being the subject of sectoral or narrowly focused laws (such as an irrigation law or a water pollution law). At this stage, little consideration is typically given to the management of water as a resource or the health of aquatic ecosystems.

Over time (Engaged), the limitations of the uncoordinated approach become clear and a water resources law is adopted. However, a key challenge for water resources legislation is implementation, in terms of both human and financial resources. It can take time for the necessary funding to be made available so that the law can be effectively implemented.

At this point (Capable), the process of effective implementation of the water resources law begins with funding made available to the WRM agency and the river basin agencies. A strategic planning process is usually initiated at this phase, but it may be driven by the WRM agency with limited input from other sectoral agencies and limited participation, and as a result may be unable to deal with the complexities of flood and drought risk management.

At the most advanced level (Effective), the country has gained more experience with WRM and its water resources

TABLE 3.1 Generic Evolution of the National WRM Sector Framework

Dimension	Nascent	Engaged	Capable	Effective
National laws and policies	No water resources law. Water resources addressed in sectoral laws that focus on their development.	A standalone water resources law is adopted but implementation is in the early stages.	Water resources law adopted but not fully implemented; river basin approach to management embraced but with limited inter-sectoral cooperation.	Well-established and fully implemented water resources law with evolutionary amendments.
National agencies	No national WRM agency.	National WRM agency designated on paper.	National WRM agency is funded and in operation but with limited interaction with other sectoral agencies.	National WRM Agency collaborating with other sectoral agencies including the DRM agency and Drought Committee.
National Strategic Plan	No Strategic Plan.	Strategic Plan not prepared.	Basic National Strategic Plan created with limited links to other sectors and low levels of implementation.	National Water Resources Strategic Plan coordinated with national DRM, drought, and flood plans.

Source: Authors.

law has evolved to incorporate lessons learned with multiple amendments or even complete revisions. The national WRM agency has close links with other relevant agencies, including those responsible for natural resources management, agriculture, and DRM. This collaboration is reflected in broad and comprehensive national strategies which directly address flood and drought risk management issues.

3.3 The National DRM Sector Framework

General Description

DRM is a broad topic that has seen significant evolution over recent years, encapsulated by the recent Sendai Framework for Disaster Risk Reduction 2015-2030. Among the four priorities of the Sendai Framework is Priority 2: "Strengthening disaster risk governance to manage disaster risk". This priority notes "the vital role of disaster risk governance at the national, regional and global levels in terms of the management of disaster risk reduction and ensuring the coherence of national and local frameworks of laws, regulations and public policies that, by defining roles and responsibilities, guide, encourage and incentivize the public and private sectors to take action and address disaster risk."[7]

Floods and droughts are invariably included among the types of natural hazards that are subject to a disaster risk management (DRM) framework along with storms, earthquakes, volcanoes, and disease outbreaks, as well as anthropogenic hazards such as transportation and industrial accidents. It follows that, as with WRM, an effective national framework for hydro-climatic risk management includes the need for an effective, functional, and comprehensive national DRM framework.

Legal and Institutional Framework

In an increasing number of countries, the legal framework for DRM is contained in a specific DRM law (IFRC and UNDP 2015). DRM programs are typically established based on the provisions of such a law. Reflecting developments at the international level, the focus of such legislation has shifted from disaster risk response to DRM.

A DRM law typically confers specific powers on a specialized DRM agency that is usually under the direct supervision of the government at a high political level, such as the president or prime minister, due to the need for inter-sectoral cooperation and rapid response during an emergency. Very often, provision is made for the establishment of an apex body, such as a National Disaster Committee, to ensure coordination between state actors, civil society, and the international community. Often too, provision is made for sub-national emergency committees, and a key role of a DRM law is to provide the necessary linkages at the sub-national level among different actors.

Nevertheless, a DRM law cannot by itself fully address disaster risk reduction. DRM laws should be viewed as part of an overall system of risk governance that includes different laws and local government mandates that can reduce exposure and underlying vulnerabilities, particularly by preventing the creation of new risks. DRM laws can be used to create formal links between the mandates and institutions created by DRM laws and sectoral and local government laws, for example building codes and land use management. Such an approach can help encourage joint policy approaches and put better mainstream DRM concepts into practice.

Many of the provisions in a DRM law are related to flood and drought risk management, either directly or indirectly, as floods and droughts are common disasters confronted by most countries. The degree to which floods or droughts are directly addressed in a DRM national framework is related to their hazard level in the country concerned.

National Strategic Plan

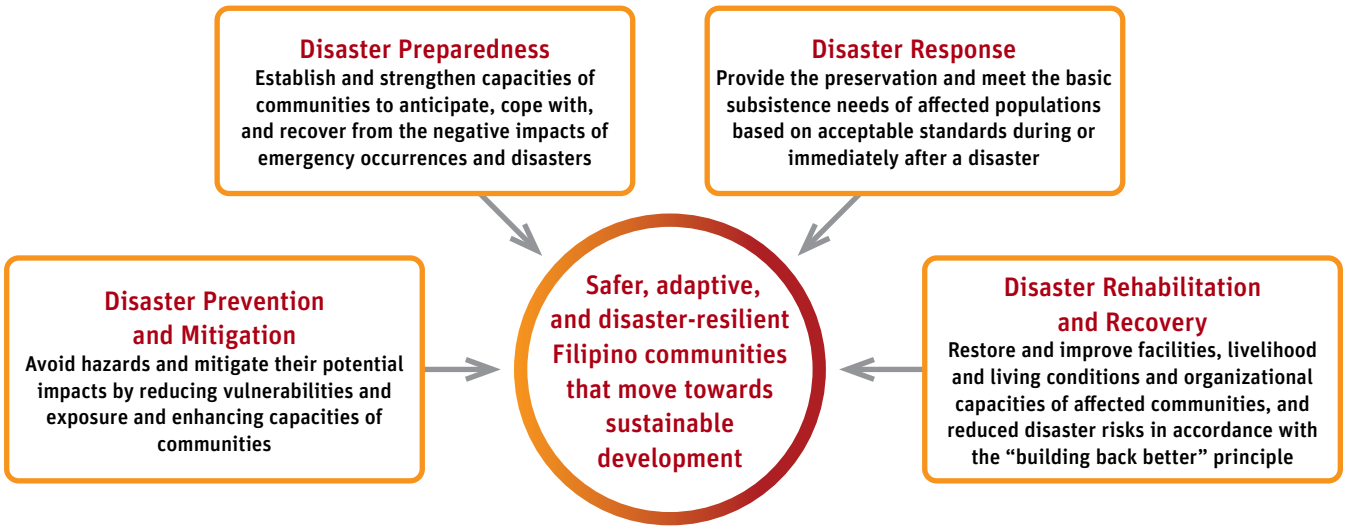
DRM laws typically require the periodic formulation of a National Strategic DRM Plan that lays out a roadmap for managing disaster risks. Such a plan typically has four elements which follow the general DRM cycle: (1) prevention and mitigation; (2) preparedness; (3) response; and (4) recovery. The plan can help a country chart a path towards a more resilient future and result in a broad and diverse portfolio of recommended actions to address critical systemic and institutional challenges. The formulation of the plan is led by the DRM agency but should also involve the active participation of other relevant agencies, including WRM, hydro-met, agriculture, natural resources management, social welfare, and finance. A broad spectrum of other stakeholders should also participate in the process, including local governments, the private sector, academia, civil society, and the general public.

The National Strategic DRM Plan is an ideal mechanism to help foster interagency collaboration and a holistic approach to disaster risk management. It provides an opportunity to assess how the country is performing with respect to flood

[7] The other priorities are understanding disaster risk, investing in disaster risk for resilience, and enhancing disaster preparedness for effective response, and to "build back better" in recovery, rehabilitation, and reconstruction. The framework also sets out seven targets for achievement by 2030.

and drought management, and to propose adjustments to the policies, laws, agencies, programs, and funding to ensure continuous advancement. The Plan does not mandate actions or make specific investment decisions, but rather provides a roadmap for policy makers and agencies to better manage disaster risks. Figure 3.4 shows the general scope of the Philippines National Disaster Risk Reduction and Management Plan, and Box 3.4 describes the country's DRM law.

FIGURE 3.4 General Scope of The Philippines National Disaster Risk Reduction and Management Plan



Source: The Philippines National Disaster Risk Reduction and Management Plan (NDRRMP) 2011-2028.

Box 3.4 The Philippines DRM Law

The Philippines Disaster Risk Reduction and Management Act of 2010 was adopted in 2010 to strengthen the disaster risk reduction and management system. It replaced an earlier Presidential Decree on disaster control and community preparedness.

The National Disaster Risk Reduction and Management Council is chaired by the Secretary of the Department of National Defense. It has some 40 members, including senior officials from the national government, the armed forces and police, and regional and local governments, as well as a broad range of civil society representatives. The Council has broad policy making, coordination, integration, supervision, monitoring, and evaluation functions. The Council chairperson can call on government and non-government "instrumentalities and entities" to provide assistance in connection with disaster risk reduction and response, as well as the power to call on the military reserve.

The Office of Civil Defense (OCD) is an organization within the Philippines' Department of National Defense and serves as the implementing arm of the National Disaster Risk Reduction and Management Council. The national DRM plan is prepared by the OCD. Regional DRM councils are also established for each region and these are chaired by civil defense officers of the OCD. Each regional council must, among other matters, establish a Regional Center to coordinate, integrate, supervise, and evaluate the activities of local DRM councils. The members of the local councils are public officials and civil society representatives, and their main tasks are to approve, monitor, and evaluate the implementation of local DRM plans. They can also recommend the implementation of forced or preemptive evacuation of residents, if necessary. Each local council is supported by a local DRM office, the tasks of which are set out in some detail in the Act. The local DRM offices take the lead in preparing for, responding to, and recovering from the effects of any disaster.

The Act sets out funding mechanisms, including the National Disaster Risk Reduction and Management Fund, which is funded from the budget and from which up to 30 percent can be allocated as a "Quick Response Fund" and supervised by the national Council.

Key Issue: The Act is very good example of a modern DRM law and also clearly demonstrates the institutional complexity of addressing DRM at multiple levels of government.

TABLE 3.2 Evolution of the DRM Framework

Dimension	Nascent	Engaged	Capable	Effective
Law	No DRM law exists. *Ad hoc* response to disasters.	DRM law focuses on disaster response.	DRM law updated to focus on disaster risk reduction and DRM.	Well-established DRM law with evolutionary amendments and clear linkages to the legislation of other national sector frameworks.
National agencies	No national entity responsible for DRM.	DRM coordination committee established to respond to disasters.	Establishment of designated national DRM agency.	Comprehensive Plan with focus on hazard mitigation and synchronized with WRM and drought plans.
National Plan	No Plan.	Emergency response plans only.	Basic National Pan but limited coordination across sectors and low levels of implementation.	Comprehensive plan with focus on hazard mitigation and synchronized with WRM and drought plans.

Source: Authors.

Generic Evolution

Table 3.2 provides an overview of how a DRM framework might evolve over time. In the beginning (Nascent), a country might focus on primarily on disaster response with limited attention to hazard reduction, preparedness, or recovery. Typically, there is no national legal framework in place, and the civil defense authorities are primarily responsible for helping communities respond to emergencies.

Over time (Engaged), the country may develop a national policy that includes a national DRM coordination entity, focused primarily on ensuring disaster preparedness and response, and ensuring coordination of various national and local entities.

The limits of this approach may become apparent as disasters increase, both in terms of frequency and magnitude. At this point (Capable), the country rallies and creates a DRM law that takes a more comprehensive view of reducing multi-hazard disaster risks, including hazard mitigation and an approach to recovery that aims to "build back better". Typically, a national DRM agency is created, and DRM entities at the sub-national and local entities are also created. The DRM law calls for the preparation of periodic National DRM Plans, but there may be low levels of coordination among the various entities and many implementation challenges.

At the most advanced level (Effective), the country has gained more experience with disaster risk management, and its DRM law has evolved to incorporate lessons learned with multiple amendments or even complete revisions. The national DRM agency has close links with other sectoral agencies and local governments with clearly defined and executed national policies. This collaboration is reflected in broad and comprehensive National Plans that emphasize the role of hazard mitigation and "building back better".

3.4 Overarching National Drought Risk Management Framework

General Description

Drought risk management is a complex endeavor that requires both WRM and DRM perspectives, but also necessitates going beyond these traditional domains. International recognition of the importance of droughts was reflected in the 1994 United Nations Convention to Combat Desertification (UNCCD) which calls upon decision makers and water and land managers to take a proactive, coordinated, and holistic approach to drought risk management.[8]

The modern conception of WRM includes both "blue" and "green" water. Blue water is mainly water stored in rivers, reservoirs, lakes, and accessible groundwater aquifers, and is available for uses such as hydropower, water supply, and irrigation. Green water refers to the water that originates from precipitation, is stored in unsaturated soil, and is absorbed and undergoes transpiration by plants or is evaporated directly from the soil. Green water plays an irreplaceable role in global ecosystems and food production, accounting for around 80 percent of global food production and exclusively sustaining grassland and forest ecosystems (Liu and Yang 2010).

WRM policies, institutions, and infrastructure have, however, historically evolved to manage primarily blue water. Drought not only affects traditional blue water uses, but also has a profound impact on green water, particularly as regards

[8] For more information about this topic, see UNCCD's website at https://www.unccd.int/.

agriculture and natural resources management. These domains thus must also be explicitly incorporated into drought risk management systems. Healthy land provides natural storage for fresh water. If it is degraded, it cannot perform that function. Managing land better and massively scaling up land rehabilitation are essential for building drought resilience and water security. Land restoration is the cheapest and often the most effective solution to improving water storage, mitigating impacts of drought, and addressing biodiversity loss.

DRM evolved primarily in response to immediate and devastating natural shocks such as earthquakes, storms, floods, and landslides. Drought, in contrast, is generally a slow-moving natural disaster in which the extent of the impact only emerges over time, sometimes years, and the understanding of future impacts is limited by the accuracy of weather and climate forecasts and socioeconomic drivers. Some of the elements of a DRM framework, such as efforts to mitigate hazards and the activation of emergency support systems, can also naturally be applied to drought risk management.

In summary, although WRM and DRM are intimately linked to drought management, it is generally necessary to develop a specific drought framework that incorporates the unique elements of drought monitoring, impact assessment, and risk characterization, in addition to providing the basis for drought agricultural response and recovery programs. In some poorer countries with large rural populations, WRM and DRM frameworks may not even exist or may be underdeveloped, and in such cases the burden of managing droughts may fall primarily on the agriculture agency and local governments.

Legal and Institutional Framework

In most cases, existing laws define some of the roles and responsibilities of sectoral agencies relating to drought management. For example, a water resources law may require the WRM agency to plan for and respond to droughts. A DRM law may authorize the DRM agency to take certain actions during a drought. At the same time, an agriculture law may provide the agriculture agency with the authority to help farmers and livestock producers prepare for and respond to drought. A drought legal framework, however, goes beyond the sector-specific laws and seeks to coordinate and synergize the efforts of several different entities.

There are various legal instruments that can be used to facilitate the establishment of a legal framework for drought risk management. A drought law can be adopted to provide a stable, long-term foundation for improving drought risk management. This might be an actual law approved by the legislature. Alternatively, it may a presidential decree or a government (cabinet) decision that can directly coordinate the activities of different agencies concerned with aspects of drought risk management.

A law, decree, or decision should typically do three things. First, it should set out a general policy on drought risk management, with an overall strategy of moving from crisis management to proactive drought risk management. Second, it should establish an interagency Drought Committee specifying its functions, membership, and secretariat. Third, it should require the preparation and periodic revision of a National Drought Strategic Plan. Within the framework of the Drought Committee, it will also be important to include local governments, particularly those overseeing affected areas, as well as other stakeholder groups such as water utilities, farmers, and industry.

The Drought Committee also usually includes specific working groups, for example to provide drought monitoring and assessment, and to prepare the National Strategic Drought Plan. The Drought Committee is essentially responsible for overseeing all the drought-related programs in the EPIC Response Framework and ensuring their continuous and synergistic development. Finally, the Drought Committee should always be active, even during non-drought periods, although meetings of the Committee may be less frequent in such circumstances.

Most of the programs related to drought risk management are mapped to the WRM, DRM, hydro-met, and agriculture frameworks and these are typically the most active agencies in the Drought Committee. Typically, one of the agencies will serve as the "anchor agency" or secretariat for the Drought Committee. In countries with well-developed water resources management systems, it is usually the WRM agency; in other countries, it may be the agriculture agency.

National Strategic Plan

The drought legal framework should require the National Drought Committee to prepare, and periodically update, a National Strategic Drought Plan. This plan is conceptually different to a WRM Plan or a DRM Plan in that it is operationally focused on a single hydro-climatic risk: drought. Both the WRM and DRM Plans should address droughts, albeit from different perspectives. The scope of a National Strategic Drought Plan depends on a country's physical as well as institutional context, but a well-formulated Plan should do the following: [9]

[9] For more detailed discussion on drought national plans and policies, see the WMO/GWP Integrated Drought Management Programme (IDMP) website at https://www.droughtmanagement.info/find/guidelines-tools/guidelines/.

- **Understand drought risks.** The Plan should examine vulnerabilities that result in social and economic impacts from recent droughts, characterize risks, and inventory resources at risk. It should also identify trends in hazards, vulnerabilities, and exposure, taking account of uncertainties in order to provide the overall context for the Plan.
- **Improve interagency and inter-governmental coordination.** The Plan should improve who does what and when within the drought management system, and consider opportunities for improving the policies and institutions for drought management.
- **Prepare for and mitigate drought hazards.** The Plan should identify opportunities for reducing drought hazards by improving management of water resources, agricultural systems, and natural resources. That will include management planning, programs, and projects.
- **Refine drought monitoring and forecasting.** The Plan should recommend improvements for long-term monitoring, forecasting, and data collection systems, and systems for tracking the real-time and potential impacts on cities, farms, industry, and the environment as droughts evolve and recede. The Plan also should review and refine the drought categorization or indicator system to track the onset of droughts and to help clearly communicate the severity of drought conditions.
- **Ensure effective drought communication and education.** The Plan should assess the effectiveness of public education campaigns to keep stakeholders and the general public informed of drought risk and efforts to mitigate the hazard. It should also conduct drought response workshops and planning exercises with different government agencies and local governments to prepare for droughts.
- **Improve drought response and recovery.** The Plan should ensure that national agencies and local governments are coordinated properly and sufficiently resourced to provide effective and timely relief from droughts. This includes reviewing the effectiveness of programs to respond to droughts, including water conservation, water allocation, and emergency water supply for cities and towns; agricultural support programs, including insurance, contingency financing, and disaster relief; and social safety nets when vulnerable people lose their livelihoods or in extreme cases, when they face starvation.

Generic Evolution

Table 3.3 provides an overview of how a drought risk management framework might evolve over time. In the beginning (Nascent), a country focuses primarily on *ad hoc* responses to drought events with limited attention to drought hazard reduction or preparedness. Generally, there is no national legal framework in place, and national agencies and local governments respond in a reactive and delayed manner to an evolving drought.

Over time (Engaged), the country develops an implicit drought management policy where each sector agency incorporates drought issues into its mandates, plans, and operations. *Ad hoc* Drought Coordination Committees are convened to respond to drought emergencies. Deficiencies may become increasingly apparent as drought impacts continue or even potentially increase.

At this point (Capable), the country adopts a national drought policy or law that calls for a more comprehensive and proactive approach. A National Drought Committee is created but its focus is primarily on drought monitoring and response. A National Strategic Drought Plan process is started but is still very rudimentary.

TABLE 3.3 Evolution of the DRM Sector Framework

Dimension	Nascent	Engaged	Capable	Effective
National laws and policies	No drought law or policy adopted.	No drought law, but sector laws incorporate drought mandates.	National drought law adopted.	Well-established drought law or policy with evolutionary amendments.
National agencies	No drought committee in place.	*Ad hoc* drought coordination committees convened during droughts.	Multi-disciplinary Drought Committee established.	Drought Committee functioning well, with effective working groups and interagency cooperation.
National Strategic Plan	No Plan.	Drought emergency response plans only.	Basic drought preparedness and response plan but primary focus on monitoring and response. Limited coordination and low implementation.	Comprehensive Plan covering all three drought pillars with high level of implementation.

Source: Authors.

At the most advanced level (Effective), the country has gained more experience with drought risk management, the Drought Committee is functioning well and sustained during non-drought periods, and there have been multiple revisions of the National Strategic Drought Plan. A more comprehensive and multi-disciplinary view of proactive drought management has solidified which focuses on drought hazard mitigation as well as drought preparedness, response, and recovery.

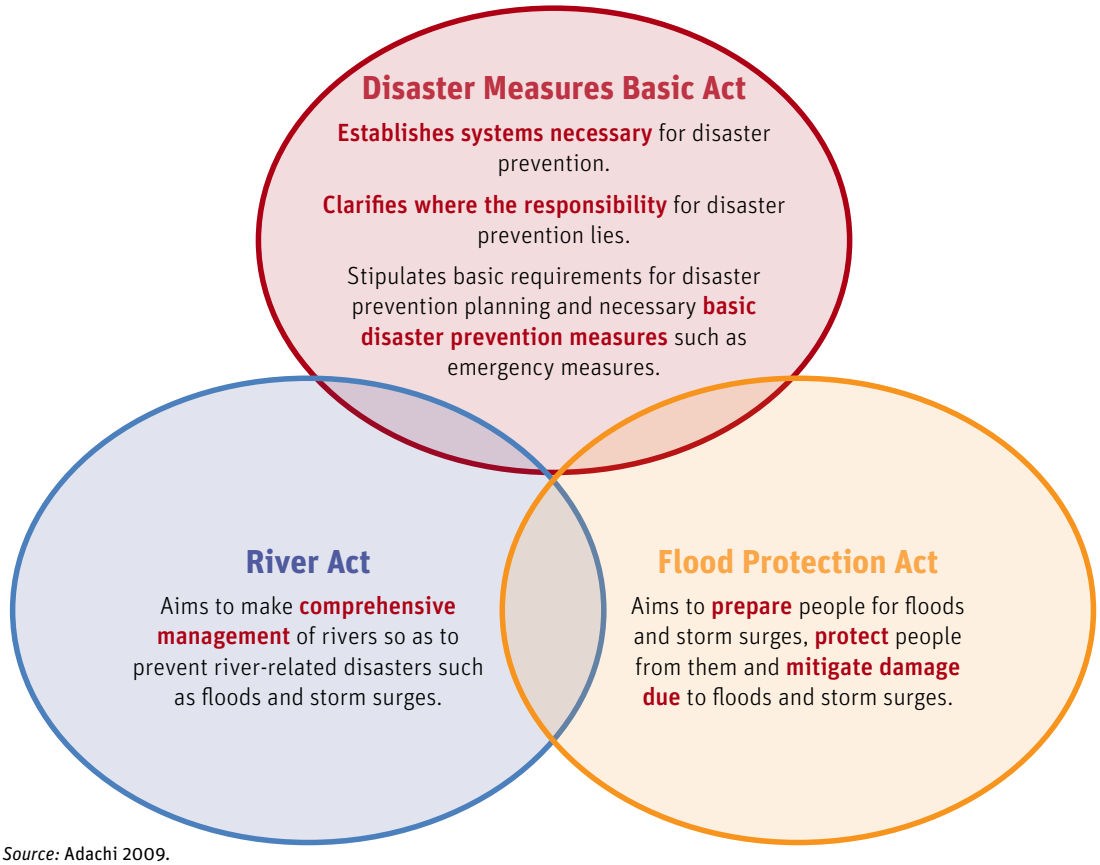
3.5 Overarching National Flood Risk Management Framework

Description and Legal Framework

In many countries, the combination of WRM, DRM, and Hydro-Met sector frameworks—if properly synchronized—should address most issues related to flood risk management. However, some more advanced countries have also found it useful to adopt additional flood management specific laws or national policies to help bind these sector frameworks more closely together. Some examples are provided below:

The European Union's Water Framework Directive[10] and Floods Directive[11] between them require member states to adopt a common approach to river basin management and flood risk assessment and management planning. As shown in Figure 3.5, in Japan there are three major interlocking laws related to flood risk management, the DRM Act, the River Act (which acts as a water resources law), and a specific Flood Protection Act. In the United States, the Federal Interagency Floodplain Management Task Force helps bring together all water-related agencies and was established under the 1975 Water Resources and Development Act.[12]

FIGURE 3.5 Interlocking Laws related to Flood Risk Management in Japan



Source: Adachi 2009.

[10] See EC (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L327, 22.12.2000.
[11] See EC (2007). Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. OJ L288, 6.11.2007.
[12] For more information about the Federal Interagency Floodplain Management Task Force, see FEMA's website at https://www.fema.gov/floodplain-management/intergovernmental/task-force.

National Strategic Planning

Ideally, the National Strategic WRM Plan and the National Strategic DRM Plan should address flood risk management in a parallel and synergistic manner. In this case, there may not be a need for a standalone National Strategic Plan for flood risk management. While the WRM Plan may focus more on reducing flood hazards, and the DRM Plan may focus more on reducing flood exposure and vulnerability, the two plans should be mutually reinforcing with different areas of emphasis. To achieve this synergy, it is critical that the DRM agency participate in the formulation of the National Strategic WRM Plan, and vice versa. This partnership may come naturally through good governance at the national level, or it may be enshrined in the country's laws and regulations.

Generic Evolution

The evolution of the national framework for flood risk management will typically closely track the development of the frameworks for WRM and DRM described above. As shown in Table 3.4, in the beginning (Nascent), a country might focus primarily on flood emergency response with limited attention to hazard reduction, preparedness, or recovery. Generally, there is no national WRM or DRM legal framework in place, and the civil defense authorities are primarily responsible for helping communities respond to flood emergencies.

Over time (Engaged), the country may develop a national DRM policy that encompasses flood response and each WRM-related sector (agriculture, hydropower, water supply, and sanitation) may have its own sector-specific law which includes flood management. When a flood occurs, *ad hoc* national flood committees may be constituted to deal with flood response and recovery. The limits of this approach may become apparent as flood damage increases, in terms of both frequency and magnitude.

At this point (Capable), the country rallies and creates DRM and water resources laws that include flood risk management mandates that are implemented by specialized WRM and DRM agencies.

At the most advanced level (Effective), the country has gained more experience and there may be a specific National Flood Policy which links the DRM and WRM frameworks, as well as others, more closely together. The WRM and DR M agencies collaborate closely and prepare complementary National Strategic Plans that include flood risk management.

TABLE 3.4 Evolution of the Overarching Flood Risk Management Framework

Dimension	Nascent	Engaged	Capable	Effective
National laws and policies	No DRM or water resources laws.	DRM law refers to flood response. Water resources law contains references to flood risk but not these are not yet implemented.	Standalone DRM and water resources laws include provisions on flood risk management but implementation patchy.	Effective implementation of DRM and water resources laws coupled with adoption of National Flood Policy.
National agencies	No national entities.	*Ad Hoc* national committees during flood emergencies.	Designated National DRM and WRM agencies with FRM mandates.	National DRM and WRM agencies collaborating to reduce flood risks.
National Strategic Plan	No Plan.	DRM has emergency response plans; no basin-level flood risk management planning.	Basic WRM and DRM National Plans with limited attention to flood risk management.	Comprehensive and coordinated WRM and DRM Plans include flood risk management.

Source: Authors.

3.6 The Importance of Interlocking WRM, DRM, and Drought Strategic Plans

As demonstrated in the report, many agencies have specific mandates related to floods and droughts that they must perform effectively. However, this is not enough; the agencies also must also collaborate when required. An important process for facilitating a joined-up approach is the periodic preparation, approximately every five years, of strategic national plans for WRM, DRM, and drought management.

These strategic plans should be formulated through a multi-agency agency process to ensure an interlocking and consistent approach to flood and drought management. Box 3.5 shows an example from the State of California. The WRM Strategic Plan should, of course, be led by the WRM agency, but it should also include the DRM agency in matters related to floods and droughts. In a similar manner, the DRM Strategic Plan needs to be led by the DRM agency, but the WRM agency should also actively participate in matters related to floods and droughts. The Drought Strategic Plan requires the active involvement of the WRM, agriculture, and DRM agencies. Finally, the NMS/NHS needs to be intimately involved in all three strategic plans.

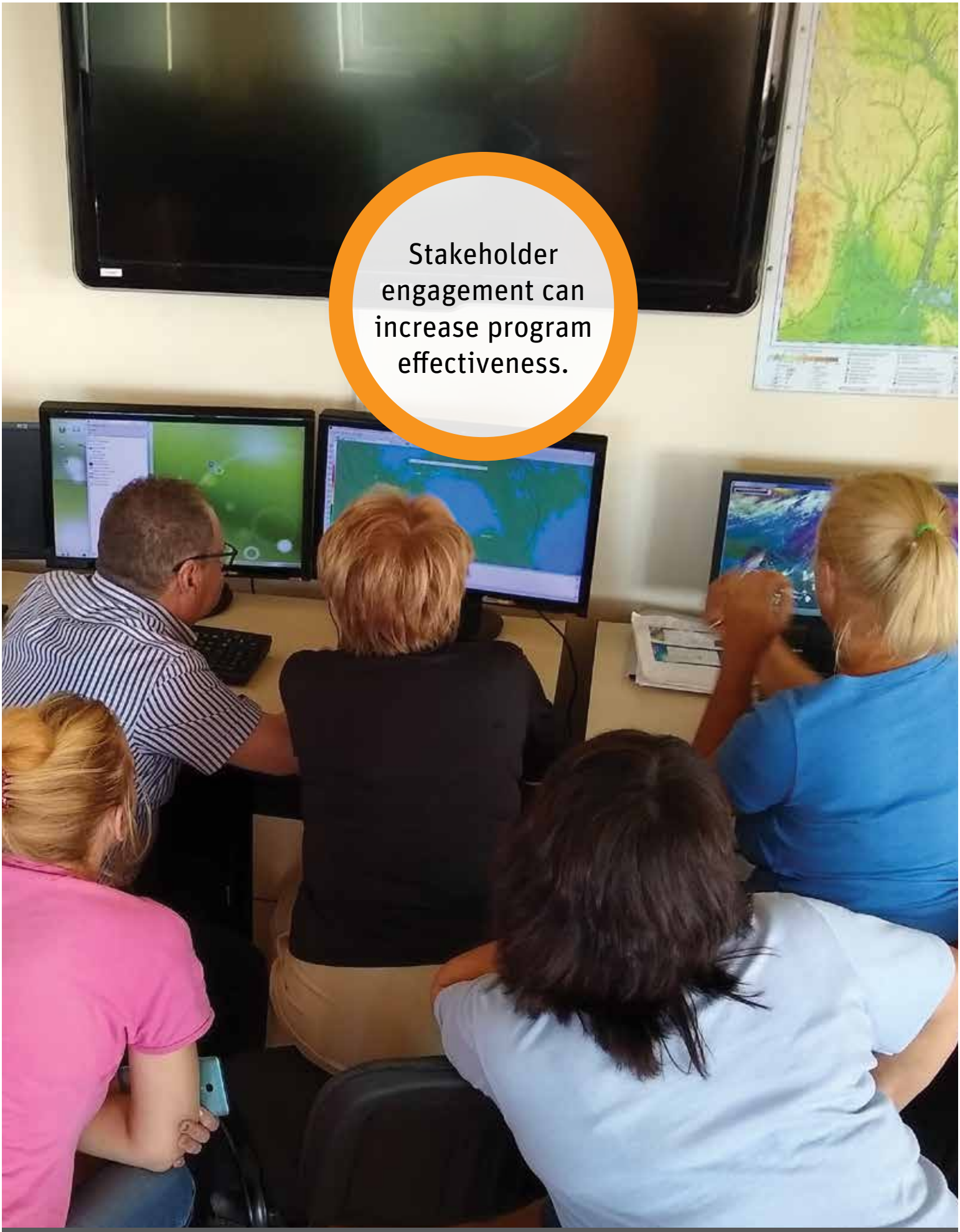
Box 3.5 California: Interlocking WRM, DRM, and Drought Plans

California has a set of interlocking plans dealing with flood and droughts that are led by the Department of Water Resources (DWR) and the Office of Emergency Services (OES), which serves as the DRM agency. The California Water Plan is the strategic plan for managing and developing water resources throughout the state. The Water Plan is mandated in the California Water Code, and DWR is required to update the plan every five years. The first Water Plan was developed in 1957 and focused on water supply development. The Water Plan has evolved over time, and the 2018 plan presents a broad and diverse portfolio of recommended actions that target the state's critical, systemic, and institutional water-related challenges, including floods and droughts.

The California Drought Contingency Plan was prepared in 2010 as mandated through an executive order of the Governor. DWR was the lead agency with support from more than 11 other agencies, including the OES. The objective is to minimize drought impacts by improving agency coordination; enhancing monitoring and early warning capabilities; preparing water shortage impact assessments; and developing preparedness, response, and recovery programs. The Plan identifies an integrated, regional approach to addressing drought, drought action levels, and appropriate agency responses as drought conditions change.

The California State Hazard Mitigation Plan provides an evaluation of California's hazards and sets the mitigation priorities, strategies, and actions. U.S. states are required to update their plans every five years to be eligible for disaster funding from the federal government. The Plan is an interagency effort led by OES, while DWR is an important contributor with respect to floods, dam safety, and droughts. OES also produces the State Emergency Management Plan, which communicates how the state government mobilizes and responds to emergencies and disasters, including floods, in coordination with partners in all levels of government, the private sector, non-profits, and community-based organizations.

Key Issue: Producing a high-quality strategic plan is a lengthy, expensive, and complex process. The production of the three California plans required significant agency staff and financial resources; this level of effort is challenging in low- and middle-income countries, and development agencies may consider prioritizing assistance for this critical activity.



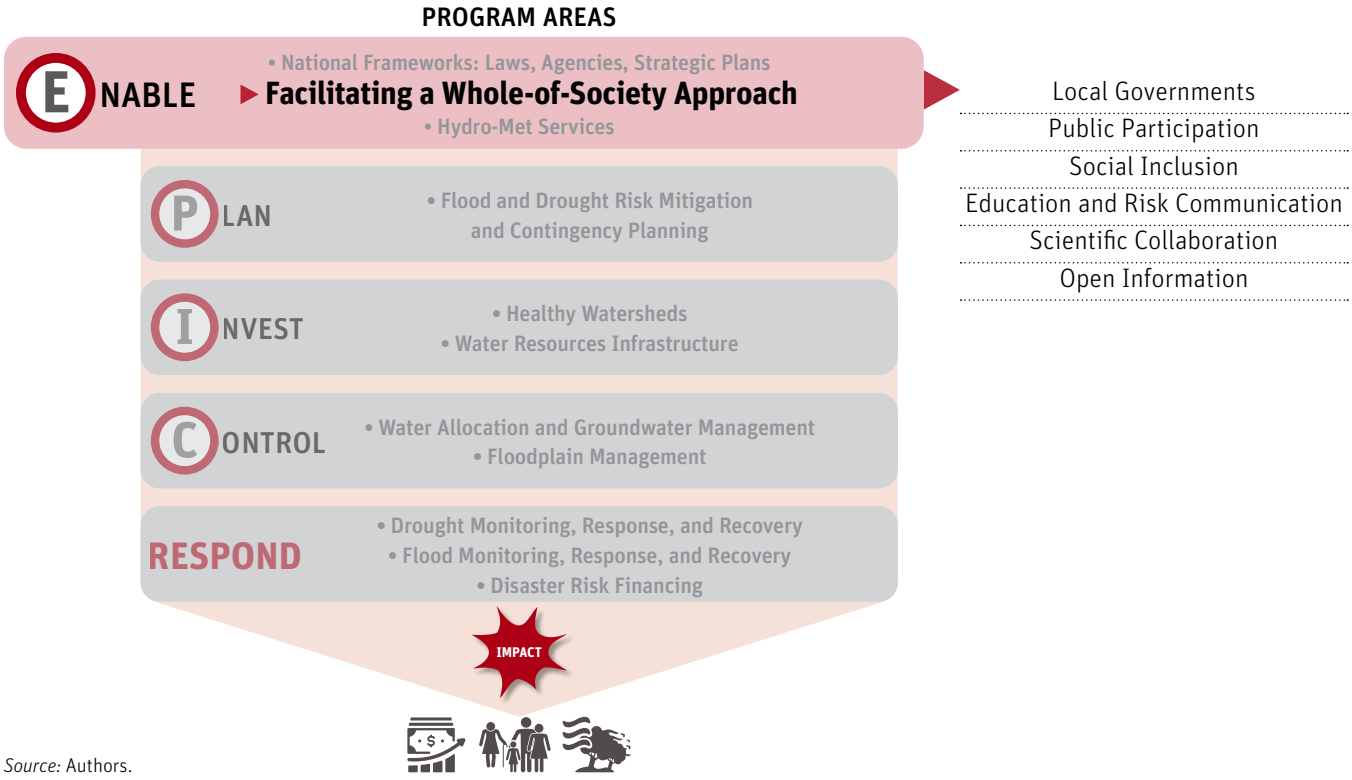
Training of radar specialists and forecasters from the State Hydrometeorological Service of Moldova. Photo: R. Keene, Enterprise Electronics Corporation (EEC)

4 Facilitating a Whole-of-Society Approach

Hydro-climatic risk management is a shared responsibility that requires a whole-of-society effort involving citizens, businesses, academia, farmers, civil society, the scientific community, and different levels of government. This chapter focuses on key principles and general actions that national agencies can take to facilitate this approach. As shown in Figure 4.1, a whole-of-society approach will have a cascading influence helping to better design and implement all subsequent programs. Most agencies have a technocratic culture as their mandates require a high level of technical expertise. This chapter calls for an evolution of agency organizational culture so that technical and social expertise are granted equal standing. In parallel, the agencies need to embody an adaptive governance ethos whereby they are dynamic and flexible, working with and responding to the needs of society to help address changing hydro-climatic risks (Cook and others 2011).

The programs that can help facilitate this whole-of-society approach are summarized below and then presented in the subsequent sections. The chapter concludes by highlighting

FIGURE 4.1 EPIC Response Framework and Whole-of-Society Approach



Source: Authors.

actions that agencies can take to help transform themselves into enablers of a whole-of-society approach. Here are the summaries of the six programs:

- **Local Governments.** Local governments are the indispensable associates of national agencies in hydro-climatic risk management. For every program in the EPIC Response Framework, local governments are key stakeholders, and for many programs, local governments play a critical role in program implementation. National agencies should work in partnership with local governments, and as appropriate assist them through capacity development, technical assistance, and grant funding. National agencies can also support legal and regulatory reforms that devolve an appropriate level of authority and responsibility to local governments.
- **Public Participation.** The aim is to encourage the public and stakeholders to have meaningful input not only on program design and implementation (such as participation in river basin planning or social protection programs), but also in the overall public policy process to monitor, evaluate, and improve the performance of the program.
- **Social Inclusion.** Socially excluded individuals or groups—which could consist of women, ethnic or religious minorities, the poor, the elderly, people with disabilities, and other groups—are typically most vulnerable to hydro-climatic risks. Agencies should first identify and understand who these individuals and groups are and then make targeted efforts to ensure that these people can benefit from hydro-climatic risk management programs.
- **Education and Risk Communication.** Ensuring broad understanding of flood and drought risks at all levels of society helps people to make better informed decisions to enhance their climate resilience, including ensuring public safety, protecting livelihoods, and safeguarding assets.
- **Scientific Collaboration.** In addition to collaborating across national agencies, governments also need to collaborate with the scientific community, tapping into both scientific organizations and private sector technical expertise. The goal should be to have both science-informed policy and policy-informed science. This also calls for more integrative and transdisciplinary hydro-climatic research that can feed into the policy making process.
- **Open Information.** Information that governments produce, collect, or pay for acts as the currency for hydro-climatic risk management. Examples include geographical information, data collected from remote sensing and monitoring networks, and reports from publicly funded research projects. Access to this information will help agencies perform their tasks and collaborate with each other, enhance scientific research, and enable citizens to better engage in the public policy process.

4.1 Local Governments

Local governments play pivotal roles in responding to flood and drought disasters (World Bank 2019). As highlighted in Chapter 12, local governments need to work in concert with national DRM agencies to respond to floods. They serve as one of many channels to warn about floods, to help evacuate residents, to ensure public safety, to provide relief to impacted people, and to help guide recovery efforts. Chapter 11 notes how local governments can work in concert with national agencies on drought issues; they can help disseminate information as the drought unfolds, implement emergency drought measures, administer drought assistance, and support social protection programs.

Local governments also play important roles in flood and drought risk mitigation (Gencer 2017). Chapter 10 on floodplain management highlights their central role in land use planning, building regulations, and preparing local flood mitigation plans. They also oversee urban water supply and drought contingency plans, as highlighted in Chapter 5. Local governments invest in localized water resources infrastructure to mitigate flood and drought hazards, including stormwater drainage systems, local flood control projects, and water supply and sanitation systems (typically through their water utilities).

The capacity and authority of local governments to contribute to hydro-climatic risk management varies considerably among, and sometimes within, countries. A 2017 survey examined the authorities, capacities, and responsibilities of 151 cities around the world with respect to disaster risk reduction. The results are summarized in Figure 4.2. The analysis indicates that most local governments are constrained in their abilities to independently undertake hydro-climatic mitigation actions.

4.2 Public Participation and Stakeholder Engagement

Agencies need to engage with the public and stakeholders to have effective programs for multiple reasons. First, the information that stakeholders bring to the program design

FIGURE 4.2 Local Government Authorities for Disaster Risk Reduction

Source: Gencer and UNISDR 2017.

is crucial to ensuring its success. Second, any program ultimately seeks to influence the decisions and actions of the impacted public and thus their understanding and acceptance are necessary. Third, public monitoring and participation generate incentives and pressure for the agency to continuously improve the program.

Ideally, public participation operationalizes a two-way communication avenue between agencies implementing programs and the communities they serve where both can inform, learn, and benefit from the process. The International Association for Public Participation (IAP2) has developed core principles that should be internalized by all agencies and incorporated into each program highlighted in this report.[13]

While there are numerous advantages associated with public participation and stakeholder engagement, if not properly structured and targeted, it may not be fully successful and can even be counterproductive. For example, a substandard public participation process can amplify privileged voices and underrepresent marginalized groups, resulting in so-called elite capture. To implement effective public participation and stakeholder engagement, agencies must make it a priority, generate a robust knowledge base of the circumstances and conflicting interests of the communities they serve, build capacity and train staff, develop targeted and inclusive participatory processes, and allocate the necessary time and budget.

Figure 4.3 provides an overview of the "public participation spectrum" developed by IAP2. The agencies will constantly need to make strategic decisions about what level of public participation is required for a specific situation. IAP2 has also developed a public participation toolbox which provides a list of principles and techniques for engaging with the public. Effectively calibrating the level of public engagement required and using the right techniques requires a collaboration between the agency's technical staff and its public engagement or social unit.

National agencies can help build more effective partnerships with local governments through various channels. They can provide technical assistance and grant funding to local governments to help build their capacities and abilities to manage hydro-climatic risks—this is a theme that is stressed throughout the report. They can help promote legal and regulatory changes that appropriately devolve more authority and responsibility to local governments. Finally, they can ensure that local governments are always engaged as key program stakeholders through dedicated outreach programs and special liaison officers.

[13] For an overview of these core principles, see the IAP2 website at https://www.iap2.org/page/pillars.

FIGURE 4.3 Public Participation Spectrum

INCREASING IMPACT ON THE DECISION

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities, and/or solutions.	To obtain public feedback on analysis, alternatives, and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision, including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Source: IAP2 2018.

4.3 Social Inclusion

In every country, certain groups face barriers that prevent them from fully participating in the nation's political, economic, and social life. These groups may, to varying degrees, be excluded from political processes, economic opportunities, and government services. Social inclusion has been defined as the process of improving the terms on which individuals and groups take part in society—improving the ability, opportunity, and dignity of disadvantaged people (World Bank 2020). Individuals or groups can be marginalized in terms of their socioeconomic status, age, gender, sexual orientation, race, ethnicity, religion, disability, or citizenship status, among other factors. Marginalized individuals and groups can be found in all countries across the development spectrum.

Social inclusion matters in and of itself, emanating from the principles of human rights and social justice. It also matters because social exclusion can carry substantial social, political, and economic costs. Exclusion often has a negative impact on human capital, preventing individuals from achieving their full potential at multiple levels, resulting in lowered education levels and impaired health. There is ample evidence that human capital is closely correlated with economic development (World Bank 2013). Moreover, excluding large groups of people can destabilize society, generating political unrest or civil strife.

Table 4.1 illustrates common inclusion issues associated with some of the key programs highlighted in this report. To simplify the presentation, while the term "marginalized individual/group" is used, the meaning of this term will depend on the specific context. The table highlights that marginalized groups are less likely to be engaged in planning processes, or to reap the benefits of healthy watershed programs or water resources infrastructure. Social exclusion can also exacerbate exposure to flood and drought hazards, for example in terms of the type and location of housing, limited access to flood and drought preparedness programs, and limited access to early warnings or resources to evacuate (SAMHSA 2017). Social exclusion may also increase vulnerability in terms of the extent to which individuals or communities can access coping mechanisms, such as finance, social assistance, and stable and high-paying jobs (World Bank forthcoming). Social exclusion may result not only in higher disaster risks and impacts to marginalized groups, but also in adverse long-term socioeconomic consequences (World Bank 2016a).

Every program in any country will almost always confront significant social inclusion issues that the relevant agency should address—even in more developed countries. A vivid

TABLE 4.1 Common Inclusion Issues in EPIC Response Framework Program Areas

Program Area	Illustrative Inclusion Issues for Marginalized Groups
Basin, coastal, water utility, and irrigation planning	■ Lack of organized stakeholder representation in planning process ■ Inadequate cultural or language outreach to ensure effective participation ■ Lack of representation in planning agency
Healthy watersheds and climate-smart agriculture	■ Lack of formal land tenure may restrict access to programs ■ Inability to meet cost-sharing requirements ■ Inadequate cultural or language outreach to ensure effective participation ■ Indigenous groups in remote locations may be excluded from programs ■ Lack of representation in natural resources management or agriculture agencies.
Water resources infrastructure (WRI)	■ Limitations to participation in the design of WRI ■ Benefits of WRI may be directed to more influential and affluent groups ■ Potentially negatively impacted through land acquisition or construction activity ■ Access to natural resources, such as fisheries, may be negatively affected by WRI
Water resources management	■ Water rights may be restricted due to lack to land tenure ■ Lack of representation in WRM organizations
Floodplain management	■ Potentially not included in flood risk maps due to lack of land tenure ■ Lack of resources to comply with floodplain regulations ■ Limitations to participation in local flood mitigation planning ■ Inability to access flood mitigation support programs ■ Lack of representation in DRM agencies and local governments
Drought monitoring, response, and recovery	■ Lack of income/livelihood to cope with drought shock ■ Difficulty accessing agro-hydro advisory services ■ Drought impacts may not be fully monitored and appreciated ■ May not receive emergency water supplies ■ May not be able to access agricultural or social protection programs ■ Lack of representation in drought committees
Flood monitoring, response, and recovery	■ Lack of income/livelihood to cope with shock ■ Difficulty in receiving flood advisories ■ May not be able to evacuate during floods or access emergency shelters ■ Needs may not be recognized in post-flood needs assessment ■ May not be able to access flood relief and recovery programs ■ Lack of representation in DRM agency and emergency response organizations

Source: Authors.

reminder of this can be seen in the impact Hurricane Katrina had on New Orleans in the United States in 2005. The hurricane had a disproportionate impact on low-income and minority communities, who also struggled the most to recover (Shapiro 2005). Moreover, about 400 million indigenous people live in territories that are highly vulnerable to the impacts of climate change (UNESCO 2015)—yet they are normally underrepresented in decision-making processes and underserved by hydro-climatic risk management programs.

Agencies need to develop specific methodologies suited to the respective programs to tackle social equity and inclusion issues. Although it unrealistic to change fundamental power dynamics or political realities through specific programs, it is important to recognize that they exist and to devise strategies to promote inclusion and equity. Fundamentally, agencies should develop their organizational culture, policies, and program design, as well as their interaction with the communities they serve, using an inclusion lens.

As a starting point, it is important to identify the different groups of people impacted by a program and to assess their socially differentiated hydro-climatic vulnerabilities and exposures. Incorporating a deeper understanding of the unique and diverse needs of a population, including its demographics, economic prosperity, culture, community networks, access to resources, experience interacting with government, and overall vulnerability, will facilitate programs' service delivery and design. This requires the programs to put in place innovative mechanisms and

analysis methodologies, since many of the obstacles faced by marginalized groups might not be captured by standard assessments. For example, due to the higher levels of vulnerability experienced by poor households, the relative benefits of risk reduction are likely to be higher for poorer than for richer households. This is also true within households, where women, children, and the elderly can be more vulnerable to risks. Moreover, marginalized groups can also enhance a program service delivery. For example, following the 2004 Tsunami in the Indian Ocean and Hurricane Mitch in Central America in 1998, women played a key role in the rehabilitation phase, carrying out such life-saving tasks as providing food assistance, clearing roads, and organizing targeted relief efforts at the community level.

It is also important to assess dynamic human responses to risks. Risk assessments often focus on how different groups are impacted by certain changes; however, people often do not simply suffer these impacts, but will also respond to them. For example, persistent flooding or droughts affecting marginalized (or other) groups may result in rural to urban migration or the exacerbation of tensions and conflicts. In addition, accelerating changes in society (such as demographic trends or technological advances) affect the ways in which individuals and groups perceive risks, and how they organize, prepare for, and respond to those risks. Taking these factors into account may also help inform program design and implementation.

Social inclusion has an important public participation dimension. Achieving inclusiveness requires that the groups of people concerned are given culturally appropriate opportunities to express what they need and how they can govern, and that they are involved in the identification of problems and potential solutions.

4.4 Flood and Drought Education and Risk Communication

Each agency should strive to help educate the general public and promote professional development. Educational programs increase public awareness and knowledge about sector issues. In doing so, they provide the public and professionals with the necessary evidence to make informed decisions and to take responsible action. Since education has strong public good characteristics, the agency should use part of its budget and professional expertise for educational programs. These can be delivered directly by the agency or in partnership with professional organizations, universities, schools, civil society, and businesses. The agency can provide grants or technical assistance to its partner organizations to further support educational activities.

This report has highlighted how different agencies have different responsibilities within the EPIC Response Framework and how their responsibilities extend beyond flood and drought risk management. Each agency should develop standalone educational initiatives related to hydro-climatic risks in the context of climate change. For example, the agriculture agency should highlight how climate-smart agriculture can help reduce flood and drought risks, as well as providing guidance on good practices. In a similar manner, the WRM and DRM agencies should focus on how educational activities address flood and drought risks.

Universities and professional organizations can also play leading roles. For example, a consortium of European universities offers a master's program on flood risk management that integrates science, engineering, and socioeconomic disciplines.[14] Ideally, a country should strive to have a group of professionals with expertise in integrated flood risk management and integrated drought risk management.

Risk communication is often distinguished from emergency or crisis communication. Risk communication needs to be done before a hazardous event occurs to inform the public about their potential exposure and to encourage them to engage in precautionary measures to avoid, reduce, and transfer these risks. Emergency communication is then used to inform people once the event is imminent or underway. After the emergency or crisis, risk communication comes into play again to help present what occurred on the basis of lessons learned (OECD 2016a). Drought and flood emergency communication is further discussed in Chapters 11 and 12.

Communicating hydro-climatic risk, especially in the context of a changing climate, is challenging. Estimating risks embodies many complex concepts, including at its core the probabilistic assessment of different hazard levels—which is typically beyond the level of most non-experts to fully grasp and act upon. Research on risk communication has shown that risk is best understood when the communication is simple, tangible, relevant, and personal.[15] Risk should be communicated in a way that is not only clear and quantifiable, but also that leads people to recognize how they could be personally affected and that motivates them to act.

[14] For more information about this flood risk master's program, see the following website: https://www.floodriskmaster.org/.
[15] For more information about communicating flood risk, see First Street Foundation's website: https://firststreet.org/flood-lab/research/communicating-flood-risk/.

Flood and drought risk communication share similar principles, but also significant differences. Floods are generally rapid onset disasters, offering a clear division between risk communication and emergency procedures. Droughts are slow onset disasters that evolve over time in an often-unpredictable fashion, thus blurring the distinction between risk communication and emergency communication. Drought risks can and should be communicated during non-drought periods, often through general education programs mentioned earlier. However, as a drought unfolds, it is necessary to provide event-specific information to potentially affected groups so they can prepare for potential impacts.

4.5 Scientific Collaboration

The scientific complexity of hydro-climatic risk management is enormous. The expertise to address this complexity, for both social and natural sciences, spans a broad range of organizations, including national agencies, research institutes, international organizations, and the private sector. The traditional model of a "supplier" of scientific information, such as a research institute, and a "user" of the information, such as a national agency, is outdated. There is a growing recognition of the need to have both science-informed policy and policy-informed science to deal with climate adaptation (Daniels and others 2020). In other words, scientific organizations and national agencies need to effectively collaborate to generate effective science applied to flood and drought risk management.

The structure of the EPIC Response Framework, with multiple program areas and cascading impacts, underscores the importance of a transdisciplinary approach. An intervention in one program area of the Framework may have unexpected impacts on other efforts to reduce hydro-climatic risks. Box 1.2 highlighted how flood and drought disaster reduction measures can physically interact. These measures can also interact through social, economic, and political channels, often resulting in unexpected outcomes. Undertaking transdisciplinary research to better understand how physical and social factors interact can help to inform flood and drought management programs (Lemos and others 2019).

Climate uncertainty is also driving the need for more transdisciplinary research to stay on top of a constantly changing environment. National agency monitoring programs can help provide data on a changing climate with standard parameters such as weather, hydrology, and land use. However, understanding the broader impacts of a changing climate and how society and economies are addressing these changes is vital to inform flood and drought programs. Scientific and research organizations are well suited to act as external monitors of climate change impacts, providing invaluable information to national agencies.

Collaboration between national agencies and the research community to generate science-informed policy and policy-informed science is not an easy task. A recent framework proposed by the Stockholm Environment Institute provides some general guidelines. Key elements include: (1) improving the way participants work together by designing co-exploration and co-production processes that bring together different fields across the science-society interface; (2) working together to understand or define decision-relevant needs of the agency; and (3) increasing the capacity for collaboration by building strong networks (Daniels and others 2020).

4.6 Open Data

We are living in the "Information Age" where the access and control of information is the defining characteristic of our time. This Age fosters disruptive technologies and new ways of doing business that can both be chaotic and transforming. The national agencies involved in hydro-climatic risk management, including WRM, DRM, hydro-met, agriculture, and natural resources management agencies, produce large amounts of information. This information can take various forms, such as on-ground and space-based monitoring data, GIS-based maps, model codes, and reports. Making this information freely available to other agencies and the public can turbocharge advances in flood and drought management through three pathways:[16]

First, since the different programs in the Framework are interrelated, sharing information will allow agencies to do their work better and collaborate more productively in a joined-up manner. As an example, information on watershed health collected by the natural resources agency serves as a critical input to river basin planning exercises led by the WRM agency. These types of linkages exist throughout all programs highlighted in this report.

Second, open data produces a better-informed public that can engage more effectively with national agencies, resulting in more effective programs. Since information is power, open data can be used to hold national governments and their agencies more accountable and increase transparency. Open data can also help different groups make better informed

[16] The concepts of "data" and "information" are often used interchangeably, and refer to any content, whatever its medium. Open data usually requires that information be machine readable, for example reports that are digitized and suitable for computer scanning for content.

risk management decisions, ideally complemented with education and risk communication programs.

Finally, open data can help drive innovation, economic growth, and environmental sustainability. As highlighted in the section on scientific collaboration, much of the expertise for managing flood and drought risks and adapting to a changing climate exists outside of national agencies. Providing these scientific and research organizations with information will enable them to undertake more accurate studies and propose better solutions. As a corollary, publicly-funded research should also be brought into the public domain, and some private companies may also find it beneficial to publicly share information. Open data will also help the private sector to develop products that can help to reduce hydro-climatic risks. As an example, the insurance industry needs extensive information—much of it collected by government—to formulate and properly price flood or drought insurance.

The generation and access to hydro-climatic information is profoundly influenced by new technologies. Digital technologies provide the opportunity for collecting and leveraging huge amounts of data at minimal costs. New disruptive technologies also have an important role in generating and making information accessible (such as through SMS and interactive voice response system (IVRS)) and enabling a feedback loop between citizens and agencies. For example, citizens can utilize a phone application to share information or pictures documenting the situation after a flood event, helping to inform impact assessments that guide relief and recovery responses.

Creating an open data environment has many challenges. National agencies often see their information as proprietary, using it to expand their influence, supplement their budgets, or to avoid accountability. There are complex issues associated with ensuring data quality and appropriate levels of information classification. Issues of inter-operability between different databases and geographic information systems (GIS) between agencies, and even within agencies, are common. Standardization and strong data management practices enable a more functional environment for data sharing.

Resolving these challenges requires action at multiple levels, the most important of which is a national data sharing policy or law that covers all sectors. National agencies need to develop clear protocols for information classification—what can be shared with whom and when—while adhering to the general principle of "open by design and default". Finally, technical issues such as the inter-operability of databases and GIS systems between agencies, and public access portals need to be worked out, sometimes guided by a lead national agency. Each country will have its own evolutionary path towards a more open data environment, but clearly faster is better.

4.7 National Sector Frameworks and Key Agency Actions

The general principles and activities presented in previous sections are applicable to programs in the EPIC Response Framework and key implementing agencies, including WRM, DRM, Hydro-met, agriculture, natural resources management and finance. Linkages to national sector frameworks and important agency actions are presented below:

- **Highlight the importance of the core social dimensions in sector laws.** The laws governing the different programs in the EPIC Response Framework should highlight the importance of key elements for facilitating a whole-of-society approach, including public participation, social inclusion, education, communication, scientific collaboration, and open data. These elements should also be incorporated into the national strategic planning exercises for WRM, DRM, and Drought. National Strategic Plans provide opportunities to analyze how effectively these elements are being implemented and to identify actions for improvement.
- **National Open Data Law or Policy.** Since open data is a cross-government issue, there should ideally be a general open data law or policy providing general principles for improving public access to information. The law or policy should designate a lead agency or organization, for example a science agency, to provide guidelines to help sectoral agencies develop their own specific open data programs. The lead agency could also help establish cross-agency information platforms by creating standards for GIS, databases, and interagency data exchanges.
- **Establish and maintain a public engagement or social unit.** There should be a dedicated unit in the agency in the form of a department or office that is responsible for ensuring that the core social dimensions of local government liaison, public participation, social inclusion, education, and communication are mainstreamed into the agency operations. The unit should be sufficiently staffed with social and communication experts to meet the specific agency needs. Ideally, the unit should have staff from marginalized groups that the agency needs to involve, for example indigenous groups, ethnic minorities, or women. The agency should also strive to have

representation from marginalized groups throughout the organization through an equal employment opportunity program. The agency might also benefit from including a community engagement help desk that citizens can have access to at any time to obtain information and to voice suggestions or grievances.

- **Maintain a comprehensive internal training program.** The technical units within an agency need to work collaboratively with the public engagement or social unit, and thus will need training with respect to social engagement. In many cases, it will be technical staffers who are directly interacting with the public and other stakeholders, so they need to be well equipped to manage the task.
- **Develop social guidelines for every program.** There should be specific guidelines related to public participation and social inclusion that are tailored to the needs of each program. The guidelines should provide guidance on which groups to interact with and how, and establish clear points for social engagement throughout the program.
- **Have an education support plan.** The agency should clearly identify its priorities for public and professional education and how it will facilitate these efforts, for example direct delivery, partnerships, or funding. Education activities related to climate adaptation and hydro-climatic risk management should be prioritized. Potential partners include professional associations, universities and research institutes, schools, and civil society.
- **Maintain a scientific advisory committee.** The agency should assemble a group of high profile and influential experts from all relevant social and natural science disciplines into a scientific advisory committee. The committee should interact collaboratively with the agency to help identify priority policy-relevant research and to seek advice on key issues confronting the agency. Ideally, the agency would reserve part of its budget for funding the most important research.
- **Maintain an information unit.** As part of the agency's overall information technology (IT) support, there should be a unit specifically for promoting open data, for interacting with other agencies, and for establishing cross-agency data platforms as appropriate. Staff in this unit not only need to understand the IT issues, but also how the data are used and by whom.

4.8 Key Resources

Local Governments

Gencer, Ebru A., and UNISDR (United Nations Office for Disaster Risk Reduction). 2017. *Local Government Powers for Disaster Risk Reduction: A Study on Local-level Authority and Capacity for Resilience*. UNISDR.

GFDRR (Global Facility for Disaster Reduction and Recovery). 2019. *Guide to Engaging Local Actors in Disaster Recovery Frameworks*. Washington, DC: World Bank.

ICLEI (Local Governments for Sustainability). 2008. *Local Government and Integrated Water Resources Management (IWRM): Parts I-IV*. Freiburg: ICLEI.

Public participation and stakeholder engagement

EPA (U.S. Environmental Protection Agency). 2018. "Public Participation Guide in Multiple Languages." February 22, 2018. https://www.epa.gov/international-cooperation/public-participation-guide.

FEMA (Federal Emergency Management Agency). 2011. *A Whole Community Approach to Emergency Management: Principles, Themes, and Pathways for Action*. Washington, DC: FEMA.

GWP (Global Water Partnership). 2017. "IWRM Toolbox: C5 Communication." March 31, 2017.

IAP2 (International Association of Public Participation). n.d. "Advancing the practice of public participation."

Social inclusion

Erman, Alvina, Sophie Anne De Vries Robbe, Stephan Fabian Thies, Kayenat Kabir, and Mirai Maruo. 2021. Gender Dimensions of Disaster Risk and Resilience: Existing Evidence. World Bank,

IFRC (International Federation of Red Cross and Red Crescent Societies). 2012. *Community Early Warning Systems: Guiding Principles*. Geneva: IFRC.

IRC (International Water and Sanitation Centre). 2019. *Quick Scan of Socially Inclusive Integrated Water Resources Management*. IRC: The Hague.

Karen Meijer, Caroline Sullivan, Judith Blaauw, Femke Schasfoort, Bouke Ottow, and Diana Morales, 2019. "Social Inclusiveness in Floods and Droughts: How Social Variations in Impacts and Responses Can Be Taken into Account." Working Paper, Deltares, Delft.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2015. "Reinforcing the Resilience of Indigenous Peoples and Sharing Knowledge to Address Climate Change." November 26, 2015.

Scientific Collaboration

Daniels, Elizabeth, Sukaina Bharwani, Åsa Gerger Swartling, Gregor Vulturius, Karen Brandon. 2020. "Refocusing the climate services lens: Introducing a framework for co-designing "transdisciplinary knowledge integration processes" to build climate resilience." *Climate Services* 19 (100181).

Risk Communication

OECD (Organisation for Economic Co-operation and Development). 2016. *Trends in Risk Communication Policies and Practices*. OECD Reviews of Risk Management Policies. Paris: OECD Publishing.

Shaw, Chris and Adam Corner. 2014. *Communicating Drought Risk in A Changing Climate*. Oxford: Climate Outreach.

WMO (World Meteorological Organization) and GWP CEE (Global Water Partnership Central and Eastern Europe). 2019. *How to Communicate Drought: A guide by the Integrated Drought Management Programme in Central and Eastern Europe, 2019*. Geneva: WMO.

Open Data

EU (European Commission). 2011. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. "Open data: An engine for innovation, growth and transparent governance."

EU (European Commission). 2019. "EU Directive 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information." OJ L 172, 26.6.2019, p. 56.

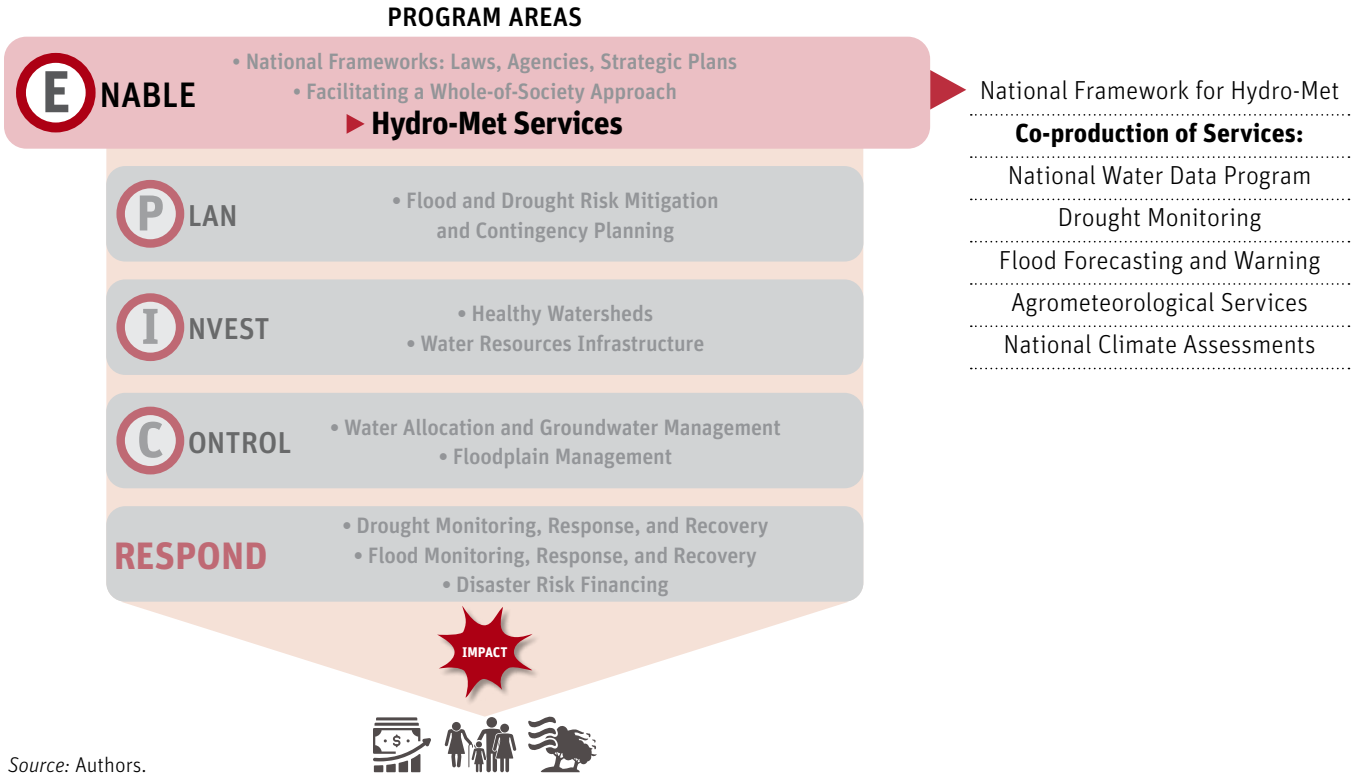
GSA (U.S. General Services Administration). n.d. "Federal Crowdsourcing and Citizen Science Toolkit."

World Bank. 2019. "Open Government Data Toolkit." Washington, DC: World Bank.

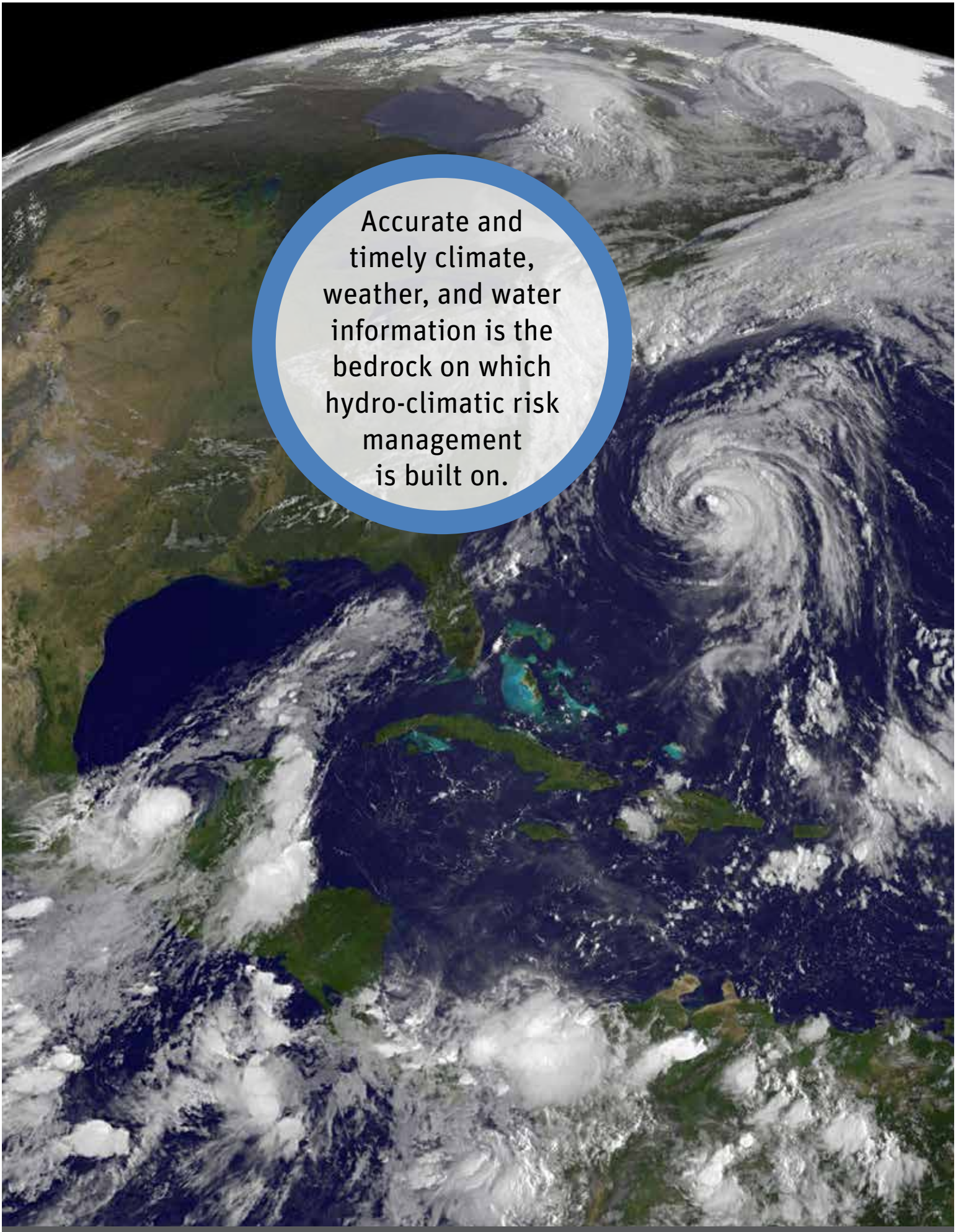
5 Hydrological and Meteorological Services

Information related to weather, water, and climate is fundamental to managing hydro-climatic risks for every program in the EPIC Response Framework. As shown in Figure 5.1, the hydro-met services program area sits near the top of the Framework as hydro-met information provides the most basic parameters for all forms of water-related planning, water infrastructure design and operation, and water management. Hydro-met information helps to delineate floodplains to better enable floodplain management. Monitoring and forecasting of floods drive emergency management responses. Drought forecasting enables drought managers to zero in on potentially affected areas to better assess impacts and identify vulnerable populations. Hydro-met information also serves to inform flood and drought recovery programs, including the structuring of insurance programs and other disaster risk financing programs. The quality of hydro-met services is of such critical importance to a country's hydro-climatic risk management that it should feature front and center in each of the National Strategic Plans discussed in Chapter 3: WRM, DRM, and Drought.

FIGURE 5.1 Hydro-met Services in the EPIC Response Framework



Source: Authors.



Satellite image of Atlantic storms Photo: NASA

This chapter starts off with a description of the core services related to weather, hydrology, and climate. Then the national framework for meteorological services (NMS) and national hydrological services (NHS) are discussed. In some countries, the NMS and NHS are combined, and in other countries they operate as separate agencies; this report therefore adopts the convention "NMS/NHS" to account for both possibilities. The next section looks at the need of NMS/NHS to work with other agencies in a joined-up manner in the co-production of services. The six key topics in the chapter are:

- **National Sector Framework and Evolution of NMS/NHS.** The legal framework for NMS/NHS should ensure that the agency can serve as a facilitator, as opposed to a monopoly provider, of weather, water, and climate services. The NMS/NHS needs to tap into the global "Weather Enterprise",[17] a broader network of global and regional centers, the weather industry, and other specialized agencies and research organizations to deliver the best possible services for the country. In the event that the NMS and NHS are separate agencies, the legal framework also needs to ensure that two agencies can collaborate in a seamless manner.
- **National Water Data Program.** The NHS usually does not have a monopoly on water data as surface water, groundwater, and water quality data are often collected and stored by different national agencies. Ensuring that all high-quality water data are freely available and accessible to all users, ideally through a single water data platform, produces value for every program in the Framework.
- **Co-production of Drought Monitoring and Impact Assessment Services.** As highlighted in Chapter 11, the NMS/NHS should play a pivotal role in drought monitoring and impact assessment as part of a collaboration nexus between NMS/NHS, WRM, Agriculture, and DRM agencies.
- **Co-production of Flood Forecast and Warning Services.** As highlighted in Chapter 12, the NMS/NHS has a critical role to play in flood forecasting and warning as part of a collaboration nexus between NMS/NHS, WRM, and DRM agencies.
- **Co-production of Agrometeorological Advisory Services.** Farmers are particularly prone to be affected by weather fluctuations and extreme events. The NMS/NHS can team up with the agriculture agency to provide weather and seasonal forecasts in a manner that is accessible and actionable by farmers.
- **Co-production of the National Climate Assessment (NCA).** The NMS/NHS typically plays a key role in producing a periodic NCA, which provides an overview of existing and potential future climate scenarios and their social, economic, and environmental impacts. This assessment helps to guide adaptation actions across multiple sectors and reduce hydro-climatic risks.

5.1 Hydro-met Services

General Description[18]

Weather Services involve the provision of routine weather forecasts provided by both public and private weather services. The NMS is normally designated as the national authority with the exclusive competence to issue warnings of hazardous weather and increasingly for warnings of the impact of hazardous weather. Weather services include: (1) maintaining a national meteorological observational network for weather and climate applications; (2) sharing national meteorological data with other WMO members through the Global Telecommunications System (GTS); (3) providing very short-, short-, medium-, and long-range forecasts of various hazards, including heavy rainfall or snow, hail, excessive heat or cold, storm surges, high winds, high waves, and bush and forest fires; (4) preparing and issuing warnings related to high impact weather; (5) providing warnings of other phenomena, depending on national requirements, such as tsunamis and other seismic hazards, landslides, avalanches, and space weather; and (6) contributing to a multi-hazard impact-based early warning system.

The provision of national services depends in large measure on international data sharing and on WMO global production centers and regional consortia for numerical weather prediction products. Some national services develop their own numerical prediction capabilities or work with neighboring countries to do so. However, the current trend is to depend on large centers to provide probabilistic forecast products with NMS/NHSs focusing more on scaling these products to their own specific needs.

Co-production of services with the private sector is emerging as a new trend to try to maximize the investment of both the public and private sectors and to harness their differentiated skills to provide services to the public and to private clients.

Hydrological services involve the provision of information on the hydrological cycle and the status and trends of

[17] For more information on the weather enterprise, see the following: Thorpe, Alan, and David Rogers. 2018. "The Future of the Global Weather Enterprise: Opportunities and Risks." *Bulletin of the American Meteorological Society* 99 (10). https://doi.org/10.1175/BAMS-D-17-0194.1.

[18] A detailed description of weather, hydrological, and climate services can be found in Rogers and Tsirkunov (2013), Rogers and others (2019), and various World Meteorological Organization publications.

a country's water resources, including surface water, groundwater, and water quality. Hydrological services include: (1) operating and maintaining a hydrological observational network to monitor major and some smaller rivers; (2) taking and integrating hydrological observations from other parties; (3) maintaining an interoperable data management system; (4) carrying out water level and flow monitoring; (5) providing short-term low flow forecasts, flood forecasts, and hydrological data products for the design and operation of water supply structures; and (6) providing seasonal stream flow outlooks and specialized hydrological products.

Climate Services are broadly defined as information and products that enhance users' knowledge and understanding about the impacts of climate on their decisions and actions. They go beyond the standard meteorological and hydrological services and provide products that meet the specific requirements of end users. Some examples of climate services include: (1) past climate information, data stewardship and rescue, reanalysis, and historical climate summaries; (2) present climate observations, monitoring, climate summaries, reports, and studies to estimate the type, range, and likelihood of variations of climate variables relevant for users such as farmers, water managers, and emergency responders; and (3) future climate forecasts and projections of climate conditions for use in mitigation, planning, and adaptation.

While the NMS/NHS may be responsible for climate forecasts, the generation of climate services is often a multi-disciplinary exercise requiring the close partnership and collaboration with other relevant agencies, users, and often research institutes. The latter are frequently responsible for the generation of past climate information and climate change forecasts. Climate services are a relatively new area but are a key component of hydro-climatic risk management, particularly under the conditions of a changing climate.

Space-Based Observations, such as remote sensing data based on satellite observations, have opened new frontiers in hydro-met monitoring. They allow for convenient and accurate measurements of parameters such as evapotranspiration, soil moisture, and net primary productivity. This information is critical to understanding land-atmosphere interactions and helps to improve weather, climate, and hydrological services. Although the space-based observations are derived from private or public satellites, the NMS/NHS and other parties can use this information to help them improve the quality of their services.

Box 5.1 Hydro-met-Related Services in The Philippines

Situated in the typhoon belt, the Philippines is usually hit by around 20 tropical cyclones every year as well as monsoons that cause floods and landslides. The country is also affected by earthquakes, tsunamis, volcanic eruptions, and other natural hazards. This vulnerability to natural hazards has put hydro-met services at the forefront of DRM activities.

The main government hydro-met service providers in the Philippines are the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and the Nationwide Operational Assessment of Hazard (NOAH) Center, with important roles also being played by the Mines and Geosciences Bureau (MGB) and the Bureau of Research and Standards of the Department of Public Works and Highways (DPWH-BRS).

PAGASA was established in 1972 and depends on the Department of Science and Technology (DOST). It is represented on the National Disaster Risk Reduction and Management Council (NDRRMC). PAGASA's three main mandates are: (1) to provide data and information on atmospheric, astronomical, and other weather-related phenomena to better protect society from the impacts of natural hazards, including floods, landslides, and storm surges as well climate change; (2) to inform decision making on DRM, climate adaptation, and IWRM; and (3) to ensure compliance with related international obligations (for instance, to the WMO).

The NOAH Center, which is managed by the University of the Philippines, is a national scientific research center tasked with generating science-based information for the purpose of climate change action and disaster risk reduction by providing timely, reliable, and readily accessible data and information, such as hazard risk maps, as a basis for action by warning and response agencies against possible disasters that may occur from floods, typhoons, and other natural hazards.

Key Issue: Over the last decade, PAGASA's role as NMS/NHS was strengthened significantly. However, there also have been ups and downs. Significant increases in government funding and in support from development agencies were needed to address issues around budget, operations and maintenance, and communication and dissemination.

National Sector Framework for Hydro-met Services

Meteorological services are often governed by a national meteorological law. If there is a combined NMS/NHS, then the law also includes hydrological topics. In other cases, hydrological issues are typically addressed through the water resources law. In cases where there are separate meteorological and hydrological laws, it is extremely important to make sure that these two legal and regulatory regimes are seamlessly integrated.

The basic legal and regulatory framework for hydro-met services has been described in detail in a 2013 World Bank report entitled "Weather and Climate Resilience" (Rogers and Tsirkunov 2013). Some of the key topics to be addressed include defining a clear mandate, including all relevant actors beyond the NMS/NHS, open data principles, revenue generation, research and development, and authorization to arrange for joint monitoring and forecasting of meteorological and hydrological disasters among government agencies.

Hydro-met laws need to evolve quickly to adjust to changing technology and to meet the increasing demands from users, specifically from the WRM, DRM, and Drought Communities. Often there is an overemphasis on NMS/NHS functions with insufficient attention paid to the broader need of providing weather and hydrological services. This can result in obligations and regulations imposed on others and insufficient accountability for what the NMS/NHS should produce. Some of the critical policy issues that should be addressed in the legal and regulatory framework include the following:

- **Ensuring Public–Private Partnerships.** Creating opportunities for the private sector should be addressed in national laws and policies. A 2019 World Bank report, "The Power of Partnership", highlights the benefits of policies that promote private sector services in hydro-met services, resulting in a win-win situation for both private and public sector clients (World Bank 2019a). Unless carefully crafted, legislation may inadvertently inhibit public and private partnerships by reinforcing the monopoly of government institutions, often to the detriment of users of these services.
- **Providing adequate funding.** Adequate public funding for public meteorological and hydrological services is an ongoing issue in most developing countries. This continues to limit the public sector in meeting the most basic needs of the government and society for weather, water, and climate information. In part, this occurs because the various potential beneficiaries of hydro-met services—national agencies, the private sector, and the general public—do not coalesce into a strong coalition that can demand better services and adequate government funding. One of the objectives of this report is to show the broad and indisputable dependence of effective hydro-climatic risk management on hydro-met information. Box 5.2 provides an overview of the economic value of hydro-met investments.
- **Ensuring Open Data.** NMS/NHS agencies are sometimes antagonistic to open data policies and an inclusive, competitive environment for weather and hydrological services. This apprehension is often driven by their precarious financial condition. They may perceive legislation and regulation as a blunt instrument to protect their interests, rather than as a tool to help the country to address its weather and water-related challenges. This impediment is best addressed by ensuring a high-level commitment from the national government. The national strategic planning process for WRM, DRM, and drought discussed in Chapter 3 can help provide a platform to advocate for sustainable funding to help deliver essential hydro-met services.
- **Collaboration with global initiatives.** Agreements brokered by the World Meteorological Organization (WMO) govern the international exchange of data and information, which is essential to provide high-quality national meteorological and hydrological forecasts and warnings. However, these agreements are not easily enforceable, and countries are not necessarily fully compliant with their obligations or at best meet only the minimum requirements. This undermines the ability of countries to meet their own needs for public weather, water, and climate services.

Generic Evolution

The World Bank is in the process of developing a detailed NMS/NHS governance model which has been adapted for this report and presented in Table 5.1. This table is more comprehensive than the generic evolution table presented for other programs in that it includes financing and management dimensions. Given the importance of hydro-met services in the EPIC Response Framework, it is important to ensure they are functioning at the highest possible levels.

Hydrometric probe to detect the height of the river and prevent floods. Photo: ChiccoDodiFC

Box 5.2 Economic Value of Hydro-met Services[a]

Understanding the full value of hydro-met services helps to focus public attention on the vital role that they play, as well as ensuring adequate government funding. The benefits of hydro-met services extend beyond the traditional financial bottom line (the cash flows) to a full suite of social, environmental, and economic benefits. Economists have identified a range of potential benefits, including the avoidance of damage, reduced mortality and morbidity, water and energy savings, and increased agricultural production.

It has long been understood that hydro-met services provide significant benefits relative to their costs. However, the value of these benefits has been harder to quantify. Since 1950, economists have undertaken a number of studies on this subject, resulting in a wide range of benefit-cost ratios. The results depend on the specifics of each country, the valuation methodology (such as non-market valuation, economic modelling, avoided cost assessment, benefit transfer), the services assessed (whether the whole of hydro-met services or a specific service), and the beneficiaries considered (individuals, households, government, or a variety of sectors). Based upon these studies, a generic benefit-cost ratio of 10-1 is often used to help highlight the importance of hydro-met services.

[a] The following information was drawn from (World Bank 2013), (Jha and Stanton-Geddes 2013), and (WMO, World Bank, and USAID 2015).

Key Issue: Investment in hydro-met systems by themselves however do not create this value. In many countries there have been significant investments in expanding hydrological and meteorological monitoring networks, often supported by development agencies in an uncoordinated manner, but the NMS/NHS may struggle to maintain this infrastructure. Equally important, the NMS/NHS needs to have dedicated professional staff who are appropriately compensated. Finally, the NMS/NHS needs to produce services that generate benefits for users. When these conditions are in place, investments in hydro-met services generate enormous value and should be a priority for governments.

TABLE 5.1 The NMS/NHS Governance Generic Evolution: Legal Framework, Financing, and Management

Nascent	Engaged	Capable	Effective	Advanced
Legal framework: no legal framework, entity operates within the overall regulations of government's administrative structure. **Financing:** NMS/NHS does not have own budget. No annual budget reviews. No explicit provision for operations and maintenance (O&M). Budget is allocated primarily for staff costs. **Management:** Head of the service has little autonomy in decision making concerning policy, strategy, and human resources; decisions are made at ministry level.	**Legal framework:** The government and its NMS/NHS recognize the need for a legal framework and regulations, which include defining the roles and responsibilities of the NMS/NHS. **Financing:** Government reviews allocation and method of financing the NMS/NHS. It may, for example, give more autonomy by changing the status from department to agency. **Management:** Authority delegated to the head of NMS/NHS for policy, strategy, and human resources.	**Legal framework:** The NMS/NHS has started the process of creating a meteorological law which may include hydrology. The latter may also be included within a Water Law. It may also have established regulations particularly for the provision of aeronautical meteorological services. **Financing:** Budget is allocated to NMS/NHS by government. NMS/NHS manages its own financial allocation but remains a government department with little or no flexibility. NMS/NHS has plans for or has initiated establishing an asset register. **Management:** In addition to the inclusions in the two previous categories, NMS/NHS has staff hiring authority with a financial and staff allocation ceiling.	**Legal framework:** A meteorological law has been adopted, which mandates the responsibilities of NMS/NHS and may define the roles and responsibilities of other actors and provide a legal framework for the production, exchange, and sharing of data related to the provision of meteorological services. Often the law may be restrictive and promotes a monopolistic position of the public sector in the provision of services. The law should define the meteorological authority and regulator for provision of meteorological services, which may or may not be the NMS/NHS. The law should cover the provision of public, private, and club goods (WMO 2015). Regulations related to the provision of services should follow from the Law. **Financing:** Budget allocation is sufficient to cover operating expenses (OPEX). NMS/NHS has a high degree of autonomy from its parent ministry in budget decisions. Cost recovery for services provided by the NMS/NHS to other government departments and agencies is defined. The NMS/NHS uses an asset register to depreciate capital equipment. **Management:** Performance targets are negotiated and agreed with government, and key performance indicators are used to manage the service. More financial autonomy is given to NMS/NHS. Cost-recovered services and revenue generated are applied directly to the NMS/NHS.	**Legal framework:** A meteorological law, which governs the provision and use of meteorological and hydrological services by all actors including the private sector, is in place. An advanced law promotes and regulates the work of the private sector alongside the provision of services by public entities. An advanced law supports an open data policy. **Financing:** Authority to establish subsidiary bodies, which may operate commercially and competitively. Budget allocation from government is sufficient to support public service responsibilities of the NMHS defined by law. **Management:** Year-on-year improvement in performance based on targets and key performance indicators (KPIs).

Source: Kootval and Soares 2021.

5.2 Co-production of Hydro-met Services

Program Descriptions

Basic weather and hydrological services are the foundation for hydro-climatic risk management, but NMS/NHS also need to collaborate with other agencies to offer services on top of this foundation. Developing interagency collaboration is not an easy task but is fundamental to creating the necessary services for flood and drought management. The key areas for the co-production of services are presented below:

National Water Data Program. The collection of hydrological data is often spread out across multiple national agencies that collect different types of information, for example surface water, groundwater, and water quality. Ideally, there would be a single (or potentially multiple) program to consolidate this information and make it freely and easily accessible to the public. There are various approaches for doing this, including creation of hydro-informatics centers, open water data initiatives, and the establishment of national water data systems. Ideally the NHS or natural resources management agency should be mandated to facilitate a national water data program and enter into interagency agreements and operational protocols to ensure the smooth flow of high-quality data. This would generate enormous value added for water-related planning, design of water infrastructure, and research. All agencies working working on hydro-climatic risk management would benefit from combining their water-related information through a national water data program.

Drought Monitoring and Vulnerability Impact Assessment. This topic is explored in depth in Chapter 11, which notes that droughts generally evolve gradually over time, cover large areas, and have broad social, economic, and environmental impacts. A national drought monitoring program is usually the best approach, requiring a nexus of cooperation among NMS/NHS, WRM, agriculture, and DRM agencies. The NMS/NHS plays a critical role in monitoring drought hazards by providing analysis on "dryness" conditions (World Bank 2019). However, this hydro-met information is only part of the story, as droughts are assessed primarily by their impacts on farmers, cities, and the environment. The NMS/NHS needs to work closely with the other agencies, local governments, and other parties to better understand vulnerabilities, risks, and appropriate drought response actions. The National Drought Framework discussed in Chapter 3 should help facilitate interagency agreements and operational protocols to ensure this nexus operates smoothly.

Flood Forecasting and Warning. This topic is explored in depth in Chapter 12, which notes that different types of flood require different approaches. Flood forecasts and warning require a cooperation nexus among the NMS/NHS, WRM, and DRM agencies. Clear interagency agreements and operational protocols need to be developed to ensure that this nexus operates efficiently. One option is to establish a National Flood Center which can foster collaboration and flexibility to handle a variety of floods. The different types of floods and potential agency roles are described below:

- **River Flooding with Infrastructure.** If a country or river basin has an extensive stock of flood control infrastructure, such as reservoirs, river embankments, or flood control gates, then the NMS/NHS needs to collaborate closely with the WRM agency to generate flood forecasts. This is ideally done through a Flood Center operated by the WRM agency with staff from the NMS/NHS providing updated weather information and forecasts. The DRM agency should liaison closely with the Flood Center to make it possible to quickly issue warnings to affected communities and act through a multi-hazard Emergency Management System (EMS).
- **River Flooding without Infrastructure.** In some cases, rivers may be unregulated and without flood control infrastructure. In this case, the WRM agency has a more limited role to play. The NMS will need to work closely with the NHS (which may be embedded in the WRM agency or a part of the NMS) to translate weather and hydrological data into river flood forecasts. The NMS/NHS should collaborate with the DRM agency to translate flood forecasts into warnings for affected communities through the emergency management system (EMS).
- **Coastal Flooding.** Most coastal flooding is associated with storm surges generated by cyclones.[19] The NMS/NHS plays the leading role in storm forecasting, and generally collaborates with the ocean or maritime agency to forecast the extent of storm surges. The NMS needs to work closely with the DRM agency, often through a Cyclone Center, to monitor and forecast storm impacts and act through the EMS. In many cases, storms also create inland river floods which interact with coastal floods requiring a response for both river and coastal flooding.
- **Impact-Based Flood Warnings.** The value of flood warnings can be significantly enhanced if the potential impacts are well understood. Chapter 10, Floodplain Management, underscores the importance of river

[19] The term cyclone covers a variety of storm types. A tropical cyclone is generally referred to as either a typhoon or a hurricane. A mid-latitude cyclone, in either the northern or southern hemisphere, is generally referred to as a storm.

and coastal floodplain mapping and how, among other benefits, this can help inform flood warning and emergency response.

Agro-Climate Advisory Services. As highlighted in Chapter 11, farmers are particularly prone to be affected by fluctuations in weather and by extreme hydro-climatic events, particularly droughts. It is estimated that 20-80 percent of the inter-annual variability of crop yields is associated with weather phenomena, and 5-10 percent of national agricultural production losses are associated with climate variability (WMO 2019). The NMS/NHS can team with agriculture agencies to help farmers better cope with climate variability and extreme events through the provision of agro-climate advisory services. Farmers receive information at different time scales to help them make informed decisions. For example, weather forecasts up to a week in advance can help them make decisions regarding planting and harvesting, fertilizer application, and irrigation requirements. Seasonal forecasts on the order of months can inform cropping decisions and livestock strategies.

Co-Producing National Climate Assessments (NCA). An NCA helps to inform the country about already observed changes, the current status of the climate, and anticipated trends for the future.[20] It typically provides analysis of the effects of climate change on the environment, agriculture, health, water resources, and coastal areas, and includes an analysis of flood and drought risks. An NCA can help guide adaptation actions across society by informing planning at all levels, influencing private investment decisions, and spurring actions to enhance climate resilience. The development of an NCA needs to be a collaborative effort with many national agencies, as well as other stakeholders. Although lead responsibility for the formulation of an NCA will vary by country, in every case the NMS/NHS needs to be front-and-center in the process as the leading authority on climate.

An NCA is a complex undertaking and less-affluent countries may need international assistance. Global experience has shown that the process of formulating an NCA and pondering the manifold impacts of climate change and its attendant risks is as important as the actual report—which in any case needs to be periodically updated. The various national agencies can build upon the knowledge gained through the NCA to develop more climate-sensitive sector strategies.

Box 5.3 Co-production of Hydro-met Services in the Netherlands: An International Approach

Flood and drought management activities in the Netherlands are coordinated by the Netherlands Water Management Center (NWCN). The NWCN is housed within the Directorate-General for Public Works and Water Management, which in Dutch is called the *Rijkswaterstaat*. The Rijkswaterstaat is a semi-autonomous entity in the Ministry of Infrastructure and Water Management (MIWM).

The NWCN combines meteorological information from the Royal Netherlands Meteorological Institute (KNMI), which is another agency of the MIWM, with actual and forecasted data on river discharges and (sea)water levels in the Netherlands. The KNMI bases its forecasts on data collected in cooperation with the European Center for Medium-Range Forecasts (ECMWF), the Network of European Meteorological Services (EUMETNET), and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The hydrological forecasts are based on models and data developed by the *Rijkswaterstaat* in cooperation with partner institutes in upstream countries.

A special feature of the NWCN is that, in addition to providing hydro-met services, it also organizes the operational response to extreme hydrological conditions (floods and droughts) by bringing together the actual water managers of the Rijkswaterstaat and the water boards, the provinces, the DRM agency (safety regions), and the knowledge institutes. Based on prescribed procedures, they jointly decide on necessary actions.

Besides short- and mid-term weather forecasts, the KNMI also provides science-based long-term climate scenarios for climate and sea level rise. This is done in cooperation with other national and international scientific institutes and the IPCC (Intergovernmental Panel on Climate Change). The activities and responsibilities of the KNMI and Rijkswaterstaat have a legal basis in national laws.

Key Issue: A key feature of the hydro-met services in the Netherlands is the international cooperation, sharing data and information. But also a simple phone call from a sister institute upstream has proven to be very effective in providing timely responses to flood and drought events.

[20] For an example of an NCA see the U.S. Global Change Research Program website: https://nca2014.globalchange.gov/.

National Sector Frameworks

Ideally, specific programs for the co-production of services should be included in the meteorological law, as well as the relevant WRM, DRM and Drought laws. The way the agencies collaborate, however, needs to be further specified among the agencies. This can take place through a variety of mechanisms, which are not mutually exclusive, including: (1) executive decisions compelling agencies to collaborate; (2) formal memoranda of understanding (MoU) or interagency agreements; and (3) promulgation of agency regulations that define how an agency will interact with another agency.

It is important to make the distinction between collaboration and coordination, where collaboration implies a degree of equality among the contributing agencies, while coordination is prone to the domination of more powerful agencies and runs the danger of becoming merely ritualized consultation. Implicit in this approach is the recognition that the co-production of services requires the exercise of the unique capabilities of different agencies in an interdependent manner and that the objective cannot be achieved by any agency acting on its own. This should not be assumed, but rather tested on a case by case, country-specific basis demonstrating that the three tests below are met:

- Production by the agencies acting together can create more value than each agency acting alone.
- Each agency has the means of inducing the others to act in manner that contributes to the realization of the value sought.
- Each agency and its potential partners judge that a reasonable level of trust exists already or can be built within a relevant time period.

In some cases, the capacity of the different agencies may vary considerably, and the ability to co-produce services will be constrained by the weakest agency. In all the cases, the NMS/NHS provides the primary inputs to these services and thus the national government should prioritize the development of NMS/NHS. In the event the NHS/NMS is the weak link, the other agencies should also advocate for upgrading the NMS/NHS to help them fulfill their own specific mandates. The strategic planning processes identified in Chapter 2 for WRM, DRM, and Drought provide platforms for assessing the performance of NMS/NHS and the quality of co-produced services and for generating strategies for further development.

Generic Evolution

Table 5.2 provides an example of the generic evolution for interagency collaboration.

TABLE 5.2 Generic Evolution of Co-production of Hydro-met related Services

Nascent	Engaged	Capable	Effective
No coordination and collaboration mechanisms exist. Planning is conducted by each agency separately. No legal or regulatory framework for joined-up government thinking. Differentiated roles and responsibilities of agencies unclear. No co-production of services.	No legal or regulatory framework, but agencies in the process of developing formal coordination and collaboration mechanisms. Planning is conducted by each agency separately, but cooperatively. Differentiated roles and responsibilities of agencies in progress. NMS/NHS engages in co-production of flood forecasts but with weak linkages to DRM agency. NMS/NHS provides drought monitoring and forecasts, but with weak linkages to Drought Committee. Water data are maintained separately and exclusively by each agency.	Legal and regulatory framework in development. Agencies have formal agreements to coordinate and collaborate. Clear, differentiated roles and responsibilities of agencies. NMS/NHS engages in co-production of flood forecasts with clear linkages to DRM warnings. NMS/NHS provides drought monitoring and forecasts, but with clear linkages to the Drought Committee. Rudimentary impact-based flood warning and impact-based drought monitoring. Water data are public and shared among agencies, but no national water data program exists.	Well-established legal and regulatory framework has evolved over time. Agencies have formal and mutually beneficial agreements to coordinate and collaborate. NMS/NHS engages in co-production of flood forecasts and impact-based warning issued by the DRM agency. NMS/NHS provides drought monitoring and forecasts, allowing the Drought Committee to monitor vulnerability and impacts. National water data program allows free and easily accessible data for all users. NMS/NHS incorporated into National Strategic WRM, DRM, and Drought Plans.

Source: Authors.

5.3 Key Resources

Rogers, David P., and Vladimir V. Tsirkunov. 2010. *Global Assessment Report on Disaster Risk Reduction: Costs and Benefits of Early Warning Systems*. United Nations International Strategy for Disaster Reduction (UNISDR) and World Bank.

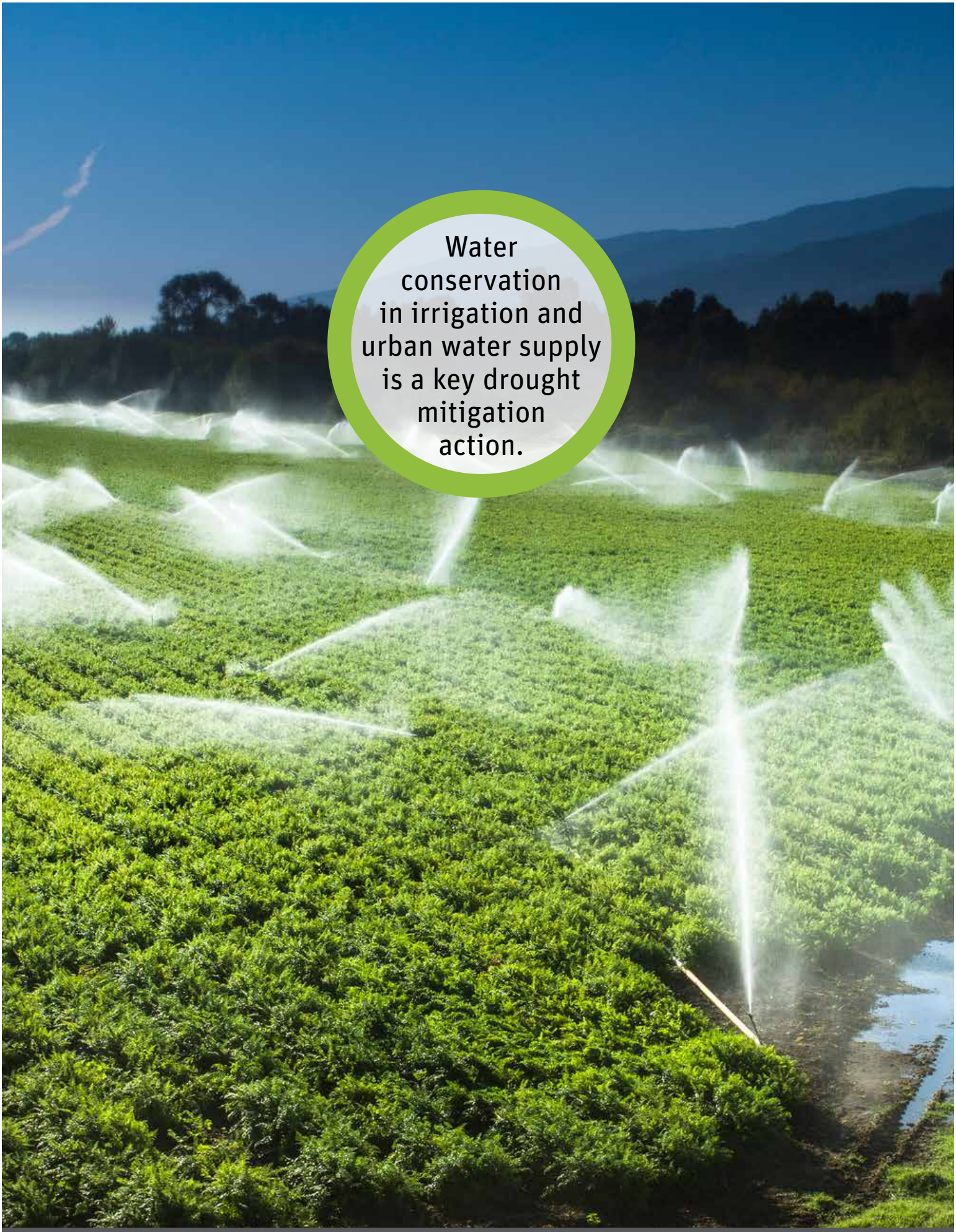
Rogers, David P., and Vladimir V. Tsirkunov. 2013. *Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services*. Directions in Development. Washington, DC: World Bank.

Rogers David P., Vladimir V. Tsirkunov, Haleh Kootval, Alice Soares, Daniel Kull, Anna-Maria Bogdanov, and Makoto Suwa. 2019. *Weathering the Change: How to Improve Hydromet Services in Developing Countries*. Washington, DC: World Bank.

World Bank. 2019.*The Power of Partnership: Public and Private Engagement on Hydromet Services*. Washington, DC: World Bank.

WMO (World Meteorological Organization). 2015. "WMO guidelines on multi-hazard impact-based forecast and warning services." WMO TD no. 1150.

WMO (World Meteorological Organization), World Bank, and USAID (United States Agency for International Development). 2015. *Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services*. Geneva: WMO.



Celery field is watered and sprayed by irrigation equipment in the Salinas Valley, California USA. Photo: Pgiam

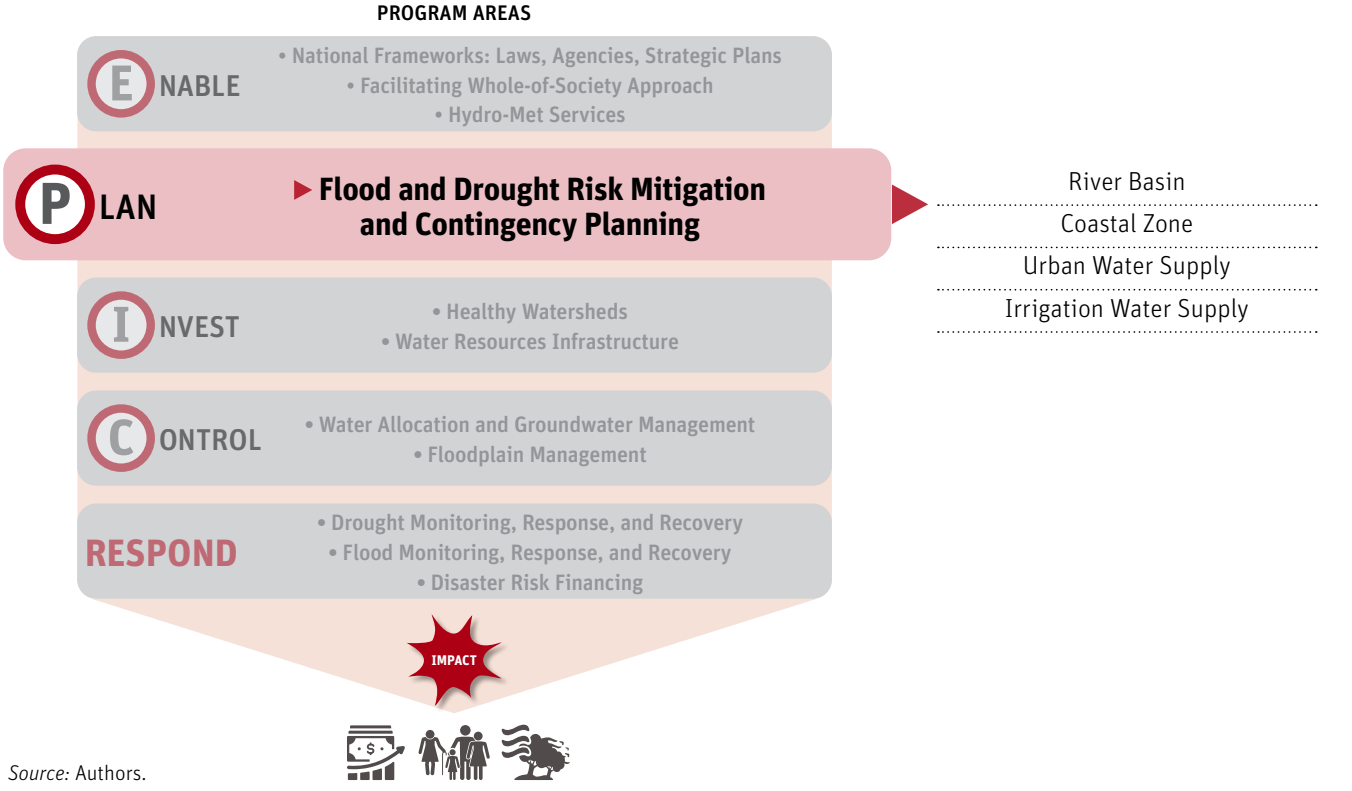
6 Flood and Drought Risk Mitigation and Contingency Planning

As reflected in Figure 6.1, flood and drought planning establishes a roadmap for many of the other programs in the lower parts of the EPIC Response Framework. Mitigation in this report is broadly defined as actions to reduce the three disaster risk components presented in Chapter 2: (1) hazard magnitude and frequency; (2) exposure to the hazard; and (3) vulnerability to the hazard. Planning can guide investments in healthy watersheds and water resources infrastructure and help set parameters for water resources management and floodplain management programs. Contingency planning provides a basis for responding to flood and drought events when they occur—the focus of Chapters 11 and 12.

Conversely, planning activities rely heavily on the enabling programs higher up the Framework. The national sector frameworks for WRM, DRM, and drought provide authorization and support for planning. Engaging with the whole-of-society ensures that the plans are well formulated and can be implemented. Finally, hydro-met information provides vital information to make informed planning decisions.

The report presents five types of plans as summarized below. The relative importance of the plans will of course depend upon the context of the country. For example, coastal zone management plans are irrelevant for land-locked countries

FIGURE 6.1 Planning in the EPIC Response Framework



Source: Authors.

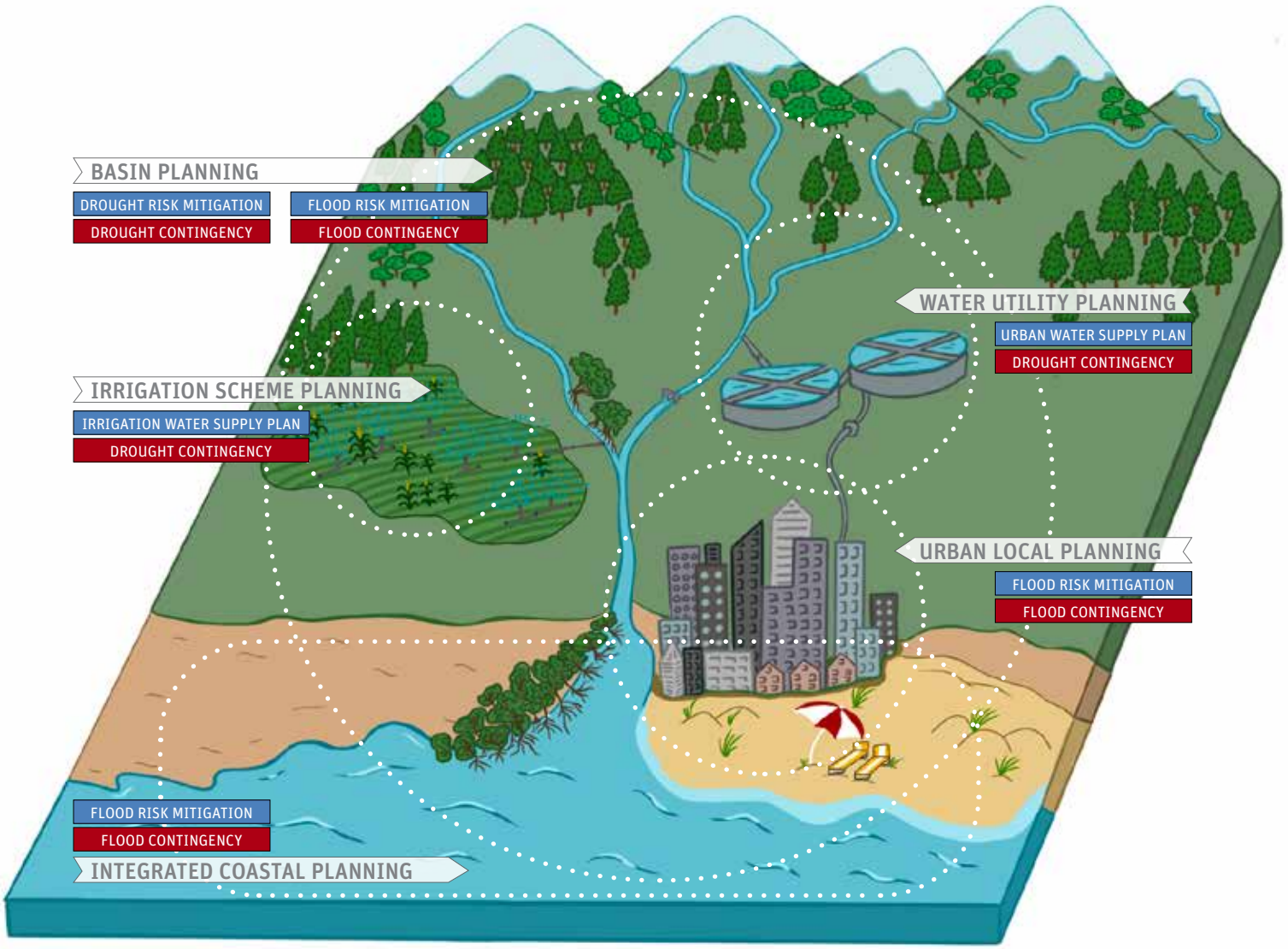
while irrigation water supply plans will be of less relevance for countries that do not have large irrigation schemes.

- **Integrated River Basin Plan.** This is a broad water resources management plan that addresses many different topics in an integrated manner, including both flood and drought risk management. The plan identifies both structural and non-structural approaches to reducing hydro-climatic risks. As part of a river basin plan, or in parallel, basin flood and drought contingency plans should be developed to help prepare for and respond to a variety of extreme hydro-climatic scenarios.
- **Coastal Zone Management Plan.** This is a broad environmental and land use plan that promotes the sustainable management of fragile coastal areas and addresses many different topics in an integrated manner. Due to the coastal flood risks associated with storm surges, rising sea levels, and more severe storms due to climate change, flood risk management should be an important element of any coastal zone management plan.
- **Urban Water Supply Plan.** As part of their overall planning processes, urban water utilities need to develop both structural and non-structural approaches to drought mitigation, such as developing new supplies, reducing leakage, and promoting water conservation. They also need to develop drought contingency plans, in collaboration with local governments, so that when water supplies become scare, they are ready to respond.
- **Irrigation Water Supply Plan.** Like water utilities, as part of their overall planning process, irrigation service providers need to develop both structural and non-structural approaches to drought mitigation, such as developing new supplies, reducing system losses, and promoting climate-smart agriculture. They also need to develop drought contingency plans so that when water supplies become scare, they are ready to respond.
- **Local Flood Risk Mitigation Plans.** Local governments need to develop plans to help reduce their flood risks, including both structural and non-structural measures. These flood risks can come from overflowing rivers or coastal surges depending on the location. Local flood risk mitigation plans are discussed in Chapter 10 on floodplain management.

Figure 6.2 depicts several important relationships in the planning process. First, planning for flood or drought mitigation takes place within a broader planning process, such as a river basin plan, an urban water utility plan, or an irrigation scheme plan. Second, the plans should be connected at different scales to ensure compatibility; for example, the river basin plan needs to be synchronized with the plans of the water utilities and the irrigation service providers. Third, mitigation planning will help to define potential scenarios for contingency planning and thus the two are closely linked. Finally, like the national strategic planning discussed in Chapter 3, the plans should be periodically updated on the order of every five years.

It is important to explicitly integrate climate change and its inherent uncertainties into the various plans. Planning for climate change requires a shift from what are usually traditional planning approaches that drive towards one outcome, towards an adaptive approach that considers multiple possible outcomes and allows the exploration of the robustness and flexibility of various planning decisions across those multiple futures. Box 6.1 provides some highlights on adaptation economics, and some of these approaches could potentially be included into the planning process.

FIGURE 6.2 Overview of Plans for Hydro-Climatic Risk Management



Source: Authors. Illustration: Andrea Fernandez and Stephanie Ijff

Flood and drought mitigation and contingency planning should be integrated into broader planning processes within a nested geographical context

Box 6.1 Adaptation Economic Concepts

Economic thinking on adaptation has evolved from a focus on cost-benefit analysis and identification of "best economic" adaptations to the development of multi-metric evaluations including the risk and uncertainty dimensions in order to provide support to decision makers. Economic analysis is moving away from a unique emphasis on efficiency, market solutions, and cost-benefit analysis of adaptation to include consideration of non-monetary and non-market measures, risks, inequities and behavioral biases, barriers and limits, and consideration of ancillary benefits and costs.

One role of economics is to contribute information to decision makers on the benefits and costs, including a number of non-monetary items, and on the equity impacts of alternative actions. It does not provide a final ranking for policy makers. A narrow focus on quantifiable costs and benefits can bias decisions against the poor, against ecosystems, and against those in the future whose values can be excluded or are understated. Sufficiently broad-based approaches, however, can help avoid such maladaptation. Indeed, the evidence shows that maladaptation is a possibility if the evaluation approaches taken are not comprehensive enough in this sense.

Economics offers a range of techniques appropriate for conducting analysis in the face of uncertainties, and the choice of the most appropriate technique depends on the nature of the problem and the nature and level of uncertainty. Uncertainty is unavoidable in analyses of adaptation to climate change because of the lack of data, the efficacy of adaptation actions, and uncertainties inherent in forecasting climate change. Approximate approaches are often necessary. There is a strong case for the use of economic decision making under uncertainty, working with tools such as cost-benefit and related approaches that include time dimensions (real options techniques), multi-metrics approaches, and non-probabilistic methodologies. There are methodologies that can capture non-monetary effects and distributional impacts, and that can reflect ethical considerations.

Sources: Chambwera 2014

Key Issue: The economics of adaptation is a complex and rapidly emerging field. In many cases, the ability of analysts to apply state-of-the-art approaches will be limited by the level of resources and expertise on the study team. Nevertheless, even using these concepts in a qualitative or semi-quantitative manner can add value and insight to the planning process.

6.1 River Basin Plans

Program Description

River basin plans guide the development, management, allocation, and use of water and related resources within a specific geographical area. Ideally, this is an actual river basin, but in some cases the planning area may be limited due to transboundary constraints or in order to ensure a more tractable planning size. In some countries, a single river basin is simply too large to plan as a single unit, so it is necessary to divide it into sub-basins. River basin plans are typically integrated plans, addressing water quantity, water quality, surface water and groundwater, and the protection of water and aquatic ecosystems while enabling the integration of upstream and downstream interests. Basin plans should also include issues such as institutional responsibilities, implementation arrangements, budgets, and monitoring. It is important that droughts and floods are addressed in a river basin plan as set out in the following paragraphs:

- **Basin Drought Planning.** A river basin plan should identify the impacts of various drought scenarios and recommend water resources-related mitigation strategies for minimizing drought impacts, including watershed management actions, the need for and location of new infrastructure, reservoir operations, and urban and agricultural water conservation and efficiency, as well as water allocation priorities. As part of, or in parallel to, the river basin management plan, a Basin Drought Contingency Plan should also be prepared that lays out specific actions to be taken at the basin level depending upon the level of drought severity. Those actions could include mandatory conservation measures, reallocation of water supplies, restrictions on agricultural production, different types of urban water use, or changes to reservoir operations. The Basin Drought Contingency Plan should be informed by assessments of risks and of vulnerable populations to help balance objectives and set priorities.
- **Basin Flood Planning.** A river basin management plan should also identify the potential impacts of various flood scenarios and recommend water resources-related mitigation strategies for minimizing flood risk, including watershed management actions, new water resources infrastructure, and protection of floodplains and wetlands as designated retention areas. As discussed in Chapter 10, the river basin management plan should inform land use planning and related decisions with

Box 6.2 Tanzania WRM Planning - Resilience in an Uncertain Future

As of 2020, six of the nine Basin Water Boards (BWBs) in Tanzania had established IWRM plans in accordance with the 2009 Water Resources Act. As conceived, these comprehensive basin IWRM plans are well positioned to improve hydro-climatic risk management because they include flood risks as part of the basin plans' water balance assessments. In practice, however, the plans do not yet incorporate key levers for reducing these risks, such as associated basin drought contingency plans.

From a longer-term perspective, however, Tanzania is on the cutting edge. Three of the basins recently embarked on an innovative process for water infrastructure investment planning to improve resilience to droughts, floods, and other risks that are likely to appear in the future. Working with the World Bank and the Hydrosystems Group of the University of Massachusetts, Amherst, the Rufiji, Wami-Ruvu, and Pangani BWBs, and the Ministry of Water, utilized decision making under deep uncertainty approaches to identify investment portfolio mixes for each basin that are robust against multiple future conditions (both climatic and non-climatic, such as shifts in water demand and changes in technologies). The process relied on broad stakeholder input to identify key challenges and vulnerabilities, test assumptions, and develop shared visions for targets and performance metrics for each basin's investments.

This participatory process, backed by high-powered computing, has allowed the basins to identify a suite of investment options that have the greatest likelihood of improving water availability, bolstering resilience, and reducing tensions between various water users in the basins. The World Bank and other development partners are now working with Tanzania to implement key priorities that were identified through this investment strategy planning process. The approaches utilized can not only be scaled for use within the remaining six basins; the tools also were developed in "open-source" platforms and are thus transferable to other locations and contexts.

respect to flood risks at the local level. As part of, or in parallel to the Basin Plan, a Basin Flood Contingency Plan should also be prepared. Such a plan should lay out specific actions to be taken depending upon the level of flood severity. Those actions could include emergency operations of reservoirs, decision rules on controlled flooding, and emergency actions such as mobilizing flood-fighting teams and evacuating populations.

Linkage to the National Sector Framework

The preparation and periodic revision (for example every five years) of a river basin management plan is typically required by the water resources law. Such a law will also typically specify the minimum content of river basin management plans and their legal relationship with other relevant plans (such as which has priority). It also will specify the plans' role in the implementation of the water resources law itself, for example in the setting of priorities and decisions on water allocation as discussed in more detail below.

The water resources law will also typically set out the procedure for the development of river basin management plans, which given their cross-cutting nature should involve broad stakeholder consultation including with agencies responsible for elements of the hydro-climatic risk framework. The law will also typically specify who is to adopt such a plan.

Water resources laws typically require the plans to be approved at a high level through adoption by the government (the cabinet) or by the high-level inter-ministerial body (if one exists), such as a national water council or a national water resources committee. Such a requirement should enable the effective participation of agencies involved in hydro-climatic risk management, particularly as regards the elements of primary concern to them (such as industry, agriculture, power generation, and environment).

The preparation of river basin management plans is typically the responsibility of the relevant river basin agency (alternatively, the WRM agency if there is no river basin agency), with the participation and ideally under the supervision of the river basin committee in which, as already mentioned, relevant stakeholders within the basin should be represented, including agencies involved in aspects of hydro-climatic risk management. Only with sufficient buy-in from stakeholders is a river basin management plan likely to be effective.

The National Drought Plan, discussed in Chapter 3, provides the overall framework for managing droughts, assigning responsibilities, ensuring a robust drought monitoring and assessment system, and overseeing the drought response. As a drought unfolds and different drought impact levels are triggered, the Basin Plan Drought Contingency Plan provides a foundation for WRM agencies to take appropriate actions. Other actors, such as urban water utilities, agriculture service providers, national agriculture agencies, natural resources management agencies, and disaster management agencies, should ideally also have their own drought management plans.

Key Agency Actions

The following activities are typically core responsibilities of WRM to ensure effective river basin planning:

- **Fostering institutional arrangements,** in terms of the establishment of river basin agencies and river basin committees and ensuring they receive adequate funding and training so that they effectively discharge their roles.
- **Issuing regulations regarding the basin planning process,** covering topics such as how often a plan needs to be prepared, the general scope and format of the plan, and the review and approval process. The role of the WRM agency in the basin planning process should be clarified, in terms of technical and financial assistance.
- **Providing technical planning guidelines for basin planning,** including general methodology, sources of data, hydrological and hydraulic modelling approaches, linkages with other sectors, and other planning processes. The guidelines should include specific guidance on flood and drought mitigation and contingency planning, particularly taking climate change into account.
- **Establishing formal roles for other national agencies** such as natural resources management, agriculture, disaster risk management, and hydro-met agencies. This could include formal review processes or co-formulation of the basin plan with the WRM agency in coordination with the basin agency or committee.
- **Ensuring public outreach and stakeholder engagement** by providing guidance on consultations, responding to feedback, and ensuring transparency. The process should ensure all relevant stakeholder groups are meaningfully engaged, including local governments, significant water users (such as urban water utilities, agricultural water providers, and power companies), civil society, and the general public. Special efforts should be made to accomplish social inclusion by ensuring culturally meaningful participation of marginalized groups.
- **Ensuring the inclusion of all water resources infrastructure projects in river basin plans** by requiring that all major projects, such as multi-purpose reservoirs or flood control structures, have been incorporated into the basin plan before permits or funding for the projects are provided.

Box 6.3 River Basin Management Planning in the Philippines

River basin planning in the Philippines is supervised by the River Basin Control Office (RBCO) of the Department of Environment and Natural Resources (DENR) in accordance with Executive Order 510 (2006). Regional Development Councils (RCDs) are supposed to be the main drivers behind integrated water planning. These RCDs are based on administrative boundaries, have little affinity with the water sector, and their capacity to supervise the planning is limited. There are only a few River Basin Organizations (RBOs) in the country and, where they exist, tend to be weakly organized and lack financial means to develop effective river basin plans.

The RBCO has initiated, funded, and supervised the development of Integrated River Basin Master Plans (IRBMPs) for 17 main river basins and 3 principal river basins. The plans are developed by consultants and are endorsed by the RDCs.The quality of these plans varies as formal standards for such plans have not been established and the financial resources to develop them are limited. The plans describe the water resources system and its problems, and present a long list of possible interventions, mainly involving infrastructure, to solve the problems. The technical and economic analyses of alternative interventions is not undertaken, which makes the plans a kind of wish list. Flood and drought issues are addressed in the plans, but mainly as infrastructure investment needs for mitigation. The risk assessment in the plans is generally weak. None of the plans include drought or flood continency plans. In developing the plans, a participatory process is followed, but without resulting in clear commitments by the implementing agencies to follow up on the proposed and endorsed actions within their regular budgets.

Key Issue: This first round of river basin planning in the Philippines shows that clear guidelines are needed on the content of the plans, the depth of the analysis to be carried out, and the institutional setting of the planning exercise. The World Bank has assisted the Philippine government in developing such guidelines. The guidelines emphasize the implementation of the plans (such as what is realistic and how to fund or finance), needed institutional arrangements, and ownership by the implementing agencies. These guidelines have been adopted by the main responsible agencies, DPWH (Department of Public Works and Highways) and DENR.

Generic Evolution

The generic evolution of river basin planning is summarized in Table 6.1.

TABLE 6.1 Generic Evolution of River Basin Plans Incorporating Flood and Drought Risk Management

Nascent	Engaged	Capable	Effective
No water resources law in place and so no river basin plans are prepared. Water resources development and management takes place in an *ad hoc* and uncoordinated manner.	Water resources law in force that requires preparation of basin plans. Several plans prepared but without involvement of stakeholders, and do not comprehensively address flood and drought risk management. No linkage with water use (urban and agriculture) or local flood plans.	Basin plans promote stakeholder engagement through formal mechanisms, such as basin committees or authorities. Drought and flood risk management are incorporated into basin plans or undertaken in a parallel process. Some linkage with water use (urban and agriculture) and local flood plans.	Basin plans formulated with active engagement by all stakeholders through formal mechanisms. Adaptive planning process utilized. Standalone basin flood management and drought management plans prepared and integrated into overall basin plan. Close linkages with water user and local flood plans.

Source: Authors.

6.2 Integrated Coastal Zone Management Plans

Program Description

More than 600 million people, around 10 percent of the global population, live in coastal areas that are less than 10 meters above sea level (UN 2017). These areas are particularly vulnerable to flooding from storms and the associated storm surges that drive seawater onto coastal flood plains. Coastal zones can also be vulnerable to water shortages and droughts with the additional risk of saline intrusion (and therefore contaminated groundwater) as a result of groundwater over-abstraction. Climate change also directly impacts coastal communities due to rising sea levels and increasing storm frequencies and magnitudes in many areas.

The most comprehensive paradigm for coastal zone management is Integrated Coastal Zone Management (ICZM), a multi-sectoral, stakeholder-informed coastal zone equivalent of river basin planning, which seeks to promote economic development in the coastal zone while also protecting valuable coastal ecosystems. These ecosystems are often important for tourism and fisheries, and act as coastal barriers against storm surges. Unlike river basin planning, ICZM has not been fully mainstreamed into most countries' planning processes, probably reflecting the complexity of the exercise.

Particularly in countries or coastal areas with extensive deltas, coastal zone planning must of necessity be linked to river basin management planning. That is because the delta represents the terminus of a river basin, where freshwater flows mix with seawater and bring sediments, nutrients, and pollutants that have a profound impact on coastal ecosystems. ICZM is also fundamentally intertwined with marine spatial planning by virtue of common geomorphological dynamics and the ecosystems providing services (such as flood protection) and goods to coastal economies.

Coastal zone management plans provide the overall framework for flood management programs operating in coastal areas and should help 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 the prioritization of areas where "hard" coastal defenses such as sea dikes or flood walls may be necessary. Coastal zone management plans rely on information provided by the coastal floodplain mapping programs discussed in Chapter 10, and conversely should also help to prioritize areas for in-depth flood risk mapping.

It is important that coastal zone management plans are used to mainstream flood risk management considerations into the overall development objectives of the coastal zone and to ensure that the planning approach is tailored for the specific circumstances of each coastal stretch. A coastal zone management plan will normally address a variety of technical issues, such as coastal erosion, sea level rise, land subsidence, saltwater intrusion, pollution, management of coastal ecosystems, and coastal risk management associated with storms and tsunamis. The impacts of climate change,

including changes in weather and sea levels, should also be considered in the plan to ensure robust and flexible approaches. Like river basin management plans, coastal zone management plans should ideally be updated periodically to adjust to changing circumstances and to incorporate lessons learned.

Linkage to the National Sector Framework

Depending on the country concerned, the national framework for coastal zone management planning may derive from a specific coastal zone management law, or as part of broader environmental law, land use planning law, or ocean governance law.

Irrespective of its title, the relevant law should set out the specific requirements for the preparation and periodic review of coastal zone management plans, for example every five years. The law should empower a national agency to facilitate the coastal planning process, which could potentially be drawn from many different sectors, 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 that are responsible for preparing or overseeing the preparation of coastal zone management plans. Coastal Planning Authorities can take on many forms, from an inter-governmental committee established for the purpose of the planning exercise to a less common permanent organization with its own budget and staff.

The water resources law should clearly indicate that the WRM agency has the lead responsibility for permitting and regulating, and in some cases constructing and operating, flood defense structures located along the coast, such as sea dikes, flood walls, storm surge barriers, and coastal groins. Ideally, the coastal zone management law should specify the general functions of the national WRM agency in the coastal zone planning process.

Key Agency Actions

Key actions for the agency responsible for coastal zone planning are similar to those for river basin planning and include the following:

- **Fostering institutional arrangements,** in terms of the establishment of coastal planning authorities or regional coastal committees and ensuring that they receive adequate funding and training so that they effectively discharge their roles.
- **Issuing regulations or guidance on coastal planning processes,** covering topics such as the appropriate coastal stretches for planning, how often a plan needs to be prepared, the general scope and format of the plan, and the review and approval process. The role of the natural resources management agency in the coastal planning process should clarified, in terms of technical and financial assistance.
- **Providing technical planning guidelines for coastal planning,** including general methodology, sources of data, coastal modelling approaches, linkages with other sectors, and other planning processes. The guidelines should include specific guidance on coastal flood mitigation actions and contingency plans, particularly taking climate change and sea level rise into account.
- **Establishing formal roles for other national agencies,** such as water resources, agriculture, disaster risk management, and hydro-met agencies. These could include formal review processes or co-formulation of the basin plan with the natural resources management agency in coordination with the coastal planning authority or committee.
- **Ensuring public outreach and stakeholder engagement** by providing guidance on consultations, responding to feedback, and ensuring transparency. The process should ensure all relevant stakeholder groups are meaningfully engaged, including local governments and groups that rely on coastal resources (such as fisher people, the tourist industry, the shipping industry, civil society, and the general public). Special efforts should be made to accomplish social inclusion by ensuring culturally meaningful participation of marginalized groups.
- **Requiring the inclusion of all major structural flood control infrastructure in coastal zone management plans,** such as sea dikes, sluice gates, and dredging operations. These should be incorporated into the plan before permits or funding for projects are provided.

Generic Evolution

The generic evolution of this program can be summarized as follows:

TABLE 6.2 Generic Evolution of Integrated Coastal Zone Management Plans Incorporating Flood Risk Management

Nascent	Engaged	Capable	Effective
No coastal zone management law exists, and coastal development takes place in an ad hoc and uncoordinated manner.	Coastal zone management law (or similar law) exists and requires natural resources management agency (or similar agency) to prepare coastal plans. Limited involvement of other sector agencies and local communities. Coastal plans do not explicitly consider food risk management.	Coastal plans promote stakeholder engagement through formal mechanisms, such as regional coastal planning committees or authorities. Flood risk management incorporated into coastal plans. Some linkage with local flood management plans.	Coastal plans formulated with active engagement by all stakeholders through formal mechanisms. Adaptive planning process utilized. Standalone coastal flood management with close linkages to local flood management plans.

Source: Authors.

6.3 Urban Water Supply Plans

Program Description

Urban water supply and sanitation utilities (hereafter "water utilities") typically prepare master plans to define system-wide strategies and guide capital improvement projects to cope with population growth, regulatory requirements, and infrastructure renewal needs. In order to ensure that current, medium- and long-term water needs can be met, such master plans usually also include what is described in this report as an Urban Water Supply Plan (UWSP) that helps to mitigate drought risks by identifying potential supply-side and demand-side options. Potential supply-side options may include the construction of infrastructure in the form of new reservoirs, long-distance conveyance structures, water reclamation and desalination plants, development of new groundwater wellfields, and the purchase of water from bulk suppliers. Potential demand-side options may include reducing physical losses, promoting water conservation, and adjusting water pricing. Water quality may also be factored into a water supply plan, as poor raw water quality can potentially reduce the availability of potable water.

A critical element of any UWSP is considering the availability of water resources from a broader regional or basin perspective. If a utility abstracts water from a river, stores water in a reservoir, or abstracts groundwater, the availability and quality of the water depends upon what happens upstream. It follows that there is a close relationship between an UWSP and the relevant river basin management plan, and of course, water utilities are key stakeholders in the river basin management planning process.

In addition to long-term resource planning, it is also important to ensure that water utilities prepare water shortage contingency plans. Such water shortages could be caused by ordinary seasonal low flow conditions, system interruptions or failures (such as a series of pump breakdowns or a risk of dam failure on a reservoir requiring a reduction in storage capacity), or, of course, droughts. Such a water shortage contingency plan (WSCP) should identify different levels of water shortage (usually between three and five levels) and set out the actions to be taken by the water utility in response to each different level. These actions might, depending on the level of shortage, include public awareness campaigns, water conservation measures, water tariff adjustments to encourage water savings, enforcement mechanisms, and the provision of emergency water supplies. Defining the different water shortage stages often requires an understanding of the river basin context, and thus there are close linkages with the Basin Drought Contingency Plan. The formulation of a WSCP should be done in close consultation with the relevant local government, which in most cases is the authority that allows the utility to take emergency measures.

Linkage to the National Sector Framework

While practice varies from country to country, water utilities typically operate within the framework of a water supply and sanitation law which will also specify their relationship with: (1) the relevant local government; (2) the agency responsible for the implementation of the law; (3) relevant sector regulators, if any (including economic regulators responsible for approving tariffs and setting service standards and regulators for ensuring compliance with drinking water standards); and (4) consumer representative bodies. Such

Box 6.4 California Urban and Agriculture Water Plans

Since 1983, urban water utilities are required by the California Water Code to prepare Urban Water Management Plans every five years. The plans are required for water utilities to be eligible for state grants. The plans must assess the reliability of water sources over a 20-year planning time frame and present demand management measures and water shortage contingency plans.

Starting in 2009, large agriculture water suppliers are required by the California Water Code to prepare an Agricultural Water Management Plan every five years. The plans are required to include water budgets, water management objectives, and implementation of water use efficiency measures. They also include a drought plan that describes actions for drought preparedness, as well as water management and water allocations during drought conditions.

The California Department of Water Resources (DWR) provides support to the water utilities and agricultural water suppliers, including guidelines and technical assistance. DWR also reviews the plans to ensure compliance with the Water Code and submits a report to the Legislature summarizing the status of the plans for each five-year cycle.

Key Issue: A key action area for many of the Agricultural Plans is modernizing irrigation infrastructure and operations to better measure and control water distribution in canals. This is in line with the adage that if you cannot measure and control water, you cannot manage it. It also highlights the challenge of managing irrigation networks even under the ideal conditions of high-value agriculture in California.

legislation may also require the preparation of UWSPs and WSCPs.

However, the actual storage and abstraction of water from natural sources by water utilities is usually subject to the water resources law and should be regulated by the WRM agency based on long-term water use permits. This, in turn, provides an opportunity to link the preparation of UWSPs/WSCPs to the river basin management planning process and even to require the preparation and periodic review of UWSPs/WSCPs as conditions for long-term water use permits or regulations adopted pursuant to the water resources law. The drought law should also ideally highlight the importance of urban drought management and its linkages to basin planning.

Key Agency Actions

Depending on the prevailing national framework, either the WRM agency or the national WSS agency should be responsible for overseeing UWSPs/WSCPs. Key agency actions include:

- **Developing regulations to guide the UWSP/WSCP process,** specifying requirements such as: (1) which utilities are required to prepare the plans; (2) the frequency of the plans; (3) the general scope and content of the plans; (4) the process for submitting and reviewing the plans; and (5) sanctions for not complying with the regulations.
- **Providing technical support to the water utilities** by preparing guidelines, conducting workshops, developing tools, and providing program staff to help water utilities prepare comprehensive and useful water management plans, implement water conservation programs, and understand their legal requirements. The development of technical guidance should be done in close collaboration with the national water utility association, which in some cases may take the lead in certain technical areas.
- **Ensuring that UWSPs/WDCPs are informed by a public consultation process** made available to the public, and that they are consistent with and help inform the river basin management plans. This is usually the responsibility of the WRM agency.
- **Conditioning grant funding or loans to water utilities** through the national government on satisfactory compliance with the regulations pertaining to the UWSPs/WSCPs.
- **Ensuring that the WRM agency or responsible sector agency works with local governments** to have a dedicated program to aid smaller utilities and rural communities at risk of drought and water shortages. Technical and financial assistance information could be provided to help these communities reduce their vulnerability to droughts, including upgrading water supply systems and preparation of contingency plans, which could identify emergency sources of water.

Generic Evolution

The generic evolution of this program can be summarized as follows:

TABLE 6.3 Generic Evolution of Urban Water Supply Plans Incorporating Drought Risk Management

Nascent	Engaged	Capable	Effective
No legal requirement for water utilities to prepare UWSPs or WSCPs and so few, if any, do.	Water resources law (or similar law) requires utilities to prepare UWSPs/WSCPs. WRM agency provides limited guidance or support to utilities. Plans focus primarily on responding to droughts.	WRM agency adopts regulations for UWSP/WSCP preparation and provides necessary support and oversight. The WSCPs are integrated into the UWSPs and focus on drought risk management. Limited linkage to basin plans.	Utility UWSPs and WSCs use an adaptive planning process and focus on drought risk management. Utilities play an active role in the preparation of basin plans and basin drought management plans.

Source: Authors.

6.4 Irrigation Water Supply Plans

Program Description

Irrigation service providers are usually the largest users of water in a river basin and are accordingly also key stakeholders in river basin management planning. The notion of the irrigation service provider encompasses a range of different actors depending on the national context and may include an irrigation department in a ministry (such as the agriculture ministry or even the WRM ministry), a separate irrigation ministry, a semi-autonomous national or regional public irrigation agency, or farmer-managed water user organizations (variously described as “irrigation districts”, “water communities”, or “water user associations”), which may have their own direct access to water sources or which may in turn be supplied in bulk by public irrigation service providers.

Because of the volumes of water involved, irrigation service providers are generally required to demonstrate more flexibility in their water allocations than are other uses such as water utilities or hydropower operators, and thus play a critical role in basin drought contingency plans. At the same time, though, reduced irrigation water availability may reduce crop production (and therefore influence food prices and food security) and adversely affect rural livelihoods.

In order to ensure sustainable and long-term operation, best practice suggests that irrigation service providers should periodically prepare irrigation scheme master plans that cover all aspects of their service, including asset management and capital planning. Ideally too, and depending on the socioeconomic context, an irrigation service provider should prepare an Irrigation Water Supply Plan (IWSP) that looks at long-term resource planning to ensure that adequate water is available to meet farmers’ existing and future uses, particularly considering changing cropping patterns and climate change. This involves balancing water supply and demand alternatives, while also considering water quality, to ensure long-term sustainability.

There are typically several critical elements in an IWSP. It should include seasonal and monthly water budgets based on quantifying all inflow and outflow components for the service area, such as: crop water use, non-beneficial evaporation, groundwater seepage, and return flows. The IWSP should present water management objectives based on the water budget as a guide to improve system efficiency or meet other objectives. This should include a program of actions to help meet these objectives, including various water conservation approaches. In many schemes there is a need to first improve flow measurement and water control within the canal network through a modernization program.

It is also important to ensure that irrigation service providers prepare a Drought Plan describing actions for drought preparedness as well as allocations of water supply during drought conditions. Unlike urban WSCPs, the IWSP Drought Plan may not need to be a standalone document as irrigation service providers generally have more flexibility during drought periods than urban water utilities which are required to maintain minimum service levels to protect public health.

Linkage to the National Sector Framework

The national framework for irrigation service providers is typically set out in a specific irrigation or agriculture law which may set out a requirement for the preparation of IWSPs. However, as with the case of water utilities,

the storage and abstraction of water by irrigation service providers is usually subject to the water resources law and should be regulated based on long-term water use permits. As necessary, this may therefore provide an opportunity to require the preparation of IWSPs as permit conditions or in accordance with regulations adopted pursuant to the water resources law. The national drought law should also ideally highlight the importance of agricultural water management and its linkages to basin planning.

Key Agency Actions

Key actions for the WRM agency and/or agriculture agency include the following:

Developing regulations to guide the IWSP process, specifying requirements such as: (1) which irrigation service providers are required to prepare the plans; (2) the frequency of the plans; (3) the general scope and content of the plans; (4) the process for submitting and review of the plans; and (5) sanctions for non-compliance with the regulations.

Providing technical support to the irrigation service providers by preparing guidelines, conducting workshops, developing tools, and providing program staff to help irrigation service provides prepare comprehensive and useful IWSPs, implement water conservation programs, and understand their legal requirements.

Ensuring that the content of IWSPs is informed by public consultation with the farmers and other users who rely upon the water provided by the irrigation provider. The IWSP should be made available to the public and be consistent with and help inform the river basin management plans. This is usually the responsibility of the WRM agency.

Conditioning grant funding or loans to irrigation service providers through the national government on satisfactory compliance with the regulations pertaining to the IWSP.

Generic evolution

The generic evolution of this program can be summarized as Table 6.4:

TABLE 6.4 Generic Evolution of Irrigation Water Supply Plans Incorporating Drought Risk Management

Nascent	Engaged	Capable	Effective
Irrigation service providers prepare water supply and water distribution plans with little if any attention to drought risk management planning.	Water resources law (or similar law) requires irrigation service providers to prepare IWSPs. WRM agency provides limited guidance or support and few plans are produced. Plans focus primarily on responding to droughts.	WRM adopts regulations and provides oversight for the IWSP preparation process. Drought plans are integrated into the IWSPs and focus on drought risk management. Some linkage to basin plans.	Irrigation service provider IWSPs and their drought plans use an adaptive planning process and focus on drought risk management. Service providers play an active role in the preparation of basin plans and basin drought management plans.

Source: Authors.

Flood and drought risk mitigation and contingency planning at multiple nested levels is hard to achieve in practice. Countries should systematically assess the effectiveness of planning exercises and recognize that it is an evolutionary process that requires constant adjustments

6.5 Key Resources

River Basin Plans: Incorporating Floods and Droughts

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Urban Water Supply Plans

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AWWA (American Water Works Association). 2019. *M60 Drought Preparedness and Response,* 2nd ed. Manual of Water Supply Practices. Denver: AWWA.

California Department of Water Resources. 2008. *Urban Drought Guidebook*. Sacramento: California Department of Water Resources.

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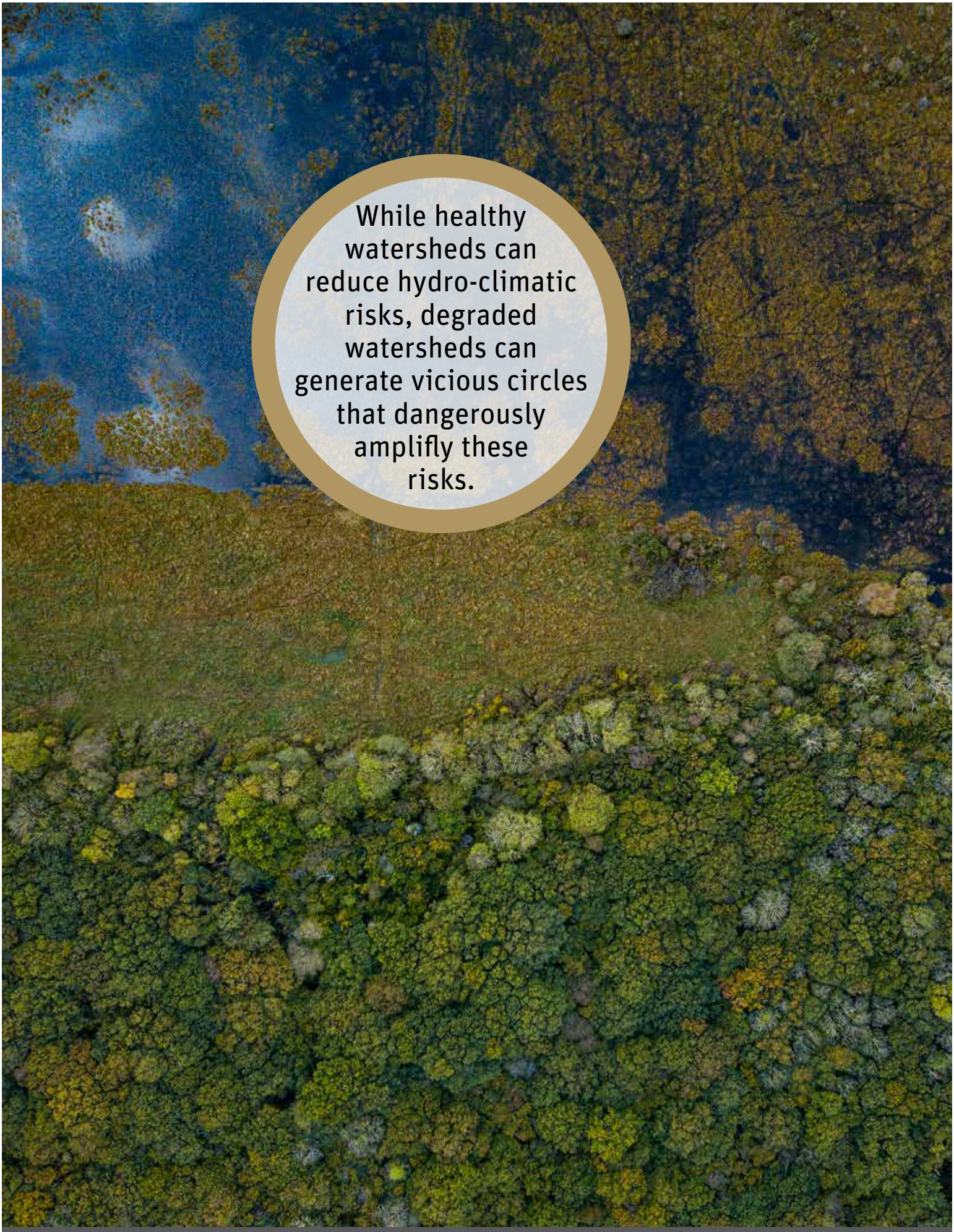


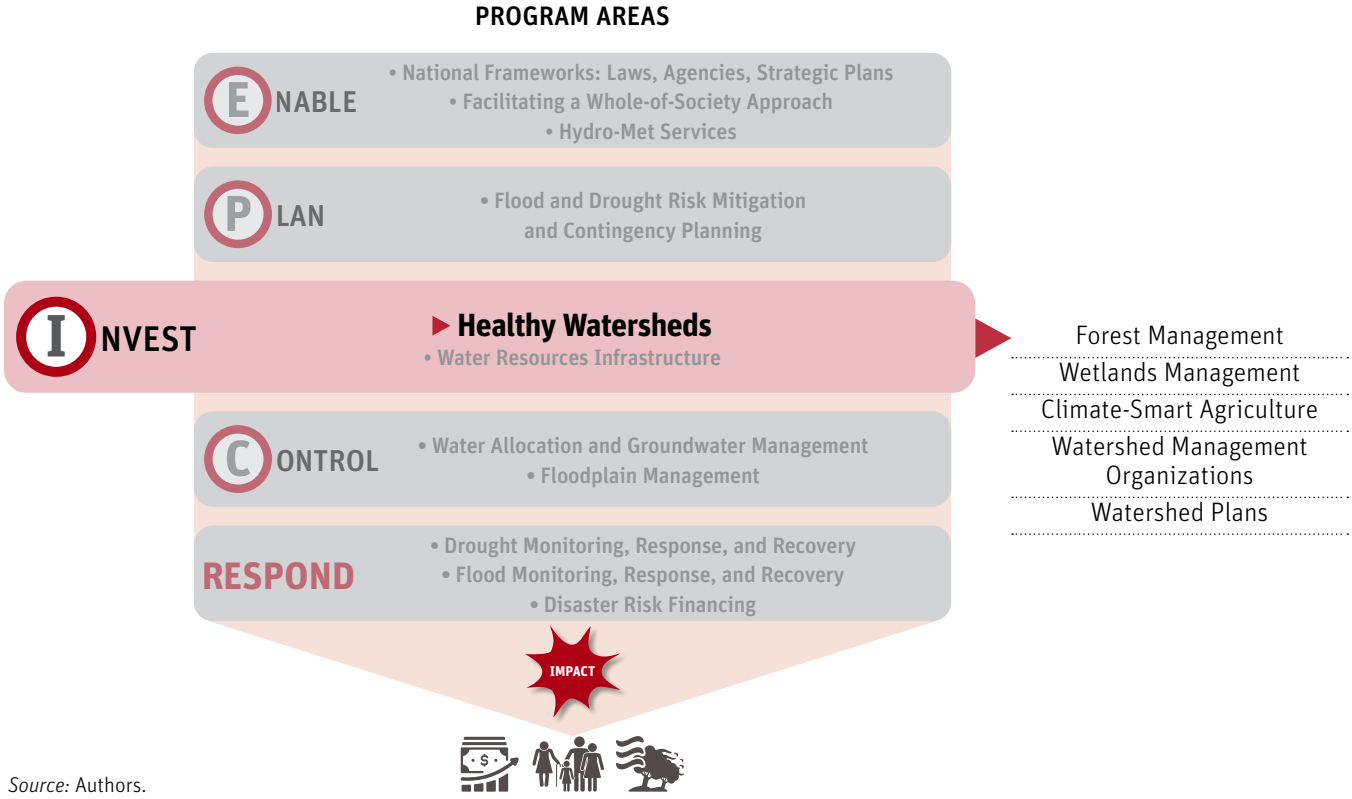
St. John's Wood, Ireland. Photo: levers2007

7 Healthy Watersheds

A river basin and a watershed cover the same geographical area, namely an area of land that drains all the streams and rainfall to a common terminus, usually the sea. As presented in Chapter 6, WRM agencies traditionally use the term "river basin" when dealing with issues related to water resources management functions. Natural resources agencies and agriculture agencies typically use the term "watershed" and put more focus on land use management. IWRM looks at both dimensions and considers how weather, watersheds, and water interact to affect water security—including during hydro-climatic extremes.

As depicted in Figure 7.1, healthy watersheds are the first physical line of defense in the Framework because they can help to reduce flood and drought hazards through natural processes. These "nature-based solutions" in turn can help reduce the demands on water resources infrastructure by providing eco-based services that reduce flood peaks, increase base flows, and improve water quality (UNESCO

FIGURE 7.1 Healthy Watersheds in the EPIC Response Framework



Source: Authors.

2018). Healthy watersheds not only help reduce hydro-climatic hazards, but they often also generate many other benefits, such as improved livelihoods, increased biodiversity, and broader ecosystem services.

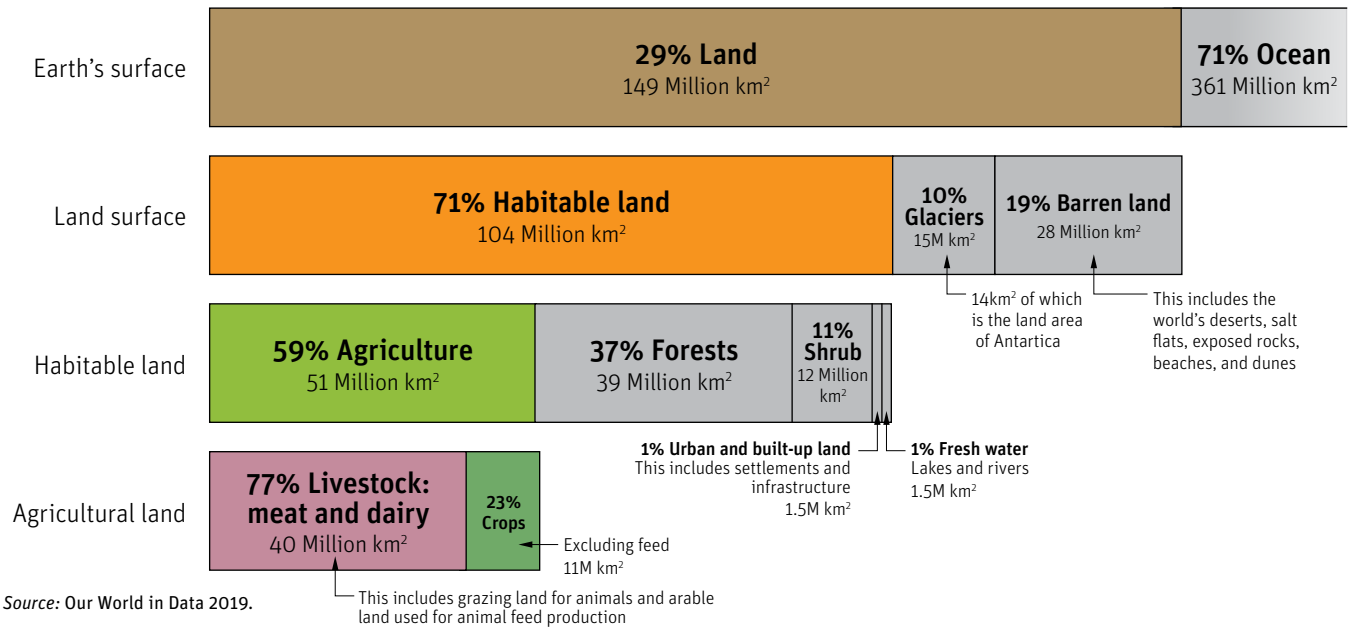
As shown in Figure 7.2, on a global basis agriculture and forests account for most of the habitable land use; even shrubland is often used for marginal livestock grazing activities. The ways we manage forests and wetlands and practice agriculture determine in large measure the health of watersheds. Land degradation is a global challenge that affects everyone through food insecurity, higher food prices, climate change, hydro-climatic hazards, and the loss of biodiversity and ecosystem services. Land degradation is happening at an alarming pace, contributing to a dramatic decline in the productivity of forests, croplands, and rangelands worldwide. Globally, about 25 percent of the total land area has been degraded and this rate is increasing at an alarming rate. Around 3.2 billion people are affected by land degradation, especially rural communities, smallholder farmers, and the very poor. The problems are particularly severe in the driest parts of the planet. Dryland landscapes cover approximately 40 percent of the world's land area and support two billion people. Many people who depend on drylands live in developing countries, where women and children are the most vulnerable to the impacts of land degradation and drought.[21]

This chapter focuses on the role that natural resources agencies and agriculture agencies play in ensuring healthy watersheds and reducing hydro-climatic risks. For the purposes of this report, the broad term natural resources agency is used to describe an agency that deals with environmental or natural resources management issues. It could be a single agency, such as a forestry department in an agriculture ministry or an environment agency. Or there could be multiple agencies, depending on the country context. Natural resources agencies can implement programs to promote healthy forests, protect wetlands, and conserve natural coastal barriers. Agriculture agencies can manage programs to promote climate-smart agriculture, including soil and water conservation, for both cropland and rangeland.

Bringing all these programs together through an integrated landscape management approach at the watershed level helps to identify priorities and ensure synergies between the different programs. Natural resources or agriculture agencies have leading roles to play in preparing watershed management plans and sustaining community-level watershed management organizations.

The key programs reviewed in this chapter are presented below. Because of the broad scope of these programs, this chapter presents the programs in a more general manner with less detail than programs in other chapters. The applicability of a specific program will depend on the geographical context of the country concerned. In addition, there will certainly be other programs that address the specific environmental or agricultural needs of a country, but the set of programs described in this chapter is often the most relevant for hydro-

FIGURE 7.2 Global Land Use Distribution



Source: Our World in Data 2019.

[21] This information was taken from the Global Environment Facility webpage on Land Degradation at https://www.thegef.org/topics/land-degradation.

climatic risk management. Chapter 10 covers issues related to floodplain management.

- **Agriculture Policies and Climate-Smart Agriculture.** Agricultural subsidy policies have a profound impact on sustainable land and water use. For example, subsidized irrigation water pricing may result in overuse of water in agriculture, while price supports for certain crops may encourage farmers to overproduce crops ill-suited for a given hydro-ecological zone. Governments thus need to adopt agricultural policies that not only promote food security and nutrition, but also environmental stewardship. Agriculture agencies should administer programs that help farmers adopt climate-smart practices that reduce soil erosion, increase soil water retention, increase climate resilience, and reduce greenhouse gas emissions. These programs can provide technical assistance and, in some cases financial incentives. Cropland and rangeland management is particularly important in arid or mountainous regions, which are more susceptible to land degradation.
- **Forest Management.** In many countries, the upper elevations of a watershed are covered by forests. Such forests play a critical role in reducing downstream peak flood discharges and sediment flows. Forests along rivers and coastlines also provide important lines of protection against floods. Managing these forests in a sustainable manner is, in many countries, a critical flood risk management activity. The natural resources agency must fashion fit-for-purpose programs that balance competing interests, such as forest conservation and the needs of local communities and timber harvesters.
- **Wetlands Management.** Wetlands play important roles in both flood and drought management. In periods of high rainfall, wetlands soak up water that would flood elsewhere. During droughts, they provide water to aquifers or streams to help reduce drought hazards. Protecting these wetlands from agricultural or urban development is typically a core mandate for the natural resources agency. That agency can use a variety of instruments, such as permitting requirements, and it can also work with local governments and communities.
- **Local Watershed Management Organizations.** To a large extent, all the programs highlighted in this chapter rely upon active community engagement. Communities are typically most knowledgeable about their local challenges and sustainable approaches. Agencies should thus help create and sustain local watershed management organizations that work in partnership in the implementation of the various programs.
- **Watershed Planning.** Natural resources agencies, working in close collaboration with other agencies and a broad group of stakeholders, should periodically prepare an overall assessment and strategic plan for improving watershed health. This includes examining overall watershed quality and the performance of various natural resources management and agricultural programs in that specific watershed. The watershed management planning should be closely linked with and serve as input into the river basin plans highlighted in Chapter 6.

A key feature of these programs is the variety of land tenure arrangements that may apply. Land may, for example, be publicly owned and managed, privately owned and managed, or publicly owned but managed or used by local communities or private entities. In many countries, local or customary law land tenure rules may be relevant, and these may or may not be recognized by the formal law of the country concerned. The specific design of the programs will need to carefully consider the nature of land tenure arrangements.

7.1 Agricultural Policies and Climate-Smart Agriculture Programs

As highlighted in Figure 7.2, almost half the habitable land on the planet is dedicated to agriculture. Livestock production accounts for 77 percent and crop production for 23 percent of agricultural land use. Agriculture agencies around the world are broadening their mandates to not only include food security (including nutrition) and economic development, but also to promote land stewardship and climate-smart agriculture.

Agriculture operates at many different scales. Around 1 percent of the world's farms operate 70 percent of crop fields, ranches, and orchards. Large industrialized agriculture is common in developed countries, and this trend is also spreading to developing countries. Globally, between 80 and 90 percent of farms are family or smallholder owned. But these small farms cover only a small and shrinking part of the land and commercial production. Asia and Africa have the highest levels of smallholdings, where human input tends to be higher than chemical and mechanical factors (Anseeuw and Baldinelli 2020).

Program Description

Agricultural Economic Policies. Agricultural economic policies can have a significant impact on land use, sometimes motivating farmers to grow inappropriate crops and utilize excessive amounts of water. To ensure food security and in

conjunction with the Green Revolution starting in the 1960s, many governments adopted subsidy programs to promote the production of key staple crops (such as rice, wheat, and maize), support poor farmers, and keep food prices low. This helped to both combat rural poverty and ensure food security. These subsidies took the forms of below-cost irrigation water, subsidized inputs such as fertilizers and pesticides, and crop price support programs. Although in many countries these policies did in fact increase the supply of cheap food and address food security concerns, they also contributed to land degradation and water use inefficiency (Pingali 2012).

Adjusting these agricultural policies to ensure the availability of nutritious food for the poor while reducing the environmental impacts of agriculture is the paramount agriculture policy imperative for the 21st century. It will not be politically easy, as many vested interests have emerged around existing subsidy regimes and governments are understandably wary about tampering with policies that may affect the production of food staples. Yet a Green Revolution 2.0 (GR2.0) is needed—and is emerging—to meet the world's food demands, ensure environmental sustainability, and meet the challenges of climate change.

By 2050, the global population is projected to increase by about one-third, which will require a 70 percent increase in food production. GR 2.0 needs to not only increase basic cereal productivity (for example, wheat, rice, and corn) to meet the demand for staples, but also to make more land available for higher value and more nutritious crops, such as fruits, vegetables, and legumes. In addition, it should allow for the movement of labor out of agriculture when other economic opportunities provide greater returns. GR 2.0 must also improve the tolerance of crops to stresses, both climatic and biotic (pest and disease). Improved varieties that are tolerant to drought or excess water would enhance smallholder productivity in marginal environments and provide tools to adapt to climate change (Pingali 2012).

Agriculture agencies, working in collaboration with farmers and agribusiness, need to show leadership in this transition to a GR 2.0. They can adjust agricultural policies to focus on improving productivity, gradually reducing subsidies that distort incentives for sustainable land management, and fund programs that support climate-smart agriculture. Governments can also work with the private sector and farmers to promote the use of new technologies, such as a greater focus on precision agriculture, the internet of things (IoT) and the use of big data—sometimes referred to as "agriculture 4.0" (De Clercq and others 2018).

Climate-Smart Agriculture Programs. Agricultural water and soil conservation programs have historically been a focus area for mitigating drought hazards. As an example, the U.S. Soil Conservation Service was created in response to the great Dust Bowl in the American prairies in the 1930s. In response to climate change, the approach has been broadened to include climate-smart agriculture (CSA). CSA aims to improve agricultural and livestock productivity while delivering greater resilience to climate change and lowering greenhouse gas emissions. There are a wide variety of CSA practices that the agriculture agency can help farmers adopt, some of which are mentioned below:[22]

Soil Management. Maintaining or improving soil health is essential for sustainable and productive agriculture. "Healthy" soil will help to push sustainable agricultural productivity close to the limits set by soil type and climate. Common soil management practices include no-till agriculture, covering soil with vegetation, reducing on-farm runoff and erosion, reducing the use of chemical fertilizers, and maintaining soil carbon levels and quality with organic fertilizers.

Crop Production. Crop productivity can be increased through the breeding of higher yielding crop varieties, though crop and crop nutrient management, and through the choice of crop species that have higher yield potentials under given environmental conditions. Crops can also be bred for greater drought tolerance, and shorter-duration varieties can be used for "terminal drought escape". Similarly, breeding for resistance to the pests and diseases that are triggered by weather events provides another important source of climate risk reduction.

Livestock Production. Climate change is likely to have considerable impacts on livestock production in the coming decades. These will include a substantial reduction in the quantity and quality of forage available in some regions and heat stress in animals. Higher temperatures, changing rainfall patterns, and more frequent extreme weather events may also impact the spread and severity of existing vector-borne diseases and macro-parasites, accompanied by the emergence and circulation of new diseases.

CSA livestock activities include improved grazing management, the use of more drought-resistant pasture and agroforestry species, and diet supplements. Animal health can be improved through better vaccination projects and the use of more disease- and heat-tolerant animal species. Herd size and age structure can also be adjusted to ensure more resilience. Better management of manure can also lead to increased productivity of both food and fodder crops.

[22] This information was drawn from the Climate-Smart Agriculture website at https://csa.guide/. The website was developed by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) for the World Bank.

It is also important to keep livestock away from sensitive riparian or wetland areas through fencing and the provision of alternative water supplies.

Water Management. Agriculture is the largest consumer of the world's freshwater resources, requiring 70 percent of the available supply. Of that, almost 40 percent is used for rice production. Chapter 6 discussed the importance of improving irrigation system water use efficiency and preparing for droughts. There are also on-farm water management practices that can help boost both productivity and resilience. Flooded rice systems emit substantial amounts of the greenhouse gas methane (CH_4). Alternate wetting and drying cycles in such systems not only save water, but also result in greatly reduced methane emissions. On-farm practices can improve the capture and retention of rainfall, helping to sustain rainfed agriculture or reduce supplemental irrigation requirements. Improved scheduling and application of irrigation water will help boost both resilience and productivity.

Agroforestry. In smallholder systems in developing countries, farms and forests are often part of complex rural landscapes, which collectively fulfill the livelihood needs of the rural population. By adopting agroforestry practices on farms, farmers are able to harvest tree products, supplement their diets, and also develop additional income streams. Integrating trees into farming systems can also improve soil quality, leading to higher and more stable crop yields. Healthy and diverse ecosystems are also generally more resilient to natural hazards. Trees on farms can be used as shelterbelts and windbreaks, and play an important role in protecting against landslides and floods. Trees also stabilize riverbanks and mitigate soil erosion. Agroforestry practices can also increase the absorptive capacity of soil and reduce evapotranspiration. The canopy cover from trees can also have direct benefits. It reduces soil temperature for crops planted underneath and reduces runoff velocity and soil erosion caused by heavy rainfall.

Linkage to the National Sector Framework

Agriculture law provides the overall framework for all agricultural-related activities in a country. It is generally broad and can address many different issues, such as price supports and subsidies, agricultural-related infrastructure, training and extension services (including farmer field schools), agricultural inputs (seed, water, and fertilizer), finance, labor, marketing, insurance, trade, and agricultural processing. As agriculture law has evolved over time, new subjects have emerged such as land stewardship and sustainability, animal welfare, and food safety.

Agriculture law should highlight the importance of land stewardship and its importance in maintaining a healthy environment and reducing hydro-climatic risks. Box 7.1 provides an overview of the European Union's Common Agricultural Policy and its environmental goals. As in other sectors, there should be periodic national strategic plans that look at agriculture from a broad and integrated perspective. Of particular importance is ensuring that different policies work in synergy. For example, subsidies and price support for water-consuming crops such as sugar cane or rice may clash with other objectives such as drought resilience, water

Box 7.1 Environmental Sustainability in the European Union's Common Agricultural Policy (CAP)

The reformed CAP has three clear environmental goals: tackling climate change, protecting natural resources, and enhancing biodiversity. Each of these goals is supported by the CAP's promotion of organic farming and the responsible management of inputs like pesticides and fertilizers. The CAP aims to reach its environmental goals in a way that is socially and economically sustainable for farmers, rural communities, and the EU as a whole.

Measures that encourage green farming and enforce environmental rules form a central part of the CAP and include: (1) cross-compliance standards that link financial support to EU rules on the environment, as well as to human, plant, and animal health; (2) green direct payments that put in place mandatory actions (such as maintaining permanent grassland, crop diversity, and ecological focus areas) geared towards protecting the environment and tackling climate change; and (3) rural development policy that supports investments and farming activities that contribute to climate action and the sustainable management of natural resources.

In the future, the CAP plans to take further steps towards achieving a green and sustainable system of agriculture in the EU. This includes actions such as a more simplified, flexible, and targeted approach; strengthened environmental conditions and standards to be met by farmers; and an expanded set of voluntary environmental actions available to farmers, through eco-schemes and rural development policy.

Source: Information included in this box was drawn from European Commission (2019).

allocation efficiency, or sustainable land management. The law should authorize the agriculture agency to implement programs that support CSA that is suitable for the specific country context.

Key Agency Actions

Agricultural activities are spread over wide areas involving large numbers of people, and thus traditional regulatory programs for land stewardship are difficult to implement. Agriculture agencies will need to develop economic policies and support programs for climate-resilient agriculture that meet the specific agricultural ecological and socioeconomic context using a variety of approaches. Some general considerations are highlighted below:

Make environmental sustainability a core agricultural policy objective. The environmental impacts of agricultural subsidy policies should be explicitly considered with an aim of gradually reducing subsidies that have negative environmental impacts. Input subsidies for water, fertilizer, and pesticides that provide incentives for overuse could be gradually scaled back. Output subsidies like price supports that encourage farmers to produce resource-intensive crops (such as sugar cane or rice) that may not be suitable for the specific agro-ecological zone could be adjusted. Conversely, agricultural policies could be utilized to promote the production of more environmentally sustainable and potentially more profitable and nutritious products such as fruits, vegetables, and pulses—potentially offering incentives for organic and sustainably produced food.

- **Create partnerships with farmers and livestock producers.** Agriculturalists need to be convinced that CSA activities not only contribute to healthy watersheds, but that these practices also will benefit them economically, including making them more resilient to hydro-climatic extremes. This requires extensive consultation with farmers and livestock producers to share knowledge on CSA programs and also to adapt these approaches to meet the specific local needs.
- **Develop CSA practice standards.** As indicated above, there are many potential CSA practices, and the agriculture agency needs to develop clear standards of practice that are suitable for the local context and that can be used to help eligibility for grant funding.
- **Provide incentive funding or green payments for smaller operations.** Many smallholder operations may not be able to implement CSA activities due to financial constraints, even when those activities are in their broader economic interests. The agriculture agency can develop specialized programs to provide technical and financial assistance to these agriculturists, making payments for activities that meet the practice standards.
- **Promote farm sustainability plans.** Larger and more sophisticated operations should be encouraged to develop farm sustainability plans that draw upon the practice standards. The agriculture agency can provide technical assistance or even grant funding for the formulation of these plans. In some cases, it may be a regulatory requirement to prepare and implement these plans with periodic monitoring by the agency. In some cases, larger farms could also be eligible to receive green payments for modified agricultural practices.
- **Create linkages to WRM plans.** Agricultural land use and practices should be addressed as appropriate in the National Strategic WRM Plans, as well as in river basin plans, to ensure recognition of the role of these practices in flood and drought risk management.

Generic Evolution

The generic evolution of agricultural programs is summarized in Table 7.1.

TABLE 7.1 Generic Evolution of Agricultural Policies and Programs

Nascent	Engaged	Capable	Effective
Agriculture law, subsidy policies, and support programs focus on agricultural production and do not address environmental sustainability.	Agriculture law expanded to include environmental sustainability. The agriculture law now authorizes environmental conservation programs. Programs in early stages of implementation.	Agriculture law and programs expanded to include environmental sustainability and climate-smart agriculture. Extension activities and financial support to help farmers implement climate-smart agriculture well-established.	Agriculture law, subsidy policies, and programs synchronized to promote environmental sustainability.

Source: Authors.

7.2 Forest Management

Forests can occur anywhere in the watershed, but in many countries the more accessible lowland forests have been cleared for agricultural and urban use. Forested areas in the higher elevations of the watershed are of particular importance for hydro-climatic risk management. Steep terrain, thin soils, and generally more intense rains due to orographic effects can result in rapid runoff with high sediment levels. Forests help to mitigate this impact through various pathways, such as acting a buffer between precipitation and the soil, and holding soil together through the trees' root systems. At the same time, it is important to recognize that the relationship between forests and water resources is complex. Forests can substantially reduce levels of runoff, leading to significant reductions in dry season flows and therefore water availability. As a result, some countries require authorization for new forest plantations based on water resources laws.

There are many different types of forests, with three broad classifications generally used: temperate, tropical, and boreal.[23] Temperate forests are found across eastern North America and Eurasia. The temperatures of temperate forests vary throughout the year because of the four distinct seasons at these latitudes. Tropical forests are common to warmer areas near the equator, such as Southeast Asia, Sub-Saharan Africa, and Central America. Boreal forests, one of the world's largest land biomes, are found across Siberia, Scandinavia, and North America (Alaska and Canada). Temperatures in boreal forests are, on average, below freezing. Forests can also be divided into natural forests or plantation forests.

Program Description

The natural resources agency has several different options for managing forests on public lands depending on the specific context. Although this is a vast and complex topic, Table 7.2 presents four general management approaches for illustrative purposes.[24] These approaches are not mutually exclusive. For example, within the same forest areas, the natural resources agency may reserve some land for conservation, ensure sustainable forestry in public and private lands, and enter into arrangements with local communities including indigenous groups.

Linkage to the National Sector Framework

Due to the importance and complexity of forest management, most countries have a standalone forest law. Such a law typically governs activities in designated forest lands, most commonly with respect to forest management and timber harvesting and pertains to both public and private land. A forest law sets out general policies such as multiple and

TABLE 7.2 General Forest Management Approaches

Approach	Description	Applicability
Conservation Forestry	Limited economic activity allowed. The forest is used primarily for protecting ecosystem services and biodiversity, and for recreational purposes.	Publicly-owned and controlled forests. This could also include easements on private lands.
Sustainable Forestry	Economic activity related to forest products and services is allowed under a natural resources agency regulatory system based on sustainable forest management practices that protects ecosystem services and biodiversity. Financial incentives and technical assistance may be offered to landowners to help them more sustainability manage forests.	Publicly-owned and controlled forests or privately-owned forests.
Community Forestry	The local community plays a significant role in forest management and land use decision making with the support and facilitation of the government and non-governmental organizations. Financial incentives and technical assistance may be offered to communities.	Forests where local communities, often indigenous peoples, have traditional forest use rights.
Unmanaged	Government has no authority in the forest area. This may be due to armed conflict, lack of accessibility, or lack of government capacity.	

Source: Authors.

[23] This information was taken from the National Geographic's webpage on Forest Biomes, available at https://www.nationalgeographic.org/encyclopedia/forest-biome/#:~:text=There%20are%20three%20general%20types,eastern%20North%20America%20and%20Eurasia.

[24] For more information about the general forest management approaches, see the FAO Sustainable Forestry webpage at http://www.fao.org/forestry/sfm/85286/en/.

Box 7.2 Forest Management in the Philippines

The Forest Management Bureau (FMB) under the Department of Environment and Natural Resources (DENR) takes the lead in the planning and implementation of watershed management programs. Most of the programs undertaken to reduce downstream flooding include reforestation, agroforestry, forest conservation, and protection. Recently, the DENR embarked on the limited construction of water retention dams in selected upstream rivers in which watersheds are highly degraded and are causing perennial flash flooding downstream. The DENR has also been implementing efforts to move from state managed forests to community-based forest management through land tenure reform.

The creation of the River Basin Control Office (RBCO) under the DENR, which is mandated to promote and advocate an integrated river basin management to ensure the protection of the environment and people against flood and natural disasters, has further strengthened the department's function in coordinating the different efforts of the government in upper watershed management. Vertical coordination among the regional, provincial, and city and municipal entities has been improved, and horizontal coordination among sectoral agencies has become more proactive.

The DENR's National Greening Program (NGP) involves the protection and restoration of degraded forest lands to increase their resilience to drought and flooding, among other environmental benefits. The program also aims at reducing poverty, mitigating and adapting to climate change, and improving food security, environmental stability, and biodiversity conservation. The NGP was launched in 2011 by Executive Order and declared by the President as a priority. Between 2011 and 2018, the NGP has successfully reforested more than 1.91 million hectares, exceeding the original target. The program was extended until 2028 to cover the remaining 7.1 million hectares of unproductive, denuded, and degraded forestlands nationwide. As of the beginning of 2020, the DENR started a "family program" that promotes the use of fast-growing indigenous species within plantations to ensure the conservation of biodiversity and the integrity of the forest ecosystem.

Key issue: Community-based forest management programs need to be based on long-term commitments from smallholders to contribute to the objectives of poverty alleviation and sustainable management of forest resources. Notably, there is no "one-size-fits-all" under these programs, as local conditions, capacities, and technical expertise may vary across areas, so the incentives in each forestation site should be individually crafted. Additionally, auditing of forest management programs and outcome-based monitoring and evaluation should be put in place to adjust the programs according to the results.

sustained use by which forest lands are to be managed and should also recognize the rights of local or indigenous communities who have traditionally relied upon forest resources. Protected area laws may also play an important role in forest management.

The role of forests in reducing flood and drought risks should be highlighted in the forest law. The law should also mandate a periodic National Forest Strategic Plan (like WRM and DRM National Strategic Plans) and the preparation of site-specific forest management plans for high-priority areas. The forest law should also authorize specific forestry management programs, which can include a wide variety of interventions such as multi-purpose public forest management, regulation of timber harvesting, and community forestry. At the same time, it is important to ensure that there is a link between river basin plans, as described in Chapter 6, with forest management planning by identifying, for example, forested areas that are in particular need of protection from a WRM perspective.

Two types of forest programs are particularly important for hydro-climatic risk management. The first are upper-watershed programs that are dedicated to promoting soil and water conservation. Globally, an estimated 400 million hectares of forest land have been designated primarily for the protection of soil and water. That represents a four-fold increase since 1990.[25]

In some cases, soil and water conservation practices can be promoted though forestry regulations. In other cases, agency-administered incentive programs may also be required to help private landowners or local communities absorb the additional costs or lost income caused by implementing forestry-related soil and water conservation practices. In this regard there is potential to link funding for improved forest management with WRM through payment for environmental services (PES) programs under which forest rights holders are paid to maintain forested areas by downstream beneficiaries of lower runoff.[26] This can be a cheaper alternative in terms of reducing flood risks than the construction of water infrastructure.

[25] This information comes from the FAO webpage on sustainable forestry management for soil and water conservation, available at http://www.fao.org/forestry/sfm/85293/en/.

[26] Payment for environmental services (PES) is also sometimes referred to as green payments or conservation payments.

The second type of program aims to protect, manage, or restore coastal forests. An important example of coastal forests are mangroves in tropical regions. Mangrove forests are important for fisheries, timber, and plant products, and they also play a critical role in coastal protection. Their dense root systems trap sediments flowing down rivers and off the land. This helps stabilizes the coastline and prevents erosion from waves and storms. In areas where mangroves have been cleared, coastal damage from hurricanes and typhoons is much more severe. By filtering out sediments, the forests also protect coral reefs and seagrass meadows from being smothered in sediment. Managing coastal mangroves typically involves working with local communities to develop management plans and often providing financial incentives.

Key Agency actions

Some general considerations for the natural resources agency managing forests include:

- **Establish dedicated forest management units.** The agency should set up and maintain dedicated forest management units to oversee specific forest-related programs (such as in upper watersheds or in coastal forests).
- **Prepare a standalone national strategic forestry plan or policy.** Standalone national strategic forestry plans or policies should be prepared and incorporated into the broader periodic national strategic natural resources management plan.
- **Identify forests at risk and prioritize responses.** The relative importance of forests in ecological, social, and hydrological terms (including as regards flood mitigation) should be identified and the protection measures should then be prioritized and implemented accordingly. Such measures could include programs for reforestation.
- **Designate forests as protected areas, where needed.** Forests with the greatest need for protection should be designated as protected areas under the natural resources management or protected areas law, particularly those areas that serve as critical watersheds for urban water supplies.
- **Adopt and implement forest management regulations.** Standards of practice for sustainable forestry, including timber harvesting, should be developed. Significant timber harvests on private or public lands should be permitted and regulated to ensure sustainability of forest ecosystems. Special approaches may be required for forests that are owned collectively by local communities.
- **Create linkages to WRM plans.** Forest management issues should also be addressed, as appropriate, in the National Strategic WRM Plans as well as in river basin plans to ensure recognition of forests' role in flood and drought risk management.

Generic Evolution

TABLE 7.3 Evolution of Forest Programs

Nascent	Engaged	Capable	Effective
Forest law focused on production with limited attention to environmental sustainability or scope for community use of public forests.	A modern forest law that highlights environmental sustainability and ecosystem services is adopted. Forestry management programs are in early stages of implementation and focused primarily on state owned land. No forestry regulations exist for privately owned land.	The natural resources agency is implementing multiple forestry programs authorized through the forest law. Regulations are in place for managing forests on private land, but regulatory control is limited. The role of forests in hydro-climatic risk management is recognized in forest policies and there is initial use of payment for environmental services (PES) schemes.	Forest laws have undergone multiple amendments and programs are operating effectively. The role of forests in hydro-climatic risk management is clearly reflected in the forest law and the water resources law and related programs. The natural resources agency is ensuring sustainable management of forests through regulation and community engagement as well as the extensive use of PES schemes.

Source: Authors.

Dust bowl, Texas Panhandle, March 1936. Photo: Arthur Rothstein

7.3 Wetlands Management

Wetlands provide vital ecosystem services, including reducing flood hazards, improving water quality, and helping to recharge aquifers. As in the case of forests, there are many different types of wetlands with five broad classifications often employed (Cowardin and others 1979):

- Marine wetlands, exposed to the open ocean.
- Estuarine wetlands, partially enclosed by land and containing a mix of fresh and salt water.
- Riverine wetlands, associated with flowing water.
- Lacustrine wetlands, associated with a lake or other body of fresh water.
- Palustrine wetlands, freshwater wetlands not associated with a river or lake.

Marine and estuary wetlands are particularly important for helping to absorb storm surges as well as being critical ecological habitat. Wetlands are among the most biodiverse ecosystems on Earth and can sometimes store more carbon per hectare than can tropical forests.

It has been estimated that wetlands cover approximately 7 percent of the world's land surface.[27] Unfortunately, wetlands are under development pressure in many countries, as urban areas grow over wetlands or farmers drain them to expand agricultural or aquaculture activities. Reduction of freshwater flows to wetlands or destructive storm surges can also damage wetlands.

Program Description

There are a variety of approaches to wetlands management which are summarized below in Table 7.4. As with forest management, these approaches are not mutually exclusive. National wetlands management programs might be linked to global efforts, particularly the Ramsar Convention, which currently has 171 Contracting Parties. The Ramsar

[27] This information was taken from Cassidy, Emily. 2019. "Map of the Month: Where Are the World's Wetlands?" Resource Watch (blog), April 17, 2019. https://blog.resourcewatch.org/2019/04/17/map-of-the-month-where-are-the-worlds-wetlands/.

Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world." National programs might benefit from the resources and analytical work provided with the Ramsar bodies (in particular from the Scientific and Technical Review Panel). They also can contribute to global monitoring efforts such as the Global Wetland Outlook.

Linkage to the National Sector Framework

Wetlands management issues are often addressed in a framework natural resources management law or, depending on the relative importance of wetlands in the country concerned, in a standalone wetlands law. Particularly where they have high ecological, botanical, or zoological importance, wetlands may be designated as protected areas on the basis of natural resources management laws or specific protected area laws. However, water resources laws also have an important role to play in wetlands management in terms of ensuring that over-abstraction does not harm wetlands through the implementation of minimum or environmental flows and identifying wetlands that merit protection from a flood defense or water management perspective.

Drawing upon the Ramsar Convention terminology (UNESCO 1971), laws should highlight the "wise use" of wetlands, which is defined as "maintenance of their ecological character, achieved through an ecosystems approach, within the context of sustainable development." The wise use concept is about maintaining wetlands values and functions, while at the same time delivering services and benefits now and into the future for human well-being (Ramsar Convention Secretariat 2010).

The wetlands law should also address generally applicable issues such as the need for integrated planning (potentially linked to river basin planning), environmental impact and permitting programs, and habitat and species conservation. The law may also authorize a variety of incentive programs for landowners and communities to help them maintain, improve, or restore wetlands. The law should also include provisions for site-specific measures, such as the designation of protected wetlands, the development of wetlands management plans, and participatory management. Coordination between different levels of government as well as international cooperation through the Ramsar Convention should be highlighted.

Key Agency Actions

- **Establish a dedicated wetlands management unit.** The natural resources management agency should set up and maintain a dedicated wetlands management unit to oversee wetlands-related programs in the country.
- **Prepare a standalone national strategic wetlands plan.** Standalone national strategic wetlands plans should be prepared and incorporated into the broader periodic national strategic natural resources management plan.

TABLE 7.4 General Wetlands Management Approaches

Approach	Description	Applicability
Wetlands Conservation	The wetland is protected by law from development, with limited economic activity allowed.	Publicly owned and controlled wetlands. This could also include wetland easements on private lands.
Wetlands Regulation	An agency-issued permit is required to modify a significant wetland. Permit principles include showing avoidance of damage to wetland resources to the greatest extent possible, minimization of unavoidable impacts, and mitigation activities where appropriate. Financial incentives and technical assistance may be provided to landowners to help them sustainably manage their wetlands.	Publicly or privately owned lands.
Community Wetlands	The local community plays a significant role in wetlands management and land use decisions with the support and facilitation of the government and non-governmental organizations. Financial incentives and technical assistance may be provided to communities.	Wetlands where local communities, sometimes indigenous peoples, have traditional wetlands use rights.
Unmanaged	Government has no authority in the wetlands area. This may be due to armed conflict, lack of accessibility, or lack of government capacity.	

Source: Authors.

- **Develop a wetlands inventory and prioritize management of wetlands at risk.** A wetlands inventory is instrumental in identifying and cataloguing wetlands as well as in establishing key indicators to monitor trends on the health and services provided by wetlands. The inventory can highlight the relative importance of wetlands in ecological, social, and hydrological terms (including as regards flood mitigation), and help identify the wetlands at risk requiring specific measures.
- **Designate wetlands as protected areas.** Wetlands with the greatest need of protection, including those relevant to the Ramsar Convention, should be designated as protected areas under the natural resources management or protected areas law.
- **Develop wetlands management plans for high priority wetlands.** Multi-purpose wetlands management plans should be developed for areas where communities rely economically upon wetlands, for example fisheries, agriculture, tourism, or other activities. These plans need to account for the economic needs of the community while ensuring wetlands ecosystem integrity.
- **Adopt and implement regulations relating to wetlands development.** The agency should develop criteria and standards of practice for assessing proposed developments in wetlands, including reclamation (by filling in the wetland). Significant development activities should be subject to an environmental impact assessment and a permitting scheme.
- **Create linkages to WRM plans.** Wetlands management issues should also be addressed, as appropriate, in the National Strategic WRM Plans as well as in river basin plans to ensure recognition of wetlands' role in flood and drought risk management.

Generic Evolution

The generic evolution of this program of wetlands management programs is summarized in Table 7.5:

TABLE 7.5 Generic Evolution of Wetlands Programs

Nascent	Engaged	Capable	Effective
Wetlands are referred to in the natural resources management law but there are no dedicated programs for their management.	Wetlands are highlighted in the natural resources management law. Wetlands management programs are authorized under the law, but still in early stages of implementation. Limited linkage with WRM programs.	The natural resources agency is implementing multiple wetlands programs. Regulations are in place for managing wetlands on private land, but regulatory control is limited. Linkages with the WRM agency and the river basin planning process/WRM programs are established.	Wetlands management programs are operating effectively. There is extensive coordination between the natural resources agency and the WRM agency and the specific role of wetlands in hydro-climatic risk management is fully reflected in river basin plans and the coordination of programs.

Source: Authors.

7.4 Watershed Management

Watershed management refers to the judicious use of all the natural resources, including land, water, and vegetation, to help ensure environmental sustainability and improve the welfare of people living in the watershed. Sound watershed management will help to alleviate drought, moderate floods, prevent soil erosion, improve water availability, and help to sustain the production of food, fodder, fuel, and fiber. The terms landscape management and watershed management are often used interchangeably with the main distinction being that watershed management focuses more on hydrological boundaries and functions.

Watershed management and river basin management have many common areas and synergies but are also distinct activities. River basin management, as highlighted in Chapter 6, is overseen by the WRM agency while watershed management is normally led by the natural resources or agriculture agency. Watershed management is a process for natural resources and agriculture agencies to help integrate and prioritize the various national forest, wetlands, and agricultural programs described in previous sections. Watershed management requires a whole-of-society approach to be successful and some of the guiding principles are highlighted in Box 7.3.

Box 7.3 Principles of Landscape/Watershed Management

Landscape management involves a holistic approach to achieving productive and healthy ecosystems by integrating social, economic, physical, and biological needs and values, and it contributes to sustainable and rural development. It is based on four overarching principles:

- Targeted policy and institutional support, including the development of incentive mechanisms for landscape management adoption and income generation at the local level.
- Land user-driven and participatory approaches.
- Integrated use of natural resources on farms and at the ecosystem scale.
- Multilevel, multi-stakeholder involvement and partnerships at all levels, including land users, technical experts. and policy makers.

Information included in this box was drawn from the FAO Sustainable Land Management webpage at http://www.fao.org/land-water/land/sustainable-land-management/en/.

Key Issue: Although conceptually sound, landscape or watershed management is extremely challenging to apply in practice as it cuts across sectors and jurisdictions and involves a wide span of stakeholders, including diverse groups of farmers and individual landowners.

Program Description

Local Watershed Management Organizations (WaMOs). These organizations can help provide a critical link between national agencies and local communities. This linkage is important because national agencies may have substantial financial resources and technical expertise, but communities often have a better sense of local priorities and are responsible for undertaking many of the actions supported by various natural resources management and agricultural programs.

In practice, WaMOs can follow hydrological or political boundaries and take on a variety of different forms and geographical coverage. In some cases, they may be legally constituted organizations that operate independently of the government. In other cases, the local government may have a specialized unit that helps organize and represent the community in its interactions with national agencies. An important consideration is that a WaMO needs to be able to take a broad landscape perspective within its area of jurisdiction and to understand how that area is nested into a larger watershed perspective. Box 7.4 provides an example of resource conservation districts in California.

Box 7.4 California Resource Conservation Districts

In response to the national Dust Bowl crisis of the 1930s, when millions of acres of cropland were destroyed by drought and the devastating loss of fertile topsoil, the U.S. Federal Government established in 1937 the Soil Conservation Service, now called the Natural Resources Conservation Service (NRCS), under the U.S. Department of Agriculture. Concern arose about whether a federal agency would be responsive to local needs, so states were asked to form Soil Conservation Districts led by local landowners serving on boards of directors to work in collaboration with and to provide local input to guide the programmatic priorities of the NRCS. The NRCS provides assistance to growers, ranchers, and landowners only in areas with Resource Conservation Districts (RCDs).

In 1938, California recognized the importance of Soil Conservation Districts and authorized their formation under the Public Resource Code. Though not governed by the state, special districts including RCDs are subject to state law concerning elections, responsibilities, and legal meetings. Soil Conservation Districts were originally empowered to work with landowners on a voluntary basis to manage soil and water resources for conservation, but these powers were expanded in the early 1970s to include “related resources”, including water quality and wildlife habitat. This expansion of powers was reflected in the change of name from “Soil” Conservation Districts to “Resource” Conservation Districts in 1971.

Most RCDs receive very little regular funding through local taxation and rely heavily on competitive grants and other types of fundraising to stay in operation. There are currently 103 RCDs, which manage diverse resource conservation projects in more than 85 percent of the state.

Agriculture and natural resources agencies should support and nurture WaMOs for a variety of reasons. WaMOs serve as an ideal conduit for public outreach and communication programs. WaMOs can also serve as a channel for implementing programs, either through block grants to WaMOs or helping to link potential beneficiaries with specific agency programs. WaMOs can also help national agencies better address social inclusion issues by providing linkages with marginalized groups such as indigenous groups, women, and landless populations. National agency support for WaMOs can take many forms, including helping in their legal establishment, funding, and providing technical assistance and training.

Watershed Management Planning. Local WaMOs working in partnership with natural resources and agriculture agencies can help address issues on a relatively small scale. It is important also to have a periodic (for example every five years) planning or assessment exercise that looks at the entire watershed and identifies key problems, objectives, and high priority activities. A watershed management plan provides an opportunity for the agriculture, natural resources, and WRM agencies to examine the effectiveness of their various programs to promote healthy watersheds and adjust where necessary. It also gives local WaMOs an opportunity to better understand how their jurisdictions are affected by and contribute to larger watershed dynamics.

Information from watershed monitoring is an important input for watershed management plans. This should be focused on aspects such as the ecological conditions and trends of key natural assets (such as strategic wetlands, forests, soil erosion, water quality and quantity, and floods and droughts), helping establish cause-and-effect relationships between natural assets and ecosystem services, and informing and updating the implementation and effectiveness of specialized programs. A strong and continuous watershed monitoring program can provide a structured framework for adaptive watershed management by associating indicator thresholds with management activities (Shames and others 2017).

Watershed planning should be done in a collaborative process with all relevant agencies, and in a participatory manner with a wide range of stakeholders including the local WaMOs. The watershed management plan should feed into the river basin plan and vice versa. This collaborative arrangement between the various agencies is a classic example of the type of joined-up government approach required to address hydro-climatic risk management.

Linkage to the National Sector Framework

Since watershed management cuts across various sectors, there is often no overarching national framework. The basic principles of watershed (or landscape) management are often highlighted in WRM, natural resources, and agriculture laws. As noted at the start of the chapter, natural resources is used in a broad sense and could include a single national sector framework or multiple sector frameworks. The relevant national framework for watershed management depends on the country context, and in many countries, it may not be well defined. This is one of the great challenges of establishing comprehensive watershed and landscape management systems.

The national sector frameworks for WaMOs and watershed planning may also be different. In some countries, the national agricultural framework is well placed to authorize the establishment of local WaMOs, as much of the watershed-related technical and financial assistance flows through the agricultural sector. A key point to note is that to be effective, WaMOs need to have independent legal authority so that they can enter into legal relationships with concerned landowners. This will usually need to be specifically addressed in a law. Watershed planning responsibility, which is more of a multi-sectoral activity, is more likely to be authorized through either the WRM or natural resources national frameworks.

Key Agency Actions

Some of the key tasks for the national agriculture or natural resources agency mandated to support local WaMOs include the following:

- **Fostering institutional arrangements,** in terms of the establishment of WaMOs at the appropriate level and ensuring they receive adequate resources so that they can effectively fulfill their functions.
- **Providing technical support to WaMOs** to enable the local implementation of preferable healthy watershed practices (such as standards of practice on upland habitat management, conservation, or crop rotation).
- **Building incentives to foster the establishment of WaMOs** and the implementation of healthy watershed programs (for example, providing benefits and support to landowners, communities, and households).
- **Supporting people-centered healthy watershed management** by providing guidance to WaMOs on how to work constantly with program beneficiaries to incorporate successful local approaches and adapt healthy watershed programs to their needs (Dargouth and others 2008). WaMOs can establish key partnerships with local communities or more permanent multi-stakeholder platforms that can be mobilized for planning, capacity building, or for a broader public awareness purpose (such as local conservation or farmer associations).

Some of the key tasks for the WRM or natural resources agency mandated to support watershed planning include the following:

- **Adopting regulations regarding the watershed planning process,** covering topics such as how often a plan needs to be prepared, the general scope and format of the plan, and the review and approval process.
- **Providing technical watershed planning guidelines,** including general methodology, sources of data, modelling approaches, linkages with other sectors, and other planning processes. The guidelines should include specific guidance on the impact of healthy watersheds on flood and drought mitigation.
- **Establishing formal roles for relevant national agencies** including WRM, natural resources, and agriculture. This could include formal review processes or co-formulation of the watershed management plan. Ensure synergies between the watershed management plan and basin or coastal management plans.
- **Ensuring public outreach and stakeholder engagement** by providing guidance on consultations, responding to feedback, and ensuring transparency. The process should ensure all relevant stakeholder groups are meaningfully engaged, with a special focus on social inclusion.

Generic Evolution

The generic evolution of watershed management programs is summarized in Table 7.6.

TABLE 7.6 Generic Evolution of Watershed Management Programs

Nascent	Engaged	Capable	Effective
No agriculture or natural resources support programs or consideration of watershed management approaches.	Agriculture and natural resources programs operational but not implemented from a watershed management perspective and no local WaMOs.	Natural resources or agriculture law authorizes creation of WaMOs and requires watershed planning. WaMOs struggle with funding and capacity. Watershed plans are formulated by a single agency.	WaMOs functioning effectively and are key partners for natural resources and agriculture agencies. Comprehensive watershed plans formulated with broad engagement by other agencies and stakeholders. Watershed plans synergize with river basin plans.

Source: Authors.

Sustainable land management is one of the greatest policy blindspots in doestic and global responses to hydro-climatic risk management.

7.5 Key Resources

Forest Management

FAO (Food and Agriculture Organization of the United Nations). 2020. "Sustainable Forestry Management for Soil and Water Conservation." November 4, 2020.

Spalding, Mark Douglas, Anna Mcivor, Femke H. Tonneijck, Susanna Tol, and Pieter van Eijk. 2014. *Mangroves for Coastal Defence: Guidelines for Coastal Managers & Policy Makers*. Wageningen: Wetlands International; Arlington: Nature Conservancy.

Wetlands Management

GWP (Global Water Partnership), and WMO (World Meteorological Organization). 2012. *Conservation and Restoration of Rivers and Floodplains*. Integrated Flood Management Tools Series no.13.

Ramsar Convention Secretariat. 2010. *Laws and Institutions: Reviewing Laws and Institutions to Promote the Conservation and Wise Use of Wetlands*. Ramsar Handbooks for the Wise Use of Wetlands, 4th ed. vol.3. Gland: Ramsar Convention Secretariat.

Climate-Smart Agriculture

CCAFS (Consultative Group on International Agricultural Research (CGIAR) Program on Climate Change, Agriculture and Food Security). 2020. "Climate Smart Agriculture."

FAO (Food and Agriculture Organization of the United Nations). 2017. *Voluntary Guidelines for Sustainable Soil Management*. Rome: FAO.

Liniger, Hanspeter, and Rima Mekdaschi Studer. 2019. *Sustainable Rangeland Management in Sub-Saharan Africa: Guidelines to Good and Protect Our Waters*. TerrAfrica Partnership. Washington, DC: World Bank; Bern: WOCAT (World Overview of Conservation Approaches and Technologies); Bern: CDE (Centre for Development and Environment, University of Bern).

NRCS (U.S. Natural Resources Conservation Service). 2020. "Conservation Practice Standards." Washington, DC: NRCS.

Watershed Management

Darghouth, Salah, Christopher Ward, Gretel Gambarelli, Erika Styger, and Julienne Roux. 2008. "Watershed Management Approaches, Policies, and Operations: Lessons for Scaling Up." Water Sector Board Discussion Paper Series no. 11. Washington, DC: World Bank.

EPA (U.S. Environmental Protection Agency). 2013. *A Quick Guide to Developing Watershed Plans to Restore and Protect Our Waters*. Washington, DC: EPA.

Mathews, Ruth. E., Anna Tengberg, Johanna Sjödin, and Brigitta Liss-Lymer. 2019. *Implementing the Source-to-Sea Approach: A Guide for Practitioners*. Stockholm: SIWI (Stockholm International Water Institute).

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2018. *World Water Development Report 2018: Nature-Based Solutions for Water*. Paris: UNESCO.

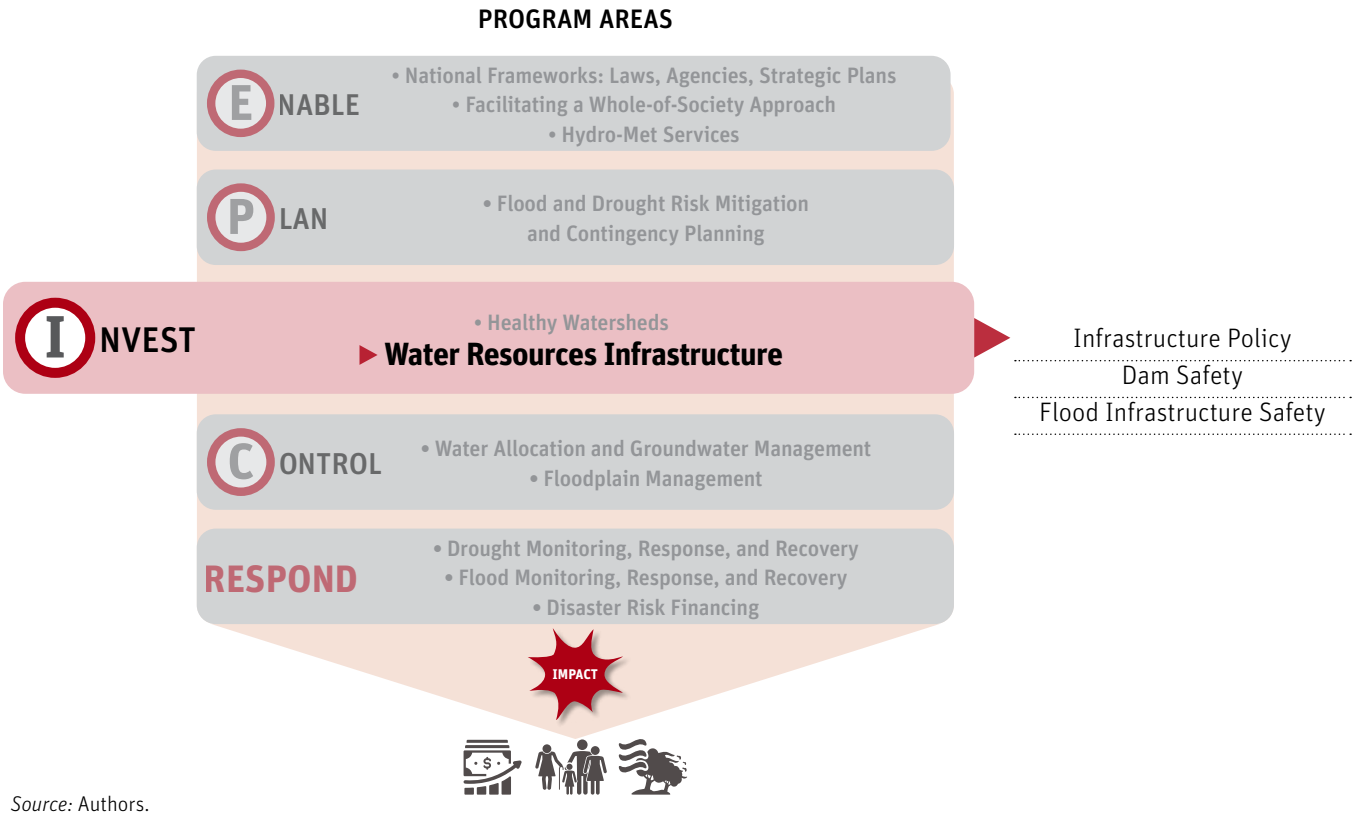
8 Water Resources Infrastructure

Water resources infrastructure (WRI) broadly refers to assets such as dams and their reservoirs, regional bulk water systems, flood control structures along rivers and coasts, and regional drainage channels and floodways. In broad terms, it is the infrastructure that the WRM agency normally operates or regulates. This infrastructure is used to help control blue water flows through the watershed and is an important tool in the arsenal to reduce hydro-climatic hazards.[28] Chapter 5 reviewed how river basin planning can help define the investment needs for WRI.

A new paradigm is emerging which also looks at how to integrate green infrastructure with traditional gray infrastructure (Browder and others 2019). Green infrastructure refers to nature-based solutions which are directly linked to gray infrastructure. For example, a watershed (green) immediately upstream of a dam (gray) can be considered part of the same WRI system as it impacts water and sediment flows into the reservoir. Another example is floodplains (green) that retain flood waters and can be combined with river dikes (gray) to form integrated green-gray flood infrastructure. Like all nature-based solutions, green infrastructure typically generates many environmental and social co-benefits. Green infrastructure can also boost resilience as it unlikely to catastrophically fail.

As shown in Figure 8.1, this chapter will examine two key elements related to WRI. First, how WRI investment policy

FIGURE 8.1 Water Resources Infrastructure in the EPIC Response Framework



Source: Authors.

[28] This chapter does not address water infrastructure used to directly delivery water services, such as water supply and sanitation or irrigation and drainage. WRI helps provides the general enabling conditions for this class of infrastructure. Infrastructure needs for water service providers should be defined through the planning processes described in Chapter 5.

Eastern Scheldt Storm Surge Barrier, the Netherlands. Photo: GAPS

can promote—or distort—good decisions on infrastructure. Second, how infrastructure safety is an important issue. WRI can be a dual-edged sword. It can help reduce flood and drought hazards. But if it fails, those hazards will be greatly increased. For example, the collapse of a dam constructed to reduce flood hazards and store water for dry seasons can result in immediate catastrophic flood damages and also increase future drought risks.

Investing in healthy watersheds and nature-based solutions, which are higher up in the EPIC Response Framework, is an important complement to water resources infrastructure. Hydrological processes are dictated by the weather and watersheds: WRI can only temper—not control—hydro-climatic hazards. Degraded watersheds can quickly overwhelm WRI functionality, for example by increasing sedimentation in reservoirs or reducing base flows. This underscores the importance of WRM agencies working with natural resources management and agriculture agencies to prioritize the health of watersheds. The key program areas reviewed in this chapter are summarized below:

- **WRI Investment Policy.** Historically, WRI has been considered a pure public good with costs borne almost entirely by the government. This often distorts investment decisions, resulting in overinvestment and inadequate maintenance. Thus, WRM agencies should strive to improve their economic analysis, allocate a higher percentage of costs to users, and ensure appropriate cost sharing by local governments. National government support for WRI investment can also be used as an incentive to encourage non-structural measures to reduce risks, for example by land management and water conservation.
- **Dam Safety.** Unsafe dams can increase flood and drought risks. These dams are often owned and operated by a wide range of entities, including WRM agencies, local governments, other sector agencies such as agriculture and energy, water utilities, and the private sector for hydropower. Thus, WRM agencies need to ensure comprehensive national programs in which WRI owners are responsible for WRI safety and in which WRM agencies ensure compliance. Dam safety programs are particularly important in the face of climate change and evolving safety criteria.
- **Flood Infrastructure Safety.** Non-dam flood infrastructures such as levees, dikes, flood control gates, and pump stations all play important roles in reducing flood hazards. Similar to dams, however, if a critical component of flood control infrastructure fails, then risks can increase. Flood control infrastructure is also typically owned by a wide range of entities, and WRM agencies need to ensure comprehensive programs for flood control safety.

8.1 WRI Investment Policies

Program Description

There is a clear need to increase funding for upgrading and constructing new water resources infrastructure, particularly to address the increasing hazards associated with climate change (HLPW 2018). WRI generates a mix of public and private benefits, yet it is generally funded by the government. Since public budgets are constrained, policies should be adopted which promote the efficient use of these funds. Investment efficiency is also important from an equity perspective because in many cases the costs (in terms of high levels of public subsidies) for WRI are borne by all taxpayers while the benefits go only to a much smaller group. Finally, national WRM agencies that depend entirely on a general budget and operate in a non-commercial manner may potentially be driven by political motivations, rent seeking, or local elite capture that distorts the decision-making process (Molle 2008).

Ideally, WRI investment decisions should be guided by sophisticated economic and environmental analysis to determine whether a proposal is justified from a broad economic perspective; this also helps to ensure a reasonable project size and cost. An economic analysis is used to determine whether a proposed project will be a worthwhile investment. It would account for all benefits and costs regardless of who is affected. An economic analysis allows for fair comparisons to be made between alternatives and demonstrates why a proposed project can be considered the best solution to meet the overall objectives. More sophisticated economic analysis can consider environmental and social costs and benefits and thus provides a useful tool, along with the technical, financial, environmental, and social assessments, to appraise a project. It is particularly important to consider the co-benefits of associated green infrastructure when analyzing a project proposal (Browder and others 2019). Ideally, economic analysis should be integrated into a broader environmental and social impact assessment (ESIA) that can be used as the government's primary decision-making document.

Although WRI is typically financed by the government, there are opportunities to recover some costs by charging water users, for example by selling bulk water supply to water utilities and irrigation schemes or by generating power from multi-purpose dams. Methods for allocating costs for multi-

purpose reservoirs and water conveyance systems have been developed, allowing for more equitable cost recovery policies from water users (OCDE 2017).

In many cases, the national government will help fund local flood control projects or the development of new water sources such as reservoirs or groundwater well fields. When funds are offered on a 100 percent grant basis there is a tendency for local governments to overbuild and undermaintain the WRI. Thus, adopting reasonable cost-sharing policies will encourage local governments to make better economic decisions, since the use of their scarce funds is also at stake. Attaching conditions to national funding of local WRI can also be used to incentivize local governments to adopt better and lower-cost management practices, for example by promoting the use of non-structural approaches for flood management or water conservation.

Linkage to the National Sector Framework

It is important for the water resources law to include provisions requiring economic efficiency, sustainability, and transparency in the planning and design of WRI. The water resources law should also ideally lay out basic principles for the planning process while allowing the responsible national WRM agency to develop the specific criteria and methodology. The efficacy and applicability of these principles could be periodically reviewed in the National WRM Strategic Plan.

The national planning agency and the national finance agency have a vested interest in ensuring sound infrastructure investment and may also require the national WRM agency to develop clear guidance on the planning and funding of WRI. An example of national WRI planning policy and principles from the United States is presented in Box 8.1.

Key Agency Actions

Key policy and institutional considerations for the WRM agency include the following:

- **Formulating WRM project planning guidance.** Develop a comprehensive policy that outlines procedures and methodologies for assessing WRI that include, among other items, applicability, guiding principles, general requirements, environmental and social assessment, and relationship to other planning processes. This guidance should be supplemented by additional technical notes that provide more detailed information, for example on methodologies for economic assessment of different types of projects, addressing climate uncertainties and resilience, and valuing ecosystem benefits. Specific guidance on green infrastructure as a special component for different types of WRI would also be useful. This

Box 8.1 Key Provisions in the U.S. 2007 Water Resources Development Act

The Act emphasizes that water resources projects should maximize sustainable economic development, avoid the unwise use of floodplains, and protect and restore natural ecosystems. The Act also requires the U.S. Army Corp of Engineers to update the "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" (referred to as Principles and Guidelines Document) to include the following considerations:[a]

(1) Use of best available economic principles and analytical techniques, including techniques in risk and uncertainty analysis.

(2) Assessment and incorporation of public safety in the formulation of alternatives and recommended plans.

(3) Assessment methods that reflect the value of projects for low-income communities and projects that use non-structural approaches to water resources development and management.

(4) Assessment and evaluation of the interaction of a project with other water resources projects and programs within a region or watershed.

(5) Use of contemporary water resources paradigms, including integrated water resources management and adaptive management.

(6) Evaluation methods that ensure that water resources projects are justified by public benefits.

[a] Information included in this box was drawn from 110th United States Congress. Water Resources Development Act of 2007, Public Law 110-114. November 8, 2007. GPO (U.S. Government Publishing Office). https://www.congress.gov/110/plaws/publ114/PLAW-110publ114.pdf.

approach would help provide a common framework for assessment of WRI and ensure analytical rigor.

- **Developing cost allocation and sharing policies.** Formulate methodologies for allocating costs between different users for multi-purpose water resources infrastructure projects. The general approach is to consider two types of costs: (1) separable costs which are directly attributable to a single user, for example a hydropower plant for a multi-purpose reservoir; and (2) joint costs that are shared by multiple users, for example the dam that stores water for hydropower, flood control, and water supply for cities and farms. Separable costs are easy to allocate, but there are various approaches to sharing joint costs that can be considered. The WRM agency should have clear cost-sharing policies to ensure that project beneficiaries assume some share of the costs to help inform rational investment decisions. Cost-sharing percentages generally vary by sector according to its financial capacity, and typically go from highest to lowest in the following order: hydropower, urban water supply, agricultural water supply, flood control, and ecosystem protection.
- **Using cost-sharing policies as incentives.** Consider cost-sharing policies for WRI that help to create incentives for more comprehensive risk management approaches. For example, local governments that adopt sound floodplain management programs could be rewarded by having a lower cost-sharing percentage for flood infrastructure. In a similar manner, cities that adopt effective water conservation programs could be rewarded by having a lower cost-sharing percentage for multi-purpose water supply projects such as reservoirs or regional water conveyance facilities. Higher levels of subsidies for green infrastructure, due to its co-benefits and climate resilience, could also be considered.

Generic Evolution

The generic evolution of WRI investment policies can be summarized as shown in Table 8.1.

TABLE 8.1 Generic Evolution of WRI Investment Policies

Nascent	Engaged	Capable	Effective
All WRI funded by national government with no cost sharing. Economic analysis limited to least-cost analysis. No consideration of green infrastructure.	National government issues WRI policy guidelines, requiring some cost sharing and linkage to river basin planning process. Green infrastructure promoted in concept but not in practice.	National government refines investment policy, requiring cost allocation analysis and some cost sharing. Issues general guidance for economic analysis. Green infrastructure and non-structural measures are utilized.	National government adopts comprehensive investment policy, requiring state-of-the-art economic analysis, well-defined cost allocation principles, and cost-sharing requirements to provide incentives for beneficiaries to include non-structural and green infrastructure approaches.

Source: Authors.

8.2 Dam Safety

Program Description

Dams comprise critical infrastructure to meet increasing demands for water, food, energy, and flood control. The failure of a dam can potentially have catastrophic impacts in terms of downstream flooding, as well as by removing an asset that communities are reliant upon to reduce flood hazards and to supply water. The two most common causes of dam failure are "overtopping" of earth dams, and foundation problems that are sometimes triggered by earthquakes. The proximate causes of dam failures, however, are often complex and myriad, and could include factors such as inappropriate design standards, bad siting decisions, poor construction, inadequate monitoring and maintenance, poor operational decisions, and lack of emergency planning. Dam safety programs are intended to address these shortcomings by ensuring a comprehensive life cycle approach.

Dams are typically owned and operated by a wide variety of organizations. WRM agencies may themselves operate dams for multi-purpose use such as flood control, water supply, hydropower, and recreation. Energy agencies or companies may operate dams primarily for hydropower but may also include other uses. Agriculture agencies, and individual irrigation surface providers, often rely upon dams to provide water supply for irrigation systems. Water utilities often own and operate their own reservoirs to meet their water supply needs. Many of these dams are typically either constructed from soil or concrete, with a wide variation in dam and associated reservoir size. Ensuring that all these dams are regulated under

Water flowing from the eroded overflow spillway of Oroville Dam, California. Photo: William Croyle, California Department of Water Resources

an appropriate national dam safety management program is an indispensable element of hydro-climatic risk management.

The core principle of dam safety management is the notion of shared responsibility. The owner is responsible for ensuring the safety of a dam, for operating and maintaining it in a safe condition, and for ultimately assuming criminal and civil liability in the event of a failure. The dam safety regulator is responsible for protecting the safety of the public by establishing dam safety standards and ensuring that these are fully implemented. The International Commission on Large Dams (ICOLD) has laid out the core pillars of dam safety, some of which are summarized below (ICOLD 2019):

- Structural integrity is the keystone of dam safety. Best current practices for dam design and construction that follow a risk-based approach appropriate for the country and specific setting should be utilized.
- Routine supervision and monitoring of dams is necessary for early detection of safety issues. Supervision of dams should be based on both the operator's self-supervision and periodic external safety reviews by an independent and competent authority.
- Risks change with time and thus should be regularly reviewed and updated, with adjustments to the dam's design and operation accordingly. Assessment of natural hazard magnitudes and frequency, for example river flows and earthquakes, can change over time as new information is obtained. Watershed characteristics can change over time, potentially increasing inflows into reservoirs and increasing dam safety risks. Finally, the number of people and assets at risk downstream of a dam typically evolves over time.
- Emergency planning is a core element of dam safety because it is impossible to eliminate the risk of dam failures. Emergency plans should be developed with the objectives of avoiding the loss of life and reducing damage to property, infrastructure, and the environment resulting from a dam failure.
- Training of operators is part of a comprehensive dam safety program. Those placed in charge of dams bear an important responsibility to maintain their training and understanding of their dam. The misoperation of a dam, especially of spillway gates, can lead to accidents, downstream flooding, or potential overtopping of the dam.
- Regulatory authorities are key to dam safety programs. Regulatory authorities should take a strong role in ensuring adequate site investigation, best practice

design standards, quality construction, contractual frameworks, emergency preparedness, and operational compliance within accepted guidelines and standards.

Linkage to the National Sector Framework

The authorization for a national dam safety program is typically provided in a national water resources or a standalone dam safety law. The law should ideally authorize a national dam safety regulator, which is typically a WRM agency.[29] However, in some countries there are multiple dam safety regulators serving different sectors, for example hydropower, mining, and water resources. In cases where there are multiple regulators, they should ideally be under a single national dam safety law with one organization—typically the WRM agency, responsible for overall coordination and supervision.[30]

The law should provide the dam safety regulator with the power to: (1) license new or modified dams; (2) perform periodic inspections during construction and operation phases; (3) require owners of dams to perform necessary maintenance or remedial work, install and monitor instrumentation, improve security, revise operating procedures, or take other actions, including holding down storage in anticipation of flood surges and breaching dams when necessary; and (4) issue sanctions, including imposing financial penalties or pressing criminal charges, and requiring the cessation of operations as necessary.

The law should include a provision for dam safety emergency management plans. However, jurisdiction over these plans may reside with either or both the dam safety regulator and the national DRM agency. Since the implementation of the emergency management plan requires coordination with downstream local government and civil defense authorities, the national DRM agency typically plays an important role.

Key Agency Actions

Key policy and institutional considerations for the WRM agency or dam regulator include the following:

- **Determining the applicability of dam safety regulations.** The regulator will need to establish which dams are under its jurisdiction, including potentially different regulatory categories based upon risk. Typically dam height and amount of water impounded are the starting criteria, but evaluations of potential downstream risks in terms of population and assets exposed can also be considered.
- **Systematically identifying dam owners.** The next step is to set up a mechanism to clearly identify the owner or person responsible for dams within the jurisdiction concerned and to set this information out in a publicly accessible form such as a register. It will also be necessary to ensure that existing dams are brought within the dam safety program.
- **Formulating engineering design and construction standards.** The regulator will need to provide guidance on appropriate design criteria for different categories of dams. These design criteria typically include hydrologic, hydraulic, geotechnical, seismic, and structural considerations, along with instrumentation for the dam and its appurtenant structures. General guidelines for construction methodology are also required for regulatory purposes. The regulator may draw upon existing design standards from other organizations, for example the International Commission on Large Dams or the U.S. Bureau of Reclamation.
- **Adopting regulations for reviewing and approving the design and construction of dams.** The regulator will need to lay out clear procedures for the submittal and approval information related to the design, construction, and commissioning of either new dams or modifications to existing dams. There are typically many points in this process that require the formal approval of the regulator before the operator can proceed on to the next phase.
- **Adopting regulations for dam safety inspection and monitoring.** The regulator will need to lay out clear guidelines and procedures for the inspection and monitoring of dams. Dam owners are required to have adequate dam monitoring instrumentation, undertake frequent periodic dam safety inspections, and file reports to the regulator. The regulator in turn should review these reports and undertake its own independent inspections on a periodic basis following well-documented procedures.
- **Adopting regulations for emergency management plans.** The dam safety regulator, along with the national DRM agency, will need to work collaboratively to develop guidelines and procedures for the formulation of dam emergency management plans. These plans guide the actions of the dam operators, downstream communities, and civil defense authorities in the event of a dam emergency that may require release of emergency flows or in the case of a dam breech. Typically, downstream

[29] In some countries there may be multiple authorities, for example in countries which rely on hydropower.
[30] As an example, Brazil has four groups of dam safety regulators: water, hydropower, industrial, and mining, which are under a common national safety law and report to the national water authority (World Bank and ANA 2015).

inundation maps are prepared that help guide emergency evacuations and response.

- **Delivering dam safety training.** The dam safety regulator should have a broad and comprehensive program to help its staff, engineering consultants, dam operators, inspectors, and disaster response personnel boost their capacity in all relevant dimensions of dam safety. Since dam safety is a highly technical subject, it requires specialized training in order to minimize the risks of catastrophic failure.
- **Providing financial support for dam safety modifications.** In some cases, a dam operator may not be able to afford the necessary structural modifications necessary to comply with dam safety standards. This is particularly common for smaller dams that provide a water supply for farmers or cities. The consequences of requiring a dam to cease operations due to safety reasons may be unacceptable. The dam safety regulator should thus be empowered to administer a program of financial support to qualified dam owners to help them meet safety standards. This could potentially be offered in the form of grants or concessionary loans.

Generic Evolution

The generic evolution of this program can be summarized as Table 8.2.

TABLE 8.2 Generic Evolution of Dam Safety Programs

Nascent	Engaged	Capable	Effective
The legal responsibility of dam owners for the safety of their dams is poorly addressed in law and there is no effective government oversight.	Different sector agencies, such as water resources, hydropower, agriculture, and mining, set up their own sector-specific dam safety programs but there is no overarching national framework.	National dam safety law is passed, requiring a uniform approach across sectors and standards. It clearly establishes the liability of the owner or operator in the case of dam failure. The regulatory framework is still developing and the capacity of the dam safety regulator(s) and operators is relatively low.	The national dam safety agency is well established and manages an effective and comprehensive regulatory system. Dam operators are well trained and have the capacity to comply with regulations and take their own appropriate actions. Both regulators and operators are able to effectively fulfil their obligations with regard to dam safety.

Source: Authors.

8.3 Flood Control Infrastructure Safety

Program Description

River and coastal flood control infrastructure provides many of the same functions as dams—essentially holding water back—and faces many of the same risks. Flood control embankments can include levees that protect land that is normally dry but that may be occasionally flooded, and dikes that protect land that would naturally be underwater most of the time. Tidal gates are important for coastal flood control and can help protect against storm surges. Large pump stations that help evacuate flood waters are critical elements of many flood control systems.

Flood embankments are typically constructed from soil and are sometimes armored with concrete. They are prone to collapse when overtopped and they can suffer foundation failures like dams do. Flood walls are constructed from concrete, and in some cases steel, and may also fail from overtopping or foundation failures. Flood embankments may also be integrated into transport infrastructure, with roads or railway lines situated on top of the embankments. In some cases, specific sections of flood embankments may be designed to be easily breached (these are called fuse plugs). When flood levels in a river are dangerously high, the fuse plugs allow water to be channeled into areas that pose the lowest risk, such as agricultural areas with minimal numbers of structures. Although a flood control infrastructure failure is generally not as immediately catastrophic as a dam failure, it can have a significant impact over a large geographical region as river or coastal flood waters pour into low-lying areas. As an example, the devastating floods in New Orleans during Hurricane Katrina in 2005 were caused primarily by the failure of levees (ASCE 2017).

Like dams, flood control infrastructure is often owned or operated by multiple entities. Larger infrastructure is typically constructed by the WRM agency, which may keep control of operations or maintenance or turn them over to local governments. In some cases, local governments or private industries, such as industrial estates, may construct

Box 8.2 WRM and Infrastructure in the Netherlands

The Netherlands water resources system relies heavily on infrastructure. In 60 percent of the country, water levels in the very extensive system of canals, lakes, and ditches are controlled by pumps and water inlet facilities. The same infrastructure is also used to control the water quality (in particular, salt concentrations) by flushing the system with fresh river water. Many locks, large and small, have been built to enable the canals also to be used for both commercial and recreational navigation. The main purpose of this infrastructure is to prevent waterlogging and flooding, but the system of canals and ditches is also used to supply water to regions in case of drought. Safety from flooding is provided by river and sea dikes in combination with controllable infrastructure to protect the country against storm surges from the sea (such as the Eastern Scheldt Barrier and the Maeslandkering).

The infrastructure is maintained (and, where necessary, further developed) by 17 self-governing water boards for the regional systems and by the *Rijkswaterstaat* (a semi-autonomous agency of the Ministry of Infrastructure and Water Management) for the national system (the main rivers and lakes of national importance). Municipalities and provinces do not have major responsibilities in water management in the Netherlands. The responsibilities of the *Rijkswaterstaat* and the Water boards are described in the Water Law. The financing of the activities of the *Rijkswaterstaat* is guaranteed by a financial paragraph in the Water Law (the Delta Fund). Water boards finance their activities from taxes from residents and businesses.

Key Issue: The main lesson learned from infrastructure in the Netherlands is to pay more attention to nature-based solutions, by integrating grey and green infrastructure. Grey infrastructure remains necessary, but adding nature-based solutions improves the resilience of the system and reduces the maintenance costs.

their own flood control infrastructure. However, a basic challenge for flood safety can be identifying precisely who owns the infrastructure or sections of flood embankments and who is therefore responsible for maintaining them and ensuring their integrity. This is because many flood embankments have been built up and extended over decades or even over centuries. Consequently, few were originally designed or constructed to modern standards. In addition, records of their construction and historical performance may not exist. Moreover, they may stand for much of their lives without being loaded to design capacity, which can create a false sense of security in the level of protection they will provide.

Flood infrastructure is typically composed of long linear structures that are only as strong as their weakest links. The structures can suffer from several potential deficiencies, such as old age, poor construction, and inadequate maintenance. They can also experience damage from burrowing animals and human activity, such as illegal construction on or adjacent to flood control structures, illegal sand exploitation and storage of building materials, and overloaded vehicles travelling on embankments. They also are typically subject to encroachments by third-party objects that are constructed or installed over, under, or through the structures. Those encroachments can adversely affect flood control infrastructure integrity, but are not always fully recorded or documented.

Linkage to the National Sector Framework

Flood infrastructure safety programs are usually linked to water resources laws but may be subject to coastal protection laws when coastal infrastructure is involved. The water resources law should highlight the need to ensure flood control infrastructure safety and should clearly impose responsibility for infrastructure maintenance and safety on the owners, while also imposing responsibility for regulatory oversight on the WRM agency.

The law should also require the WRM agency to set up a national flood control infrastructure safety program and identify funding sources for maintenance and rehabilitation (which may include local governments). Elements of the national flood control infrastructure safety program should include a national database or register to which relevant agencies and the public should have access, the establishment of a national flood infrastructure safety committee, the establishment of a hazard classification system, the adoption of regulations and guidelines for flood control infrastructure management, an emergency response plan, the provision of technical assistance and training, efforts to raise public awareness, and provision of insurance.

Key Agency Actions

Key actions for the WRM agency include:

- **Establishing and maintaining a national flood control infrastructure database or register** that contains information on the location and ownership of flood control in-

frastructure. The database or register should be available for public inspection and should contain information about the general condition of the infrastructure and an assessment of the population and structures that would be adversely impacted by its failure.

- **Setting up an interagency committee on flood control infrastructure safety** that should include the DRM agency, local governments, and as appropriate natural resources management and agriculture agencies.
- **Establishing, implementing, and periodically reviewing** a hazard potential classification system for existing flood control infrastructure to act as the basis of identifying funding needs for priority repairs, rehabilitation, and upgrading of flood control infrastructures.
- **Adopting regulations and technical guidelines for** the maintenance, construction, modification, and rehabilitation of flood control infrastructure. The regulations and guidelines should also include risk assessment and require decision making based on flood system performance assessment, flood risk analysis, and risk attribution to system segments.
- **Setting out procedures for flood emergency responses** linked to the Emergency Management System and Local Emergency Response Plans. Responses should be planned for the breaching of embankments and for undertaking emergency repairs.
- **Providing technical assistance and training to local governments and the owners of flood control infrastructure** about such matters as asset management, maintenance, and risk identification and mitigation, along with the rehabilitation, improvement, or modification of flood control infrastructure.
- **Promoting public awareness of and involvement in flood safety programs** including risk communication to beneficiary communities and local governments, and mechanisms to allow members of the public to alert the owner of signs of damage or failure.
- **Certifying compliance with the relevant elements of** the national flood control infrastructure safety program as a prerequisite for subsidized or mandatory flood insurance programs.

Generic Evolution

The generic evolution of this program can be summarized as Table 8.3.

TABLE 8.3 Generic Evolution of Flood Infrastructure Safety Programs

Nascent	Engaged	Capable	Effective
There is no clear legislation on flood control infrastructure safety, and information is lacking as to the extent and location of flood control infrastructure and its owners.	A new water resources law places responsibility for flood control infrastructure safety on infrastructure owners and provides for the establishment of a flood control infrastructure safety program, but this is largely unimplemented.	Steps have been taken to implement the national flood control infrastructure safety program in terms of establishing an interagency flood control infrastructure safety committee, compiling a register or database of flood control infrastructure, implementing a national flood control infrastructure safety program, and adopting regulations and technical guidelines.	The national flood control infrastructure safety program is largely implemented, with an updated register or database, regular meetings of the interagency committee, adoption of regulations and emergency response procedures, the provision of training, and implementation of public awareness programs.

Source: Authors.

8.4 Key Resources

WRI investment policies

OECD (Organisation for Economic Co-operation and Development). 2012. *A Framework for Financing Water Resources Management*. Paris: OECD.

OECD (Organisation for Economic Co-operation and Development). 2017. "Multi-Purpose Water Infrastructure: Recommendations to Maximise Economic Benefits." OCDE Policy Perspectives. Paris: OCDE.

US CEQ (U.S. Council on Environmental Quality). 2013. *Principles and Requirements for Federal Investments in Water Resources*. Washington, DC: CEQ.

Dam and flood control infrastructure safety program

ICOLD (International Commission on Large Dams). 2014. "Regulation of Dam Safety: An Overview of Current Practice Worldwide." Technical Bulletin no. 167. Paris: ICOLD/CIGB.

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Flood infrastructure safety program

CIRIA (Construction Industry Research and Information Association). 2013. *The International Levee Handbook*. London: CIRIA.

U.S. National Committee on Levee Safety. 2011. *Creating a National Levee Safety Program: Recommendations from the National Committee on Levee Safety*. Washington, DC: U.S. National Committee on Levee Safety.

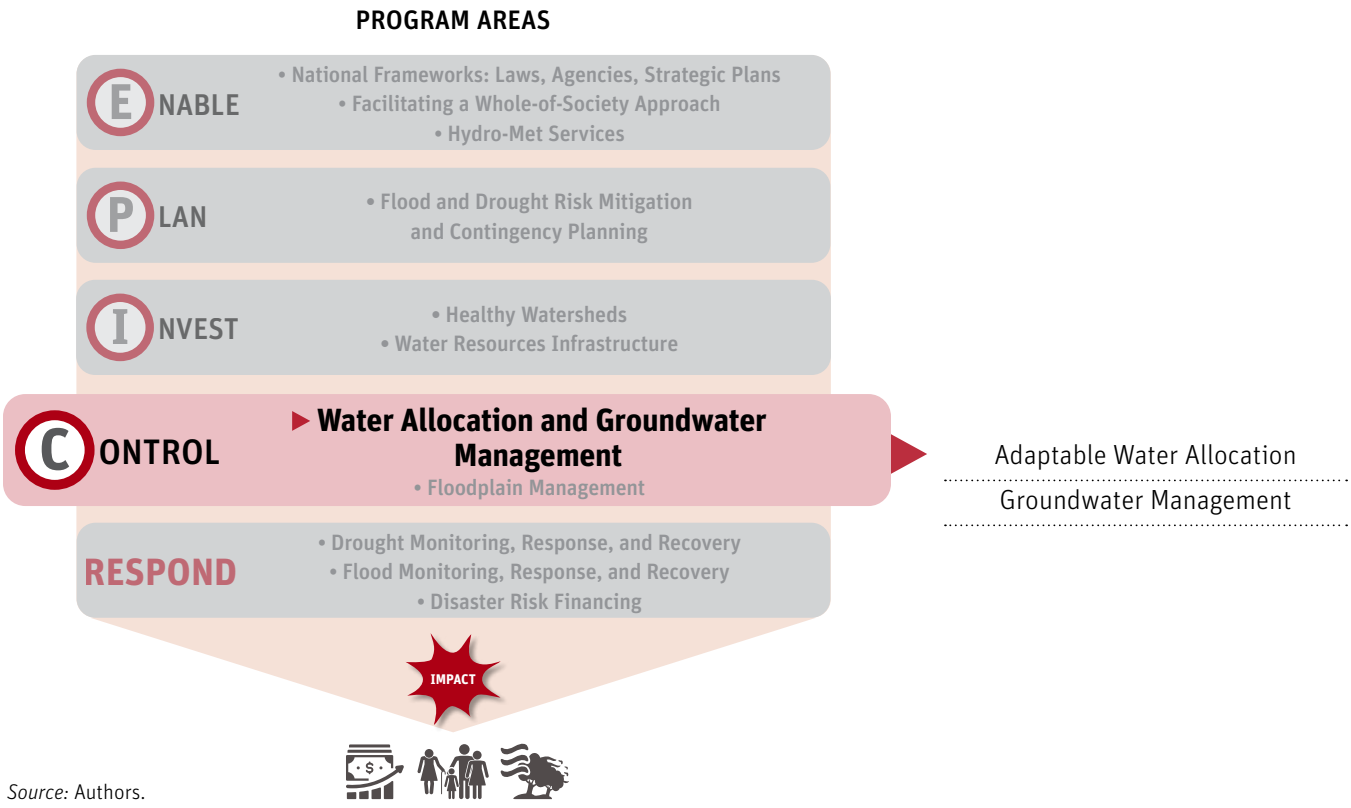
Ho Pui Reservoir, Hong Kong. Photo: Chunyip Wong

9 Water Allocation and Groundwater Management

This chapter focuses on two key water resources management programs for reducing drought risk: adaptable water allocations and conjunctive groundwater management. As reflected in Figure 9.1, these programs are influenced by the state of the watersheds as well as the stock of water resources infrastructure. Healthy watersheds can help store water in soils, aquifers, and wetlands, thereby increasing base flows during dry periods. In a similar manner, water resources infrastructure such as multi-purpose reservoirs can help store water. Regional water conveyance systems serve to redistribute water supplies to help address variabilities in local water supplies. There are, however, limits on the extent to which water resources infrastructure can store and redistribute water. When periods of extreme dryness occur, the WRM agency can play a pivotal role in helping to manage drought risks by drawing upon programs for flexible water allocations and conjunctive groundwater management.

The two key programs are summarized below. These programs are closely linked to drought monitoring, response, and recovery as discussed in Chapter 11. However, these programs must be in place and functioning smoothly prior to the onset of a drought.

FIGURE 9.1 Water Allocation and Groundwater Management Programs in the EPIC Response Framework



Source: Authors.

- **Flexible water allocations.** WRM agencies should manage water allocations to ensure that water is not overallocated and that there is enough slack in the system to help mitigate drought impacts. This includes having a formal system of adaptable water allocations whereby water can be transferred from lower value users to higher value users, for example through administrative decisions, negotiated settlements, or water markets.
- **Conjunctive groundwater management.** This program involves balancing surface water and groundwater use, including managed groundwater recharge where possible, and ensuring that groundwater is available as a strategic reserve to help meet demand during droughts. Where groundwater aquifers exist, they provide an ideal water storage option. Too often, however, aquifers are overexploited resulting in unsustainable yields thus diminishing their effectiveness as strategic sources of water during droughts.

9.1 Adaptable Water Allocation

Program description

A key function of water resources management is to allocate water resources (both surface water and groundwater) among different sectors and different water users. Depending on the country concerned, formal water allocation may take place based on different types of water tenure arrangement that may co-exist within the same river basin. These include: (1) "modern" long-term permit-based volumetric water rights (that are not intrinsically tied to land ownership); (2) water rights of indefinite duration that derive from land ownership or the prior appropriation and use of water resources; (3) powers conferred by law upon public irrigation or other agencies to develop and use water resources; and (4) long-term concession agreements in the form of investment contracts concluded between the government and (often foreign) investors and which usually provide for the resolution of disputes through international arbitration (FAO 2016). In addition, small-scale uses of water resources for personal or household needs can generally be undertaken without the need for any administrative formalities.

In many countries, people access and use water resources based on customary or "local law" arrangements, which may or may not be recognized and protected by formal law, as well as on a range of informal water tenure arrangements. Such arrangements may contain their own mechanisms for re-allocating water in times of drought. A key challenge is how to bring such types of water tenure arrangements within the broader formal water allocation framework. Box 9.1 provides further insights on the complexity and importance of informal water tenure.

A key objective of formal water tenure arrangements is to confer the necessary legal security upon water users to enable them to safely invest in activities that involve the use of water resources. In simple terms, the longer the water right, the greater the legal security (provided, usually, that the water is actually used). The problem is that as a result of growing water demand, many river basins around the world are either completely "closed", in the sense that there are no water resources available for new uses, or are approaching that "closed" stage.

Formal water allocation is a key element in drought risk management for three reasons. First, if water in a basin is fully allocated (or overallocated) during a normal hydrological year, then in a drought year a significant percentage of users will need to reduce their consumption, potentially increasing conflicts among users and generating negative

Box 9.1 Informal Water Tenure

In many parts of the world, the use of water resources takes place on the basis of informal water tenure arrangements agreed upon at the local level between different users. Sometimes this is because the water resources law is outdated or ill adapted to peoples' needs. Elsewhere, it is because the water law has not been fully implemented, often due to a lack of capacity on the part of the WRM agency. Such informal water tenure arrangements may be known to and tolerated by the WRM agency, sometimes over periods of many years.

But the notion of informal tenure can also be used to describe water tenure arrangements that are simply illegal. These can take the form of deliberately unlawful use of water resources without a permit or the willful disregard of permit requirements coupled with weak enforcement on the part of the WRM agency. This type of illegal water use may be undertaken by a range of actors with different motivations, from people who feel they have no alternative in order to survive to the rich and politically connected who consider themselves about the law. This is a growing problem. A recent report suggests that between 30-50 percent of the world's water supply is stolen, particularly by agricultural users (Loch and others 2020).

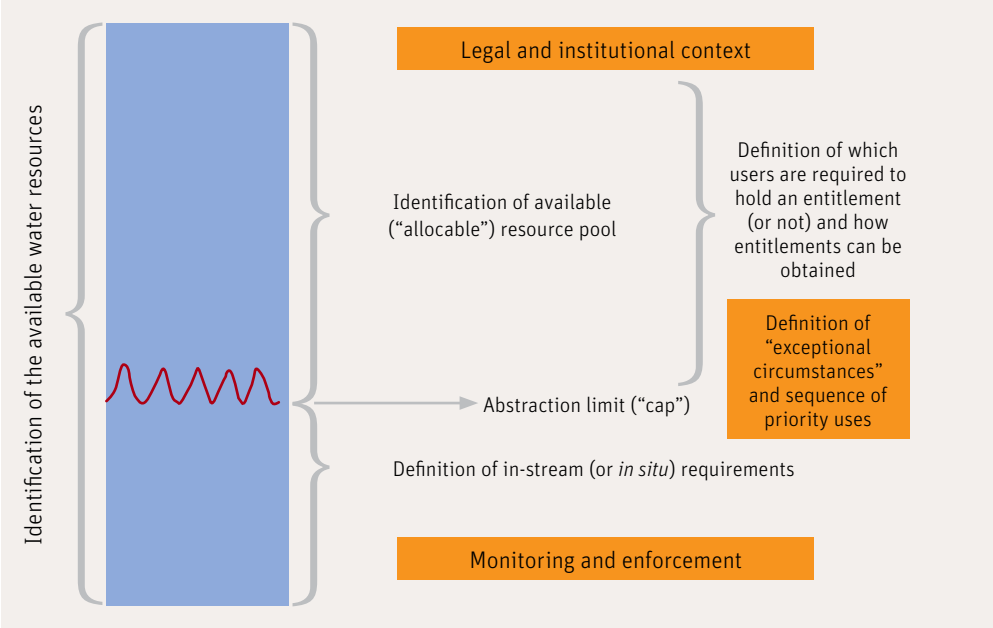
impacts. Second, even if there is some unallocated water in the basin during normal hydrological circumstances, during exceptionally dry years there will need to be a reduction in water consumption among some or all of the water users. Third, as the climate changes, many regions will experience more pronounced dry seasons and increased aridity, requiring periodic adjustments in water allocations.

Flexible water allocations, whether short term in response to drought conditions or longer term in response to changing societal priorities or a changing climate, are a key tool for hydro-climatic risk management. In this regard, modern water resources laws typically provide for the issuance of long-term water use permits by the WRM agency that last for 10-15 years, although longer periods may be applied for major WRI (such as hydropower dams) in order to enable a return on investment. Water use permits (which are also subject to a range of conditions to ensure the sustainable use of water resources) usually may not be permanently varied or cancelled by the WRM agency except on public interest grounds and on the provision of water from another source or the payment of compensation. The objective of such a rule is to ensure relative security of water tenure. However, a condition of such permits is that they may be temporarily varied or even suspended in times of low river flow or drought. In such cases, compensation is not payable. On the expiration of a water use permit, the holder can apply for a renewal, but with no guarantee that it will be granted. Instead, a renewal application will be determined just like an application for a new water use permit in accordance with the water resources law (usually based on water resources availability, the river basin plan, and specified priorities for the use of water resources).

Depending on the provisions of the water resources law, the trade and transfer of permit-based water rights may also allow the direct reallocation, temporarily or permanently, between water users, although this is usually subject to the approval of the WRM agency in order to prevent negative third party social, environmental, and economic impacts. In some jurisdictions, where water rights of indefinite duration derive from the prior appropriation and use of water resources, sale or leasing is often the only viable reallocation mechanism. Water rights based on foreign investment contracts, for example for hydropower projects, will typically be difficult to vary during the terms of the contracts without the agreement of the investors, an issue that should be considered before such contracts are concluded. For this reason, it is essential to ensure that the WRM agency is consulted before such contracts are concluded and that provisions on such water rights are subject to the water resources law.

The development of a water rights administration system that can manage flexible water allocations is a complex process that is constantly evolving and may take decades to achieve. A general framework for water allocations is provided in Figure 9.2.

FIGURE 9.2 Key Elements of a Water Allocation System



Source: OECD 2015.

Linkage to the National Sector Framework

The water resources law provides the basis for a water rights administration system. It specifies general principles for water allocation and typically authorizes the WRM agency to issue water use permits and to monitor and enforce those permits. The water resources law usually either establishes priorities for use or sets out a procedure for such priorities to be set at the national or river basin level, typically providing that water for human consumption and ecological needs is given the highest priority use.

The water resources law will also set out the basic rules relating to the temporary and permanent variation or suspension of water use permits. There is a close relationship between the national drought law and water allocation. The national drought law typically provides the authority to declare different levels of drought severity, which may trigger mandatory conservation measures and the temporary reallocation of water among users. Provisions in a water law that relate to water allocation should in turn be implemented in close coordination with provisions on the setting and enforcement of minimum or environmental flows and the protection of such flows during droughts.

Key agency actions

Key policy and institutional considerations for the WRM agency include the following:

- **Harmonization with basin plans.** As noted in Chapter 6, river basin management planning provides the foundation for water resources development and management. The WRM agency should ensure that the basin planning regulations include an assessment of available water resources. The WRM agency and the basin planning regulations also should govern how the water is used, including for meeting environmental requirements. The WRM agency should ensure that the basin planning process sets abstraction limits and avoids overallocating water to ensure resilience in the system. The basin plan should have a drought continency plan that flexibly reallocates water based on the level of drought severity and that is consistent with the system of water rights.
- **Adopting regulations on water use permitting and water tenure.** While the basic elements of water use permitting and other water tenure regimes are set out in the water resources law, the WRM agency will typically need to establish regulations to complete the legal framework for the issuance and enforcement of water permits. Some of the key issues include: (1) who is entitled and required to obtain a water permit; (2) the nature of the permit, including location, volume, flow, timing, use, and duration; (3) the level of security conferred by the permit during droughts, and ability to trade, transfer, or lease the permit; and (4) sanctions for non-compliance with water use permit conditions, including fines and potential loss of use rights if these are not provided for in the water resources law. It is important to have a well-defined procedure for ensuring that applications for new permits or the variation of existing permits are grounded in the relevant river basin management plan.
- **Developing water use monitoring systems.** Monitoring water use and ensuring users abide by their use permits is a key responsibility of the WRM agency. Typically, permit holders are required to self-report on their own water use with periodic WRM agency inspections. The WRM agency should develop technical requirements for water measuring devices, including for measuring flows in pipes and open surface flows in rivers and canals. Measuring open surface flows, for example canals in irrigation systems, can be a complex task and the WRM agency should develop standard designs to help ensure accuracy and reliability. Space-based monitoring, for example of cropping patterns and their evapotranspiration use, is an important complement to on-ground flow measurement. Finally, the WRM agency needs to ensure a comprehensive database of permit holders and their water use.
- **Adopting regulations on water use and reallocation during droughts.** Ideally, the basin drought contingency plan would provide a framework for conservation measures and water allocations corresponding to different drought levels, taking into account minimum or environmental flow requirements. The WRM agency should develop regulations to ensure that this process proceeds in an orderly and transparent fashion. One approach is to allocate water on a percentage share basis of the total available water resources rather than on a fixed volumetric amount. During drought periods, the WRM agency determines the total availability of water and each user gets its specified share of the total. This can be further refined so that some users, for example low-value agricultural crops, have their share percentages reduced according to the severity of the drought. In some countries, the WRM agency does not have the legal right to administratively reduce the allocation of water to a user. In these cases, the WRM agency may develop regulations for alternative mechanisms, such as a negotiated sale for temporary reallocation from a lower-value agricultural user to a higher-value urban or

industrial user. In the most advanced cases, and where the physical context allows easy transfers of water, the WRM agency may set up water markets to allow for either the temporary or permanent reallocation of water.

- **Adopting regulations for the permanent reallocation of water rights.** The WRM agency should set up mechanisms to facilitate the long-term reallocation of water as necessary using the same general set of approaches: administrative reallocation, negotiated reallocation, or water markets. Longer term reallocations, however, can prove more politically complex, as their economic and social impacts are potentially more permanent. Under ideal conditions, water users should become more efficient and increase the productivity of water (in terms of "yield per drop" or "dollars per drop") so that the transfer of water does not have negative economic consequences. Therefore, it is vitally important that the WRM agency work with cities, farms, and industries to constantly improve their water efficiency while limiting or even reducing their water allocations over time. Not only does this help the transition to more economically efficient allocations of water, but when droughts do occur the potential negative impacts are tempered as water users have already adapted to using less water.

Generic evolution

The generic evolution of water allocation programs is summarized in Table 9.1.

TABLE 9.1 Generic Evolution of Water Allocation Programs

Nascent	Engaged	Capable	Effective
Water users independently develop their own water sources, with no administrative control over abstractions.	The water resources law provides for the formal allocation of water on the basis of permits, but the implementation of such provisions is incomplete and in the absence of a full understanding of the available water resources.	WRM agency has defined available water resources within a basin and has systematically issued water permits to relevant users. Provisions in the water law that allow the temporary suspension of permits in times of drought or low flows have not been systematically used.	The WRM agency has developed, in consultation with stakeholders, a fair and transparent mechanism for the temporary reallocation of water to higher priority users during droughts, and the need for possible longer-term reallocations to ensure efficient use of water in the basin is addressed in river basin plans.

Source: Authors.

9.2 Conjunctive Groundwater Management

Program description

Aquifers can play a critical role in drought risk management by serving as natural storage reservoirs that can be recharged during wet periods and abstracted during dry spells. In some areas, the groundwater aquifers are so productive that they can serve as the primary source of water for human use or provide a supplement to rainfed agriculture. Indeed in arid areas, aquifers can be the only or main source of freshwater. In most cases, the ideal approach is to use both surface water and groundwater together in a practice known as "conjunctive management". Simply stated, this implies relying on surface water sources when they are plentiful and transitioning to groundwater as surface water becomes scarcer during dry periods. Conjunctive management also involves proactively recharging groundwater aquifers when and where possible, for example by maintaining floodplains, using agronomic techniques to keep water in the soil where it can percolate into the groundwater, and even purposely using water infrastructure to recharge groundwater.

Groundwater is obviously a key water resource, and ideally should be considered in the overall basin planning process and as part of the overall water rights administration system. The challenge, however, is that aquifers are complex subsurface structures that are difficult to characterize; the flow of water through aquifers is usually poorly understood and groundwater monitoring is typically limited. The development of a sound knowledge base is of pivotal importance for conjunctive management.

Effective conjunctive management considers both quantity and quality issues, and in some cases, treated recycled water is used to recharge aquifers. Owing to this complexity, formulating groundwater management plans as part of the overall basin planning process is a daunting task, and the administration of groundwater typically lags that of surface water.

Some more advanced countries have made considerable progress in conjunctive groundwater management, helping

Underground well for storing drinking water. Photo: Anneliese Gruenwald-Maerkl

to ensure the sustainable management of groundwater aquifers and groundwater use during droughts. Successful management involves characterizing the safe yield of aquifers, managing groundwater abstractions, controlling recharge, and managing surface water and groundwater together as a unitary resource to ensure groundwater can help meet the basin's water demands and be safely utilized during drought periods.

Linkage to the National Sector Framework

The water resources law typically governs the use and management of groundwater resources. Whereas surface water is always front and center in the water resources law, the status of groundwater is often more ambiguous. However, the same basic water tenure arrangements typically apply to groundwater, including water use permits and water rights that derive from land ownership or prior appropriation and use. However, the enforcement of groundwater permitting regimes can be challenging and as a result there is a growing trend towards co-management between the WRM agency and groundwater users.

While groundwater is also, in principle, subject to river basin management plans, in arid countries where there are particularly important aquifers, a water resources law may provide for the preparation and implementation of aquifer management plans, the setting of sustainable extraction yields, and also the classification of aquifers by reference to their state of exploitation, with overexploited aquifers being closed to the drilling of new boreholes or wells and to the issuance of water use permits. Since each aquifer will require its own unique plan, it is common for the water resources law to authorize "groundwater management organizations" (GwMOs) which operate under the jurisdiction of the WRM agency.[31] Box 9.2 provides an example of groundwater management in California.

The strict control of well drilling is important. This is done by licensing qualified well drillers as well as by using licenses to control where and how many wells may be drilled, how drilling is to take place in terms of aquifer protection (such as by ensuring that test wells are capped to prevent the entry of contaminants), and that the results are communicated with the WRM agency.

[31] As an example, see Babbitt, Christina, and Daniel M. Dooley. 2018. "The groundwater manager's dilemma: How to comply with new California law without changing water rights." *EDF Voices* (blog), September 4, 2018. Washington, DC: EDF (Environmental Defense Fund). http://blogs.edf.org/growingreturns/2018/09/04/groundwater-managers-sgma-compliance/.

Box 9.2 Groundwater Management Act in California[a]

Groundwater provides 40-50 percent of California's total annual agricultural and urban water supply in an average year. During droughts, that figure reaches as much as 60 percent. Some parts of the state are entirely dependent on groundwater for their supplies. Yet some regions of California are pumping out more groundwater than is replenished. Several problems are associated with overdraft, such as the increased energy costs to pump water, the mobilization of toxic materials, and land subsidence.

Under California water law, landowners are in general entitled to the reasonable use of groundwater on property overlying the groundwater basin. A 1992 law allowed local governments to voluntarily create groundwater management districts and gave the districts the authority to charge fees to pay for the management of groundwater. In 2014, the Sustainable Groundwater Management Act (SGMA) was enacted, providing a state framework to regulate groundwater for the first time in California history. The law stipulated that it is not a "one size fits all" approach and that each groundwater basin is different. It did not remove the distinction between surface water rights and the personal, private property right to pump groundwater. SGMA calls for a bottom-up approach that mandates the establishment of local groundwater agencies and requires them to show how they will sustainably pump groundwater by 2040.

SGMA identified 43 groundwater basins as high-priority and 84 as medium-priority. These 127 basins account for about 96 percent of the groundwater used in the state. The high-priority local groundwater agencies must develop groundwater management plans by 2022. Overall, local groundwater agencies have until 2040 or 2042 to achieve groundwater sustainability. If the deadlines aren't met, the State Water Resources Control Board can intervene and establish an interim plan, after public notice and hearing. The state, according to the SGMA, can intervene only in extreme conditions when local control is inadequate.

[a.] Information included in this box was drawn from the Water Education Foundation webpage on Groundwater Management: https://www.watereducation.org/aquapedia/groundwater-management.

The water resources law should also explicitly promote the use of conjunctive water management, whereby groundwater management plans are nested within a larger basin context for both planning and operational purposes. The national WRM agency should also allow for the possibility of "groundwater banking", whereby a GwMO can utilize its aquifer for either temporary (during droughts) or permanent transfer of water to other users; this can be particularly attractive for agricultural areas that can sell water to urban users during periods of extreme drought.

Key agency actions

Key policy and institutional considerations for the WRM agency include the following:

- **Defining and characterizing groundwater aquifers.** The WRM agency should undertake the necessary studies to define the basic characteristics of significant aquifers, including surface and subsurface mapping, geological conditions, and storage volume. To the extent possible, the WRM agency should establish groundwater monitoring systems and look at historical and current groundwater levels, and identify groundwater uses. Based upon this analysis, the WRM agency should attempt to define a sustainable yield for the aquifer to help in the formulation of a groundwater management plan. Characterizing an aquifer is a complex and ongoing process, and thus the WRM agency will need to prioritize its efforts.
- **Supporting groundwater management organizations.** Based upon the defined aquifers, the WRM agency should facilitate the establishment of GwMOs. These organizations can take many forms, ranging from a committee advising the WRM agency, to a localized or village-based organization that has authority to set and enforce rules in accordance with the aquifer plan, to an aquifer-wide agency with responsibility for the overall enforcement of the aquifer management plan, with the general structure framed in the water resources law. The WRM agency will need to develop regulations governing and establishing the GwMOs and help facilitate their start-up and operation. The WRM agency should also provide financial and technical assistance to support GwMOs, for example by providing them with consultant support and funding flow measurement instruments for groundwater wells.
- **Developing aquifer management plans.** The WRM agency will need to work collaboratively with the GwMOs to develop sustainable aquifer management plans. This will require the WRM agency to issue regulations covering the process, objectives, scope, and

methodology for developing the plan. The WRM agency may also need to develop technical guidance on specific issues, such as monitoring groundwater levels and water use, approaches to aquifer recharge, and the use of space-based observation tools to assess water use on the basis of crop evapotranspiration.

- **Implementing the water use permitting regime for groundwater use.** The WRM agency will need to implement the system for groundwater permitting, with permits being issued to individual groundwater users or GwMOs. Such permits will usually be similar those for surface water use. The issuance of such permits should take place in accordance with the relevant river basin management plan as well as the aquifer management plan if there is one.
- **Incorporating groundwater into basin planning and drought contingency plans.** The WRM agency should explicitly incorporate groundwater into the basin planning process, integrating information on groundwater and aquifer management plans as they develop over time. Critically, the WRM agency should proactively facilitate the natural and artificial recharge of aquifers wherever possible, for example by ensuring active floodplains and potentially using treated wastewater to recharge aquifers. The use of aquifers as supplemental or emergency supplies during droughts should also be considered in the drought contingency plan.

Generic evolution

The generic evolution of this program is summarized in Table 9.2.

TABLE 9.2 Generic Evolution of Conjunctive Groundwater Management

Nascent	Engaged	Capable	Effective
Groundwater use decisions are decentralized and exercised by well owners without control. There is no technical knowledge of the hydro-geological system. Rights to use groundwater derive from land tenure rights or prior appropriation and use.	The water resources law provides that groundwater may only be used on the basis of permits issued by the WRM agency, but the agency is unable to characterize aquifers and does not have the resources or capacity to issue permits.	WRM agency has developed aquifer management plans in consultation with local users and these are implemented on the basis of a combination of water use permits and co-management with GwMOs.	WRM agency manages aquifers in a conjunctive manner, fostering recharge through natural and artificial means. Groundwater is integrated in basin planning process and used as a strategic resource to cope with droughts.

Source: Authors.

9.3 Key Resources

Adaptable water allocation program

FAO (Food and Agriculture Organization of the United Nations). 2006. *Modern Water Rights: Theory and Practice*. Rome: FAO. http://www.fao.org/3/a0864e/a0864e.pdf.

GWP (Global Water Partnership). 2019. "Sharing Water: The Role of Robust Water-Sharing Arrangements in Integrated Water Resources Management." Perspectives Paper. Stockholm: GWP. https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/gwp-sharing-water.pdf.

OECD (Organization for Economic Co-operation and Development). 2015. *Water Resources Allocation: Sharing Risks and Opportunities*. OECD Studies on Water. Paris: OECD. https://www.oecd.org/fr/publications/water-resources-allocation-9789264229631-en.htm.

OECD (Organization for Economic Co-operation and Development). 2016. *Mitigating Droughts and Floods in Agriculture: Policy Lessons and Approaches*. OECD Studies on Water. Paris: OECD. https://www.oecd.org/publications/mitigating-droughts-and-floods-in-agriculture-9789264246744-en.htm.

Groundwater management program

FAO (Food & Agriculture Organization of the United Nations). 2016. *Global Framework for Action to Achieve the Vision on Groundwater Governance*. Rome: FAO. http://www.fao.org/3/a-i5705e.pdf.

Kresic, Neven. 2009. *Groundwater Resources: Sustainability, Management, and Restoration*. New York: McGraw-Hill.

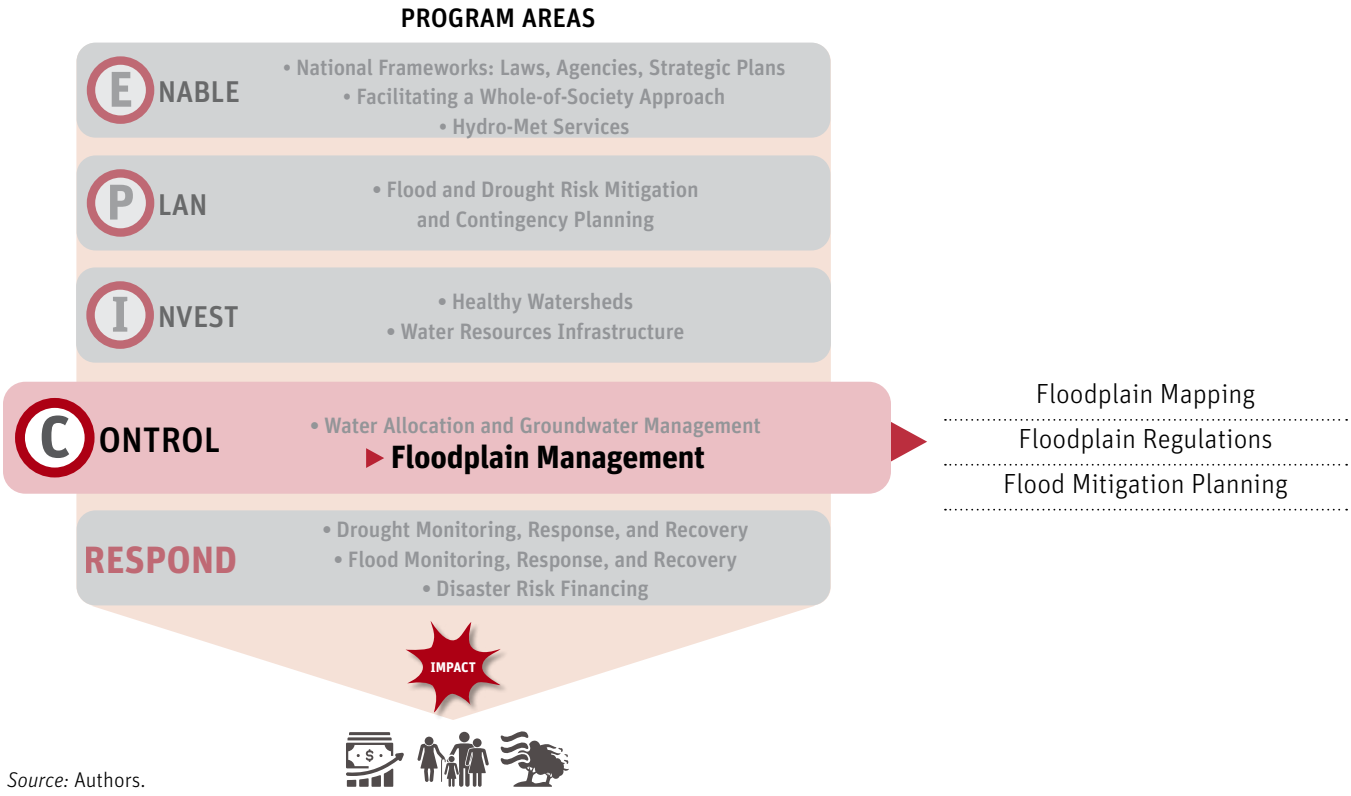
10 Floodplain Management

River and coastal floodplains are often convenient places for the establishment of cities, farms, and industries. Easily accessible waterways facilitate commerce, rich river floodplain soils increase agricultural production, and rivers offer readily available sources of freshwater. In addition, living close to rivers and beaches, and enjoying their natural beauty, is a powerful draw. These attributes have attracted people throughout the ages to rivers and coastlines around the world. The challenge is that floodplains are also prone to inundation, putting people and assets at risk.

Figure 10.1 shows that floodplains are influenced by healthy watersheds and water resources infrastructure, both of which can help reduce flood hazards and shape floodplain physical characteristics. This chapter is about floodplain management, allowing people to live in harmony with river and coastal floods, and making room for the river and the sea while also reaping the benefits of living close to water.

There are four broad strategic options for managing floodplains as shown in Figure 10.2 (Doberstein and others 2019). These

FIGURE 10.1 Floodplain Management in the EPIC Response Framework



Source: Authors.

Oka River Delta, Botswana. Photo: © 2bears | Dreamstime.com

Box 10.1 Room for the River Program in the Netherlands

In 1993 and 1995, floods threatened to devastate several regions in the Netherlands. As a precautionary measure, more than 200,000 people were evacuated. In the end, no dikes failed. But these near-floods convinced the government that safety measures against flooding should be increased. The political decision was that the safety level of the river system should be brought to standard of one flood in 1,250 years. The program was active from 2006 to 2018 with a budget of €2.2 billion and was completed on time and within budget, which is quite exceptional for major projects like this.

The measures in the project aimed to lower flood levels and included moving levees back from rivers, creating and increasing the depth of flood channels, reducing the height of groins, removing obstacles, and constructing a "Green River" that can serve as a flood bypass. At the same time, the measures aimed to restore rivers' natural floodplains and increase ecological value. The key purpose of the approach was to restore the rivers' natural floodplains in places where this was least harmful in order to protect those areas that needed to be defended. Measures were taken at more than 30 locations.

Key to the program was that the project was designed and implemented in close cooperation with all partners, in total 19, including provinces, municipalities, regional water authorities, and the *Rijkswaterstaat*. The involvement of all these partners was crucial as upstream partners were impacted by measures that would mainly benefit downstream partners. At the end, a win-win situation was achieved. The project was rooted in the overall Delta Program on Water Management in the Netherlands, which provided the policy guidance and financial means.

Key Issue: An important feature of this program was the intensive cooperation with the stakeholders. The interaction with the stakeholders took a lot of time and effort. But once all partners agreed on the design of the Room for the River Program, the implementation took place smoothly, which helped enable completion on time and within budget.

FIGURE 10.2 Strategic Options for Floodplain Management

Source: Authors, adapted from Doberstein and others 2019.

options are "protect, accommodate, retreat, and avoid." "Protect" implies the use of water resources infrastructure, such as river embankments and sea dikes. "Accommodate" refers to the practice of reducing the vulnerability of structures and facilities, for example by raising building elevations. "Retreat" involves removing assets at risk, for example by removing structures that are repeatedly flooded. Finally, "avoid" means not putting assets in floodplains in the first place. Floodplain management is the science and art of using these strategic options in an appropriate manner given the specific circumstances of a river or coastal reach.

The key programs presented in this chapter are summarized below. Since many floodplains were inappropriately developed before the risks of flooding were fully understood, floodplain management is typically a long-term and continuous process of constantly reducing exposure and vulnerability over time. In most cases, it offers an economical and resilient option that is a core pillar for reducing flood risks.

- **Floodplain Mapping.** To properly manage river and coastal floodplains, the hazards should be well understood and communicated to local governments and the public. This is an enormously complex and continuous process that the DRM or WRM agency typically manages due to the technical challenges involved. It cannot be done quickly and needs to be constantly updated as flood hazards change over time due to climate change, watershed development, and new water resources infrastructure.

Flood proofing can reduce the vulnerability of structures exposed to floods.

Traditional buildings on stilts on Inle Lake in the Shan Hills of Myanmar. Photo: Ana Nunez Sanchez

- **Floodplain Regulation.** Floodplain regulation helps to reduce exposure and vulnerability of people and assets and has two dimensions: (1) a permitting process to authorize development and activities; and (2) standards and codes to reduce the vulnerability of buildings and facilities. Land use management is generally a local government responsibility, and local governments should have their own specific floodplain management units. Some countries have even created multi-jurisdictional floodplain authorities to manage entire river or coastal stretches. The DRM agency has an important role to play in helping local governments by defining permitting guidelines and developing uniform standards. In some cases, the DRM agency may be legally mandated to oversee the implementation of local government floodplain regulations.
- **Local Flood Mitigation Planning.** River basin and coastal management planning are the tools generally used to reduce overall flood hazards at the regional level with a focus on watershed health and large-scale water resources infrastructure. Local flood mitigation planning plays an important complementary role to basin planning, and may often be part of a broader multi-hazard local government mitigation plan that includes other potential threats, such as earthquakes, landslides, and fires. Local flood mitigation plans go beyond regulation to proactively manage risks by identifying priority actions, such as refining land use plans and regulations, identifying infrastructure projects, conserving and restoring natural systems, and implementing education and awareness programs. The DRM agency has an important role in providing guidelines and technical assistance to local governments in the formulation of flood mitigation plans. In some cases, the DRM agency may be legally mandated to oversee local government flood mitigation plans.

10.1 Floodplain Mapping

Program description

Mapping and characterizing river and coastal floodplains is a challenging but essential process that forms the foundation for floodplain management. There are many different levels of characterizations and an ongoing flood hazard mapping program is needed to constantly refine the hazard maps and adjust to evolving circumstances, such as changes in the watershed, new water resources infrastructure, and climate change. At the most basic level, simple flood hazard maps show the spatial extent of flooding and can be generated from historical information, including satellite imagery.

More advanced approaches for river flooding include hydrological and hydraulic modelling using statistical information and accurate topographical maps generated through lidar surveys. Coastal flood hazard mapping involves assessing storm surges, tides, and wave heights associated with coastal storms and estimating how far inland the seawater will penetrate. In some circumstances, coastal and river floods will interact, resulting in complex and often devastating flood dynamics.

Floodplains are usually delimited based on the probability that a flood of a certain level will occur. For example, a 500-year flood has a 0.2 percent probability of occurring in any given year and a 100-year flood has a 1 percent probability of occurring in any given year. Although in the past, a 100-year flood was often used to define floodplains and set regulatory standards, there is now general movement towards using a 500-year design flood—particularly in more developed areas. The design flood is a statistical probability based upon historical information, which is often lacking in many countries. Moreover, these statistical properties can change over time as the watershed develops and the climate changes. A 500-year design flood thus provides a more robust floodplain characterization.

In addition to elevation, and where sufficient analytical capability exists, other parameters can be used to characterize design floods, including spatial extent, depth, velocities, and durations. In cases where there is an extensive system of river or coastal flood control infrastructure, these parameters should also be considered when defining the floodplain. Ideally and where justified, flood hazard maps can be combined with land use maps that provide information on populations and assets exposed within floodplains to generate "flood risk maps." Flood hazard or flood risk maps can be used for many purposes, including: (1) increasing awareness of flood risks by policy makers, developers, and the general public; (2) guiding basin planning, land use, and flood mitigation planning; (3) informing emergency planning and evacuations; and (4) providing a basis for flood insurance.

Linkage to the National Sector Framework

The establishment of a national flood mapping program should be mandated through either the water resources law or the DRM law. The law should authorize the WRM agency or DRM agency to implement a prioritized and continuous program of river and, as appropriate, coastal floodplain mapping. The law should also provide that the mapping information be freely available to the public in a manner that is digital geospatial data compliant. Given the complex and often contentious nature of flood mapping, consideration should be given to the establishment of a technical mapping advisory committee and potentially a dispute resolution mechanism. No single agency has the capacity to independently produce flood maps, and the law should also specify the necessary interagency and local government cooperation mechanisms so that the WRM or DRM agency can freely access available data. Finally, the law should require a vigorous communications and outreach program to communicate the results, uses, and limitations of floodplain mapping.

Key agency actions

Key agency actions for the WRM or DRM agency include the following:

- **Formulating a strategic mapping plan.** The development of national flood maps is an enormous task that needs to be done systematically and strategically. Ideally, this is done through a periodically updated strategic plan—for example every five years—which identifies priority areas for flood mapping along with the general mapping parameters. The strategic plan should balance the need to produce useful information to guide floodplain development with the desirability of accuracy. For example, the first generation of maps might rely primarily on satellite photos, while the second generation could utilize modelling to estimate the extent and depth of flooding.
- **Developing and regularly updating flood mapping technical standards.** In order to ensure consistency and quality, the agency should develop detailed technical standards to guide the mapping process. There are many technical decision points involved in the mapping process and a consistent approach is required, for example how to calculate return flood periods, topographic mapping requirements, modelling approaches, and how to deal with a changing climate and watershed. Since the mapping process is a long-term process, there are likely to be different versions of technical standards that should be properly documented and understood in the interpretation of map results.
- **Establishing an Interagency Task Force and Technical Advisory Committee.** The agency should establish an interagency task force to help support and guide the mapping process. Neither the DRM agency nor the WRM agency will have all the required information to independently develop river and coastal flood maps, and the interagency task force will allow for the free exchange of information and support as required. The agency should also consider establishing a technical advisory committee of experts to help provide guidance

on the technical challenges of flood mapping and potentially resolve any mapping disputes.

- **Performing post-flood hazard verification.** The agency should ensure that it has the capacity and methodology to lead a coordinated effort to collect and disseminate accurate flood data and risk information to aid response and recovery efforts after a flood disaster occurs. This information supports the "Post-Flood Disaster Needs Assessment" discussed in Chapter 11 but also provides actual flood information that complements the flood maps—which are an approximation of reality based upon a set of assumptions. The results of this post-flood hazard verification should be made available through the flood map center to provide additional information on floodplain risks.
- **Creating communications and outreach programs.** The agency should establish a flood map center which serves as the official public source for flood hazard information. The center could provide maps, databases, reports, educational resources, and other tools to help better understand flood risks. Coupled with this there should be an active communications and public outreach program to ensure that the floodplain information is conveyed to policy makers, developers, and the general public. This communications process should concentrate on the period during which maps are being developed or updated, so that communities can provide feedback on the mapping process and be made aware of the implications of floodplain designations. The agency should then work with the local governments to continuously remind the public of floodplain areas and potential risks.

Generic evolution

The generic evolution of this program is summarized in Table 10.1.

TABLE 10.1 Generic Evolution of Floodplain Mapping

Nascent	Engaged	Capable	Effective
No information on floodplain hazards is available, and developers and local governments do not take flood risks into consideration.	The DRM or water resources law requires the national agency to map river and coastal floodplain hazards, but capacity is limited and results are not incorporated into local land use plans.	The WRM or DRM agency has prepared rudimentary river and coastal floodplain hazard maps, and the local government has incorporated this information into land use plans.	The WRM or DRM agency has prepared several iterations of floodplain hazard maps and provides asset and exposure information to help local governments assess risk and develop local mitigation plans.

Source: Authors.

10.2 Floodplain Regulation

Program description

Local governments are generally responsible for land use management within their jurisdictions, but typically within a framework provided by the national (or regional) government. Local governments generally have the power to adopt local level rules regarding land use (described in this report as "ordinances"), to zone land for different purposes, to issue permits for development, and to require structures and facilities to meet certain code requirements. The extent to which local governments have the capacity to implement these tools varies greatly between countries, and sometimes even within countries. Floodplain regulation is usually contained in a set of instruments to help manage land within river and coastal floodplains and can help:

- to protect human life and health and to minimize disruption to local economies;
- to minimize expenditure of public money for costly flood control projects;
- to minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public;
- to minimize future blighted areas caused by flood damage; and
- to ensure that owners and buyers are aware that property is in a flood hazard area and can assume responsibility for their decisions.

Typically, a local government will adopt a "local floodplain ordinance" that provides the legal authority to manage floodplains as a separate zone and which sets out objectives, how the floodplain will be defined, and the general scope and administration of the ordinance. The ordinance will identify which department is responsible for its administration and has responsibility for preparing more specific regulations.

The national flood mapping program often defines the floodplain in which the ordinance applies, and the actual spatial extent of the floodplain and flood hazards may change over time as the maps become more accurate and as the nature of flooding changes. The floodplain ordinance should specify which uses require permits, generally focusing on proposed new uses or the retrofitting of existing uses. The ordinance should cover all relevant uses, such as new or modified building structures; infrastructure such as water, power, and roads; modifications to water courses; filling, dredging, mining, grading, land clearing, and material storage; and new or expanded subdivisions or industrial estates.

One of the goals is to ensure that proposed new uses do not actually increase the flood hazard, for example by increasing water levels. Another goal is to ensure that if a use is permitted, it must conform with certain flood resistant design principles. Internationally, there are various model flood resistant codes that a country or local government can draw upon. For buildings and structures, there are generally two approaches to flood resistance, which are not mutually exclusive. The first is to raise the structure so that it sits above the design flood level. The second is to floodproof the structure so that water does not penetrate inside the building. To be effective, the floodplain regulations must be implemented through an administrative process of permitting, design reviews, and inspections. As discussed in the next section, ideally the development of floodplain regulations will be informed by a more comprehensive floodplain mitigation plan.

Linkage to the National Framework

Land use management is generally the legal responsibility of local governments in accordance with land use planning legislation but is subject to controls promulgated by the national (or regional) government, particularly in matters related to public safety, environment, and defense. The DRM law may specifically mandate that local governments adopt and implement acceptable floodplain management ordinances; alternatively, the DRM law may provide incentives or sanctions to help compel local governments to adopt floodplain management ordinances, for example by controlling funding for flood control infrastructure, flood disaster aid, or flood insurance. The DRM law should mandate the DRM agency to prepare model flood ordinances

Box 10.2 Low-Income Communities Living on Floodplains in the Philippines: the Pasig River Case

The Pasig River connects the lakes of Laguna de Bay to Manila Bay. The 26-kilometer-long river, with an average width of 50 meters, runs through Metro Manila, the most populated area in the Philippines. It used to be a major source of transportation, water, food, and livelihood for many Manila residents. Over time, shanty towns filled with squatters were created at the borders and floodplains of the river, sometimes on stilts. Pollution increased to such a level that the river was declared biologically dead in the 1990s. To make things worse, flood frequency increased in the Pasig River as a result of upstream development. In 1999, the Pasig River Rehabilitation Commission (PRRC) was created by an Executive Order as a state commission to improve the situation. The PRRC faced major challenges in finding a balance between achieving its objectives to clean the river while considering the interest and well-being of more than 700,000 urban poor and fisherpersons who relied on the Pasig River.

Actual rehabilitation efforts began in 2010 with a loan from the Asian Development Bank of US$176 million to implement a 15-year upgrade program for Manila, including the rehabilitation of the Pasig River. The loan was provided under the condition that the relocation and livelihoods of the illegal squatters would have equal importance with the environmental aspect of the rehabilitation. The combined approach of pollution abatement and floodplain management was a key feature of the project.

The information included in this box is based the Wikipedia webpage on the Rehabilitation of the Pasig River, available at https://en.wikipedia.org/wiki/Rehabilitation_of_the_Pasig_River.

The key lesson of the project was that although the road to rehabilitate the Pasig River area was rough, in particular related to the resettlements, major results could be achieved. At the project's termination in 2018, the PRRC had resettled 18,719 families from the riverbanks to decent homes, dismantled 376 encroaching private structures, established 37,000 linear meters of environmental preservation areas, diverted almost 22,000 kilograms of solid waste, and supported the residents of the former shanty towns to develop more environmentally responsible practices. This has resulted in significant water quality improvements, as well as the revitalization and development of the Pasig River system. In 2018, the PRCC was awarded the prestigious Asia Riverprize from the International River Foundation for its achievements on the Pasig River.

and guidelines, provide technical assistance to local governments, and as appropriate approve and regulate the implementation of local floodplain management programs.

Key agency actions

Key actions for the DRM agency include the following:

- **Developing model floodplain ordinances and guidelines.** The agency should prepare model floodplain ordinances for local governments to build upon. The model ordinances should include various options depending upon the specific local circumstances, for example whether subject to river, coastal, or other flood hazards. The DRM agency should either require a set of national flood resilient codes and standards or identify other suitable national or international codes and standards that local governments can use.[32]
- **Overseeing floodplain regulation programs.** The agency should periodically visit the local government to provide technical assistance and assure adequate enforcement of floodplain management regulations. This typically consists of a tour of the floodplain, an inspection of permit files, and meetings with local officials. The DRM agency should actively work with the local government and other stakeholders to help them implement their programs, and in extreme cases, and where legally mandated, take enforcement action as necessary.
- **Providing technical assistance to local communities.** The agency should support local communities by providing floodplain information and helping to increase awareness of the perils of flooding and the importance of good floodplain management. The assistance could be provided in the form of outreach, education, general information, or site visits to assist on specific issues. As described in the next section, helping local governments develop flood mitigation plans is an important tool for improving floodplain management.
- **Supporting a professional association of floodplain managers.** The practice of floodplain management is increasingly being recognized as a distinct profession that draws upon expertise from different areas, including hydrology, land use planning, disaster management, civil engineering, and public administration. The agency should support an association of floodplain managers to build the community, share experiences, and build professional capacity. An example of this exists in the United States in the form of the Association of State Floodplain Managers, which offers professional certification on flood plain management.

Generic evolution

The generic evolution of this program is summarized in Table 10.2.

TABLE 10.2 Generic Evolution of Floodplain Regulations

Nascent	Engaged	Capable	Effective
There are no national floodplain permitting guidelines or standards for floodproofing buildings and facilities.	The DRM law requires the DRM agency to provide general regulations for floodplain permitting and floodproofing standards. The regulations are rudimentary and not fully adopted by local governments.	The DRM agency has promulgated comprehensive floodplain permitting regulations or technical guidelines on the adoption of such regulations by local governments, and these are implemented by local governments.	Local governments, with assistance from DRM agencies, have tailored floodplain regulations and standards to conform with their specific flood mitigation plans.

Source: Authors.

[32] Examples of international standards for FEMA can be found in the following publication: FEMA (U.S. Federal Emergency Management Agency). 2018. *Flood Resistant Provisions of the 2018 International Codes*. Washington, DC: FEMA, https://www.fema.gov/media-collection/flood-resistant-provisions-2018-international-codes-2018.

10.3 Flood Risk Mitigation Planning

Program description

Flood mitigation planning allows local governments to adopt an appropriate strategic mix of "protect, accommodate, retreat, and avoid" actions highlighted in Figure 10.2 and to proactively manage flood risks in their jurisdictions. Mitigation planning also helps to enhance and improve the effectiveness of floodplain regulation programs. The plans should set objectives, analyze flood hazards and risks, and identify mitigation actions to reduce long-term risks. Mitigation actions typically include: (1) refining local land use plans and ordinances; (2) identifying flood control infrastructure projects; (3) protecting and enhancing natural systems such as wetlands or undeveloped floodplains; and (4) education and awareness programs. The plans can also potentially include emergency preparedness and response actions.

For areas prone to river flooding, flood mitigation plans should be complementary and synergistic with river basin plans. Basin plans typically take a basin-wide perspective on flood hazards, for example by assessing the needs for storage reservoirs to control flood peaks, for large river embankments to protect developed areas, and for flood bypass channels to convey excess flows. Flood mitigation planning typically works within the framework provided by a river basin plan and attempts to mitigate the impacts of flooding through more local action.

For areas prone to coastal flooding, coastal flood mitigation planning is also complementary and synergistic to coastal zone management plans and, in some cases, may even be combined. A common challenge is that in the absence of a coastal-wide perspective, local governments may construct their own flood control defenses that then may shift the flooding to other areas in the basin. Any significant structural measures proposed in a flood mitigation plan, for example a river or coastal embankment, should be approved by the WRM agency (or responsible coastal authority) to ensure that flood protection measures enacted in one community do not have adverse impacts on either downstream or upstream areas. There are various approaches to structuring the flood mitigation planning process, organized around three general approaches. As appropriate, all three approaches could be undertaken in parallel and operate in synergy.

- **Multi-Hazard Mitigation Plans.** In some cases, flooding is included as part of a multi-hazard mitigation plan. Local governments may face a set of natural hazards, which are often coupled together, such as floods, storms, earthquakes, landslides, and fires. A multi-hazard planning approach has some clear advantages as it allows local governments to see the full set of hazards. It thus helps local governments prepare for compound or cascading events and to prioritize mitigation actions in a comprehensive and holistic manner.
- **Standalone Flood Mitigation Plan.** In some circumstances, the flood hazards are so complex that a local government may choose to have an independent flood management plan. This plan can be informed by or combined with an urban stormwater management plan, depending on the extent to which flooding from rivers and coasts interacts with stormwater generated within the urban area.
- **Regional Plans.** Local government planning processes may in some cases be insufficient for either multi-hazard planning or standalone flood mitigation planning, and it may also be useful to address the issue from a regional perspective. Local governments, however, will probably still need to develop their own flood or multi-hazard plans.

Box 10.3 California Local Hazard Mitigation Plans

The 2000 U.S. Disaster Management Act (the Stafford Act) requires state and local governments to develop and adopt Federal Emergency Management Agency (FEMA) approved local hazard mitigation plans (LHMPs) as a condition for receiving certain types of disaster and mitigation assistance. In many cases, floods are one of the primary hazards confronting a local government. The Plan must present the local government's floodplain management program and how it will comply with the National Flood Insurance Program requirements.

California's Office of Emergency Services (CalOES) assists local governments in the development of LHMPs by providing technical assistance, training, and outreach. CAlOES reviews all LHMPs to ensure compliance with FEMA requirements. This also helps CalOES gather hazard, vulnerability, and mitigation information from the local level for use in state-level planning.

Information in this box is based on the California Office of Emergency Services: https://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/hazard-mitigation-planning/local-hazard-mitigation-program.

Linkage to the National Sector Framework

The DRM or water resources law should specify the appropriate geographical scale for flood mitigation planning, as well as the scope of the plan. The DRM law may mandate that local governments prepare multi-hazard mitigation plans, which should include flood (and potentially drought) plans as appropriate. Alternatively, the DRM law may provide incentives or sanctions to help compel local governments to prepare hazard mitigation plans, for example by controlling flood infrastructure funding, flood disaster aid, or flood insurance. The DRM law should mandate that the DRM agency prepare hazard mitigation plan guidelines, provide technical assistance and funding to local governments for preparation of the plans, and ideally include a grant program to support funding of priority flood mitigation investments.

In some cases, the water resources law may mandate standalone river floodplain management plans or strategies that are separate from the river basin plans and that span multiple local government jurisdictions. Since many of the mitigation actions must be undertaken by local governments, it is imperative to include local governments in river floodplain management plans or strategies. In some cases, it may be possible—even ideal—to develop complementary local government multi-hazard mitigation plans and regional river floodplain management plans.

Key agency actions

Key agency actions for the DRM and WRM agencies include the following:

- **Preparing hazard mitigation planning regulations and guidelines.** The DRM agency should prepare a set of regulations governing the preparation, review, and approval of local government hazard mitigation plans. The regulations should include items such as: (1) general plan requirements; (2) periodic planning process; (3) plan contents, including risk assessment, mitigation strategy, and local government approval; and (4) procedures for DRM agency review and approval.
- **Providing technical assistance for the formulation of hazard mitigation plans.** The DRM agency should proactively support local governments in the preparation of their hazard mitigation plans by providing guidelines, training, and support to the process so that local governments can tailor their hazard mitigation plans to specific local circumstances. Since the DRM agency may be responsible for approving the plan, it is important that the DRM agency becomes familiar with local circumstances and provides advice during the planning process.
- **Integrating the Flood Mitigation Plan with the River Basin or Coastal Management Plan.** The WRM agency will need to actively work with the DRM agency and the local government to ensure that flood mitigation actions, particularly with respect to new flood control infrastructure, are consistent with the overall basin or floodplain management plan. The DRM hazard mitigation plan regulations should ensure that the appropriate partner agencies are involved in the planning process, particularly the WRM agency where there are river flood hazards.
- **Providing grant support program for the implementation of the Hazard Mitigation Program.** The DRM agency or the WRM agency should establish a grant program for local governments to help implement priority actions in the flood mitigation plan. The agency will need to develop regulations to govern the administration of this program, including eligibility requirements and criteria for competitive selection of proposals. This will help motivate local governments to undertake flood mitigation plans and implement key actions.

Generic evolution

The generic evolution of this program is summarized in Table 10.3.

TABLE 10.3 Generic Evolution of Local Flood Mitigation Plans

Nascent	Engaged	Capable	Effective
Local governments do not proactively manage floodplain risks.	The DRM or water resources law requires local governments to prepare flood mitigation plans and authorizes the DRM or WRM agency to prepare guidelines and provide assistance. Local governments are slow to prepare hazard mitigation plans.	The DRM or WRM agency has implemented comprehensive flood mitigation planning regulations or technical guidelines and supports local governments that have mainstreamed hazard mitigation into their plans.	The DRM or WRM agency implements financial and regulatory incentives and sanctions for local governments to prepare and implement local hazard mitigation plans.

Source: Authors.

10.4 Key Resources

Floodplain mapping program

FEMA (Federal Emergency Management Agency). 2020. "Risk Mapping, Assessment and Planning (Risk MAP)." FEMA, December 17, 2020.

Martini, Frederique, and Roberto Loat. 2007. *Handbook on Good Practices for Flood Mapping in Europe*. Paris/Bern: European Exchange Circle on Flood Mapping (EXCIMAP).

WMO (World Meteorological Organization) and GWP (Global Water Partnership). 2013. "Flood Mapping. Integrated Flood Management Tool Series." Technical Document no. 20. Geneva: WMO.

Floodplain regulation program

Association of State Floodplain Managers (https://www.floods.org).

FEMA (Federal Emergency Management Agency). 2009. *A Local Administrator's Guide to Floodplain Management and the National Flood Insurance Program*. Washington, DC: FEMA.

FEMA (Federal Emergency Management Agency). 2018. *Flood Resistant Provisions of the 2018 International Codes*. Washington, DC: FEMA,

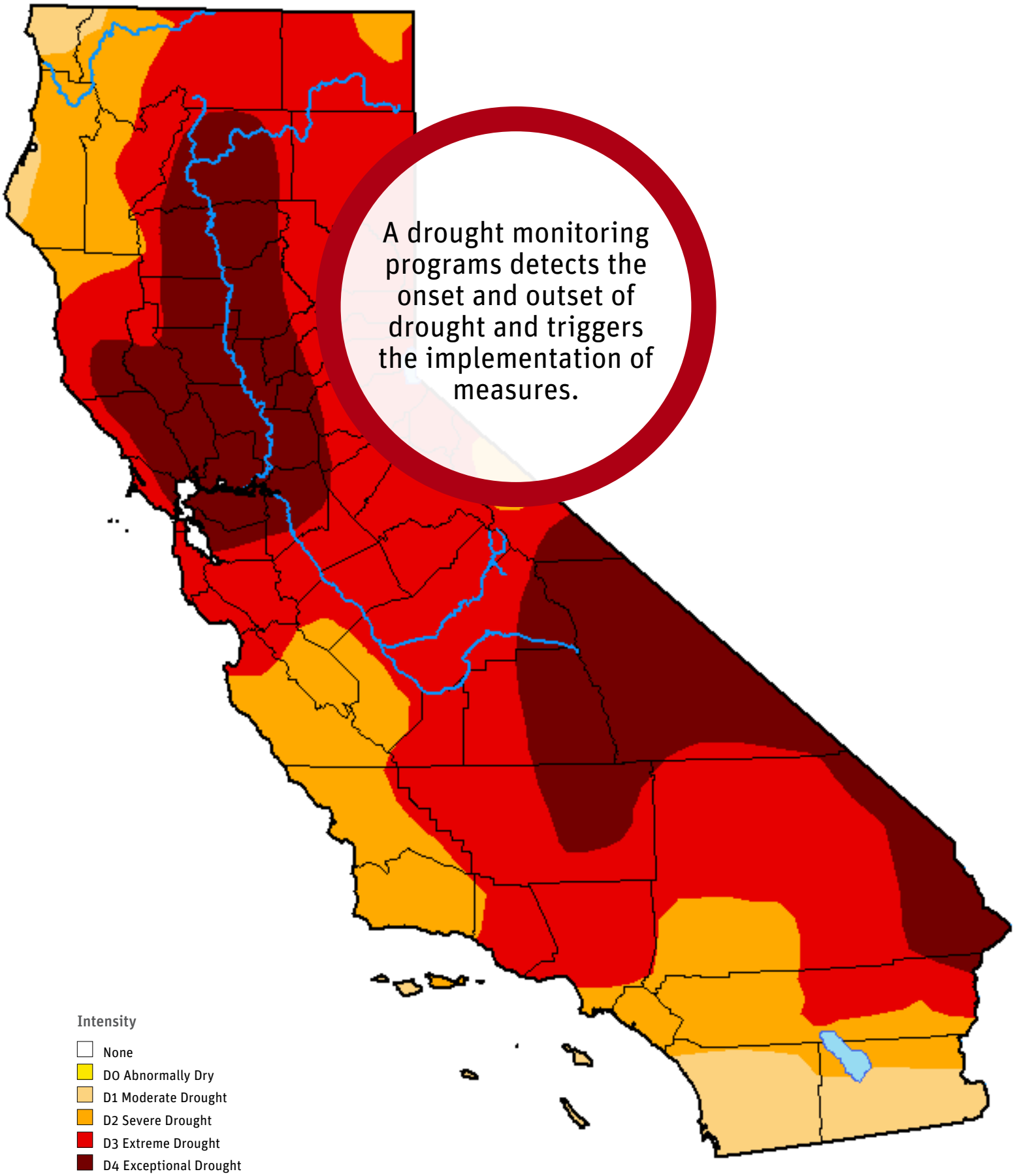
WMO (World Meteorological Organization) and GWP (Global Water Partnership). 2016. "The Role of Land Use Planning in Flood Management." Integrated Flood Management Tool Series, Technical Document no. 7. Geneva: WMO.

Flood mitigation planning program

AIDR (Australian Institute for Disaster Resilience). 2013. *Managing the Flood Plain: A Guide to Best Practice in Flood Risk Management in Australia*. East Melbourne: AIDR.

FEMA (Federal Emergency Management Agency). 2013. *Local Mitigation Planning Handbook*. Washington, DC: FEMA.

WMO (World Meteorological Organization) and GWP (Global Water Partnership). 2017. "Selecting Measures and Designing Strategies for Integrated Flood Management: A Guidance Document." Policy and Tools Documents Series no.1 version 1.0. Geneva: WMO.



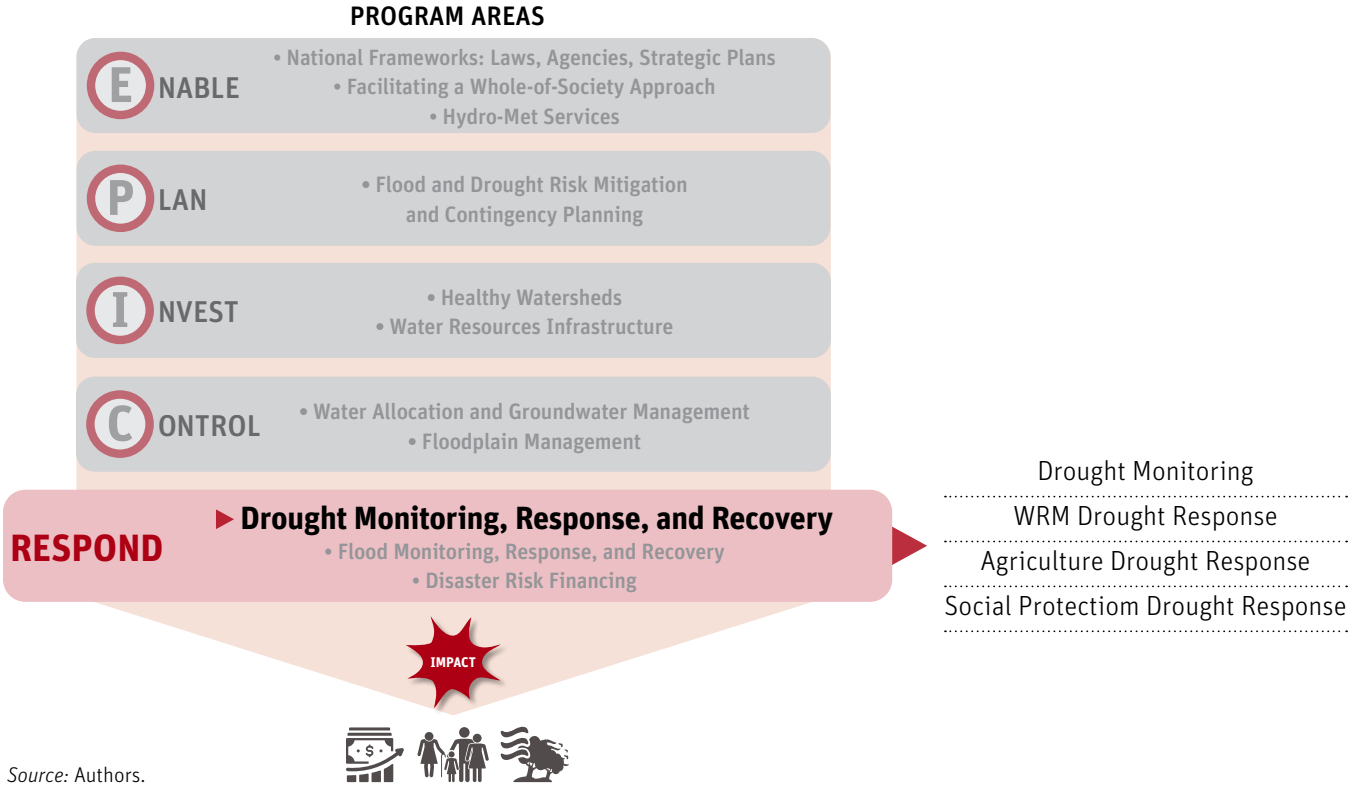
U.S. Drought Monitor California. Source: Adam Hartman

11 Drought Monitoring, Response, and Recovery

Droughts are an inevitable part of the hydro-climatic cycle and the goal of proactive management is to prepare for a drought, monitor the drought as it evolves, and then help reduce the impact of the drought on people, the economy, and the environment. As shown in Figure 11.1, actions taken to promote healthy watersheds, develop water resource infrastructure, allocate water flexibly, and conjunctively manage groundwater should also contribute to reducing drought risks. This chapter focuses on programs to monitor, respond to, and recover from droughts to further reduce the overall impacts.

As described in Annex 1, the distinguishing characteristic of a drought as a hazard is that it typically evolves over time, in some cases years, with each drought event being unique in terms of its geographical scope and social, economic, and environmental impacts. Droughts are driven by meteorological conditions that produce an abnormally high level of dryness in comparison to some "normal" level for that specific region. This period of dryness can impact agriculture by reducing soil moisture, thereby putting stress on plants and reducing their productivity. As the dryness

FIGURE 11.1 Drought Monitoring, Response, and Recovery in EPIC Response Framework



Source: Authors.

persists, it can have hydrological and eventually ecological impacts, reducing the amount of water available for cities, irrigated agriculture, industry, and the environment.

Chapter 3 highlighted the importance of having an overarching national framework for drought management, consisting primarily of a permanent, multi-sectoral Drought Committee and a periodically updated National Strategic Drought Plan. The National Strategic Drought Plan helps ensure a clear definition of institutional responsibilities and procedures for responding to droughts. Nevertheless, since each drought unfolds in its own unique manner, the Drought Committee needs to be proactive and flexible to tailor the response appropriately. The programs that are reviewed in this chapter are summarized below:

- **Drought Monitoring Program (DMP).** This program should ideally be multi-sectoral but anchored in a specialized agency (such as the NHS/NMS or WRM agency). The program should be constantly providing public assessments to the Drought Committee, local governments, and the general public on drought status throughout the country. As a drought emerges and evolves, the Drought Committee should mobilize standing or a*d hoc* Impact Assessment Groups (IAGs) with the membership and scope adjusted to the circumstances in a specific region. These IAGs should be composed of representatives from specialized national agencies, local governments, the private sector, and civil society as appropriate and provide publicly available situation reports. The DMP should classify and report on the level of drought for specific regions of the country.
- **WRM Drought Response.** Chapter 6 highlighted the importance of having drought contingency plans at the basin, city, and irrigation scheme levels. As different levels of drought are declared, this should help trigger actions outlined in specific river basin plans, urban water supply plans, and irrigation water supply plans. The WRM agency should help support, monitor, and report on the implementation of these plans as part of its overall responsibility within the Drought Plan and membership in the Drought Committee.
- **Agriculture Drought Response.** Rural populations depend on agriculture for their livelihoods, including both crops and livestock, and are particularly vulnerable to droughts. This is especially true in low-income countries that may not have well-developed water infrastructure to help buffer the impact of dry periods. Chapter 7 highlighted the importance of climate-smart agriculture programs in helping to mitigate drought impacts. When a severe drought does strike, the agriculture agency should have drought support programs in place to help agriculturalists respond to and recover from droughts. The agency should administer and report on the implementation of these programs as part of its overall responsibility within the Drought Plan and membership in the Drought Committee.
- **Social Protection Drought Response.** These programs help vulnerable populations, particularly in rural areas, cope with droughts and can include measures such as cash transfers, temporary labor, and in extreme cases camps for displaced people. It is important that the social protection programs be pre-planned and scalable to help the meet specific needs of the drought. The Drought Committee has an important role in ensuring the effectiveness of social programs, and social protection agencies should be members of the Drought Committee.

After every significant drought event, the Drought Committee should undertake a Post-Drought Assessment. The assessment report should look the evolution, responses, and impacts associated with the drought and distill lessons learned. This will help inform the next iteration of the national Drought Plan, as well as the specialized programs supporting drought risk management.

11.1 Drought Monitoring

Program description

A comprehensive Drought Monitoring Program (DMP) encompasses two interrelated activities: (1) the monitoring and forecasting of meteorological and hydrological conditions; and (2) the assessment of actual and potential on-the-ground drought impacts and risks. The DMP should classify and report on the level of drought for specific regions of the country. The designations often range from 1 to 5, from a low level (1) of "abnormally dry" to the highest level (5) of "an exceptional drought". The designation of a drought level is important because it should help communicate the relative severity of the drought to different parts of the country and trigger actions identified in the National Drought Plan.

A drought monitoring program identifies climate and water supply trends and detects the emergence or probability of occurrence of droughts, usually by categorizing severity through a percentile ranking approach, and the likely impacts associated with each category. The information can be used to communicate broadly to the general public, as well as to inform specific regional, local, and sector-specific drought management plans and actions. This information can be used to trigger drought mitigation and response measures, as well as disaster declarations and eligibility for drought-related

Box 11.1 The Netherlands National Coordination Commission for Water Distribution

In years with insufficient precipitation and low discharges of the rivers, the Netherlands faces drought conditions and decisions have to be made on how to distribute the available water. The main organization for dealing with droughts is the National Coordination Commission for Water Distribution (*Landelijke Coordinatiecommissie Waterverdeling* or LCW) in which all water managers (at the national, provincial, and water board levels) are represented. The activities of the LCW include monitoring, forecasting, and reporting (bi-weekly and, when needed, more frequent) on the situation, if needed. The LCW decides on the crisis situation (using one of four levels: regular management, imminent shortages, actual shortages, and crisis shortages), when to involve higher governmental levels (up to the Ministerial level), and what prescribed actions to take depending on the shortage situation.

The main trigger for the determination of a drought in the Netherlands is the combined situation of a high precipitation deficit (evaporation minus rainfall), the river inflow of the Rhine and the Meuse in the country, and a general picture of the groundwater levels. The designation of the drought level is based on pre-defined values of river inflow and the precipitation deficit. In cases of actual shortages, actions are taken in the water distribution system by allocating water to specific regions, and a pre-defined priority list is applied. The highest priority is afforded to safety by ensuring that dikes do not dry out and become structurally compromised. This is followed by public services (drinking water and energy), then high-value water use (horticulture and process water in industry), with all other uses in the lowest category (agriculture, shipping, and recreation). The activities of the LCW are formalized in Ministerial documents and ratified by the Inter-Ministerial Steering Group on Management of Water Crises and Flooding.

Key Issue: Recent severe drought conditions (in 2003, 2018, and 2020) have shown that LCW functions well. The strength of the LCW is the strong involvement of key stakeholders in decision making and the transparent procedures on how to communicate and deal with the various levels of the crisis situation.

programs, such as disaster relief, insurance, and eligibility for low-interest loans. It can also be used to help inform food relief efforts, water tanker truck deliveries, and other policy and management responses.

Monitoring and forecasting should also be coupled with programs to assess drought risks and impacts. Ideally, drought risk analysis should take place at different levels and through different planning processes, for example through the National Strategic Drought Plan and the basin, city, and irrigation drought contingency plans discussed in Chapter 6. The agriculture and social protection agencies should also undertake a drought risk analysis to be prepared when a drought occurs.

There are two main reasons for drought impact reporting and assessment. First, impact reporting mechanisms enable feedback, validation, and ultimately improvements to the monitoring and early warning system itself. Second, impact assessments help to gain a more holistic perspective on drought conditions as they are unfolding, thus helping to improve overall response efforts. For both reasons, ground-truthing from stakeholders on the actual impacts of droughts should be in place and coordinated through the National Drought Committee or a subcommittee on monitoring and impacts assessment. This helps to increase the trust of stakeholders with respect to the program and build ownership, while helping to calibrate assessments of severity for local areas. Stakeholder feedback can also be archived into a historical database for future risk assessments.

In summary, an effective drought monitoring program will include the following:

- Cover important sectors of the country and different spatial resolutions (local, regional, and national);
- Institutionalize a process to collect and assimilate information on the key drought indicators, including the assessments of its severity and impacts, a clear categorization process for when a country is entering and exiting a drought, and feedback mechanisms for validating the status of the drought;
- Foster and support a research environment that focuses on improving drought early warning;
- Provide accurate, timely, and usable information on drought conditions and associated risks to facilitate proactive decision making;
- Help to increase public awareness and education on how and why droughts occur, and how they impact human and natural systems; and
- Function at high capacity even during periods of wet or normal conditions.

Linkage to the National Sector Framework

The drought law should highlight drought monitoring, forecasting, and risk and impact assessment as core functions under the overall auspices of the Drought Committee. The law should spell out the institutional arrangements for a DMP. Given the multi-disciplinary nature of drought monitoring, it is important to include all relative agencies, including but not necessarily limited to meteorological, hydrological, water resources, agriculture, disaster risk management, and natural resources management agencies.

The drought law should therefore create a Drought Monitoring Subcommittee anchored in one of the specialized agencies. The drought law should also provide the authorization to the Drought Committee or the Drought Monitoring Subcommittee to establish standing or *ad hoc* "Impact Assessment Groups" which can operate based on terms of reference appropriate to the specific drought conditions. The drought law should also spell out the authorizing power of the Drought Committee, or of the Government on the recommendation of the Drought Committee, to formally issue a Drought Level for a specific region based upon its independent assessment. The drought law may also authorize the Government to formally declare a disaster in a region if the drought level reaches a certain threshold, thus initiating disaster management protocols.

Key agency actions

Key actions for the Drought Committee and its constituent sector agencies include the following:

- **Establishing the governance document (the charter and terms for reference) and procedures for the Drought Monitoring Subcommittee.** The Drought Committee should establish a formal charter for its monitoring subcommittee, identifying its objectives, membership, procedures, and obligations of the different entities participating in the Monitoring Subcommittee. One of the specialized agencies should serve as the anchor or secretariat for the Subcommittee, typically the Hydro-met or WRM agency. The Committee could also potentially include research institutes operating within or outside of the country. As discussed in Chapter 5, it is particularly important to develop linkages with international agencies or centers providing global weather information. In many cases, formal MOUs linking the specialized agencies and institutes to the Subcommittee may be useful. Clear operational procedures for the Subcommittee should also be established, including frequency of meetings, reporting, and decision-making process.
- **Developing protocols and guidance for drought monitoring and impact assessment.** The Subcommittee should develop protocols for operationalizing the production of a drought monitor, as well as risk assessments, that build cross-agency and cross-sectoral agreement on how droughts will be defined and characterized; identify the institutions involved with producing a drought monitor and procedures for updating the monitor; contain feedback mechanisms for validating the monitor with various stakeholder groups; and provide guidance for conducting vulnerability assessments, such as how to quantify costs and characterize the risks faced by key sectors and vulnerable populations. These protocols should also include procedures for constituting IAGs to examine drought

Box 11.2 Composite Drought Indicator Taking Root in Southern Africa

The development of a robust drought monitoring and early warning program is critical to improving the effectiveness and efficiency of drought preparation and response interventions—a realization that is beginning to proliferate throughout the Southern Africa region. Several countries, including Botswana, Eswatini, and Zimbabwe, are in the process of developing a composite drought index (CDI), which will lay the foundation for an improved drought management system.

The efforts involve working with the World Bank and the National Drought Mitigation Center of the University of Nebraska, Lincoln, to collect drought-relevant data from satellites, surface observations, or computer models and to develop drought indicators based on data availability, quality, and decision-making needs. These indicators are now being placed into historical context, using the percentile ranking method to categorize the data and assign severities and relative weights, and will then be used to create a single CDI monitoring product. Critical to the ultimate utility of the CDI is the feedback and validation process put in place by the respective "champion" institutions in each country to understand how individual drought indicators represent drought conditions and to establish the relative accuracy and performance of the full CDI. Once the CDI is operational, agencies and ministries can establish triggers based on the CDI to initiate drought management actions according to several levels of drought severity, linking them with a national drought plan and city and town drought contingency plans. This will ultimately help to increase awareness and create consensus on "who does what and when" as a drought is unfolding in these countries.

Box 11.3 Cautionary Tale

It is critical to have a process for declaring the different levels of severity as a drought develops. It is equally important to have defined procedures and triggers for exiting a drought. Maintaining drought declarations at high levels when in reality the drought situation on the ground has subsided can not only erode public confidence in the veracity of the associated drought mitigation and response measures, it also exposes the process to perceived politicization and political capture (such as local politicians wanting to keep the status 'high" to receive government support).

impacts and risks in a specific region for a drought event, including the production of "drought situation reports". These IAGs should include specialized agencies, local governments, and a broad spectrum of stakeholders, including business, agriculture, and civil society. The protocols should ensure that the IAGs produce periodic and structured situation reports over the course of the drought, including a final report after the drought is declared to be over that summarizes the overall social, economic, and environmental impacts of the drought as well as lessons learned.

- **Establishing procedures for drought declarations.** The Drought Committee should establish clear procedures for agreeing on drought levels for specific regions based upon the recommendations of the Drought Monitoring Subcommittee. Determining a drought level is not a mechanical task, but rather should be a flexible process taking all social, economic, environmental, and political factors into consideration. Nevertheless, there should be a formal process for declaring a certain drought level, preferably including open hearings with public comment.
- **Operating a Drought Information Center.** Information generated by the Drought Monitoring Program should be easily accessible and freely available to the public through an integrated information system or portal. The information should include the underlying hydrological and meteorological data, current and historical drought maps, and situation reports generated by IAGs. The Drought Information Center can also serve a central function in drought education and awareness. During periods of drought, the Information Center has a critical role in disseminating information on the drought status, impacts, and potential risks. The Information Center should support the specialized agencies so they can provide the necessary information to their constituencies through their own public outreach programs.

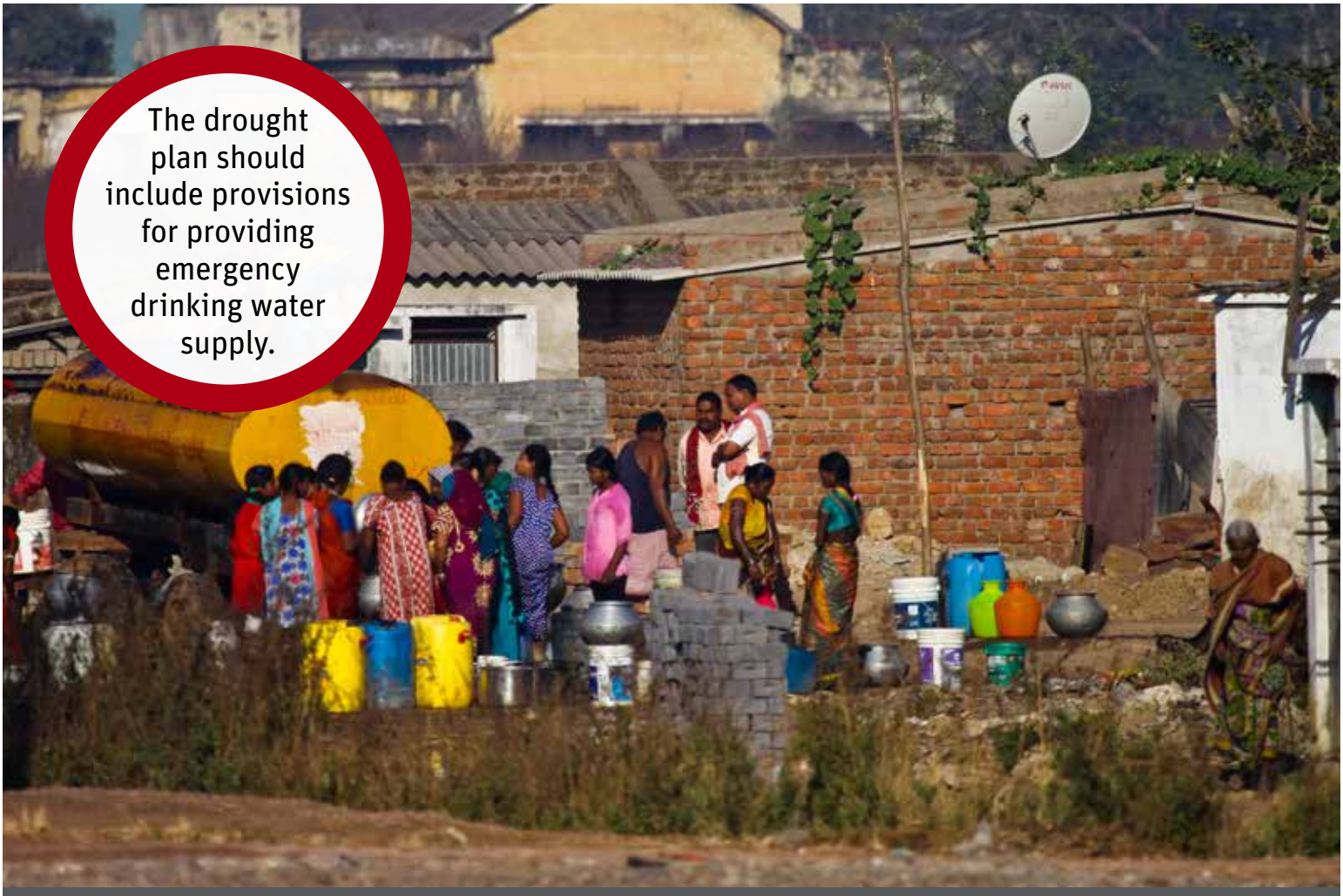
Generic evolution

Table 11.1 provides a generic overview of a national DMP.

TABLE 11.1 Generic Evolution of Drought Monitoring Programs

Nascent	Engaged	Capable	Effective
No drought monitoring, forecasting, or risk assessment programs in place, leading to *ad hoc* crisis management and emergency response. Decision making is siloed by sector and based on single index values (such as the Standardized Precipitation Index). There is minimal capacity to estimate and track sectoral vulnerabilities and risks.	National drought law has been promulgated but the DMP is at an incipient stage. Institutional mechanisms exist for data integration to develop and maintain a composite drought index mapping product that provides a national overview of drought conditions. However, risk and impact assessment mechanisms are weak and not fully institutionalized.	Drought monitoring program includes forecasting, monitoring, and risk and impact assessment. However, information from the DMP is still not fully utilized by the Drought Committee and the formal system for drought declarations that can temporary suspend or limit water use permits or trigger initiating actions in the National Drought Plan and other drought contingency plans has yet to be used. Drought impact situation reports are provided on a regular basis to the Drought Committee.	The Drought Committee uses the DMP to issue formal drought declarations that trigger actions in various drought contingency plans and programs. The Drought Monitor provides feedback on the effectiveness of drought response actions and allows the Drought Committee to adjust as necessary. Following the drought, a comprehensive drought impact assessment study is prepared to assess impacts and lessons learned.

Source: Authors.



Villagers collecting drinking water in Raipur, India. Photo: KuntalSaha

11.2 WRM Drought Response

Chapter 6 discussed programs for drought contingency planning at the river basin level, as well as for cities and large irrigation schemes. As a drought unfolds, and a region transitions through different levels of drought severity as informed by the DMP, these various drought contingency plans need to be activated. Each of these plans will most likely have even more detailed pre-determined thresholds and triggers for sector- or location-specific drought actions. For cities and irrigation schemes, this generally means increasing levels of voluntary and then mandatory water conservation coupled with prioritization of water uses. In the most extreme droughts, cities and rural communities may have to tap into emergency sources of water or distribute water through tankers.

During droughts, water use needs to be coordinated at the basin level to ensure water allocations are in alignment with the overall basin drought contingency plan. As highlighted in Chapter 9, the WRM agency should ideally administer a water use permit system that has clear rules of priority during periods of water shortage or drought. Ideally, this permit system would be flexible enough to accommodate priority and equitable use of water during droughts, either through administrative decisions by the WRM agency—preferably within the context of deliberations within the Drought Committee—or through a water rights trading system. The role of conjunctive groundwater management was also highlighted in Chapter 9, underscoring the need to facilitate the storage of water in aquifers during non-drought periods and then abstracting groundwater for use during droughts. The challenge is to ensure that the sustainable yield of an aquifer is not exceeded over the long run.

The WRM agency often, but not always, serves as the anchor agency for the Drought Committee. In regions where cities, industries, and farms rely heavily on surface water or groundwater, particularly when delivered through regional water conveyance systems, the WRM agency has a critical role to play in drought response. As a core member of the Drought Committee, it should monitor and report on the implementation of the various drought management measures, as well as the overall water balance at the river basin level. The WRM agency also has a central role to play in drought communications and public outreach during droughts, reaching out through its various channels to create a culture of water conservation and water use efficiency. The WRM agency can build upon emergency water conservation activities during droughts to help promote the necessary

policy, legal, and institutional reforms to further the agenda of water stewardship.

The national sector framework and key agency actions for the various WRM programs were discussed in previous chapters. Table 11.2 provides a generic evolution of how these different programs could respond and evolve over time.

TABLE 11.2 Generic Evolution of WRM Drought Response

Nascent	Engaged	Capable	Effective
River basins, cities, and irrigation schemes do not have drought contingency plans. Each water user responds to droughts independently through a chaotic process with little or no effort to allocate water efficiently.	The water resources law is promulgated, and the WRM agency attempts to manage droughts on an *ad hoc* basis, without clear mechanisms for water allocation and in the absence of drought contingency plans at the basin, city, and irrigation scheme level.	The WRM agency has river basin drought contingency plans and has approved drought contingency plans for cities and irrigation schemes. However, water allocation is done in a rigid manner without ensuring equity and efficiency. Groundwater is overdrawn in an unsustainable manner to meet water needs.	The WRM agency oversees the dynamic and flexible allocation of water among users through administrative decisions, negotiated agreements, or water markets. Groundwater is managed conjunctively with surface water and ample reserves exist for emergency use of groundwater.

Source: Authors.

11.3 Agriculture Natural Hazard Response

Program description

Agriculture, including both crop and livestock production, is an inherently risky endeavor and subject to many types of natural hazards, such as droughts, floods, pestilence, fires, tornadoes, and hail. Agriculture is also confronted with many market risks, such as price fluctuations, logistical interruptions, and sudden export restrictions. Therefore, it is important that the agriculture agency develop a sector-wide agriculture risk management program that considers all risks in a holistic manner to help farmers and livestock producers cope with this broad range of uncertainties (World Bank 2016).

As highlighted in Chapter 6, climate-smart agriculture programs can help mitigate potential drought impacts by promoting improved agronomic practices. When a severe drought does strike, however, agricultural disaster support programs can be powerful tools to protect the livelihoods of agriculturalists. Such programs can also help de-risk the agricultural sector and contribute to increasing agricultural output through improved access to credit and encouraging agricultural investments.

Agricultural disaster support is generally organized around two approaches: (1) direct government-administered relief; and (2) relief administered through agricultural insurance. Direct relief programs provide financial support, such as payments or concessional loans, to agriculturalists who suffer damages due to natural hazards. Natural hazard insurance programs, on the other hand, are typically established, regulated, and subsidized through the agriculture agency, which works through insurance companies that offer plans to agriculturalists. Specialized direct relief or insurance programs are required to deal with different types of producers, for example different programs may be required for annual crops, perennial crops such as orchards or plantations, and livestock.

Depending on the specific country context, there may be a mix of direct relief programs and insurance programs. There are many advantages to insurance programs, which provide the following benefits:

- They help share risk between the government and agriculturalists, providing incentives for the agriculturalists to make more climate-informed decisions.
- Depending on the mechanism used, insurance companies can often provide relief more efficiently and quickly than government agencies can.
- Relief does not have to rely on government appropriations, which may or may not be enough to respond to an agricultural disaster at a given point in time.

Nevertheless, agricultural insurance programs are challenging to establish and regulate due to their complexity. For most developing countries, securing adequate resources for financing insurance subsidies over time has also proven challenging. One option to simplify the process and reduce the financial burden is for the agriculture agency to simply provide free insurance for the layer of catastrophic risks experienced by the most vulnerable. For example, the insurance could use a parametric approach, in which insurance payments are made when a specific area reaches a predetermined drought

level. With this approach, individuals and institutions would have the option of purchasing top-up insurance to cover less catastrophic risk layers. Providing free insurance for the catastrophic layer could potentially lower the overall cost of insurance and help create a minimum market size. Such "smart" subsidies must include a clear exit strategy or rely on secured, long-term financing where required.

One of the key challenges is to ensure that agriculture insurance and disaster support programs are complementary. If the government steps in and provides disaster relief to an agricultural business that opted out of buying insurance, then this will potentially undermine the insurance market. Insurance programs may not cover all agricultural circumstances, for example specialty crops, and thus usually a mix of insurance and direct support programs may be required.

A key element in protecting agricultural producers is the provision of agro-climatic services. This includes meteorological and hydrological information specifically tailored to meet the needs of agriculturalists, often with crop-specific information and advice. As noted in Chapter 5, the agriculture agency typically should work closely with the NMS/NMHS to develop a customized agro-climatic program that disseminates information to producers in a timely and targeted manner. Typically, there are two-way information flows between the DMP and the agro-climatic services program.

Linkage to the National Sector Framework

The agriculture law provides the authorization for the establishment of the various agricultural disaster support programs. Typically, the law will authorize each specific disaster support program and provide broad principles and guidelines for its implementation. The agriculture agency is then mandated to administer the various programs. The drought law should specify that the agriculture agency is a core member of the Drought Committee, helping to shape the government's response to drought as well as serving as a channel for representing agricultural interests and impacts. In addition, the drought law may specify the general role of the Drought Committee in providing objective drought information to help guide the administration of the agricultural disaster support programs.

Key agency actions

Key actions for the agriculture agency include the following:

Establishing a partnership with the NMS/NMHS to provide agro-climatic services. The agriculture agency should work closely with the NMS/NHMS to develop a program to deliver customized weather, climate, and advisory services for agriculturalists. This typically requires interagency agreements so that the NMS/NHS can provide tailored information needed by the agriculture agency. The agriculture agency will then need to find effective and appropriate channels to disseminate this information, potentially in partnership with the private sector.

Setting up an Agriculture Risk Management Program. The agriculture agency should set up a risk management program that can be used to provide support to farmers to help manage a variety of risks, including natural disasters. Some of the tools to support agriculturalists potentially include insurance or direct support programs. The program should offer information to producers regarding markets and risk, technical assistance coping with common risks including hydro-climatic risks, protection from the spread of animal and plant diseases and pests, and assistance recovering from natural disasters.

Developing tailored Agricultural Disaster Support Programs. The agriculture agency should develop customized disaster support programs for different types of producers, for example common annual crops, perennial crops, livestock producers, and specialized niche crops. Each of these programs should have specific regulations for eligibility, verification, and payment based on sound risk assessment analysis. The different programs may need to be explicitly authorized by the agriculture law. For drought-related impacts, the triggering of support for these programs may be linked to the DMP.

Facilitating an Agricultural Insurance Program. Where appropriate and feasible, the agriculture agency should facilitate the development of a national insurance program. The agency should develop the capacity to undertake agricultural risk assessments and decision support services, such as agriculture statistics and agro-climatic information services. Policies and regulations related to agricultural insurance programs should ensure appropriate risk assessments and encourage comprehensive analysis of agricultural risks to assess the viability of proposed insurance contracts. Typically, a joint taskforce including the agriculture agency, the finance agency, and insurance companies is necessary to coordinate the development of the agriculture insurance market. A multi-stakeholder working group should also be formulated to advise this taskforce, comprised of members from farmers' organizations, (re)insurers, other financial institutions, public sector institutions, development partners, and sector experts. In the case of relatively small economies, the working group might also advocate for an enabling regional policy and regulatory framework to facilitate risk pooling by insurers in countries within the same region.

Generic evolution

The generic evolution of this program is summarized in Table 11.3.

TABLE 11.3 Generic Evolution of Agriculture Drought Response

Nascent	Engaged	Capable	Effective
No disaster support exists for farmers or herders who are left to absorb the economic and social shock of droughts.	The agriculture law requires the agriculture agency to provide disaster relief to agricultural producers, but this is done in an *ad hoc* manner without clear programs in place.	The agriculture agency has developed a set of agricultural disaster support programs with clear regulations. Insurance markets, supported by the agriculture agency, are starting up. The agriculture agency offers basic agro-climatic services.	The agriculture agency has a set of support programs, based primarily on insurance. The DMP provides information to implement the programs. Sophisticated agro-climatic and risk management services are in place.

Source: Authors.

11.4 Social Protection Drought Response

Program description

Dedicated agricultural disaster support programs may function well in middle-income countries where the agriculture sector is commercialized, and where agriculturalists have the capacity to apply for assistance. In many developing countries, however, farming and livestock production is managed in a more informal and often subsistence level, and different approaches focused on social protection are required to help rural households respond to and recover from droughts (and from floods, for which social protection programs are discussed in Chapter 12). Even with commercialized agriculture, agricultural disaster support programs may not be enough to meet the needs of the impacted population. For example, people employed on farms or who operate as sharecroppers may lose their jobs due to droughts. In addition to their economic impacts, droughts in rural communities may also have deep and long-lasting social impacts related to malnutrition and lack of access to water and sanitation. They can have a profound short-term impact on health as well as longer term impacts such as childhood stunting or lack of access to schooling.

For these reasons, countries should have preconceived programs for ensuring food and water security in rural areas impacted by natural disasters. Social protection programs that help facilitate effective drought responses in rural areas include offering traditional safety nets and, in extreme conditions, humanitarian aid.

Types of social protection programs to address droughts include, but are not limited to unconditional cash transfers; conditional cash transfers; social pensions; food and in-kind transfers; school feeding programs; public works (particularly those mobilized during a drought); fee waivers and targeted subsidies; contributory old-age, survivor, and disability pensions; sick leave; maternity and paternity benefits; health insurance coverage; other types of social services and insurance; active labor market programs (training, employment intermediation services, and wage subsidies); and passive labor market programs (unemployment insurance or early retirement incentives).

Food and in-kind transfer programs (regular and emergency) are common in countries that have historically suffered from droughts. These programs focus particularly on vulnerable groups, such as malnourished children under five years of age, pregnant and breastfeeding mothers in food-insecure areas, and refugees. For drought response, countries often focus on the use of short-term safety nets aimed at supporting people affected by a drought, or those who have temporally fallen into poverty or food insecurity. Regular or longer term poverty-targeted cash transfer programs represent other mechanisms to address drought risks, while also reducing poverty. Rural shock-responsive safety nets can be rapidly scaled horizontally (increasing the coverage of beneficiary households) or vertically (increasing transfer amounts) when a drought emergency occurs. Again, the scale-up mechanism is generally activated via an objective, pre-defined trigger, linked to the drought early warning system. Finally, supporting rural livelihoods during a drought also involves being prepared to most efficiently and comprehensively deliver emergency food aid and water supplies. This requires the DRM, Civil Defense, or other designated agency to have a well-articulated plan for deploying food and water tanker trucks to the communities most likely to face shortages during droughts.

The Drought Committee has a critical role to play in facilitating social protection programs, and the key national agencies responsible for providing social protection should either

be represented on the Drought Committee or be called up to participate when a drought is forecasted or in the early stages of development. There is a wide variety of social protection delivery mechanisms among countries, often delivered through different national agencies with the support of local governments, national and international humanitarian organizations, and development agencies. It is beyond the scope of this report to review the design and implementation of different social protection programs, and the reader is referred the references below for more information. Since each drought event is unique in terms of its geographical extent, evolution, and intensity, a key function of the Drought Committee is to help guide the social protection agencies to adjust and calibrate their support accordingly.

Linkage to the National Sector Framework

The drought law should highlight the importance of social protection programs during droughts and mandate that national agencies providing social protection develop specific drought contingency plans. The drought law should also mandate that the lead social protection agencies are members of the Drought Committee, and that drought-related social protection programs are included in the National Drought Plan. Either the DRM law or the water resources law should require the responsible agency to work with local governments to ensure that contingency plans are in place for the provision of emergency water and food supplies for towns and rural areas.

Key agency actions

Key actions for the agriculture agency and the various social protection agencies include the following:

- **Facilitating the provision of social safety nets during droughts.** The agriculture agency, being on the front lines of rural development, and the social protection agencies should play facilitating roles in the provision of social safety nets during droughts. This includes coordinating across agencies and helping to define roles and responsibilities for all actors, as well as linkages and information-sharing arrangements with humanitarian actors. The country's Executive and Cabinet also play crucial roles in coordination and funding support during periods of national crisis.
- **Ensuring the flexibility and adaptability of social protection programs.** The agriculture agency and the social protection agencies should ensure that the social protection programs have the flexibility to rapidly scale up and are adapted to the needs following a major drought, with pre-established contingency plans and funding mechanisms.
- **Targeting the rural chronic poor and most vulnerable households.** Even when countries have well-established policies and institutions with respect to social protection, large overlaps often occur, along with significant inclusion errors. Resultant gaps leave some members of the poorest and most excluded groups without enough support. Policies that identify and target the poorest families and individuals within these groups during drought emergencies are a critical backstop to avoid devastation. This includes pre-negotiated contracts for hauling and distributing food and water, pre-planned mapping and logistics details for moving food and water, and thorough communications and outreach mechanisms around these emergency distributions.
- **Ensuring sound governance and accountability mechanisms.** The agriculture agency and the social protection agencies should ensure sound governance and accountability mechanisms, with the effective participation of beneficiary groups, proper communication and feedback mechanisms, clear guidelines and safeguards to reduce fiduciary risk, and a system of monitoring and evaluation that allows for measuring impacts and outcomes to inform future efforts.
- **Building longer term adaptive capacity.** During and following a drought, the agriculture agency should prioritize and target the climate-smart agriculture programs discussed in Chapter 6 on the socially vulnerable and drought-impacted population. This helps them recover more quickly and also increase their longer term adaptive capacity.

Generic evolution

The generic evolution of social protection programs is summarized in Table 11.4.

TABLE 11.4 Generic Evolution of Social Protection Drought Response

Nascent	Engaged	Capable	Effective
Rural communities are left to fend for themselves during droughts leading to severe social and economic impacts, particularly for the most vulnerable.	The drought law mandates that the government provide social protection to vulnerable populations impacted by drought. However, social protection may not be a priority issue for the Drought Committee. The agriculture agency and other social protection agencies do not have preconceived programs in place. Droughts may evolve into an emergency that requires humanitarian assistance.	The Drought Committee prioritizes social protection as an objective. The agriculture agency and other specialized social support agencies have preconceived programs in place to provide social support. However, the support is provided in an uncoordinated manner with significant gaps in coverage.	There are well-formulated social protection programs in place that can respond quickly to meet the specific needs of a drought event. The Drought Committee closely follows the implementation of the programs, informed by the drought impact assessment process. The most vulnerable populations are identified, and their basic needs are met.

Source: Authors.

11.5 Key Resources

Drought monitoring program

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Rescue in Bangkok, Thailand. Photo: robru

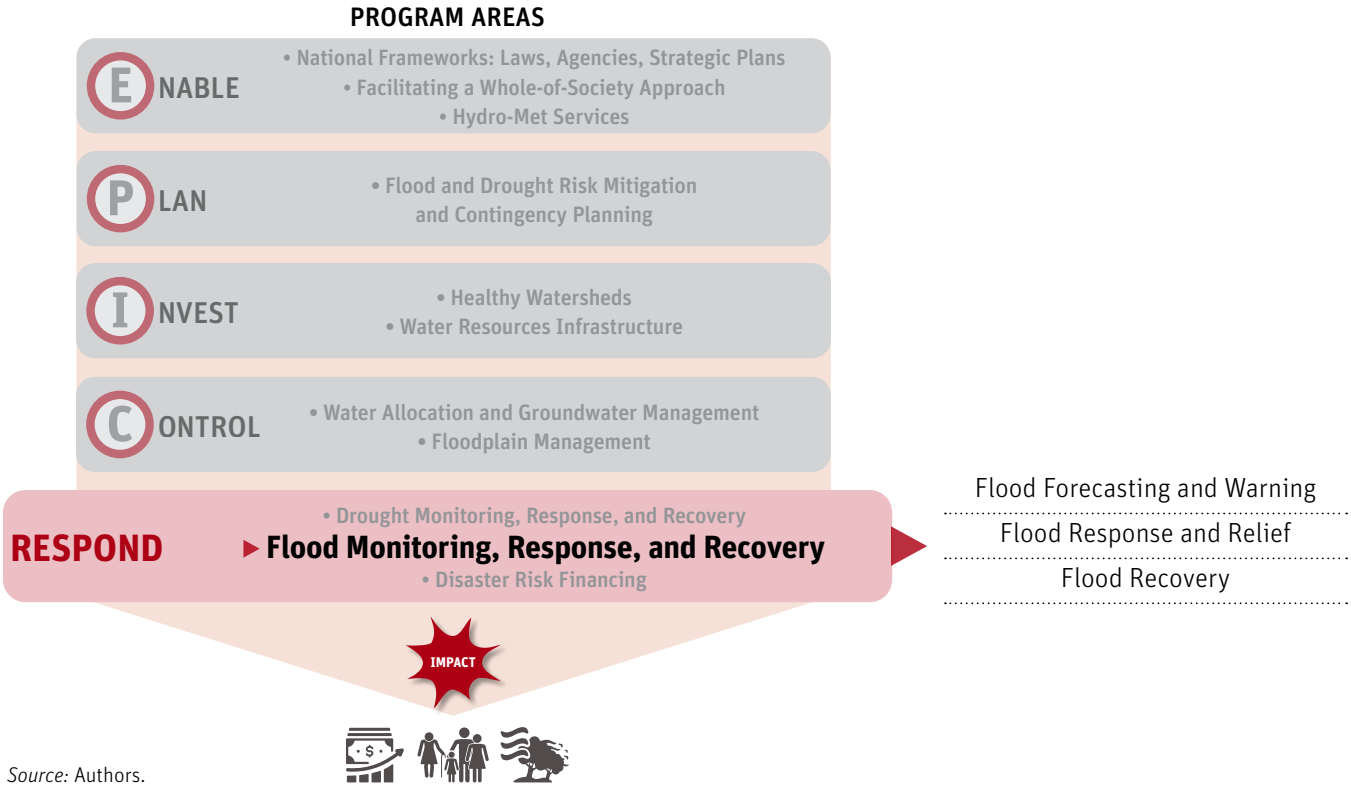
12 Flood Monitoring, Response, and Recovery

Like droughts, floods are an inevitable part of the hydro-climatic cycle and the goal of proactive management is to prepare for floods, forecast and monitor them, and respond effectively through emergency action and immediate relief for affected communities. Recovering from floods by building back better and smarter is the final step in the process of minimizing the social and economic impacts.

Flooding is a natural phenomenon that brings important ecosystem benefits. The delicate balancing act is maintaining these benefits while also minimizing the impact of floods on people and the economy. As shown in the Figure 12.1, actions taken to promote healthy watersheds, develop water resources infrastructure, and manage floodplains should also contribute to reducing flood risks. This chapter focuses on programs to monitor, respond to, and recover from floods to further reduce the overall risk.

As discussed in Annex 1, there are many different types of floods and each flood event has its own unique characteristics in terms of geographical scope, duration, and physical characteristics. This chapter focuses primarily on river and

FIGURE 12.1 Flood Monitoring, Response, and Recovery in the EPIC Response Framework



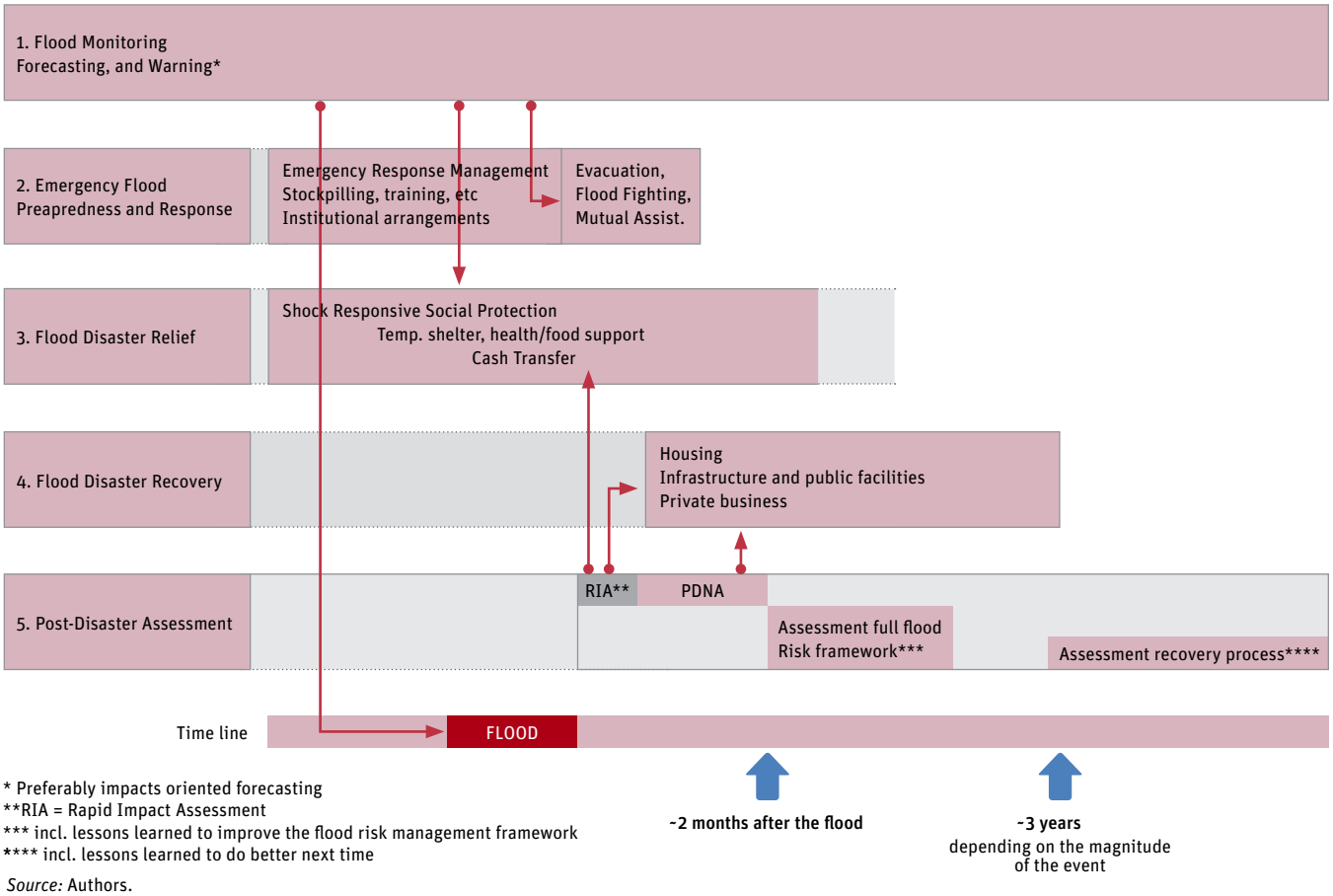
Source: Authors.

coastal flooding, although many of the same principles apply to other types of floods. In contrast to droughts, floods are relatively short-duration hazards, generally lasting from days to weeks with immediate and often devastating impacts—making emergency response and relief of paramount concern. Floods are often, but not always, driven by other meteorological hazards such as cyclones, often resulting in multiple-hazard disasters occurring at the same time.

There are many moving parts to a system for flood monitoring, response, relief, and recovery as shown in the diagram in Figure 12.2. The programs presented in this chapter are summarized in the following paragraphs:

- **Flood forecasting and warning.** A multi-agency approach, dependent on the circumstances of the country, is typically required for flood forecasting. As highlighted in Chapter 5, the NMS/NHS plays a key role in facilitating weather forecasts, and for coastal and localized flash flooding generally provides the flood forecasts. For river flooding, the WRM agency typically provides the flood forecasts if there is extensive flood infrastructure; for unregulated rivers the NHS (which may be embedded in the WRM agency or part of the NMS) typically provides the forecasts. Ideally, there should be impact-based warnings based on the flood forecasts that provide information on potential impacts. This information is generally derived from floodplain mapping, as discussed in Chapter 10. Generally, the DRM agency is best placed to take the flood forecasts and provide flood warnings utilizing its multi-hazard emergency communications system and disseminating the information through various channels.
- **Flood emergency preparedness.** The DRM agency should have multi-hazard emergency operations plans in place to respond to a variety of natural hazards. These emergency operations can be utilized as a foundation for developing flood emergency plans in collaboration with the WRM agency. The DRM agency will need to work in close collaboration with local governments and civil defense authorities to prepare for local flood emergencies.
- **Flood emergency response and relief.** Emergency response also requires a multi-agency approach under the leadership of the DRM agency, which is responsible for coordinating overall disaster preparedness, response, and recovery efforts for natural hazards. In cases where there is extensive flood control infrastructure, the DRM agency needs to work closely with the WRM agency. The WRM agency may operate a flood control center that monitors conditions and coordinates flood infrastructure operations and flood fighting efforts. In parallel, the DRM agency also may need to activate its emergency response system to oversee evacuation and relief efforts.
- **Post-flood assessment process.** A structured assessment process informs relief and recovery efforts at three critical junctures. In the immediate aftermath of a flood, the DRM agency in collaboration with local government needs to undertake a Rapid Impact Assessment to ascertain critical relief needs. The second assessment comes after the emergency has subsided and involves a Post-Disaster Needs Assessment (PDNA) that defines medium- and longer-term recovery efforts with an aim of "building back better" and examines the causes and response to the flood event to inform future policies. The final assessment should come near the end of the recovery period to assess the effectiveness of the recovery program and the final social and economic impacts of the flood event.
- **Flood disaster relief.** Based upon the rapid impact assessment, the DRM agency should work in collaboration with other agencies and local governments to ensure an effective flood relief effort including providing adequate food and shelter for vulnerable populations, flood aftermath clean-up, and resumption of critical infrastructure and public health services. The DRM agency should have immediate access to disaster relief funds from the national government to provide the necessary support.
- **Flood disaster recovery.** Recovery is about ensuring that households, businesses, and communities are no worse off after the flood, and that their future flood risk is significantly reduced. The DRM agency should channel disaster recovery funds through programs that help local governments and impacted populations make strategic decisions following the principles in Chapter 10 on floodplain management. A supplemental approach for flood recovery is for the DRM agency to facilitate a flood insurance program. This program is typically administered by the private sector, spreads out risks, and ensures timely flood recovery funding. However, the flood insurance program needs to be carefully designed to ensure that it does not encourage additional floodplain development and works in harmony with disaster relief programs.

FIGURE 12.2 Key Elements of a Flood Monitoring, Response, and Recovery System



* Preferably impacts oriented forecasting
**RIA = Rapid Impact Assessment
*** incl. lessons learned to improve the flood risk management framework
**** incl. lessons learned to do better next time

Source: Authors.

12.1 Flood Forecasting and Warning

Program description

Flood monitoring, forecasting, and warning is a complex multi-agency process that requires coordination and technical expertise. Figure 12.3 depicts the general relationship among the three key agencies for producing river and coastal flood forecasts and warnings.

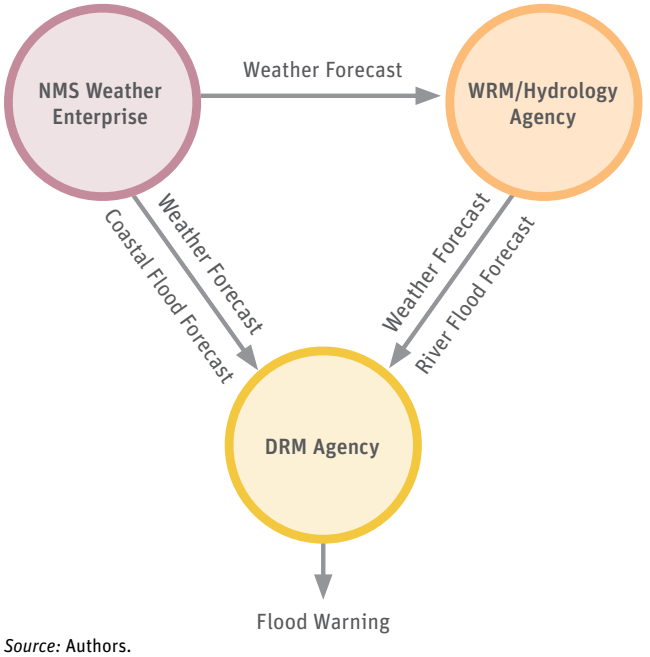
The "weather enterprise" as discussed in Chapter 5, consisting of the NMS working in collaboration with the private sector and regional and global weather centers, is the source of information for weather data and forecasts. This weather information is an essential input into flood forecasts.

For coastal flooding, the NMS typically combines weather forecasts and oceanographic information (including tides) with storm surge models to issue forecasts in the form of the storm tide height over normal sea level. Ideally, the coastal floodplains should be mapped, and the forecast can also provide information on how far inland the storm tide will extend and its potential impacts.

For river flooding, the weather information needs to be combined with watershed hydrological and river hydraulic models to forecast river levels. Ideally, the floodplain will have been mapped and the forecast can include information on the extent and depth of the flooding, as well as potential impacts. Machine-based learning models that correlate weather and watershed conditions to river levels are also becoming more common as a supplement to traditional river flood forecasting methods (Noymanee and Theeramunkong 2019).

For a completely unregulated river, meaning a river with no water resources infrastructure, river flood forecasts can be done by the NMS/NHS or the WRM agency. In cases where there is water resources infrastructure, the WRM agency is usually best placed to issue river flood forecasts. WRM agencies must consider the influence of infrastructure, such as reservoirs, river embankments, flood bypass channels, and flood gates, in their river flood forecasts. The WRM agency should have a flood control center which coordinates the operation of infrastructure and provides flood forecasts. In coastal areas, there may be a need to simultaneously issue

FIGURE 12.3 Flood Forecasting and Warning Linkages



Source: Authors.

river and coastal flood forecasts. Storms may move from coastal areas producing storm surges onto land generating heavy rainfall that produces river floods. In many instances, the coastal storm surges can affect river floods due backwater effects increasing river heights.

The information on current and forecast flood levels should be made available to the public, other agencies, and local governments. The forecasts should be translated into flood warnings with location and impact specific information. The DRM agency is ideally positioned to provide the flood warnings utilizing its multi-hazard warning and emergency response system. The flood forecasts can be combined with river or coastal floodplain topography, derived from the flood mapping, to provide an estimate of critical areas and the likely extent of floods as water flows onto river or coastal floodplains. Ideally, in sensitive areas there will be flood risk maps which provide information on assets and populations to provide impact-based warnings.

Flash floods represent another class of floods, distinct from river or coastal floods. Most flash floods occur when there is a heavy amount of precipitation and that water is then rapidly channeled through streams or narrow gullies. Flash flood warnings are provided by the NMS and are based primarily on forecast rainfall intensity and duration, coupled with topography, soil conditions, and ground cover.

Flood warnings can help trigger various emergency response actions, including: (1) mobilizing flood fighting teams and emergency personnel; (2) warning the public of the timing and location of the event and the likely impacts; (3) giving households, businesses, and local governments time to prepare for the flood; and (4) enabling evacuation and emergency procedures.

Linkage to the National Sector Framework

The roles and responsibilities of the various agencies involved in flood monitoring, forecasting, and warning need to be clearly spelled out in the various national frameworks to enable the necessary collaboration. As noted in Chapter 5, the meteorological law should provide the NMS/NHS with the authority to help facilitate the "weather enterprise" in the country, encouraging collaboration with regional and global weather centers, as well enabling the private sector to both generate and disseminate weather information and forecasts as appropriate.

The meteorological law typically authorizes the NMS/NHS to issue coastal storm surge forecasts. Ideally, the meteorological law should also mandate the cooperation of the responsible oceanographic agency if this function is separate from the NMS/NHS. For river flooding, the water resources law usually authorizes the WRM agency to provide flood forecasts. Some countries have created a National Flood Forecasting Center which is authorized either through the WRM or meteorological law and can consist of staff from both the NMS and the WRM agency.

The DRM law should authorize the DRM agency to issue geographically-specific flood emergency warnings as one component of its multi-hazard warning and emergency response system. However, the DRM law should clearly spell out that the flood warnings must be issued in consultation with the agency responsible for the flood monitoring and forecasting.

Key agency actions

Some of the key actions for the NMS/NHS, WRM, and DRM agency include the following:

- **NMS/NHS collaboration with Ocean Agency.** In some countries, the ocean agency is separate from the NMS/NHS. However, since coastal storm surge warnings are both an atmospheric and oceanographic phenomenon, it is critical that the NMS collaborate with the ocean agency both in terms of developing storm surge models and of monitoring oceanographic conditions. This collaboration can be facilitated through an interagency agreement,

which defines the protocols for information sharing and joint action during potential storm surge situations.

- **NMS/NHS collaboration with the WRM Agency.** In cases where the WRM agency is responsible for river flood forecasting, it will need to work closely with the NMS/NHS to obtain the necessary weather information. The NMS/MHS should provide not only its own weather forecasts, but also draw upon the broader "weather enterprise" to provide the WRM agency with as much information as possible to help inform river flood forecasts. Close collaboration between the NMS/NHS and WRM agency is also necessary during coastal storms, such as hurricanes, to consider potential coastal river interactions. This collaboration can be facilitated through an interagency agreement, or even better through an integrated Flood Forecasting Center.
- **Consider establishing a National Flood Forecasting Center.** Perhaps the most elegant approach to untangling the different forecasting agency responsibilities is to establish a National Flood Forecasting Center, combining meteorology, hydrology, and oceanographic expertise to provide a specialized service. This could function as a partnership between the different agencies and the Center could be equipped to handle all forms of flooding, quickly bringing together the expertise as needed to address specific flood hazard situations.
- **Collaboration between the DRM agency and the NMS/NHS and WRM agency issuing flood forecasts.** The DRM agency must have up-to-date information on flood forecasts to inform its emergency management decisions. This involves consulting with the agency responsible for the flood forecasting in the issuance of emergency warnings, including evacuation orders. The DRM agency typically has a multi-hazard emergency operations center (EOC) to help coordinate emergency responses to coastal or river floods (as well as other threats). To facilitate this cooperation, there should be interagency agreements between the forecasting agency and the DRM agency, ideally with DRM agency staff embedded within the forecasting agency, or vice versa.

Generic evolution

The generic evolution of this program is summarized in Table 12.1.

TABLE 12.1 Generic Evolution of Flood Forecasting and Warning Programs

Nascent	Engaged	Capable	Effective
The NHS/NMS issues weather forecasts but there is no structured flood forecasting or issuance of warnings.	A hydro-met law clarifies responsibilities for flood forecasts, at either the NMS/NHS or WRM agency. These agencies take weather information and generate flood forecasts. General emergency warnings may be provided by multiple agencies, such NMS, WRM agency, and DRM agency.	The NMS/NHS, WRM, and DRM agencies work collaboratively to issue weather and flood forecasts and emergency flood warnings. The flood warnings are disseminated through the DRM Emergency Management System (EMS) and provide information on flood physical characteristics but not on potential impacts.	The NMS/NHS and WRM agency work collaboratively with the broader "weather enterprise" to provide weather forecasts and inform flood forecasts. The DRM agency utilizes the forecasts and information derived from floodplain mapping to issue impact-based warnings through the EMS.

Source: Authors.

12.2 Flood Emergency Preparedness, Response, and Relief

Program description

Emergency preparedness and response for floods should take place at many levels: national, regional, local, private sector, and households. The National DRM Plan should include a specific component on disaster response that establishes a standard Emergency Management System (EMS) that allows for multi-agency and multi-jurisdictional responses to emergencies. Some key elements include: (1) definition of command structure; (2) regional EOCs; (3) emergency warning dissemination system; (4) master civil defense mutual aid agreements; and (5) multi-agency coordination processes.

Although this system is set up to manage all types of emergencies, such as earthquakes, fires, storms, and floods, there also needs to be flood-specific emergency preparedness plans and response actions. The EMS serves to coordinate the actions of the key actors, including relevant national agencies and local governments, and emergency responders such as police, fire, and the military as necessary. The EMS should include provisions as necessary for mobilizing the national level Disaster Management Committee which often consists of Cabinet-level officials and may be chaired by the Executive.

For river flooding, the WRM agency should prepare a River Basin Flood Contingency Plan as discussed in Chapter 6, which looks at different flood scenarios and operational responses. The WRM agency should also have a Flood Control Center which serves as the focal point for flood monitoring, forecasting, and operations, working in close collaboration with the DRM agency. In partnership with the DRM agency, the WRM agency also has an important role to play in flood preparedness. Raising awareness about flood risk and emergency response with local governments, businesses, and the private sector is an important preparedness activity. The WRM agency can also provide flood fighting training for its staff, other agencies, and local governments. Finally, the WRM agency should periodically coordinate with the DRM agency and local governments to prepare for local flood and emergency risk management and response.

Local governments are generally the first responders in a flood emergency, with national assets being deployed as needed—and sometimes with delay. Paralleling the process at the national level, local governments should have Multi-Hazard Mitigation Plans as discussed in Chapter 10 that include floods and should also have Local Emergency Response Plans. To the extent that either river or coastal storms and floods are an issue for the local government, there may be specific Flood Emergency Plans. The local Emergency and Flood Response Plans typically include elements such as: (1) the emergency management organization structure; (2) policies, responsibilities, and procedures to respond to floods; and (3) approaches for after-flood analyses and follow-on activities. Floodplain mapping provides critical information on the potential extent and impacts of floods which can help inform the Emergency Response Plan and flood response actions.

There are many flood emergency response actions that can be taken depending on the specifics of the flood. The WRM agency has many tasks, such as operating its own flood infrastructure (including reservoirs); controlling the operations of other reservoirs; identifying potential areas of embankment failure; authorizing controlled flooding; and supporting flood fighting (using sandbags, temporary pumps, and other measures). As discussed in Chapter 8, the WRM agency has an important role to play in ensuring a national dam safety and embankment safety program, including overseeing Dam Safety Emergency Plans.

The DRM agency, working through the EMS, also has several important functions, including search and rescue operations; providing evacuation warnings and orders including evacuation routes and shelter areas; and helping to mount temporary flood defenses for critical facilities and infrastructure. For coastal flooding, there is often a broader cyclone emergency response effort coordinated by the DRM agency working through the EMS.

In the latter stages of a flood, or in the immediate aftermath, it is important for the DRM agency to coordinate a Rapid Impact Assessment to assess the immediate relief needs. The EMS should include procedures for mobilizing appropriate multi-disciplinary teams to assess impacts and mobilize relief support. Innovative approaches to rapidly gathering information can be used, such as drone videos, social media, or even deploying local universities for data collection. The immediate relief support can include actions such as shelter, food, water, and attending to the public health needs of affected populations. Other priorities include restoration of critical services such as power, transport, water, and sanitation, and cleaning up flood debris. In poorer countries, international aid agencies often have an important role in providing humanitarian aid in the aftermath of a disaster.

It is important that the immediate relief efforts are not hampered by lack of funding or questions of financial responsibilities. One approach is to have Mutual Aid Agreements in place between different national agencies, local governments, and utilities such as power and water. These types of agreements obligate the different entities to aid each other during an emergency as directed under

Box 12.1 California Flood Emergency Response

The California Office of Emergency Services (CalOES) coordinates the State's disaster preparedness, response, recovery, and mitigation activities. The California Department of Water Resources (DWR) works closely with CalOES when emergency operation centers are activated during a flood or dam safety event.

When significant weather events have been forecast, DWR is responsible for coordinating local, State, and federal flood operations. The State-Federal Flood Operations Center (FOC), located in the state capital, Sacramento, is the focal point of this effort. The FOC, when activated during a major weather event, operates 24 hours a day to monitor changing conditions, coordinate flood fighting efforts with local and federal partners, and keep the public informed.

the EMS without consideration of reimbursement; under specific conditions the national government may reimburse agencies or local governments who incur additional expenses responding to emergencies.

As soon as possible after a flood, the DRM agency should facilitate a Post-Disaster Needs Assessment (PDNA), which is an extension of the rapid impact assessment. A PDNA encompasses two perspectives: (1) the valuation of physical damages and economic losses; and (2) the identification of human recovery needs based on information obtained from the affected population. These perspectives are integrated into a single assessment process to support the identification and selection of response options that cover the full spectrum of efforts from relief through to recovery. If there is extensive and widespread damage, then the national government may make a Disaster Declaration to facilitate access to disaster support programs.

Longer term relief efforts depend on the specific flood context and commence shortly after the emergency response activities. The extent and types of relief efforts should be guided by the PDNA but typically include social protection measures such as temporary housing, cash transfers, temporary labor opportunities, and ensuring that impacted people have access to health and educational facilities. The DRM agency may oversee and fund some of these relief measures, but as in the case of droughts, the country's existing social protection programs should be tailored and directed to meet the specific needs of the impacted communities with a special focus on vulnerable and marginalized populations.

Linkage to the National Sector Framework

The DRM law provides the overarching framework for responding to emergencies, including floods. It should authorize the DRM agency to lead the periodic formulation of a multi-sectoral and multi-jurisdictional National Strategic DRM Plan that includes a component on disaster response. The DRM law should authorize an EMS and provide the DRM agency with authority to direct different agencies and local governments in a unified response to an emergency. The law may also require local governments to formulate local Emergency Plans, potentially regulated by the DRM agency.

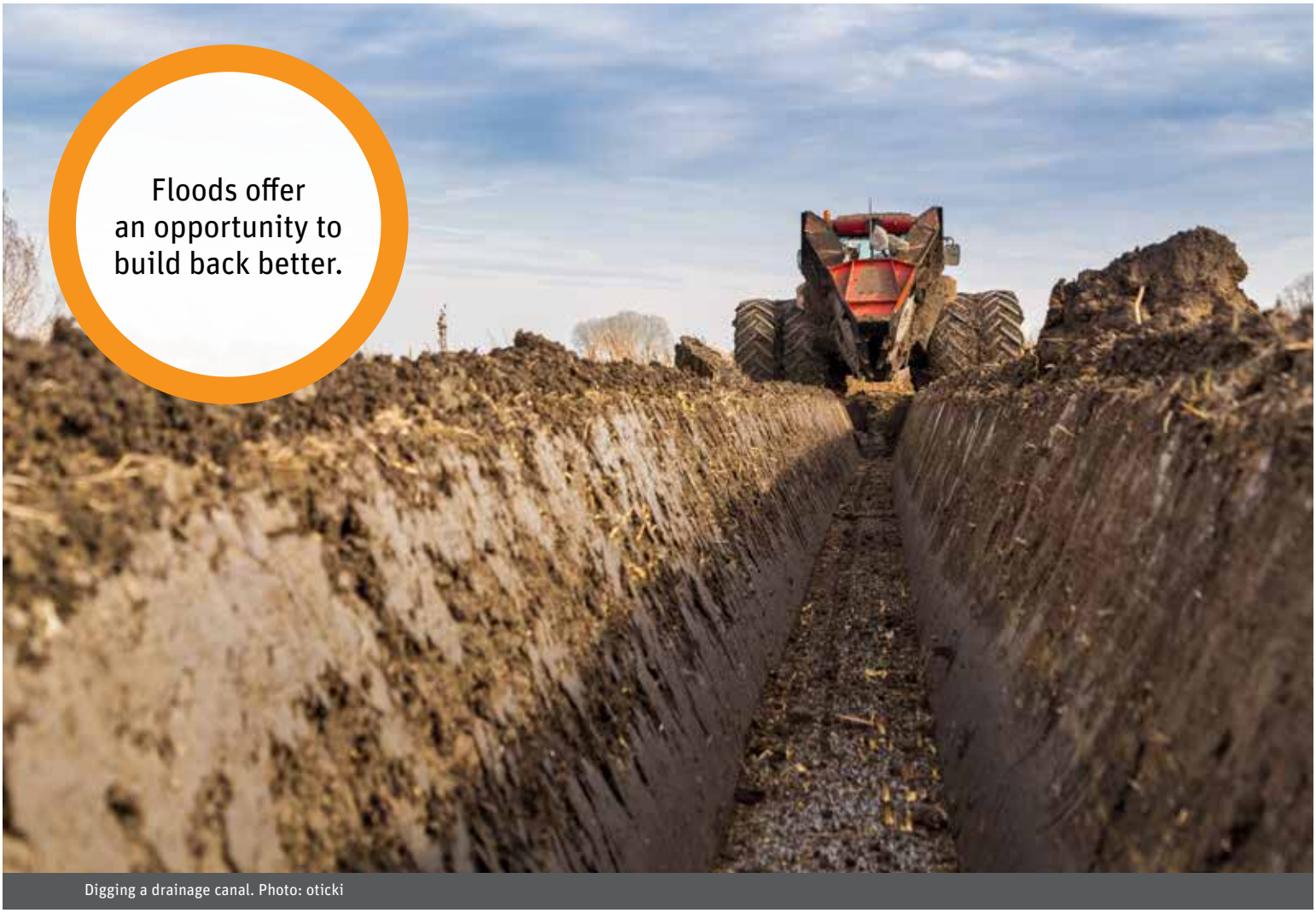
The DRM law may also create a government (Cabinet level) Disaster Management Committee to oversee the response to large-scale disasters, and provide for the issuing of Disaster Declarations, usually issued by the Executive. A flood Disaster Declaration may be linked to the provision of flood recovery programs as discussed in the next section.

The water resources law should provide the WRM agency with the authority to act in the event of a flood emergency, including authorizing reservoir releases that result in downstream flooding as a dam safety measure, and controlled flooding through designated flood channels or intentionally breaching an embankment. As highlighted in Chapter 6, the water resources law should require the WRM agency to prepare basin-level flood contingency plans.

Key agency actions

Some of the key actions for the DRM and WRM agencies include the following:

- **Formulate a National Disaster Response Plan.** The DRM agency should work with key agencies, local governments, and other stakeholders to prepare a National Disaster Response Plan, which provides the framework for responding to natural or human-induced emergencies. Some of the key elements include: (1) identifying potential hazards and likely impacts; (2) defining an EMS, including levels, organizations, functions, activation procedures, and regional emergency operation centers; (3) outlining emergency preparedness actions, including planning, training, exercises, communications, and stockpiling resources and equipment; (4) preparing an "Emergency Response Concept of Operations", including an alert and warning system, situation reporting, public information, and mutual aid arrangements; (5) presenting a "Relief and Recovery Framework" which outlines programs and actions, including Disaster Declarations; and (6) clarifying the roles of national agencies during disasters, including DRM, WRM, health, social protection, and agriculture agencies.
- **Oversee the Emergency Management System (EMS).** The EMS should be guided by the Emergency Response Concept of Operations, which provides the blueprint for responding to emergencies. The DRM agency should sustain and constantly improve the EMS and ensure that it is always functional and ready to deploy as necessary. This requires constant capacity building, training, and exercises at multiple levels to ensure that all agencies and local governments understand how the EMS works and what their roles are under different emergency situations. The EMS should include specific procedures and actions for river and coastal flooding. The EMS is usually anchored in regional Emergency Operations Centers that are managed by the DRM agency, thus requiring a certain level of decentralization by the DRM agency.
- **Assist local governments in preparing Emergency Response Plans.** The DRM agency should help local governments prepare emergency plans, including specific



Digging a drainage canal. Photo: oticki

plans for dealing with floods as appropriate. The plan should also help households, businesses, and other organizations prepare for and respond to floods. The floodplain mapping and local flood mitigation plans are key inputs into the local flood emergency plans. The DRM agency should provide a general format and technical and financial assistance to the local government. The WRM agency should work collaboratively with the DRM agency and local governments to ensure flood-specific issues are included in the plan. Where legally required, the DRM agency should establish clear regulations for the preparation, review, and approval of the local government emergency plans.

- **Operate Flood Operations Center.** The WRM agency should establish flood operations centers as appropriate, for example at the basin level or national level, to serve as the nerve center for monitoring and responding to river floods. The flood center should ideally be co-staffed with NHS and DRM agency personnel so that forecasting, operations, and emergency responses are well coordinated. This usually requires a multi-agency agreement which clearly lays out the functions of the different agencies. The emergency operations center, which serves to respond to all emergencies, should be closely linked to the flood operations center.
- **Prepare Rapid Impact Assessment (RIA) and PDNA protocols.** The DRM agency should prepare procedures and protocols for ensuring rapid deployment of RIA and PDNA teams. This includes having generic terms of reference that can be adjusted to the specific emergency, and interagency agreements that will allow for the rapid mobilization of teams with functions and responsibilities clearly defined beforehand. Of importance in the RIA phase is temporarily restoring utilities and communications, clearing transportation access, and providing temporary housing.
- **Attend to the needs of poor and marginalized communities.** These groups not only tend to have less resilience and are more exposed to floods, but they also typically do not have easy access to formal flood disaster recovery programs or flood insurance. As part of the PDNA process, there should be a focused effort on identifying the most vulnerable households and communities and identifying both their relief and recovery needs. This typically requires close collaboration with social and health agencies, as well as with local governments. The PDNA should include an action plan to help address the needs of the vulnerable populations in the relief and recovery process.

- **Ensure access to resources and funding for emergency response and relief.** The DRM agency should work with the national government to ensure access to funding to respond to emergencies and provide relief. As discussed in Chapter 13, it is important for the national government to have emergency funds available or have quick access to disaster financing to ensure that immediate relief needs can be addressed. The DRM agency should also facilitate mutual aid agreements between different national agencies (including the military) and local governments to ensure that they respond to emergencies and provide relief as required without consideration of funding. The DRM agency can help facilitate the reimbursement of costs based on these agreements, potentially drawing upon emergency funds and disaster financing mechanisms.
- **Develop a program to provide temporary relief to households.** The DRM agency should have a program in place to provide temporary relief for impacted households with clear procedures and criteria that can be applied to any disaster. Potential areas of support include: (1) temporary housing assistance; (2) lodging expenses reimbursement; (3) subsistence payments to cover expenses; and (4) temporary employment opportunities. In cases where flood victims need to move into temporary shelters, there should be provisions for providing all the necessary support including public health and safety.

Generic evolution

The generic evolution of these programs can be summarized in Table 12.2.

12.3 Flood Disaster Recovery

Program description

The PDNA should help identify flood impacts and scope out the recovery process, including needs for: (1) housing; (2) restoring public infrastructure and public facilities; (3) restoring business and other organizational assets; and (4) restoring livelihoods. As highlighted in the previous section on flood relief, the PDNA should also identify initiatives to assist impacted people while they are waiting for recovery support.

Disaster recovery programs should have dedicated components to meet different needs. For households, support can be provided to repair, replace, or relocate housing. For local governments, support can be provided for emergency works, such as debris removal or flood protection measures, or more permanent works such as roads, water infrastructure, public buildings, and other public utilities. Recovery support can also be provided to businesses and other organizations such as centers of worship or community centers. Finally, recovery support can be provided for flood hazard mitigation projects such as new structural or nature-based projects.

Disaster recovery support can be provided in the form of grants, concessional loans, or through subsidized insurance programs. Typically, eligibility for disaster recovery support (except for insurance) is contingent upon a Disaster Declaration, often issued by the Executive.

It is important to note that these disaster recovery programs, usually administered or overseen by the DRM agency, can be employed to address a wide variety of potential disasters, for example storms, earthquakes, and fires, as well as floods. However, since the core principle in any disaster

TABLE 12.2 Generic Evolution of Flood Emergency Preparedness, Response, and Relief Programs

Nascent	Engaged	Capable	Effective
No efforts are made to prepare for floods, and emergency responses are *ad hoc* with minimal relief support. Local governments are left to respond to disasters primarily with their own resources.	DRM law mandates the DRM agency to facilitate disaster preparedness, response, and relief but there is no National Emergency Plan or Emergency Management System (EMS) in place. Response and relief activities are coordinated between national and local governments but in a reactive manner.	A National Emergency Plan and EMS exist but are still in an early evolutionary phase. The DRM agency works with local governments to help develop local Emergency Plans. Collaboration between actors within the EMS is not yet fine-tuned. Rapid Impact Assessments (RIA) and Post-Disaster Needs Assessments (PDNA) are undertaken but access to funding is uncertain.	There have been several generations of the National Emergency Plan and the EMS is functioning well with close coordination among all actors. Emergency funds to support RIA and PDNA relief actions are guaranteed. The emergency support and relief need of the most vulnerable are prioritized.

Source: Authors.

recovery effort is to "build back better", it is important that the programs be tailored to help mitigate the hazard that caused the disaster. For example, if an earthquake resulted in significant destruction of buildings, the DRM agency should ensure adequate buildings regulations in terms of seismic design and require that the buildings regulations are utilized in the reconstruction process.

For floods, the disaster recovery programs should consider the principles of floodplain management outlined in Chapter 10 and centered on the PARA concept: protect, avoid, retreat, or accommodate. If these principles are not employed, then the government is potentially creating a moral hazard: people and businesses may not take preventative steps to reduce flood risks on the expectation that future losses will be reimbursed through disaster recovery programs. The DRM agency can create strong incentives for building back better by setting conditions on disaster support, for example:

- Requiring that repair or reconstruction for structures and facilities meet minimum flood design standards.
- Declining to help with repair or reconstruction for structures or facilities that have previously received disaster recovery assistance (or repetitive insurance claims) and instead providing rapid funding support for their relocation.
- Linking disaster recovery assistance to local governments and their citizens with effective floodplain management programs.

A special type of recovery program is flood insurance. In some countries, the private sector may offer flood insurance, but the premiums can often be prohibitively high. The high costs may be due the actuarial complexities of floods requiring an extra "risk premium" as well as a reflection of the real costs of floods. A common approach is where the government offers subsidized flood insurance that is delivered through private insurance companies to property owners, renters, and businesses. Typically, the DRM agency understands the flood risks reasonably well and oversees the administration of the insurance program. The flood insurance program should be closely linked with the floodplain management activities discussed in Chapter 10.

Flood insurance has several advantages over traditional disaster recovery programs. For traditional programs, taxpayers cover the costs of the relatively small percentage of people impacted by floods, whereas flood insurance allows for more sharing of costs and risks between the beneficiaries and the government. Insurance programs can also be used as an instrument to prompt proactive management, as eligibility for flood insurance can be contingent on risk reduction actions associated with good floodplain management. Finally, insurance companies may facilitate a more rapid reimbursement of losses than government-managed disaster recovery programs can.

However, there are also some caveats with flood insurance programs. The programs must be synchronized with other flood disaster recovery programs. For example, if a business

Box 12.2 Philippines Recovery Program from Yolanda – the Tacloban Case

In November 2013, the Philippines was struck by Typhoon Yolanda, internationally known as Haiyan, one of the strongest storms ever recorded with storm surges of over four meters. The typhoon caused widespread flooding and landslides, which brought about thousands of deaths and unprecedented damage to the affected areas. The Philippine Office of Civil Defense conducted a PDNA in December 2013. The PDNA presented a Strategic Framework for Recovery, grounded on the Republic Act No. 10121, known as the Philippine Disaster Risk Reduction and Management Act of 2010. The President appointed the Presidential Assistant for Rehabilitation and Recovery to unify the efforts of all the government agencies and other institutions and organizations involved. Based on the PDNA, the Yolanda Comprehensive Rehabilitation and Recovery Plan was developed. This plan aimed to improve the communities' physical, social, and economic resilience, consistent with the build back better principle, and to use locally-driven, centrally-supported processes with a strong focus on local conditions.

One of the cities hit hardest was Tacloban. The City of Tacloban, in cooperation with UN-Habitat, developed the Tacloban Recovery and Rehabilitation Plan. One of the elements of this plan was coastal protection. The main national agencies involved were the Philippine Reclamation Authority (PRA), the Department of Public Works and Highways (DPWH), and the Department of Environment and Natural Resources (DENR).

A **key lesson learned** from the Tacloban case is the challenge of organizing the cooperation among the national and regional governmental institutions, the many humanitarian NGOs, and international donors. There was also pressure to respond quickly with protection measures in the form of sea dikes, while others advocated for greener nature-based solutions.

Box 12.3 Tanzania's first PDNA

Heavy flooding in the Tanga Region of Tanzania in October 2019 caused loss of life, damaged and destroyed people's properties and critical infrastructure, and disrupted the provision of important services, such as transportation, education, and health. In line with the provision of the 2008 Tripartite Agreement on Post-Crisis Assessments and Recovery Planning, the Government of the United Republic of Tanzania undertook a Post-Disaster Needs Assessment (PDNA) with the support of the United Nations, the World Bank, and the European Union. The Disaster Management Department (DMD) of the Office of the Prime Minister (OPM) led the assessments, which were conducted by sector teams drawn from various national and regional government sector ministries.

The assessment covered eight subsectors in the following sectors of the regional economy: Productive Sector (agriculture, industry, and commerce); Physical Sector (transport, electricity, water, and sanitation); Social Sector (housing, health, and education); and one cross-cutting sector (disaster risk reduction). The PDNA for the flood disaster, the first undertaken in Tanzania, provided an assessment of flood damage, loss, and impacts to quantify needs for each of the sectors and recommend a recovery and resilience strategy.

The PDNA estimated that the 2019 flood disaster caused direct damage and losses totaling T Sh 43,211.1 million (US$18.8 million), comprising T Sh 31,518.3 million (US$13.7 million) in damage to assets and T Sh 11,692.8 million (US$5.1 million) in losses. The total estimated cost of recovery of the nine sectors assessed from the 2019 disaster was T Sh 65,671.2 million (US$28.6 million). The recovery cost was 155 percent higher than the total cost of the assessed effects of the disaster (T Sh 37,105 million), partly due to the higher cost of DRR-oriented investments recommended for the sectors.

Being the first PDNA in Tanzania, the report furthermore recommended the strengthening of post-disaster assessment capacity in the country to enhance the country's response to future events.

is eligible for flood insurance but chooses not to purchase a policy, then it should not be eligible for disaster recovery assistance—a practice which is often difficult to enforce due to political pressure. Successful flood insurance programs may also encourage more floodplain development as people may perceive lower overall risks. Ideally, flood insurance should be provided only for existing floodplain development, and the local government should restrict any new development—once again a practice that may be politically difficult to implement.

Agricultural producers can also be negatively affected by floods, although from a wider perspective, vigorous rain often produces an overall boost to the agricultural sector. As discussed in Chapter 11, the agriculture agency should offer a range of drought disaster assistance programs that are often multi-hazard in nature, covering floods, droughts, storms, and pestilence.

Linkage to the National Sector Framework

The DRM law typically authorizes disaster recovery programs and mandates the DRM agency to establish regulations for their implementation. Given the urgency and local nature of most disaster recovery activities, the DRM law may authorize the DRM agency to transfer—or approve the transfer of—disaster recovery funds to other specialized agencies and local governments. The DRM law may authorize the use of emergency review processes and procurement methods to meet urgent needs. The DRM law typically authorizes a national insurance program mandating the DRM to administer the program. Given the financial complexity of a flood insurance programs, there may be a special "national insurance unit" either within or outside of the DRM agency.

Key agency actions

Some key actions for the DRM agency include the following:

- **Administer flood disaster recovery programs.** The DRM agency should develop regulations to administer tailored recovery programs for different groups, including: (1) households; (2) businesses and other non-governmental organizations; and (3) public infrastructure and utilities. Each of these programs should require: (1) clear eligibility criteria; (2) procedures for applying and receiving assistance; (3) requirements for use of funds in order to "build back better;" and (4) clear procurement rules for public infrastructure and utilities. The circumstances under which the DRM agency will directly administer the funds or transfer the responsibility to local governments or other specialized agencies needs to be clearly formulated. In some cases, the national government may directly allocate the funds to the specialized agencies, for example transport, health or energy, or local governments to facilitate rapid recovery. However, it is important that the DRM agency monitor

the use of these funds to ensure that "build back better" principles and good floodplain management practices are followed.

- **Administer a flood insurance program.** The DRM agency should work with private insurers to help generate a flood insurance market. To promote informed sharing of risks, the DRM agency will need to work with insurance companies to utilize actuarial data related to flood frequency and damages to assess proposed flood insurance policies and premium rates. A strategic decision will need to be made regarding the level of government subsidy, if any, for the insurance policies. Typically, the policies are partially subsidized to ensure affordable premiums. However, subsidizing flood insurance may create economic incentives to take more risk. The mapping of floodplains, as described in Chapter 10, is essential for understanding flood hazards and assessing risks.

  The DRM agency will need to clearly delineate who is eligible for flood insurance based upon their location in the floodplain and whether local governments have met minimum floodplain management requirements, such as functional floodplain regulations and ideally a flood mitigation plan. The DRM agency will also need to establish regulations regarding the use of insurance funds to ensure a "build back better" approach. The DRM agency should work closely with the private sector to ensure efficiency and financial stability of the insurance program. The policies can be sold through private insurers who can help market them and ensure rapid damage appraisals and payouts. In some cases, mortgage companies may require evidence of flood insurance if the borrower is in a floodplain. The private insurance companies can help facilitate this information to both the borrowers and mortgage companies. The DRM agency will need to work closely with, and help train, insurance companies so they can adequately sell and honor the insurance policies. To help manage future exposure to flood risks, the agency may transfer some of this risk to private reinsurance companies and capital markets investors; this provides an additional method to fund payment of flood claims after catastrophic flood events.

- **Facilitating recovery for vulnerable groups.** As part of the PDNA protocols, the DRM agency should work with local governments, social protection agencies, and the impacted communities themselves to assess the needs of poor, marginalized, and vulnerable populations. This interagency team, often composed of social, housing, and health agencies with local governments, and non-governmental organizations, should develop and implement tailored plans to meet the needs of vulnerable populations. The DRM agency has an important role in monitoring these efforts and may also provide funding to help these organizations deliver necessary social protection measures.

Generic evolution

The generic evolution of these programs is summarized in Table 12.3.

TABLE 12.3 Generic Evolution of Flood Disaster Recovery Programs

Nascent	Engaged	Capable	Effective
There is no organized recovery response, and the national government responds to flood disasters on an *ad hoc* basis.	The DRM law promotes the principle of "build back better" and designates the DRM law to oversee recovery efforts. However, specialized recovery programs do not exist and access to funding is limited.	The DRM agency has developed specific programs to assist households, businesses, and the public sector in recovering from floods. These programs are generally well funded and guided by PDNAs, but do not always follow sound floodplain management principles. The special recovery needs of vulnerable populations are recognized but not fully addressed.	The DRM agency has developed specific flood programs that incorporate sound floodplain management principles to "build back better". The recovery effort is a multi-agency effort in collaboration with local government guided by the PDNA. Access to recovery funds is guaranteed. Dedicated social protection actions are included in the PDNA to meet the needs of vulnerable populations.

Source: Authors.

12.4 Key Resources

Flood forecasting and warning program

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Governments should have financial support programs for farmers affected by droughts.

Australian government Drought Community Support Initiative Round 2.

Victoria, Australia, outback farmer. Photo: VM Jones

13 Disaster Risk Financing

The programs for flood and drought relief and recovery were presented in Chapters 11 and 12. These programs depend on adequate funding, and this chapter explores how national governments can adopt a multi-layered risk financing approach to meeting this challenge. As shown in Figure 13.1, disaster risk financing sits at the bottom of the EPIC Response Framework. If all the programs in the Framework are effectively implemented, then the overall disaster risk financing burden can be reduced, but of course never eliminated. Effective mitigation measures such as healthy watersheds, water resources infrastructure, watershed management, and floodplain management all help to reduce the risk. When an extreme event occurs, the programs for disaster response, relief, and recovery can help to minimize the final social, economic, and environmental impacts—provided funding is available to implement these programs.

This chapter presents the following financial instruments: national disaster fund, insurance programs, budget allocations, international aid, contingent disaster credit, and sovereign catastrophe (CAT) bonds. The supporting national framework for disaster risk financing is then discussed, followed by key actions for the finance and DRM agencies.

FIGURE 13.1 Disaster Risk Financing in the EPIC Response Framework

Source: Authors.

Box 13.1 Disaster Risk Financing in the Philippines

Given the large number of natural disasters that have befallen the Philippines, the nation has a strong pool of resources for disaster financing. Piggybacking on existing policies and regulations (i.e. NDRRRM Plan and National CC Action Plan), in recent years, the country adopted a proactive approach to protect the Government's fiscal capacity across all possible disasters and to reduce impacts on the vulnerable communities. It also recognized the need of new instruments and policies for financial protection in face of a "new normal", which is based on recurrent disasters and estimated to be associated with 1.3 percent of GDP in public and private asset losses every year.

Through this approach, the country has invested in innovative financial solutions to deal with disasters and embarked on developing and implementing a Disaster Risk Finance and Insurance (DRFI) Strategy that involves establishing catastrophe risk financing facilities for national and local levels of government; establishing a private sector catastrophe insurance pool; and strengthening DRFI management at the individual level and in the law. At the national and provincial level, the parametric insurance program considers insurance policy that establishes pre-agreed lines of contingent credit to be accessed in the event of a disaster, providing emergency liquidity to enable rebuilding and recovery. The Philippines Government Service Insurance System (GSIS) acts as the insurer and international reinsurers have been selected to transfer the risk to the global reinsurance market. The amount of payouts depends on estimated losses as determined by a catastrophic risk model.

Key issue: This type of program takes time to implement and a building block approach is needed. For this, the program must be based on solid analytical ground (risk models) and must include capacity strengthening activities, piloting activities to test the program implications and results on the ground, and effective incentives to encourage private companies to increase investments in disaster preparation. Additionally, regional cooperation could help make catastrophic risk insurance available to allow for greater access of financial services that protect against disaster risks in the region. The Philippines has been leading the region in terms of disaster risk financing programs, and has a key role to play in the regional capacity building on DRFI.

13.1 Disaster Risk Financing Instruments

Extreme hydro-climatic events can cause significant financial and economic shocks to households, the private sector, and government budgets. Floods and droughts therefore form a contingent liability for governments since they cause unexpected expenditures and loss of fiscal revenues. Having access to adequate and timely financial resources for response and recovery reduces the impacts of these shocks and helps the economy bounce back quickly. A lack of such resources causes a delay in the provision of life-saving responses and pushes back the reconstruction of critical public and private structures, facilities, and infrastructure, which brings higher long-term impacts of a disaster and a more significant effect on poverty and development.

There are a variety of risk financing instruments, each with specific characteristics that make each type well-suited to address certain situations but less effective in others. The optimal mix of instruments depends on the overall fiscal situation of the country as well as its disaster risk profile. Table 13.1 categorizes the instruments according to their applicability based upon the frequency and magnitude of the disaster. These instruments can be used for any type of disaster, such as earthquakes, storms, floods, droughts, or industrial accidents. For illustrative purposes, examples of floods and droughts are provided in Table 13.1. The following paragraphs provide a description of each instrument:

Having access to adequate and timely financial resources for response and recovery reduces the impact of floods and drought and helps the economy bounce back quickly.

TABLE 13.1 General Applicability of Financing Instruments according to Disaster Type

Disaster Type	Financing Instrument
Low impact and high frequency Limited floods with moderate damages Limited low-level droughts	National disaster fund Flood or drought insurance
Medium impact and medium frequency Limited floods with catastrophic damages Widespread medium-level droughts	Disaster-specific budget allocation Disaster relief aid (low-income county)
High impact and low frequency Widespread catastrophic floods Widespread high-level droughts	Contingent disaster line of credit Sovereign catastrophe (CAT) bonds Disaster relief aid (middle-income county)

Note: These instruments are not exclusive, for example a national disaster fund can also be utilized during a high impact event to address immediate relief needs.

Source: Authors.

- **National disaster fund.** The national government puts money into a dedicated and well-regulated Disaster Fund which is kept in reserve to help respond to disasters. Typically, the fund is managed by the DRM agency, which can utilize the resources to help direct, coordinate, and fund relief and recovery efforts. Maintaining the fund entails an economic opportunity cost for the country, and a political decision must be made regarding appropriate level of funding. The political calculus regarding the size of the fund will be influenced by the country's level of economic development and the government's fiscal situation. The advantage of a fund is that resources are immediately available to respond. Thus, it is ideal for smaller-scale disasters, as well as immediate relief efforts for larger-scale disasters. For larger-scale disasters, the resources available in the fund may be inadequate, particularly for supporting extensive recovery efforts.

- **Government-facilitated flood and agriculture insurance.** Chapter 11 on droughts discussed agriculture insurance and Chapter 12 presented flood insurance. Typically, the costs of private flood or agriculture insurance are high due to the uncertainties and the complexities of developing profitable products. Government-facilitated, and often subsidized, insurance programs thus provide a bridge to the insurance markets. Typically, the government will help develop the insurance products, which are then marketed and managed by private insurance companies. Policy holders, such as individuals, businesses, and local governments, pay a premium for the insurance. That enables the government to shift part of the burden for funding and administering relief and recovery actions to potentially affected groups.

  Insurance is useful for recovery efforts but is less useful for immediate relief as it may take time to process and distribute claim payments. Insurance can be used to support recovery from any size disaster, as the payouts are not dependent upon the geographical extent of the disaster. One of the challenges in developing countries is that there may not be a mature insurance market to leverage, and in some countries, there is significant insurance protectionism restricting competition.

  One advantage of government-facilitated insurance is that the policies can be structured to provide incentives and conditions for risk reduction. For example, buildings located in a floodplain may not be eligible for flood insurance unless they meet certain flood design standards. If the insurance is partly subsidized, however, the policy owners may not fully account for climate-related risks in their decision making. Finding the formula for providing affordable insurance with enough conditions to ensure informed decision making has proven challenging in many countries.

- **Disaster-specific budget allocations.** In this case, the national government authorizes funding to assist in the recovery from a specific disaster event. This allows the government to channel significant amounts of money to help meet specific disaster recovery needs. The approach is less effective in meeting more immediate relief needs as it usually takes time for the national government to authorize and disburse the necessary funding. Allocated amounts may also be influenced by the political processes and may not be necessarily well matched with actual needs. Like a national disaster fund, the ability of a country to draw upon its national budget will depend upon its level of economic development and the government's fiscal situation.

- **Disaster relief aid.** Aid provided by both official devel-

opment agencies and international humanitarian organizations is important for many poorer countries. However, relief aid is pledged or provided only during and after the event, and the amount generated is unpredictable. Pledges made can also be slow to materialize, with examples of payments taking months or even years. In some cases, however, disaster relief aid provided by humanitarian organizations can be deployed faster and more effectively than through the government's own programs.

- **Contingent line of credit.** The government enters into an agreement with a lender to provide immediate liquidity in the event of a disaster that meets agreed-upon trigger conditions. Development agencies, including the World Bank (see Box 13.3), offer this type of instrument to national governments on the condition that countries adopt policies and programs to strengthen their overall resilience. This instrument allows governments to spread out the cost of disaster response and relief efforts over time according to the loan or credit repayment conditions. Sovereign contingent disaster credits or loans are generally not available through capital markets, however, as the inherent risks for the lender—and the costs for the borrower—may be unacceptably high.
- **Sovereign catastrophe (CAT) bonds.** These are debt instruments that allow governments to tap the capital market and raise money from investors willing to bet against the likelihood of a disaster occurring in a place over a defined period. Governments typically set up a special purpose vehicle (SPV) to facilitate the transaction. The SPV invests the money from investors and pays interest to them. At the end of the term, the SPV will return the investors' money if a disaster does not happen. However, a payout is made to the issuer upon the occurrence of a pre-specified event, which typically involves a parametric trigger, such as a pre-defined hurricane wind speed or earthquake intensity. There are some limitations to the use of sovereign CAT bonds, including their high transaction costs, long structuring periods, and strict terms and conditions. The CAT payout conditions may not be triggered in the event of small- and medium-sized disasters, particularly for more localized flood and drought events.

13.2 National Sector Framework and Key Agency Actions

National framework

Two sets of laws provide the foundation for the legal and regulatory framework for disaster risk finance: budget law and DRM laws. The budget law should explicitly authorize the finance agency to develop and implement a disaster risk financing strategy. Another important element concerns the process by which the budget is allocated, and level of discretionary funding by national agencies or local governments to accommodate the needs during the response, relief, and recovery phases. The budget law should also include a provision for a national disaster fund, including guidelines for the size of the fund, and its utilization. Of importance are the emergency procurement procedures that may need to be employed to rapidly respond to disaster needs.

The DRM law should mandate the DRM agency to work with the finance agency to develop a disaster risk financing strategy. The role of the DRM agency in administering or overseeing disaster funds should be outlined in the DRM or budget law. The law should require the DRM agency to develop procedures for recommending or declaring a state of national emergency, as this may be used to trigger contingent credit lines or provide access to a national disaster fund.

Key agency actions

Some of the key agency actions for the finance agency and the DRM agency include the following:

- **Integrate disaster risk financing into the finance agency.** Most finance agencies have created fiscal risk management departments to help analyze and mitigate the impact of macro-economic shocks. These departments should also be given the mandate to manage the economic and fiscal impacts of natural disasters. The finance agency will need to collaborate closely with the DRM agency, which is responsible for collecting information on the impacts of disasters and defining the country's natural disaster risk profile.
- **Develop a disaster risk financing strategy.** The finance agency should develop a strategy for disaster risk financing. Some key elements include conducting a "Public Expenditure Review" to understand the extent of past disaster-related expenditures as well as a clear understanding of the country's disaster risk profile. The National DRM plan highlighted in Chapter 3 is a foundational document for helping to inform—and to reflect—the country's hydro-climatic risk profile. It should be accepted that no single risk financing instrument can deal with the entire range of small and large disaster shocks. A country's risk financing strategy should develop a multi-layered approach using a set of solutions in accordance with the contingent risk profile. Finance agencies should analyze the characteristics of each disaster risk financing instru-

Box 13.2 Africa Disaster Risk Financing (ADRF)

Sub-Saharan Africa has known more than its fair share of hydro-climatic disasters. Between 2010 and 2019, the region experienced an average of 157 disasters per year, claiming the lives of roughly 10,000 people annually. These disasters not only take a large human toll, but the response and recovery also require significant financial means from governments already facing public finance challenges.

Disaster Risk Financing (DRF) aims to strengthen countries' abilities to manage economic and fiscal stresses when disasters strike. There is no one-size-fits-all approach to disaster risk financing—countries have a wide array of financial protection policies and instruments to consider, including sovereign risk finance and social protection programs, as well as agriculture and risk insurance programs.

Launched in 2015, the Africa Disaster Risk Financing (ADRF) Initiative implemented activities in 21 Sub-Saharan African countries to develop tailored financial protection policies and instruments designed to help them respond quickly and resiliently to disasters. The ADRF Initiative was the first program in Africa to focus on the broad DRF agenda. The Program ended in February 2020. It was financed by the European Union (EU) and implemented by the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR), as part of the Africa, Caribbean and Pacific (ACP) – EU Building Disaster Resilience in Sub-Saharan Africa Program.

To reach the objectives of strengthening DRF in Africa, the ADRF Initiative was structured around three operational components: (1) gathering and developing disaster risk information to help countries make informed decisions; (2) supporting countries in developing DRF strategies to achieve national financial protection priorities; and (3) facilitating regional risk financing knowledge sharing and lessons learned. Over the course of its implementation, the ADRF Initiative improved the understanding of risk exposure to natural disasters in 14 countries; participated in the development of risk financing strategies in 8 countries, including Kenya and Malawi; introduced new approaches for strengthening shock-responsive safety nets in Benin, Kenya, Malawi, Niger, Sierra Leone, and Uganda; and improved access to credit for low-income farmers in Kenya, Rwanda, Uganda, and Zambia. The program therefore contributed to help Sub-Saharan African countries drive their disaster risk financing agendas, adopt innovative solutions to meet their risk financing needs, and lay the groundwork for further investments in risk financing, enabling the leverage of over US$600 million of additional resources from the World Bank and other donors.

Key issue: While the ADRF Initiative has contributed to the pioneering of DRF across the region, it does take time for policy and institutional changes to take effect and to build the strong relationships with governments that are needed to get strong DRF systems off the ground. Yet against the backdrop of intensifying hydro-climatic risk, the program has made it clear that risk financing has a key role to play in the financial resilience of African countries.

ment and develop a comprehensive combination of approaches that best meets their needs. The strategy may also include actions to help create or strengthen national disaster insurance programs.

- **Regulate the use of disaster risk financing instruments.** The finance agency should develop clear regulations for the different risk financing approaches. For example, the rules governing access to the National Disaster Fund should be clearly promulgated. Under some circumstances, the DRM agency may be authorized to directly access the Fund, for example to provide immediate relief, whereas in other circumstances the Executive may need to formally declare a "disaster" before funds are released. The finance ministry should also develop regulations to enable the insurance markets to function effectively and equitably. Establishing clear principles and procedures for the issuance of contingent disaster loans and sovereign CAT bonds is also necessary.
- **Consider international collaboration.** Given the probabilistic and geographically-specific nature of most hydro-climatic events, countries in the same region are often not hit by disasters at the same time. International collaboration in disaster risk financing through regional risk pools can be a cost-effective and diplomatically interesting mechanism to help meet disaster risk financing needs. Governments should consider such collaborations with regional partners to explore possible international financing mechanisms.

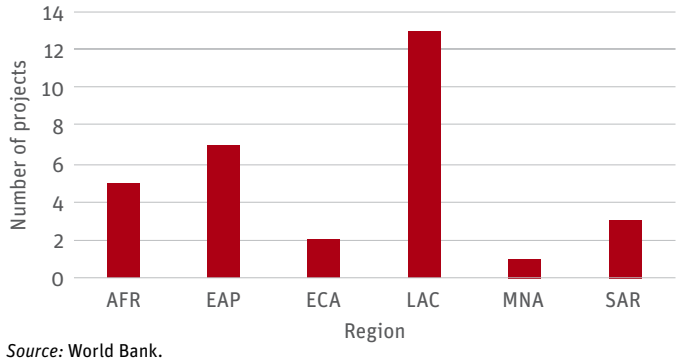
Box 13.3 Cat-DDO – A World Bank Financing Instrument for Disasters as a Contributor towards Hydro-Climatic Risks Management

The Development Policy Loan (DPL) with a Catastrophe Deferred Drawdown Option (Cat DDO) is a contingent World Bank (WB) financing instrument[a] that provides immediate liquidity to countries to address shocks related to natural disasters or health-related events.[b] It is approved prior to the disaster, serves as a first level of budget support once the event happens, and can be drawn down in full or in part when the trigger is met.

When countries prepare and implement a DPL with Cat DDO, they commit to an ambitious program of institutional, regulatory, and policy reforms critical for climate and disaster resilience and for protecting lives and livelihoods and reducing the fiscal impacts of natural shocks. These reforms are packaged in prior actions, which should be approved for the operation to be taken to the Board.[c] As with any other development policy operation, an appropriate macroeconomic policy framework is required at approval. At the time of the disaster, typically upon declaring a state of national emergency, the financing is available within 48 hours of receipt of the government's request.[d]

Since 2008, around 30 Cat DDO projects have been approved, covering 25 countries globally (including IDA (35 percent), IBRD (58 percent) and Blend (6 percent)). As a result, 27 Cat DDOs have provided a total of close to US$3.5 billion in financing, of which 50 percent of the amount was disbursed due to a trigger of a natural disaster and 50percent due to the COVID-19 pandemic. Around 10 of the 27 Cat DDOs that have been triggered were due to the incidence of floods directly or as an outcome of a tropical storm. Due to the slow-onset nature of droughts, no Cat DDO has yet been triggered in response to a drought. Almost 65 percent of these Cat DDO projects are located in either the LAC or EAP region. In the first half of 2020, 15 countries in six regions triggered Cat DDOs in response to COVID-19, providing access to US$1.73 billion to help prepare for and respond to the pandemic.

FIGURE 13.3.1 Cat DDO Projects by Region (2008-2020)



Source: World Bank.

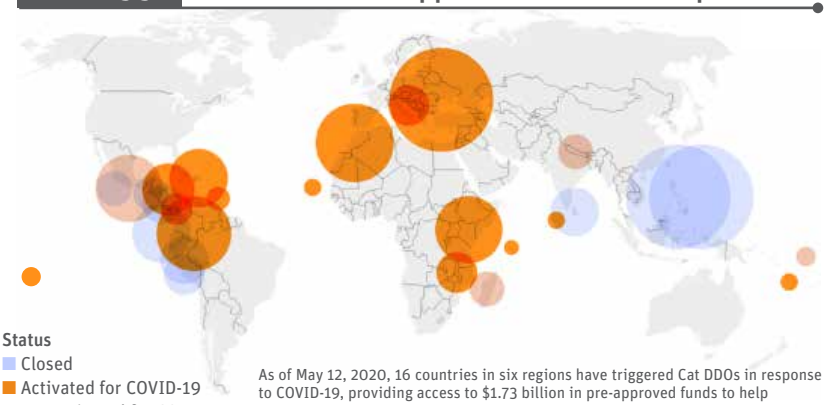
Cat DDOs typically have three main objectives under which the policy reforms are grouped, which align with the pillars of the hydro-climatic risk framework: (1) strengthening the institutional framework, information systems, and coordination mechanisms for disaster and climate-related resilience; (2) enhancing climate and disaster resilience in sectoral and territorial development; and (3) strengthening the country's adaptive social protection systems and financial capacity to respond to disaster and climate shocks. An analysis of the prior actions of the 30 Cat DDOs shows that the prior actions address five areas of the hydro-climatic risk framework: National Framework (100 percent of Cat DDOs), Hydro-met Services (42 percent), Planning (6 percent), Flood and Drought Response and Recovery (10 percent), and Cross-Cutting Areas (68 percent).

Prior actions under the first objective generally address activities related to the strengthening of the national Disaster Risk Management System (DRM) with most of the policy actions focusing on updating the multi-sectoral legal framework and mainstreaming disaster risk in the National Development Planning and Investment Programs. This sometimes includes WRM and developing and validating in a participatory process a national program for Disaster Reduction and Prevention. That national program includes budgetary allocations and strengthening policies, institutions, and planning capacity for national disaster risk management and prevention.

The second objective focuses on the mainstreaming of resilience across sectors and spatial planning in order to strengthen countries' capacities to systematically identify and reduce disaster and climate risks and to operationalize the governing structures for climate change adaptation. Under this objective, the strengthening of land use and basin planning, and the improvement of Hydro-met Services, are frequently included as prior actions. At least 13 (42 percent) of the Cat DDOs covered hydrology, meteorology, and climate, including the strengthening of early warning systems. Two (6 percent) of the Cat DDOs included support

continues

FIGURE 13.3.2 GFDRR's Initial Support to COVID-19 Response



As of May 12, 2020, 16 countries in six regions have triggered Cat DDOs in response to COVID-19, providing access to $1.73 billion in pre-approved funds to help prepare for and respond to the pandemic.

Source: GFDRR 2020.

to land use and basin planning, including the development of a new integrated urban land use plan. Other areas of engagement under this pillar include the use of integrated hazard and risk analysis in risk-based physical planning and evidence-based policy-making; adopting cooperation frameworks to strengthen flood management and early warning systems in the country; preparing Nationally Determined Contributions (NDCs) based on the Paris Agreement; incorporating DRM and climate change as cross-cutting topics and facilitating the development of other policy instruments needed to improve urban resilience; using multi-hazard resilient design and construction in infrastructure and public investment projects; and creating community-integrated management plans to increase resilience to the impacts of climate change and natural disasters.

The third objective for the Cat DDOs, which is aligned with the cross-cutting pillar of the hydro-climatic risk framework, covers two key areas: strengthening financial resilience to disasters, including disaster risk financing; and providing social protection and inclusion. Prior actions under this objective focus on strengthening institutions and systems in order to reduce the fiscal vulnerability of countries in the event of a disaster. The aim is to enhance national financial systems and institutional capacities so that they can effectively access and disburse funds, as well as to manage, monitor, and report on fiscal needs, and to minimize the impacts of shocks. Policy actions related to financial resilience include the creation and regulation of a National Disaster Fund to finance disaster preparedness and emergency response; the creation of a dedicated unit and guidelines for fiscal risk management in the Ministry of Finance; the development of a budget classifier to include provisions that enable the classification and reporting on post-disaster expenditures in relief, recovery, and reconstruction; and the development of insurance laws and policies that allow the purchase of sovereign catastrophe insurance and allow insurers to develop products that will assist households and enterprises to improve their climate and disaster resilience.

With respect to social protection and inclusion, policy reforms support the development of systems to reduce the impacts of disasters on the poorest and most vulnerable households. Those may include the development of emergency cash transfer programs as part of the social protection programs for faster and more effective post-disaster recovery; the strengthening of the legal framework to implement a shock-responsive social protection mechanism; and the strengthening of the beneficiary registration and enrollment procedures for social protection.

Based on the analysis, there is room for the further application of the Cat DDO instrument to support policy reforms along the pillars of the hydro-climatic risk management framework. This report aims to provide guidelines for governments and World Bank teams to identify such gaps and further opportunities. Furthermore, the analysis shows that the Cat DDO instruments are often disbursed in response to floods and storms, but have not yet been triggered in response to droughts due to the slow-onset nature of the latter. This shows the importance of the definition of the trigger of such an instrument and the specific attention that needs to be paid to droughts in the design of risk financing solutions.

[a] More information can be found in the following document: World Bank. 2018. "Suspending the Offer of the Fixed-Spread Terms of IBRD Flexible Loan." Product Note. http://pubdocs.worldbank.org/en/526461507314946994/product-note-cat-ddo-ibrd-2018.pdf.

[b] A disaster may include geological and hydro-climatic events.

[c] This information was taken from Stanton-Geddes, Zuzana, and Jolanta Kryspin-Watson. 2017. "Disasters, funds, and policy: Creatively meeting urgent needs and long-term policy goals." World Bank Blogs. June 29, 2017. https://blogs.worldbank.org/sustainablecities/disasters-funds-and-policy-creatively-meeting-urgent-needs-and-long-term-policy-goals.

[d] This information was taken from Wahba, Sameh, Alanna Simpson, Ana Campos Garcia, and Joaquin Toro. 2020. Preparedness can pay off quickly: Disaster financing and COVID-19, World Bank Blogs. April 7, 2020. https://blogs.worldbank.org/sustainablecities/preparedness-can-pay-quickly-disaster-financing-and-covid-19.

Food donation to flood victims in Samut Sakhon near Bangkok. Photo: justhavealook

13.3 Key Resources

ADB (Asian Development Bank). 2018. "Catastrophe Bonds Explained." Development Asia. February 21, 2018.

Benson, Charlotte, Olivier Mahul, Martin Luis Alton. 2017. "Assessing Financial Protection against Disasters: A Guidance Note on Conducting a Disaster Risk Finance Diagnostic." Working Paper. Washington, DC: World Bank; Manila: ADB (Asian Development Bank).

GFDRR (Global Facility for Disaster Reduction and Recovery). n.d. "Financial protection: Strengthening Financial Resilience to Disasters." (https://www.gfdrr.org/en/financial-protection.)

OECD (Organization for Economic Co-operation and Development). 2017. *OECD Recommendations on Disaster Risk Financing Strategies*. Paris: OECD.

World Bank. 2017. "Catastrophe Deferred Drawdown." Product Note. Washington, DC: World Bank.

World Bank. 2020. "Technical Note on Agricultural Risk Financing Options for World Bank Group Operations." Washington, DC: World Bank.

14 Summing Up

The previous chapters reviewed the 43 programs embedded in the EPIC Response Framework and presented at the start of the report in Table 2.1. The term "program" has been used in a general sense to refer to a continuous set of activities with clearly defined objectives, usually mandated through a law, and implemented by a national sector agency. For most programs, the report has: (1) provided a general description; (2) discussed the linkage to the national sector framework, (3) identified key agency tasks; (4) presented a generic evolution table; and (5) cited key references for further information.

Figure 14.1 provides an overview of the main functions of the key sector agencies. Social protection and finance agencies also play important roles but are not included in the figure. Each agency has been mandated to lead specific programs in the EPIC Response Framework. This concluding chapter highlights two key points:

- The hydro-climatic risk management system is more than the sum of the various programs.
- Constant evaluation and adaptation at both the program and system level are required.

Volunteers filling sandbags to reinforce the dam surrounding the city in Torgau, Germany. Photo: Philartphace

FIGURE 14.1 Summary of Agency Roles

Hydro-met

Provides information for water resources and floodplain management. Leads flood and drought forecasting. Supports agriculture with agro-hydro advisory services.

WRM

Oversees planning and operation of water resources infrastructure. Regulates water allocations and strategic use of groundwater to help mitigate droughts. Key role in flood and drought response.

DRM

Lead coordinating agency for flood, and sometimes drought, disaster response. Provides leadership in floodplain management. Works with other agencies to mitigate risks.

Agriculture

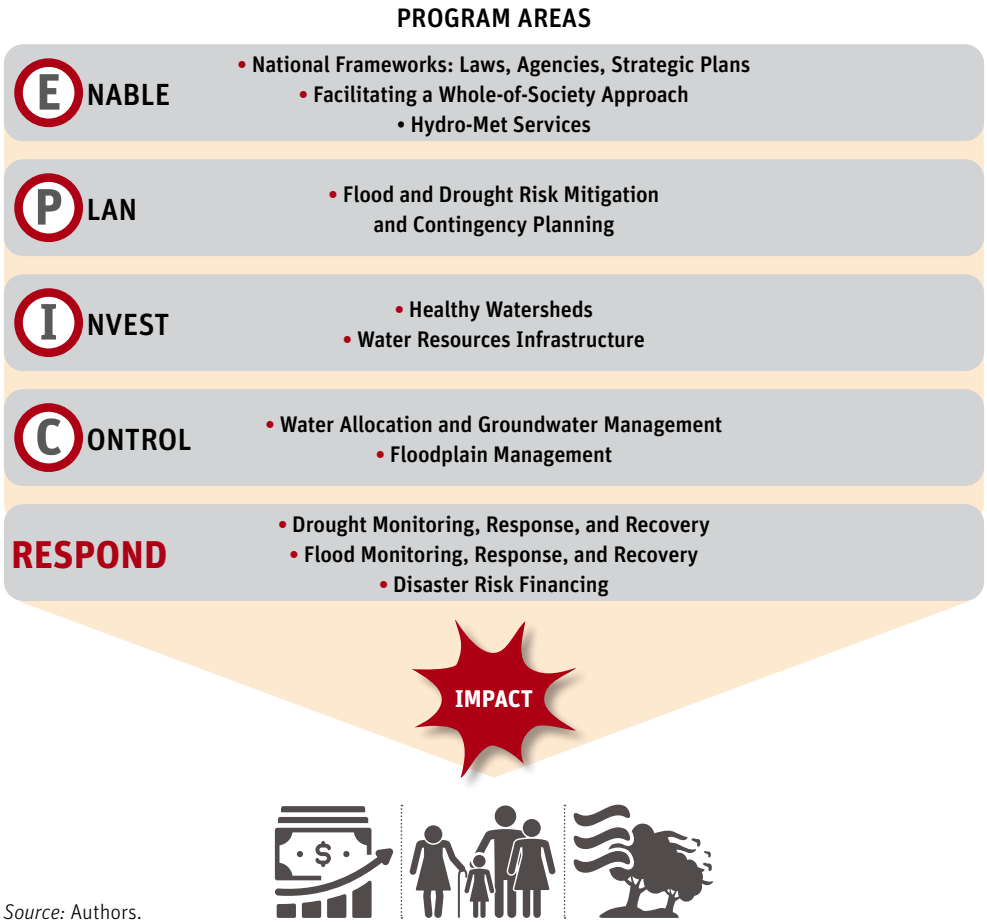
Promotes healthy watersheds through sound agricultural policies and climate-smart agriculture. Helps boost farmer incomes and resilience. Key role in drought response. Collaborates with natural resources and WRM on watershed management

Natural resources management

Promotes healthy watersheds by sustainably managing forests, wetlands, and coastal barriers. Collaborates with agriculture and WRM on watershed management.

A hydro-climatic risk management system is greater than the sum of the programs. Each agency is tasked with implementing a specific set of programs. However, the effectiveness of programs mapped to other agencies will have a dramatic impact on how well the agency can perform its functions. If the NMS/NHS has effective hydrological monitoring and weather forecasting programs, this will help the WRM and DRM agencies. If agriculture and natural resources agencies are successful in creating healthy watersheds, this will reduce the flood and drought hazards confronted by the WRM and DRM agencies. If the WRM agency has ensured a stock of safe water resources infrastructure, this will reduce flood and drought hazards and make the DRM agency's task easier. The report provides many examples of the linkages among different programs, and this is illustrated in the general downward cascading influence of the program areas highlighted in the EPIC Response Framework below.

FIGURE 14.2 The EPIC Response Framework



Source: Authors.

In many cases, multiple agencies need to collaborate to achieve a specific program objective. Drought monitoring programs require the active participation of NMS/NHS, WRM, and agriculture agencies (among others). River basin planning, typically led by the WRM agency, needs the active participation of natural resources and agriculture agencies. The report has provided many such examples of where agencies need to collaborate in a joined-up government effort to achieve program success.

Constant evaluation and adaptation at both the program and system level are required. Designing and implementing effective programs is difficult. Most programs in lower- and middle-income countries are still at the lower end of the generic program table presented below; many higher-income countries still have some less-than-effective programs, often after decades of effort. Given the stakes involved, national governments need to constantly evaluate the performance of the programs to adjust and adapt as necessary. The public policy process highlighted in Chapter 2 must be accelerated to keep ahead of a changing climate.

TABLE 14.1 Generic Program Development Table

Nascent	Engaged	Capable	Effective
There is no organized recovery response, and the national government responds to flood disasters on an *ad hoc* basis.	The DRM law promotes the principle of "build back better" and designates the DRM law to oversee recovery efforts. However, specialized recovery programs do not exist and access to funding is limited.	The DRM agency has developed specific programs to assist households, businesses, and the public sector in recovering from floods. These programs are generally well funded and guided by PDNAs, but do not always follow sound floodplain management principles. The special recovery needs of vulnerable populations are recognized but not fully addressed.	The DRM agency has developed specific flood programs that incorporate sound floodplain management principles to "build back better". The recovery effort is a multi-agency effort in collaboration with local government guided by the PDNA. Access to recovery funds are guaranteed. Dedicated social protection actions are included in the PDNA to meet the needs of vulnerable populations.

Source: Authors.

Improving the performance of individual programs is important, but a system-wide perspective on how the country is managing its hydro-climatic risks is also necessary. National governments should undertake periodic and interlocking national strategic planning exercises for WRM, DRM, and Drought to evaluate how the country's hydro-climatic risk management system is performing. National climate adaptation planning also provides an opportunity for system-wide assessment. This system-wide planning will hopefully identify gaps, constraints, opportunities, and priorities for improving the relevant set of programs.

The EPIC Response Framework can be used as guide to undertake a system-wide assessment, and this is one of its unique contributions to the field of flood and drought risk management.

Periodic, interlocking strategic national plans for WRM, DRM, and Drought will help drive the evolution of climatic risk management in a country

Appendix A
Primer on Floods and Droughts and their Socioeconomic Impacts

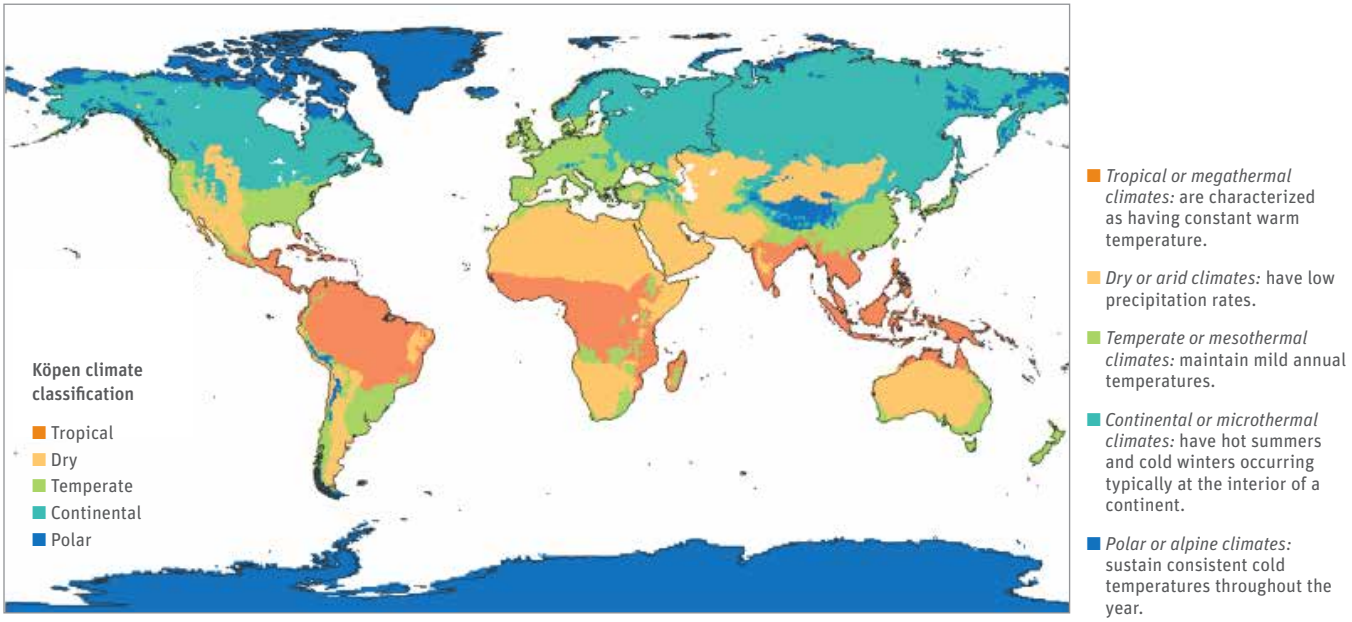
Hydro-Climatology

The term "hydro-climatology" was first defined by Langbein (1967) as the "study of the influence of climate upon the waters of the land." It includes hydrometeorology as well as the surface and near surface water processes of evaporation, runoff, groundwater recharge, and interception. The total hydrologic cycle, then, is the basis for a discussion of hydro-climatology. This annex provides more background on the concept of hydro-climatic risks—of which floods and droughts are the two most important.

Climate and Weather. Climate is the average course of weather conditions for a location over a period of many years. Climate represents the summation of all interacting atmospheric and land processes affecting a locality over a period long enough to ensure representative values. Climate conceptually differs from weather. The WMO differentiates the terms as follows: "At the simplest level the weather is what is happening to the atmosphere at any given time. Climate is usually defined as the 'average weather,' or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period." The classic period for this averaging is 30 years (WMO 2020).

Climate and Hydrological Zones. Climatic classifications are often based on rainfall, temperature, crop ecology, humidity, and vegetative and geographic criteria. The most common, the Köppen-Geiger climate classification system, divides the world into five major climate groups as shown in Figure A.1, with a further subdivision into 39 subgroups. Systems for classifying hydrological zones also exist. One approach (Weiskel and others 2014) uses the green-blue index to classify the hydrological zones within a river basin. The green-blue index is defined as the ratio between the vertical fluxes (composed of precipitation and evapotranspiration and defined as "green water") and the horizontal fluxes (composed of runoff and groundwater and defined as "blue water").

FIGURE A.1 Köppen Climate Classification



Source: EarthHow 2020.

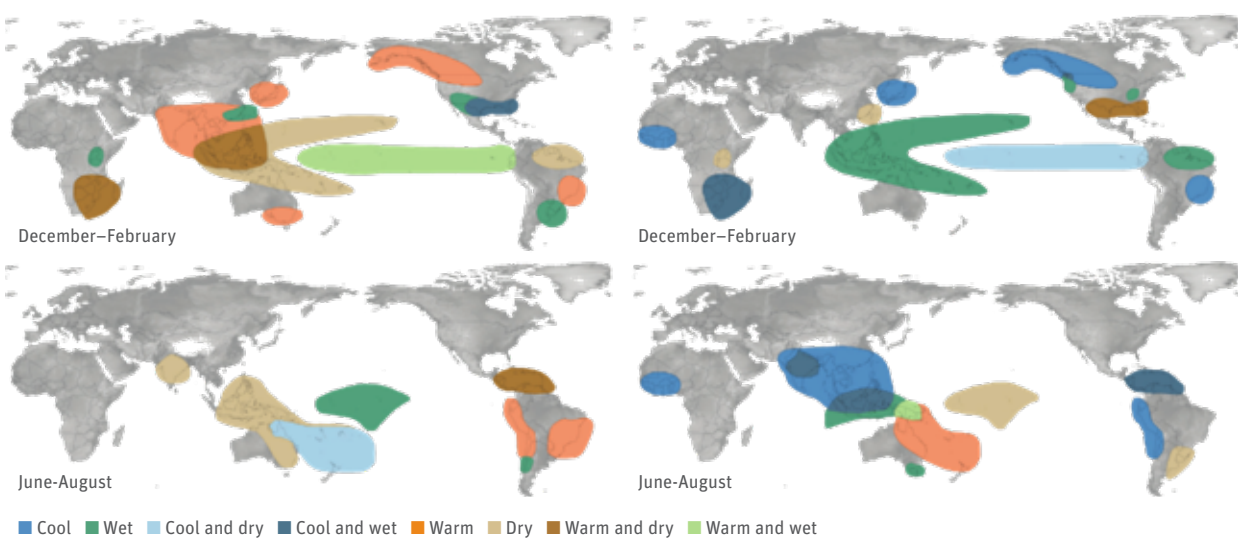
Box A.1 Climate, weather, and their variations

Interactions between the atmosphere and the ocean affect climate and weather patterns globally, generating variations in extreme events. These interactions are especially strong in the tropics. Tropical oceans influence atmosphere circulation patterns locally, and these changes can propagate through the atmosphere and cause changes in the climate in distant regions throughout the world, potentially giving rise to or exacerbating extreme events, such as floods and droughts.

The El Niño-Southern Oscillation (ENSO) is a climate variability phenomenon originating in the equatorial Pacific that drives interannual to decadal weather variability in many regions. In neutral conditions, ENSO is associated with a gradient in sea surface temperatures that goes from warmer in the west to colder in the east, and with "normal" atmospheric circulation patterns. During an El Niño event, the temperature gradient in the equatorial Pacific Ocean is reduced or even reversed, fundamentally changing the global atmospheric circulation patterns. During a La Niña event, the normal west to east temperature gradient is increased, once again resulting in a change in global atmospheric circulation patterns.

As shown in the figure below, the influence of El Niño and La Niña is nearly global, with regions on almost every continent experiencing some shift in weather and climate during these events. For most areas affected by ENSO, the impacts are often (but not always) opposite in sign and magnitude for those of La Niña.

FIGURE A.2 Global Climatic Impacts of El Niño (left) and La Niña (right)



Source: NOAA Climate.gov 2016

Climate Variability. Each climate zone experiences extreme hydro-climatic events, although in different ways. Weather and climate phenomena reflect complex thermodynamic processes over a very wide range of geographical and temporal scales. These processes result in variable hydro-climatic conditions, and extreme conditions occur when climate, weather, or hydrological variables are at the upper or lower ends of the range of historical values.[33] Naturally occurring oscillations in ocean temperatures have an important impact on general atmospheric circulation patterns, often driving extreme hydro-climatic events. Box A.1 provides information on the most prominent ocean oscillation, the El Niño-Southern Oscillation (ENSO).

Climate change is also altering the distribution of climate zones and thereby affecting the hydrological balances and water resources. Climate change[34] leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme events, and can result in unprecedented

[33] For simplicity, both extreme weather events and extreme climate events are referred to collectively as "climate extremes." A detailed analysis can be found at IPPC 2012.

[34] A definition of climate change can be found on the Climate Change Knowledge Portal at https://climateknowledgeportal.worldbank.org/themes/custom/wb_cckp/resources/data/CCKP_Glossary_Oct_2018.pdf.

extremes. The IPCC (2018) projects a substantial warming in temperature extremes by the end of the 21st century, with higher and longer daily temperature extremes at the global scale. Projected increases in global temperatures will drive changes in the hydrologic cycle, including increased atmospheric water vapor and changes in precipitation patterns, as well as changes in groundwater and soil moisture. Increasing temperature generally results in an increase in potential evaporation, largely because the water-holding capacity of air is increased (IPCC 2001). It is likely that the frequency of intense precipitation events will increase in the 21st century over many areas of the globe. This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. Heavy rainfalls associated with cyclones are likely to increase with continued warming.

Consequently, climate change will exacerbate flood and drought risks. Climate model projections indicate that climate change will lead to increased frequency and intensity of droughts and floods (He and others 2020) at regional scales. Many regions already experiencing water stress will experience even more water scarcity. High temperatures will also increase land evapotranspiration, creating more arid conditions in many parts of the world. Flood hazards are also projected to increase in more than half the world's regions, although this varies greatly for individual river basins (World Bank 2016). The growth of coastal cities, where vulnerability to floods is high due to rising seas and more intense storms, will also increase flood risks in many parts of the world.

In addition to climate change impacts, it is also important to factor in other pressures affecting the hydrological system and water resources. Changing land use and land management practices are altering the availability of water resources and in many cases increasing flood risks. Increasing populations and rising incomes may also increase the demand for water in many parts of the world.

Flood and Drought Definitions

Floods. There are a wide variety of floods with different characteristics. Table A.1 defines the most common types of floods. The magnitude of a flood depends on precipitation intensity, volume, timing, and antecedent conditions of rivers and their watersheds (such as the presence of snow and ice, soil character, wetness, urbanization, and existence of dikes, dams, or reservoirs).

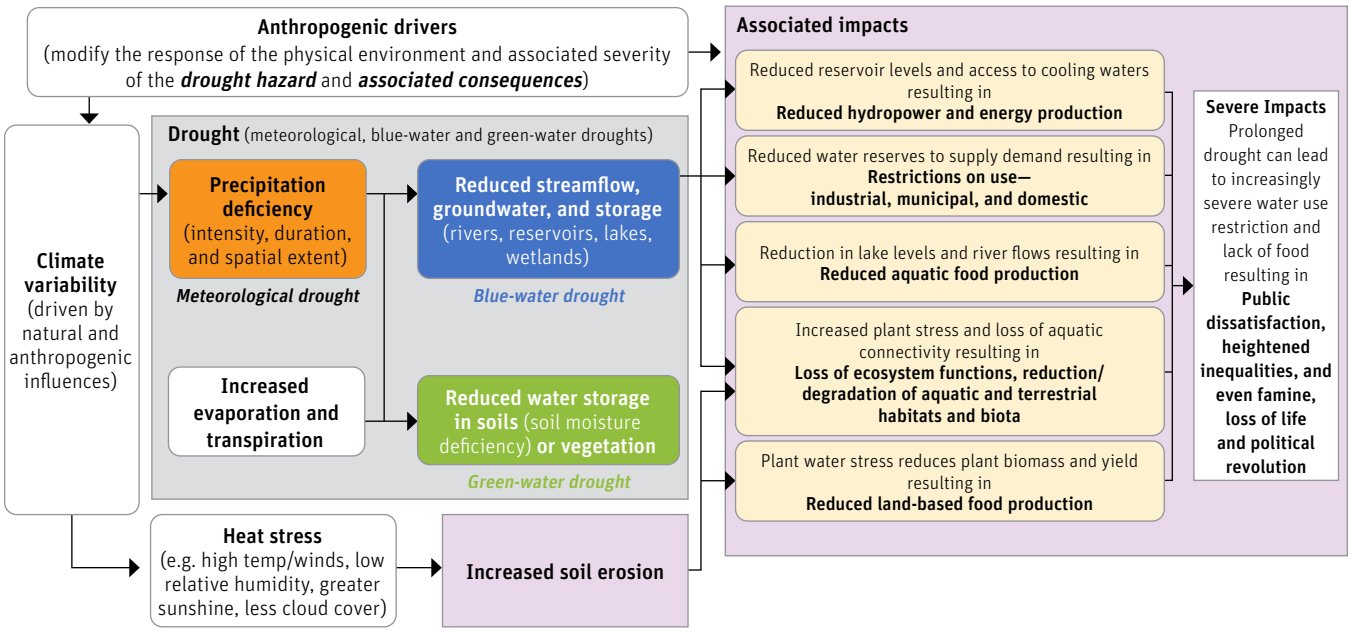
TABLE A.1 Types of Floods and Description

Flash flooding – Quickly forming floods with high-velocity flows, often the result of heavy rains of short duration. Typically occurs on steep slopes and impermeable surfaces, and in areas adjacent to streams and creeks. This particular type of event commonly washes away houses, roads, and bridges over small streams and so has a critical impact on communities and transportation in these often remote areas.
Fluvial (riverine) floods – Occur over a wide range of river and catchment systems. Floods in river valleys occur mostly on floodplains as a result of flow exceeding the capacity of the river channels and spilling over the natural banks or artificial embankments.
Coastal floods – Generally caused by storm surges and high winds generated by marine storms, often coinciding with high tides. In particular configurations, such as estuaries and deltas, this effect can be amplified by confinement or shallow seabeds. Coastal floods and river floods often interact in complex ways.
Urban floods – Urban flooding occurs when intense rainfall within towns and cities creates rapid runoff from paved and built-up areas, exceeding the capacity of storm drainage systems. Can be worsened by obstruction of drainage channels and pipes.
Snowmelt floods – In upland and high-latitude areas where extensive snow accumulates over winter, the spring thaw produces meltwater runoff. If temperature rises are rapid, the rate of melting may produce floods, which can extend to lower parts of river systems. The severity of meltwater floods will increase if the thaw is accompanied by heavy rainfall and can be further exacerbated if the subsoil remains frozen. Even though snowmelt floods may produce beneficial flooding in downstream areas, severe effects can occur on smaller scales.
Ice- and debris-jam floods – In areas that experience seasonal melting, if melting is rapid, ice floes can accumulate in rivers, forming constrictions and damming flows, causing river levels to rise upstream of the ice jam. A sudden release of the "ice jam" can cause a flood wave similar to that caused by a dam break to move downstream. Both meltwater and heavy rainfall in steep areas can cause landslides and debris flows. As these move downstream, major constrictions can build up. When these collapse or are breached, severe flooding can result. Both of these phenomena are very difficult to predict.
Engineered structure failure flooding – Flooding as a result of dam failure or levee failure presents the potential of catastrophic impact, depending on amount of water impounded and location of populated areas downstream.

Source: Authors based on State of California and Army Corps of Engineers 2013 and WMO 2011.

Droughts. On the other side of the spectrum, drought is ultimately about a lack of water, although multiple definitions exist. One way of classifying droughts is shown in Figure A.2, which identifies three different dimensions, meteorological, green water, and blue water, and their potential associated impacts. Each drought evolves in its own unique manner in terms of duration, geographical extent, and impacts. In general, droughts evolve relatively slowly, and it is difficult to forecast how they will develop over time and their potential impacts. For this reason, a drought monitoring system, which includes an assessment of actual impacts and potential risks, is fundamental to drought risk management.

FIGURE A.3 Defining Water Security, Scarcity, Drought, and Related Concepts



Source: Sayers and others 2015.

Floods and drought events appear to be related in some areas of the globe (He and Sheffield 2020). Pluvials, defined as periods of high "wetness", are increasingly following droughts, resulting in an increasing "see-saw" effect generating more intense floods and droughts.

Floods and Droughts - Social and Economic Impacts

Hydro-climatic extremes drive most natural disasters. Water-related disasters have comprised approximately 90 percent of natural disasters in the past century, showing an increasing trend over the past half-century (Grayman 2011). In addition, floods and droughts rank highest when looking at the number of people affected (Yoganath 2009), posing major impediments to achieving human security and sustainable socioeconomic development.

Droughts and floods (if not properly managed) can turn into disasters with devastating impacts on a wide range of sectors including water availability, food security, energy production, infrastructure, and ecosystem health. As shown in Table A.2, droughts and floods have cost US$764 billion in damages in the period 2000-2019, with floods being the most recurrent

TABLE A.2 Estimates of Impacts from Floods, Droughts, and Storms during 2000-2019

	Floods	Droughts	Storms
Number	3,254	338	2,043
Recorded economic damage	$651 billion	$128 billion	$1,390 billion
People affected (Millions)	1,650	1,430	727

Source: CRED and UNDRR 2020.

disaster; storms have resulted in an additional US$1,390 billion in damages, much of it from storm-related flooding.

Besides these direct costs, impacts can propagate into other sectors due to losses of ecosystem services, disruptions of global supply chains, and increased risk mitigation costs (He and others 2020). Between 2000 and 2019, over 4 billion people worldwide were affected by disasters, and the highest tolls were associated with floods and droughts (CRED and UNDRR 2020). There is a growing body of literature exploring the effects of droughts and floods on human health, migration, and conflicts (He and others 2020).

The impacts of floods and droughts are often different in terms of scale, impacts, and timing. Floods tend to be spectacular yet fleeting events which can cause great destruction within a limited area, and garner significant attention. Floods can take lives, destroy property, and spread diseases. Droughts on the other hand are often referred to as "misery in slow motion" as they develop slowly over large geographical areas with wide-ranging impacts. Some of these impacts are obvious, such as water shortages, failed crops, and reductions in hydropower generation. Other drought impacts are more insidious such as malnutrition, stunting, and loss of educational opportunities—often resulting in multigenerational impacts. According to a World Bank report, Shock Waves (Hallagette and others 2016), poverty exposure bias is more evident in droughts than in floods, particularly in Asia and Africa. The report emphasizes that poor people who rely on agriculture and ecosystems for their income sources are more vulnerable to droughts.

The macro-economic impacts of pluvials (periods of extreme wetness) and droughts can be quite different. As shown in Table A.3, flood disasters, which are usually associated with pluvials, are often correlated with increased economic growth. The reasons are explained below, but it should be stressed that floods can cause significant local economic losses, death, and human suffering. Droughts, in contrast, are almost always associated with a reduction in economic growth.

Economic and Social Impacts of Floods. Pluvials can generate positive economic impacts in many countries by increasing agricultural productivity and hydropower generation, which help increase a country's GDP. When pluvials result in flood damages, the recovery effort often generates significant economic activity through rebuilding efforts, thus also increasing GDP. On the other hand, flood damage to infrastructure, assets, businesses, homes, and livelihoods is usually not included in GDP calculations, but can cause significant economic setbacks for a city, business, or household.

Flood disasters can generate lingering disruptions in public services, such as water supply, wastewater management, solid waste collection, transportation, electricity, and education. Infrastructure in poor neighborhoods is often not well maintained or protected, and these areas are usually not the priority areas for recovery and reconstruction. Therefore, poor people who depend on poor infrastructure are more vulnerable to the secondary effects of floods, such as loss of hourly wages due to longer traveling time, health and hygiene concerns, mental stress, and even temporary or permanent separation of families. Women are also more vulnerable over the long term, as they tend to spend more time taking care of sick or injured family members or cleaning the house after a flood, rather than going back to school or work.

The impact of floods over the short term is highly dependent on where they occur. In urban areas, they can be highly destructive, particularly if they occur with little preparation or warning. They can destroy assets and infrastructure, cause major hygiene crises by blocking drains and spreading

TABLE A.3 Growth Effect of a "Typical" (Median) Disaster

		Effect on			
		GDP growth	Agricultural growth	Industrial growth	Service growth
Median Intensity of	Droughts	-0.6%***	-1.1%***	-1.0%**	-0.1%
	Floods	1.0%***	0.8%***	0.9%***	0.9%***
	Storms	-0.1%	-0.6%***	0.8%*	-0.2%

Note: the effects on GDP growth rates – the rate of change of output – and not output levels.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Source: adapted from World Bank and United Nations 2010.

wastewater, shutter businesses, and of course result in fatalities. Floods in rural areas on the other hand can have different types of impacts. Much of the world's rainfed agriculture relies on floods or monsoonal rains, particularly in South and East Asia and large parts of Africa. Thus, floods can generate large agricultural productivity boosts (Damania and others 2017). Nevertheless, if flood waters are too slow to recede, they can lead to waterlogging and major crop losses. Coastal flooding can do damage by moving saline water inland, spoiling soils and potentially salinizing groundwater supplies.

Poor people are often more exposed to floods, particularly in urban contexts. The impacts vary among types of floods, areas of living, and regions. The experience of floods could be different from person to person, depending on age, gender, disability conditions, social status, education level, employment, or poverty level. In urban areas, for example, poor people are more exposed to flood risks, as they tend to live in flood-prone areas with lower rents. Moreover, poor people lose more relatively when they are affected by floods due to poor quality or protection of their assets. From the gender lens, women may be the most affected in some cases. For example, in Bangladesh, 140,000 people died from the flood-related effects of Cyclone Gorky in 1991, and deaths among women outnumbered those of men by 14 to 1 because of women's limited mobility, social norms (such as caste), and gender roles and responsibilities. Another example is Argentina, where women were identified as mostly affected by floods in the city of Buenos Aires, with higher educational losses and labor tolls. However, these results can be attenuated by more gender-sensitive efforts when managing risks.

Economic and Social Impacts of Droughts. The impacts of droughts can be significant and are almost always negative. Drought typically strikes agriculture hardest by diminishing crop yields and reducing the quality of rangeland used for livestock. In some poorer countries, this lower productivity due to droughts can accelerate the expansion of agriculture into natural habitats. Finally, the reduction of agricultural production can exacerbate food security problems by increasing the price of food staples.

Cities struggle to cope with water shortages during droughts. Water shortages disproportionally affect the poor as basic sanitation conditions may deteriorate and as people use more of their limited income to purchase bottled water. The financial situation of water utilities usually deteriorates during droughts as water sales drop. Businesses often suffer. A World Bank study (Damania and others 2017) estimated that, on average, in lower- and middle-income countries, water outages reduce the sales of formal firms by about 9 percent and informal firms by 35 percent. For countries that rely on hydropower to meet a significant percentage of their power needs, droughts have dramatic economy-wide implications due to potential price increases and power shortages.

Perhaps most important, droughts can have long-term and often intergenerational impacts on poor people, and particularly on the rural poor. Poor people are more vulnerable to higher food prices because of their limited incomes. Poor families provide less nutritious food to their children and are less likely to seek medical consultation for sick children due to the cost. That could have long-term impacts on child development and prospects because of malnutrition and poor health conditions. Moreover, evidence shows that children in poor households face more difficulties in continuing their educations after disasters (Hallegatte and others 2016). The situation could be even more severe for girls and women, and the negative impacts could trickle down to subsequent generations, affecting not only the women who experience a particular drought but also their children (Damania and others 2017).

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