GUIDELINES FOR CLIMATE PROOFING INVESTMENT IN THE WATER SECTOR

Water Supply and Sanitation

ASIAN DEVELOPMENT BANK

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Foreword

Climate change represents a critical challenge to the continued and sustainable development of Asia and the Pacific. Its ongoing impacts are projected to intensify for many decades to come. Countries in the region are among the most vulnerable globally to the adverse impacts of climate change, with poor and marginalized communities likely to be most severely impacted.

Water abstraction, treatment, and distribution, and wastewater treatment infrastructure as well as water resources availability and quality are highly vulnerable to the impacts of climate change. These impacts will have consequences for the design, construction, location, and operations of water supply and sanitation infrastructure. Inadequate attention to these impacts during the project concept and project preparation phases will increase the long-term costs of these investments and reduce their performance.

Strategy 2020, the long-term strategic framework of the Asian Development Bank (ADB), and its midterm review confirm ADB's commitment to support its developing member countries in addressing the increasing challenges posed by climate change and to build a climate-resilient region. Adjusting to the need for climate-resilient development will mean integrating actions and responses to the physical, social, and economic impacts of climate change into all aspects of development planning and investment. ADB will assist its developing member countries in enhancing the climate resilience of vulnerable sectors—such as transport, agriculture, energy, water, and urban development—by climate proofing investments in these sectors and ensuring their intended outcomes are not compromised by climate change.

ADB continues to develop a package of technical resources to assist both its own operational staff and those of developing member country partners in managing climate-related risks throughout the project cycle. This package now encompasses rapid risk-screening tools as well as a software-based climate risk assessment tool. It also includes an increasing number of knowledge products aimed at disseminating specific and actual experience with climate proofing investment projects. Finally, it includes technical guidelines for climate proofing investments in critical development sectors. This package reflects a growing experience with climate-proofing approaches, methods, and tools for diverse investment projects in various socioeconomic and geographical settings.

This publication is the fourth in a series of technical guidelines for climate proofing investment projects (guidelines for the transport sector, the agriculture, rural development, and food security sector, and the energy sector are available on ADB website). It is intended to guide project preparation teams as they integrate climate risk management into the project cycle. The report encompasses lessons learned and good practices identified through several completed and ongoing ADB water supply and sanitation investment projects. We hope that it improves—and simplifies—the work of development professionals in their efforts to enhance the climate resilience of such projects.

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Any remaining errors should be attributed to the authors of this report and not to the individuals listed immediately above.

Abbreviations

ADB	Asian Development Bank
CRVA	climate risk and vulnerability assessment
GCM	general circulation model
GEF	Global Environment Facility
GHG	greenhouse gas
GIS	geographic information system
IPCC	Intergovernmental Panel on Climate Change
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
RCM	regional climate model
UNFCCC	United Nations Framework Convention on Climate Change
WSS	water supply and sanitation

Executive Summary

Water supply and sanitation is an important sector of investment supported by the Asian Development Bank (ADB). For the period 2006–2010, ADB-approved investments in water supply and sanitation amounted to approximately $4 billion, representing 7% of ADB's lending portfolio over the same period. Total investment in water supply and sanitation for the period 2011–2014 reached in excess of $5 billion.

The provision of water supply and sanitation services is particularly vulnerable to projected changes in climate conditions (temperature and precipitation among others), in the frequency and intensity of extreme weather events, as well as in the projected rise in sea level and the intensification of storm surges:

- In coastal areas, sea-level rise and the increased intensity of storm surges may lead to saline intrusion into groundwater aquifers as well as surface water.
- Increased glacial melting, decreased seasonal snowpack accumulation, and earlier spring snowmelt may lead to lower warm season flows in surface waters and lower summer water levels in reservoirs.
- Warmer temperatures may increase evaporation from surface waters and reduce water supply availability.
- Higher water temperatures may induce a greater presence of existing or new microorganisms which water and wastewater treatment facilities may find increasingly difficult and costly to treat to required standards.
- Water supply and wastewater treatment infrastructure may experience a greater risk of damage as a result of more frequent and/or more intense extreme weather events, floods, and drought.

These possible impacts may have significant consequences for achieving Goal 6 of the Sustainable Development Goals to ensure universal access to water and sanitation.

This publication, *Guidelines for Climate Proofing Investment in the Water Sector: Water Supply and Sanitation*, presents a step-by-step methodological approach to assist project teams in managing climate change risk in the context of water supply and sanitation investment projects (where "sanitation" is to be limited to sanitation sewerages). This methodological approach is consistent with other climate risk management approaches developed and used by other institutions but is embedded within ADB's project cycle and aims to be consistent with ADB's practices. While the focus of the guidelines is at the project level, an improved understanding of climate change impacts should also be used in the preparation of infrastructure planning and development policies and strategies to ensure appropriate resource allocation.

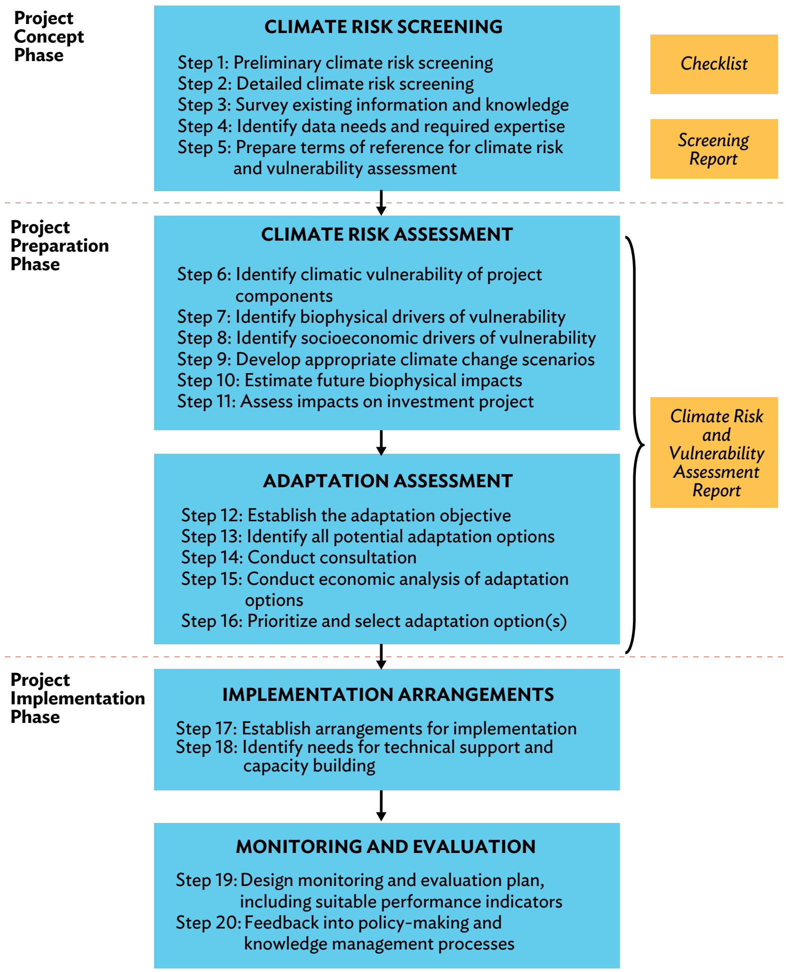
In this publication, the methodological approach for climate proofing water supply and sanitation investment projects is divided into five sets of activities and 20 steps (Figure E1). The process begins with initial climate risk screening. The core activities pertain to vulnerability assessment, impact assessment, and climate-proofing assessment. The process ends with defining implementation arrangements and monitoring frameworks.

The outcome of a climate risk and vulnerability assessment may result in three different types of decisions: (i) climate proof the project at the time of project implementation; (ii) ensure that the project can be climate proofed at a later time, if needed; or (iii) do not undertake any climate-proofing action while collecting information and data to support a reassessment of climate-proofing needs at a later time, if needed. The technical feasibility and economic assessments of the climate-proofing options will provide guidance as to the most desirable means of proceeding.

Decision makers may elect to invest in climate-proofing measure(s) at the time the project is being designed (climate proof now) under circumstances where any of the following applies:

- The costs of climate proofing now are estimated to be relatively small, while the benefits (the avoided expected costs from not climate proofing), even though realized only under future climate change, are estimated to be very large under most climate scenarios. This is occasionally referred to as a low-regret approach.
- The costs of climate proofing at a later point in time are expected to be prohibitive or climate proofing later is technically not possible.
- Among the set of climate-proofing options, one or more options deliver net positive economic benefits regardless of the nature and

Figure E1: Steps for Climate Risk Management of Investment Projects



extent of climate change. Such options are occasionally referred to as no-regret climate-proofing options.

- The set of climate-proofing options includes at least one option that not only reduces climate risks to the project, but also has other social, environmental, or economic benefits (co-benefits). Such options are occasionally referred to as win–win climate-proofing options.

Alternatively, decision makers may elect to invest minimally at the time of project design and implementation to ensure that the project can be climate proofed in the future if and when circumstances indicate this to be a better option than not climate proofing. This type of decision aims to ensure that the project is "ready" for climate proofing, if and when required. As such, the concept of climate readiness is occasionally referred to in this situation. This concept is akin to the real option approach to risk management. It involves avoiding the foreclosure of climate-proofing options and preserving flexibility to improve climate resilience as climate change is actually observed (as opposed to projected).

Finally, decision makers may elect to make no changes or incremental investment at the time of project design and implementation, but instead to await further information on climate changes and their impacts on the infrastructure assets, and to invest in climate proofing if and when needed at a later point in time.

This type of decision may result under one or more of the following circumstances:

- The costs of climate proofing now are estimated to be large relative to the expected benefits.
- The costs (in present value terms) of climate proofing (e.g., retrofitting) at a later time are expected to be no larger (or little different) than climate proofing now.
- The expected benefits of climate proofing today are estimated to be relatively small.

The last two types of decisions are akin to an adaptive management approach, which consists of monitoring changes in climate and putting in place climate-proofing measures over the project's lifetime as changes in climate conditions and their impacts are observed (as opposed to being simply projected). Key to both types of decisions is to ensure that appropriate data and information are collected.

The process of climate proofing investment projects aims both at assessing the climate risk to a project's future costs and benefits and at undertaking a technical and economic analysis of options to alleviate or mitigate those risks. Accounting for climate change at the outset of the project cycle does not imply that climate-proofing measures with large and costly investments need to be put in place as project implementation is initiated. It does imply, however, that decisions about project design and the adoption and timing of climate-proofing measures be informed with the possible impacts of climate change in the initial phases of the project cycle and that decisions of an irreversible nature be avoided.

Introduction

Asia and the Pacific is at high risk from climate change and will experience significant climate-related impacts due to its vast and varied geography as well as being home to the largest populations of the poor and vulnerable. Approximately 600 million people of the region live in coastal areas that lie at less than 10 meters above sea level. In 21 countries, more than half of the country's population lives in such coastal zones (ADB and APWF 2013). Of the 25 cities most likely to be impacted by sea-level rise and storm surge intensification, 12 are located in the Asia and Pacific region (Brecht et al. 2012).[1]

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013) notes that climate change will

- reduce renewable surface water and groundwater resources, exacerbating competition for water among sectors above and beyond other direct human sources of pressure such as population increase, land-use change, pollution, and inadequate practices of water resources management;
- increase the risk of submergence, coastal flooding, and coastal erosion in coastal systems and low-lying areas including those of the Pacific developing member countries. By 2100, hundreds of millions of people on the region's coastlines alone are projected to be affected by climate change, with the majority of these affected people being in East Asia, Southeast Asia, and South Asia; and
- adversely impact human health by further exacerbating health problems associated with heat stress, extreme precipitation, flooding, drought, and water scarcity.

[1] Those being Manila, Jakarta, Bangkok, Ho Chi Minh City, Taguig, Kalookan, Davao, Ujung Pandang, Butuan, Malabon, Iloilo, and Surabaya.

The Fifth Assessment Report (IPCC 2014, 15) also notes:

> Climate change is projected to reduce raw water quality and pose risks to drinking water quality even with conventional treatment, due to interacting factors: increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; increased concentration of pollutants during droughts; and disruption of treatment facilities during floods.

In Asia specifically, the Fifth Assessment Report notes that runoff could go up or down and that there is significant variation in projected changes across the region.

Water supply and sanitation (WSS) is an important sector of investment supported by the Asian Development Bank (ADB). For 2006–2010, ADB-approved investments in WSS amounted to approximately $4 billion, representing 7% of ADB's lending portfolio over the same period. Total investment in WSS for 2011–2014 reached in excess of $5 billion.

Climate change and climate change impacts will have consequences for the design of WSS investment projects. Inadequate attention to these impacts can increase the long-term costs of WSS investments and increase the likelihood that such investments will fail to deliver the benefits for which they were intended.

This publication, *Guidelines for Climate Proofing Investment in the Water Sector: Water Supply and Sanitation*, presents a step-by-step methodological approach to assist project teams in managing climate risk in the context of WSS investment projects. While the focus of the guidelines is at the project level, an improved understanding of climate change impacts should also be used in the preparation of infrastructure planning and development policies and strategies to ensure appropriate resource allocation.

The information presented here draws in part from the existing climate change and WSS literature and knowledge. It also draws from the experience of ongoing WSS projects in the region in which climate change risks have been identified and addressed.

Climate risk and vulnerability assessments undertaken across numerous investment projects have demonstrated that such assessments

- can be undertaken within a reasonable time frame and with limited resources;
- provide a more comprehensive understanding of how an investment project may be affected by projected changes in key climate parameters;
- can offer, in most cases, a large menu of climate proofing measures, both engineering and nonengineering;
- can increase the climate resilience of an investment project without requiring significant changes to project design; and
- do not necessarily require large incremental costs to project investment.

At the outset, it should be noted that in this publication, the expression "climate proofing" (or adaptation)[2] is meant as a process that aims to identify risks that an investment project may face as a result of climate change and to reduce those risks to acceptable levels. It does not imply a complete mitigation of the potential risks of climate change. The expression is used in a way similar to the meaning provided in UNDP (2011, v):

> Climate proofing refers to the explicit consideration and internalization of the risks and opportunities that alternative climate change scenarios are likely to imply for the design, operation and maintenance of infrastructure. In other words, integrating climate change risks and opportunities into the design, operation, and management of infrastructure.

A similar meaning of "climate proofing" is used in Ebinger and Vergara (2011, 75):

> Climate Proofing: actions taken to lessen, or perhaps eliminate, the potential negative impacts through the life cycle of a project of weather and climate variability and of climate change based on a CRA and on CRM principles.

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[2] Unless otherwise indicated, "climate proofing" and "adaptation" are used interchangeably for convenience of presentation in this publication.

Part A offers a more detailed discussion of the possible impacts of climate change on the WSS sector and of the nature of the adaptation options available. It also includes a presentation of the climate risk management process in ADB.

Part B describes the step-by-step approach to assessing climate risk vulnerabilities as well as climate-proofing options relevant to the WSS sector.

Part C discusses issues concerning mainstreaming adaptation into WSS sector development policy and planning.

PART A

Vulnerability and Climate Risk Management

Vulnerability of Water Supply and Sanitation to Climate Change

Water supply and sanitation (WSS) is vulnerable to projected changes in mean climate conditions such as mean temperature and rainfall, projected changes in climate variability (climate variability is expected to increase in a warmer climate), as well as projected changes in the frequency and intensity of extreme weather events and changes in sea level. These will impact both the quantity and quality of available water resources; water and wastewater infrastructure will face greater risks of damages; and services may be disrupted with greater frequency and at greater costs. Specific impacts include the following:

- Sea-level rise and the increased intensity of storm surges may increase the risk to WSS infrastructure located in coastal areas and lead to saline intrusion into groundwater aquifers.
- Increased glacial melting, decreased seasonal snowpack accumulation, and earlier spring snowmelt may lead to lower warm season flows in surface waters and lower summer levels in reservoirs.
- Warmer temperatures may increase evaporation from surface waters and reduce water supply availability. Increased evaporation may also act to reduce soil moisture and exacerbate drought conditions.
- Higher water temperatures may induce a greater presence of existing or new microorganisms which water and wastewater treatment facilities may find increasingly difficult and costly to treat to required standards.
- Water supply and wastewater treatment infrastructure may experience greater risk of damages as a result of more frequent and/or more intense floods and extreme weather events.

Additional potential impacts of climate change on the WSS sector are presented in Table 1.[3]

Table 1: Potential Impacts of Climate Change on Water Supply and Sanitation Infrastructure and Operations

Climate Impacts	Impacts on Water Resources
Sea-Level Rise	• Increased saline intrusion into groundwater aquifers. • Increased salinity of brackish surface water sources.
Warmer Temperatures	• Increased glacial melting, decreased seasonal snowpack formation, and earlier spring snowmelt may lead to lower summer flows in surface waters and lower summer levels in reservoirs. • Changes in watershed vegetation may alter the recharge of groundwater aquifers and change the quantity and quality of runoff into surface waters. • Increased evaporation in surface sources of water. • Increasing biological and chemical degradation of water quality. • Changes in watershed vegetation and increased wildfire and pest risks in watershed areas. • Changes in watershed agricultural practices and in the resulting pollution loads from agriculture. • Increased frequency or intensity of drought.
More Frequent and/or Intense Extreme Weather Events	• Increased turbidity and sedimentation of surface water. • Changes in nature of rainfall pattern leading to inadequate infiltration/groundwater recharge resulting in reduced flow and/or yield of water. • More frequent and/or intense flash floods damaging infrastructure and disrupting services. • Potential loss of reservoir storage as a result of increased erosion in watershed. • Increased loading of pathogenic bacteria and parasites in reservoirs. • Operational challenges to aquifer storage and recovery and water reclamation facilities. • More frequent overflow events of combined sewer systems.
Changes in Precipitation	• Reduced replenishment rates of groundwater resulting in declining water tables where net recharge rate is exceeded.

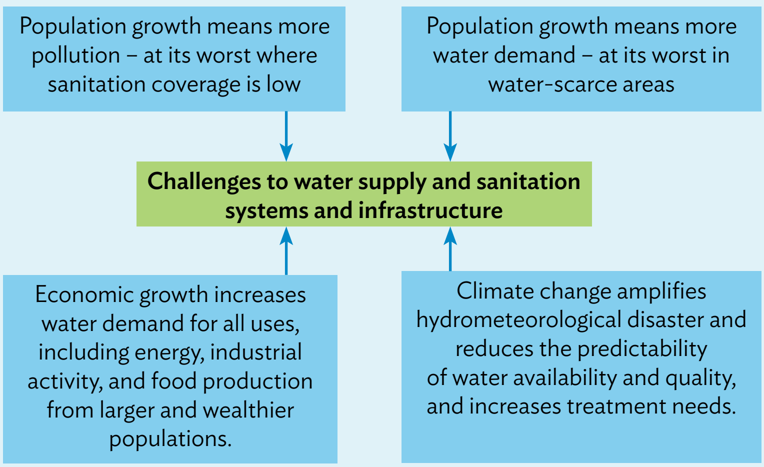
[3] Stratus Consulting and MHW Global (2009) presents a detailed description of the impacts of climate change on wastewater and stormwater management agencies.

Climate Impacts	Impacts on Water Supply Treatment and Infrastructure
Sea-Level Rise	• Assets on the coasts or in floodplains may be at increased risk from flooding, storm damages, and coastal erosion. • Increasing seawater intrusion into coastal aquifers.
Warmer Temperatures	• Increased urban water demand as a result of more frequent or more intense heat waves and dry spells.
More Rrequent and/or Intense Extreme Weather Events	• Increased risk of direct flood damage to treatment plant, pumping and conveyance, and outfall. • Increased risk of landslide which may damage infrastructure.
Climate Impacts	**Impacts on Wastewater Treatment and Infrastructure**
Sea-Level Rise	• Assets on the coasts or in floodplains may be at increased risk from flooding, storm damage, and coastal erosion. • Increased risk of operational impairment of outfalls including reduced ability to discharge wastewater into coastal waters. • Changes in treatment and compliance requirements as a result of altered biology and chemistry of receiving waters.
Warmer Temperatures	• Increased operating challenges to biological and chemical processes of treatment facilities. • Increased temperatures and increased evaporation in receiving water bodies, changing chemical balances and increased eutrophication. • Reduced capacity to meet wastewater treatment requirements and standards.
More Frequent and/or Intense Extreme Weather Events	• Increased risk of direct flood damage to treatment plant, pumping and conveyance, and outfall. • Increased risk of untreated sewage overflows contaminating water supply sources. • Changes in quantity and quality of watershed runoff and in the resulting non-point source pollution loads to receiving waters.

Sources: Cromwell, Smith, and Raucher (2007); Water Environment Research Foundation (2010); O'Neill (2010); Major et al. (2011).

These impacts of climate change on WSS are taking place in a context where the sector is facing multiple and significant challenges including population growth, industrial and economic growth, and increasing urbanization (Box 1).

Box 1: Impacts of Climate Change on Water Supply and Sanitation in a Context of Multiple Challenges



Sources: Adapted from World Health Organization. 2010. *Vision 2030: The Resilience of Water Supply and Sanitation in the Face of Climate Change*. Geneva.

These possible impacts may have significant and potentially adverse consequences for achieving Goal 6 of the Sustainable Development Goals to ensure universal access to water and sanitation (Box 2).

Box 2: Sustainable Development Goals: Goal 6

Goal 6 of the recently adopted Sustainable Development Goals aims to ensure access to water and sanitation for all. It includes the following targets:

- By 2030, achieve universal and equitable access to safe and affordable drinking water for all
- By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
- By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
- By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
- By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
- Support and strengthen the participation of local communities in improving water and sanitation management

Source: United Nations. Goal 6. http://www.un.org/sustainabledevelopment/water-and-sanitation

According to Danilenko, Dickson, and Jacobsen (2010), the effects of climate change, if left unplanned and unmitigated, will imply additional cost for water and wastewater service providers resulting from the need to perform more frequent technical maintenance, undertake unscheduled rehabilitation, and, in some cases, scale down operations (Box 3). Global adaptation costs for the continued provision of industrial and municipal water have been estimated to reach in excess of $12 billion each year (Ward et al. 2010a).

A growing (albeit still relatively small) number of national, state, and local governments have undertaken systematic assessments of the potential

Box 3: Possible Impacts of Climate Change on a Sanitation Project in Indonesia

Indonesia has one of the lowest coverage rates of conventional off-site urban sewerage in Asia. Only 11 out of its 330 cities have partial sewerage systems, and only 2% of the national urban population is connected to central wastewater treatment plants (WWTPs); the remaining urban population depends on poorly constructed and maintained septic tanks and unlined pit latrines, which result in leachates penetrating the aquifers. Some 80% of gray water drains directly to surface waters. The present sanitation services are inadequate and unintegrated due to inadequate and poorly enforced regulations. This results in limited desludging of septic tanks, inadequate septage treatment facilities, and fragmented operational responsibility.

The Metropolitan Sanitation Management Investment Project aims to deliver sanitation systems (wastewater treatment plant and sewer connections) in five cities of Indonesia (Cimahi, Jambi, Makassar, Palembang, and Pekanbaru). The initial environmental examination (IEE) prepared for each of these subprojects raises the possible impacts of climate change on the project infrastructure components. For example, the IEE of the Cimahi subproject includes the following statement (ADB 2013, 18):

> Climate change adaptation considerations shall be included in the design of Cimahi's proposed WWTP at Leuwigajah which is in close proximity to Cisangkan Stream. Changes in the intensity of extreme weather events as well as gradual changes in climate parameters such as precipitation can be damaging to the proposed WWTP. Inadequate attention to this impact can increase the long-term costs of sewerage investments for Cimahi City and increase the likelihood that such investments will fail to deliver the benefits for which they were intended. Flooding could affect the structural integrity of the proposed WWTP. Flooding can also prevent the WWTP from operating by reducing the head available across the plant. It may also submerge facility components that are supposed to be dry for proper operation. These situations may result to the release of untreated sewage into the environment and increase the risk to public health.

Similar statements are found in the IEEs of the other four subprojects.

Source: ADB. 2013. *Initial Environmental Examination: Indonesia: Metropolitan Sanitation Management Investment Project—Cimahi City Off-Site Wastewater Collection System and Treatment.* Manila.

impacts of climate change on their infrastructure in general, and WSS infrastructure in particular.[4] A number of studies have focused on assessing the impacts of climate change on specific municipal water systems.[5]

This suggests that climate risk screening and climate risk and vulnerability assessment will increasingly become crucial to guide investments in the sector.

Numerous climate-proofing measures (some of which are standard practices in WSS projects) are available to the WSS sector (Table 2), including both engineering (structural) and nonengineering options. Note that a decision not to climate proof, or to maintain a "business-as-usual" approach ("do nothing" option), should also be retained as a possible option. In a number of circumstances, findings from the impact, vulnerability, and adaptation assessments may indicate that doing nothing (no climate proofing) is the best course of action.

Table 2: Climate-Proofing Options for Water Supply and Sanitation Investment Projects

Investment projects	Climate-Proofing Options
Water Supply	• Demand-side management with a view of decreasing water demand • Reduction of nonrevenue water • Water metering and water tariffs (which can contribute to reducing water demand) • Low water use applications • Diversification of water sources • Enhancing storage capacity • Water reuse and desalination • Aquifer recharge using recycled water • Relocation of flooded infrastructure • Impounding reservoir to store freshwater

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4 For example, in Australia, see Australian Academy of Technological Sciences and Engineering (2008); in Canada, see McCulloch, Forbes, and Shaw (2002) and Infrastructure Canada (2006); in the United Kingdom, see London Climate Change Partnership (2002); in New Zealand, see Jollands et al. (2007); and in the United States, see Larsen et al. (2008). Similar vulnerability analyses of WSS systems to climate change have been conducted in developing countries around the world, for example, in Nicaragua (Cestti et al. 2013); in Moldova (OECD 2013); and in Malawi, Tanzania, and Sierra Leone (Oates et al. 2014), among others.

5 See among others, Palmer and Hanh (2002), Medellin-Azuara et al. (2008), Nie et al. (2009), and Rosenberg et al. (2010). The vulnerability to climate change of water supply and sanitation systems of 10 European cities as well as of Melbourne in Australia and Seattle in the United States are examined in EU (2015).

Table 2 *continued*

Investment projects	Climate-Proofing Options
Water Treatment and Quality	• Protection of the water source and treatment of wastewater discharges • Integrated water resources management • Prevention of saltwater intrusion into coastal zones
Water Distribution	• Adjustment to operation below design capacity
Wastewater Collection	• Prevention of sewer overflow • Adjustment to operation below design capacity • Relocation of flooded sewers
Wastewater Treatment	• Adjustment of treatment technology to new effluent composition • Adjustment of treatment level to revised dilution capacity of discharge point • Relocation of flooded wastewater treatment facilities

Climate Risk Management of ADB Investment Projects

Along with its overall financial support and technical assistance to countries in Asia and the Pacific, which now spans over 4 decades, ADB has also supported climate risk management in investment projects for numerous years. This extensive experience offers a number of important insights (ADB 2015).

Since these early efforts, ADB has continued to develop and pilot test methods and tools to assess climate change vulnerability and impacts and to identify adaptation needs and options. These methods and tools aim to assist ADB and developing member countries in managing climate change risks throughout the project cycle. They include (i) risk screening tools that enable rapid risk assessment at the project preparation stage; (ii) sector briefings on adaptation; and (iii) technical guidelines for the assessment of climate impacts, evaluation of risks, identification and prioritization of adaptation options, and monitoring and evaluation of adaptation measures. ADB's approach to climate risk management has evolved from an initial identification of entry points for promoting adaptation in operations to a more rigorous framework to systematically identify proposed investments that may be adversely affected by climate change at the very early stages of project development and incorporate risk reduction measures in the project design.

This framework (Figure 1) was institutionalized in early 2014, as a response to the mandated requirement that exposure and vulnerability to climate change risks be identified and accounted for in the preparation of investment projects. As shown in Figure 1, the framework includes climate risk screening undertaken during the project concept phase, climate risk and vulnerability assessment (CRVA) undertaken during the project preparation phase, and monitoring and reporting undertaken during the project implementation phase. To facilitate the implementation of the overall framework, the activities are subdivided into 20 steps (Figure 2). The various activities presented in this framework and steps are discussed in greater detail in Part B.

Figure 1: Flowchart for Climate Risk Management of Investment Projects

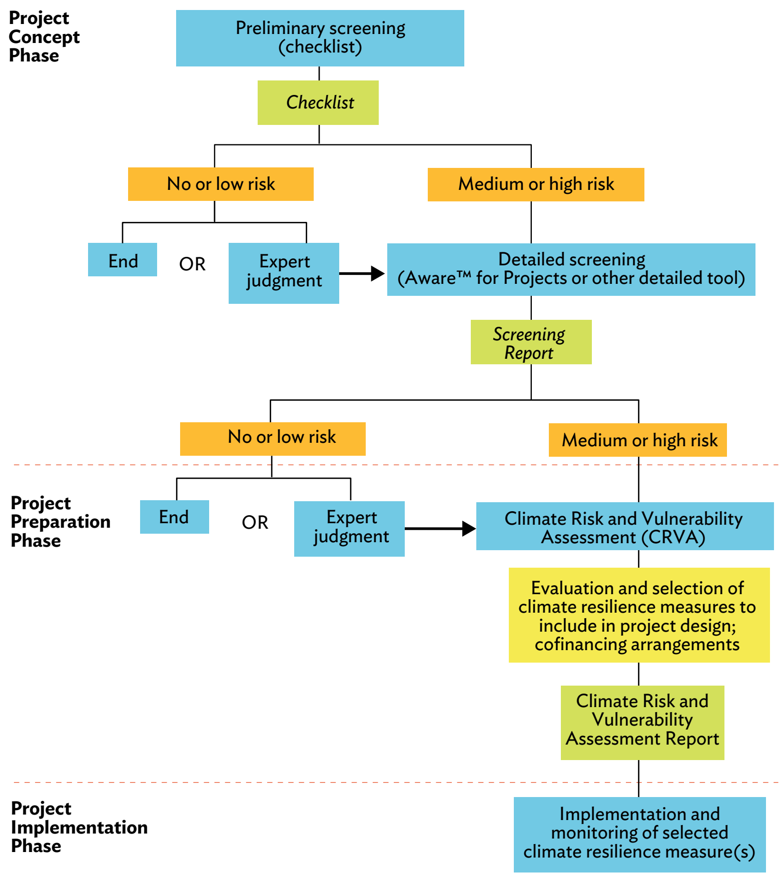
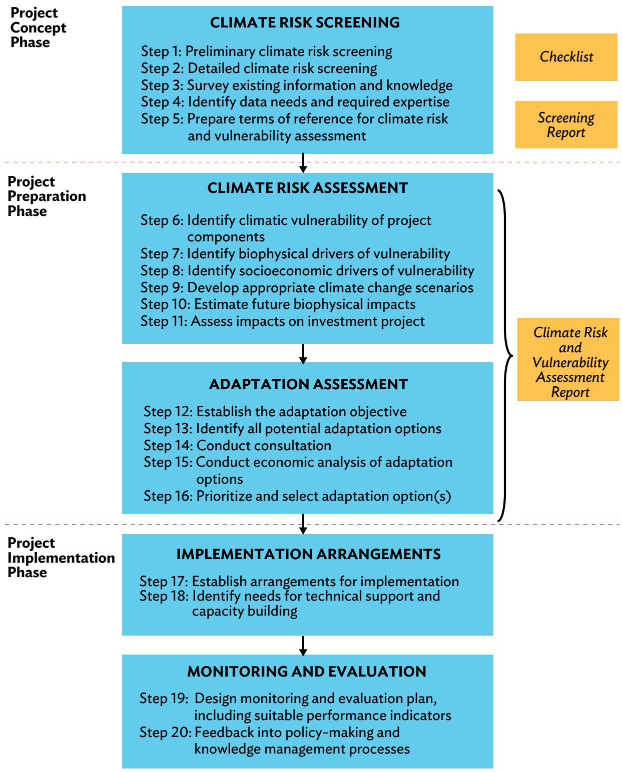


Figure 2: Steps for Climate Risk Management of Investment Projects



The climate risk management approach and tools described in this report have benefited from material developed by other institutions (Box 4). In general terms, the climate risk management approach presented in this publication is also similar in nature to the concept of adaptation science developed in Meinke et al. (2009, 69) as "the process of identifying and assessing threats, risks, uncertainties and opportunities that generates the information, knowledge and insight required to effect changes in systems to increase their adaptive capacity and performance."

However, where needed, the approach differs from available alternatives as it is more importantly embedded in and consistent with ADB's project cycle and project assessment practice.

This step-by-step approach to the climate risk management of investment projects, with specific references to WSS investment projects, is discussed in more detail in Part B.

Box 4: Selected Climate Change Risk Management and Climate Risk Screening Tools

The Institute of Development Studies (IDS) has developed a climate risk screening methodology known as ORCHID (Opportunities and Risks from Climate Change and Disasters). The methodology has been applied to development interventions in Bangladesh and India. The methodology and outputs are available at http://www.ids.ac.uk/climatechange/orchid

GIZ has developed a climate-proofing tool comprising a number of steps similar to the approach presented here. The methodology is described GIZ. 2012. *Manual: Climate Proofing Tool*. Eschborn, Germany. It is accessible at http://www2.giz.de/wbf/4tDx9kw63gma/Climate_proofing_tool.pdf

The World Bank maintains a climate change knowledge portal which includes adaptation tools. It is accessible at http://sdwebx.worldbank.org/climateportal/

The United Nations Environment Programme (UNEP) has made available a guidance document on assessing vulnerability, impacts and adaptation to climate change: PROVIA. 2013. *PROVIA Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change*. Consultation document, United Nations Environment Programme, Nairobi, Kenya, 198 pp. It is accessible at http://www.unep.org/provia

The International Institute for Sustainable Development (IISD) has developed a community-based risk screening tool referred to as CRiSTAL. It is accessible at https://www.iisd.org/cristaltool/

With respect specifically to water supply and sanitation, the European Commission has funded a collaborative project known as PREPARED. The project originates from the Water Supply and Sanitation Technology Platform (WSSTP) thematic working group Sustainable Water Management in Urban areas. In collaboration with multiple cities, the project has developed strategies to meet anticipated challenges in the water supply and sanitation sectors brought about by climate change. Material is accessible at http://www.prepared-fp7.eu/

Under its Climate Ready Water Utilities initiative, the United States Environmental Protection Agency has developed a climate risk assessment tool known as CREAT (Climate Resilience Evaluation and Awareness Tool). Its purpose is to assist water, wastewater, and stormwater utility owners and operators in the United States in assessing climate risks to utility assets and operations. For more information and free download of the CREAT software, visit http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm

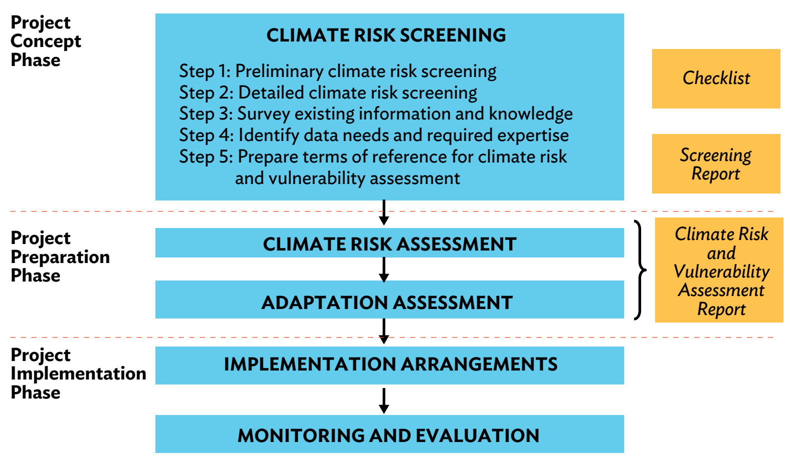
PART B

Climate Proofing Water Supply and Sanitation Investment Projects

Climate Risk Screening

Climate risk screening is carried out during the project concept phase by project teams. Its goal is to alert project teams in the early phase of the project cycle of the potential exposure and vulnerability of the project to climate change. An additional goal of climate risk screening is to facilitate and initiate early on the process of cofinancing of the climate-proofing measures in the event that such measures may be warranted.

Figure 3: Climate Risk Screening



Step 1: Preliminary Climate Risk Screening

Disaster and climate risk screening tools have been developed by a number of organizations to rapidly assess the risks posed to a planned project as a result of climate change and natural hazards. These assessments are meant to alert a project officer to the potential risks of climate change to the project and to determine whether further exploration is warranted. While different risk screening tools use slightly different approaches, it has been recognized that expert opinion and judgment, based on awareness and knowledge of climate change and hazards, remain essential for all.

For preliminary climate risk screening, ADB has developed a checklist used by project officers to score the possible level of climate risk to which a project may be exposed. This checklist is presented in Table 3.

Table 3: Checklist for Preliminary Climate Risk Screening

	Screening Questions	Score	Remarks
Location and Design of Project	Is siting and/or routing of the project (or its components) likely to be affected by climate conditions, including extreme weather-related events such as floods, droughts, storms, and landslides?		
	Would the project design (e.g., the clearance for bridges) need to consider any hydrometeorological parameters (e.g., sea-level, peak river flow, reliable water level, peak wind speed)?		
Materials and Maintenance	Would weather, current and likely future climate conditions (e.g., prevailing humidity level, temperature contrast between hot summer days and cold winter days, exposure to wind), and humidity hydrometeorological parameters likely affect the selection of project inputs over the life of project outputs (e.g., construction material)?		
	Would weather, current and likely future climate conditions, and related extreme events likely affect the maintenance (scheduling and cost) of project output(s)?		

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Table 3 *continued*

	Screening Questions	Score	Remarks
Performance of Project Outputs	Would weather/climate conditions and related extreme events likely affect the performance (e.g., annual power production) of project output(s) (e.g., hydropower generation facilities) throughout their design lifetime?		
	Total Score		

Each of the five questions presented in the checklist is scored by project officers with 0 (not likely), 1 (likely), or 2 (very likely). When all scores are added together, a total score of 0 indicates a project at no or low risk to climate change. A total score of 1, 2, 3, or 4 indicates a project at medium risk to climate change, provided that no individual question has received a score of 2. A score of 2 to any individual question indicates a project at high risk to climate change. Similarly, a total score of 5 or more (the maximum score being 10) indicates a project at high risk to climate change (Box 5).

Project officers are encouraged to provide remarks based on expert judgment on the sensitivity of project components to climate conditions, such as how climate parameters are considered in design standards for infrastructure components, how changes in key climate parameters and sea level might affect the siting or routing of project, the selection of construction material and/or scheduling, the maintenance cost/scheduling of project outputs, and overall project performance.

Projects identified to be at medium or high risk through this rapid screening exercise must undergo a further and more detailed level of screening.

Box 5: Preliminary Climate Risk Screening of the Ebeye Water Supply and Sanitation Project

Ebeye is a small island of approximately 32 hectares located on the Kwajalein Atoll of the Republic of the Marshall Islands. In 2011, the estimated resident population was approximately 11,400.

The water system distributes an estimated 45 liters per capita per day. The public water system experiences low system pressure and insufficient water treatment. In addition, only one of the three reverse osmosis water units is functional. The sewerage system is characterized as dysfunctional with dilapidated sewers and pump stations, and a wastewater treatment plant that has not been operational for 10 years. The effluent outlet of the existing outfall pipeline is approximately 30 feet from the existing shoreline, leading to high fecal coliform counts in the lagoon coastal waters.

The project aims to improve water and sewage services (as well as power supply) in Ebeye. The water supply component of the project includes (i) installing a new water treatment plant, (ii) constructing a new freshwater pumping station, (iii) installing an elevated freshwater tank, and (iv) upgrading and expanding the water distribution pipeline. The wastewater and sanitation component includes upgrading of the sewage pumping stations, constructing a new sewer pipeline, and improving wastewater treatment.

The following preliminary climate risk screening was prepared by the project team:

	Screening Questions	Score	Remarks
Location and Design of Project	Is siting and/or routing of the project (or its components) likely to be affected by climate conditions including extreme weather-related events such as floods, droughts, storms, landslides?	1	
	Would the project design (e.g., the clearance for bridges) need to consider any hydrometeorological parameters (e.g., sea-level, peak river flow, reliable water level, peak wind speed)?	0	
Materials and Maintenance	Would weather, current and likely future climate conditions (e.g., prevailing humidity level, temperature contrast between hot summer days and cold winter days, exposure to wind), and humidity hydrometeorological parameters likely affect the selection of project inputs over the life of project outputs (e.g., construction material)?	1	

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Box 5 *continued*

	Screening Questions	**Score**	**Remarks**
	Would weather, current and likely future climate conditions, and related extreme events likely affect the maintenance (scheduling and cost) of project output(s)?	0	
Performance of Project Outputs	Would weather/climate conditions and related extreme events likely affect the performance (e.g., annual power production) of project output(s) (e.g., hydropower generation facilities) throughout their design lifetime?	0	
	Total Score	2	

Given the above score, the project was deemed at medium risk and undertook a detailed climate risk screening.

A summary of the preliminary risk screening is provided in Table 4.

Table 4: Preliminary Climate Risk Screening: Timing, Description, and Output

Timing	**Project Concept Phase**
Description	A *preliminary climate risk screening* (checklist) aims to provide an initial and rapid assessment of the possible level of sensitivity of the project location and project components to climate variables such as temperature, and rainfall quantity and temporal distribution and impacts such as flooding.
Output	A score indicating whether the project is considered to be at low, medium, or high climate risk. A rating of *medium* or *high* indicates that a more detailed risk screening should be undertaken.

Step 2: Detailed Climate Risk Screening

Projects identified to be at medium or high risk undergo a further and more detailed screening. This second step is also implemented by the project team during the project concept phase. While still a screening mechanism, this step aims to detail further the specific nature of the climate risks. To support this process, ADB has developed tools and materials to support climate risk management at the sector and project levels. A rapid climate risk screening tool, AWARE for Projects, is available to project teams for this purpose.[6]

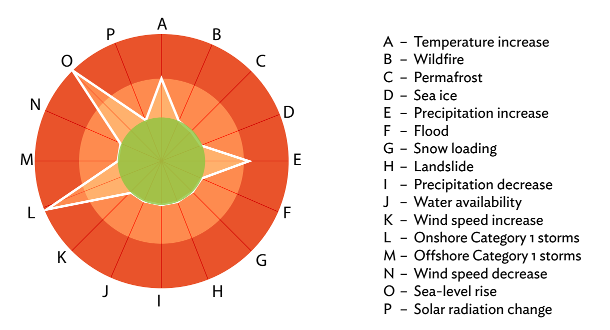
AWARE for Projects uses data from 16 general circulation models, as well as numerous databases on temperature increase, wildfire, permafrost, sea ice, precipitation increase or decrease, floods, snow loading, landslide, water availability, wind speed increase or decrease, onshore and offshore Category 1 storms, sea-level rise, and solar radiation change. For each project, the tool generates an overall climate risk ranking of low, medium, or high (Boxes 6 and 7). It presents key risk areas, and produces a narrative on the potential impacts of climate change on the project as well as a menu of possible climate-proofing measures. Operational departments may also apply more detailed climate risk screening approaches that suit their needs in conjunction with the in-house knowledge and expertise.

Box 6: AWARE for Projects Detailed Climate Risk Screening of the Ebeye Water Supply and Sanitation Project

AWARE for Projects provided the following climate risk rating for the Ebeye water supply and sanitation project described earlier in Box 5. In the radar chart below, the red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

Final project risk rating: MEDIUM RISK

Breakdown of risk topic ratings



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6 At the time of writing, AWARE for projects can be accessed by project officers requesting such access by means of a password.

Box 6 *continued*

AWARE for Projects categorizes this project at medium risk overall from the potential impact of climate change. Specifically, the data suggest that the project is at high risk in relation to onshore Category 1 storms and sea-level rise. This results from the project being located in a region which has experienced at least one Category 1 storm over the period 1968–2009. Furthermore, the project (or some of its components) is located in low-lying coastal areas, which makes the project vulnerable to impacts of sea-level rise.

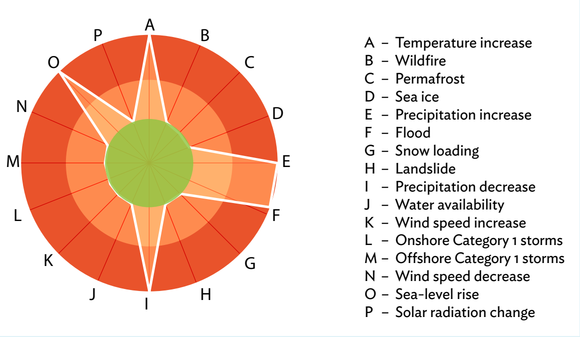
Box 7: AWARE for Projects Detailed Risk Screening of the Colombo Wastewater Management Program – Tranche 3

The Colombo water and sewerage system is under capacity and has been suffering from technical deficiencies including serious blockages and overflows, pollution of waterways, overloading, equipment failures, and high operational costs. The system requires significant rehabilitation and upgrading. Interventions under the program includes sewer rehabilitation, upgrading, and realignment; provision of services to unserved areas; rehabilitation of pumping stations; and construction of additional wastewater treatment facilities.

AWARE for Projects provided the following climate risk rating.

Final project risk rating: HIGH RISK

Breakdown of risk topic ratings



AWARE for Projects shows that the project is at high risk overall and the identified high risk factors are increase in temperature, precipitation increase, precipitation decrease, flood, and sea-level rise. In particular, the project is located in a region that has experienced recurring large flood events in the recent past.

Unless an expert judgment indicates otherwise, a risk rating of *medium* or *high* should then lead to the undertaking of a climate risk and vulnerability assessment.

A summary of the detailed risk screening is provided in Table 5.

Table 5: Detailed Climate Risk Screening: Timing, Description, and Output

Timing	Project Concept Phase
Description	A *detailed climate risk screening* aims to detail further the specific nature of the climate risks. A risk rating of *medium* or *high* should then lead to the undertaking of a climate risk and vulnerability assessment.
Output	A detailed climate risk screening report should include information pertaining to • climate sensitivity of key project components; • current trends in key climate variables in project area; • broad understanding of projected change in key climate variables in project area; • categorization of potential climate risks; and • if needed, terms of reference for the undertaking of a climate risk and vulnerability assessment.

Step 3: Survey Existing Information and Knowledge

A large amount of work related to climate change is ongoing in many countries, including government planning and policy processes as well as research and development programs such as those under the United Nations Framework Convention on Climate Change (UNFCCC). Identifying existing available information can help to avoid duplication and ensure that coordination efforts within countries and between donors are being supported. Each country has a climate change focal point under the UNFCCC and will, in most cases, have prepared a national communication to the UNFCCC.[7] These national communications may provide appreciation of a government's understanding of the possible impacts of climate change on WSS and of its intent to address them (Box 8).[8] These national communications may also provide reference to national or local studies and reports on the impact of climate change on the sector.

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7 Details of the national focal points are available at http://maindb.unfccc.int/public/nfp.pl

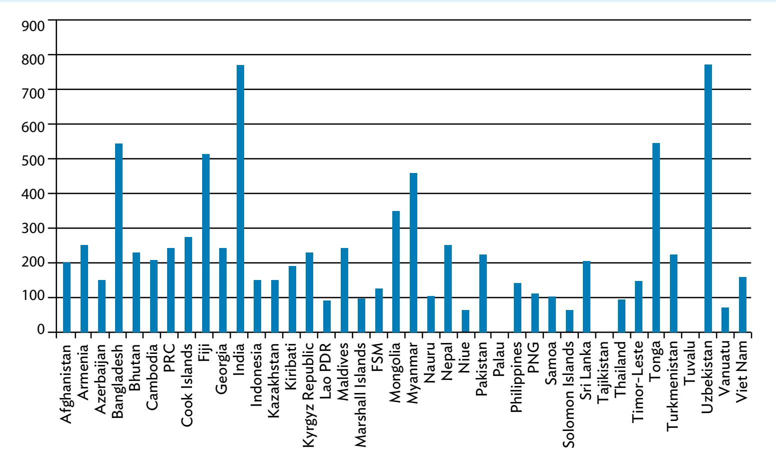
8 All developing member countries of ADB have prepared and submitted national communications to the UNFCC. All communications are available at http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

A number of least developed countries have also prepared national adaptation programs of action (NAPAs) to identify their most urgent adaptation needs.[9] While some of these documents may benefit from revisions and updates, they may provide a good basis for identifying country needs and a focal point around which to coordinate the multiple climate change initiatives under way.[10]

Box 8: Water in Countries' Communications to the United Nations Framework Convention on Climate Change

As an illustration of the extent of the concerns pertaining to projected impacts of climate change on water resources in general, the figure below presents the number of times the word "water" appears in the countries' most recent communications to the United Nations Framework Convention on Climate Change (UNFCCC). For both India and Uzbekistan, this number exceeds 750.

Figure B8.1: Appearance of the Word "Water" in National Communication (Total Frequency)



PRC = People's Republic of China, FSM = Federated States of Micronesia, Lao PDR = Lao People's Democratic Republic, PNG = Papua New Guinea.

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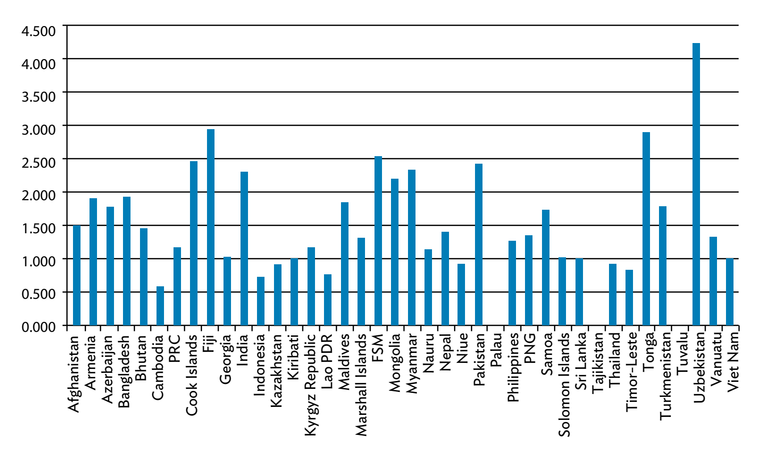
9 The following 14 ADB developing member countries have prepared and submitted NAPAs to the UNFCC: Afghanistan, Bangladesh, Bhutan, Cambodia, Kiribati, the Lao People's Democratic Republic, the Maldives, Myanmar, Nepal, Samoa, Solomon Islands, Timor-Leste, Tuvalu, and Vanuatu. These NAPAs are available at http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4585.php

10 Part C discusses in greater detail the use of these documents.

Box 8 *continued*

However, communications vary in number of pages from 38 pages (Tuvalu) to 340 pages (India). The figure below presents the number of times the word "water" appears on average per page of the country's communication to the UNFCCC. In Uzbekistan's communication, the word "water" appears on average 4.2 times per page (over a total of 184 pages). After Uzbekistan, Fiji, Tonga, the Federated States of Micronesia, the Cook Islands, and Pakistan exhibit the largest frequency.

Figure B8.2: Appearance of the Word "Water" in National Communication (Frequency per Page)



PRC = People's Republic of China, FSM = Federated States of Micronesia, Lao PDR = Lao People's Democratic Republic, PNG = Papua New Guinea.

In addition, the Global Environment Facility's Adaptation Learning Mechanism (ALM) provides a list of country-level adaptation initiatives, together with relevant technical resources relating to climate change impacts and vulnerability assessments.[11]

Step 4: Identify Data Needs and Required Expertise

A preliminary identification of all climate change parameters most relevant to the project should be initiated during the project concept phase, and this can be further developed in later phases. Climate change parameters relevant to WSS investment projects may include temperature (both

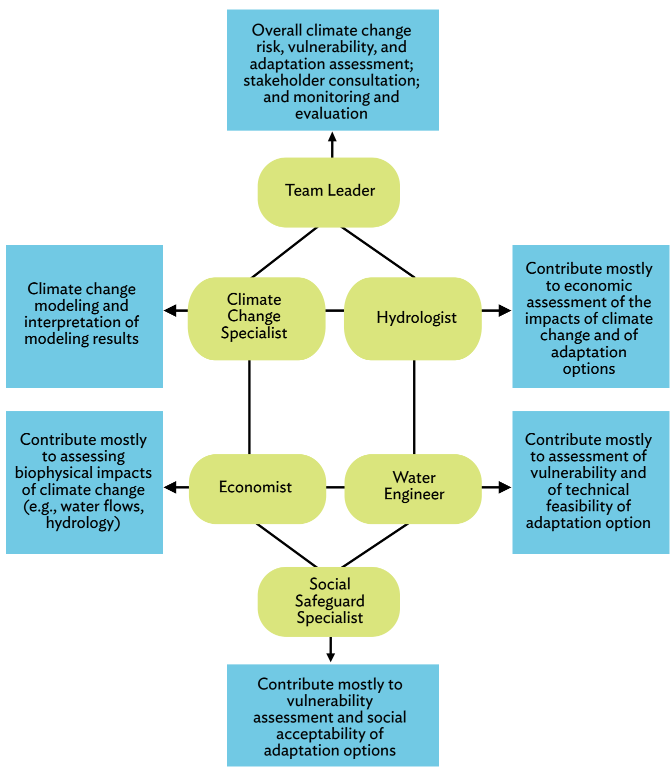
[11] All developing member countries of ADB are represented on the ALM website, which can be accessed at http://www.adaptationlearning.net/country-profiles

average and extreme temperatures), precipitation (including extreme precipitation), sea-level rise, and, more generally, extreme weather events.

Specifying these concerns at the outset will help guide and focus the nature and extent of the information to be collected and used for assessing the potential vulnerability of the investment project.

The assessment of vulnerability and of climate-proofing options requires interaction between different experts (Figure 4). However, many of the activities constituting a climate risk and vulnerability assessment (CRVA) may be undertaken through an expansion of the tasks of a traditional project preparation team, such as the project engineer, the environmental specialist, and the project economist.

Figure 4: Assessing Climate Change Risk, Vulnerability, Impacts, and Adaptation: A Web of Interaction



Step 5: Prepare Terms of Reference for the Climate Risk and Vulnerability Assessment

In the event that a CRVA is required, the terms of reference for this exercise must be prepared. An example of terms of reference for such an assessment (given in the Appendix) is meant to indicate the general nature of the tasks and deliverables that may be required. The example will need to be tailored given the findings and outputs of the detailed risk screening.

Climate Risk and Vulnerability Assessment

The goal of the CRVA is to characterize climate risks to the project by identifying both the nature and likely magnitude of climate change impacts on the project, and the specific features of the project that make it vulnerable to these impacts. A CRVA attempts to identify the underlying causes of a system's vulnerability to climate change. The CRVA process embodies the recognition that many of the future impacts of climate change are fundamentally uncertain and that project risk management procedures must be robust to a range of uncertainty. In addition, a CRVA seeks to ensure that adaptation measures are locally beneficial, sustainable, and economically efficient.

Climate change risks to a project are jointly defined by the likely impacts of climate change itself in the form of changes in the values of important hydrometeorological and environmental variables and by the inherent vulnerability of the project and of specific project components to such changes.[12] The climate impact assessment component of a CRVA is focused on identifying, evaluating, and, to the extent possible, quantifying environmental conditions associated with climate change and variability in physical terms, and the effects of such changes on natural and human systems. When climate impacts are negative, such as increased flood magnitude, they are referred to as climate (or hydrometeorological) hazards. The impacts of climate change can also be positive, such as projected increases in precipitation in basins that are historically water-constrained.

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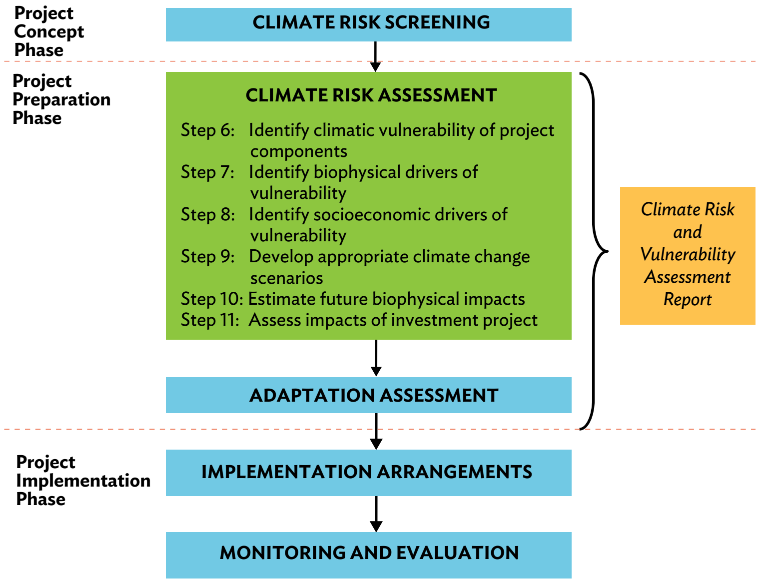
[12] The Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report (2007), defines *vulnerability* in a manner consistent with risk as it is used here: "... a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity." The approach to CRVA presented in this document emphasizes the IPCC Fourth Assessment definitions of risk and vulnerability since they provide a coherent framework for disaggregating climate risks into analytically useful elements.

Figure 5: Climate Risk Assessment



By contrast, the focus of the vulnerability assessment component of a CRVA is the project, and the objectives are to identify systems, structures, or functions of the project that are vulnerable to alterations in environmental conditions and to understand the reasons why. These activities help to compensate for uncertainties in the future behavior of climate and to ensure that adaptation measures are locally beneficial and sustainable because of their explicit relevance to the socioeconomic context in which adaptation may be taking place. Vulnerability is often conceptualized formally as an increasing function of the project's degree of exposure to the projected impacts of climate change (often determined explicitly by location), and its sensitivity to those impacts if exposed; and is inversely related to its adaptive capacity, defined as "[t]he ability of a system to adjust to climate change […] to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007, 869).[13]

Many recent studies make strong distinctions between climate scenario-driven impact assessment approaches, often referred to as "top-down" or "predict-then-act," and vulnerability-oriented approaches, often called

13 See Figure 6.

Figure 6: Climate Risks as Climatic Impacts and Project Vulnerability Context

Climate Impact Assessment	Project Vulnerability Assessment

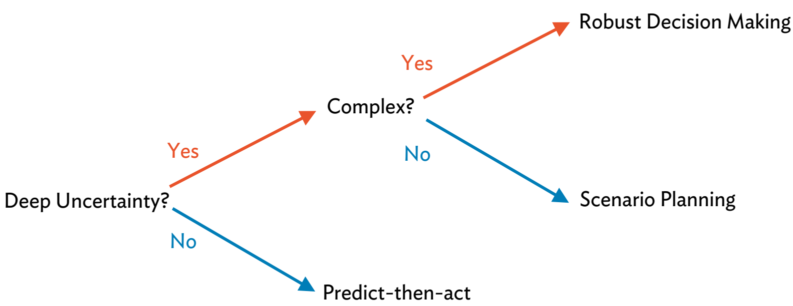
$$\text{Risk} = \text{Climate Impact} \times \frac{\text{Exposure x Sensitivity}}{\text{Adaptive Capacity}}$$

"bottom-up." While current good practice in adaptation emphasizes risk management, and increasing recognition of the fundamental uncertainty of future climate discourages the overinterpretation of model-generated climate projections, impact and vulnerability assessments should be understood as complementary processes in project climate risk management, and they can be conducted in parallel. An impact assessment is useful in narrowing and illuminating the potential range of future conditions with which project designers must be concerned. A vulnerability assessment provides an understanding of how robust the project and specific project components are to departures from design assumptions and identifies critical thresholds of vulnerability past which the project fails to perform as designed.

The extent to which climate change projections and scenarios are used directly in the design of water sector projects will depend both on the sensitivity of design parameters to specific assumptions about the behavior of hydroclimatic variables and on the confidence that the climate change specialist and project team have in the available projections and scenarios. In some instances, the design issues are straightforward, and the nature and magnitude of climate change are understood with reasonable confidence. An example is the design of a wastewater outfall in a coastal area. Sea level is known to be increasing, although the local rate of increase may not be known with high confidence. In this case, proceeding to design using the higher end of the range of projected sea-level rise over the project lifetime is appropriate, unless there are significant incremental costs or performance issues involved in doing so.

By contrast, for more complex projects involving multiple hydroclimatic variables, at least some of which (e.g., annual peak rainfall and runoff) are subject to high levels of uncertainty, strong assumptions about future values of these variables may lead to improper design, project underperformance, and, possibly, to maladaptation. Under these circumstances, an approach such as robust decision making, which requires no strong assumptions about future climate, may be appropriate (Figure 7).[14]

Figure 7: Factors Determining When Impact-Driven or Vulnerability-Driven Approaches Are Appropriate

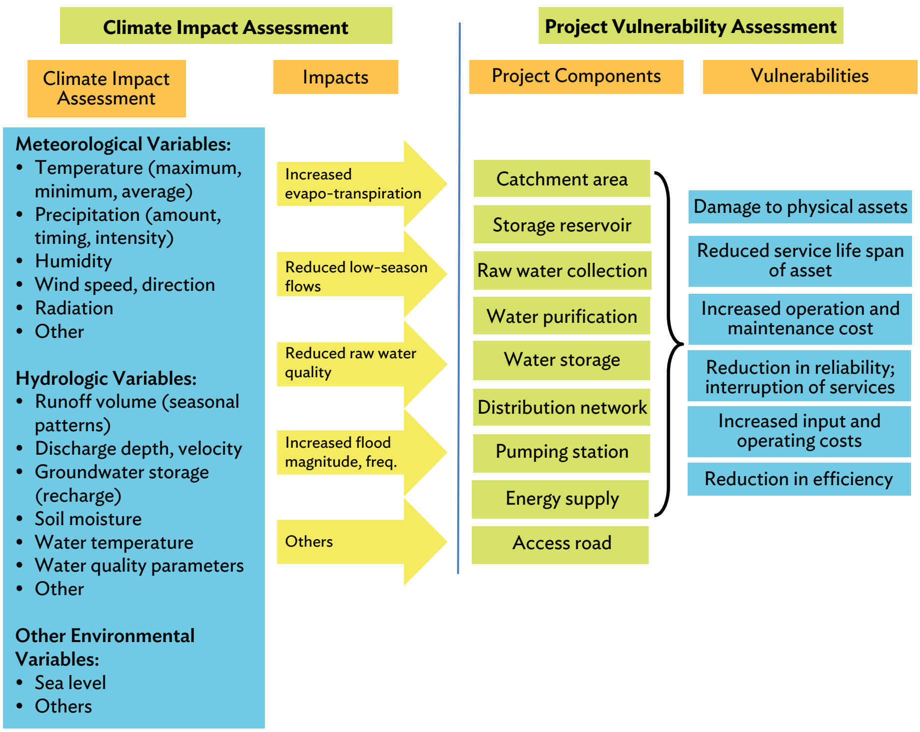


The complementarity between impact and vulnerability assessment is illustrated in Figure 8. An initial scoping of the project will identify the climatic and hydrological variables of interest to project designers. These are typically variables that guide engineering design (e.g., mean and variability of annual river discharge) and variables associated with hazards to the project (e.g., peak flood discharge). The impact assessment (left panels of Figure 8) consists of developing plausible assumptions about the behavior of these variables of interest over the project design life span. This can involve analysis of historical (measured) data, model-generated projections, analogue data, and/or the results of existing studies. An important aspect of impact assessment is the interpretation of changes in primary meteorological and hydrological variables with respect to more complex phenomena such as floods, drought, and changes in watershed condition and hydrology. Simulation modeling is often required for these tasks.

The vulnerability assessment (right panels in Figure 8) examines each project component or asset and attempts to establish causal relationships

14 A description of the approach is provided in Lempert and Kalra (2013).

Figure 8: Conceptual Framework for Climate Risk and Vulnerability Assessment



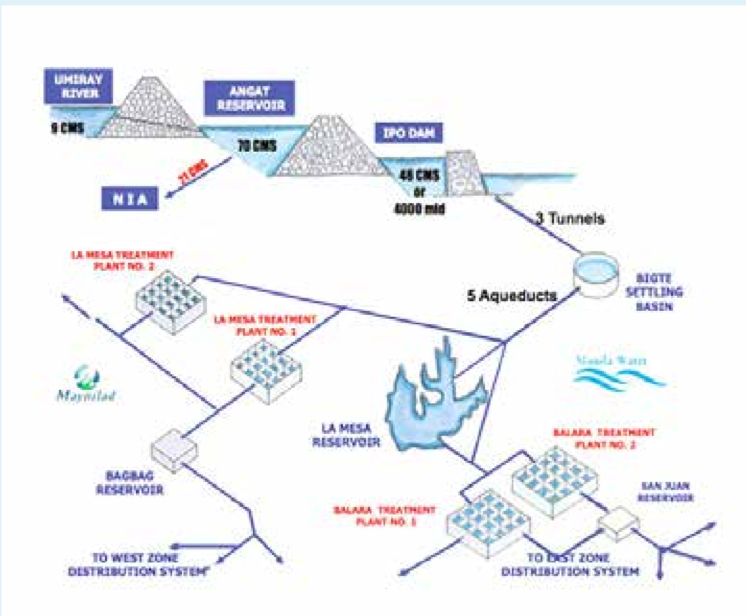
between the projected or anticipated impacts of climate change and the performance and/or physical integrity of each asset. An important output of this process is an understanding of physical and economic thresholds, both related to performance and to structural integrity. Each component of the CRVA is supported by the other.

Step 6: Identify Vulnerability of Project Components

A water supply and a wastewater sewerage system comprises multiple components, including mains, treatment systems, conveyance and distribution systems, pumping stations, and wastewater treatment systems among others (Box 9).

Box 9: Metro Manila Water Supply System

In the Philippines, the Metro Manila Water Supply System comprises multiple infrastructure components including reservoirs, dams, tunnels, settling basins, treatment plants, and distribution systems. Different components of the system will have different degrees of exposure to climate risk and will have different degrees of vulnerability to these risks.



CMS = cubic meter per second, mld = million liters per day, NIA = National Irrigation Administration.

Source: Government of the Philippines, Metropolitan Waterworks and Sewerage System. Metro Manila Water Supply System. http://mwss.gov.ph/?page_id=232

Vulnerability refers to the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change. As presented in the IPCC's Fourth Assessment Report, vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed; the extent of exposure; its sensitivity; and its adaptive capacity. Vulnerability and, in particular, exposure and adaptive capacity manifest themselves locally. Indeed, the specific nature and degree of vulnerability are often highly site-specific and must be assessed at the project level, often with the assistance of geospatial analysis.

The identification and assessment of vulnerability at the local level will increase the likelihood that the proposed adaptation measures are relevant. Both vulnerability and adaptive capacity are also a result of the interaction between socioecological factors and processes such as income level and income diversification, education, settlement patterns, infrastructure, ecosystem and human health, gender, political participation, and individual behavior (OECD 2009).

Hence, the information gathered during a vulnerability assessment may include local experiences related to shifting precipitation patterns and water availability, effects of warming on vegetative health, incidence of extreme climate events such as floods, and melting of permafrost. These are relevant to designing both engineering and nonengineering solutions. They are based on observable information and can be both qualitative and quantitative. Extrapolating from the present to predict how vulnerability may change in the future, given both climate and non-climate trends, is an essential step to capture the climate change impacts.

A useful exercise in vulnerability assessment is to examine each critical subsystem of the investment project and identify the relationships between design configurations and assumptions about environmental conditions. As examples, what assumptions are made concerning the reliable yield of a catchment above a storage reservoir? What assumptions are made concerning the design flood? How do these assumptions influence the configuration of critical infrastructure components (e.g., capacity, location)? How much variation in these assumed conditions can the system tolerate while still performing as intended? At what point does the system (or subsystem) fail? How vulnerable is the system to failures in other systems (e.g., the operation of the water supply system relies on the consumption of energy that is produced by a power supply system which itself will have its own degree of exposure and vulnerability to climate risks)?

Step 7: Identify Biophysical Drivers of Vulnerability

Some biophysical drivers of vulnerability include poor land management, deforestation, slash-and-burn agriculture, monoculture cropping, slope instability, and geophysical instabilities. Some ecosystems are also inherently more sensitive to changes, such as mountain ecosystems, while others are more exposed to climate changes and risks, such as low-lying coastal areas.

Using geographic information system (GIS), it is possible to map areas that are particularly vulnerable to a combination of local conditions and climate variability. This assessment can be conducted in the context of initial environmental and social assessments for a water project. The mapping can point out areas that are vulnerable through their geographic and socioeconomic characteristics:

- Areas that are sensitive due to topography (e.g., steep slopes), soil composition, geophysical instabilities, or elevation (e.g., meters above sea level);
- Areas in a watershed that are exposed to climate-related hazards, including floods, landslides, and drought; and
- Areas with a large number or concentration of poor households.

From this type of assessment, it is possible to develop a significant understanding of the areas, populations, and components of the water supply and sanitation (WSS) system most exposed and most vulnerable to climate change.

Step 8: Identify Socioeconomic Drivers of Vulnerability

Socioeconomic drivers should be included in the overall vulnerability assessment to provide a clear understanding of possible areas of intervention. For this purpose, biophysical vulnerability maps can be extended to examine overlaps with population area as well as projected populations based on future growth scenarios. It is useful at this stage to identify those socioeconomic factors that influence adaptive capacities. Common indicators of adaptive capacity include human development indices, population density, level of economic diversification, and extent of dependence on agriculture for livelihoods. Education levels and literacy rates have also been associated with a population's ability to adapt to changes.

It is important to recognize that both climate risks and adaptive capacity may change over the lifetime of an investment project. This particularly may be the case in developing countries where socioeconomic conditions are often rapidly changing and population is rapidly growing. For example, an area with low population may become highly populated over the lifetime of the project. Hence, the assessment of the adaptation options may be considerably different if based on an assumption of *existing* population, ignoring that *future* population may be considerably different over the lifetime of the project. These changes in vulnerability need to be explicitly accounted for in the assessment, including the costs and benefits of the adaptation options identified during the vulnerability assessment.

Although such assessments can be time-consuming, many countries have prepared development assessments that can be drawn from, such as the country profiles and International Human Development Indicators produced by the United Nations Development Programme (http://hdr.undp.org/en/countries/). ADB also collects key development statistics and publishes them online (http://www.adb.org/Economics/default.asp).

Finally, community participation in identifying vulnerabilities and adaptation strategies promotes good governance and ensures that measures are relevant and sustainable. As indicated earlier, the involvement and awareness of local communities in identifying vulnerability and adaptation options contribute to the community acceptance of project activities.[15]

Where there can be co-benefits between climate change adaptation and other economic or social objectives, there will be increased motivation for early action. Affected stakeholders can often identify risks, benefits, and lessons from past experiences that can be factored into the design of the adaptation strategy. These factors, which are not always easily quantifiable, can contribute to the decision-making process leading to the selection of adaptation strategies.

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[15] The ADB manual on consultation and participation tools, techniques, and templates offers further specialized information on this subject and is available online (http://www.adb.org/participation/toolkit.asp). While many of these tools do not specifically focus on climate change, they can be adjusted to include such inquiries. Many countries have prepared national adaptation programs of action with an emphasis on community-level vulnerability analysis.

Step 9: Develop Appropriate Climate Change Scenarios

Climate projections are representations of the responses of the climate system to greenhouse gas (GHG) emissions or atmospheric GHG concentrations. They are typically based on general circulation model (GCM) simulations. Climate change projections can be useful in determining how climate variables, such as temperature and precipitation, may change in the future under various assumptions about GHG emissions. However, projections based on climate model outputs are limited by the imperfect representation of the climate system within such models and by uncertainties associated with future GHG emissions among other factors. Therefore, climate projections should not be viewed as forecasts or predictions, but rather as plausible alternative characterizations of future climate conditions. They are helpful in exploring "what-if" questions; they do not aim to provide accurate or definitive predictions of how climate will behave in the future. Other sources of information useful in developing climate change scenarios include temporal analogues (e.g., paleohydrologic reconstruction of past climatic regimes) and spatial analogues (e.g., contemporary climatic conditions in warmer regions). Stochastic weather generators are often used when short-duration (daily or hourly) projections are required. Sensitivity analysis can be used to assess the robustness of hydrologic design against a wide range of hypothetical changes in climate variables without explicit reliance on the outputs of climate models.

The IPCC's Task Group on Data and Scenario Support for Impact and Climate Assessment provides general guidance on the use of data and scenarios in impact and adaptation assessments.[16] The following points provide further guidance in the development of climate change scenarios.

Identifying relevant climate variables needed for the impact assessment

The construction of climate change scenarios begins with an understanding of which climate variables are likely to affect the project, including both the integrity of project components and project outputs. Specialists developing climate change scenarios need to discuss data needs with the team of experts assessing impacts for the water project. The impact assessment experts must identify the variables they need as well as the required spatial and temporal resolution (e.g., 100 kilometers [km] x 100 km at a daily time step). The climate change expert then will be in a position to determine how to meet the expressed needs for information.

[16] The guidelines (IPCC-TGICA 2007) can be accessed at http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf

Primary hydrological and climatological data needs to support various types of water sector decisions are summarized in Table 6. In many cases, the desired climate variable will not routinely be available from GCM simulations, particularly since these models do not demonstrate high levels of skill in simulating short-duration (daily or hourly) events or the behavior of climate at fine spatial resolution (below 100 km x 100 km). In cases where fine spatial and/or temporal resolution projections are needed in decision support, additional processing of GCM outputs using downscaling techniques or the use of statistical techniques such as stochastic weather generators may be required.

Table 6: Basic Meteorological Information Needed to Support Water Sector Decisions[a]

Field of Application	Hydrological Element Needed	Meteorological Element Needed	Temporal Scale	Spatial Scale
Water Balance	Runoff Evaporation Soil moisture Groundwater	Precipitation Radiation Sunshine duration Air temperature Air humidity Wind speed	D, M, Y D, M D, M D, M D, M D, M	A P, G P, G P, G P, G P, G
Water Supply	Runoff Groundwater	Precipitation Air temperature	D, M, Y M, Y	A
Irrigation	Runoff Evaporation Soil moisture Groundwater	Precipitation Radiation Sunshine duration Air temperature Air humidity Wind speed	D, M, Y H, D, M H, D, M H, D, M H, D, M H, D, M	A, G A, G A, G A, G A, G A, G
Hydroelectric Power	Runoff Snowpack	Precipitation Air temperature	M, Y D, M	P, A
Flood Control (Extreme value statistics)	Runoff Channel discharge Stage	Precipitation	H, D Min, max	P, A
Low Flows (Extreme value statistics)	Runoff Channel discharge Stage	Precipitation Air temperature	D, M, Y D, M	A
Water Quality	Runoff Channel discharge Water temperature	Precipitation Air temperature	H, D, M	A

Temporal scales: H = hour, D = day, M = month, Y = year; min = minimum, max = maximum.
Spatial scales: P = point; A = area (e.g., catchment); G = grid square (raster).
Sources: Adapted from Stakhiv and Stewart (2010); World Meteorological Organization (2012).

Establishing the climate baseline

Historical climate data are generally needed to develop and to utilize climate projections in impact assessment, since both natural and human systems are typically adapted to historically prevailing climatic regimes. In addition, biases are often found in climate model simulations. Observed meteorological data are also more reliable than climate model outputs when it comes to representing climate variability at the project site. The analysis of historical data helps to identify trends in the main climate variables and also allows for the ground-truthing of the simulation results from climate models. Historical climatic data can be used to assess the ability of a given climate model to reproduce local climate conditions (skill score)[17] and to enable calibration and validation of model simulations against the observational record. In addition, a climate baseline is needed to serve as a benchmark against which potential impacts of projected climate change can be assessed.

Impact assessments typically use observed meteorological data to define the "current climate baseline." It is established practice to define climate in a given setting on the basis of 30 years of systematic records, although records of the desired length and quality may not always be available. The baseline can be used to calibrate impact models (e.g., basin hydrologic models) and to quantify climate change impacts with respect to the climate baseline. This historical analysis can then shed light on potential changes in the climate variables that crucially affect water projects.

In general, detailed climatic data can be obtained from the national meteorological service of a given country. The main challenge in using local climate data is often the limited availability of hydrometeorological stations with sufficient and consistent data representative of climate conditions at the project site. In many countries, weather data may be found to be inconsistent (e.g., the weather station changed location) or incomplete (e.g., the weather station was not operational for periods of time). Furthermore, the weather station network may not cover the project area—the closest station may be far away from the project site. In such circumstances, spatial interpolation techniques may be used to solve coverage problems, and data generation algorithms can improve completeness and consistency of data.

Other sources of climate data can be used to supplement locally observed data in many parts of Asia and the Pacific. These include the Asian Precipitation Highly Resolved Observational Data Integration towards

17 See, for example, Tebaldi et al. (2006).

Evaluation of Water Resources (APHRODITE) project,[18] which has produced high-resolution (0.5 degree) gridded daily precipitation coverage for the entire Asian domain; and the Tropical Rainfall Measuring Mission (TRMM),[19] which has developed daily and 3-hourly precipitation estimates globally at 0.25° x 0.25° grid resolution since 1998 using satellite remote sensing data validated with observational data. Gridded climatic data for many variables, including temperature and precipitation, are also available at 0.5° spatial and monthly time resolution for the period 1901–2014 from the Climatic Research Unit (CRU), University of East Anglia,[20] although the quality of these data locally reflects the quality and density of historical meteorological observations used to construct the gridded dataset. Re-analysis data can also be used to supplement locally observed meteorological data.[21]

Using climate projections from general circulation models: Model selection

Climate change scenarios are normally constructed using climate projections from GCMs.[22] GCMs are computer models used to numerically simulate the earth's climate systems. GCMs are the main tools used to project future climate changes due to the continued anthropogenic GHG inputs. The major advantage of using GCMs as the basis for creating climate change scenarios is that they estimate changes in climate for a large number of climate variables, including temperature, precipitation, pressure, wind, humidity, and solar radiation, in a physically based and internally consistent manner.

However, an analyst faces some issues concerning the construction of climate scenarios using the projections from GCMs:

- *Model errors and biases:* GCMs may underestimate or overestimate current temperatures and precipitation, and hence may not properly represent historical climate within a region.
- *Uncertainty*: An additional disadvantage of GCM-based scenarios is that a single GCM, or even several GCMs, may not represent the full range of potential climate changes in a region.

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18 See http://www.chikyu.ac.jp/precip/products/index.html

19 See http://trmm.gsfc.nasa.gov/data_dir/data.html

20 See http://www.cru.uea.ac.uk/cru/data/hrg/

21 See https://climatedataguide.ucar.edu/climate-data/atmospheric-reanalysis-overview-comparison-tables

22 See Trenberth et al. (2007) for an in-depth discussion on general circulation models.

Resolution: GCMs do not produce information on geographic and temporal scales fine enough for many impact assessments at the project level. GCMs typically provide projections at a horizontal resolution of hundreds of kilometers, and are generally reported at monthly or seasonal timescales. In particular, GCMs may not demonstrate high levels of skill in simulating events such as orographic and convective precipitation, which may be important elements of climate in specific regions.

The most advanced GCM simulations now available are those performed for the Fifth Round of the Coupled Model Intercomparison Project (CMIP5), which provide the primary basis for climate projections appearing in the IPCC Fifth Assessment Report (2013).[23] The CMIP5 experiments utilize a new range of standardized scenarios that describe the trajectories of GHG concentrations in the atmosphere, identified as Representative Concentration Pathways (RCPs). RCP scenarios include 2.6 watts per square meter (W/m^2), 4.5 W/m^2, 6.0 W/m^2, and 8.5 W/m^2. The lowest (RCP2.6) represents a world in which global temperature increases might be kept below 2.0°C, consistent with the Paris Agreement of 2015. The highest scenario (RCP8.5) is currently the most consistent with observed emissions trends.

Outputs from roughly 40 CMIP5 GCMs are reported in the IPCC Fifth Assessment Report. The results of CMIP5 model simulations are summarized in Annex I to Volume 1 (Science) of the IPCC Fifth Assessment Report.[24] Maps and figures appearing in Annex 1 can be useful in gaining a sense of the potential range of changes in temperature and precipitation at continental, subcontinental, and seasonal scales over the 21st century, but may not provide sufficient guidance at the project scale.

No single GCM can be shown to demonstrate the highest level of skill in simulating the full range of meteorological variables globally, or over specific regions. In addition, no specific GCM projection can be viewed as most likely to occur. For this reason, it is good practice to avoid using the outputs from a single GCM, or even a limited number of GCMs as the basis for project climate impact assessments. Similarly, the use of averages of model projections should be avoided. Good practice increasingly involves the use of model ensembles (including multiple GHG emissions scenarios) in order to understand the potential range of uncertainty in important climatological variables. In some instances, studies have been conducted to

23 See Taylor et al. (2012) for a description of the CMIP5 experiments.

24 See IPCC (2013, Annex I: Atlas of Global and Regional Climate Projections).

identify subsets of available GCMs that appear to demonstrate greater skill in simulating climate within a specific region.[25] However, skill in simulating historical (observed) climate is no guarantee that a specific GCM will also provide more skillful projections under altered future conditions. It is more useful to ensure that any model ensemble selected includes a wide range of projections, so that the impacts of more challenging future conditions on the project can be anticipated.

Downscaling: From global to local climate projections

The limitation due to the coarse resolution of GCMs can be reduced by a process known as downscaling. Downscaling methods increase both spatial resolution (e.g., from hundreds to tens of kilometers) and temporal resolution (e.g., from monthly to daily).

There are two main approaches[26] for downscaling: dynamical downscaling (using regional climate models) and statistical downscaling (using empirical relationships). Each downscaling method has its strengths and limitations, and the appropriate method will depend on the specific needs of the impact assessment, data availability, and budget. However, since downscaling is a transformation of GCM outputs, it cannot add skill or accuracy that is not present in GCMs. If GCMs do not accurately project changes in large-scale atmospheric circulation patterns, downscaling techniques cannot correct the errors.

Models will require calibration when used for specific areas over a specific period of time. Such calibration will depend on meteorological data. Limited availability and quality of such data could create serious practical limitations to model calibration. Less-than-adequate calibration can introduce doubts on the quality and reliability of climate projections.

Spatial and temporal analogue scenarios

Analogue scenarios can be used either as complements to GCM-based projections or as alternatives. Analogue scenarios are constructed either by (i) identifying periods of time in the past which resemble future conditions anticipated in the region of interest as a result of climate change (e.g., interglacial warming periods) for which hydroclimatic conditions can be reconstructed (temporal analogue); or (ii) identifying regions that currently possess climatic conditions similar to what is anticipated

[25] Among others, see Cai et al. (2009).

[26] For a comprehensive discussion on the topics of downscaling, see Wilby and Wigley (1997), Wilby et al. (1998), Wood et al. (2004), and Wilby and Fowler (2011).

in the region of interest as a result of climate change (spatial analogue). Temporal analogue scenarios (based on reconstructed paleo-hydrological records) have been used in many settings to assess potential changes in the frequency, duration, and severity of flood and drought events.[27] Spatial analogue scenarios might involve the analysis of climate in locations at lower latitudes and/or elevations relative to the region of interest. In each case, all important factors controlling or influencing climate must be taken into account.

Stochastic weather generators

Stochastic weather generators are statistical models typically used to generate physically realistic daily sequences of climate variables, most often precipitation occurrence, intensity, and duration, when these variables are required in impact assessment. They have been used in constructing climate change scenarios to provide the fine timescale resolution that is often poorly or inadequately simulated by GCMs. Commonly used stochastic weather generators[28] include LARS, SDSM, and CAT.[29] CAT is not strictly speaking a stochastic weather generator since it involves the modification of observed sequences of climate variables on the basis of user-defined assumptions about the influence of climate change. Like statistical downscaling routines, stochastic weather generators require calibration using observational data, and the quality and availability of such data can constrain the use of generators.

Analysis of historical trends

Statistical trends in the observed time series of climatological variables (in particular temperature and precipitation) have in some instances been used to construct scenarios or projections for the purposes of project climate risk management. A primary justification for the use of trends is that observed data are inherently more credible than model-generated projections. The use of trend analysis is most appropriate when (i) observational meteorological data of high quality, consistency, and continuity and long duration (several decades) are available at or near the project site; and (ii) the project design lifetime does not exceed 20–25 years or so. Many (although not all) long-term local time series of air temperature will display warming trends, and it is often useful to compare these trends

27 See Baker (1987).

28 See http://www.ipcc-data.org/guidelines/pages/weather_generators.html

29 For descriptions of case studies using CAT, see https://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=242952

with regional warming trends projected by GCMs and regional climate models (RCMs). Both maximum and minimum temperatures should be examined for trend. Trends in annual and/or seasonal precipitation are often less apparent or statistically robust as compared to temperature trends. Several caveats apply to the use of historical trend analysis in project climate risk assessment. These include the following:

- Historical data may not provide a sufficient statistical basis for trend analysis and estimation. If the projection period exceeds the length of systematic records available for estimating trends (a common situation), projections will have wide confidence bounds (high uncertainty) toward the end of the projection period, regardless of the apparent strength of the trend (the out-of-sample prediction problem). A statistically weak trend will greatly compound this problem.
- There may be no statistically significant trend in historical data (particularly for short record length); or a pseudo-trend may result from starting-point or end-point bias due to, for example, a shift in El Niño conditions or other episodic or periodic phenomena.
- It is not clear on the basis of climate science that climate changes in any particular location will manifest as gradual, incremental changes observable year-by-year. Relatively abrupt regime shifts are often observed in Paleoclimate records.

Trend analysis is best viewed as a complement to model-based projections, and attempts should be made to understand any divergence between observed trends (assuming they are statistically robust) and model-generated projections over the same period.

Sensitivity analysis

Sensitivity analysis is a method for testing the robustness of proposed project designs or adaptation interventions that does not rely specifically on GCM projections or related products, nor makes any strong assumptions about future climate in the project location.[30] Sensitivity analysis can be understood as a project stress test. The basic approach involves changing key climatic parameters systematically over a range defined by scientific plausibility and consistency with global and regional projections, and evaluating the impacts on the project. For example, temperature changes of +1.0°C, +2.0°C, +3.0°C, and +4.0°C could be combined with

30 IPCC-TGICA (2007) refers to sensitivity analysis as synthetic scenarios.

hypothetical changes in annual or seasonal precipitation of −20%, −15%, −10%, −5%, 0%, +5%, +10%, +15%, and +20% to explore the potential range of plausible changes over the relevant project time frame. Sensitivity analysis is an important element in several innovative methods of climate risk management, including robust decision making.

Since it does not rely explicitly on model-generated projections, sensitivity analysis can be conducted at relatively low cost in terms of data processing and analysis. In addition, scenarios developed through sensitivity analysis are easy to interpret and can assist in the identification of critical thresholds in project integrity or performance relative to climatic behavior. However, sensitivity analysis may involve unrealistic combinations, for example, that of temperature and precipitation change within a particular region, and should thus always be informed by the results of GCM or RCM analysis.

Sea-level rise

Sea-level rise is not a direct output of most GCMs. Methods to derive sea-level rise include both global (global thermal expansion and meltwater from glaciers, ice caps, and ice sheets) and local (local land subsidence and local water surface elevation) components. Estimates of local apparent sea-level rise take into account the vertical movement of land and coastal erosion. In spite of the importance of global sea-level rise scenarios, when assessing impacts, it is the local change in relative sea level that matters, not the global average. Relative—or observed—sea level is the level of the sea relative to the land. Subsidence of the land results in a relative sea-level rise that is higher than the global rise, whereas uplift of the land leads to a relative rise that is less than the global average. This indicates that using global estimates of sea-level rise (as provided by the IPCC, for example) may not be appropriate given local circumstances.

Accurately estimating sea-level rise at a project site requires extensive data collection. The most relevant variables are (i) coastal geomorphology and topography, (ii) historical relative sea-level changes, (iii) trends in sediment supply and erosion and accretion patterns, (iv) hydrological and meteorological characteristics, and (v) oceanographic characteristics. Using these data, hydrological digital elevation models can be used to estimate the area inundated given a specific assumption about the amount of sea-level rise. When available, a detailed assessment on inundation areas with and without flood protection infrastructure can be done. For many countries where information on coastal elevations is lacking, surveying (sometimes airborne laser scanning) can be conducted to provide these most basic and essential data for sea-level rise projections.

Since coastal surveying and hydrodynamic simulations can be quite expensive, the use of a GIS approach is an acceptable alternative to identify geographical areas that may be exposed to sea-level rise. An overlay of coastal elevation data from satellite measurements and different sea-level rise conditions can produce a reasonable approximation of coastal impacts.

The output of Step 9 will take the form of climate change scenarios (projections of future climate parameters, with temperature and rainfall often of greatest interest) for a specific location over a specific period of time. While these climate change scenarios may result from the downscaling of GCMs, it is important to note the following:

- While it is accepted that climate change involves rejecting basic assumptions about the stationarity of climate conditions (Milly et al. 2008), it does not imply that historical meteorological data must be avoided. In fact, in many circumstances, climate-proofing sector investments to observed existing climate variability may be an appropriate step toward ensuring the climate resilience of these investments. As observed in Lopez et al. (2011): "In parts of the world that suffer water stress under current climate, it makes sense to start any adaptation planning by making the system resilient to current climate variability, and build on that to think about adaptation (…)" (p. 130).
- Climate change scenarios should not be interpreted as representing the most likely future values of the climate variables of interest.[31] The outcome of a downscaling exercise for assessing the desirability of climate-proofing options may be more useful if it establishes plausible lower and upper bounds to allow testing for climate change sensitivity. For this reason, the use of scenarios based on outputs from a single (or small number of GCM) is discouraged, and the use of ensembles of projections is increasingly viewed as embodying good practice.

Table 7 provides a summary of the primary applications, strengths, and limitations of various scenario construction methods.

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31 As such, climate change projections should not be interpreted as predictions.

Table 7: Uses, Strengths, and Limitations of Scenario Development Approaches

Scenario Approach	Primary Application	Strengths	Limitations
General Circulation Model (GCM) Projections	To characterize and assess climate change at regional and seasonal space- and timescales	• Physically-based • Internally consistent • Multiple models • Well documented • Accessible	• Coarse spatial and temporal scales • Possible biases relative to historical data • Persistent phenomena poorly simulated
Dynamically Downscaled GCM Projections	To generate projections of key climate variables at space- and timescales relevant to water resources modeling and decision making	• Results based on physically consistent processes • Can resolve atmospheric processes that GCMs cannot (orographic, rain shadow effects)	• Computationally intensive; limits number of ensemble members • Dependent on GCM forcing (GCM biases enter estimates) • Dependent on regional climate model parameterizations: different specifications can lead to different results
Statistically Downscaled GCM Projections	To generate projections of key climate variables at space- and timescales relevant to water resources modeling and decision making	• Relatively inexpensive • Computationally efficient • Can provide point estimates from GCM-scale outputs • Observations incorporated directly into method	• Does not account for nonstationarity in relationships • Climate system feedback not represented • Dependent on GCM forcing (GCM biases enter estimates) • Dependent on statistical model structure: different methods can lead to different results

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Table 7 *continued*

Scenario Approach	Primary Application	Strengths	Limitations
Climate Analogues (Temporal and Spatial)	To assess potential changes in the frequency, duration, and severity of flood and drought events; agricultural conditions	• Easy to apply (spatial analogues) • Requires no future climate change information • Reveals multisector impacts, vulnerability to past climate conditions or extreme events	• Limits to spatial, and temporal resolution • Suitable analogues may not exist • Assumes similar socioeconomic or environmental responses recur under similar climate conditions • Requires data on confounding factors such as population growth and technological advances
Stochastic Weather Generators	To provide fine timescale resolution of key meteorological variables that are poorly or inadequately simulated by GCMs	• Modest computational demand • Provides daily or subdaily meteorological variables • Preserves relationships between weather variables • In widespread use for simulating present climate • Tools freely available	• Needs high-quality observational data for calibration and validation • Assumes a constant relationship between large-scale circulation patterns and local weather • Scenarios sensitive to choice of predictors; quality of GCM output • Provides time-slices (not transient)

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Table 7 *continued*

Scenario Approach	Primary Application	Strengths	Limitations
Analysis of Trends	Design and operation of hydrologic systems with relatively short design lifetimes (<25 years)	• Easy to apply • Reflects local conditions • Uses recent patterns of climate variability and change • Observed series can be extended through environmental reconstruction • Tools freely available	• Typically assumes linear change • Trends are sensitive to choice/length of record (starting/ending point bias) • Assumes underlying regional climatology is unchanged • Needs high-quality time series • Confounding factors can cause false trends
Sensitivity Analysis	Stress-testing of project design and/or operations criteria	• Easy to apply • Requires no climate projections • Shows most important variables/system thresholds • Allows comparison between studies	• Provides no insight into likelihood of associated impacts • Impact model uncertainty seldom reported or unknown

Source: Adapted from Wilby et al. (2009).

Step 10: Estimate Future Biophysical Impacts

Once climate change scenarios have been constructed, key relationships between changes in climate parameters—such as average temperature, average precipitation, temperature and precipitation extremes, sea-level rise, and storm surges—and impacts on hydrologic systems and water sector investments must be quantified.

Biophysical models constitute one way to analyze the physical interactions between climate and an exposure unit such as a watershed or a road. Here are some examples of how different biophysical models can be used:

- *Dose–response models.* These models can elicit the effects of changes in environmental parameters, such as water quality parameters, on aquatic and biological systems.

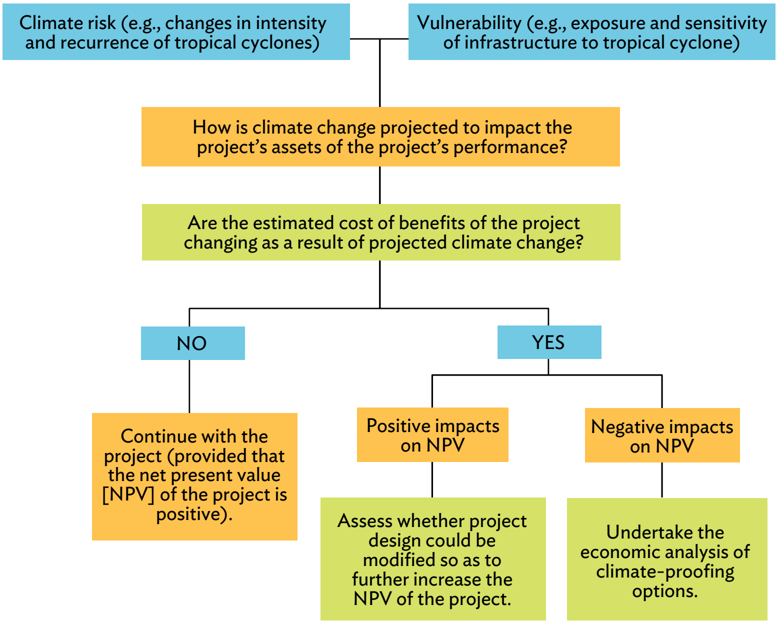
- *Hydrologic models (rainfall–runoff models)*. These models translate changes in precipitation, temperature, and other climate variables into changes in evapotranspiration, soil moisture, runoff, and discharge. They can be useful for estimating the future availability and reliability of water resources for specific purposes such as municipal or agricultural water supply; and changes in the frequency and severity of hydrologic extremes (floods and droughts).
- *Hydraulic and/or hydrodynamic models*. These models can be used to simulate future extent of inundated areas on the basis of changes in both hydrometeorological variables and the nature and extent of protective infrastructure. Coastal hydrodynamic models can be used to simulate the impacts of projected sea-level rise on coastal infrastructure and coastal flooding.

It should be noted that the results of model-based impact assessments, if incorporated into project designs, may have significant implications on the cost of the project. Therefore, such assessments should provide, in addition to the estimates of biophysical impacts, an explicit account of the caveats and uncertainties associated with the methods (including the underlying climate and sea-level scenarios) and resulting impacts.

Step 11: Assess Impacts on Investment Projects

A key objective of the CRVA is to provide information on the impacts of projected climate change on the project's performance and outputs, and, where appropriate, to transform the quantification of these impacts into economic costs and/or benefits. As shown in Figure 9, the outcome of the assessment may reveal that the project's costs and/or benefits may or may not be affected by climate change. In the event that the project's net present value (NPV) is not significantly modified as a result of climate change, the recommendation would be to proceed with the project (provided that the NPV is and remains positive). However, assuming a negative impact on the project's performance (e.g., a projected increase in maintenance cost resulting from a projected increase in extreme precipitation leading to more severe flood events), the economic impact of climate change at the project level will be measured as the difference between the NPV of the project without climate change, and the NPV of the project with climate change. The economic analysis of climate change impacts and climate proofing is discussed in detail in ADB (2015).

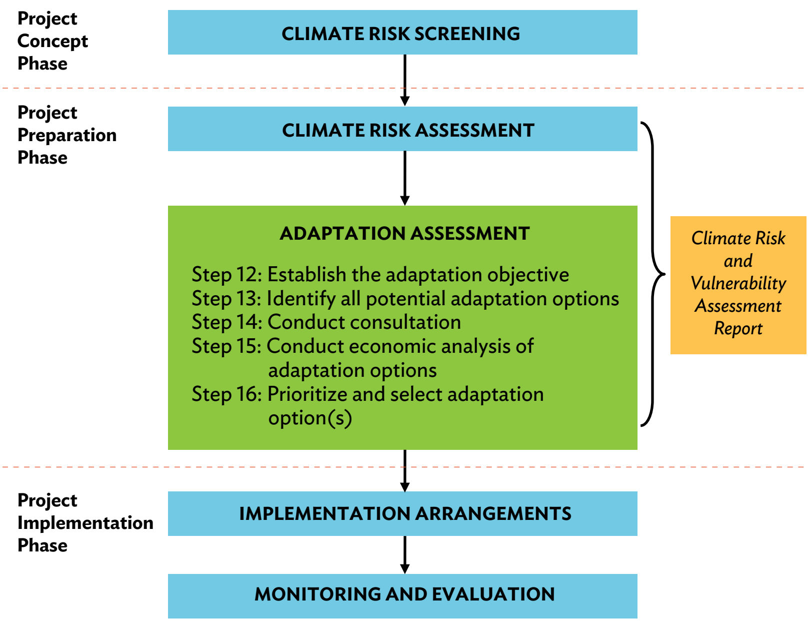
Figure 9: How Will Climate Change Impact the Project?



Adaptation Assessment

The goal of the adaptation assessment is to identify and prioritize the most appropriate adaptation measures to incorporate into the project. This includes the identification of strategies to minimize damage caused by the changing climate and to take advantage of the opportunities that a changing climate may present.

Figure 10: Adaptation Assessment



Step 12: Establish the Adaptation Objective

The adaptation-related activities should seek to minimize the potential negative effects. Establishing how climate change may affect the project site and outcomes will assist in ensuring that the right data are collected throughout, that the right expertise is recruited from the outset, and that the most appropriate national or regional partners are brought in to the project. The vulnerability, impact, and adaptation assessments that follow are intended to assist in further refining how climate change may impact a project and options for managing these impacts.

Step 13: Identify All Potential Adaptation Options

Based on an understanding of the project's vulnerability to climate change, the project team will have to identify a range of technically feasible adaptation options to reduce climate risk to the project. The nature of these options will vary across technical features of the investment project itself and across the geophysical characteristics of its location.

Table 2 provides a brief list of possible adaptation options. Charles, Pond, and Pedley (undated) provided an exhaustive list of adaptation options for both WSS facilities. The authors divided the options into four categories: capital expenditure (which may not necessarily be suitable for immediate implementation), operational expenditure (which include adaptation to existing systems), monitoring (to facilitate and support planning decisions), and socioeconomic tools (such as community education, training, and public awareness).

In some cases, the best adaptation solutions may be beyond the scope of an existing project but should be taken up as part of upstream planning and can be "flagged" for such higher-level discussions, as discussed in Part B of this report. For example, improved upstream land management may be the most effective way of reducing damages from flooding downstream but can be difficult to address in the context of a specific water supply project.

Nevertheless, this observation can be used to revise policies and plans to prioritize more integrated or "climate-resilient" WSS planning and management. For this reason, casting the identification of adaptation options widely is encouraged in order to influence both the project and policy levels. In some cases, project implementation arrangements may be flexible enough to incorporate nonsector-specific adaptation measures, as can be the case with executing agencies with cross-cutting mandates.

Step 14: Conduct Consultations

As may be understood from the partial list of adaptation options presented in Table 2 in Part A, the identification of adaptation options will necessarily involve inputs from a number of stakeholders.

Conducting roundtable consultations provides useful input for identifying and appraising the whole range of adaptation options.

The expertise required is multidisciplinary and, as such, is one of the more challenging aspects of adaptation planning. Options must be scientifically sound, socially beneficial, and economically viable. Roundtable discussions involving different stakeholders can work well and can include, for example, the project engineers, environmental specialists, social safeguard experts, nongovernment organizations, implementing entities, and national climate change representatives.

Step 15: Conduct Economic Analysis

In the context of climate proofing investment projects, the economic analysis aims to answer the following important questions:

- How will projected climate change impact the estimated costs and benefits of the investment project? If there were no technically feasible measure to mitigate these impacts, would the project still be economically viable?
- Is climate proofing the investment project desirable from an economic efficiency point of view? If yes, should climate proofing take place at the time of project implementation (built into project design), or should it be delayed to a later point in time? What is the "best timing" to climate proof the investment?
- Should benefits other than those strictly associated with climate proofing the investment project be included in the economic analysis?
- If there are multiple technically feasible and economically desirable climate-proofing options, which of them should be recommended?

A key feature of the economic analysis approach is that it recognizes that the costs and benefits of the climate-proofing options must be assessed by identifying and quantifying the climate change impacts along two scenarios:

- **Scenario without climate proofing:** What are the expected impacts of climate change on the project *in the future* if there were to be no climate-proofing measures in place?
- **Scenario with climate proofing:** What are the expected impacts of climate change on the project *in the future* if there were to be climate-proofing measures in place?

The two scenarios will give rise to the computation of the project's NPV (or economic internal rate of return) with and without climate proofing. In this respect, the economic analysis of climate proofing investment projects does not differ from the economic analysis of any investment project.

Five issues of importance are briefly discussed below. A detailed discussion is provided in ADB (2015).

Time horizon

The selection of the time horizon over which to conduct the economic analysis of an investment project is a key feature of any economic analysis and is of particular interest in the context of climate change, which is projected to span numerous decades, if not centuries.

With respect to the economic analysis of climate proofing investment projects, the following guidance is provided.

In circumstances where a climate-proofing measure pertains to modifications to project design or similarly in circumstances where a climate-proofing measure provides no benefit other than those provided to the investment project itself, then the time horizon for the analysis of the climate-proofing measure must coincide with the time horizon of the investment project itself—regardless of how this time horizon is set. Selecting a longer time horizon would implicitly assume that the climate-proofing measure provides benefits to a project which, for the purpose of analysis, has ceased to exist.

Discount rate

Regardless of the justification provided for the use of a specific discount rate, all projects funded by ADB must be evaluated using the same discount rate whether or not the project design is modified to respond to climate change risk. Similarly, the economic analysis of climate-proofing options, when such options are considered on their own as separate incremental investments, must use the same discount rate as is used in the economic analysis of the investment project itself. Hence, provided the guidance that a 12% discount rate be used, climate proofing investments should be evaluated using a 12% discount rate.

Ancillary benefits and ecosystem-based climate proofing measures

While all options shall primarily aim to climate proof specific investments (though different options may do this to various degrees), some options may also deliver economic benefits additional to the climate-proofing benefits to the project itself. These additional benefits are generally referred to as co-benefits or ancillary benefits.[32]

For example, the reforestation of a hillside to reduce the likelihood of landslides may also deliver fruit crops as well as serve as a regulating

[32] In its Fifth Assessment Report, the IPCC (2014) defines co-benefits as "[t]he positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices. Co-benefits are also called ancillary benefits."

mechanism for water supply; or the planting of mangrove or restoration of a degraded coastal wetland to protect a water supply infrastructure from storm surges may also serve as habitat for fisheries. There is increasing interest in assessing the potential of ecosystem-based approaches to adaptation and resilience in general and to climate proofing investment projects in particular.

Least-cost analysis

In the context of climate proofing, the conduct of a least-cost analysis would be essential in the following two circumstances:

First, the least-cost analysis is appropriate when two options yield nearly or exactly the same climate-proofing benefits—whether or not this benefit is expressed in monetary values. In such circumstances where the benefits are identical, the use of the least-cost analysis must yield the same ranking of options as would be obtained under a cost–benefit approach (if the benefits are the same, the least-cost option must also yield the highest NPV).

As a variant of the above circumstance, consider the situation where a project outcome has been identified and is deemed vulnerable to climate change. In such a circumstance, project preparation teams may seek to identify climate-proofing options that would ensure that the intended project outcome is not compromised by climate change. If there were to be more than one option capable of achieving this objective, a least-cost analysis could be used to prioritize among these options.

Second, the least-cost analysis is especially relevant when the impacts of climate change may prevent compliance with national standards, thresholds, or regulations. For example, climate change may prevent achieving thresholds for maximum occupational temperatures or for risk of water supply disruption. In such circumstances, the issue is not whether to climate proof the investment (so as to comply with norms, standards, regulations, or treaties), but more simply to determine how to achieve compliance at least cost. In this situation, the cost (in present value terms) of all available climate-proofing options yielding the same outcome (achieving compliance) should be estimated, and options should be ranked from least cost to highest cost. Unless other factors are deemed of greater importance, the least-cost option will be recommended.

Finally, once a project outcome has been identified and is deemed vulnerable to climate change, project preparation teams may seek to identify adaptation options that would ensure that the intended project outcome is not compromised by climate change.

In a number of circumstances, the above approach may be limited to simply estimating the incremental cost of the sole adaptation measure considered to be technically feasible (Box 10).

In all cases, the incremental cost of adaptation to the project for investing in climate proofing must be reported in the project classification system. This reporting of the incremental cost of adaptation is then used for accounting of the annual climate financing provided by ADB in any given fiscal year.

Box 10: Estimating the Incremental Cost of Adaption in the Fiji Water Supply Project

Fiji has a population of approximately 868,000, of which 53% is urban. This percentage is rapidly growing with the population of the greater Suva area (GSA; with Suva the capital city) expected to increase by approximately 13% by 2023.

However, urban infrastructure and services have not kept pace with rapid urban growth. As a result, some of the served areas of the GSA have increasingly experienced intermittent service. Service interruptions are more frequent and more pronounced in duration especially during drought periods when the flow of the Waimanu River—the only water source currently serving the GSA—is insufficient to operate at full capacity the Waila and Tamavua water treatment plants. Further service interruptions are experienced during periods of high rainfall, resulting in a high level of turbidity of the Waimanu waters then requiring more frequent backwashing of the filters.

The Urban Water Supply and Wastewater Management Project in Fiji aims to increase access to reliable and safe water supply in the GSA by designing and constructing a new water supply source in the Rewa River, allowing an increase in production capactity of 30,000 cubic meter, per day. The project will address the existing shortfall in bulk water supply during dry periods, allow the servicing of areas not currently supplied by the water supply system, and allow the servicing of the growing population in the GSA in the future.

An original 1999 feasibility study recommended the water intake to be located approximately 29 kilometers (km) upstream of the river mouth. This recommendation was in part based on expectations of increased salinity up to

continued on next page

Box 10 *continued*

20–23 km from the river mouth. However, newer investigations have accounted for a sea-level rise of up to 1 meter by 2100. As a result, the salinity wedge is expected to move farther up the Rewa River. For climate-proofing purposes, it was thus recommended that the water intake be relocated to a new site 49 km upstream the river mouth. This proposed revised water intake location takes into account new insights concerning the impact of climate change on seawater levels.

The relocation of the water intake will have the following consequences: (i) a new water treatment plant will be needed instead of extending the existing Waila treatment plant; (ii) new power lines and new access roads will be needed to the site; (iii) new land acquisition (which would not be needed if the Waila treatment plant were to be extended); and more importantly, (iv) new transmission main pipelines (approximately 19.6 km in length) will have to be constructed.

The total incremental cost of climate proofing the project was assessed to reach $23.5 million (see table). Note that only those costs *incremental* to the baseline scenario (with water intake at 29 km) were included to estimate the cost of climate proofing.

Item	Cost[a]
River intake and raw water pumping station Balance reservoirs	No additional cost as these components are required regardless of the location of the water intake.
Pumping stations	No additional cost as raw water pumps are approximately the same.
New water treatment plant	No additional cost relative to extending the Waila treatment plant.
Land acquisition	$500,000
Power to the new water treatment plant	$2,500,000
Access road	$500,000
Transmission main pipelines	$20,000,000
Total (incremental) cost of climate proofing	**$23,500,000**

[a] The incremental cost of climate proofing, which was originally estimated in Fiji dollars (F$), is expressed here in US dollars using an exchange rate of F$2.00 per $1.00.

Uncertainty

Conducting any cost–benefit analysis implies looking into the future and asking what the "universe of interest" might look like without the project and with the project (the impacts of the project being the difference between these two scenarios). The exercise is fraught with incomplete information, risk, and uncertainty; this is true of all cost–benefit analyses, whether related to climate change or not. Hence, the same analytical tools currently available to account for risk and uncertainty in the conduct of a project cost–benefit analysis are of relevance in the context of assessing the costs and benefits of climate change adaptation options.

Numerous approaches, including sensitivity analysis, probabilistic analysis, scenario analysis, and real option analysis, facilitate decision making in a context of uncertainty. These are discussed in greater detail in ADB (2015).

Outcomes of the economic analysis

Based on the outcome of the economic analysis, decision makers may elect to invest in climate-proofing measure(s) at the time the project is being designed (climate proof now) under circumstances where any of the following applies:

- The costs of climate proofing now are estimated to be relatively small, while the benefits (the avoided expected costs from not climate proofing), even though realized only under future climate change, are estimated to be very large. This is occasionally referred to as a low-regret approach.
- The costs of climate proofing at a later point in time are expected to be prohibitive, or climate proofing later is technically not possible.
- Among the set of climate-proofing options, one or more options deliver net positive economic benefits regardless of the nature and extent of climate change. Such options are occasionally referred to as no-regret climate-proofing options.
- The set of climate-proofing options includes at least one option that reduces climate risks to the project and has other social, environmental, or economic benefits (co-benefits). Such options are occasionally referred to as win–win climate-proofing options.

Alternatively, decision makers may elect to invest minimally at the time of project design and implementation to ensure that the project can be climate proofed in the future, if and when circumstances indicate this to be a better option than not climate proofing. This type of decision aims to ensure that the project is "ready" for climate proofing if and when required (Box 11). As such, the concept of *climate readiness* is occasionally referred to in this situation. This concept is akin to the real option approach to risk management. It involves avoiding the foreclosure of climate-proofing options and preserving flexibility to improve climate resilience as climate change is actually observed (as opposed to projected).

Box 11: Climate Readiness in the Context of the Khulna Water Supply Project

A study was conducted to assess the impacts of climate change on the urban water supply system in Khulna and to identify adaptation options to climate proof a proposed water supply investment project. The study found that projected decreases in river flows in the dry season and sea-level rise would increase the salinity of the river, which is an important source of water supply. Two adaptation options were proposed: shifting the water intake point farther upstream by 4 kilometers or increasing the size of the impounding reservoir by 12 million cubic meters. A further detailed analysis was conducted to determine the required size of the impounding reservoir. The city has planned to gradually increase the size of the impounding reservoir while continuing the monitoring of the salinity levels in the river.

Source: ADB. 2011. *Adapting to Climate Change: Strengthening the Climate Resilience of Water Sector Infrastructure in Khulna, Bangladesh.* Manila.

Finally, decision makers may elect to make no changes or incremental investment at the time of project design and implementation, but instead to await further information on climate changes and their impacts on the infrastructure assets, and to invest in climate proofing if and when needed later.

This type of decision may result under one or more of the following circumstances:

- The costs of climate proofing now are estimated to be large relative to the expected benefits.
- The costs (in present value terms) of climate proofing (e.g., retrofitting) at a later time are expected to be no larger (or little different) than climate proofing now.
- The expected benefits of climate proofing today are estimated to be relatively small.

The process of climate proofing investment projects aims both at assessing the climate risk to a project's future costs and benefits and at undertaking a technical and economic analysis of options to alleviate or mitigate those risks. Accounting for climate change at the outset of the project cycle does not imply that climate-proofing measures with large and costly investments need to be put in place as project implementation is initiated. It does imply, however, that decisions about project design and the adoption and timing of climate-proofing measures be informed with the possible impacts of climate change in the initial phases of the project cycle and that decisions of an irreversible nature be avoided.

Step 16: Prioritize and Select Adaptation Options

The adaptation assessment results in a prioritized list of adaptation options for implementation, which are selected from among several possibilities: changes in engineering designs, biophysical and ecosystem-based measures, alignment changes, and business-as-usual approach ("do nothing" option). Their prioritization can be based on an assessment of their technical feasibility, their benefits and costs, their social acceptability, and the opportunities they may offer for synergies with national priorities. While the use and outcome of a cost–benefit analysis are often given more weight in the prioritization process, it is important to recognize that other factors and criteria may also influence decision making.

The expertise required to prioritize and select adaptation options is multidisciplinary and, as such, is one of the more challenging aspects of adaptation planning. Options must be scientifically sound, socially beneficial, and economically viable. Roundtable discussions involving different stakeholders can work well and can include, for example, the project engineers, environmental specialists, social safeguard experts, nongovernment organizations, implementing entities, and national climate change representatives.

The ingredients of multi-criteria analysis (MCA) are objectives, alternative measures/interventions, criteria (or attributes), scores that measure or value the performance of an option against the criteria, and weights (applied to criteria). As indicated in the IPCC (2007, 64) report:

> Responding to climate change involves an iterative risk management process [...] taking into account actual and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk. Risk management techniques

> can explicitly accommodate sectoral, regional and temporal diversity, but their application requires information about not only impacts resulting from the most likely climate scenarios, but also impacts arising from lower-probability but higher-consequence events and the consequences of proposed policies and measures.

Adaptation decisions may also be akin to an *adaptive management* approach, which consists of monitoring changes in climate and putting in place climate-proofing measures over the project's lifetime as changes and their impacts are observed.

Some authors have indeed pointed out the inherent difficulty associated with undertaking impact and vulnerability assessments given the degree of uncertainty associated with climate change. Wilby and Dessai (2010, 1092) pointed out that "*characterizing* uncertainty through concerted scientific action may be a tractable proposition, but there appears to be no immediate prospect of reducing uncertainty in the risk information supplied to decision makers" (emphasis in original).

As an alternative to the top-down approach (i.e., first asking what climate change may entail in the future and then assessing the possible impacts of various climate projections on the project's performance), a different approach lies in first identifying the extent of climate change that the project can cope with before its performance is adversely impacted and then assessing when (e.g., if vulnerability pertains to sea-level rise) or how often (e.g., if vulnerability pertains to peak wind or peak water discharges) these adverse conditions may be met.

As a result, some authors refer to the concept of *robust adaptation* to climate change (Box 12). A detailed applied demonstration of the approach is available in Lempert and Kalra (2013, 3) in the context of flood risk management in Ho Chi Minh City. The robust adaptation approach to climate change does not rule out the use of climate projections, and of the overall step-by-step approach described earlier. It also does not invalidate the significance of the economic analysis. As noted in Lempert and Kalra (2013), "an analyst using a simple spreadsheet model to compare the cost-benefit ratios of alternative investments could use [robust-decision making] to run the spreadsheet over many thousands of combinations of assumptions and to identify those futures where one investment was consistently more cost-effective than another."

Box 12: Robust Adaptation to Climate Change

Wilby and Fowler (2010) noted that scenario-led adaptation is hampered by the scale of the uncertainty pertaining to climate change, and that the adaptation paradigm is better based on robustness, flexibility, monitoring, and review.

Robust adaptation measures are defined as measures that (i) satisfy a number of "robustness principles" such as low-regret, reversible, and flexible (to minimize the cost of being wrong about future climate change); (ii) incorporate safety or security margins into design criteria; and (iii) employ "soft" (e.g., institutional and planning) solutions.

The search for robust adaptation measures has been characterized as follows (Wilby and Dessai, 2010):

Step 1: Construct an inventory of all adaptation options for the most significant risks caused by climate change.

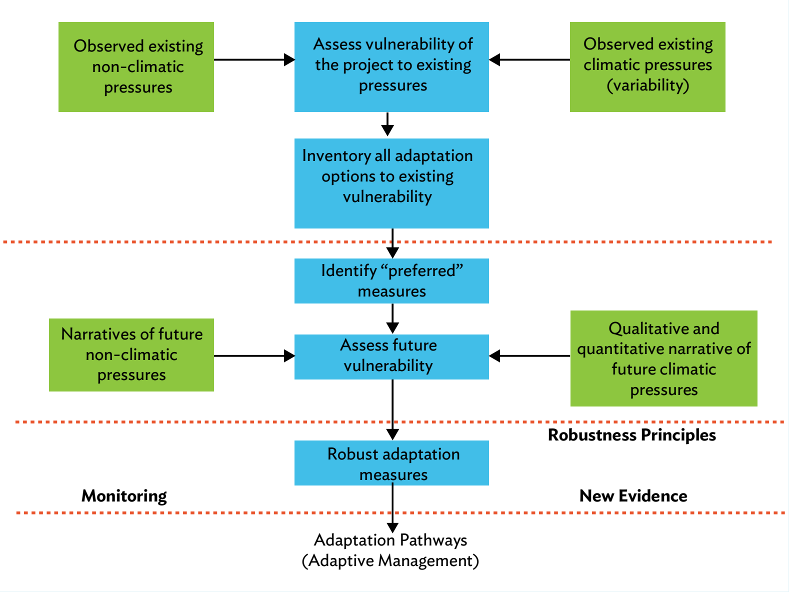
Step 2: Through a process of screening and appraisal, identify "preferred" adaptation options that would reduce vulnerability under the present climate regime.

Step 3: Describe quantitatively and qualitatively plausible changes in climate and non-climate variables to identify future vulnerability.

Step 4: Among the set of "preferred" adaptation options (Step 2), identify those measures that are robust to future vulnerability.

Step 5: Establish an "adaptation" pathway that will be shaped by a careful monitoring of the changing climate and environmental conditions, the scientific evidence, and society's attitudes to climate risk (adaptive management).

Box 12 *continued*

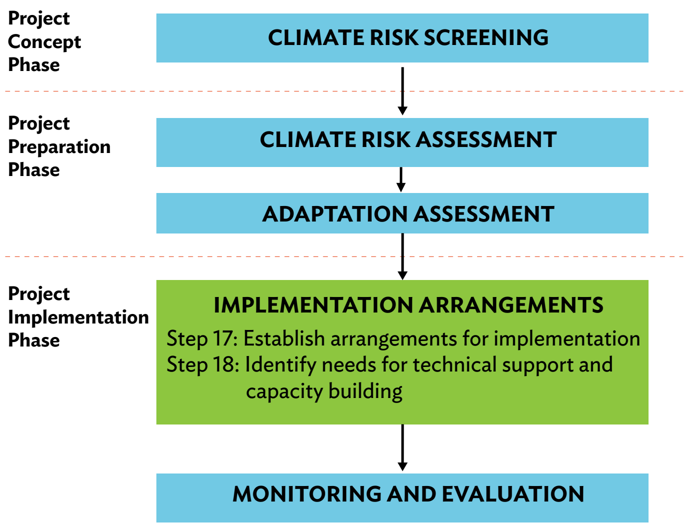


Source: Adapted from R. L. Wilby and S. Dessai. 2010. Robust Adaptation to Climate Change. *Weather*. 65(7). 180–185.

Implementation Arrangements

The goal of establishing implementation arrangements is to ensure the effective implementation of the identified adaptation option(s).

Figure 11: Implementation Arrangements



An ideal adaptation strategy will be fairly comprehensive and will include a mix of solutions. This is because the causes of vulnerability are diverse and will relate to social, environmental, engineering, policy, and institutional challenges. The effective implementation of adaptation strategies requires the establishment of roles and responsibilities, training needs, and a monitoring and evaluation framework. Also, recognizing that the policy processes include uptake of information and recommendations from the project level, opportunities to feed back into policy processes should be seized.

Step 17: Establishing Arrangements for Implementation

A lead organization should be selected to implement the adaptation measures. While this organization may be the main executing agency responsible for the water sector project (such as a public works ministry or planning ministry), other ministries, organizations, and institutes in the country may be involved given the nature of the adaptation activities, which may cut across sectors. For instance, focal points for climate change and disaster risk management will need to be engaged with planned activities to improve the information base or early warning systems in areas where key components of WSS systems are deemed to be particularly exposed and vulnerable. Many of the "low-risk" adaptation strategies, such as improved watershed management, groundwater management, or mangrove rehabilitation to protect coastal infrastructure, may require engagement of water, land management, and forestry experts and organizations.

In all cases, identifying executing partners with capacities and mandates to coordinate and manage adaptation-related projects is required. While it may not be appropriate for climate change experts to be responsible for implementing projects rooted in sector plans, scientific and technical backstopping from the climate change expertise in different countries may assist in building overall capacity in the country. Finally, community participation may not be limited to the identification of vulnerabilities and adaptation options and strategies, but may also include and play an important role in the implementation phase.

When the project partners are already selected, the scope of the project is likely to be limited by each partner's lines of responsibility. For instance, while the ideal adaptation approach may include engineering and environmental measures, the latter is likely to fall outside the roles and functions of a public works ministry. This adds further reasons for addressing adaptation at the earliest stages of policy and strategy development, as will be discussed in Part C.

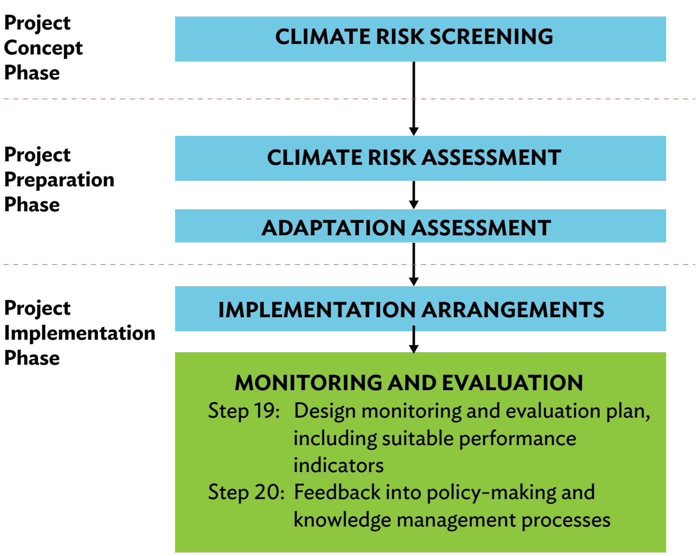
Step 18: Identify Needs for Technical Support and Capacity Building

Experience indicates that the capacity and awareness required in managing climate change and adaptation is currently limited. Provisions for training and capacity building will likely be needed for executing agencies, partner institutes, local communities, project management units, and contractors. An institutional assessment of existing capacity and gaps should inform this plan.

Monitoring and Evaluation

The goal of establishing monitoring and evaluation frameworks is to ensure accountability and ensuring that lessons are learned to inform future adaptation efforts.

Figure 12: Monitoring and Evaluation



Finally, establishing monitoring and evaluation (M&E) frameworks will ensure accountability and implementation and is important for collecting lessons learned of effective adaptation with a view to continuous improvement and replication of good practices.

Step 19: Design Monitoring and Evaluation Plan Including Suitable Performance Indicators

There is little experience worldwide in understanding how effective different adaptation options will be to reduce vulnerability to climate change in the WSS sector. In such a context, M&E systems are all the more important to develop this knowledge.

As indicated in Spearman and McGray (2011), M&E systems can provide critical support in learning "what works" in adaptation by helping understand

- how an adaptation intervention influences and is influenced by policies, institutions, and other factors;
- what factors contribute to autonomous adaptation;
- historical coping mechanisms and evidence of resilience to previous climate-related events;
- socially of economically acceptable levels of risk in decision making; and
- how to develop new adaptation strategies for addressing the effects of climate change.

M&E systems can also provide information to

- adjust adaptation activities based on how successful they are in achieving intended adaptation objectives;
- adjust adaptation activities to address unexpected events and challenges;
- compare results across various interventions and/or different locations; and
- share learning about the outcomes of adaptation initiatives.

There are some challenges in developing M&E indicators, including the long-term nature of actual climate change, the need to acquire appropriate baseline data and metrics for measuring vulnerability, and isolating vulnerability to climate change from other sources of pressure.[33]

The development of outcome-level and output-level indicators is ongoing to assess the impacts of adaptation investments. ADB identifies three levels of results monitoring: impacts, outcomes, and outputs.[34]

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[33] See the UNFCCC synthesis report on monitoring and evaluating adaptation for further details at http://unfccc.int/resource/docs/2010/sbsta/eng/05.pdf

[34] See http://www.adb.org/documents/guidelines-preparing-design-and-monitoring-framework

Step 20: Feedback into Policy-Making and Knowledge Management Processes

An adequate adaptation strategy is likely to be composed of activities including engineering measures (such as incorporating changes to standard designs, guidelines, and standard drawings) and nonengineering measures (such as ecosystem resilience measures and early warning systems for disasters). Lessons from adaptation measures undertaken at a project level should inform policy makers about appropriate approaches at the sector and/or national levels. This issue is discussed in greater detail below.

The adaptation assessment promoted here is fairly broad, where all options should be listed. A few scenarios may arise:

- The ideal mix of adaptation solutions is feasible in the context of the current project partners.
- The ideal mix of adaptation solutions requires a broadening of the partnership base to include a wider range of executing partners. Some resources for increased coordination should be foreseen.
- The adaptation assessment highlights the need for critical decision making regarding major issues such as land-use planning and revised country strategies and sector policies.
- The adaptation assessment highlights needs which may not be appropriate in the context of a given project but warrant the development of a new unique project.

PART C

Building Adaptation into Policy and Sector Planning

Mainstreaming Adaptation in National Policy Processes

Decisions pertaining to priority areas, alignment, land zoning, spatial planning, technology, and implementation plans are made at the policy and sector planning levels. Many of the examples of comprehensive adaptation strategies rely on the participation of multiple partners, such as infrastructure ministries and environment ministries, which is more readily established if set at the policy level.

Countries undertake policy processes to establish overarching frameworks for making decisions and setting priorities. Enhancing decision making by factoring in climate change risks will require a different process than for project-level interventions, where many key parameters are established, such as geographic location, scale, and technology. Therein lies the difficulty with policy mainstreaming: merely mentioning climate change in policy documents does not ensure such mainstreaming. In part, this is often because of lack of information about climate change, poor interministerial coordination, weak implementation capacity and resources, and a lack of experience in designing and implementing climate change adaptation in both developed and developing countries.

For these reasons, many of the first climate change adaptation funds have advocated learning by doing or through pilot project initiatives.[35] Establishing some implementation experience can inform the development of appropriate policy-level guidance. Another approach for developing policy experience that has been tested is policy-driven information gathering, or the explicit

[35] For example, see Least Developed Countries Fund, Special Climate Change Fund, Adaptation Fund Guidelines. Also UNFCCC Decision 5/CP.7 and Decision 5/CMP.2.

link between pilot project and policy mainstreaming. Adaptation strategies are tested and evaluated in the context of a given policy sphere, and successful measures are fed back up into the given policy. This integration can help improve the policy's general direction and achievement of its objectives.

The Organisation for Economic Co-operation and Development (OECD) identifies the national and sector levels as policy entry points that may be useful for adaptation mainstreaming (OECD 2009). National policies and plans (note that in some countries, the word "policies" is used while in others these are referred to as "plans") include national visions, poverty reduction strategies, multiyear development plans, and national budgets. Sector development plans, such as water development master plans and their budgets, often flow from national plans and policies. Projects support sector plans and, in some cases, also national plans, particularly those that are cross-sector, regional, and of extremely high priority. Therefore, influencing these overarching frameworks can affect which projects are prioritized and the criteria they must meet in order to be financed.

The OECD guidance recommends two main courses of action for integrating adaptation at this level:

- A clear recognition at the national level of climate risks and the need for adaptation within relevant national policies. Incorporating climate change at this level can ensure that it filters down into sector plans and other levels of decision making. In the case of water supply and sanitation (WSS), and for infrastructure development generally, guidance intended to strengthen cross-sector cooperation between ministries can be very helpful. For instance, flood management around critical WSS infrastructure can be better managed between ministries of water and hydrology, meteorology, and public infrastructure. Integrated planning around geographically vulnerable areas can produce high-quality development plans for disaster-prone areas.
- Applying a climate change lens in the formulation of national policies and strategies. A climate lens is an analytical process or tool to examine a policy, plan, or program. It can be useful, for example, to identify areas of the country that are most vulnerable to climate change impacts and where priority action can be directed (Box 13).

Box 13: Applying a Climate Lens

The application of a climate lens at the national or sector level involves examining

(i) the extent to which the policy, strategy, regulation, or plan under consideration could be vulnerable to risks arising from climate variability and change;

(ii) the extent to which climate change risks have been taken into consideration in the course of program formulation;

(iii) the extent to which the policy, strategy, regulation, or plan could lead to increased vulnerability, leading to maladaptation or, conversely, to missing important opportunities arising from climate change; and

(iv) for preexisting policies, strategies, regulations, or plans that are being revised, what amendments might be warranted in order to address climate risks and opportunities.

A first quick application of the climate lens should enable a policy maker to decide whether a policy, plan, or program is at risk from climate change. If deemed to be at risk, further work is required to identify the extent of the risk, assess climate change impacts and adaptation responses in more detail, and identify possible recommendations and downstream actions.

Source: Organisation for Economic Co-operation and Development. 2009. *Integrating Climate Change Adaptation into Development Co-operation*. Paris.

As indicated earlier, national communications prepared by national governments in the context of the United Nations Framework Convention on Climate Change (UNFCCC) offer an opportunity for governments to express their understanding of the possible impacts of climate change on water resources in general, and on WSS in particular, and of their intent to address them (Box 14).

Box 14: Water Supply and Sanitation in Selected Country Communications to the United Nations Framework Convention on Climate Change

Armenia's Second Communication to the United Nations Framework Convention on Climate Change includes the following legal-organization measures to address climate change on water supply and sanitation: (i) development of procedures for taking into account the climate change factors during assessment of water demand; (ii) introduction of legal, economic,

continued on next page

Box 14 *continued*

and administrative incentives for reducing leakages from drinking water and irrigation water systems; (iii) introduction of water-saving technologies and initiation of legislative changes to promote water saving; and (iv) development of procedures for defining the priorities of water use by priority sectors considering the climate change impacts in river basin management plans.

Pakistan's Initial Communication notes that "there is an urgent need to devise policies, both economic and structural, to practice water conservation in the urban areas to lower the rising pressure on the drainage and supply systems and to lower the pressure on sewage treatment, which has become essential for the preservation of water quality" (p. 55).

Tonga presents some adaptation options that involve better utilization of existing water resources, while others are aimed at developing additional or supplementary water resources. Adaptation options aimed at better utilization of existing freshwater resources, which can be classified under the broad heading of demand management measures, are (i) leakage control, (ii) consumer education and awareness, (iii) pricing policy that discourages high usage, and (iv) water conservation plumbing measures. Adaptation options aimed at developing additional or supplementary freshwater resources, or maximizing the use of currently available resources, are (i) expansion of rainwater collection schemes; (ii) groundwater protection measures (water reserves, nonpolluting sanitation systems); (iii) desalination; (iv) reclamation of land for increased groundwater pumping; and (v) importation.

Tonga's Second Communication notes that institutional settings need to identify better ways to allocate water, using principles such as equity and efficiency. These settings also need to consider the management of water catchments, surface and groundwater basins.

Sources: Government of Armenia, Ministry of Nature Protection.. 2010. *Second National Communication on Climate Change*. Yerevan; Government of Pakistan. 2003. *Pakistan's Initial National Communication on Climate Change*. Islamabad; Government of Tonga. 2012. *Second National Communication*. Nuku'alofa.

National adaptation programs of action (NAPAs) may indicate and prioritize adaptation needs for the WSS sector (Box 15).

Box 15: Water Supply and Sanitation Priority Projects in the Maldives and Nepal National Adaptation Programs of Action

In the **Maldives**, the National Adaptation Programme of Action include the following two goals, subdivided into objectives and activities pertaining to water supply and sanitation:

- Goal: Enhance adaptive capacity to manage climate change-related risks to freshwater availability by appropriate technologies and improved storage facilities.
- Objectives: (i) Increase rainwater harvesting capacity and storage, and (ii) acquire technology for emergency freshwater provision.
- Activities: (i) Establish rainwater harvesting and storage facilities on all public buildings, (ii) develop community awareness on safe rainwater harvesting and storage practices, and (iii) establish emergency backup desalination system.
- Goal: To increase resilience of water resources, human health, and coral reef biodiversity to climate change-related hazards by improving present wastewater treatment and disposal capacity.
- Objectives: (i) Identify and demonstrate innovative, appropriate, and cost-effective wastewater treatment and disposal systems; and (ii) Educate the community on appropriate wastewater treatment.
- Activities: (i) Design and construct appropriate wastewater treatment and disposal system, and (ii) develop information material for public on best practices on wastewater treatment.

In **Nepal**, a key activity of the National Adaptation Programme of Action is to empower vulnerable communities through sustainable management of water resources. Key components of this activity include (i) conserving lakes supplying water and ecological services to urban areas, (ii) promoting rainwater harvesting structures and technologies, (iii) conserving water supply source and strengthening programs of existing projects affected by source reduction, and (iv) developing nationwide urban groundwater monitoring system and enhancement of regulatory measures.

Sources: Government of the Maldives, Ministry of Environment, Energy and Water. 2006. *National Adaptation Programme of Action*. Male; Government of Nepal, Ministry of Environment.. 2010. *National Adaptation Programme of Action to Climate Change*. Kathmandu.

Mainstreaming Adaptation in Sector Policies and Plans

Sector-level policies are important for climate change, because it is often at this stage that criteria such as engineering designs, alignment, technology, and priority areas will be established. Adaptation responses vary significantly by place and sector, and therefore this publication seeks to develop some highly specific approaches for the water sector. There is, however, little detailed experience at the policy level to draw from, with few sector ministries going beyond awareness raising and research.

Incorporating adaptation considerations into water sector development master plans, for example, will further secure the likelihood of meeting the given sector objectives and may also identify new priorities. The simplest way for a water sector development plan to incorporate climate change adaptation is to acknowledge the relationship between climate change impacts and the plan's goals, for example, a reliable and effective water supply network. The structure of this incorporation will vary from case to case. It may include stand-alone components within the water development strategy, such as conducting a climate change risk assessment for each project identified, or involve incorporating climate change adaptation within other subgoals.

Challenges faced by the physical infrastructure with respect to climate change cannot be separated from the interaction between the built environment and the natural environment. Infrastructural changes that do not address some of the root causes—such as deforestation, land degradation, and water use efficiency—will provide only a temporary and superficial fix. Sector ministries overseeing the water sector and/or public infrastructure sector will need to coordinate more effectively with other line ministries in dealing with climate change issues. There are a number of options for doing this:

- Establish or enhance cross-ministerial committees for managing adaptation to climate change, including for water.
- Strengthen departments of disaster risk management and meteorology to improve information on which to make decisions.
- Introduce early warning and response systems to improve maintenance schedules and to respond quickly to post-disaster recovery needs.

- Promote *low-regret or no-regret* adaptation strategies that will have development benefits regardless of the nature of climate changes that may take place. This is a useful approach where uncertainty is high regarding climate change and capital investments cannot be justified for large-scale infrastructural changes.

Incorporate climate change adaptation into environmental impact assessments and strategic environmental assessment guidelines. This can take place specifically in the WSS sector or, preferably, as part of the national standards. Water and/or public infrastructure ministries can test tools and adaptation approaches by applying strategic environmental assessments with climate change to their sector policies and plans.

Such inter-sectoral coordination and collaboration is more likely to lead to the assessment of a broader set of adaptation options, which may provide multiple benefits across multiple sectors, and also recognizes that effective adaptation in one sector (e.g., water) may lie in better operation or more investment in another (e.g., forestry).

Further, ministries can incorporate the following measures into their implementation plans:

- Introduce climate change vulnerability and adaptation considerations to criteria used for selecting projects for implementation and financing.
- Develop sector-specific and country-specific screening tools to identify projects at risk.
- Incorporate contingency budgets for specific adaptation interventions as the need arises.
- Adjust zoning regulations for WSS sector infrastructure (e.g., to avoid flood or permafrost zones).
- Design flexible infrastructure that can accommodate incremental changes over time.
- Incorporate climate change indicators into WSS sector planning budgeting frameworks to ensure accountability.

Practical steps may be followed to incorporate climate change in water planning and policy, even in the short term. Suggested actions include the following:

Conduct a climate change impact, vulnerability, and adaptation assessment in the WSS sector at the national level

This assessment should cover the following aspects of climate change and WSS sector investments:

- Direct threats to investments (e.g., effect of extreme weather events on infrastructure).
- Underperformance of investments (e.g., investments that fail to pay off when rainfall decreases).
- In addition, there is the risk of forgoing opportunities that may arise from climate change and could be captured if factored into plans and projects.

Examples of outputs from this activity are as follows:

- Scenarios for water supply in the country assessed on the basis of global and regional climate models
- Flood- and drought-prone areas analyzed and alternative land-use plans developed based on climate-risk scenarios

Identify priority areas for intervention and implement pilot initiatives

Although this step is not fundamental in the policy mainstreaming work, it can generate grounded information about adaptation policy options and investments, and their feasibility and potential for replication. Reviewing past pilot adaptation initiatives in the country can also be helpful at this stage.

This set of actions can be implemented in the short term to guide the planning of climate-proofing investments (Box 16).

Box 16: Climate-Proofing Actions

Ebinger and Vergara (2011) identified the following set of climate-proofing actions:

- **Support awareness and knowledge exchange.** Disseminate experience and learn from the increasing data and knowledge of climate impacts on the sector.
- **Undertake climate impacts needs assessment.** Quantify the impacts and risks through the project life cycle to guide adaptation practice.
- **Develop project screening tools.** Develop templates to screen individual projects for climate vulnerability and risks.
- **Develop adaptation standards for the sector.** Such standards should cover engineering matters and information requirements.
- **Revisit planning time frames and the use of historical data for future investments.** Traditional planning approaches that use historical data may need to be revisited and adjusted to reflect anticipated climate trends.
- **Assess potential climate impacts when retrofitting existing infrastructure.** Already available technologies, such as environmental audits, can help identify any needed changes in operational and maintenance protocols, structural changes, and/or the relocation of existing plants.
- **Implement specific adaptation measures.** Adaptation measures can include a range of off-the-shelf and innovative solutions which may require investment in pilot or demonstration project to illustrate their costs and benefits.
- **Identify policy instruments.** They are needed to support climate impact management.
- **Support capacity building.** Increase the capacity of key stakeholders including water sector policy makers, regulators, and operators for climate risk management.

Source: Adapted from J. Ebinger and W. Vergara. 2011. *Climate Impacts on Energy Systems: Key Issues for Energy Sector Adaptation*. Washington, DC: The World Bank.

Identify relevant institutions and their role and mandate with respect to water and public infrastructure and climate change to build capacity by disseminating results of the previous steps

Despite the uncertainty associated with climate risk, institutions can take a number of practical steps to reduce the climate vulnerability of the sector they manage and increase resilience to climate threats (Box 17).

Box 17: Nine Hallmarks of Institutions That Are Adapting to Climate Change

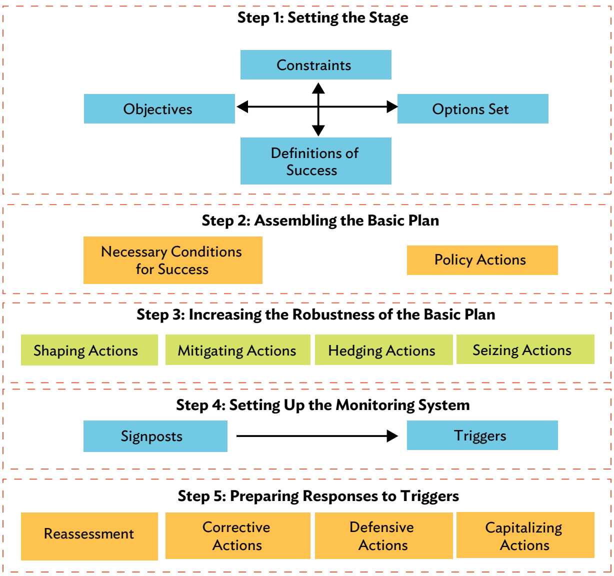
1. Climate change champions are clearly visible, setting goals, advocating and resourcing initiatives on climate change adaptation.
2. Climate change adaptation objectives are clearly stated in corporate strategies and regularly reviewed as part of a broader strategic framework.
3. Flexible structures and processes are in place to assist institutional learning, upskilling of teams, and mainstreaming of adaptation within codes of practice.
4. Progress in adapting is monitored and reported against clearly defined targets.
5. Comprehensive risk and vulnerability assessments are being undertaken for priority activities at early stages of the planning cycle.
6. Scientifically based, workable guidance and training on adaptation is being put in place for operational staff.
7. Adaptation pathways are being guided by the precautionary principle in order to deliver low-regret solutions that are robust to uncertainty about future risks including, but not exclusively, climate change.
8. Multi-partner networks are in place that are sharing information, pooling resources, and taking concerted action to realize complementary adaptation goals.
9. Effective communication with internal and external audiences is raising awareness of climate risks and opportunities, realizing behavioral changes, and demonstrating adaptation in action.

Source: R. L. Wilby and K. Vaughan. 2011. Hallmarks of Organizations That Are Adapting to Climate Change. *Water and Environment Journal*. 25 (2). pp. 271–281.

Adaptive policy pathways

Haasnoot et al. (2013) develops an approach referred to as "adaptive policy pathways" in which adaptation planning at the sector level is explicitly presented as an iterative process responding to new information over time (Figure 13). The design of a basic plan (Step 2) follows an assessment of the existing conditions of the system and the objectives of future development of the system (Step 1). An increased robustness of the basic plan is achieved through different types of actions: shaping actions (taken to reduce failure or enhance success), mitigating actions (to reduce the likely adverse effects of the plan), hedging actions (to reduce the uncertain adverse effects of the plan), and seizing actions (to seize opportunities). Once the plan is in place, signposts indicate the nature of the information which should be monitored to determine the status of the implementation of the plan relative to targets and objectives. If triggers are reached, actions can then be implemented. These actions include defensive actions (to clarify the basic plan, preserve its benefits, or meet outside challenges); corrective actions (adjustments to the plan); capitalizing actions (to take advantage of opportunities); and reassessment of the plan itself (when assumptions critical to the design and success of the plan are no longer valid).

Figure 13: Adaptive Policy-Making Approach



Source: Adapted from M. Haasnoot et al. (2013).

The approach taken when analyzing adaptation in the sector should acknowledge that

- Climate impacts may not be the most important constraint on development objectives of the sector; climate considerations therefore need to be embedded in a planning process that considers all risks.
- The basis for adapting to the future climate lies in improving the ability to cope with existing climate variations. Climate change projections inform this process to ensure that current coping strategies are consistent with future climate change.
- In tackling climate hazards, adaptation processes can draw on approaches to disaster risk reduction, as well as tackling gradual changes and new hazards.
- Because of uncertainty over future climate variability and change, management responses should build in flexibility to cope with a range of different potential future climate regimes.
- Managing climate impacts enables an examination of how wider development processes can contribute to reducing vulnerability to climate change.

Mainstreaming Adaptation in Water Supply and Sanitation Utilities

The National Drinking Water Advisory Council of the United States Environmental Protection Agency offers the following set of recommendations supportive of the development of climate ready water utilities including (US EPA 2010):

- The United States Environmental Protection Agency should develop a well-coordinated program to articulate and support the adoption of climate ready activities by utilities.
- Establish for utility staff a climate change continuing education and training program.
- Increase interdependent sector knowledge of water sector climate-related challenges and needs.
- Improve and better integrate watershed planning and management in response to climate uncertainty and impacts.
- Improve access to and dissemination of easy-to-understand and locally relevant climate information.

- Develop an adaptive regulatory capacity in response to potential climate change alteration of underlying ecological conditions and systems.
- Develop a comprehensive water sector climate change research strategy.

It further suggests an adaptive response framework in two stages of engagement with water utilities (Table 8).

Table 8: Climate Ready Adaptive Response Framework

	Stage 1: Understand and Assess	
Areas of Utility Engagement	**Elements of Basic Engagement**	**Elements of Focused Engagement**
Understand climate impacts and uncertainties	• Maintain basic awareness of climate science developments and implications for local operational conditions. • Encourage utility personnel to examine operating conditions in light of the potential for climate change challenges. • Conduct screening-level climate impact assessment to identify obvious threats and opportunities. • Integrate climate impact considerations into normal planning and decision making, including emergency response, capacity, and capital planning.	• Conduct vulnerability assessment of a range of water system component responses to potential climate change impacts. • Develop strategies to address any identified vulnerabilities. • Transition from long-range planning based on the historic past to uncertainty-based planning methods. • Cultivate relationships with the scientific community to stay abreast of new developments in climate science and to generate top-down (downscaled climate impacts data) and bottom-up impact assessments for use in local planning. • Provide input to scientific community on information needed for vulnerability analysis and long-range planning purposes.

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Table 8 *continued*

Areas of Utility Engagement	Stage 1: Understand and Assess	
	Elements of Basic Engagement	**Elements of Focused Engagement**
Understand utility climate adaptation opportunities	• Understand organizational, operational, and capital investment options undertaken by similar utilities to better understand opportunities for no and low-cost no-regrets, operational actions, and capital investments.	• Expand efforts to identify, understand, and evaluate utility climate adaptation and mitigation practices (e.g., enhanced long-range planning methods, hedging strategies, and supply and treatment diversification options).
Understand climate-related community conditions	• Establish awareness of local/state/regional climate adaptation efforts to ensure effective utility participation. • Understand local community leadership perspectives on climate change impacts in the local setting.	• Actively engage with community leaders to ensure sophisticated awareness of climate change implications. • Actively engage in local/state/regional climate adaptation efforts to ensure a fully synergistic relationship between utility-based adaptation plans and strategies and those plans developed by other entities.
Understand interdependent actor and sector conditions	• Establish awareness of critical interdependent actor and sector climate-related water resource actions, to ensure effective utility representation.	• Actively involve interdependent actors and sectors in utility planning and operational climate-related strategies to ensure high compatibility and leveraging of efforts.

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Table 8 *continued*

	Stage 2: Implement and Evaluate	
Areas of Utility Engagement	**Elements of Basic Engagement**	**Elements of Focused Engagement**
Create internal understanding, support, and capacity	• Provide general education and training to internal staff on potential climate change impacts. • Involve staff in identifying and implementing no and low-cost operational changes designed to provide a hedge against potential climate impacts.	• Promote and gain support from staff for the integration of climate considerations into utility planning and development. • Cultivate an internal culture to support establishing and maintaining an adaptive response footing for climate change. • Engage wider expertise in day-to-day operations and decision making (e.g., meteorologists and land-use planners).
Establish shared risk and responsibility partnerships	• Establish ongoing dialogue with interdependent actors and sectors to enable basic coordination of key actions that affect water resources management.	• Engage interdependent sectors (e.g., energy, agriculture, maritime, and navigation sectors) and institutional actors (e.g., local land-use and economic development departments) to jointly and proactively maintain awareness of the potential need to collaborate on climate adaptation management. • Establish and strengthen formal collaborative partnerships with critical interdependent actors both within and outside of the basin focused on establishing joint climate adaptation management responsibility and development of shared risk strategies.

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Table 8 *continued*

Areas of Utility Engagement	Stage 2: Implement and Evaluate	
	Elements of Basic Engagement	**Elements of Focused Engagement**
Generate community understanding and support	• Seek to understand community interest and perspectives on climate change. • Tailor climate-related activities and messaging consistent with identified community interests.	• Acknowledge the importance of, and establish a clear basis for, climate adaptation action and build local decision maker and general community support for planned organizational and operational climate-related changes.
Establish organizational and operational flexibility	• Implement opportunistic, no-regrets, multiple benefits, operational, and capital investment actions that target no and low-cost operational approaches that can perform well under current as well as a range of possible future climate impact conditions. • Avoid making large, long-term investments that do not consider and reflect the potential need to adapt to or minimize climate impacts.	• Implement a diversified portfolio of near, mid-, and longer-term managerial, operational, and capital investment actions consistent with an organizational emphasis on identifying robust solutions that perform well under a variety of climate impact scenarios.

Source: Adapted from United States Environmental Protection Agency. 2010.

Conclusions

This publication has presented a step-by-step approach to help project teams incorporate climate change adaptation into water sector investment projects. The steps are based on ADB's experience to date on climate proofing water supply and sanitation investment projects, and these guidelines may change as experience evolves. Though it is premature to offer conclusions, the points below should help guide ADB and its partners toward developing and implementing climate-proofed projects.

- **Additional and predictable financing** is needed to support approaches that seek to fully integrate adaptation into development planning and processes. Most adaptation financing is now allocated by donors on a project-by-project basis, which forcibly separates adaptation activities from mainstream development work. While separating out funding for adaptation is important for accountability and transparency purposes, it can also add to the challenge of mainstreaming efforts, particularly when adaptation funds and sector budgets are administered independently. A shift toward programmatic approaches and budget support, which are being piloted by some of the international climate change funds and bilateral donors, will be important models to monitor and assess how these approaches might influence future financing architecture for adaptation.
- **Holistic adaptation solutions** are cross-sector. Sector-based approaches have their limits, and regional ecosystem-based assessments and analysis are needed to influence integrated planning in the water sector. Given that water infrastructure has a long life cycle, its planning should be developed further and integrate new approaches such as green infrastructure planning. Most adaptation responses will require participation across ministries; coordination efforts are intense and should be supported. When working with line and sector ministries, support should also be extended to strengthen the ability of often-weaker environment ministries to participate within their given mandates. This strengthens climate change adaptation efforts throughout the whole government rather than single ministries.

- **Adaptation is characterized by decision making under uncertainty.** Uncertainties associated with climate science and socioeconomic trends require a pragmatic, participatory, and flexible approach to constructing scenarios and assessing impacts, vulnerability, and adaptation. Adaptation policies, strategies, and options would be more robust with a certain level of flexibility to take advantage of new developments in climate science and technology.
- **Mainstreaming adaptation into the water sector should take place at the national and project levels.** Each level has a specific role to play in addressing planning, budgeting, and community-level vulnerability issues. There is value in conducting sector-specific vulnerability and climate proofing assessments at the national level to guide long-term planning and decision making. Simultaneously, mainstreaming the climate-proofing process at the project level may ensure that climate risks are minimized. In general, there is a need for sector experts themselves to develop practical climate-proofing experience.

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APPENDIX

Draft Terms of Reference

Sample Additional Activities for Project Preparation Team Members

The project team will undertake the following activities to identify and recommend an adaptation strategy for the project, both in terms of protecting the investment and ensuring that the project does not increase the vulnerability of the relevant area and people. This work will include a detailed climate change risk, impact, vulnerability, and adaptation assessment, including an economic assessment, in the project context. The Asian Development Bank (ADB) technical note, *Guidelines for Climate Proofing Investment in the Water Sector: Water Supply and Sanitation*, may serve as a useful guide.

The results of the assessment should be fully incorporated into the project design including the detailed engineering design, environmental management plan, social safeguard measures, monitoring and evaluation framework, and budget. Inputs will consist of approximately 4 person-months by international consultants and 5 person-months by national consultants assisting the international consultants.

Team Leader (International, 1 person-month)

(i) Oversee and coordinate the implementation of the draft strategy for climate change risk, vulnerability, impact, and adaptation assessments.
(ii) Identify and discuss the adaptation objective with all relevant stakeholders.
(iii) Synthesize vulnerability and impact information collected by other members of the team into the decision matrix provided by ADB.
(iv) Organize and lead multi-stakeholder consultations to identify and prioritize adaptation options based on economic assessment in addition to any other prioritization conditions identified (i.e., through multi-criteria analysis).

(v) Recommend adaptation options in a presentation to the government, ADB, and other relevant stakeholders.
(vi) Ensure integration of adaptation components into the project design.
(vii) Identify additional training needs, indicators for monitoring, and budget for adaptation components, as needed.

Civil Engineer (International, 1 person-month)

(i) Identify structural adaptation options, including their costs for the project.
(ii) Assist other team members in identifying all benefits of the adaptation options from structural perspective.
(iii) Prepare revisions to standard designs and drawings, taking into account climate change.
(iv) Recommend to ADB adjustments and improvements toward to support development of a replicable model to be used in the project and in the future.
(v) Contribute specialist advice, including preliminary designs and cost estimates.
(vi) Prepare technical documentation, including standard design and specifications that include adaptation considerations.

Economist (International, 1 person-month)

(i) Identify and estimate all costs and benefits of the various adaptation options, taking into account engineering, environmental, and socioeconomic perspectives, including the economic assessments.
(ii) Apply a cost–benefit/cost-effectiveness analysis for the identified adaptation options.
(iii) Recommend improvements based on the cost–benefit and/or cost-effectiveness analysis with a view to developing a replicable model for future projects.

Environmental and Social and Poverty Specialist (International, 1 person-month)

(i) Identify the climate parameters of concern for the project, including but not limited to changes of precipitation, temperature regimes, and sea-level rise.

(ii) Conduct a vulnerability assessment in the project area to identify vulnerability of the planned infrastructure as well as the project's potential effects on the vulnerability of the area and people.

(iii) Coordinate the climate impact assessment with assistance from a climate modeler and in coordination with the team hydrologist.

(iv) Facilitate participation of government counterparts in ongoing capacity-building activities to ensure skills transfer for improved sustainability of designs.

(v) Conduct community and expert consultations to verify and refine selected adaptation options.

(vi) Revise the environmental management plan in line with findings.

(vii) Assist the economist in estimating the life-cycle project costs and benefits of climate change adaptation options, including socioeconomic and environmental benefits.

(viii) Assist the project manager in adjusting the project design to incorporate climate change adaptation.

(ix) Provide recommendations and suggestions for environmental or nonstructural adaptation interventions.

Environmental and Social and Poverty Specialist (National, 4 person-months)

(i) Facilitate participation of government counterparts in ongoing capacity-building activities to ensure skills transfer for improved sustainability of designs, and identify additional training needs.

(ii) Undertake initial poverty and social assessment, including field assessment of vulnerability to climate change.

(iii) Collect existing impact assessments and reports and prepare a summary of existing information and potential gaps.

(iv) Collect all relevant climate change data from government ministries and international and community organizations.

(v) Identify potential adaptation options.

Hydrologist (National, 1 person-month)

(i) Undertake hydrological assessments under various climate change scenarios.

(ii) Produce flood and drought maps and hot spots for current and future scenarios.

Draft Terms of Reference for Impact Assessment Specialist

Objective of the Assignment

Based on available and relevant information, conduct a desktop assessment of anticipated climate change impacts on a selected transportation project, using various and integrated impact assessments techniques.

Skills Required

It is preferable for this contract to be implemented by a team of consultants with expertise in climate change modeling (including downscaling techniques) and hydrological modeling, and who have the engineering and/or economic knowledge to prepare impact assessments in the relevant sector.

Scope of the Work

The purpose of this contract is to conduct a detailed climate change impact analysis as input for project design. The assessment will, in part, consider the identified climate parameters relevant to the project design, such as

- change in onset and intensity of seasonal rains;
- increase in very hot days and heat waves;
- sea-level rise;
- increase in intensity and frequency of hydrometeorological events;
- changes in seasonal precipitation and flooding patterns; and
- increase in cyclone intensity, frequency, and duration, and associated storm surge and wave action.

The consultant will also provide an expert opinion as to the probability and reliability of climate scenarios.

Detailed Tasks

(i) Review the project preparation technical assistance and of the climate change adaptation methodology prepared for the project.

(ii) Identify with the project team the climate change parameters to be assessed and the modeling scale (temporal and spatial) to be used in the impact assessment. Identify the goal of the climate change impact assessment in the context of the overall project objectives.
(iii) Survey the existing information, such as relevant climate change projections and local historical climate data. Prepare an assessment on the reliability of existing climate changes projections based on the model's ability to represent past climate conditions. Evaluate the range of climate projections and select those that would be representative of this entire range. Identify any need for further modeling, or where existing modeling is sufficient for the project, prepare a short synthesis report.
(iv) Identify the probabilities of specific climate change occurrences and the level of certainty. Identify assumptions and limitations of using the projections for influencing project design.
(v) Formulate downscaled climate change scenarios for the time horizon of the project, specifying the technique used for downscaling.
(vi) Identify possible technical gaps that limit the development of climate change projections for the country.
(vii) Submit for review and approval a draft outline of the analysis to be undertaken, including recommended methodology for impact assessment (e.g., hydrological modeling, stating clearly the climate scenarios and impact models to be used in the analysis and a justification for their choice).
(viii) Provide an expert opinion on the probability of further climate change research altering the project design protocols or operations requirements, including master planning.
(ix) Submit a draft report for review.
(x) Finalize the report based on comments received by ADB.

Output and Report Requirements

Final report containing estimated projections for key climate parameters, probability analysis, impact assessment, risks, and assumptions.

Draft Terms of Reference for Vulnerability Assessment Specialist

Objective of the Assignment

To identify the root causes of a system's vulnerability to climate changes and existing trends in climate.

Skills Required

The consultant is expected to have a multidisciplinary environmental or natural resource management background and a good understanding of the social and economic aspects of vulnerability. (Note: This work can often be led by the environmental specialist with inputs from other technical assistance team members.)

Scope of the Work

The goal of the vulnerability assessment is to identify existing vulnerabilities and coping strategies. A vulnerability assessment attempts to identify the root causes of a system's vulnerability to climate changes. This includes collecting and analyzing raw and observational data of current practices to compensate for vulnerability. (Note: Local nongovernment organizations may be appropriate partners for conducting local consultations.)

Detailed Tasks

(i) Collect data and identify observed trends in climate.
(ii) Work with impact modeler to verify and ground-truth climate change predictions.
(iii) Conduct field consultation with local community groups on existing vulnerabilities and coping strategies.
(iv) Prepare climate vulnerability maps based on existing environmental and climate data, including land cover, vegetation cover, slopes, geological hazards, and precipitation distribution.
(v) Identify priority areas with high vulnerability, to be verified during ground-truthing, along the proposed road corridors and assess current observed changes and coping practices.

Final Outputs

1. A vulnerability and risk map based on geographic information systems.
2. Report containing a summary of key observable vulnerabilities, sensitivities, coping strategies, and needs.

Size of Contract: 1 person-month

Draft Terms of Reference for Adaptation Specialist

Objective of the Assignment

The consultant's objective is to lead the identification and prioritization of climate adaptation options related to the project and to highlight findings to ADB for future work (optional).

Skills Required

The consultant is expected to have a multidisciplinary environmental or natural resource management background and a good understanding of the social and economic aspects of vulnerability. (Note: This work can often be led by the environmental specialist with inputs from other technical assistance team members.)

Scope of the Work

Adaptation is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects for the purpose of moderating harm or exploiting beneficial opportunities. The objective of the adaptation assessment is to identify all potential adaptation options, identify their costs and benefits, and prioritize their implementation in the context of the project goals.

Detailed Tasks

(i) Identify all potential adaptation solutions, including soft and hard measures.
(ii) Conduct multi-stakeholder consultations to identify and confirm all options, including their costs, benefits, and risks.

(iii) Based on tasks 1 and 2, evaluate adaptation measures and options for the proposed water supply and sanitation (WSS) project in conjunction with the executing agency, technical assistance team economist, WSS engineer, and poverty reduction expert to provide an economic assessment of adaptation options and to define co-benefits for other aspects of development.
(iv) Organize a second consultation meeting with the project executing agency and other stakeholders to seek agreement on prioritized adaptation measures to undertake during project implementation.
(v) Incorporate selected adaptation priorities into the project design, including institutional arrangements and budget.
(vi) Identify any additional capacity building required for the project implementation unit.
(vii) Identify indicators to monitor reductions in vulnerability and sustainability of adaptation measures in the context of the project implementation.

Final Outputs

1. Synthesis of the results from the impact assessment, vulnerability assessment, and economic analysis. Recommendations should be included in this report.

2. Adaptation strategy including prioritized adaptation options, implementation arrangements, implementation risks, training and capacity-building plan, budget, and input into the project design and monitoring framework.

Size of Contract: 1 person-months

Draft Terms of Reference for Economic Analysis Specialist

Objective of the Assignment

The overall objective of this study is to conduct a cost–benefit analysis or a cost-effectiveness analysis of the various technically feasible adaptation measures which may be implemented to climate proof the transport infrastructure under consideration. This study aims to inform project officers and policy makers with respect to the desirability (from an economic point of view) of investing into adaptation, and to assess and rank adaptation options with respect to their economic outcomes (using net present value as the preferred criterion to undertake this ranking).

Detailed Tasks and Outputs

Specific tasks and deliverables may be divided into two phases.

Phase 1: Assessment of Historical Records and Data and Design of Methodology

Tasks

(i) Prepare a detailed review of the relevant historical damage and loss data, especially those pertaining to direct damages to WSS infrastructure, indirect impacts resulting from the damaged WSS infrastructure, and repair costs.

(ii) Provide a list of alternative adaptation measures that may have already been undertaken and implemented for similar situations in the country, or are in the process of being designed and implemented, along with their expected impacts and costs. For this purpose, all available information from primary and from secondary data should be used.

(iii) Identify datasets that can be used to implement the objectives of the study.

(iv) Prepare a detailed framework (tasks, activities, responsibilities and time lines) for the successful implementation of the study.

(v) Prepare a report early in the study to identify possible means by which the expected impacts of adaptation measures may be modeled, along with their possible costs and benefits, and validate the proposed methodological approach and framework.

Final Output

A report covering in detail all of the above tasks.

Phase 2: Cost–Benefit Analysis of Adaptation Measures

Tasks

(i) Evaluate the effectiveness of the past and present adaptation initiatives with quantitative estimates (to the extent data allow) with notes on circumstances behind successes or failures of the initiatives.

(ii) Based on historical data and the study information, provide an estimate of the benefits and costs of adaptation for each possible adaptation measures.
(iii) Based on the outcome of the analysis, make recommendations pertaining to the adoption of adaptation measures in the context of the project.

Final Output

Analysis and report on the costs and benefits of potential adaptation measures to climate proof the road infrastructure of interest, along with recommendations for prioritizing the adaptation measures.

Size of Contract: 1 person-month

Guidelines for Climate Proofing Investment in the Water Sector
Water Supply and Sanitation

The provision of water supply and sanitation services is particularly vulnerable to projected changes in climate conditions (temperature and precipitation among others), in the frequency and intensity of extreme weather events, as well as and in the projected rise in sea-level and the intensification of storm surges.
The process of climate proofing investment projects aims both at assessing the climate risk to a project's future costs and benefits, and undertaking a technical and economic analysis of options to alleviate or mitigate those risks. Accounting for climate change at the outset of the project cycle implies that decisions about project design, and the adoption and timing of climate-proofing measures be informed with the possible impacts of climate change in the initial phases of the project cycle so that decisions of an irreversible nature will be avoided. This publication, Guidelines for Climate Proofing Investment in the Water Sector: Water Supply and Sanitation, presents a step-by-step methodological approach to assist project teams in managing climate change risk in the context of water supply and sanitation investment projects.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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