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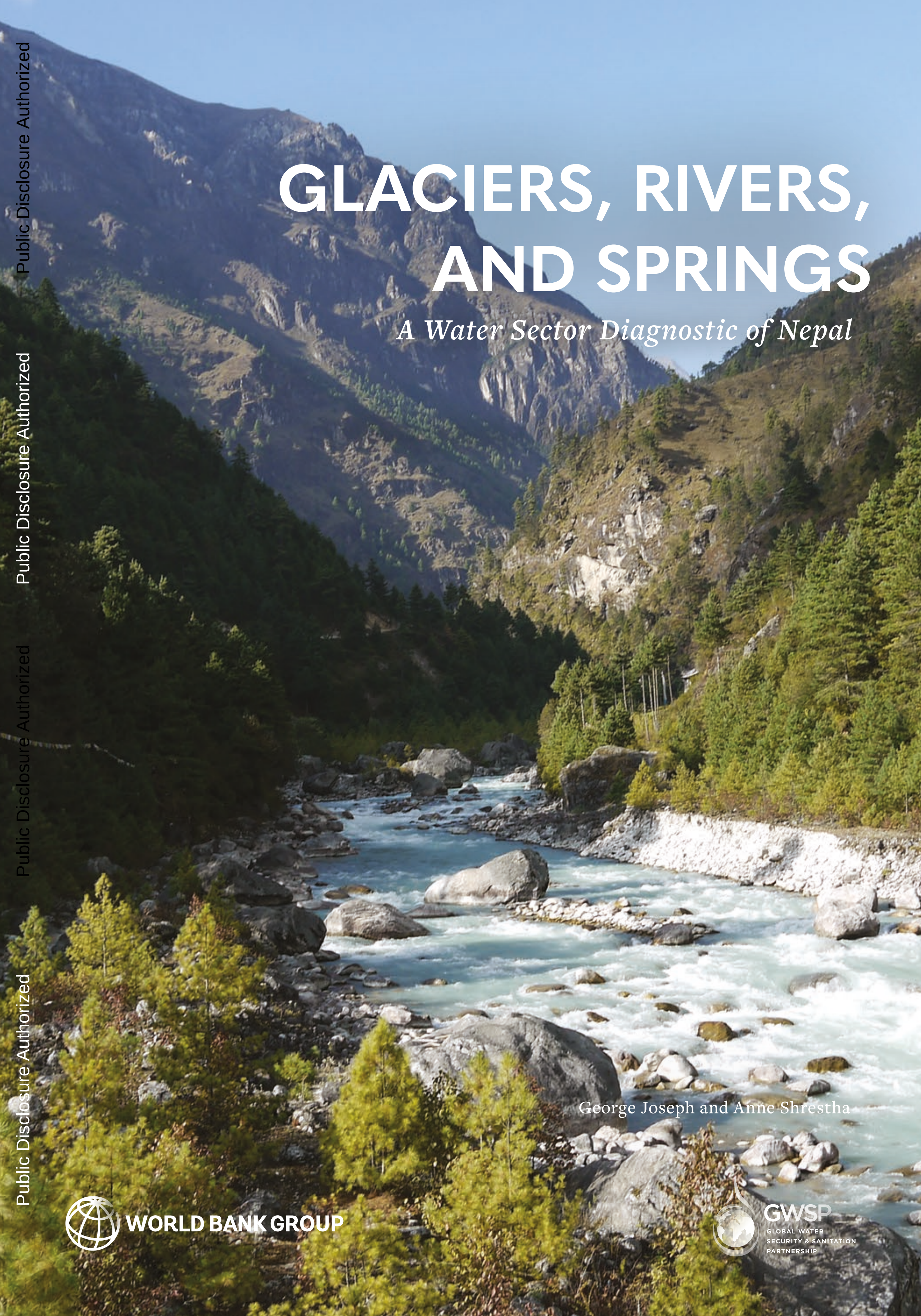

GLACIERS, RIVERS, AND SPRINGS

A Water Sector Diagnostic of Nepal

George Joseph and Anne Shrestha

WORLD BANK GROUP

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This publication received the support of the Global Water Security & Sanitation Partnership (GWSP). GWSP is a multidonor trust fund administered by the World Bank's Water Global Practice and supported by Australia's Department of Foreign Affairs and Trade, Austria's Federal Ministry of Finance, the Bill & Melinda Gates Foundation, Denmark's Ministry of Foreign Affairs, the Netherlands' Ministry of Foreign Affairs, the Swedish International Development Cooperation Agency, Switzerland's State Secretariat for Economic Affairs, the Swiss Agency for Development and Cooperation, and the U.S. Agency for International Development.

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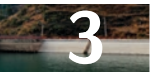
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Acknowledgments

This work was made possible with contribution by the Global Water Security and Sanitation Partnership (GWSP). This report was prepared under the guidance of Takuya Kamata, Practice Manager, World Bank Water, South Asia, as a knowledge product of the Nepal Water Platform.

We thank the Nepal Water Platform team members—Alex McPhail, Feriha Mugisha, Joep Verhagen, Lalima Maskey, Lixin Gu, Lilian Pena Pereira Weiss, Qiao Wang, Qiong Lu, Rubika Shrestha, Shyam KC, Suman Prasad Sharma, Xingchi Wang, Yi Rong Hoo— for substantial contributions and comments on several drafts. The International Institute for Applied Systems Analysis (IIASA) and Francis Gassert provided key analytic inputs on water balance and climate risk assessment, respectively.

We are also grateful for comments from colleagues beyond the team, including Andrea Kutter (Senior Natural Resources Management Specialist), Andrew D. Goodland (Program Lead), Bipul Singh (Senior Energy Specialist), Demetrios Papathanasiou (Practice Manager, Energy), Greg Browder (Lead Water Resources Management Specialist), and Pratibha Mistry (Senior Water Supply and Sanitation Specialist). We also thank our peer reviewers; Jonas Parby (Sr. Urban Specialist), Purna Chhetri (Sr. Agricultural Specialist), and Jason Russ (Water Economist) for their valuable comments, and Faris H. Hadad-Zervos (Country Director) for chairing the review meeting.

This document also benefited from consultations with several government officials and development partners. We are thankful for insightful comments on a draft from the Asian Development Bank (ADB), Ministry of Energy, Water Resources and Irrigation (MoEWRI), Ministry of Forests and Environment (MoFE), Ministry of Water Supply (MoWS), Ministry of Agriculture and Livestock Development, Embassy of Finland, Japan International Cooperation Agency (JICA), United Nations Children's Fund (UNICEF), and WaterAid.

Executive Summary

Nepal is rich in water resources with a dense network of glaciers, lakes, rivers, and springs that originate in the Himalayas. However, only an estimated 15 billion cubic meters (BCM) of the 225 BCM water available annually is utilized for economic and social purposes.[1] Several elements have contributed to this low rate of utilization, including Nepal's rugged geography, inadequate institutional capacity, a history of prolonged political instability, and highly skewed seasonality—more than 80 percent of the precipitation in a year falls within a span of four months. As a nascent federal state, Nepal has the potential to redraw its development trajectory, conditional on maintaining a stable political climate. Water lies at the heart of Nepal's main economic sectors, namely, agriculture and energy, and therefore is central to food and energy security. For sustained economic growth and poverty reduction, and to enhance shared prosperity, Nepal must increase its investments in water-related infrastructure and institutions and improve the effectiveness of these investments. These efforts are doubly important, and challenging, given Nepal's rapid urbanization and the growing climate crisis.

The national narrative on water resources development has prominently featured hydropower, but it is important for Nepal to plan for broader water security for its people and implement an integrated approach to water management. A public expenditure review showed that almost 38 percent of Nepal's water-related public expenditure in 2017 and 2018 was on hydropower. Although there is much to be done to harness this vital resource, it is important to broaden the development focus and integrate hydropower in a larger water resource management strategy. This strategy would ensure that water is available for basic and economic needs—even through the dry season—as a core component of Nepal's overall development plan.

Given Nepal's development context and challenges, this document aims to analyze the most pressing sector challenges and identify strategic sector priorities that are aligned with the country's partnership framework. It offers a snapshot of water in Nepal's development story and situates the water sector in the broader context of the national economy, highlighting the importance of managing water resources for sustained economic growth and poverty reduction. It then presents five pressing sector-related challenges and concludes with a set of priority areas.

Water and Nepal's Development Trajectory

With a stable, high gross domestic product (GDP) growth rate of more than 6 percent from 2017 to 2020, Nepal had shown promising signs of being on the path to escaping its high-remittance, low-growth trap. Despite growth in the service sector, exports, and tourism, Nepal still relies heavily on remittances, which have grown to about 30 percent of its GDP. Growth has been primarily consumption driven. Conditional on a more stable political climate, Nepal has the potential to increase domestic productive capacity, which can be catalyzed by investments in water sector development. However, as the COVID-19 pandemic unfolds, both remittances and tourism have been severely hampered, with dire economic consequences.

To meet Nepal's goal of reaching a middle-income status by 2030, the country needs to boost investments significantly by about 10 to 15 percent of its GDP annually through 2030 (Ezemenari and Joshi 2019). The country aims for rapid hydropower development as a part of that goal. However, the failures of the decade from 2008 to 2018 in the hydropower sector—as severe governance issues hampered the selection and execution of large civil works—highlight the importance of ongoing institutional reforms that could create the necessary enabling environment. Meanwhile, various crucial water-related investments outside of the hydropower sector are in need of as much attention and investments.

To improve competitiveness and create domestic jobs, Nepal needs to expand safe and reliable water supply for domestic, agricultural, and industrial use. Sanitation and wastewater services also need significant investments. The status quo is not conducive to growth and human capital development; the main hubs for nonfarm economic production like Kathmandu, Birgunj, and Biratnagar have extremely poor water, sewerage, and wastewater management. Most of Kathmandu receives about four hours of piped water supply per week, which obliges households and firms to bear significant costs for storage and alternative sources. The situation is comparable for other rapidly urbanizing cities. Agriculture continues to remain a gamble. Because of low adaptation to climate variability, it is common to find macroeconomic outlooks citing weather as the prime predictor of sectoral output: for example "assuming normal monsoons, agricultural growth is expected to average 4.4 percent" (Ezemenari and Joshi 2019, 2). Nevertheless, agriculture remains the major source of employment in the country, with most of the poor relying on it for their livelihoods. These realities signal the need to prioritize water management more holistically and broaden investments for human and economic needs.

What Are the Major Challenges?

The following five challenges capture some of the main hurdles in water-related service delivery and in harnessing water resources for Nepal's sustainable development.

Challenge 1: Service Delivery in Water Supply and Sanitation

Despite considerable progress over the decade, the relatively high access rates of technologically improved water supply and sanitation (WSS) do not meaningfully convey the status of their services in the country. One of the most salient problems in water service provision is the low degree of functionality of existing infrastructure, which has affected the adequate and reliable delivery of safe drinking water. A nationwide functionality study found that, of a sample of 41,205 piped water supply schemes, only 25.4 percent were described as well functioning and 31.8 percent did not have year-round supply (GoN 2014b).

Rapid urbanization is likely to worsen the pressures on water infrastructure. Kathmandu, the fastest-growing urban area and the biggest economic hub, meets less than 32 percent of demand in the wet season and less than 19 percent in the dry season (Udmale et al. 2016). Poor access to safe water and sanitation poses a major threat to health, especially during a pandemic like COVID-19. The condition is particularly worrisome for those many city residents who live in slums, where access levels are very low. This problem is not unique to Kathmandu. Although secondary towns fare better in terms of per capita water consumption and supply hours per day, their coverage rates are lower. The average nonrevenue water for the 26 cities assessed is about 40 percent, and none has a 24-hour water supply (GoN 2016a). Moreover, safe fecal sludge management and wastewater treatment is not commonly practiced in the country.

Poor water quality is a persistent problem. A nationally representative survey from 2019 estimated that the percentage of households with safe drinking water without *Escherichia coli* contamination was as low as 19.1 percent, a slight improvement from 14.5 percent in 2014.[2] In 2014, only 50 percent of the 26 urban utilities had a water quality monitoring system in place, and although all of them had chlorination units, their application and maintenance were irregular (GoN 2016a). The human capital costs of poor water supply, sanitation, and hygiene (WASH) are high, which is manifested in poor maternal and child health, with lasting consequences for the productivity and earnings of the next generation.

Challenge 2: Water Governance for Service Delivery and Integrated Management in a Federal Framework

In the new federal system, the Local Governance Operation Act 2017 places the responsibility for providing safe water, sanitation, irrigation, and disaster mitigation services with local governing bodies. Although the proximity of local authorities to citizens signals the potential for better accountability, the institutional vacuum left by the absence of local elections for over two decades (until 2017) suggests the need for building strong frameworks for accountability in the first place. Effective local governance would need significant support to build administrative capacity for service delivery and water resource management. The existing capacity at the federal level also needs strengthening, as evidenced by poor planning, chronic underspending, and the massive time and cost overruns of infrastructure projects.

The role that local governments will play in facilitating integrated water resource management or basin-scale planning is yet to be specified, but the requirement for greater coordination and conflict resolution is likely to be one of the biggest challenge. Coordination across subsectors like irrigation, water supply, and hydropower also calls for significant effort.

Challenge 3: Irrigation for Greater Agricultural Productivity and Food Security

Because agriculture constitutes one-third of Nepal's GDP and the largest portions of its formal and informal jobs, improving agricultural productivity remains a priority for both sustained growth and poverty alleviation. Despite its vast water resources, Nepal's rugged terrain allows cultivation of only about 24 percent of its total land area, of which 64 percent is considered suitable for irrigation. About 47 percent (1.1 million hectares) of the total cultivable farmlands are irrigated, of which less than half have year-round irrigation (GoN and ADB 2019; Pradhan and Belbase 2018).

Agricultural productivity in Nepal since the 2000s has remained nearly stagnant (Cosic, Dahal, and Kitzmuller 2017). The slow growth has been further threatened by extreme weather events and restricted by weak irrigation infrastructure, among other drawbacks. The dearth of year-round irrigation indicates the sector's low adaptive capacity to respond to normal climatic variations. Changing precipitation patterns induced by climate change, such as a delayed onset of the monsoon season, are becoming more frequent and have affected not only agricultural output but also child development indicators (Bharati et al. 2014; Tiwari, Jacoby, and Skoufias 2013). However, evidence from smaller-scale groundwater irrigation interventions in Terai indicates considerable scope for productivity growth and return on investment (ADB 2012).

Challenge 4: Building Resilience—Dealing with Climate Variability and Change

Human development and growth in all sectors hinge on climate adaptation to ensure that there is enough water through the dry seasons to drink, irrigate, and run businesses, industries, and hydropower plants. Nepal has yet to build resilience against normal annual climate variability, let alone long-run climate change. Evidence from regional studies has shown that sustained water shortages affect labor incomes, employment levels, and firm revenue (Damania et al. 2017; Desbureaux and Rodella 2019). This water insecurity is manifested in Nepal's energy insecurity and food insecurity.

Moreover, Nepal needs to focus on resilience against water-induced disasters that are predicted to become more frequent with climate change. Floods, landslides, and droughts have punctuated Nepal's development through setbacks to livelihoods and the economy. Without adequate adaptation measures to secure water needs and protect against hydrological disasters, Nepal could suffer significant economic losses by 2050.

Challenge 5: Transboundary Management

Cooperation and treaties between India and Nepal pertaining to water resources date back to the Exchange of Letters of 1920 with the then-British government in India regarding the Sarada Barrage project in the Mahakali River, planned for irrigation facilities in the adjacent states (Upreti 2006). Since then, four other agreements have been signed between the two riparian countries that have been politically contentious and inadequate in achieving the goals of either country. Both countries have expressed grievances regarding the management of transboundary issues. While initiating cooperation and addressing grievances will require dedicated efforts from both countries, Nepal needs to first develop a strong knowledge base and capacity for transboundary management. Since Nepal shares the basin with China and Bangladesh as well, their cooperation where relevant will also be important for adequate basin-scale planning.

Priority Areas

All things considered, Nepal is still at the initial stages of development, where it needs to work toward providing enough water, year-round, for human, economic, and ecosystem needs while addressing the growing necessity to build climate resilience. There is much to be done in practically every subsector; however, it is strategic to focus on the following six priority areas as first-order considerations for this decade. These priorities indicate the need for collaboration within the World Bank and externally with the government and development partners.

Strengthen state capacity and institutions

First, building state capability for strong governance deserves immediate and sustained policy attention and a multisectoral effort, especially across agriculture, energy, disaster risk management, and the environment. Budget execution rates have been low, indicating the need for substantial improvement in implementation capacity. Taking guidance from emerging evidence and assessments such as the Federalism Capacity Needs Assessment report (World Bank 2019a) Nepal should develop an implementation plan for strengthening water-related governance and service delivery, particularly at the local level.

Maintain Reliable Water Supply and Sanitation Services for Basic and Economic Needs

The need of the hour is to have enough water for human and economic needs. The lack and poor quality of services have enormous economic, environmental, and social costs for broad segments of Nepal's population. These costs are bound to be amplified by a crisis like COVID-19, especially in the major urban centers, which have some of the worst water supply infrastructure despite being the country's growth engines. The importance of ramping up investments in safe water and sanitation stands out in the context of this pandemic. Moreover, WSS is one of the fundamental subsectors in which local governments must be supported in managing public investments.

Smooth out Climate Variability for Water Security and Resilience

Although Nepal has begun to tackle the problem of climate extremes, the country still needs investments that will shield drinking water needs and economic activities from normal annual water variability. The evidence overwhelmingly points to the need for buffer mechanisms for the dry season, such as small-scale, localized storage and sustainable, multipurpose storage projects. For an integrated approach, this strategy needs to be complemented with watershed management and continued improvement in hydrological and meteorological (hydromet) systems.

Boost Agricultural Productivity to Promote Growth and Poverty Reduction

Although the Terai region is already home to most of Nepal's irrigation investments, it needs to focus on increasing year-round productivity and commercially viable farming that would be more conducive to greater economic growth. Expanding larger irrigation schemes as well as groundwater irrigation are important elements for this. Despite a gradual structural change in the economy away from agriculture, a large proportion of the poor remain reliant on small-holder farming. The farmer-managed irrigation systems that small farms depend on are weakening due these structural changes, driven by outward migration and urbanization. Therefore, to reach the poor and vulnerable who depend on subsistence farming, strengthening irrigation systems is an important issue.

Develop Strong Regulatory Institutions to Enable Effective Private Sector Investments

Given the massive investment needs and financing gap, private sector participation will have continued importance. Drawing lessons from Nepal's experience in public-private partnerships in municipal water supply and the hydropower sector, a politically independent regulator and strong contracting capabilities for the lifetime of projects constitute the minimum preparedness required for reliable and efficient private sector engagement.

Build Knowledge on Transboundary Collaboration for Resolving Issues in Irrigation, Energy, and Flooding

Continued efforts to build knowledge on transboundary cooperation are fundamental to enhancing basin-level planning and addressing riparian challenges. Water sharing, irrigation, and disaster management all rely on trust and understanding among riparian countries. Resolving these challenges based on sound evidence and coordination can significantly improve lives and livelihoods in the greater basin.

Notes

1. Based on a 2011 estimate (WECS 2011).
2. Based on Multiple Indicator Cluster Surveys (MICSs) 2014 and 2019 (CBS 2015, 2020).

Abbreviations

ADB	Asian Development Bank
BCM	billion cubic meter
COVID-19	Coronavirus Disease 2019
CPF	Country Partnership Framework
DALYs	disability-affected life-years
DPC	development policy credit
DRM	disaster risk management
EWSs	early-warning systems
FMISs	farmer-managed irrigation systems
GCM	global circulation model
GDP	gross domestic product
GoN	Government of Nepal
GW	gigawatt
GWh	gigawatt-hour
ha	hectare
hydromet	hydrological and meteorological
IFC	International Finance Corporation
IWRM	integrated water resource management

JICA	Japan International Cooperation Agency
LPCD	liters per capita per day
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoFE	Ministry of Forests and Environment
MWSP	Melamchi Water Supply Project
NEA	Nepal Electricity Authority
NRW	nonrevenue water
NWSC	National Water Supply Corporation
PPP	public-private partnership
SDG	Sustainable Development Goal
WASH	water supply, sanitation, and hygiene
WECS	Water and Energy Commission Secretariat
WRM	water resource management
WSS	water supply and sanitation
WUSCs	water users and sanitation committees

1

Introduction

Nepal is rich in water resources with a dense network of glaciers, lakes, rivers, and springs that originate in the Himalayas.[1] The country has a high level of annual water availability per capita but harnessing this has proved to be an uphill battle. Less than 10 percent of total water resources (15 billion cubic meters [BCM] out of 225 BCM available annually, as per available estimates from 2011) is utilized for economic and social purposes per year.[2] Several factors lie behind this challenge, including rugged geography, weak institutions, a history of prolonged political instability, and highly skewed seasonality (more than 80 percent of annual precipitation falls within a span of four months). As a result, precipitation patterns continue to define the rhythm of Nepal's main economic sectors, namely, agriculture and energy, and therefore, strong water management is central for its food security and energy security.

As a newly federalized country, Nepal has the potential to redraw its development trajectory, conditional on maintaining a stable political climate. Strengthening water resource management (WRM) and service delivery are strategic imperatives, but gaps are significant in every domain. An analysis of water security—which measured water availability across five dimensions (households, the overall economy, urban areas, the environment, and resilience)—ranks Nepal among the bottom five in all of Asia (ADB 2016). Nepal was deemed water insecure in each dimension; of a possible score of 20, it got 5.3 for households, 11.3 for the economy, 6.0 for urban areas, 10.7 for the environment, and 4.0 for resilience. Water plays a central role in achieving 15 of the 17 United Nations Sustainable Development Goals (SDGs) for 2030. Therefore, for sustained economic growth and poverty reduction and to enhance shared prosperity, Nepal must increase investments in water-related infrastructure and institutions, and improve the efficacy of these investments. These efforts are doubly important, and challenging, given rapid urbanization and the growing climate crisis.

It is critical for Nepal to adopt an integrated approach to water management with a broader focus on water security for holistic development, even though hydropower has taken center stage in the past couple of decades. Since the launch of the National Electricity Crisis Resolution Action Plan 2008, Nepal renewed its bet on hydropower, with its promise of relieving the country of debilitating electricity shortages[3] and making it energy independent and possibly even a net exporter. The electricity sector's performance improved from 2016, as a decade-long political and constitutional process came to an end. The improved management of existing generation, completion of domestic generation projects, reduced system losses, and increased electricity imports from India helped eliminate the nationwide load shedding and brought a decade-long electricity crisis to an end (appendix C).[4] However, the prospects for hydropower development over the medium and long term continue to be severely hamstrung by weak institutional capacity and regulatory barriers. Several current and proposed reforms now seek to address the barriers that the hydropower sector has faced since the 2000s.[5] These reforms are essential for Nepal. Yet, sustainable development will need adequate prioritization of other critical water uses as well. As the lessons from the Mekong basin (Intralawan et al. 2019; Jusi 2009, 2010; Matthews 2012) suggest, it will need the adoption of a holistic approach, which entails wider consideration of basic, economic, and ecosystem needs and the management of water-related climate risks.

Meanwhile, despite apparent progress—based on standard access measures—on the water supply and sanitation (WSS) front, millions of Nepali people do not have access to reliable, safe drinking water, especially in the dry winter months. Although 95 percent have some form of technologically improved drinking water within a 30-minute walking distance, fewer than 15 percent have drinking water that is free of bacteriological contamination (MoH, New ERA, and ICF 2017). Even the fastest-growing urban agglomerations such as Kathmandu, Birgunj, and Biratnagar—the main hubs for nonfarm economic production—have inadequate water, sewer, and waste management infrastructure, and though public investment in municipal infrastructure is growing, it remains insufficient (Muzzini and Aparicio 2013). Despite greater access to technologically improved sanitation, proper management of fecal sludge in both urban and rural areas is largely absent. These service delivery gaps have significant health implications for the population, manifested in the high stunting and anemia rates among children under five years of age (MoH, New ERA, and ICF 2017).

Agriculture continues to be a gamble, primarily because of the high seasonal variation of rainfall and limited expansion of reliable irrigation services. The coverage of year-round irrigation is low (39 percent of irrigated land as per the Irrigation Master Plan 2018) and concentrated in Terai. The contribution of value-added growth from the agriculture sector has remained below 1.4 percentage points since the 1970s, and many households continue to rely on subsistence farming, trapped in a vicious cycle of poverty (Cosic, Dahal, and Kitzmuller 2017). Competing water uses call for integrated management, which accounts for trade-offs. For equitable and adequate WRM and water utilization, the country must invest in ensuring year-round availability of water for domestic, industrial, and agriculture uses and in meeting the demands of ecosystem services.

This document aims to identify strategic sector priorities—aligned with the Country Partnership Framework (CPF)—given Nepal's development context and challenges. It considers all water users and uses necessary for a stronger economy, healthier people, and sustainable ecosystems. Using evidence from literature, analyses, and consultations, this document highlights the most pressing sector-related challenges that merit the focus of the World Bank and development partners.

The rest of the document is organized into three sections. The first section gives a snapshot of Nepal's development and situates the water sector in the broader context of the national economy, highlighting the importance of managing water resources for sustained economic growth and poverty reduction. The next section expands on five pressing water sector challenges. The document concludes with a set of priority areas in the sector for this decade.

Notes

1. Situated at the headwaters of the Ganges basin, more than 6,000 rivers originate and flow through Nepal. On aggregate, annual averages show that Nepal has one of the highest water availability levels per capita in the world, at about 7,000 cubic meters.
2. Based on an estimate from WECS (2011).
3. The decade-long electricity crisis that ended in 2015 cost the economy up to 7 percent of its gross domestic product annually (Timilsina, Sapkota, and Steinbuks 2018). The government came up with the National Electricity Crisis Resolution Action Plan 2008 to drive up generation by 10 gigawatts.
4. Domestic hydropower generation increased by about 72 percent from 2008 to 2020, though ending the electricity crisis took an upsurge in imports of more than 500 percent and a reduction in transmission and distribution losses of more than 10 percentage points. This information is based on data obtained from hydropower generation summaries from the Nepal Electricity Authority Annual Reports 2016/17, 2017/18, and 2018/19 (NEA 2017, 2018, and 2019). In 2008, domestic generation was 2,752 gigawatt-hours (GWh) and imports were 425 GWh. In 2019, domestic generation was 4,728 GWh and imports were 2,813 GWh. Domestic hydropower generation includes NEA production and purchases from independent power producers. A complete timeline is available in appendix C.
5. The World Bank's Development Policy Credit (DPC) for the energy sector aims to reform institutions including the NEA.

2

Where Are We? Water and Nepal's Development

This section briefly discusses Nepal's development context and situates the role of the water sector in its economy.

Legacy of a High-Remittance, Low-Growth Trap

Nepal was in a low-growth trap for more than a decade, with an average GDP growth rate of 4.4 percent between 2007 and 2017, mostly attributable to growth in the service sector. There are welcome signs of the economy benefiting from the peace dividend and subsequent political stability. Economic growth picked up to more than 6.0 percent per year until 2020, when the 2019 coronavirus (COVID-19) was designated a pandemic, but primarily driven by consumption instead of investments. Contributions to growth from agriculture and industry have remained stagnant (Cosic, Dahal, and Kitzmuller 2017). Instead, information and communication technology and tourism have emerged as significant contributors to economic growth. Political instability has been a driving factor of Nepal's economic woes; as an example, the country went through 22 governing coalitions in 26 years.[1] The problems of its economy are manifest in the plight of droves of labor migrants who have left in search of livelihoods abroad; between 2008 and 2017, Nepal issued 4 million labor permits for outbound migration.[2] Most of the poverty reduction that occurred between 1995 and 2011 is attributable to the rise in labor migration that resulted in more remittance transfers and higher labor incomes. Remittances have grown to about 30 percent of GDP, the fifth highest remittance-to-GDP ratio in the world, and this steady flow of foreign exchange allows Nepal to rely heavily on imports from other countries. However, remittances have suffered because of the COVID-19 pandemic, as have tourism earnings, leaving Nepal exposed to economic decline. Nevertheless, conditional on a more stable political climate, the country can take the right steps to lessen the blow of the crisis. Its medium-term transition to productivity-led growth can partly be driven by coordinated investments in water-related infrastructure, in addition to the necessary crisis response.

Investments in Hydropower

For Nepal to meet its goal of reaching a middle-income status by 2030, it needs to boost investments significantly—by about 10 to 15 percent of GDP annually through 2030 (Ezemenari and Joshi 2019). The country aims for rapid hydropower development as a part of that goal.[3] As of 2019, pipeline investments in hydropower totaling at least 2.6 gigawatts were under construction—worth about 13 percent of GDP[4]—and at least another 2.8 gigawatts were awaiting financial closure.[5] If the projects already under construction successfully come into operation, it would increase generation capacity twofold, and if all pipeline projects go through, this would mean a fivefold increase. Increased electricity availability would also mean a better balance of payments through decreased oil and electricity imports. However, the lessons since the 2000s—on why the subsector has failed to thrive despite of all the planning and resources that has been dedicated to it—highlight the importance of the ongoing institutional reforms that could create the necessary enabling environment. These reforms will be crucial for improving planning and implementation capacity. Alongside hydropower, several other water-related investments are necessary to boost growth.

Water Supply and Sanitation Services Insufficient for Human or Economic Needs

To improve competitiveness and create domestic jobs, Nepal also needs to expand safe and reliable water supply for domestic, agricultural, and industrial use. The country faces major challenges in providing WSS services in both rural and urban areas. Although some small towns are making laudable progress on water supply and fecal sludge management in particular,[6] larger urban areas continue to suffer despite their outsized role in economic growth. Kathmandu has the worst municipal water infrastructure in terms of supply hours, and public investment in municipal infrastructure has been shown to be biased against the city (Muzzini and Aparicio 2013). Based on one study, households in the capital received only about four hours of water supply per week in 2015, on average (Shrestha et al. 2017). Urban residents increasingly rely on underregulated groundwater and tanker water with uncertain quality. In rural areas, the functionality of water schemes is low because of prevailing institutional and financial constraints. The lack of water supply on household premises, poor access to safe water in crowded urban spaces, and reliance on public taps means that Nepali people face a higher risk of exposure during public health crises such as the COVID-19 pandemic. Sanitation services have been improving, but only 7 percent of the national population has access to a private sewer connection (MoH, New ERA, and ICF 2017). Wastewater management is practically nonexistent in urban areas. Safe fecal sludge management is relatively absent, with serious public health consequences.

Nepal's Human Capital Index estimates that a child born in Nepal today will be only 49 percent as productive when she grows up as she could have been if she enjoyed a complete education and full health care (Ezemenari and Joshi 2019). In a scenario in which all Nepali children receive full education and good health services, Nepal's GDP could be as much as two times larger than the GDP under the status quo scenario. Realizing the full potential of the country's human capital would require a sharp reduction in stunting, which is as high as 36 percent based on the 2016 Demographic and Health Survey estimates (MoH, New ERA, and ICF 2017). Although data and evidence are sparse on the costs to economic growth of poor water supply, sanitation, and hygiene (WASH), the additional expenditure that households and businesses make to gain access to safe water indicates that the poor quality of services has considerable direct and indirect toll on the economy.

Poverty Reduction and GDP Growth Hinge on Agricultural Productivity Growth

The agriculture sector remains responsible for the largest share of the GDP (27 percent) and of formal jobs (22 percent), based on the Nepal Labour Force Survey 2017/18 (CBS 2019). If we are to include employment in informal and subsistence agriculture, then its share of jobs rises to about 65 percent.[7] With nearly 40 percent of the labor force trapped in subsistence agriculture, sustained poverty alleviation needs improvements in agricultural productivity and farm incomes. This, among other factors, hinges on consistent and reliable water for irrigation and adequate conservation of forests and watersheds (World Bank 2019e), which are key determinants of water availability, especially in the mountain regions.

In a largely agrarian economy such as Nepal's, adequate water provision requires expanded and reliable irrigation facilities, implemented in tandem with complementary agricultural and watershed interventions. There has been little improvement in the productivity of agriculture since the 1970s. It is common to find macroeconomic outlooks citing weather as the prime predictor of sectoral output: for example, "assuming normal monsoons, agricultural growth is expected to average 4.4 percent" (Ezemenari and Joshi 2019, 2). This goes to show the extent to which the economy is exposed to climate shocks because of the lack of water storage and distribution infrastructure to buffer against intraannual climate variability. As highlighted in a 2017 macroeconomic report (Cosic, Dahal, and Kitzmuller 2017), reforms are needed in the agriculture space to alleviate poverty, improve productivity, and release the labor force to leverage new sources of growth.

Notes

1. From 1990 to 2016 (see Jha 2016).
2. Based on the National Migration Report (MoLESS 2020).
3. The government of Nepal announced its plan in 2016: National Energy Crisis Reduction and Electricity Development Decade 2016–2026 (GoN 2016c).
4. Assuming US$1.5 million per megawatt, at 2019 GDP for US$29.8 billion (nominal).
5. The Nepal Electricity Authority Annual Report 2018/19 (NEA 2019), regarding independent power producer and NEA projects under construction as well as pipeline projects.

6. Based on ADB's Small Towns Water Supply and Sanitation Project reports: https://www.adb.org/sites/default/files/evaluation-document/614201/files/pvr-688.pdf.
7. Based on the 2008 Labor Force Survey (LFS), which includes subsistence agriculture workers as part of the labor force. They are not included in the 2018 survey (CBS 2008, 2019).

3

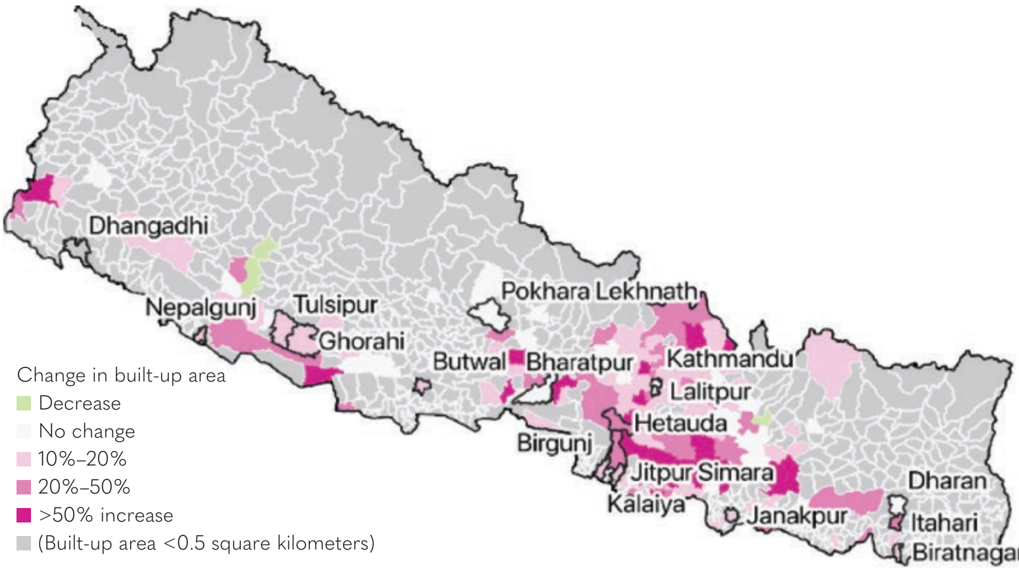
What Are the Challenges?

The following five challenges capture some of the main hurdles in water-related service delivery and harnessing water resources for Nepal's sustainable development.

Challenge 1: Service Delivery in Water Supply and Sanitation

As the coronavirus disease 2019 (COVID-19) pandemic spreads across the world, Nepal, like many other developing countries, is faced with the hard reality that a significant portion of its population is unable to follow the basic guidelines for pandemic prevention, such as handwashing and social distancing. Those who live in crowded slums with poor access to water and sanitation and those who rely on public taps for water are invariably more vulnerable. Developing water supply services to provide sufficient clean water throughout the year for basic human and economic needs is an indispensable part of the development process. Quality, quantity, and reliability of drinking water supply are significant challenges in both rural and urban areas. By the Sustainable Development Goal (SDG) basic standard, 95 percent of Nepal's population has access to technologically improved sources of drinking water, of which 31 percent have piped water within premises (MoH, New ERA, and ICF 2017; GoN 2019). The access figures are comparable between rural and urban areas. However, these statistics do not meaningfully convey the status of water services in the country.

MAP 3.1 Greatest Absolute Increases in Built-Up Areas, Kathmandu and Surrounding Districts, 2000–14



Source: World Bank Cartography Unit, using World Bank (2019f and Pesaresi et al. 2015).

Low functionality, limited quantity and reliability

One of the most salient problems in water service provision is the low functionality of existing infrastructure, which has affected the adequate and reliable delivery of drinking water. A nationwide functionality study found that in a sample of 41,205 piped water supply schemes, only 25.4 percent were described as well functioning and 31.8 percent did not have year-round supply (GoN 2014b). Most needed major repair, rehabilitation, or reconstruction or were beyond repair. About 20 to 25 percent of the water sources in the rural midhills have dried up since 2000, with disproportionate effects on low-income households and women, on whom the burden of water collection falls more heavily (Gurung et al. 2019).

In urban areas, an official report on the 26 biggest urban utilities showed that on average, supply hours vary from 2 to 12 hours per day with an average of 6.5 hours per day (GoN 2016a, figure 3.1). However, in some of the largest cities, such as Kathmandu, an estimate showed that water is supplied intermittently, for only one to four hours over a period of three to six days (Udmale et al. 2016). Similarly, another study estimates about 4 hours of water supply per week, which was further reduced to 2.3 hours after the April 2015 earthquake because of the damage sustained to pipe infrastructure (Shrestha et al. 2017).

Rapid urbanization is likely to worsen the pressures on water infrastructure. Whereas Nepal is one of the 10 least urbanized countries in the world, it is also one of the top 10 fastest-urbanizing countries (Bakrania 2015). The greatest absolute increases in built-up areas are around Kathmandu and surrounding districts (Pesaresi et al. 2016; map 3.1).[1] The severe water deficit in Kathmandu has meant that there isn't sufficient water to meet the demands for basic needs and less for industries, businesses, and agriculture. The average domestic water consumption in Kathmandu was found to be 36.9 ± 11.1 liters per capita per day (LPCD; Pasakhala et al. 2013), which is well below the 50 LPCD recommended as the minimum water requirement for basic needs (Gleick 1996) and the 135 LPCD that the government aims to provide (Udmale et al. 2016). (See box 3.1 for details on the valley and the Melamchi project intended to increase supply.) On aggregate, the deficit is so severe that water supply is reported to meet less than 32 percent of household demand in the wet season and less than 19 percent in the dry season (Thapa et al. 2018). This finding is corroborated by official statistics on the 26 largest urban utilities, where the capital places last in terms of per capita water consumption (GoN 2016a).

BOX 3.1 State of Water Service Delivery and Cost of Shortages in Kathmandu

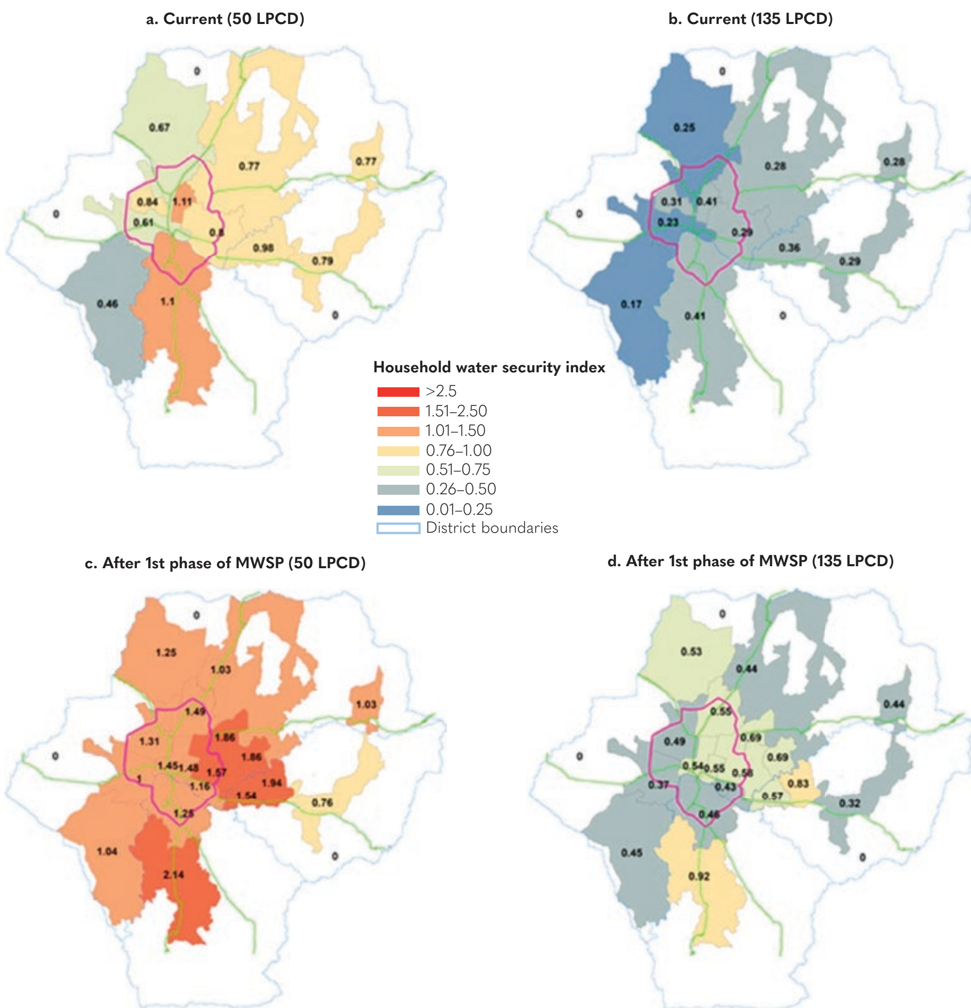
Kathmandu, the densest and fastest-growing urban center in Nepal, has about 200,000 household connections and a coverage rate of 80 percent (GoN 2016a). By comparison, the second-largest city, Pokhara, has about 36,000 connections and a coverage rate of 70 percent. The capital's water utility (Kathmandu Upatyaka Khanepani Limited) meets about 31 percent of water demand in the wet season and about 19 percent in the dry season (Thapa et al. 2018). On average, water supply is reportedly available for only four hours a week, although official statistics claim two hours per day (Shrestha et al. 2017). A major project under way since the early 2000s, the first phase of the Melamchi Water Supply Project (MWSP), would alleviate some of the shortage for basic water needs. Yet it would still leave a considerable gap vis-à-vis the 135 LPCD requirement, with significant disparities across the valley (Thapa et al. 2018; map B3.1.1). However, in 2021, demand is estimated to outstrip supply even in the baseline scenario, after the completion of phase 1 of the MWSP as water demand is projected to rise by 31 percent by 2021 compared with 2016 (445 million liters per day; Udmale et al. 2016. Building on prior work (Thapa et al. 2018) the Kathmandu Valley Water Supply Management Board (KVWSMB) is in the process of conducting a comprehensive water security mapping for the whole valley that is expected to shed light on the extent of the need and potential sustainable interventions. Municipal spending is extremely low and biased against Kathmandu, but it deserves greater attention because it is the biggest economic hub and the fastest-growing agglomeration that pulls in the most domestic migrants (Muzzini and Aparicio 2013).

Alternative sources—such as rainwater, tubewells, tanker water, public taps, private storage, and informal water markets—and limiting consumption have been the main coping mechanisms. This scarcity has driven households to pump groundwater, which is reported to have high levels of arsenic, ammonia, iron, nitrates, and *E. coli* (Muzzini and Aparicio 2013). A survey of 120 water vendors and 1,500 households shows that less than 20 percent of the population in the Kathmandu Valley receive reliable drinking water supply (Raina et al. 2019). The survey finds a heavy dependence on informal water service providers for domestic needs and that the national law requiring licensure for commercial water vendors was not enforced. In the dry season, consumers paid up to 3.4 times the price of public piped water to buy water from informal vendors (Raina et al. 2019). In addition to purchasing costs, households bear further costs of coping, such as collecting from multiple sources, pumping, treating, and storing. These costs can amount to as much as twice the monthly water utility bills (Pattanayak et al. 2005). This finding reveals not only the significant economic costs of water scarcity but also the high revenue potential associated with improved public service delivery of water.

(continued)

BOX 3.1 ***(continued)***

MAP B3.1.1 Household Water Security Index, MWSP, Current and after First Phase



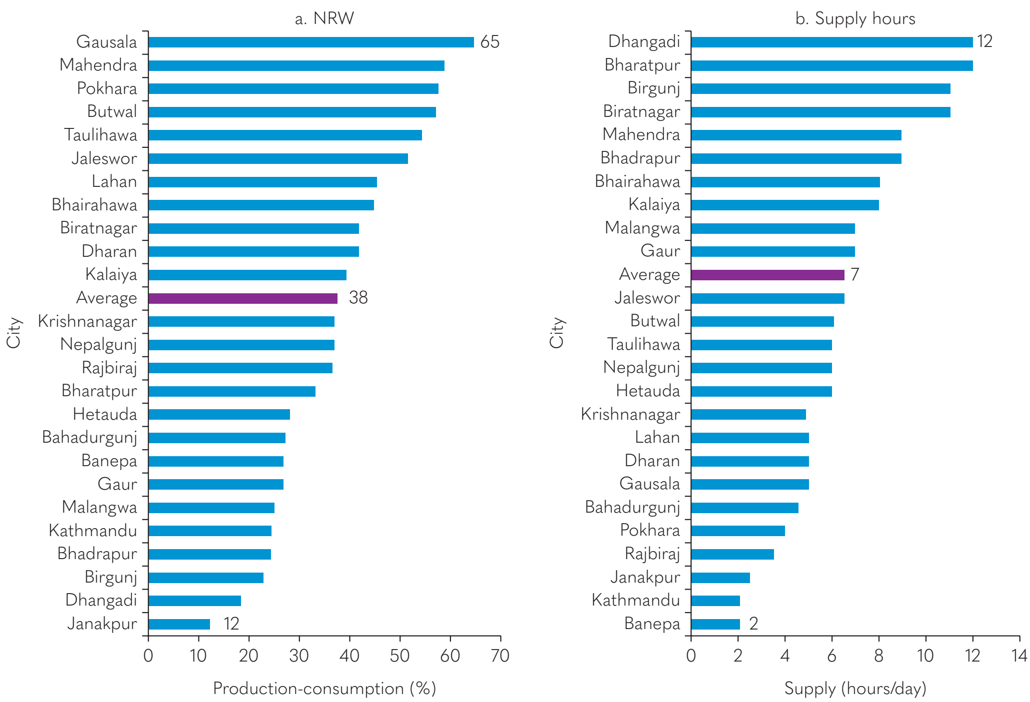
Source: Thapa et al. 2018

Note: LPCD = liters per capita per day; MWSP = Melamchi Water Supply Project.

But this problem is not unique to Kathmandu; although secondary and smaller towns fare better in terms of per capita water consumption and supply hours per day, their coverage rates are lower. The National Water Supply Corporation (NWSC) has been providing water supply services in 22 urban areas outside the Kathmandu Valley. As the populations in towns have grown rapidly, NWSC has been confronted with institutional and management capacity constraints to meeting growing water demands. The draft Urban Water Supply and Sanitation Sector Policy 2014 (drafted by the Ministry of Urban Development) lists several problems facing urban utilities: poor supply coverage, low supply pressure, intermittent supply, poor water quality, high levels of nonrevenue water (NRW), and low customer satisfaction (GoN 2016a). The average NRW for the 26 cities assessed is about 40 percent, and none of them has 24-hour water supply (figure 3.1). Water service providers across all provinces are operating on decreasing returns to scale; on average, resources are spent at 63 percent efficiency (World Bank 2019b). Policy interventions to address these infrastructure constraints in Nepal's strategic urban growth centers will also be important for industrial expansion.

The poor quality of service delivery has driven households to rely on other sources, such as rainwater, tubewells, and informal water markets, and to limit water consumption to a basic minimum. However, coping measures tend to be different for lower-income households that cannot afford expensive vended water, own large water storage tanks, or use a rainwater harvesting system. Poorer households tend to spend more time collecting water from different sources and to reduce water consumption further by limiting usage to drinking, cooking, and basic hygiene, as well as reusing gray water generated from laundry, bathing, and dishwashing (Pasakhala et al. 2013). This practice carries health risks, highlighting the need for targeted interventions to improve equitable and inclusive service delivery. So far, the government's efforts have not reached the bottom quintiles of the income distribution as much as the top ones. An analysis of public expenditure in the water sector shows that the benefits of government spending on WSS services have been regressive (World Bank 2019b). The bottom 20 percent of the population (in terms of wealth distribution) received only a 12 percent and an 11 percent share of the benefits of sewer connections and piped water, respectively, whereas the top 20 percent received 33 percent in each category.

FIGURE 3.1 NRW and Supply Hours, Nepali Cities, 2014–15



Source: GoN 2016a.
Note: NRW = nonrevenue water.

Poor water quality and its consequences

Another problem with water supply in Nepal is its poor quality. Only a small fraction of those with technologically improved sources have access to safe drinking water, devoid of bacteriological or chemical contamination. A nationally representative survey from 2019 estimated that the percentage of households with safe drinking water without *Escherichia coli* contamination was as low as 19.1 percent, a slight improvement from 14.5 percent in 2014.[2] In 2014, only 50 percent of the 26 urban utilities had a water quality monitoring system in place, and although all of them had chlorination units, their application and maintenance were irregular (GoN 2016a). Households invest in chemicals, ceramic filters, boiling, and reverse osmosis-ultraviolet water purification, among other treatment methods. One estimate shows that the monthly cost of treating 9 liters a day was about US$3.30 (380 Nepalese rupees) per household, which adds a significant burden for poor households (Shrestha et al. 2018). Geogenic contamination, primarily caused by arsenic, is prevalent in many regions. A blanket test carried out in 25 districts in Nepal, yielding about 737,009 samples of groundwater, found that close to 10 percent of the water samples had an arsenic concentration of more than 10 micrograms per liter, which is more than the permissible limit set by the World Health Organization (Thakur et al. 2011). Almost 2.6 million of the country's population across the 25 districts included in the study are at risk of exposure to arsenic through contaminated groundwater sources.

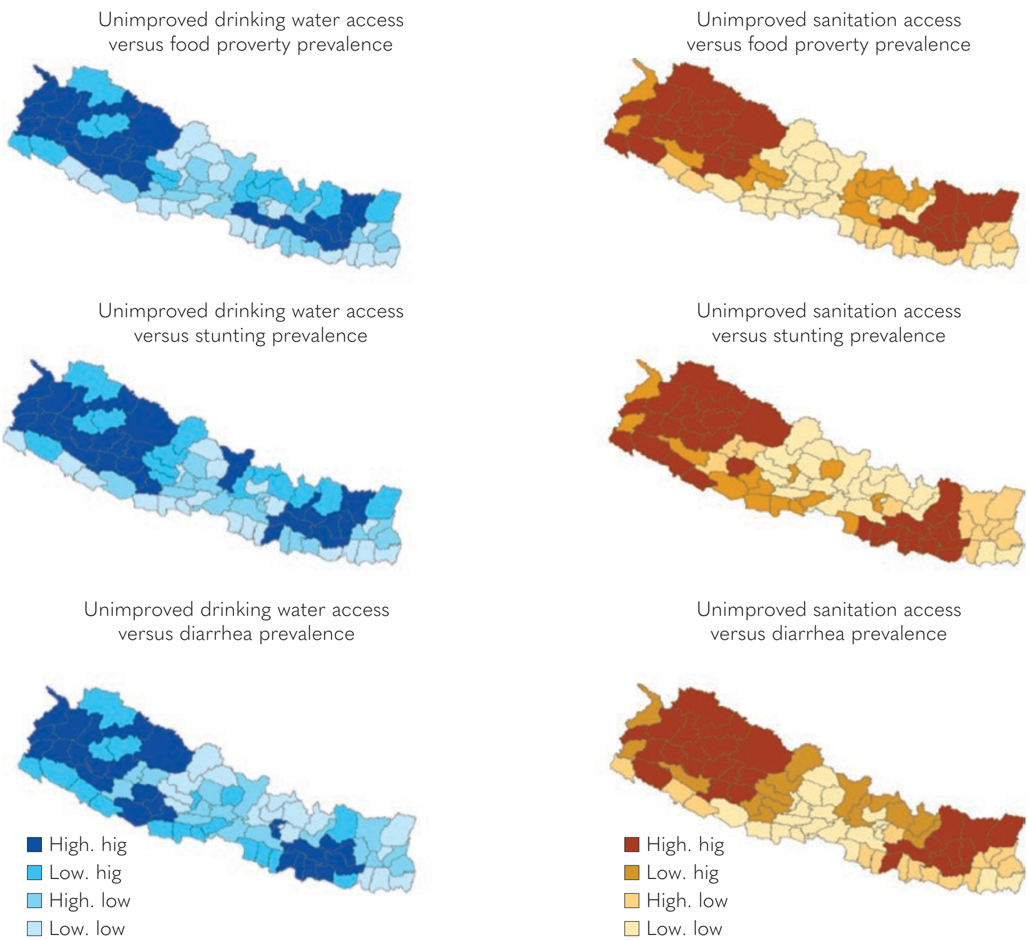
Inadequate sanitation and wastewater management

The shortage of clean water also impinges on the progress in sanitation and hygiene. Nepal saw a 45 percent increase in access to improved sanitation facilities from 2006 to 2016, based on data from the Demographic and Health Survey 2016, but the lack of adequate running water continues to be a barrier in reaping the full benefits of this improvement in sanitation. In 2016, 82 percent of the population had improved sanitation access, of which 7 percent were connected to a private sewer network, and 18 percent of the population still relied on unimproved sanitation, of which 16 percent resorted to open defecation. Having pushed through its mission to eliminate open defecation after the 2009 cholera outbreak, the government declared Nepal "open defecation free" in 2019, but experts agree that maintaining this status is a challenge (Rodriguez 2019).

Although Nepal envisions climbing up the sanitation ladder to increase private sewer connections, this will not be possible without adequate wastewater treatment. According to the WHO/UNICEF Joint Monitoring Programme (JMP) definition, safely managed sanitation should account for the proper treatment of excreta in-situ, off-site or through treated wastewater. Improvements in sanitation services will remain incomplete and ineffectual at improving health outcomes so long as proper fecal sludge and wastewater management are not implemented in both rural and urban areas. An estimated 42 percent of the urban population in Nepal have access to safely managed sanitation as of 2020 (WHO/UNICEF 2020). None of the municipalities, other than Kathmandu and Hetauda, have wastewater treatment facilities (GoN 2016a). Hetauda's facility is deemed to be nonfunctional, whereas Kathmandu has one functional facility out of four, which can handle less than 5 percent of the city's sewage, although a project to improve capacity to 80 percent is under way (ADB 2013). In rural areas, containment and safe disposal of fecal sludge need significant scaling up. It is estimated that only about half of the rural population in Nepal have access to safely managed sanitation as of 2020 (WHO/UNICEF 2020).

The human capital costs of poor water supply, sanitation, and hygiene (WASH) are high and are manifested in poor maternal and child health, with lasting consequences for the productivity and earnings of the next generation. In Nepal, 36 percent of children under the age of five are stunted. The poor are the worst affected; stunting among children from the lowest wealth quintile is 49 percent compared with 17 percent among the highest wealth quintile. Poor sanitation is also an important contributor to low hemoglobin and anemia in children under the age of five (Coffey, Geruso, and Spears 2017). Data from the World Health Organization attributes 310.2 disability-affected life-years (DALYs) to exposure to inadequate WASH in Nepal, comprising 3 percent of the total DALYs. Despite declines in WASH-attributable mortality, inadequate WASH remains an important determinant of the disease burden, especially among young children. One estimate shows that approximately 3,500 children die of waterborne diseases every year (Aryal et al. 2012). The incidence of high levels of food poverty, stunting, and diarrhea, which overlap with areas of widespread unimproved drinking water or poor sanitation access, is highest in the westernmost regions (map 3.2). Despite a sizable reduction since

MAP 3.2 Districts Vulnerable to High Levels of Food Poverty, Stunting, and Diarrhea with Unimproved Drinking Water or Poor Sanitation Access



Source: World Bank Cartography Unit using Haslett et al. (2014), and Nepal National Population and Housing Census (2011).

2006, inadequate WASH remains high; in 2015, direct economic losses resulting from forgone labor output were an estimated US$76.8 million, which represented about 0.4 percent of GDP including welfare losses. (Kaczan, Chen, and Arin 2019). With safely managed WASH as per SDG conditions, these costs could fall to less than US$3.0 million by 2030 (Kaczan, Chen, and Arin 2019).

Pending policies and legislation holding back progress

The legislation and policies necessary for the mandates of the Ministry of Water Supply (MoWS, formed in 2015, once a department under the former Ministry of Water Resources) have not been finalized, leaving considerable uncertainty among stakeholders in the sector, amid an ongoing federal transition. The GoN drafted a water sector development plan (SDP) for the period of 2016–30, which shows a US$10 billion financing requirement to achieve the SDGs (GoN 2016b). However, implementation modalities are unclear. WSS projects for populations larger than 1,000 will be under MoWS, whereas those smaller than that number will be under the Ministry of Federal Affairs and Local Development. The NWSC will be the operator of large urban schemes, whereas the operators for towns and rural schemes will be water users and sanitation committees (WUSCs). But the draft SDP gives WUSCs several overlapping roles (as the operator, service provider, regulator, monitor, fundraiser, and manager)—which, as global experience shows, is a recipe for poor performance and inefficiency—while leaving out details for integrating the role of municipal governments in WSS service delivery.

Persistence in patterns of social exclusion based on caste and gender

Despite significant progress, there are gender, caste, ethnicity, and locational disparities in the level of access to WSS services. The access rates for basic improved water, and basic water on household premises are lower in hill regions than the Terai (owing to the feasibility of tubewells in the plains), but within each region, the marginalized caste of Dalits have lower rates of access than other castes: only 54 percent of hill Dalits have access to basic water on premises, compared to around 60 percent or more for other hill castes and the national average of 70 percent (CBS 2020). The lack of proper monitoring systems and disaggregated data to fully capture the change in the livelihoods of women and marginalized communities is part of the challenge (Shrestha and Clement 2019).

Although caste-based discrimination has been outlawed, the concepts of purity, or the lack thereof, rooted in broadly adopted religious beliefs, continue to inform social norms on the rights and access of women and Dalits to water, which contribute in perpetuating legacies of poverty and inequality based on gender and caste. Traditionally, Dalits were considered too impure to be given access to public water taps used by "higher" castes. Although overt exclusion is less common today in fast-urbanizing spaces, such legacies continue in different forms, including in the inability of Dalits to obtain prior use rights like other groups (Shrestha, Joshi, and Roth 2020). In locations with increasing scarcity, quarrels or social conflicts over water rights are common (Goodrich et al. 2017). When compounded by the lack of economic, social, and political capital to invest in new infrastructure or negotiate for their rights, Dalits tend to lose out on existing access or on obtaining new sources of access (Shrestha, Joshi, and Roth 2020).

Their underrepresentation in water-related decision-making is part of the problem. Just a decade ago, as of 2011, a survey found that of the 1,511 employees of the Department of Water Supply and Sanitation, 94 percent were men, 2 percent Dalit, and 61 percent Brahmin/Chhetri, and there was no staff or structure with dedicated responsibility for gender and inclusion (ADB, DFID, and World Bank 2011). The GoN has since introduced gender and social inclusion provisions in the new Constitution and recent policies (such as the Irrigation Regulation 1999, National Sanitation and Hygiene Master Plan 2011, and draft WASH Sector Development Plan 2016–30), to increase representation and participation of women and marginalized communities in water-related decision-making, which continues to lag (Shrestha and Clement 2019; Goodrich et al. 2017). Though insufficient to date, relevant legal and policy measures and participatory planning are critical to combat issues that stem from entrenched patriarchal and caste-based norms.

Challenge 2: Water Governance for Service Delivery and Integrated Management in a Federal Framework

The water sector's governance requires substantial progress in institutional, policy, and legal aspects. Much of the legal framework necessary remains pending. The Water Resources Act and the Water Supply and Sanitation Act have yet to be finalized. Similarly, the corresponding policies and sector development plans have remained drafts for the past few years.

With the new federal structure, the roles and responsibilities of each tier of government have changed, though the transformation is not fully realized. The Local Governance Operation Act 2017 places the responsibility for providing safe water, sanitation, irrigation, and disaster mitigation services on local bodies, whereas the provincial and federal tiers of government are relegated to more of a planning and coordination role. How this will be merged with the previous acts—such as the 1992 Water Resources Act or the 1990 Nepal Water Supply Corporation (NWSC) Act, which grants authority over service delivery, human resources decisions, and asset ownership to water user committees and corporations—remains to be addressed.

Apart from these emerging legal challenges, Nepal faces three major institutional constraints: (1) low capacity for service delivery of local governments; (2) trade-offs in water allocation across subsectors; and (3) implementation of an integrated water resource management in a federal framework.

Low state capability for service delivery in a newly created administrative system

The federal transition poses both opportunities and challenges. The opportunities include added accountability and ownership at the local level—in program formulation, planning, design, implementation, and operation and maintenance (O&M)—because of reduced information asymmetries and proximity to the clientele. Among others, the challenges arise from the institutional vacuum and weak linkages of accountability left by the absence of local elections for almost two decades.[3] Overall, since the federal transition, the national and local governments were not able to spend a significant portion of the budgeted allocations primarily because of a lack of capacity (World Bank 2019a). Effective local governance would need significant support to build administrative capacity for service delivery and WRM. Box 3.2 illustrates this challenge for one newly formed municipality, Birendranagar.

BOX 3.2 Institutional Challenges of a Newly Formed Municipality under the Federal System

Birendranagar municipality, formed as a part of the federalization process, had a population of about 48,000 as of 2020. It is the planning authority for the water and sanitation sector within the municipality's borders and is still in the process of preparing its master plan. Moreover, the municipality plays the regulator's role concerning tariff issues. It collects some of its budget locally but relies heavily on transfers from the central government. It needs to coordinate with the provincial Infrastructure Development Directorate for resource allocation and monitoring. Located within the Surkhet Valley, its water supply and sanitation services are managed and operated by the Surkhet Valley Water Users Committee (SVWUC). It has a piped service for potable water, while sanitation services are at an early stage of development with individual septic tanks and fecal sludge collection. The water source is insufficient and features seasonal fluctuations, meeting only 50 percent of the design capacity during the dry season, resulting in low continuity of water supply, ranging from at the most three hours per day during the wet season to less than one hour per day in the dry season. It also has a high rate of technical nonrevenue water. Amid these service delivery challenges, these are some key institutional questions Birendranagar faces:

- *Status of SVWUC*. How can SVWUC's status change to move toward taking full responsibility of the development of the water supply and sanitation sector or will they integrate within the municipality that is now ultimately responsible for WSS delivery?
- *Funding of water supply and sanitation projects*. What is the best ownership, funding, and investment strategy for water source assets, considering the low level of funding capacity at the municipality level?
- *Access to additional water resources*. What are the most cost-effective solutions for augmenting bulk water supply to meet current and future domestic demand?
- *Nonrevenue water reduction*. What strategies can be implemented to reduce leakages?
- *Expansion of network and service*. How can coverage be improved for Surkhet residents while expanding the revenue base for financially sustainable operations?

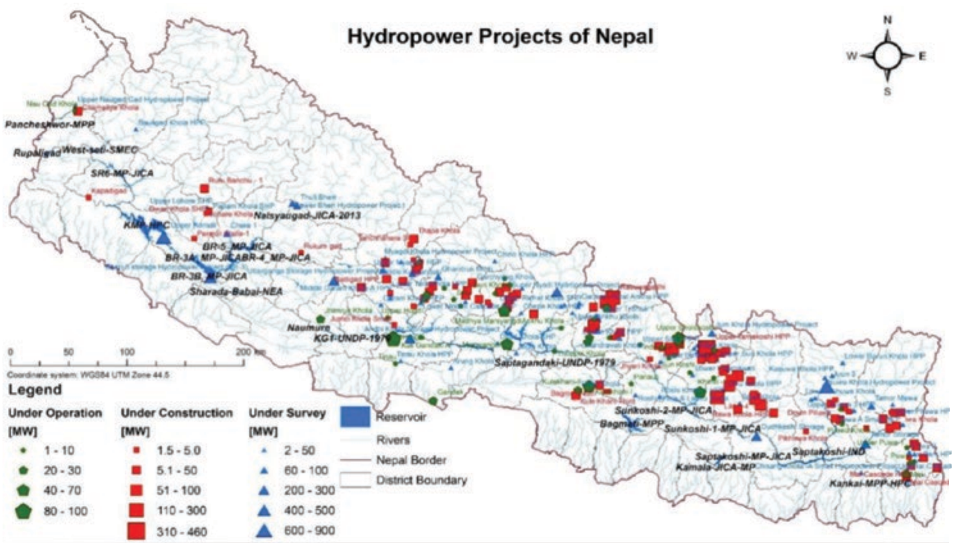
Source: World Bank 2020.

Strengthening state capability for water governance is key to reaching Nepal's service delivery goals. Poor regulatory, institutional, and policy frameworks are overarching factors that appear to drive poor functionality of water, sanitation, and irrigation services, as well as hydropower development. The degree of WSS nonfunctionality indicates a lack of adequate planning, oversight, and regulation and an absence of continued support systems to assist users' committees. The public expenditure review results show that water service providers in Nepal are operating on decreasing returns to scale (World Bank 2019b). On average, one-third of resources spent were lost through inefficiencies in fiscal year 2017/18 (World Bank 2019b). Moreover, there is significant underspending of the capital budget, averaging 70 to 80 percent of the amount budgeted in the WSS sector and about 7 percent in the irrigation sector (figure 3.2). This finding suggests a low absorptive capacity in the sector, compared to what is necessary for the implementation of investments. With local governments responsible for planning and implementation, and given their limited experience and capacity, these issues are likely to intensify without adequate support.

BOX 3.3 Governance Lessons from the National Electricity Crisis Resolution Action Plan 2008

In 2008, amid a debilitating electricity crisis, the Government of Nepal (GoN) attempted to bring in private investment for large-scale hydropower development. The National Electricity Crisis Resolution Action Plan 2008 aimed to build 10 gigawatts (GW) of hydropower generation capacity within 10 years. The former Ministry of Water Resources was split into the Ministry of Energy and Ministry of Irrigation soon after in 2009 (those ministries were merged into the Ministry of Energy, Water Resources and Irrigation in 2018; the Department of Water Supply and Sanitation, which was also under the same ministry, was turned into a separate ministry in 2015). Survey licenses were given away for 450 sites (ADB 2010), of which 292 are more than 1 megawatt, with little transparency regarding project selection or coordination with other water resource projects. (Map B.3.3.1 shows the array of hydropower plants under operation, construction, or survey as of 2015 across the country.) The 2008 plan barely reached 4 percent of its goal by 2018.

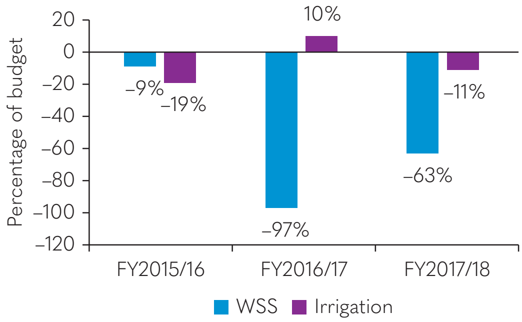
MAP B.3.3.1 Hydropower Plants under Operation, Construction, or Survey, as of 2014



Source: World Bank Cartography Unit using GoN (2014c).
Note: MW = megawatts.

The plan did not succeed in achieving its 10 GW goal primarily due to political instability and several institutional weaknesses, such as poor planning and a poor process for engaging private participation that led to stalled projects. The difficulty in attracting financing—because of the electricity utility's poor financial health and political risks—was also a major barrier. These governance lessons[5] provide important guidance for the government's current 10 GW plan, the National Energy Crisis Reduction and Electricity Development Decade 2016–2026 (GoN 2016c). The ongoing river basin master planning for hydroelectricity and the World Bank's Nepal Energy Sector Development Policy Credit Series aim to tackle many binding constraints to enable successful investments. However, these reforms will take time. In the medium term, the private sector will continue to face strong headwinds in mobilizing finance for larger projects, which puts the burden of undertaking larger projects—such as storage projects—on the public sector.

FIGURE 3.2 Underutilization of Budget Allocations, 2015–18



Source: World Bank 2019b.
Note: WSS = water supply and sanitation.

Massive delays in project completion and high time/cost overruns also indicate poor capacity and institutional weaknesses. The average time needed to complete an irrigation or hydropower project is 16 or 9 years, respectively (Cosic, Dahal, and Kitzmuller 2017).[4] The longest-standing projects in the construction phase in these sectors have been 38 or 18 years, respectively. As a comparison, construction time for smaller hydropower projects should typically take 9 to 18 months and for medium and larger ones, up to four years (IFC 2015). The MWSP for Kathmandu has been ongoing since 2001, which exemplifies the systemic delays that are pervasive across the sector. Cost overruns are also routine; the ratio is estimated to be approximately 1 to 4, on average, for planned to actual costs for large hydropower projects (Plummer and Guthrie 2016). None of the eight must-have institutional features of an effective public investment management system are present in Nepal (Plummer and Guthrie 2016). The missing features in Nepal include critical functions such as project selection, budgeting, project implementation, adjustment of projects in construction, and *ex post* evaluation. Building the institutional capacities for these functions is a necessary step toward better water governance.

However, the World Bank and donor engagement in the sector overall has largely focused on project implementation, and policy dialogue has been limited. (Development partner engagements are summarized in appendix A.)

Managing trade-offs among different uses of Nepal's water resources

Water resources have various competing uses and are important to several economic sectors. A successful hydropower sector is vital to Nepal, yet it is only one piece of the country's development puzzle. As the experience of the Lao People's Democratic Republic (PDR) shows, the country's ambitions to become the "battery of Asia" through the production of hydroelectricity for exports revealed significant institutional weaknesses (Greacen and Palettu 2007) with major effects on both economic and hydrological spheres (Intralawan et al. 2019; Jusi 2010). The country has since moved to adopt an IWRM strategy to improve WRM alongside hydropower development.

For Nepal too, there are trade-offs among different water uses, and the country stands to gain more from optimizing project selection and design so as to meet multiple objectives, accounting for the water-energy-food nexus, upstream-downstream linkages, and environmental flow requirements (Dhaubanjar, Davidsen, and Bauer-Gottwein 2017). Multipurpose water infrastructure has the potential to maximize overall resource use efficiency and productivity across sectors (Gyawali 2015). Unlike Lao PDR, Nepal is still in the initial phases of hydropower development and can prioritize hydropower investments based on an integrated approach. The efforts of the Water and Energy Commission Secretariat (WECS), which launched the river basin-scale master plan for water resource and hydropower development in 2018, is a promising step in the direction of integrated development (Lahmeyer International 2018).

Challenges to integrated management

IWRM or the nexus approach do not have institutional blueprints, and it is up to each country to shape it. In Nepal, IWRM has so far failed to gain enough momentum because of a power imbalance across ministries, despite its use as a guiding principle in water policy documents since 2005 (Suhardiman, Clement, and Bharati 2015). The most recent policy document that could shape IWRM in Nepal is the Water Resource Policy approved in December 2020, led by WECS. The federal and provincial governments have major responsibilities when it comes to integrated water management; however, the role the local governments will play to facilitate its operationalization, or basin-scale planning, is unclear. In practice, the requirement for greater coordination and conflict resolution is likely to be one of the biggest hurdles. Institutional and regulatory arrangements must be put in place for planning and implementation across administrative jurisdictions, ensuring economies of scale and scope and sharing of benefits.

The power imbalance among ministries could undermine integrated water management efforts in the absence of strategic interventions. Multiple ministries have sought to create basin-level authorities, although the most recent draft of the Water Act 2020 does not have provisions for the creation of any basin-level institution.[6] There are four river basin management offices in the major basins that focus on environmental conservation but their jurisdictions do not extend to water use or allocation. This suggests that bringing together all stakeholders, despite the approval of the National Water Resource Policy (GoN 2018a), will take significant efforts.

Although a major concern is that the federal tier may retain complete authority over water resources, compromising local governments' ability for service delivery, integrated water resources management invariably needs some level of central planning and coordination at the basin scale. Unless basin-level planning is supported by the upcoming Water Act, the question of how the GoN plans to operationalize integrated management of water resources remains to be resolved. River basin organizations could provide a good base in the short term for integrated planning in the sector. It is important to note that without incorporating the participation of provincial and local governments into basin planning, IWRM risks turning into the top-down but unintegrated process that federalization seeks to restructure, with serious implications for inclusion. When established, the rest of the government bodies involved must confer on the legitimacy of the new basin organizations or authorities, which will depend on coordination efforts to bring together local and provincial governments into the decision-making process. Without the representation of local and provincial voices in the basin units, the local governments will be rather powerless to use water resources to fulfill their mandates.

Moreover, operationalizing river basin planning through the various tiers of government in the new federal setup is a tremendous challenge for Nepal, because each basin has numerous municipalities (*palikas*) and is spread across provinces. For instance, 151 *palikas* share the Kosi basin alone. But without it, the business-as-usual development of water resources is at best suboptimal and at worst detrimental to sustainable development. WRM is not sufficiently coordinated. Licenses for hydropower, irrigation, and drinking water schemes are doled out without adequate planning and coordination. The project selection process for these licenses has remained opaque. Optimal water project planning and selection must consider the order and scale of projects catering to multiple water uses (upstream versus downstream). The River Basin Plans prepared by WECS and the 2019 Irrigation Master Plan, among others, recognize this need for coordination based on IWRM principles. The implementation of the plans, however, requires substantial effort from all stakeholders.

Integrated water management has been successfully tested on a smaller scale at the local level in rural areas through water use master plans (Water Resources Management Programme 2012). However, scaling up has been a challenge and will need considerable work across all levels of governance. There is an institutional and policy vacuum that needs to be filled to enable planning, service provision, benefit sharing, and arbitration across horizontal and vertical tiers of government. Large knowledge gaps exist regarding optimal development planning at the basin or subbasin levels and how these would affect the upstream and downstream municipalities. Moreover, integrated water management requires the GoN to identify and agree on a clear, evidence-based, and widely accepted rationale for prioritizing water use across water users.

Challenge 3: Irrigation for Greater Agricultural Productivity and Food Security

Because agriculture constitutes one-third of Nepal's GDP and a substantial share of the population depends on it for their livelihoods, irrigation development—its rehabilitation, revitalization, modernization, expansion, and management—is important for fostering agricultural productivity and economic growth. Irrigation is the single-largest source of water demand in Nepal, as is the case for primarily agrarian economies (World Bank 2019d). As it represents more than 80 percent of water demand, managing irrigation systems is integral to water resource management. Despite its vast water resources, Nepal's rugged terrain limits the share of arable land, which is estimated to be 3.6 million hectares (ha) (GoN and ADB 2019)—about 24 percent of Nepal's total land area. Of the total arable land, about 2.3 million ha is irrigable, which is about 64 percent of the total arable land and just 15 percent of the country. However, only about 1.1 million ha (48 percent of net irrigable land) is currently irrigated, of which 0.7 million (32 percent of net irrigable land) is under managed irrigation—farmer-managed irrigation systems (FMISs), agency-managed irrigation systems (AMISs), and joint-managed irrigation systems (JMISs). The shares of these break down to about 49 percent JMISs/AMISs and 51 percent FMISs (GoN and ADB 2019). Roughly 39 percent of the existing irrigated land has access to irrigation water around the year (GoN and ADB 2019; Pradhan and Belbase 2018).

Of the total irrigated land area, 59 percent uses surface water irrigation, 22 percent uses groundwater irrigation, and 19 percent uses both surface and ground water (GoN and ADB 2019). The Terai has the highest proportion of irrigable lands (65 percent), followed by hills (28 percent) and mountains (7 percent) (GoN and ADB 2019). There is considerable scope for the expansion of irrigation services in terms of both area and seasons. The lack of year-round irrigation, particularly in the Terai, is one of two binding constraints to productivity growth in the sector (Cosic, Dahal, and Kitzmuller 2017). The 2019 Irrigation Master Plan (IMP) aims to improve performance across 1.45 million ha of existing irrigated land and 1.18 million ha of new irrigated land over the next 25 years. Building capacity across the three tiers of government for managing irrigation systems that follow IWRM principles is an important focus area that the IMP highlights (GoN and ADB 2019).

Productivity growth in the Terai

Agricultural productivity in Nepal has remained nearly stagnant since the 2000s (Cosic, Dahal, and Kitzmuller 2017). However, evaluation of smaller-scale groundwater irrigation interventions in the Terai shows considerable returns on investment. Households that used shallow tubewell irrigation earned three times more in net income because of higher yields and had a 26 percent greater cropping intensity than households that depended on rainfed agriculture (ADB 2012). Another study on the sources of growth in agriculture in Nepal showed that the highest return on investment in the Terai is for irrigation (World Bank 2016). Annual groundwater extraction for irrigation, domestic, and industrial use is estimated to be 1.9 BCM, whereas the total groundwater recharge is about 8.8 BCM, which indicates that there is significant room to expand groundwater use for irrigation (Nepal et al. 2021). Moreover, the means to extract groundwater are equally important, as reliable electricity distribution remains a challenge especially in rural areas. Exploring viable opportunities for productivity growth through better irrigation facilities will be important in Nepal's development efforts, particularly in the rural areas.

Subsistence farming and poverty

The centrality of agriculture to the labor force makes irrigation modernization and expansion essential to a strong poverty reduction strategy, along with complementary agriculture and environment interventions. Agriculture employs the largest share of Nepal's formal labor force (21 percent) and up to two-thirds of its combined formal and informal labor force (including subsistence agriculture).[7] It is crucial for household food security, more so in places where import markets for food are not well developed. The estimated incidence of poverty in irrigated areas is half that in rainfed areas, adding to the evidence base on irrigation's role in mitigating poverty (ADB 2005), although the strategies must differ by geographic region. Rainfall shocks—both dry and wet—affecting agricultural output are shown to reduce weight-for-height in children under the age of five (Tiwari, Jacoby, and Skoufias 2013), which research has shown to be a powerful predictor of low levels of educational attainment and earnings in the future. A study of food insecurity in the Terai, midmountain, and trans-Himalayan regions of the Kaligandaki basin showed that irrigation is a primary determinant of food security in all three ecological zones (Pandey and Bardsley 2019). It showed that more than one-third of the households had experienced food insecurity, and although the Terai region has the potential for alleviating this through a reliance on food markets, the remaining two ecological zones where food insecurity was greater have limitations because of the inaccessibility of markets or prohibitively high transport costs. In these regions, focusing on increasing local productivity through smaller-scale interventions in agricultural mechanization and irrigation, forestry, and watershed conservation remains the most sustainable solution. Forest and watershed conservation are indispensable for sustained water availability for irrigation, especially in the mountain regions. The relationship can go both ways; dry shocks and lack of irrigation can also lead to further deforestation and encroachment of wetlands (Damania et al. 2017).

Irrigation interventions targeted toward small-holder farmers and rural communities must consider the changes in the socioeconomic structures that are afoot. Traditional farming-based communities are changing because of the increased labor migration of mostly young men. This mass outward migration has had significant implications for FMISs, which make up about 70 percent of the total surface water irrigation systems in Nepal. Lower participation in FMISs has been associated with poorer management and rehabilitation. Traditionally, FMISs have outperformed centrally managed systems in terms of agricultural productivity, water distribution, fee collection rates, and overall system maintenance. However, FMISs and WUSCs that manage irrigation facilities need considerable institutional revamping in the wake of socioeconomic changes and federalization, because most rural households still rely on agriculture for food security (Pradhan and Belbase 2018).

Year-round irrigation

Investment in irrigation also stands to help Nepal achieve greater national food security through an increased capacity to buffer against dry shocks and other exogenous shocks such as pandemics that disrupt global supply chains. Nepal imports key crops such as rice and maize to meet domestic demand due to insufficient production. The sector has been further threatened by extreme weather events and restricted by weak irrigation infrastructure, among other drawbacks. The low prevalence of year-round irrigation indicates a low adaptive capacity of the sector to respond to climatic variations. Changing precipitation patterns, such as delayed onset of the monsoon season, are becoming more frequent and have further affected agricultural output in the country (Bharati et al. 2014). Farmers have reported delayed onset of the monsoon, fewer rainy days, but more intense rainfall over shorter periods. The winter droughts of 2008–09 in Nepal caused a significant drop in barley and wheat yields, putting nearly 2 million people in danger of food insecurity (Bharati et al. 2014). Direct losses resulting from climate change in agriculture are equivalent to about 0.8 percent per year of current GDP, and there will be a US$2.4 billion adaptation deficit by 2030 in three sectors, including agriculture (GoN et al. 2014). The losses are more severe in years of extreme rainfall variability and are expected to hit poor and vulnerable households the hardest, which is why irrigation, as part of greater water resource management, is integral to food security and poverty reduction strategies.

In the Agriculture Development Strategy 2015–2035 and the Irrigation Master Plan 2018, the GoN has included year-round irrigation as a part of its growth plan, along with improvements in crop fertilization and pest management. Improved water and irrigation management has the potential to save costs, increase productivity, and reduce water demand. However, for the protection of water quality, this approach should be coordinated with regulation of the use of pesticides and fertilizers, which usually follows the intensification of crop cultivation enabled by irrigation expansion (World Bank 2019a).

Challenge 4: Building Resilience—Dealing with Climate Variability and Change

The impacts of climate change are manifested primarily through water or the lack thereof. Whereas challenge 3 touched on the climate's role in agriculture, this section discusses projected climate risks and the need for a coherent climate strategy within water resource management in Nepal, focusing on adaptation and "no regret" investments.

Since the formulation of the Climate Change Policy in 2011, Nepal has made significant progress in mainstreaming climate change adaptation plans into sectoral plans and projects. The revised Climate Change Policy of 2019 has strategies and working policies for watershed conservation; water resources, energy, agriculture, and food security; WSS services; and disaster risk reduction and management (MoFE 2019). The National Water Policy 2020 and the National Policy for Disaster Risk Reduction (MoHA 2018) also address climate-change-related challenges. Coherent implementation of these policies calls for strong coordination between the Ministry of Forest and Environment, which oversees climate change policies and budgets, and other relevant ministries such as the Ministry of Energy, Water Resources and Irrigation (MoEWRI). However, the climate policies do not yet have a supporting legal provision to guide and enforce sectoral implementation. At this stage of development, there are two crucial aspects to building climate resilience in Nepal.

First, Nepal has yet to build resilience against normal annual climate variability. Managing water resources to smooth out fluctuations in water availability throughout the year is an imperative for reliable water supply for human and economic needs. Evidence from regional studies has shown that sustained water shortages affect labor incomes, employment levels, and firm revenue (Damania et al. 2017; Desbureaux and Rodella 2019). This water insecurity is manifested in Nepal's energy insecurity and food insecurity.

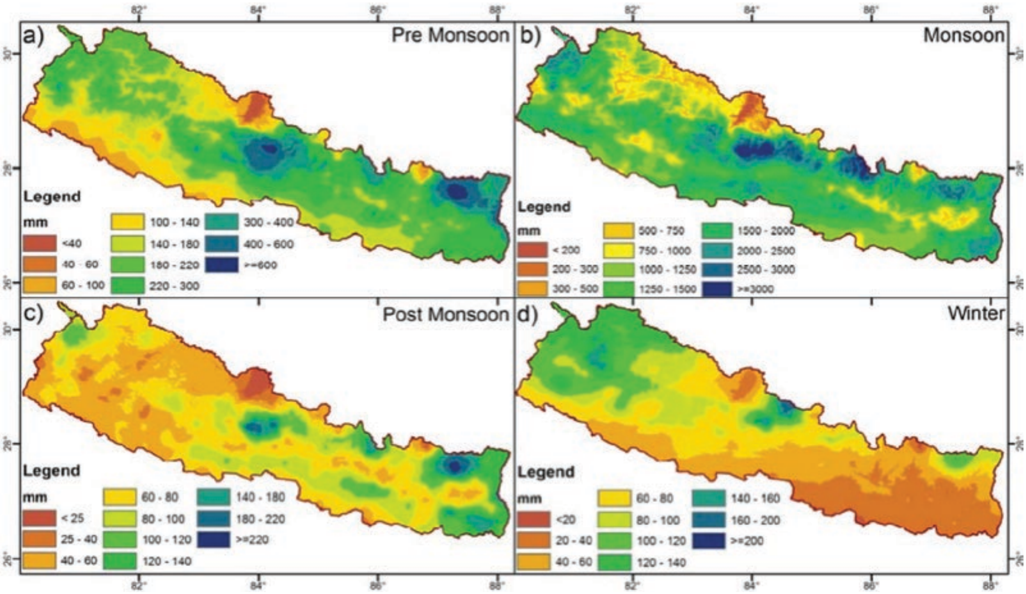
Second, Nepal needs to continue its focus on resilience against water-induced disasters that are predicted to become more frequent with climate change. In each of these types of resilience building, there are short-, medium-, and long-term efforts necessary to minimize social and economic losses. Without adequate adaptation measures, Nepal could face between 2 to 3 percent of GDP in average annual economic losses by 2050 across the three sectors (agriculture, hydropower, and disaster; GoN et al. 2014).

The following subsections explore how water resources fluctuate with normal climate variability, changing weather patterns from climate change, and climate extremes.

Climate variability: The norm

Normal space and time variations of water availability are high in Nepal. This implies higher costs and complexity for water infrastructure development. As discussed earlier, both water supply and agriculture suffer from inadequate year-round water availability. A cursory glance into Nepal's geography explains its climate variability. Situated at the precipice of the Himalayas, Nepal's climate swings from subtropical to alpine within a short breadth of about 180 kilometers. The dominating climatic feature, the monsoon, brings dramatic fluctuations in water levels throughout the year (map 3.3). The average annual precipitation is about 1,500 millimeters (mm), 80 percent of which occurs during the monsoon.

MAP 3.3 Annual and Spatial Distribution of Mean Precipitation, by Season, 1981–2000



Source: World Bank Cartography Unit using Karki et al. (2017).
Note: Legend scale adjusted to map.

In addition to temporal variation, the spatial variation ranges from about 250 mm per year in the northwest to 5,000 mm in the mideast (Shrestha and Aryal 2011).

Without the necessary infrastructure for buffer, this normal climate variation is directly passed on to every subsector with significant economic consequences. In hydropower, because most of the generation fleet is run-of-river type of plants, winter brings severe domestic electricity shortages, and a greater need for imports. In agriculture, it means the loss of productivity for winter crops and seasonal migration of labor. In WSS, it means fewer hours of water supply and taps that run dry. Adequate, sustainable multipurpose storage is an imperative for greater productivity and human development. Without it, the economy will continue to fluctuate with the vagaries of the climate. An analysis that assessed the direct economic costs of climate variability in Nepal for agriculture and hydroelectricity found high economic costs estimated at 1.5 to 2 percent of the 2013 GDP equivalent in an average year (approximately US$270–360 million/year in 2013 prices) and as high as 5 percent in extreme years (GoN et al. 2014). Indirect and macroeconomic costs are estimated to be 25 to 100 percent higher than direct costs (GoN et al. 2014).

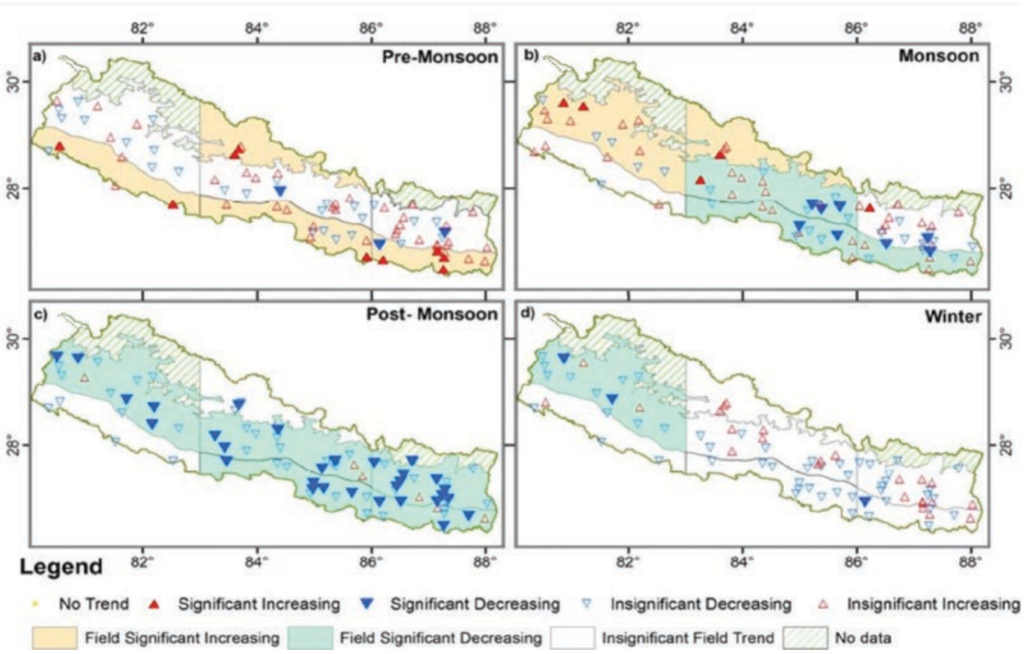
Climate change: The new norm

The science of how climate change will affect water availability and precipitation patterns, which has gained increasing clarity and certainty in recent years, is an unequivocal clarion call for action. Since 2019, two major studies (Bolch et al. 2019; Immerzeel, Lutz, and Andrade 2020) on precipitation and glacial melting have shown consistent results with serious policy implications for Nepal and the entire subcontinent. Decrease in snowfall, increased snowline elevations, and longer melt seasons are projected to cause a decline in glacier volumes by up to 90 percent by the turn of the century in the business-as-usual scenario, reducing an important contributor to dry season flows (Bolch et al. 2019).

Effects of climate change are already palpable in the increased temperatures (Eriksson et al. 2009), decreased winter season duration, increased frequency and length of droughts, and erratic rainfall patterns experienced in the country (Sharma and Dahal 2010). An analysis of precipitation data from 210 stations across Nepal between 1981 to 2012 shows a mixed pattern of increasing and decreasing trends across all seasons (map 3.4; Karki et al. 2017). The study notes a significant increase in 12 percent of the stations in the premonsoon season, mostly in the lowlands, but a significant decrease across all regions in the postmonsoon period (Karki et al. 2017) Post-monsoon precipitation, though low in volume, is vital for rain-fed winter crops. The study also finds high-intensity precipitation extremes, with a significant positive trend in the number of consecutive dry days and a significant negative trend in the total number of wet days (Karki et al. 2017).

Spring water in the midhills is what makes life possible for about 80 percent of the 13 million Nepalis who live there (CBS 2011; Sharma et al. 2016; Poudel and Duex 2017). Several studies have reported a significant decline in winter flows and the drying up of 15 to 30 percent of midhill springs (Agarwal, Agrawal, and Nema 2014; Negi and Joshi 2002; Poudel and Duex 2017; Sharma et al. 2016; Tambe et al. 2012). Moreover, climate impacts are projected to be more pronounced and varied at smaller scales

MAP 3.4 Significant Trends in Seasonal Precipitation Totals for (a) Pre Monsoon; (b) Monsoon; (c) Post Monsoon; and (d) Winter Season by Field Trend (significance at 0.1)



Source: World Bank Cartography Unit using Karki et al. (2017).
Note: Legend scale adjusted to map.

(seasonal and subbasin level) than at larger scales (annual and basin level)—which have significant policy implications for the scale of planning. Combined with the pressures of greater demand, the variability will be more conspicuous. The International Institute for Applied Systems Analysis's projections show that in the business-as-usual scenario, water availability in all regions is projected to decrease by 2030 and decrease further by 2050, meaning that water stress will continue to rise.[8]

Climate disasters: The extremes

Water-related disasters have punctuated Nepal's development through setbacks to livelihoods and the economy. Floods, landslides, and droughts have ravaged many regions over the years, and these events are predicted to become increasingly extreme.

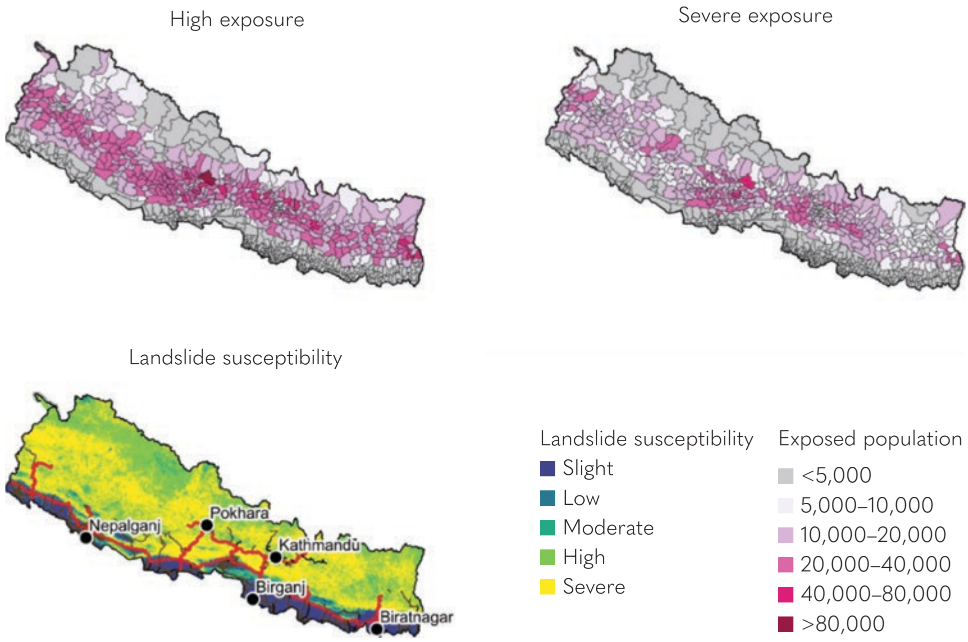
Flooding and landslides are the most frequent disasters in Nepal. Between 1971 and 2011, floods have affected 3.9 million people and caused economic losses of about US$5.8 billion (Bhandari et al. 2018). In 2017 alone, severe flooding caused an estimated US$585 million in damages (Bhandari et al. 2018). Based on downscaled projections, there will be an expected 15 to 40 percent increase in projected annual maximum river discharge and an expected 30 to 40 percent increase in river discharge for 1-in-10-year flood events by 2030, compared to a 1995 baseline (World Bank 2019f, using Lutz et al. 2016; Wijngaard et al. 2017). As of 2019, about 1.47 million people are exposed to 1-in-10-year floods, assuming no flood protection, and this number is projected to rise to about 1.95 million by 2030 in the low-emission scenario (RCP 4.5) (World Bank 2019f). Intense rainfall events also lead to flash flooding in areas with insufficient drainage and landslides in high-slope areas with weak soil or poor vegetation. There is significant population and infrastructure exposure to landslides throughout the midhills (map 3.5; see appendix D for details on climate models). A study comparing the variations in rainfall-triggered landslides and earthquake-induced landslides found that rain-fall triggered landslides are more than twice as likely to occur within 100 meters of roads, with strong policy implications for both road development and drainage management for reducing disaster risks of landslides (McAdoo et al. 2018). Nepal also has a high risk for glacial lake outburst floods. Such floods can occur when avalanches or rockfalls enter high-altitude lakes, causing the lakes to overflow. An estimated 11 lakes are at high risk and 31 lakes at very high risk of outburst flooding (Rounce, Watson, and McKinney 2017).

Droughts, though less common than floods, have an outsized effect in many regions, worsening household food insecurity. Estimates of late monsoon onset derived from Lutz et al. (2016) show that although the average date of onset is likely to stay constant, its variability is expected to increase.[9] About 11.6 million people in the Terai region face more than 60 consecutive dry days per year, which is projected to increase even in the moderate climate change scenario (map 3.6).

Integrated approach to risk management

Building resilience requires preventive measures through proper WRM, including through conservation and adequate infrastructure such as sustainable storage and embankments, as well as the building of strong hydrological and meteorological (hydromet) and early-warning systems (EWSs). Although the country needs to invest and prepare on all these fronts simultaneously, managing water resources forms a strong basis for disaster risk reduction. Therefore, an integrated approach to disaster risk management

MAP 3.5 Population Exposure to Landslides



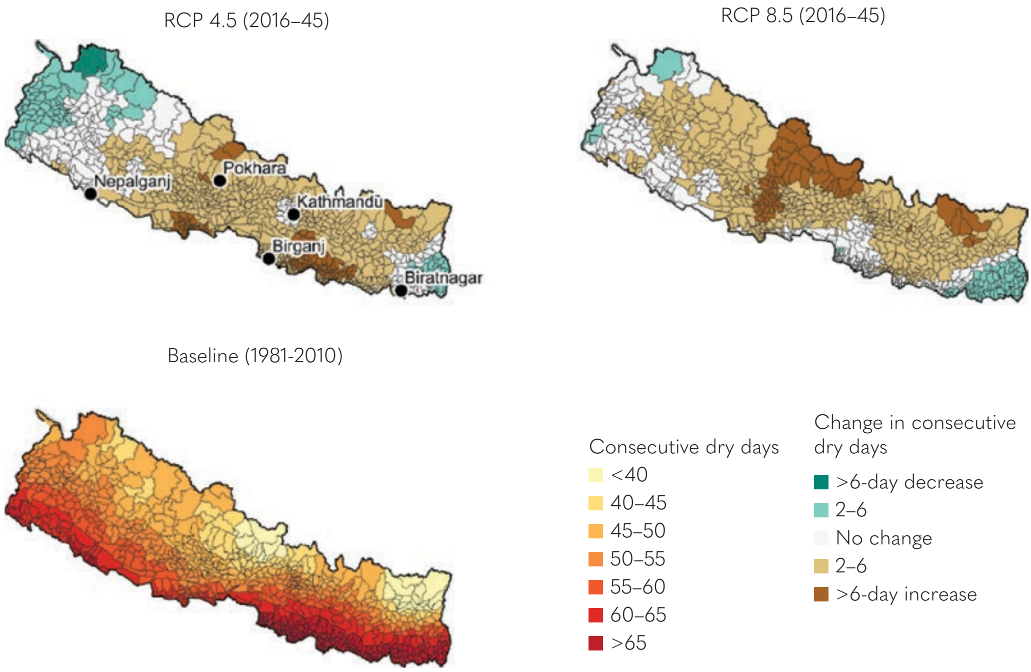
Source: World Bank Cartography Unit using World Bank (2019f).

(DRM) can help build a cascade of preventive measures, which starts with watershed management, among many measures, and extends through strong EWSs and disaster response systems.

The first step in risk mitigation calls for water resource and wetland management. Wetlands make up 5 percent of Nepal's area (MoFE 2018). They regulate groundwater recharge and water quality and prevent inundation, erosion, and sediment transport. They are effective carbon sinks and are classified as the most productive type of ecosystem. Wetlands remain the main source of livelihood for 85 percent of agrarian communities, which rely on them for food and fodder, and 10 percent of the rural ethnic communities. One study estimated the economic valuation of Phewa Lake of Pokhara, Koshi Tappu, and Jagadishpur Reservoir at US$43 million, US$16 million, and US$1 million, respectively (MoFE 2018). Though the GoN does not systematically value the benefits and services provided by wetlands, a comprehensive economic valuation of wetlands and their contribution to GDP can help in transitioning towards integrated water resource management. The challenge lies in effective coordination among the Ministry of Forests and Environment (MoFE, formerly the Ministry of Forests and Soil Conservation), which holds the mandate for their conservation, and the Ministry of Agriculture, Land Management and Cooperatives and MoEWRI, whose actions depend on and affect them.

In addition to integrated forest and watershed conservation, water infrastructure, particularly for multipurpose storage and flood protection, is crucial for managing temporal and spatial variability and building resilience. The World Bank and International Water Management Institute's joint 2017 report considers the stress to be severe at the subcontinent level, citing the highly variable monsoon, low storage capacity, rapid urbanization, anthropogenic pollution, drying wetlands, and unmanaged

MAP 3.6 Projected Change in Consecutive Dry Days, 2016–45 versus 1981–2010 Baseline



Source: World Bank Cartography Unit using World Bank (2019f).
Note: Projected change is measured as the maximum number of consecutive days per year with less than 1 millimeter of rainfall. Future scenarios are ensemble medians of four models for each of two scenarios (RCP 4.5: stabilization scenario and RCP 8.5: business-as-usual scenario). The Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change.

groundwater abstraction, disputes, and conflicts (Hirji, Nicol, and Davis 2017). Nepal's storage volume requirement to satisfy annual average seasonal water demand is 29.86 cubic kilometers, of which it has none so far. In comparison, Bangladesh covers 33 percent of its storage needs and India covers up to 76 percent (ICIMOD 2009; table 3.1). Environmentally sustainable storage is a key strategy for climate change adaptation (Bolch et al. 2019; ICIMOD 2009; Vaidya 2015). For hydroelectricity alone, the Japan International Cooperation Agency's (JICA's) nationwide master plan on storage-type hydroelectric power development showed that by 2032, Nepal will need at least 1,993 megawatts of storage capacity in the business-as-usual power-demand scenario; 3,154 megawatts for the high-demand scenario; and 1,664 megawatts for the low-demand scenario. The plan identifies various sites after evaluation of social and environmental considerations (JICA 2014). As this study recommends, the projects are more likely to be successful if developed in coordination with irrigation and environmental conservation such that their economies of scope and scale can be achieved.

Nepal also faces the challenge of strengthening its hydromet and EWSs. The ongoing Building Resilience to Climate Related Hazards Project for Nepal,[10] led by the Department of Hydrology and Meteorology, began the modernization of forecasting technology. The project aims to bring accuracy and availability of monitoring data and real-time collection to replace an older system based on manual measurements (World Bank 2012). Going forward, federalization gives Nepal an opportunity to build resilience from

TABLE 3.1 Gap between Storage Capacity and Storage Needs, by Country, 2006

Country	Seasonal storage index (km^3)	Current storage (% of seasonal storage index)
Bangladesh	62.28	33
Bhutan	0.40	0
India	356.60	76
Nepal	29.86	0

Source: ICIMOD 2009.
Note: The seasonal storage index indicates the volume of storage needed to satisfy annual water demand based on the average seasonal rainfall cycle. The Brown and Lall (2006) study identified 23 of 163 countries as having a positive storage requirement, that is, a need to reduce the effect of rainfall variability on food and livelihoods by transferring water availability from wet to dry months.

the ground up with more monitoring stations at higher spatial and temporal resolutions that can be maintained by local governments with more effective EWSs (Brown et al. 2019).

In summary, managing climate-related water variation and extremes is indispensable for Nepal's growth. As discussed, human development and growth in all sectors hinge on climate adaption to ensure enough water in the dry seasons to drink, irrigate, and run businesses, industries, and hydropower plants. Similarly, they hinge on Nepal's effort to ensure resilience so that its people and economy are not trapped by preventable setbacks. Finally, as a country at the headwaters of a basin that sustains more than 0.5 billion people across the region, Nepal's foresight today on climate-related water management is likely to bear a fruitful legacy, potentially even beyond its borders.

Challenge 5: Transboundary Management

Adequate transboundary cooperation is an important part of WRM in the region. The Ganges basin that encompasses Nepal stretches up to China and across to India and Bangladesh. The headwaters flow downstream to sustain more than 400 million people in the Ganges plain, in addition to 28 million in Nepal. Cooperation and treaties between India and Nepal pertaining to water resources date back to the Exchange of Letters of 1920 with the then-British government in India regarding the Sarada Barrage project in the Mahakali River planned for irrigation facilities in the adjacent states (Upreti 2006). Since then, four other agreements (table 3.2) have been signed between the two riparian nations that have been politically contentious and inadequate in achieving the goals of either country. Both countries have expressed grievances regarding the management of transboundary issues. Based on the treaties, they have relied on structural embankments, but flood preparedness and EWSs are not in place, communication is poor, and infrastructure has been neglected by both for decades (Gokarn and Sajjanhar 2014). Physical structures for larger rivers have been breached regularly. When the Koshi flood broke through an embankment in 2008, it washed away the livelihoods of more than 70,000 people in the Terai and more than 3.5 million people in India (Dixit et al. 2009). Grievances on the Nepal side regarding other treaties relate to a smaller actual command area compared with the agreed area; a barrage location changed to the border area, making upstream territories in Nepal more prone to flooding; one-third of the agricultural command area being inundated during the monsoon because of poorly located embankments; irregular water release conducted without prior consultation; deficient and poorly maintained cross-drainage; unequal water allocations (Mahakali); and stalled joint reservoir projects (Gokarn and Sajjanhar 2014; table 3.2).

Dialogue between the stakeholder countries on these issues have been limited so far. The South Asia Water Initiative (SAWI) rekindled consultations for greater regional cooperation on the issue of glacier melting. It also facilitated technical work on flood forecasting in Bihar, drawing on an existing memorandum of understanding between Nepal and India to facilitate rainfall-related data sharing (World Bank 2019c). SAWI has admittedly had limited success in directly advancing joint collaborative action among riparian countries in the Ganges basin, highlighting the magnitude of this challenge. For optimal benefits, water management calls for transboundary cooperation, such as basin-level planning, across administrative boundaries. Designing infrastructure for optimal water management is also likely to be more economically viable when all users and demands are considered. However, Nepal's capacity for transboundary assessments and cooperation is relatively low. The grievances based on the past treaties indicate that Nepal needs to develop a significant knowledge base and planning capacity to successfully engage in bilateral and/or trilateral cooperation.

TABLE 3.2 Summary of Treaties, India and Nepal, 1920–96

River	Date	Project	Intended design	Allocation constraints	Concerns or complaints
Mahakali	1920	Sarada Barrage	Irrigation for India		Permanent exchange of riverine land; water allocation to Nepal low and conditional on availability (Upreti 2006)
Koshi	1954, revised 1966	Koshi Barrage	Irrigation, flood control, and power		Smaller actual command area compared with agreement (10,000 versus 66,000 hectares); barrage siting changed to border area, making upstream territories in Nepal more prone to flooding (Dixit et al. 2009)
Gandak	1959, revised 1964	Gandak Barrage, Irrigation, and Power Project	Irrigation, flood control, and power	✓	Water released irregularly and without prior consultation, despite repeated farmer requests to the barrage operators in India; deficient and poorly maintained cross-drainage works in the two canals; flash floods and longer inundations (Dixit and Shukla 2017), with one-third of the command area inundated during the monsoon because of infrastructure
Mahakali	1991, revised 1992	Tanakpur Barrage		✓	Unequal water allocations; electricity pricing (Upreti 2006, Gyawali and Dixit 1999; Gokarn and Sajjanhar 2014; Bagale and Adhikari 2020)
Mahakali	1996	Proposed Pancheshwor Multipurpose Dam		✓	Stalled (Gokarn and Sajjanhar 2014; Bagale and Adhikari 2020)

Source: Adapted from Shrestha and Silwal (2017), comparing the designed benefits versus actual benefits derived from the treaties.

Notes

1. Based on data from the Landsat-derived Global Human Settlement Layer.
2. Based on Multiple Indicator Cluster Surveys (MICSs) 2014 and 2019 (CBS 2015, 2020).
3. The local election before the 2017 election was held in 1997.
4. Based on World Bank calculations using National Planning Commission data; Cosic, Dahal, and Kitzmuller 2017.
5. In addition to the DPC, the following study, among many, provides useful lessons (Ogino, Dash, and Nakayama 2019, 14): "The foregoing analysis also suggests a number of policies to be applied for optimal hydropower development designs and schemes. In this regard, project planners, including policy makers, developers and financers, should pay attention to the following practical points: (i) selection of project sites to value the head for generation for the purpose of project cost reduction per unit of installed generation capacity; (ii) adequate contingency plans for cost overruns and implementation challenges in exploiting large water discharges; (iii) cost-efficient design of compact project facilities with fewer risks in social and environmental impacts and project implementation in order to attract funding resources, including any additional carbon emissions related funds; (iv) work-contractual and financial arrangements to reduce substantial burdens of project management and funding costs during construction through risk-sharing mechanisms; and (v) careful scoring between benefits and risks arising from the purposes and uses of hydropower projects (e.g., run-of-the-river or reservoir types; power export or domestic consumption; and power generation, irrigation, or multipurpose)."
6. Four other government departments—the Nepal Planning Commission, the Department of Water Induced and Disaster Prevention and the Groundwater Resources Development Board (both under the MoEWRI), and the Department of Soil Conservation and Watershed Management (under the MoFE)—in addition to WECS, have proposed establishing river basin authorities to preside over basin planning, as mentioned in their draft policies and acts such as the Watershed Policy and River Law of the MoFE.
7. According to the 2008 Labor Force Survey (LFS), two-thirds of the employment share was in agriculture. The 2018 LFS changed the definition of the labor force to exclude subsistence agriculture (CBS 2008, 2019).
8. In the high-growth scenario, total water demand is projected to double by 2050 compared with the present-day demand in many parts of Nepal, driven by domestic and industrial demand. All districts in the Terai show a water stress index above one (denoting conditions under which the water demand surpasses the available surface water resources).
9. From a standard deviation of ±13 days for 1981–2010 to ±20 days in 2030.
10. In 2013, the World Bank provided approximately US$31 million to Nepal to assist the country's effort in building resilience to climate-related hazards.

4

Where Do We Go?

The preceding discussion highlighted key points that must be considered when scoping out viable opportunities for development investments in Nepal. They include: a fledgling federalized system of governance, high climate variability and vulnerability, rapid and unplanned urbanization, large fiscal gaps, and low state capacity as reflected in a poor track record of large public investment projects.

Strengthening governance capacity, particularly at the local level, is a first step needed to set in motion changes in the political economy that will enable the necessary infrastructure investments for ensuring safe and reliable water for all users and uses across human, economic, and environmental needs. Considering the context and challenges, six priority areas emerge as important guides for Nepal's water resources development in this decade. The following paragraphs discuss these areas and outline their alignment with the World Bank Country Partnership Framework (CPF) objectives. Furthermore, table 4.1 details the key processes that are expected to change with the successful operationalization of these priorities, and also lists the SDG targets with which they are aligned.

Strengthen State Capacity and Institutions

First, building state capability for strong governance deserves immediate and sustained policy attention and a multisectoral effort, especially involving agriculture, energy, disaster risk management (DRM), and the environment. While significant resources have already been dedicated to this end, progress remains slow. Budget execution rates have been low, indicating the need for substantial improvement in implementation capacity. Taking guidance from the lessons learned from past capacity building initiatives and the Federalism Capacity Needs Assessment (FCNA) report (World Bank 2019a), Nepal can improve its strategy to build capacity at all three tiers of governance. This plan should recognize that local governments primarily need to build capabilities for managing the demands of all users and user committees inclusively, operate and maintain service structures, build integrated water resource management planning capacity, establish environmental and social safeguards, and develop a system of financial procurement and management. The integrated management approach, which is well aligned with the Water Resource Policy 2020, the Irrigation Master Plan 2019, and the Watershed Management Strategy of the National Forest Policy 2019, merits significant support. However, the participation of the local and provincial tiers is indispensable for fostering cooperation and efficient water management among competing uses across newly formed boundaries.

Aligned to CPF objectives:

- *Objective 1.1.* Improved budget and revenue management
- *Objective 1.2.* Strengthened institutions for public sector management and service delivery

Maintain Reliable Water Supply and Sanitation Services for Basic and Economic Needs

Second, the need of the hour is to have enough water for human and economic needs. Dealing with water insecurity is a high priority for Nepal. This means that water supply requirements need to be accounted for in upstream water resources management. Water shortages and poor sanitation have enormous economic, environmental, and social costs for broad segments of Nepal's population, and primarily the poor, vulnerable, and marginalized people. These costs are likely to be amplified by a crisis like COVID-19, especially in the major urban centers, which have some of the worst water supply infrastructure despite being the country's growth engines. The importance of ramping up investments in safe water and sanitation, including wastewater treatment, stands out in the context of this pandemic, with a renewed focus on closing inequalities in access to basic services.

Water supply and sanitation (WSS) are among the services that the newly formed local governments must be supported in managing. Although development partners like the Asian Development Bank are working in small towns and in the capital city, there is much to be done across the country, especially in secondary cites. Kathmandu's pace of growth shows greater need than what is in the pipeline so far. WSS projects are an opportunity to engage in strengthening the service-delivery mechanisms of nascent local governments. The GoN needs to rationalize the roles and responsibilities of federal ministries and local governments in planning and implementing services, and put accountability systems in place. Furthermore, the country needs to regularize budgeting and reliable fund flow mechanisms from the federal to the local government levels. Implementing accurate data and information systems to track inputs, outputs, and outcomes at the local level—with disaggregated data to track progress across time, regions, genders and disadvantaged groups of people—(through the new N-WASH system) is an imperative for continued inclusive development of the sector.

Considering the existing financial gaps in improving basic service delivery and its urgency for the country, budget allocation and use across the water subsectors need to minimize efficiency gaps. Nepal also needs to prioritize multipurpose storage projects that extend to water supply. This is one of the areas in which private sector participation[1] can be tested once adequate institutional prerequisites, such as a politically independent pricing regulator, are established.

Aligned to CPF objectives:

- *Objective 1.2.* Strengthened institutions for public sector management and service delivery
- *Objective 3.2.* Improved access to services and support for the well-being of vulnerable groups

Smooth Out the Effects of Climate Variability for Water Security and Resilience

Third, as a sector that is highly vulnerable to climate change and disaster risks, investments toward resilience should continue, not only in crisis response but also upstream water management. With the ongoing development policy credit with catastrophe deferred drawdown, Nepal is taking a proactive stance toward improving its institutional and regulatory framework, integrating climate resilience in key sectors, and enhancing crisis preparedness. Although this approach begins to tackle the problem of climate extremes, Nepal still needs investments at the upstream management level that will shield economic activities from normal annual water variability. It should also include forest and wetland management—aligned with the National Forest Policy 2019, Wetland Policy 2012, and National Ramsar Strategy and Action Plan 2018–24—as part of an integrated approach to resilience and risk reduction, especially because they form the basis of the livelihoods of vulnerable communities.

The evidence overwhelmingly points to the need for buffer mechanisms for the dry season. Sustainable multipurpose storage and transfer schemes will be an important step toward this need for all sectors. Another step is to invest in further strengthening hydrological and meteorological (hydromet) information systems and the local capacity to use evidence from monitoring stations to influence programs and policies. These steps will be crucial for climate resilience and, eventually, basin-level planning.

Aligned to CPF objectives:

- *Objective 3.3.* Increased resilience to health shocks, natural disasters, and climate change
- *Objective 3.4.* Improved adoption of sustainable natural resource management; increase in number of farmers adopting climate smart agricultural practices in targeted districts or states

Boost Agricultural Productivity to Promote Growth and Poverty Reduction

Fourth, although the Terai is already home to most of Nepal's irrigation investments, increasing year-round productivity and commercially viable farming in the region would be conducive to greater economic growth. There is a need to expand irrigation services with appropriate technologies to more than 900,000 hectares of nonirrigated irrigable land, alongside other complementary investments in agriculture. This approach would require modernization of irrigation facilities and also their adequate operation and maintenance to ensure year-round services.

Despite a gradual structural change in the economy away from agriculture, a large proportion of the poor remain reliant on small-holder farming. However, the farmer-managed irrigation systems that small farms depend on are weakening due to these structural changes, driven by outward migration and urbanization. Therefore, to reach subsistence farmers, strengthening farmer-managed irrigation systems with stronger support from the local governments is important. Moreover, for a comprehensive solution, interventions should embed appropriate agricultural extension services and forest and watershed conservation.

Aligned to CPF objectives:

- *Objective 2.5*. Improved income opportunities
- *Objective 3.2*. Improved access to services and support for the well-being of vulnerable groups
- *Objective 3.3*. Increased resilience to health shocks, natural disasters, and climate change

Develop Strong Regulatory Institutions to Enable Effective Private Sector Investments

Given the massive investment needs and financing gap, private sector participation will have continued importance. However, Nepal needs to strengthen its governance and regulatory environment to enable reliable and effective private participation. The 2015 Constitution and the 14th Periodic Plan prioritize private sector development for greater growth. The World Bank's Nepal Infrastructure Sector Assessment Program highlights several interventions that combine short- and longer-term structural and policy changes that will relieve bottlenecks for infrastructure investments, including in water supply, sanitation, and waste management. These investments can contribute to the necessary water infrastructure for people and for firms to operate, grow, and maintain competitiveness.

Drawing lessons from Nepal's experience in public-private partnership (PPPs) in the hydropower sector and water supply management, a politically independent regulator and strong contract design are minimum requirements to prepare the government to enable reliable and efficient PPPs

(Engel, Fischer, and Galetovic 2020). Although donors such as the US Agency for International Development are assisting with PPP lawyers and transaction advisors for strong contract preparation, Nepal is lacking in its plan to strengthen the domestic governance structure required for the lifetime of such projects. Independent, fair pricing and service quality regulation and enforcement capacity are critical institutional elements that need early attention. Finally, it is an imperative for the government to ensure that privately delivered services are inclusive and affordable.

Aligned to CPF objectives:

- *Objective 2.4.* Improved regulatory environment for competitiveness

Build Knowledge on Transboundary Collaboration for Resolving Issues in Irrigation, Energy, and Flooding

Continued efforts to build transboundary cooperation are fundamental for greater basin-level planning and addressing riparian challenges; however, Nepal should first focus on building the necessary knowledge base and capacity to be well informed in all matters relating to hydro-diplomacy. Key topics include cooperation, benefit- and risk-sharing, international water law, water resource modeling and engineering, the best approach to determine allocation, among others. This knowledge base—combined with a commitment to an evidence-based approached for pursuing transboundary projects—is critical for creating a common ground where all the riparian countries have the same technical perception of the problem at hand, and the ability to plan for Pareto-Admissible[2] outcomes at the basin scale (Rogers 1993).

Water sharing, irrigation, and disaster management all rely on trust and understanding among the riparian countries in the basin. But first, these countries need to adopt basin-level planning internally. In Nepal, these plans are still in their initial phases, as they are in India and Bangladesh. Starting small in building knowledge on mutually beneficial collaborations like irrigation and hydropower may pave the path for more complex pursuits such as water sharing. Resolving these challenges based on sound evidence and cooperation can significantly improve lives and livelihoods in the greater basin.

In summary, Nepal is still at the initial stages of development in which it needs to work toward providing enough water, year-round, for its people, its economy, and the environment while addressing climate change. There is much left to be done in practically every subsector; however, it is strategic to focus on the outlined priorities. These priorities indicate the need for collaboration with the agriculture, hydropower, environment, DRM, and governance sectors to ensure a coordinated approach within the GoN, the World Bank, and beyond. Table 4.1 summarizes the priority policy areas, outlines potential interventions, provides initial outputs that could be used as performance indicators, and lists the relevant sub-sectors and aligned SDG targets.

TABLE 4.1 Policy Areas, Interventions, and Potential Performance Indicators

	Policy area	Reforms or investments	Performance indicators	Relevant sectors
1	Strengthened state capacity to enable basin-level planning and improved service delivery in a federalized context [SDG targets 6.5, 16.7, 17.9, 17.14]	▪ Build local government mechanism and capacity for basin-level planning ▪ Support WECS for basin-level planning and incentivize local government participation ▪ Rationalize mandates and role overlaps ▪ Establish and enforce a regulatory framework ▪ Invest in river basin modeling and hydromet information systems for evidence-based policy making ▪ Create accountability mechanisms	▪ River basin planning and conflict resolution systems built across horizontal and vertical tiers of governance ▪ Clear mandates for each of the subsectoral institutions in the federal framework; clarity across water-related acts on issues such as asset ownership, autonomy of different stakeholders. ▪ Data systems set up for risk calculations necessary for disaster and climate-related investments ▪ Adequate allocations for O&M established in the subsector budgets ▪ Established public accountability systems	▪ Water ▪ Governance ▪ Energy ▪ Agriculture ▪ Transport ▪ Environment ▪ Urban ▪ DRM
2	Reliable, inclusive WSS services for basic and economic needs [SDG targets 1.4, 6.1, 6.2, 6.3]	▪ Build local government gender and social inclusion capacity for service delivery ▪ Implement monitoring and O&M ▪ Support water utilities and expand piped water supply and sewer systems in the capital and in secondary towns ▪ Build and ensure functionality of wastewater plants	▪ Percentage of functional water schemes in rural areas ▪ Increased coverage, continuity, and reliability of municipal and urban water supply (hours per week) ▪ High household water security and greater access rates to safe WSS ▪ Improved utility finances (NRW, O&M cost recovery)	▪ Water ▪ Urban ▪ Governance ▪ Social protection ▪ Health ▪ Education
3	Resilience against climate variability and change [SDG targets 1.5, 2.4, 6.4, 6.6 13.2]	▪ Invest in river management and watershed conservation ▪ Invest in sustainable disaster-resilient infrastructure ▪ Invest in sustainable, feasible, and socially responsible multipurpose storage capacity to reduce vulnerabilities associated with climate variability ▪ Invest in further strengthening hydromet and EWSs for adaptation and resilience ▪ Create safety net against climate shocks and vulnerabilities	▪ Year-round water availability for domestic supply, irrigation, energy, and ecosystem needs ▪ Functional flood control infrastructure and dedicated O&M funds ▪ Functional hydromet stations and data availability ▪ Functional EWSs ▪ Effective disaster response and relief mechanisms ▪ Longer-term social protection systems for affected populations	▪ Water ▪ Agriculture ▪ Energy ▪ Environment ▪ DRM ▪ Social protection ▪ Climate change

(continued)

TABLE 4.1 (*continued*)

	Policy area	Reforms or investments	Performance indicators	Relevant sectors
4	Boost agricultural productivity [SDG targets 2.4, 6.4]	▪ Expand irrigation services to nonirrigated irrigable land, prioritizing productivity and viability ▪ Provide local government support for FMISs in tandem with agricultural interventions and watershed management ▪ Provide year-round irrigation where feasible ▪ Modernize irrigation facilities and ensure functionality	▪ Percentage of agricultural land with year-round irrigation ▪ Agricultural productivity in the dry season ▪ Watershed management as part of FMISs	▪ Water ▪ Agriculture ▪ Environment ▪ Climate change
5	Governance and regulation for private sector participation [SDG targets 17.5, 17.17]	▪ Establish mechanism for fair and transparent project selection ▪ Establish mechanism for fair and transparent procurement of contractors ▪ Establish independent pricing and service regulator ▪ Implement institution for management for the lifetime of the PPP ▪ Adopt fair arbitration protocols	▪ More private sector financing ▪ Fewer cost overruns of infrastructure projects ▪ Fewer time overruns ▪ Minimal need for renegotiation ▪ Greater efficiency of projects	▪ Water ▪ Governance ▪ IFC ▪ MIGA ▪ Energy ▪ Legal
6	Build knowledge on transboundary cooperation [SDG 6.5]	Build knowledge base required to initiate bilateral and trilateral cooperation for basin planning and climate resilience	▪ Reliable evidence base and capacity built to help establish transboundary cooperation ▪ Committed government units for negotiations	▪ Riparian authorities ▪ Governance ▪ Irrigation ▪ DRM ▪ Energy ▪ Water

Note: DRM = disaster risk management; EWSs = early-warning systems; FMISs = farmer-managed irrigation systems; hydromet = hydrological and meteorological; IFC = International Finance Corporation; MIGA = Multilateral Investment Guarantee Agency; NRW = nonrevenue water; O&M = operation and maintenance; PPP = public-private partnership; WECS = Water and Energy Commission Secretariat; WSS = water supply and sanitation.

Notes

1. Inviting water vendors into PPPs in the urban WSS sector where they maintain minimum service delivery and water quality standards has emerged as a policy option (Opryszko et al. 2009) and may be a viable short-term solution while larger schemes are completed. Without proper standards and their enforcement, water supplied by informal markets may pose serious health risks, undermine equitable services, and carry the risk of monopoly rents or high tariffs through collusions.
2. A plan/allocation is Pareto-Admissible when no other allocation can make either party better off.

Appendix A: Water-Related Institutions

TABLE A.1 Government Ministries and Departments Responsible for Water-Related Issues

Ministry	Function	Major water-related departments or units	Scope
Ministry of Energy, Water Resources and Irrigation	Irrigation development	▪ WECS ▪ Department of Water Resources and Irrigation ▪ Department of Hydrology and Metrology ▪ Groundwater Resources Development Board ▪ Water Resource Research and Development Center	▪ WRM, policy, and planning ▪ Countrywide surface and ground irrigation ▪ Hydromet services—central ▪ Groundwater research and management—countrywide ▪ Water resources research
	Power sector development	▪ Department of Electricity Development ▪ WECS ▪ Department of Water Resources and Irrigation ▪ Water Resource Research and Development Center ▪ Nepal Electricity Authority (NEA) ▪ Alternative Energy Promotion Center ▪ Hydroelectricity Investment and Development Company ▪ Vidyut Utpadan Company	▪ Hydropower development, policy, licensing ▪ WRM, policy, and planning ▪ Countrywide surface and groundwater irrigation ▪ Water resources research ▪ Development and sales of hydropower ▪ Microhydropower ▪ Hydropower (mostly financing) ▪ Hydropower development

(continued)

TABLE A.1 (*continued*)

Ministry	Function	Major water-related departments or units	Scope
Ministry of Water Supply	Drinking water supply and sewerage provision	▪ Department of Water Supply and Sanitation Management ▪ Rural Water Supply Fund Development Board ▪ Nepal Water Supply Corporation ▪ Kathmandu Valley Water Supply Management Board /Kathmandu Upatyaka Khanepani Limited ▪ Melamchi Water Supply Development Board ▪ Water users and sanitation committees (WUSCs)	▪ Countrywide, rural, and urban WSS ▪ Countrywide and rural WSS ▪ WSS for 23 towns ▪ Kathmandu Valley WSS ▪ Melamchi water transfer investment program ▪ Respective WSS
Ministry of Agriculture, Land Management and Cooperatives	Crop production and agricultural development	▪ Department of Agriculture	
Ministry of Forests and Environment	Forest management and soil conservation		
Ministry of Urban Development	Water related to urban development	▪ Department of Urban Development and Building Construction ▪ High Powered Committee for Integrated Development of Bagmati Civilization	▪ Selected larger cities ▪ River basin management ▪ Wastewater
Ministry of Science, Technology, and Environment	Innovation and scientific research		
Ministry of Population and Environment	Environmental conservation and pollution control		
Ministry of Physical Infrastructure and Transport	Development of physical infrastructure to link rural areas		
Ministry of Federal Affairs and Local Development	Development of local infrastructure	▪ Municipalities and municipal boards	▪ Selected large cities (Ilam, Bharatpur, Hetauda, Kavre Valley, Dharan Biratnagar, Birganj, Butwal, and Nepalgunj)

Note: hydromet = hydrological and meteorological; WECS = Water Energy Commission Secretariat; WRM = water resource management; WSS = water supply and sanitation.

Appendix B: Development Partner Engagement

TABLE B.1 Preliminary Mapping of Development Partner Engagement in the Water Sector

Subsector	Development partners	Service delivery	Policy and institutional strengthening
Water supply and sanitation	World Bank	▪ Rural Water Supply and Sanitation Improvement Program ▪ Nepal Urban Governance and Infrastructure Project	Limited
	ADB	▪ Melamchi Drinking Water Supply Project ▪ Kathmandu Valley Wastewater Management Project ▪ Kathmandu Valley Water Supply Improvement Project ▪ Urban Water Supply and Sanitation Sector Project ▪ Third Small Town Water Supply and Sanitation Sector Project ▪ Regional Urban Development Project ▪ Fecal Sludge Management pilots in two towns (including public-private partnerships)	Limited, integral part of specific projects but policy support being conceptualized

(continued)

TABLE B.1 (*continued*)

Subsector	Development partners	Service delivery	Policy and institutional strengthening
	UNICEF, WHO, and UN-Habitat	▪ Water and sanitation system ▪ Water Safety Plan ▪ ODF status	Primarily focused on ODF status and water safety plan
	Government of Finland	▪ Rural Village Water Resource Management Project Phase III (cofunded by the European Union) Sustainable WASH for All (SUSWA) ▪ Hariyo Tatha Baliyo Pashchim (A Green and Strong West) ▪ Capacity Building in Arsenic Mitigation in Nepal	Part of integrated local development
	JICA	▪ Capacity Development Project for the Improvement of Water Supply Management in Semi-Urban Areas (WASMIP II) ▪ Project for Improvement of Water Supply in Pokhara ▪ Data Collection Survey on Water Supply and Waste Water in Larger Cities ▪ Master Plan Development of Sewerage System in Pokhara City ▪ Strengthening KUKL (TCP) ▪ Melamchi Drinking Water Project (Consessional Loan)	Focused on WUSCs and NWSC
	UK Department for International Development	▪ Rural Water & Sanitation Program (Gurkha Welfare Scheme) Phase V	Focused on Gurkha Welfare Society
	USAID	▪ Safa Pani Project ▪ Swachchhata (Health and Hygiene Activity) ▪ Suaahara II (Integrated Nutrition Activity) ▪ WASHFin ▪ WASHPAL-Action Research on MHM in the workplace ▪ Karnali Water Security Activity (Upcoming)	WUSCs
	(International) nongovernmental organizations	▪ WaterAid, Save the Children, Plan, SNV Nepal Oxfam, etc., active in small-scale integrated WASH linked with education, health, and nutrition	WUSCs focused, evidence-based advocacy

(continued)

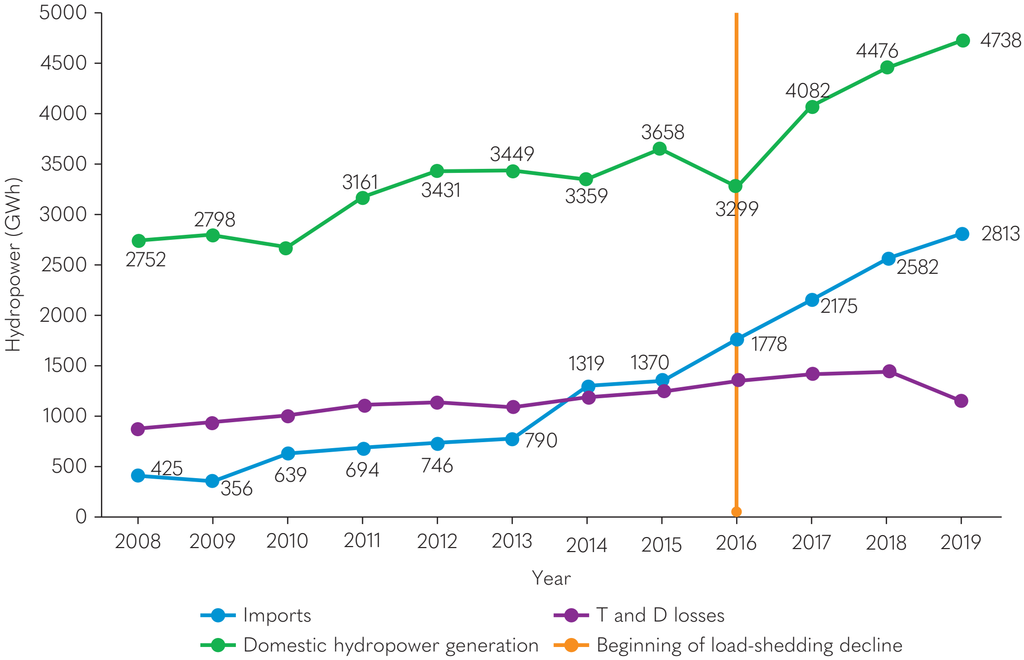
TABLE B.1 (*continued*)

Subsector	Development partners	Service delivery	Policy and institutional strengthening
Irrigation	World Bank	▪ Irrigation and Water Resources Management Project ▪ Rani Jamara Kulariya Irrigation Project	Policy reform
	ADB	▪ Community Managed Irrigated Agriculture (Sector) Project ▪ Water Resource Preparatory Facility Project	Policy development
	Saudi Fund	▪ Dunduwa Irrigation Project	Policy links
	Kuwait Fund	▪ Irrigation Systems Improvement Project	Policy links
	OPEC Fund for International Development	▪ Sikta Irrigation Project	Policy links
Hydropower	World Bank	▪ Programmatic Energy Sector Development Policy Credit ▪ Power Sector Reform and Sustainable Hydropower Development Project ▪ Nepal India Electricity Transmission and Trade Project 2011, plus additional financing in 2013	Policy reform and institutional strengthening
	ADB	▪ South Asia Sub Regional Economic Cooperation Power System Expansion Project ▪ Energy Access and Efficiency Improvement Project, Electricity Transmission Expansion and Supply Improvement Project ▪ Power Transmission and Distribution Efficiency Enhancement Project ▪ Tanahu Hydropower Project, Project Preparatory Facility for Energy	Policy reform and institutional strengthening
	KfW	▪ Reconstruction and upgrading of electricity supply ▪ Middle Marsyangdi Hydrolectric Project ▪ Chilime Trishuli Transmission Line Project	Policy links
	Saudi and Kuwait Fund	▪ Budhi Ganga Hydropower Project	Policy links

Source: Based on the Development Cooperation Report (GoN 2018b).
Note: ADB = Asian Development Bank; JICA = Japan International Cooperation Agency; KfW = Development bank of the German Federal Ministry for Economic Cooperation and Development; ODF = open defecation free; OPEC = Organization of the Petroleum Exporting Countries; UN-Habitat = United Nations Human Settlements Programme; UNICEF = United Nations Children's Fund; USAID = US Agency for International Development; WASH = water supply, sanitation, and hygiene; WHO = World Health Organization; WUSCs = water users and sanitation committees.

Appendix C: Electricity Sources and Loss

FIGURE C.1 Generation, Import, and System Loss of Hydropower, Nepal, 2017–19



Source: NEA 2017, 2018, and 2019.
Note: T&D losses = technical and distribution losses.

Appendix D: Methods for Climate and Disaster Risk Analysis

1. **Ensemble median statistics derived from NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP; NASA 2015)**

Average daily precipitation, 99th percentile precipitation, and average daily maximum temperature for South Asian countries were derived from the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset (Thrasher and Nemani 2015). NEX-GDDP includes global daily temperature and precipitation data downscaled to a 0.25° resolution for 21 global circulation models (GCMs) released under the Coupled Model Intercomparison Project Phase 5 (CMIP5).

Three indicators were derived from NEX-GDDP in this analysis:

1. Average daily precipitation: mean precipitation
2. 99th percentile precipitation: the 99th percentile of daily precipitation each year, or the amount of precipitation that is exceeded 1 percent of days each year
3. Average daily maximum temperature: mean maximum temperature

Indicators were calculated on a per-pixel basis for each year, then averaged over 31-year windows for baseline (1970–2000) and future (2035–65) periods to minimize the effect of interannual fluctuations. Indicators were calculated independently for each model, and the median value across all 21 models

TABLE D.1 CMIP5 Models Included in the NEX-GDDP Dataset

ACCESS1-0	GFDL-CM3
BCC-CSM1-1	GFDL-ESM2G
BNU-ESM	GFDL-ESM2M
CanESM2	INMCM4
CCSM4	IPSL-CM5A-LR
CESM1-BGC	IPSL-CM5A-MR
CNRM-CM5	MIROC-ESM
CSIRO-MK3-6-0	MIROC-ESM-CHEM

Source: Thrasher and Nemani 2015.

(ensemble median) was taken as a representative value. Country-level statistics were created by averaging the value for all pixels within that country.

2. **High-resolution representative precipitation and discharge fields derived from Lutz et al. (2016) and Wijngaard et al. (2017)**

Within Nepal, four additional indicators were derived from high-resolution precipitation and discharge data produced by Lutz et al. (2016) and Wijngaard et al. (2017). Lutz et al. selected four representative CMIP5 GCMs for each of two RCP scenarios for the upper Indus, Ganges, and Brahmaputra River basins. Models were selected based on historical performance and coverage of the range of possible future outcomes: warm-wet, warm-dry, cool-wet, and cool-dry (table D.2). The Lutz et al. dataset, which includes temperature and precipitation data from each of these models, was downscaled to a high-resolution 10 km grid. Wijngaard et al. (2017) use these data to model future hydrological fluxes.

Cumulative daily precipitation, average onset of monsoon, and consecutive dry days for Nepal were calculated from Lutz et al. (2016). Cumulative daily precipitation is the average daily precipitation in Nepal on each calendar day of the year. Average date of monsoon onset was calculated as the first day each year with at least 5 mm of precipitation followed by at least 10 days of at least 1 mm of precipitation. Consecutive dry days for areas within Nepal were calculated as the maximum number of consecutive days each year with less than 1 mm of precipitation. All indicators were first calculated on a per-pixel, per-year, per-model basis and then aggregated into 31-year averages for each model for baseline (1990–2010) and future (2015–45) periods. Ensemble medians were calculated as representative values across the set of models for each RCP scenario.

Annual hydrographs for the Karnali, Gandaki, and Kosi rivers were derived from modeled daily discharge for three simulated river gauges from Wijngaard et al. (2017). Hydrographs show average daily discharge for each calendar day of the year, averaged over 31-year periods. For each river we also estimated the probability of extreme discharge values by fitting Gumbel distributions to the annual maximum discharges for 31-year windows using the Python SciPy library. Gumbel distributions are widely used to model the probabilities of extreme events (e.g., Morrison and Smith 2002).

TABLE D.2 Selected GCM Runs

RCP4.5	Cold, wet	BNU-ESM_r1i1p1
	Cold, dry	inmcm4_r1i1p1
	Warm, dry	CMCC-CMS_r1i1p1
	Warm, wet	CSIRO-Mk3-6-0_r4i1p1
RCP8.5	Cold, dry	inmcm4_r1i1p1
	Warm, dry	CMCC-CMS_r1i1p1
	Cold, wet	bcc-csm1-1_r1i1p1
	Warm, wet	CanESM2_r3i1p1

Source: Lutz et al. 2016.

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