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WATER RESOURCES PROFILE SERIES

The Water Resources Profile Series synthesizes information on water resources, water quality, the water-related dimensions of climate change, and water governance and provides an overview of the most critical water resources challenges and stress factors within USAID Water for the World Act High Priority Countries. The profile includes: a summary of available surface and groundwater resources; analysis of surface and groundwater availability and quality challenges related to water and land use practices; discussion of climate change risks; and synthesis of governance issues affecting water resources management institutions and service providers.

Nepal Water Resources Profile Overview

Nepal has abundant water resources and is not considered water stressed at a national scale. Per capita water availability is well above the Falkenmark Water Stress Index's[i] threshold for water stress and only 8 percent of water supply is abstracted.[ii] However, extreme seasonal and topographical differences can create water stress sub-nationally.

Water risks in the Terai's Southern Rivers Basin relate to monsoon flooding and dry season stress. Most rivers in the Southern Rivers Basin are seasonal, and agricultural demand for water and population density are high. Drinking water availability is strained in major basins throughout the Siwalik, driven by widespread catchment degradation that reduces spring outflows.

Agriculture in the Terai is wholly dependent on seasonal surface water, while groundwater is underutilized. Groundwater potential decreases with increasing elevation. The Siwalik's springs, and Himalayan glaciers contribute to year-round flow in major river basins.

Catchment destruction, agricultural runoff, untreated residential and industrial wastewater, and a lack of national integrated monitoring and coordination are degrading both surface and groundwater quality. Poor sanitation systems and industrial effluent in the Kathmandu Valley pollute water sources with heavy metals and degrade ecosystems. Groundwater levels in the Valley have declined significantly due to over-exploitation.

Nepal has one of the lowest dam storage capacities in Asia and has high inter-seasonal water availability. Without water storage, dry season hydropower generation and municipal water service delivery is reduced, particularly in Kathmandu.

Nepal is naturally prone to landslides and flooding due to its steep topography and climate, but catchment degradation is increasing erosion and sedimentation, particularly in the Koshi Basin, which has caused the River to reroute and create massive transboundary floods.

Climate change will increase monsoon rainfall and intensity, melting of glaciers and snowmelt, and increase flood risks nationwide. Snow and ice coverage has declined by 40 percent due to warmer temperatures, reducing a critical buffer to surface water shortages in major river basins. Droughts will become more common and can reduce spring outflows, while also increasing risk from forest fires which degrade watersheds.

Nepal's water sector is fragmented across several institutions and the water management roles and responsibilities of sub-national governments are not yet defined under the new federalist system. The Water and Energy Commission Secretariat lacks the legal and budget authority to implement the National Water Plan, resulting in a lack of basin-level management institutions.

[i]The Falkenmark Water Stress Index measures water scarcity as the amount of renewable freshwater that is available for each person each year. A country is said to be experiencing water stress when water availability is below 1,700 m^3 per person per year; below 1,000 m^3 is considered water scarcity; and below 500 m^3 is absolute or severe water scarcity.

[ii]SDG 6.4.2 measures water stress as the percentage of freshwater withdrawals against total renewable freshwater resources. The water stress thresholds are: no stress <25%, low 25%-50%, medium 50%-75%, high 75%-100%, and critical >100%.

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Water Resources Availability

KEY TAKEAWAYS

- Many rivers in the Lowland areas (the Terai) run dry, however, lowland aquifers are highly productive.
- Major middle-elevation (the Siwalik) basins are sustained year-round by mountain springs, and glacial and snowmelt. Aquifers often have limited or moderate water availability.

This section summarizes key characteristics of surface and groundwater resources. Table 1 summarizes key water resources data and Figure 1 presents key surface water resources, wetlands, and dams.

Surface Water Resources

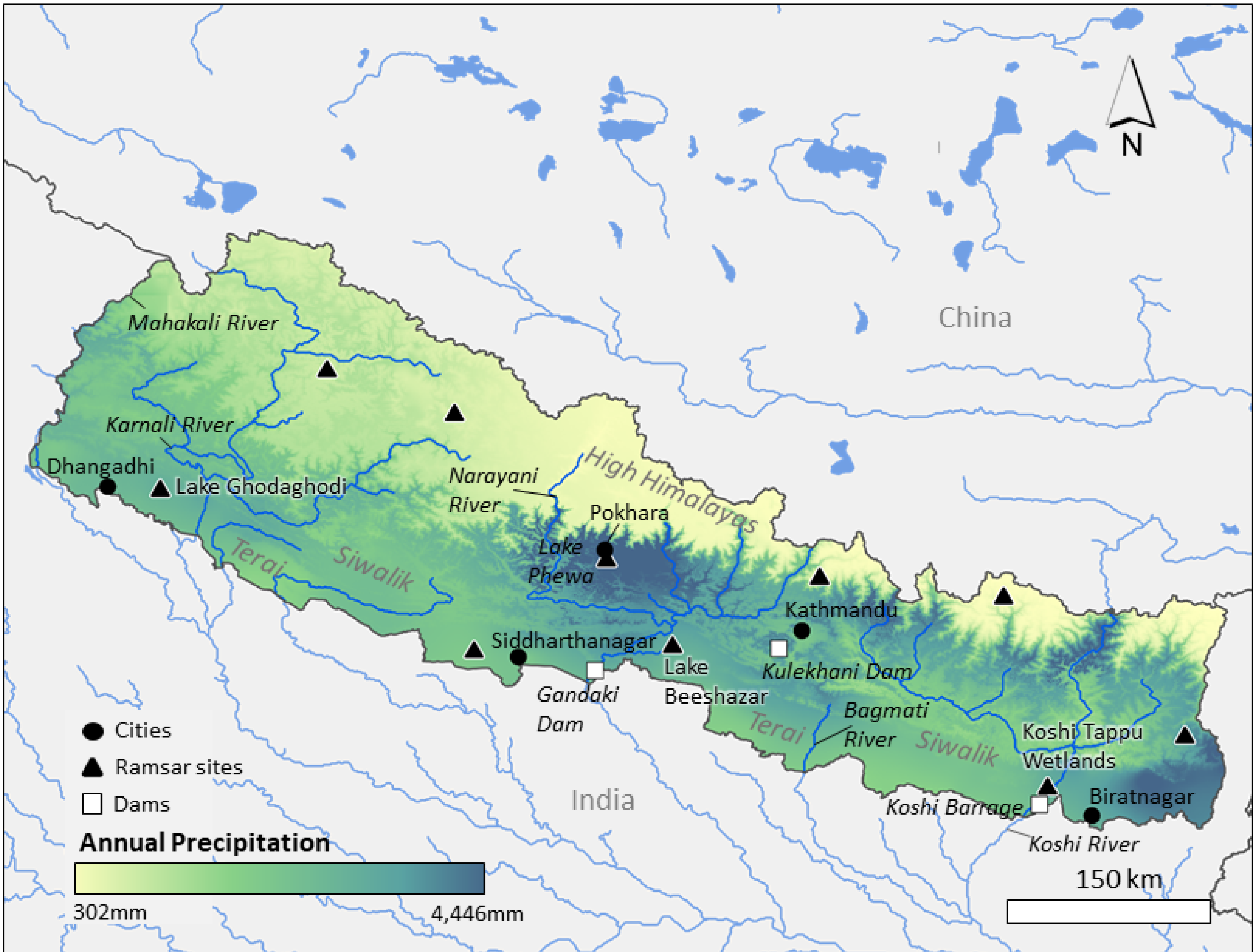
Nepal is divided into three main topographic regions. The 'Terai' is a flat, lowland river plain running the length of the southern border, is well suited for agriculture, and has a high population density. The 'Siwalik' (central hills) features deep valleys and steep slopes, mountain springs, terraced agriculture, and livestock farming. The High Himalayas run along the northern border and feature rangelands, glaciers, and low population density. All of Nepal is within the transboundary Ganges Basin, but surface water is organized and managed through five major basins: the Mahakali, Karnali, Narayani, Koshi, and Southern Rivers.[12] Collectively, these basins provide 70 percent of the Ganges River's dry season flow and 40 percent of its annual flow.[3] More than 6,000 rivers drain from north to south to the Ganges. The Karnali, Narayani, Koshi, and Southern Rivers Basins have robust surface water yields ranging from 44,000 to 65,000 MCM.[1] Most of the Karnali and Narayani Basins exist within Nepal whereas the Koshi Basin's headwaters originate in the Tibetan Plateau in China and less than half of the Basin is in Nepal.[2] One-third of the Mahakali River Basin is in Nepal and its runoff is comparatively lower.[1,2] The Southern Rivers Basin has the highest runoff, and includes lowland and hilly areas in central Nepal, including Kathmandu.[1]

Glacial melt, snowmelt, and springs sustain dry season flows in most basins, although surface water availability is extremely limited in the dry season in the Southern Rivers Basin.[4,5] Nepal's 3,252 glaciers provide 481 MCM in natural water storage in the Karnali, Gandaki, and Koshi Basins,[5] while also sustaining over 5,000 lakes.[3] Melting snowpack and glaciers provide around two-thirds of dry season flow for some rivers.[6] Nepal has four Ramsar sites in the Terai, two in the Siwalik, and four in the Himalayan region.

TABLE 1. WATER RESOURCES DATA	Year	Nepal	South Asia (median)
Long-term average precipitation (mm/year)	2017	1,500	1,712
Total renewable freshwater resources (TRWR) (MCM/year)	2017	210,200	210,200
Falkenmark Index - TRWR per capita (m3/year)	2017	7,173	2,529
Total renewable surface water (MCM/year)	2017	210,200	210,200
Total renewable groundwater (MCM/year)	2017	20,000	20,000
Total freshwater withdrawal (TFWW) (MCM/year)	2002	9,497	12,950
Total dam capacity (MCM)	2015	85	17,144
Dependency ratio (%)	2017	5.709	5.71
Interannual variability	2013	1	1.30
Seasonal variability	2013	4.10	3.55
Environmental Flow Requirements (MCM/year)	2017	95,940	83,790
SDG 6.4.2 Water Stress (%)	2016	8.31	15.67

Source: FAO Aquastat

FIGURE 1: MAP OF WATER RESOURCES



Source:
Cities: World Cities – ArcGIS Hub, **Country Borders:** GADM, **Dams:** FAO Aquastat Dams Database, **Ramsar Sites:** Ramsar Sites Information Service, **Lakes and Wetlands:** WWF - GLWD (Level 1), **Rivers:** WWF – HydroRivers, **Precipitation:** WorldClim, **Flood and Drought:** WRI Aqueduct 2019

Groundwater Resources

Lowland areas in the Terai have highly productive alluvial aquifers (250m deep) and robust recharge, although aquifers are often transboundary and can be impacted by groundwater pumping in India. Groundwater availability is variable in the Siwalik's hard rock aquifers, and productivity and recharge is moderate. Groundwater springs in the Siwalik sustain dry season river flows. The Kathmandu Valley has highly productive, but complex, alluvial aquifers (10-300m deep). The high Himalayas have no groundwater potential.[7–9]

Surface Water Outlook

KEY TAKEAWAYS

- Most surface water is used for seasonal irrigation in the Terai, although it is also an important source of municipal water supply, including Kathmandu.
- Nepal lacks dam capacity to adequately cope with its high inter-seasonal water supply variability, limiting hydropower generation and municipal service delivery in the dry season.
- Land use changes are increasing erosion, sedimentation, landslides, and flooding in the Siwalik and Terai. Sedimentation is highest on the Koshi River and has caused the river to alter its course, resulting in extensive flooding.
- The Bagmati River is highly polluted from inadequate treatment of industrial and municipal waste, reducing dissolved oxygen. Industrial wastes also contaminate surface water with heavy metals and arsenic.
- Municipal waste and agricultural runoff cause eutrophication in key lakes and wetlands, threatening biodiversity, especially in the Terai.

This section describes key sources of demand and uses of surface water, and associated challenges stemming from water availability and water quality challenges.

Agriculture accounts for 96 percent of total water withdrawals, with surface water used for 80 percent of all irrigated cropland, mostly in the Southern Rivers Basin's Terai lowlands. Most irrigation in the Terai is seasonal due to limited surface water availability.[1,5] Nationally, surface water is not a major resource for municipal systems, although surface water from the Bagmati River supplies half of the demand for drinking water in Kathmandu. Hydropower is an emerging non-consumptive use, although there are a limited number of small, run-of-the-river hydropower dams mostly in the Gandaki and Koshi Basins.[5,11]

Nepal has one of the lowest per capita dam capacities and highest inter-seasonal variabilities in water availability in Asia, with significant shortages during the dry season. Limited storage capacity in the Southern Rivers Basin, where many rivers are seasonal, increases risks of wet season floods and dry season shortages. For example, dry season shortages in the Bagmati River reduce municipal service delivery in Kathmandu by 35 percent.[12] Nepal is implementing an inter-basin water transfer from the Melamchi Basin to the Southern Rivers Basin and is building several small reservoirs to address these shortages.[13] Low storage and seasonal flows also reduce hydropower production by 65 percent each dry season.[14]

Catchment degradation increases erosion, sedimentation, flooding, and landslide risks, particularly in the Koshi Basin. Over 3 million hectares are seriously degraded by deforestation, terraced agriculture, and rangeland conversion. The Koshi Basin is naturally vulnerable to erosion and landslides due to its topography and climate.[15] In 2008, increased sedimentation caused the Koshi River to shift course 100 km eastwards,[17] which resulted in flooding that affected over three million people in India and 65,000 people in Nepal.[18]

The Bagmati River is critically polluted due to limited sanitation systems and treatment of industrial effluent. Only 10 percent of Kathmandu's wastewater is treated.[19] Five treatment plants are constrained by technical and maintenance issues[20] and most waste is discharged or washed into surface waters. This has raised biological oxygen demand (BOD) and reduced dissolved oxygen levels in the lower reaches of the river, harming biodiversity and ecosystems.[20] Additionally, unregulated industrial effluent in Kathmandu contaminate surface water with high levels of arsenic, oil, and other contaminants.[21]

Municipal waste, pesticides, and agricultural fertilizers are causing eutrophication in lakes, reservoirs, and Ramsar wetlands throughout the Terai and Siwalik. Pesticides and agricultural runoff threaten over 60 percent of wetlands in the Terai.[22] The Kulekhani Reservoir, Lake Phewa, and Ramsar sites such as Lake Ghodaghodi and Lake Beeshazar are eutrophic.[23–25] These water bodies are prone to outbreaks of invasive species, such as water hyacinth, southern cutgrass, and sedge.[26] Agricultural runoff also lowers pH and dissolved oxygen, while excess phosphates harm aquatic species.[25] Poor water quality in the Koshi Tappu Wetlands, one of the most important wetlands for migratory birds in Asia, has contributed to stark declines in waterfowl populations.[27]

Groundwater Outlook

KEY TAKEAWAYS

- Catchment degradation and drought are drying freshwater springs in the Siwalik, which is increasing dry season water stress and threatening a major source of drinking water.
- The water table in Kathmandu Valley is declining due to over-exploitation from numerous, unregulated wells.
- Groundwater in the Terai has naturally high levels of arsenic. Shallow and deep aquifers in the Kathmandu Valley have toxic heavy metals and high microbial contamination.

This section describes key sources of demand and uses of groundwater, and associated challenges stemming from water availability and water quality challenges.

Groundwater is an important water resource for irrigation and drinking water. Only 1,900 MCM out of 20,000 MCM in renewable groundwater are abstracted annually.[10,11] Groundwater is used in 20 percent of irrigated cropland,[10] primarily in the Terai.[5] Groundwater is also used by over half of the population in Kathmandu Valley often through shallow wells[28] and 80 percent of the population in Siwalik.[29]

Springs are drying up, particularly in the Siwalik, due to increasing demand, land use changes, and climate change. In the past decade, outflows have declined at more than 70 percent of freshwater springs in western Nepal.[30] Similarly, one-third of the springs in the Kavrepalanchok District (Koshi Basin) have dried up completely in the last ten years.[31] High elevation forests are critical to groundwater recharge in these areas. Forest fires and widespread deforestation in the Siwalik have reduced groundwater recharge.[29,32] Climate change is also increasing the frequency of droughts that will intensify surface water shortages in the dry season.[33] Natural disasters can also impact water availability, as the 2015 earthquake dried up almost 20 percent of springs in one catchment near Kathmandu.[34]

Concentrated demand and urbanization in the Kathmandu Valley are rapidly depleting aquifers. The water table is estimated to have fallen 15-20 meters since the mid-1980s due to poorly regulated and concentrated demand from private wells.[35] The proliferation of boreholes and shallow wells is causing the water table to fall by 70 to 80 cm per year and is increasing land subsidence[iii].[36–39] The Valley's shallow aquifer is highly dependent on rainfall for recharge and is susceptible to the impacts of drought. Urban sprawl is accelerating and limiting the shallow aquifer's recharge.[40] The deeper aquifer has extremely low recharge, and estimates suggest that abstraction rates are over 20 times recharge.[41] Greater emphasis on groundwater recharge and alternative water supplies may relieve strain on the Valley's aquifer.[35,42]

Groundwater in the Terai is naturally high in arsenic in some locations while the Kathmandu Valley has heavy metal and microbial pollution from municipal and industrial waste. Natural arsenic contamination occurs in shallow groundwater in some parts of the Terai, but is still generally suitable for irrigation.[8,43] In the Kathmandu Valley, high levels of toxic heavy metals such as lead, cadmium, and chromium are present. The Valley's shallow aquifer is contaminated by industrial and municipal waste while the deep aquifer has geogenic contamination from ammonium.[8] Lead pollution in the shallow aquifer is nearly five times higher than WHO guidelines for drinking water.[44] Additionally, both shallow and deep wells are polluted with E. Coli.[45,46] Microbial contamination stems from poor sanitation systems, including seepage from septic tanks and latrines, low sewerage coverage, and the infiltration of polluted surface water from the Bagmati River.[11,47]

Water Resources and Climate

KEY TAKEAWAYS

- Climate change will increase monsoon rainfall, raise temperatures, and increase drought. This poses risks to dry season water availability as melting of glaciers and snow accelerate.
- Flooding is already a major concern nationwide, and higher precipitation intensity and annual rainfall will increase risks from landslides, erosion and sedimentation, and flooding in both the Siwalik and Terai.
- Winter droughts will become more frequent, particularly in the western Terai, and threaten food security and livelihoods for rainfed agriculture.

[iii]Phenomenon in which the land sinks due to over pumping groundwater. In addition to threatening infrastructure, subsidence also permanently reduces aquifer storage capacity.

This section covers climate variability and climate change, their impacts on water availability and water quality, and the risks they pose to local communities and their economies.

Annual precipitation varies widely, with the highest rates in the central region and lowest in the northwest. Precipitation patterns are highly heterogeneous due to extreme topography and the seasonality of monsoons. Around 75 percent of Nepal's precipitation is received during the summer monsoon season. About one quarter of Nepal lies above the permanent snowline,[5] and in the winter, snowfall usually occurs in all locations above 3,000 meters.[1]

Average temperatures have increased by 1 to 1.3°C,[33] with the highest increases in the Himalayan region.[48] General impacts on annual precipitation are uncertain but generally limited, although wet areas may receive more precipitation and drier areas less.[33] These changes have reduced snow and ice coverage by 40 percent and increased melting rates, leading to sooner and larger peak flows in many rivers.[5]

Climate change is increasing monsoon precipitation and melting glaciers. Faster melting snowpack will intensify dry season shortages. Climate change is expected to increase average temperatures between 2.2 and 4.3°C by the end of the century. Annual precipitation may increase 62-148 mm due to stronger monsoon seasons,[49] leading to a net gain in renewable water resources.[33] However, climate change is also causing snowpack to melt faster and is melting glaciers, which are nonrenewable water reserves that buffer dry season river flows.[5,50] Even in the most optimistic warming scenarios, the Eastern Himalayas are expected to lose half their volume by the end of the century.[51] Glacial melt produces short short-term increases in river flow, but flow contributions will diminish over time as glaciers are depleted. These trends will intensify inter-seasonal variability in water supply and increase dry season water stress.

Higher precipitation intensity and increased melting of glacier and snowpack will increase flood and landslide risks, and are worsened by watershed degradation. Peak flows may increase 20-100 percent in some rivers.[52] In highland areas, flooding will increase from glacial lake and landslide dam outbursts, while lowland areas in the Terai face risks from dam failure and monsoon rainfall.[5] The Koshi Basin has experienced thousands of landslides in recent decades, and has dozens of glacial lakes that are at risk of outburst flooding.[53,54] The number of people impacted by flooding may double and economic losses may triple.[33] The economic losses from climate variability and extreme weather events, especially flooding, are equivalent to 1.5-2 percent of Nepal's GDP on average.[52]

Risks from monsoon and winter droughts threaten rainfed agriculture, posing risks to food security and livelihoods. Rainfed agriculture accounts for 75 percent of agricultural production.[56] The frequency of severe droughts in the monsoon and winter seasons will increase slightly,[49,56] particularly in the western Terai plains where rice production is common.[56] Winter droughts will inhibit the replenishment of glaciers and may increase forest fires.[56] The 2006-2007 monsoon drought reduced rice cultivation 21 to 30 percent,[55] while a major winter drought in 2008-2009 reduced wheat production by 16 percent.[57] The recent 2020-2021 drought was one of worst winter droughts on record, causing a 60-80 percent reduction in precipitation in western Nepal.[58]

FIGURE 2: DROUGHT RISK

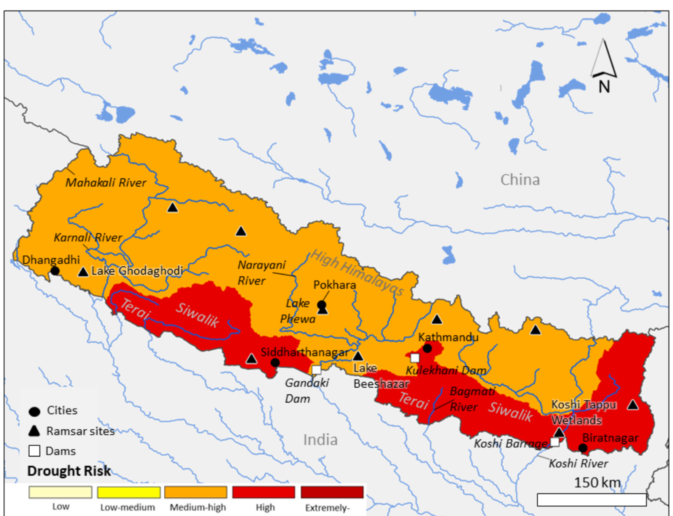


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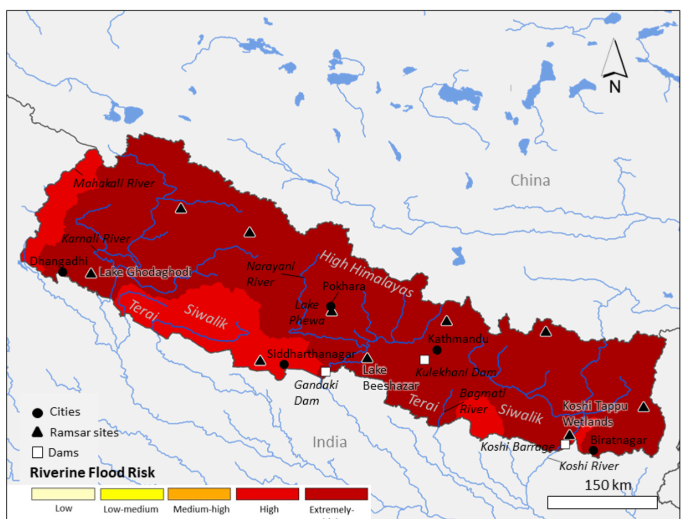
FIGURE 3. RIVERINE FLOOD RISK



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Water Policy and Governance

KEY TAKEAWAYS

- Decentralization under the new constitution has commenced but key water management responsibilities for sub-national entities are still being defined.
- Basin-level water management institutions do not exist as outlined in the National Water Plan. The Water and Energy Commission Secretariat lacks fiscal and decision-making abilities that hinder its ability to streamline water sector activities.
- International tensions between India and Nepal due to aquifer depletion and flooding in the Koshi and Mahakali Basins, while a lack of treaties and basin management institutions with China hinder management of the Koshi River.

This section provides an overview of key policies, institutions, and management challenges. Key laws, policies, and plans are summarized in Table 2 and the roles and responsibilities of select transboundary, national, and sub-national water management entities are summarized in Table 3.

TABLE 2. KEY LAWS, POLICIES, AND PLANS

Name	Year	Purpose
Water Resources Act	1992	Enables the formal creation of Water User Associations (WUAs) to govern water projects, prioritizes water allocations for drinking water and irrigation, requires permits for abstraction, outlines water quality protection principles, and establishes penalties for any violations of the Act.
Water Resources Regulation	1993	Establishes and outlines the structure and functions of District Water Resources Committees (DWRCs), including permit management and dispute resolution.
Water Resources Strategy (WRS)	2002	Defines water sector priorities and outlines actions, indicators, and timelines to address them. Adopts Integrated Water Resources Management (IWRM) principles for basin management, proposes river basin planning units, and calls for IWRM basin management plans.
National Water Plan (NWP) (2002- 2027)	2005	Defines the long-term investment portfolio for water sector and assigns the WECS to develop and coordinate water policy and sectoral development. Restructured District Water Resources Committees (DWRCs) around IWRM principles and created Sub-Basin Committees, River Basin Authorities, District Water Assemblies, and inter-district District Water Resource Committees (DWRC). Implementation of the plan has been incomplete.
Local Government Operation Act (LGOA)	2017	Defines local government responsibilities for resource management, including forests, watersheds, wetlands, water use, and biodiversity.
Environment Protection Act	2019	Defines environmental regulatory authorities, establishes an Environmental Fund, and requires environmental impact assessments.
National Water Resources Policy	2020	The new Water Policy integrates water policy and all water uses and seeks to ease water sharing disputes between provincial, district, and local governments. Establishes new federal, state, and local bodies for optimizing water use, development, management, and protection.

TABLE 3: WATER RESOURCES MANAGEMENT ENTITIES

Mandate	Institution	Roles and Responsibilities
Transboundary	Nepal-India Joint Committee on Water Resources (JCWR)	Oversees bilateral hydraulic development and flood mitigation measures for shared rivers. Headed by the ministers of water resources for each country.
National	The National Water Resource Development Council (NWRDC)	Highest authority for decision-making on water resource management. Issues directives to be implemented through provincial, district, and municipal governments.
	Ministry of Energy, Water Resources and Irrigation (MoEWRI)	Responsible for the management of all water resources, irrigation, and hydropower. The Department of Water Resources and Irrigation (DWRI) leads planning, development, and operation of irrigation projects, as well as river and catchment management projects to mitigate flood related disasters. The Department of Hydrology and Meteorology (DHM) collects and disseminates hydrological and meteorological data related to ambient water quality, hydrology, and snowpack and glaciers.
	Water Resources Research and Development Centre (WRRDC)	Overseen by the MoEWRI, the WRRDC leads research and training, and manages labs and research facilities.
	Groundwater Resources Development Board (GRDB)	Overseen by the MoEWRI, the GRDB manages eight branch offices that map and monitor aquifers, groundwater quality, and groundwater development for irrigation.
	Water and Energy Commission Secretariat (WECS)	Overseen by MoEWRI, WECS is the Secretariat of the Water and Energy Commission (WEC) and is in charge of developing national water policy and coordinating water sector development.
	Ministry of Water Supply and Sanitation (MoWSS)	In charge of developing and implementing water and sanitation policies, plans, and regulations, as well as monitoring drinking water quality.
Sub-national	District Water Resource Committees (DWRC)	Issue permits for water use, define district-level water allocations, register WUAs, and resolve local water disputes. Composed of district-level representatives from water related line agencies.
	Water User Association (WUA)	Local organizations (often for irrigation supply management) that operate and maintain water infrastructure.
	Provincial and Municipal governments	Provincial and municipal governments have crosscutting responsibilities for hydropower development, water service delivery, irrigation, and water management, but exact responsibilities are still being defined.

Nepal lacks a clear institutional structure to coordinate water resources management at the basin-level. Water management entities are organized around sub-national administrative boundaries, but there is currently no platform to coordinate basin planning for rivers that span multiple provinces, municipalities, and districts. This results in a fragmented approach to basin planning and causes disputes between upstream and downstream communities.[61]

Sub-national water management responsibilities need to be clarified under the new federalization process and capacities need to be strengthened. Nepal's new 2015 constitution, the 2017 LGOA, and 2020 National Water Resources Policy introduced significant changes to the water sector. The water management mandates, roles, and responsibilities of the DWRCs, provincial, and municipal governments broad mandates' need to be clarified to align with the new constitution and 2020 National Water Resources Policy.[11,62,63] Further, the sector lacks a clear institutional framework and water use plans[64] and allocation decisions may not always be compatible or feasible across basins.[62] Limited capacity within district and local water management entities impede implementation of existing policy. For example, DWRCs often struggle to register new WUAs due to limited engagement and infrequent meetings.[65] Many rural municipalities lack budgets for basic needs, including office space, internet, and adequate staffing, while targets for trainings and water plans are unfulfilled.[66,67]

Limited coordination and management challenges of key transboundary water resources and hydraulic

infrastructure, especially the Koshi and Mahakali Basins, compound flood risks and groundwater management challenges. Nepal has several agreements for sharing transboundary waters with India, including the Mahakali Treaty and Koshi Agreement, but there are no agreements with China. The Koshi Barrage often contributes to flash floods in India that could be mitigated through improved coordination and communication regarding flood releases.[68] Similarly, India's dam operations can cause severe flooding in the Terai,[69,70] and overexploitation of transboundary aquifers by water users in India have caused water tables to fall up to 50m in some parts of the western Terai, preventing farmers from accessing groundwater with traditional pumps.[4,71]

Water Quality Monitoring

Water quality monitoring responsibilities are fragmented across various government entities and the WRC has not fulfilled its mandate to consolidate data. When it was established, the WECS was intended to coordinate the exchange of water resources data, including water quality results, across the sector in a centralized database, however the WECS struggles to fulfill this mandate as the sector lacks a strong coordinating body to consolidate information from various line ministries.[62]

References

(1) FAO. Country Profile-Nepal; Rome, 2011.
(2) Ministry of Energy Water Resources and Irrigation. National Water Plan- Nepal; 2005.
(3) WEPA. State of Water Resources http://www.wepa-db.net/policies/state/nepal/state.htm (accessed Jun 14, 2021).
(4) Nepal Water Conservation Foundation (NWCF). Water Scarcity: Nepal Country Snapshot; 2019.
(5) Water and Energy Commission Secretariat. Water Resources of Nepal in the Context of Climate Change; Kathmandu, 2011.
(6) Wood, L. R.; Neumann, K.; Nicholson, K. N.; Bird, B. W.; Dowling, C. B.; Sharma, S. Melting Himalayan Glaciers Threaten Domestic Water Resources in the Mount Everest Region, Nepal. Front. Earth Sci. 2020, 29. https://doi.org/https://doi.org/10.3389/feart.2020.00128.
(7) Shrestha, S. R.; Tripathi, G. N.; Laudari, D. Groundwater Resources of Nepal: An Overview. In Groundwater of South Asia; A., M., Ed.; Springer: Singapore, 2018; pp 169–193. https://doi.org/https://doi.org/10.1007/978-981-10-3889-1_11.
(8) British Geological Survey. Groundwater Quality: Nepal; 2001.
(9) Bricker, S. H.; Yadav, S. K.; MacDonald, A. M.; Satyal, Y.; Dixit, A.; Bell, R. Groundwater Resilience Nepal: Preliminary Findings from a Case Study in the Middle Hills; 2014.
(10) FAO. Aquastat Main Database http://www.fao.org/nr/water/aquastat/data/query/results.html (accessed Jul 8, 2020).
(11) Nepal, S.; Neupane, N.; Belbase, D.; Pendey, V. P.; Mukherji, A. Achieving Water Security in Nepal through Unravelling the Water-Energy-Agriculture Nexus. Int. J. Water Resour. Dev. 2019, 37 (1), 67–93. https://doi.org/https://www.tandfonline.com/action/showCitFormats?doi=10.1080/07900627.2019.1694867.
(12) Gurung, Y.; Zhao, J.; Kumar K.C., B.; Wu, X.; Suwal, B.; Whittington, D. The Costs of Delay in Infrastructure Investments: A Comparison of 2001 and 2014 Household Water Supply Coping Costs in the Kathmandu Valley, Nepal. Water Resour. Res. 17AD. https://doi.org/10.1002/2016WR019529.
(13) Thapa, B. R.; Ishidaira, H.; Pandey, V. P.; Bhandari, T. M.; Shakya, N. M. Evaluation of Water Security in Kathmandu Valley before and after Water Transfer from Another Basin. Water 2018, 10 (224). https://doi.org/10.3390/w10020224.
(14) Bhatt, R. P. Hydropower Development in Nepal - Climate Change, Impacts and Implications. In Renewable Hydropower Technologies; Ismail, B., Ed.; InTech, 2017. https://doi.org/http://dx.doi.org/10.5772/66253.
(15) Uddin, K.; Murthy, M. S. R.; Wahid, S.; Matin, M. A. Estimation of Soil Erosion Dynamics in the Koshi Basin Using GIS and Remote Sensing to Assess Priority Areas for Conservation. PLoS One 2016. https://doi.org/10.1371/journal.pone.0150494.
(16) Sinha, R.; Gupta, A.; Mishra, K.; Tripathi, S.; Nepal, S.; Wahid, S. M.; Swarnkar, S. Basin-Scale Hydrology and Sediment Dynamics of the Kosi River in TheHimalayan Foreland. J. Hydrol. 2019, 570, 156–166. https://doi.org/https://doi.org/10.1016/j.jhydrol.2018.12.051.
(17) Kaur, B. Why does Kosi river cause devastating floods so often? Answer lies in massive siltation: study https://www.downtoearth.org.in/news/water/why-does-kosi-river-cause-devastating-floods-so-often-answer-lies-in-massive-siltation-study-60014 (accessed Jun 21, 2021).
(18) Kafle, K. R.; Khanal, S. N.; Dahal, R. K. Consequences of Koshi Flood 2008 in Terms of Sedimentation Characteristics and Agricultural Practices. Geoenvironmental Disasters2 2017, 4.
(19) Shukla, A.; Timilsina, U. R.; Jha, B. C. Wastewater Production, Treatment and Use in Nepal. In Proceedings of IOE Graduate Conference; 2015.
(20) Project Implementation Directorate; Kathmandu Upatyaka Khanepani Limited; Ministry of Water Supply; Government of Nepal for the Asian Development Bank. Initial Environmental Examination. NEP: Kathmandu Valley Wastewater Management Project – Guheshwori; 2018.
(21) Baniya, B.; Khadka, N.; Ghimire, S. K.; Baniya, H.; Sharma, S.; Dhital, Y. P.; Bhatta, R.; Bhattarai, B. Water Quality Assessment along the Segments of Bagmati River in Kathmandu Valley, Nepal. Nepal J. Environ. Sci. 2019, 7. https://doi.org/https://doi.org/10.3126/njes.v7i0.34314.
(22) Adhikari, R. C. Anthropogenic Impacts on Koshi Tappu Wetland, a Ramsar Site of Nepal. J. Entomol. Zool. Stud. 2019, 7 (6), 655–662.
(23) Sthapit, M.; Gurung, S.; Kafle, B. K.; Dahal, B. M.; Sharma, C. M.; Kafle, K. R.; Raut, N.; Manandhar, S. Preliminary Eutrophication Status Assessment in Kulekhani Reservoir and Lake Phewa, Nepal. In International Conference on Natural Resources, Agriculture and Society in Changing Climate; 2020.
(24) Bhatta, R.; Tuladhar, S.; Regmi, D.; Gurung, S.; Joshi, R.; Dahal, B. M.; Raut, N.; Kafle, K. R.; Kayastha, R.; Prasad, A.; Tripathee, L.; Sharma, C. M. Water Quality of Ghodaghodi Lake: A Ramsar Site in Western Nepal. In International Conference on Natural Resources, Agriculture and Society in Changing Climate; 2019.
(25) Niraula, R. Evaluation of the Limnological Status of Beeshazar Lake, a Ramsar Site in Central Nepal. J. Water Resour. Prot. 2012, 4, 256–263.
(26) Sharma, A.; Bhattarai, S.; Bhatta, B. An Assessment of Abundance of Aquatic Invasive Plants and Their Management in Beeshazar Lake, Chitwan. J. Agric. For. Univ. 2018, 2, 225–230.
(27) Baral, H. Updated Status of Nepal's Wetland Birds. Banko Janakari 2009, 19 (3), 30–35. https://doi.org/http://dx.doi.org/10.3126/banko.v19i3.2209.
(28) Shrestha, S.; Nakamura, T.; Magome, J.; Aihara, Y.; Kondo, N.; Haramoto, E.; Malla, B.; Shindo, J.; Nishida, K. Groundwater Use and Diarrhoea in Urban Nepal: Novel Application of a Geostatistical Interpolation Technique Linking Environmental and Epidemiologic Survey Data. Int. Health 2018, 10 (5). https://doi.org/https://doi.org/10.1093/inthealth/ihy037.
(29) Poudel, D. D.; Duex, T. W. Vanishing Springs in Nepalese Mountains: Assessment of Water Sources, Farmers' Perceptions, and Climate Change Adaptation. Mt. Res. Dev. 2017, 37 (1). https://doi.org/Mountain Research and Development 36 http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00039.1.

(30) Adhikari, S.; Gurung, A.; Chauhan, R.; Rijal, D.; Dongol, B. S.; Aryal, D.; Talchabhadel, R. Status of Springs in Mountain Watershed of Western Nepal. Water Policy 2021, 23 (1), 142–156. https://doi.org/https://doi.org/10.2166/wp.2020.187.
(31) Sharma, B.; Nepal, S.; Gyawali, D.; Pokharel, G. S.; Wahid, S.; Mukherji, A.; Shrestha, A. Springs, Storage Towers, and Water Conservation in the Midhills of Nepal; Kathmandu, 2016.
(32) Chaudhary, R. P.; Uprety, Y.; Rimal, S. K. Deforestation in Nepal: Causes, Consequences, and REsponses. In Biological and Environmental Hazards, Risks, and Disasters; Shroder, J. F., Sivanpillai, R., Eds.; Elsevier, 2016; pp 335–372.
(33) World Bank Group. Climate Risk Country Profile Nepal https://climateknowledgeportal.worldbank.org/sites/default/files/2021-05/15720-WB_Nepal Country Profile-WEB.pdf (accessed Jun 14, 2021).
(34) Chapagain, P. S.; Ghimire, M.; Shrestha, S. Status of Natural Springs in the Melamchi Region of the Nepal Himalayas in the Context of Climate Change. Environ. Dev. Sustain. 2019, 21, 263–280. https://doi.org/https://doi.org/10.1007/s10668-017-0036-4.
(35) Chinnasamy, P.; Shrestha, S. R. Melamchi Water Supply Project: Potential to Replenish Kathmandu's Groundwater Status for Dry Season Access. Water Policy 2019, 21, 29–49. https://doi.org/https://doi.org/10.2166/wp.2019.080.
(36) Krishnan, P. V. S.; Kim, D. Subsidence Due to Groundwater Withdrawal in Kathmandu Basin Detected by Time-Series PS-InSAR Analysis. Korean J. Remote Sens. 2018, 34 (4), 703–708. https://doi.org/https://doi.org/10.7780/kjrs.2018.34.4.12.
(37) Awale, S. Put back what you pump out https://archive.nepalitimes.com/article/nation/water-table-of-kathmandu-valley-falling-fast-recharge-to-replenish,4100 (accessed Jun 18, 2021).
(38) Gautam, D.; Prajapati, R. N. Drawdown and Dynamics of Groundwater Table in Kathmandu Valley, Nepal. Open Hydrol. J. 2014, 8, 17–26.
(39) Bhattarai, R.; Alifu, H.; Maitiniyazi, A.; Kondoh, A. Detection of Land Subsidence in Kathmandu Valley, Nepal, Using DInSAR Technique. Land 2017, 6 (39). https://doi.org/http://dx.doi.org/10.3390/land6020039.
(40) Prajapati, R.; Upadhyay, S.; Talchabhadel, R.; Thapa, B. R.; Ertis, B.; Silwal, P.; Davids, J. C. Investigating the Nexus of Groundwater Levels, Rainfall and Land-Use in the Kathmandu Valley, Nepal. Groundw. Sustain. Dev. 2021, 14. https://doi.org/https://doi.org/10.1016/j.gsd.2021.100584.
(41) Chapter 2: Groundwater Quantity. In Kathmandu Valley Groundwater Outlook; Shrestha, S., Pradhananga, D., Pandey, V. P., Eds.; Asian Institute of Technology (AIT), The Small Earth Nepal (SEN), Center of Research for Environment Energy and Water (CREEW), International Research Center for River Basin Environment- University of Yamanashi (ICRE-UY), 2012.
(42) Dixit, A.; Upadhya, M. Augmenting Groundwater in Kathmandu Valley: Challenges and Possibilities; Kathmandu, 2005.
(43) Kansakar, D. R. Understanding Groundwater for Proper Utilization and Management in Nepal; 2006.
(44) Chapagain, S. K.; Kazama, F. Chapter 6: Overview of Chemical Quality of Groundwater in the Kathmandu Valley. In Kathmandu Valley Groundwater Outlook; Shrestha, S., Pradhananga, D., Pandey, V. P., Eds.; Asian Institute of Technology (AIT), The Small Earth Nepal (SEN), Center of Research for Environment Energy and Water (CREEW), International Research Center for River Basin Environment- University of Yamanashi (ICRE-UY): Kathmandu, 2012.
(45) Sakamoto, Y.; Nishida, K.; Kazama, F.; Imaizumi, Y.; Hiraga, Y.; Nakamura, T.; Chapagain, S. K. Chapter 7: Microbial Pollution in Groundwater and Surface Water of the Kathmandu Valley. In Kathmandu Valley Groundwater Outlook; Shrestha, S., Pradhananga, D., Pandey, V. P., Eds.; Asian Institute of Technology (AIT), The Small Earth Nepal (SEN), Center of Research for Environment Energy and Water (CREEW), International Research Center for River Basin Environment- University of Yamanashi (ICRE-UY): Kathmandu, 2012.
(46) Bhandari, P.; Banjara, M. R.; Singh, A.; Kandel, S.; Rawal, D. S.; Pant, B. R. Water Quality Status of Groundwater and Municipal Watersupply (Tap Water) from Bagmati River Basin in Kathmanduvalley, Nepal. Jounral Water, Sanit. Hyg. Dev. 2021, 11 (1), 102–111. https://doi.org/10.2166/washdev.2020.190.
(47) Warner, N. R.; Levy, J.; Harpp, K.; Farruggia, F. Drinking Water Quality in Nepal's Kathmandu Valley: A Survey and Assessment of Selected Controlling Site Characteristics. Hydrogeol. J. 2008, 16 (2), 321–334.
(48) DHM (Department of Hydrology and Meteorology). Observed Climate Trend Analysis of Nepal (1971-2014); Kathmandu, 2017.
(49) World Bank Group. Climate Projections. Nepal https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-projections (accessed Jun 14, 2021).
(50) Biemans, H.; Siderius, C.; Lutz, A. F.; Nepal, S.; Ahmad, B.; Hassan, T.; von Bloh, W.; Wijngaard, R. R.; Wester, P.; Shrestha, A. B.; Immerzeel, W. W. Importance of Snow and Glacier Meltwater for Agriculture on the Indo-Gangetic Plain. Nat. Sustain. 2019, 2, 549–601. https://doi.org/https://doi.org/10.1038/s41893-019-0305-3.
(51) Bolch, T.; Shea, J.; Liu, S.; Azam, F.; Gao, Y.; Gruber, S.; Immerzeel, W.; Kulkarni, A.; Li, H.; Tahir, A.; Zhang, G.; Zhang, Y. Status and Change of the Cryosphere in the Extended Hindu Kush Himalaya Region; Springer International Publishing, 2019. https://doi.org/10.1007/978-3-319-92288-1.
(52) (MoSTE), M. of S. T. and E. Economic Impact Assessment of Climate Change in Key Sectors in Nepal; Kathmandu, 2014.
(53) ICIMOD. Inventory of Glacial Lakes and Identification of Potentially Dangerous Glacial Lakes in the Koshi, Gandaki, and Karnali River Basins of Nepal, the Tibet Autonomous Region of China, and India; Kathmandu, 2020.
(54) Gupta, N. Water, disasters and people https://myrepublica.nagariknetwork.com/news/water-disasters-and-people/ (accessed Jun 21, 2021).
(55) GFDRR. Climate Risk and Adaptation Country Profile: Nepal; Washington, D.C., 2011.
(56) USAID. Climate Risk Profile Nepal; Washington, D.C., 2017.
(57) Dixit, A. Climate Change in Nepal: Impacts and Adaptive Strategies; 2010.
(58) Sharma, S.; Pokharel, B. Nepal under severe drought condition: Winter crops affected https://thehimalayantimes.com/opinion/nepal-under-severe-drought-condition-winter-crops-affected (accessed Jun 14, 2021).
(59) DAI Global LLC. West Seti Watershed Profile; Washington, D.C., 2019.
(60) Pioneer Law. Environment Protection Act, 2076 (2019) http://www.pioneerlaw.com/news/environment-protection-act-2076-2019#:~:text=The Act prescribes formation of,quality of air and water.&text=Environmental Fund will constitute amounts,State Government and Local Bodies (accessed Jun 10, 2021).
(61) Devkota, K.; Khatri, D.; Neupane, K. R. Water Conflicts in Urbanizing Regions in the Himalaya: Case Studies From Dhulikhel and Bidur in Nepal. Nepal J. Soc. Sci. Public Policy 2019, 5 (1), 49–73.
(62) Regmi, B. R.; Shrestha, K. Policy Gaps and Institutional Arrangements for Water Resources Management in Nepal; 2018.
(63) New Spotlight Online. National Water Resources Policy 2077 Unveiled https://www.spotlightnepal.com/2020/12/17/national-water-resources-policy-2077-unveiled/ (accessed Jun 10, 2021).
(64) HELVETAS. Water Use Master Plan (WUMP).
(65) Devkota, K.; Neupane, K. R. Water Governance in Rapidly Urbanising Small Town: A Case of Dhulikhel in Nepal. J. Water Secur. 2018, 4. https://doi.org/https://doi.org/10.15544/jws.2018.002.
(66) United Nations Development Programme. Nepal Country Sector Assessment; 2010.
(67) White, P.; Haapala, J. Water Security and Social Inclusion: Local Governance Within the Newly Established Rural Municipalities in Nepal. 2019, 5 (1), 99–127.
(68) Sangomia, A. Communication gap: Bihar floods show why India, Nepal need to get their act together https://www.downtoearth.org.in/news/climate-change/communication-gap-bihar-floods-show-why-india-nepal-need-to-get-their-act-together-65961 (accessed Jun 10, 2021).

(69) Sharma, B.; Schultz, K. As Deadly Floods Engulf Nepal Border, Anger Turns to India https://www.nytimes.com/2019/09/29/world/asia/nepal-india-flood-dam.html (accessed Jun 21, 2021).
(70) Uprety, A.; Ozaki, A.; Senoo, Y.; Yoshida, I.; Leppold, C.; Higuchi, A.; Tanimoto, T. Flood Damage in Nepal Exacerbated by Underlying Conflict with India. Lancet Planet Heal. 2017, 1 (9). https://doi.org/10.1016/S2542-5196(17)30159-6.
(71) Hanasz, P. Power Flows: Hydro-Hegemony and Water Conflicts in South Asia. Secur. Challenges 2014, 10 (3).

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