USAID FROM THE AMERICAN PEOPLE

SWP SUSTAINABLE WATER PARTNERSHIP

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.

India Water Resources Profile Overview

India is one of the most water stressed countries in the world. Per capita annual freshwater availability (1,427 m3) is lower than the Falkenmark[i] threshold for water stress and 66 percent of water resources are abstracted.[ii] Approximately 31 percent of India's water resources originate in neighboring countries. Water is abundant in the lower reaches of the Ganges River Delta in the east but deficits are common in the northwest, west, and south depending on timing and course of summer and winter monsoons.

Total water demand is projected to exceed renewable supply in almost every state by 2030. Growing water stress may significantly impact agricultural output, particularly in the northwest, and cause significant economic losses.

Insufficient water storage and poor reservoir management threaten municipal water supply, particularly in periods of drought. Shortages are worsened by high groundwater abstractions that reduce base river flow, watershed deforestation and degradation, and concentrated demand in urban areas.

Lack of municipal wastewater treatment has led to microbial contamination and reduced dissolved oxygen in many rivers. This has impacted ecosystems and biodiversity, particularly in the Yamuna (Delhi), Cooum (Chennai), and the Mithi Ulhas rivers (Mumbai).

Groundwater use is unsustainable in many cities and agricultural areas. Aquifer depletion is most rapid in northwestern India. Declining groundwater levels threaten livelihoods in rural communities and urban water supply.

Fluoride (northwest and south) and arsenic (lower reaches of the Ganges Basin) are naturally occurring in groundwater. High salinity (northwest) is also natural and caused by flood irrigation and over-pumping coastal aquifers. Heavy metal contamination in urban areas derives from industrial and municipal waste.

Climate change is increasing the frequency and scale of severe droughts, particularly in the northwest and south. Glacial melt and more intense monsoon precipitation will contribute to landslides and severe flooding in the northern highland areas and the lower reaches of the Ganges and Brahmaputra Basins. Flood risks are severe and cause over $7 billion in losses each year.

India has a strong federalist system in which states have primary domain over water allocation and water use within their territories. State policies are not always legally or practically compatible, which can impede integrated water resources management. States are not obligated or incentivized to employ IWRM approaches.

---

[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%.

WINROCK INTERNATIONAL · TETRA TECH · IUCN · mWater · SEI Stockholm Environment Institute · World Resources Institute · The CEO Water Mandate

Water Resources Availability

KEY TAKEAWAYS

- Water availability is seasonally and regionally variable, and is influenced by the intensity, timing, and duration of summer and winter monsoons.
- 60 percent of India's renewable surface water derives from the Ganges and Brahmaputra Basins.
- Alluvial aquifers cover one-third of India throughout the Indo-Gangetic Plain and contain half of India's renewable groundwater resources.

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

India divides its surface water into 22 basins. The Ganges, Indus, Godavari, and Brahmaputra Basins cover more than half the country.[9] The Ganges and Brahmaputra Basins have headwaters in the Himalayas and are part of the transboundary Ganges-Brahmaputra-Meghna Basin which outlets through the Ganges Delta.[10] Almost 60 percent of India's renewable water is in the Ganges and Brahmaputra Basins.[11] However, only 37 percent of the water is exploitable.[12] High volume and rapid flows into the Bay of Bengal during the summer monsoons are hard to store and almost none of the flow in the Brahmaputra Basin is considered usable.[13,14] The Ganges is the longest river (2,500 km) and flows across 11 states.[15] The Indus Basin does not contribute much to India's total renewable water supply, but its flows are critical to downstream water users in Pakistan. Many rivers within the Indus Basin are seasonal and terminate in seasonal salt marshes called the Rann of Kutch in the Thar Desert. The Western Ghats coastal mountain range form the upper catchments of numerous river basins, including the Krishna and Godavari Basins, which provide 10 percent of India's renewable water.[11]

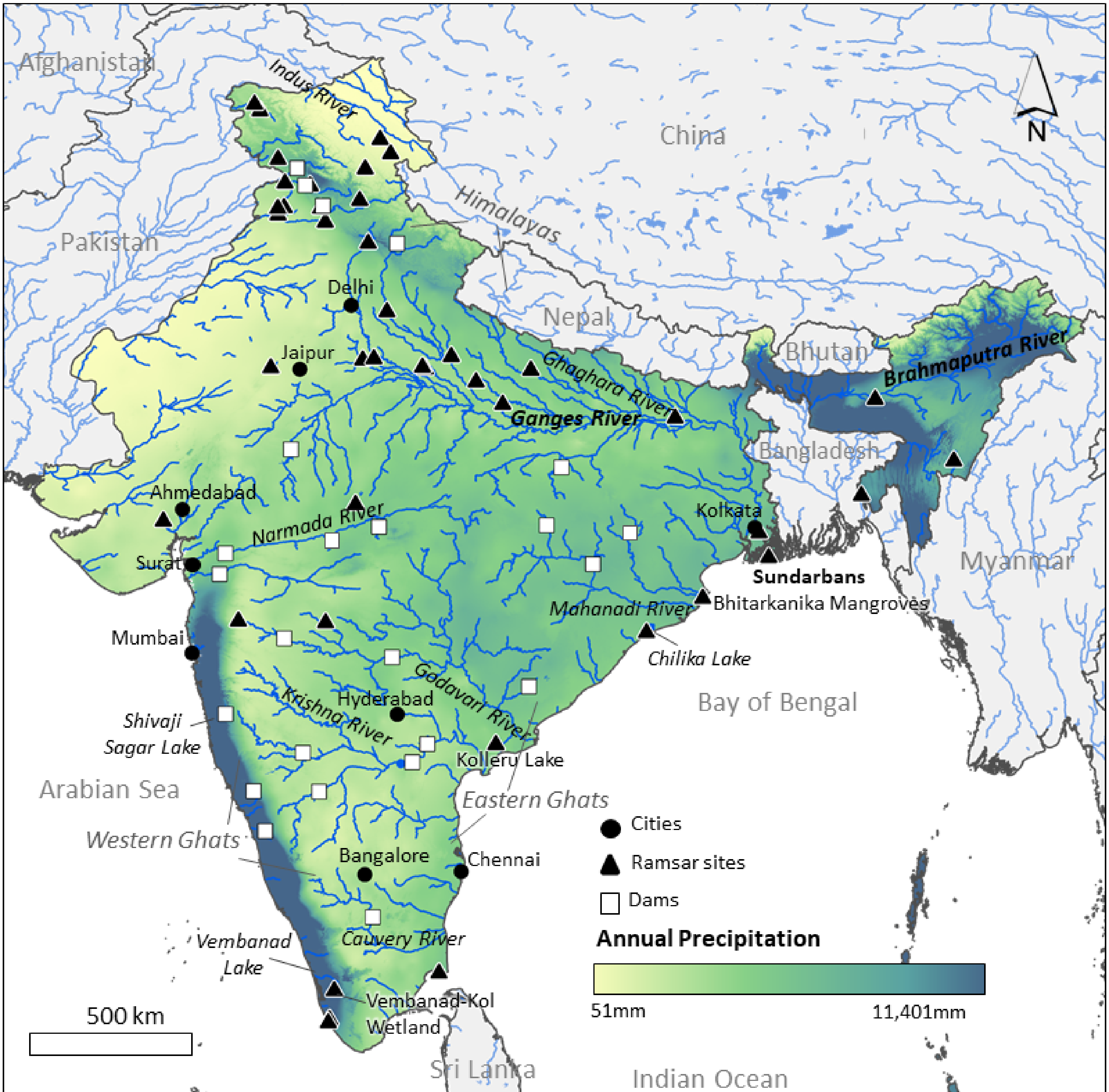
The summer monsoons (June-September) provide 60 to 90 percent of annual precipitation and sustain river flows at lower elevations.[16–19] River flow in highland areas of the Indus, Ganges, and Brahmaputra Basins is sustained by melting snowpack and glaciers. There are more than 4,000 glaciers in the upper Ganges Basin alone.[20] Snowpack and glacial melt constitute between 50 and 75 percent of total highland river flows and are a critical resource in the Himalayan foothills.[19]

India's has over 1,000 large and medium-sized lakes and reservoirs. The largest freshwater reservoirs are the Shivaji Sagar, Indira Sagar, and Sardar Sarovar.[21] Prominent brackish lakes include the Vembanad, Chilika, and Pangong. The Sundarbans wetlands near the Ganges River Delta contains one of the largest mangrove forests in the world.[22]

TABLE 1. WATER RESOURCES DATA	Year	India	South Asia (Median)
Long-term average precipitation (mm/year)	2017	1,083	1,712
Total renewable freshwater resources (TRWR) (MCM/year)	2017	1,911,000	210,200
Falkenmark Index - TRWR per capita (m^3/year)	2017	1,427	2,529
Total renewable surface water (MCM/year)	2017	1,869,000	210,200
Total renewable groundwater (MCM/year)	2017	432,000	20,000
Total freshwater withdrawal (TFWW) (MCM/year)	2010	647,500	12,950
Total dam capacity (MCM)	2005	224,000	17,144
Dependency ratio (%)	2017	30.52	5.71
Interannual variability	2013	1.7	1.30
Seasonal variability	2013	4.2	3.55
Environmental Flow Requirements (MCM/year)	2017	937,100	83,790
SDG 6.4.2 Water Stress (%)	2010	66.49	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

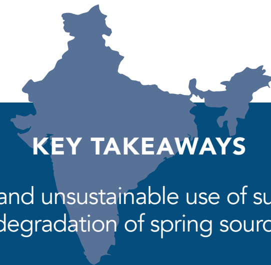
Groundwater Resources

Groundwater is classified into 14 principal systems that are further subdivided into 42 major aquifers.[23] Most of these aquifers can be broadly characterized as consolidated and unconsolidated formations. Groundwater availability is more consistent and robust in unconsolidated formations.

Consolidated, hard rock aquifers underlay the two-thirds of India in the central and southern regions. The aquifers have variable hydrogeologic properties that depend on the degree of fracturing.[24] Groundwater in consolidated aquifers is accessible at shallow depths but storage capacity within these aquifers is generally low.[25] Deeper, potentially more productive aquifers can be found in some locations, but drilling costs are high and drilling success rates are variable as borehole depths can range between 60 to 100 meters.[24]

Aquifers in the unconsolidated formations contain roughly half of all renewable groundwater in lowland areas, along parts of the eastern coastline, and in a broad band across the Indo-Gangetic Plain in northern India.[25] These aquifers have greater storage capacity and support high well yields.[25] The depth to water table in northwestern India is more than 40 meters and is less than 10 meters throughout the eastern Indo-Gangetic Plain.[26]

Surface Water Outlook



KEY TAKEAWAYS

- Canal and flood irrigation contribute to inefficient and unsustainable use of surface water. Base flow rates in many rivers are also decreasing due to over-abstraction, drought, and degradation of spring sources.
- Several large cities, especially in the south and west, are vulnerable to drought and reduced flows due to poor reservoir management and low storage capacity. The Ganges and Brahmaputra Basins are at risk of severe flooding during monsoons.
- Aquatic biodiversity in wetlands is vulnerable to upstream hydraulic development, water quality threats, and reductions in river flow rates.
- Municipal and agricultural waste are depleting surface waters of dissolved oxygen, particularly downstream of cities in the dry season. Industrial effluent are contaminating surface waters with heavy metals, surfactants, and pesticides.

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

Irrigation accounts for 90 percent of all freshwater withdrawals, and over 60 percent of the withdrawals are from surface water.[5] Surface water for irrigation is generally conveyed through extensive canals in the Ganges Basin in the states of Uttar Pradesh, Madhya Pradesh, Haryana, and Bihar.[5,27,28] Urban municipal water services rely on surface and groundwater, although surface water abstractions are slightly higher. In rural areas, groundwater is the main water source for domestic use.[30,31] Industry accounts for only two percent of total withdrawals.[5,32] There are also numerous non-consumptive surface water uses including hydropower generation (10 percent of total power generation) and transportation and shipping through over 5,000 km of navigable rivers.[33,34]

Over-abstraction and inefficient irrigation, primarily of rice and wheat, threaten surface water availability, economic growth, and food security. Since the 1960s, India's "Green Revolution" more than quadrupled irrigated croplands.[35] This has increased water stress and jeopardized economic development and food security.[1] Canal distribution systems and flood and furrow irrigation systems are only 35-45 percent efficient[36] and water stress from these losses may contribute to a more than 6 percent decline in GDP by 2050.[2] India's National Water Mission aims to increase water use efficiency by 20 percent and promote micro-irrigation systems.[39]

Declining base flow rates are reducing dry season flows and impacting irrigation, ecosystems and biodiversity, and municipal use, especially in the Ganges, Cauvery, Narmada, and Mahanadi Rivers. Reduced base flow rates are caused by unsustainable groundwater abstraction, more intense and frequent drought, and degraded headwater springs. The Ganges River base flow rate has declined 59 percent over the past few decades in some of its lower reaches.[40] Similarly, deforestation, fires, and land use changes, among other factors have reduced spring outflows throughout India, especially in the Western and Eastern Ghats and Himalayan regions.[41] Urbanization and agriculture in the Krishna Basin have reduced forest cover to only 3 percent, increased flooding, degraded water quality, and increased sedimentation in dams.[42] In the Himalayan regions, 15 percent of the population depend on springs, which periodically dry up. Around half of all springs in the region have reduced outflows.[43]

Poor reservoir management and low storage capacity threaten municipal water supply in several major cities, especially in the southern peninsula and the west. Two-thirds of national storage capacity are held in 123 major reservoirs but their capacity fluctuates between 20 and 70 percent between June and October due to seasonal water availability.[44] Low storage capacity worsened by sedimentation from upstream land use changes and poor reservoir operations compound these fluctuations. Lower than average monsoon rainfall and low reservoir storage capacity have resulted in water crises in several major cities, including Bangalore, Hyderabad, Delhi, and Chennai, which experienced acute water shortages during a 2016-2019 drought. In 2019, Chennai suspended municipal water distribution urban residents as its reservoirs dried up.[45]

Monsoon flooding is a key risk to agriculture, infrastructure, economic growth, and human health. Approximately 12 percent of India faces high risk of flooding, particularly in the states of Assam, Bihar, Orissa, Uttar Pradesh, and West Bengal.[46] Floods cost almost $7 billion per year and routinely cause massive loss of human life.[4] In 2019, monsoon flooding killed 1,800 people, destroyed infrastructure and cropland, and displaced of 1.8 million people.[47] Flood management strategies have focused on infrastructure, including the construction of dykes, although there is a need for improved technical capacity, flood forecasting and warning outreach, and better land use planning and flood plain mapping.[4,48] Expanding urban slums that encroach on flood plains and along the coast are vulnerable, particularly in cities like Mumbai.[49]

Wetland and riverine biodiversity are threatened by decreasing inflows of freshwater, surface water abstraction for municipal and agricultural purposes, and drought. India has over 700,000 wetlands, including 37 official Ramsar Sites which span over a million hectares.[22,50] The five largest Ramsar Sites include the Sundarbans (423,000 hectares (ha)), Vembanad-Kol (151,250 ha), Chilika Lake (116,500 ha), Kolleru Lake (90,100 ha), and Bhitarkanika Mangroves (65,000 ha).[51] Dams reduce river flows to downstream brackish wetlands and estuaries[52] and droughts have caused relatively large rivers, such as the Ken in central India, to dry up.[53,54] Declining flow rates in the Ganges River have increased salinity in the Delta.[55] The recently approved National Waterways Act, which calls for expanded fluvial transportation capacity, will affect 90 percent of the Ganges River Dolphin's habitat and may further strain its population without appropriate mitigation measures.[56]

Widespread discharge of untreated municipal waste and agricultural runoff have reduced dissolved oxygen (DO) threaten aquatic ecosystems and biodiversity. Over 38 million liters of untreated municipal sewage are discharged directly into the environment each day.[57,58] Watercourses are also heavily polluted with solid waste, particularly downstream of urban areas, and can suffer from erosion and siltation caused by illegal in-stream sand and gravel mining.[59] These have threatened aquatic life by depleting oxygen levels.[60] Dissolved oxygen in portions of the Yamuna (near Delhi), Cooum (near Chennai), and Mithi and Ulhas Rivers (both in Mumbai) have been found to be too low to support aquatic life.[61]

Heavy metals and surfactants from industrial waste threaten public health. Heavy metals in surface water include cadmium, chromium, and lead at concentrations that exceed WHO guideline limits for drinking water. These are likely derived from diverse sources of industrial waste. Notably, lead concentrations exceeded WHO guideline limits for drinking water by more than 20 percent in approximately 70 rivers.[62]

Agrochemical contamination is particularly high in the Ganges Basin, threatening water quality and human health. Concentrations of numerous pesticides, including malathion, are several times higher than WHO guideline limits for drinking water in the lower reaches of the Ganges Basin in West Bengal.[63] Organochlorine pesticides constitute up to 70 percent of all pesticides used. These pesticides present serious threats to water quality and public health as they persist in the environment and are neurotoxic.[64]

Open cast mines, particularly in the Western Ghats, threaten surface water quality and biodiversity. Heavy tropical rainfall can rapidly disperse mine tailings and increase siltation of watercourses, increasing the risk of landslides and reducing downstream reservoir capacity. Most of the Western Ghats may soon attain protected status, although 15 percent of the proposed ecologically sensitive area may be reserved for mining and industry.[65–67]

Groundwater Outlook

KEY TAKEAWAYS

- Aquifers in northwestern India are severely overexploited and unsustainable groundwater abstraction will affect most states by 2030. Domestic wells in many cities such as Chennai and Delhi face declining water levels and in some cases have run dry during drought.
- Natural contamination in groundwater widespread. Arsenic is found within the Indo-Gangetic Plain and high salinity occurs naturally and is caused by flood irrigation and over pumping.
- Poor sanitation systems, heavy metal contaminants from industry, and fertilizers and pesticides threaten public health and degrade groundwater quality.

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

Total freshwater demand is projected to exceed supply by as much as 50 percent by 2030 due to increased demand for groundwater.[3] Groundwater abstractions are mostly for irrigation, especially in the Ganges Basin and the northwest, and constitute 60 percent of total irrigation withdrawals.[1,5,68,69] Groundwater is a relatively minor water source for municipal systems but is used to supplement surface water supply. Over 20 percent of urban residents obtain water through private or community wells and groundwater is the primary source of drinking water in rural areas.[70] Over one-third of industrial withdrawals are from groundwater, although total withdrawals are low compared to other sectors.[30] Groundwater overexploitation is widespread and conditions are expected to worsen nationwide.[73] The crisis is most severe in the northwest, particularly in Punjab, where total abstractions exceed recharge by over 65 percent.[74,75] If trends continue, Punjab's groundwater will be fully depleted in most locations by 2040.[74]

Poor management, high demand, and drought threaten groundwater availability in urban areas throughout India, particularly in southern India and in Delhi. Declining groundwater has been observed in major cities throughout southern India.[77] Wells in Chennai dried up after the 2019 drought, which coincided with municipal reservoirs becoming depleted.[78] Groundwater in Delhi has declined 0.5 to 2 meters annually, threatening domestic water sources for many residents.[79]

Natural contamination from fluoride is widespread and naturally-occurring arsenic can be found across the Indo-Gangetic Plains. Fluoride is one of the largest sources of contamination nationally, with the highest concentrations being in the northwest and in the south.[23,80] Fluoride can be found in excess of WHO guidelines in nearly half of India's districts and has been implicated in fluorosis afflicting over 60 million people.[81–83] Over 10 million people are also exposed to concentrations of arsenic in groundwater, particularly in the lower reaches of the Ganges Basin in West Bengal, Bihar, and Jharkhand and also in Uttar Pradesh and Delhi.[31]

Saline groundwater is naturally present in many locations but is worsened by over pumping in coastal aquifers and flood irrigation. Groundwater salinity is high in the northwest and in the south from natural and anthropogenic sources.[84] For example, soil salinization has affected approximately 10 percent of the cultivated areas in Haryana (northwest).[85] Over-pumping of coastal aquifers has also led to saline intrusion in Mumbai.[86]

Untreated wastewater, agrochemicals, and industrial wastes such as lead, chromium, and cadmium threaten public health and groundwater. Elevated nitrate concentrations can be found in groundwater in more than half of India's administrative districts.[81,84] Nitrates are attributed to inadequate sanitation systems, including septic systems and latrines, that allow wastewater to infiltrate directly into groundwater and agricultural fertilizers. Lead, chromium, and cadmium can also be found at high concentrations and are likely the tied to industrial and solid waste.[81] Chromium contamination has been linked to tanneries and chromium ore processing.[87] Cadmium concentrations are also consistently high, up to 20 times WHO guideline limits for drinking water, in western Uttar Pradesh due to the processing electronic wastes.[88]

Water Resources and Climate

KEY TAKEAWAYS

- Climate change will lead to higher total precipitation and increased rainfall intensity, but the frequency and spatial extent of droughts will increase, particularly in northwestern and southern India.
- Flood risks will increase due to heavy rainfall and melting glaciers, threatening highland populations with natural disaster. Coastal cities, particularly in the Bay of Bengal, are threatened by rising sea levels and more frequent cyclones.

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.

Rising temperatures will increase evaporation, but precipitation is projected to increase. India's climate is highland in the north, arid in the west, and tropical or sub-tropical in all other locations.[7] Summer and winter monsoon seasons are critical for replenishing water resources. The summer (southwestern) monsoon generates 80 percent of the total precipitation. The summer (northeastern) monsoon provides most of the precipitation in the coastal southeast. Average temperatures have increased 0.6 °C of over the past century and projections suggest temperatures will increase 2-4°C later this century.[89,90] Total annual precipitation and summer monsoon rainfall have decreased in recent decades, although projections suggest precipitation gains between 61 and 110 mm/year.[90,91] Warmer temperatures and higher evaporation rates may offset these increases.[90]

Droughts will become more frequent and impact larger areas, especially in the northwest and south where risks are already high. Approximately 16 percent of India is considered drought prone. The area susceptible to drought is expected to grow by 150 percent, primarily in northern, northwestern, and southern India.[92,93] Overall, the frequency of severe droughts is expected to increase between 10 to 15 percent nationwide,[90] while the frequency of rapid onset "flash droughts" may increase seven-fold by the end of the century.[94]

Increased temperatures will accelerate melting of snowpack and glaciers in highland areas and increase flooding. Cyclones and sea level rise will threaten the coastal communities and groundwater quality. The percent of total precipitation from extreme rainfall events is expected to increase between 30 and 48 percent. Increases will be highest in the Brahmaputra Basin, which is already vulnerable to flooding.[90,95] In 2013, one of India's worst floods occurred when a glacial lake outburst flood (GLOF) in Uttarakhand killed thousands of people and caused extensive damage and in 2021, a collapsed glacier destroyed a dam.[96] Rising sea levels and heavy monsoon precipitation threaten coastal cities with increased flooding, especially Mumbai, Chennai, Kolkata, and Surat.[97,98] It is projected that cycles will be more frequent and intense in the Bay of Bengal.[99,100] Cyclone Phailin caused over $4 billion in crop damage throughout Orissa in 2013 and Cyclone Amphan flooded West Bengal in 2020 and caused over $13 billion in damage.[101,102]

FIGURE 2: DROUGHT RISK

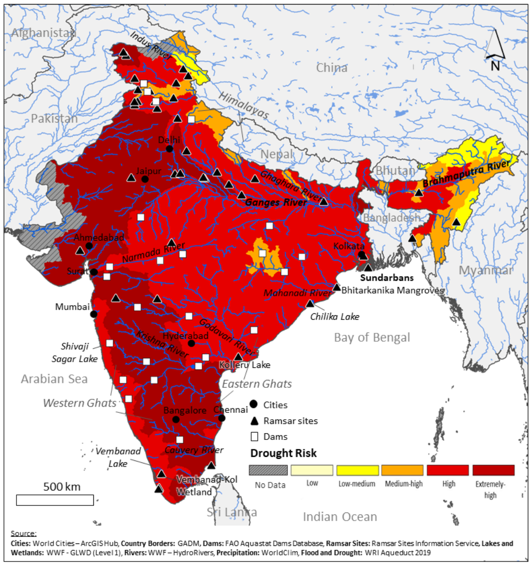
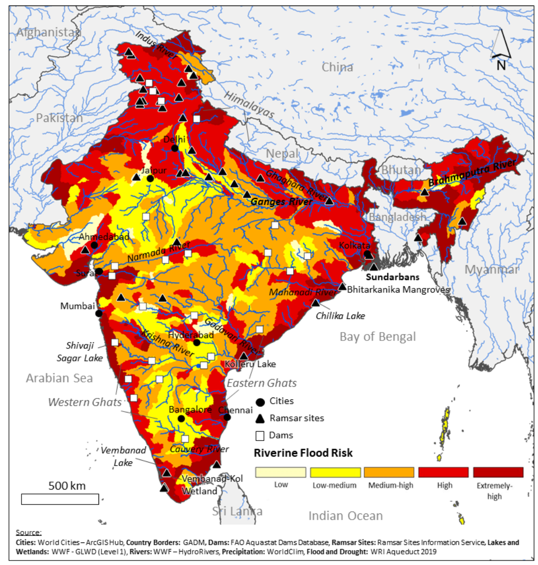


FIGURE 3. RIVERINE FLOOD RISK



Water Policy and Governance

KEY TAKEAWAYS

- India has a strong federalist system in which states have primary domain over water allocation and water use within their territories. State policies are not always legally or practically compatible, which can impede integrated water resources management. States are not obligated or incentivized to employ IWRM approaches.
- Key water resource management decisions and hydraulic developments are often determined through top-down planning, including national-level infrastructure such as the Indian Rivers Inter-link project which will significantly alter inter-state and international river flows.

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.

States have heterogeneous water laws and policies that vary in enforceability and compatibility. State-level IWRM approaches do not always align with the NWP.[108] India has a strong federalist system in which states have primary domain over water allocation and water use within their territories. National "model" water laws and policies are intended to provide a common vision for state-level water governance. The NWP espouses IWRM basin-planning and encourages multi-sectoral coordination among relevant entities. Only 16 out of 36 states and territories have aligned their water policies with the NWP, which was approved in 2012. Coordination among key water sector entities at the state-level is variable and generally limited.[109]

Inter-state coordination in IWRM is limited despite efforts to promote cooperation. Key bills and amendments (see Table 2 above), such as the proposed River Basin Management Bill and the Dam Safety Bill, seek to address inter-state cooperation but they have been criticized for potentially curtailing state authority.[113,114] Only a few River Boards exist but they were established through water dispute tribunal decisions and independent legislative acts, rather than through state-led initiatives.[110] Water dispute adjudication processes disincentivize states from participating in inter-state River Boards because under the current framework a member state of a River Board cannot file a dispute without the consent or participation of other member states.[110] Water disputes between states are common, particularly as they relate to water allocation and sharing arrangements.[111] For example, the national Indian Rivers Inter-link project, which will transfer surface water via canals from areas with surplus resources to areas with deficits, was ultimately greenlighted by the Supreme Court in 2015.[115,116] This project will involve building 3,000 new reservoirs and could submerge 2.7 million hectares and displace 1.5 million people.[117]

TABLE 2. KEY LAWS, POLICIES, AND PLANS

Name	Year	Purpose
National Water Policy (NWP)	2012	"Model bill"[iii] outlining integrated water resources management. Clarifies institutional framework, sector roles, responsibilities, and priorities. Policy is currently being revised by the Ministry of Jal Shakti to emphasize the role of public-private partnerships in water management and the creation of a "model" national water law.
River Board Act	1956	Provides legal mechanism for states to organize interstate River Boards to govern water resources across state lines.
River Basin Management Bill	2019 (approved)	Intended to replace the 1956 River Board Act. Establishes 13 transboundary river basin authorities (including the Ganges, Indus, Godavari, and Cauvery Basins) to develop basin management master plans with a two-tier governance structure composed of a Governing Council and an Executive Board. Approved but pending enactment.
Dam Safety Bill	2019 (approved)	Shifts power from the states to the federal government to manage larger reservoirs. Approved, but pending enactment.
Inter-State Water Disputes Tribunal Bill	2019 (approved)	Amends original bill enacted in 1956. Establishes clear and expedited timelines for resolving water disputes among states through dispute resolution committees and a single, permanent tribunal for all disputes. Approved, but pending enactment.
Act for the Conservation, Protection, Regulation and Management of Groundwater	2016	Builds on several prior "model" groundwater bills. Recommends the establishment of groundwater protection zones and security plans, institutional frameworks for groundwater monitoring and management, permitting, and environmental impact assessments.

Transboundary agreements and management institutions do not allow for comprehensive management of international waters. The Ganges Water Sharing Treaty between India and Bangladesh, which is slated to expire in 2026, does not employ a basin-wide approach[118] and Bangladesh does not always receive the minimum required flows as defined by the Treaty.[119] India is not party to any water sharing treaties with China, Bhutan, and Bangladesh for the Brahmaputra Basin, although several bilateral and multilateral memoranda of understanding and working groups have been established related to hydropower development. India is a signatory to the Indus River Treaty with Pakistan and the Mahakali Treaty with Nepal, however, coordination remains limited.

Water Quality Monitoring

Surface and groundwater quality data is routinely collected, consolidated, and publicly disseminated. The CWC and CGWB monitor surface and groundwater quality, respectively, while the CPCB (through SPCBs) also monitors water quality to verify compliance with effluent discharge permits. Surface water quality is monitored regularly by the CWC at over 500 testing locations covering all major river basins covering 67 main rivers and numerous tributaries.[121] These surface water monitoring stations routinely monitor basic physiochemical parameters (including dissolved oxygen), however, microbial testing and more comprehensive chemical studies are conducted as needed at numerous regional laboratories. The CPCB recently deployed a real-time water quality network in the Ganges Basin capable of monitoring 10 key parameters.[122] The CGWB manages a network of 23,000 observation wells from which samples are obtained quarterly and analyzed.[123] Three quarters of CGWB samples analyzed in the most recent reporting period were only analyzed for basic chemical constituents while most remaining samples were also tested for trace elements such as heavy metals.123 Low technical capacity of SPCB staff impedes enforcement of permits and often results in non-compliance from industrial polluters.[120]

[iii]As national level laws/policy regarding water resources management are non-binding, they are referred to as "models" which may be adopted, modified, or remain unused by state governments as they deem appropriate.

TABLE 3. WATER RESOURCES MANAGEMENT ENTITIES

Mandate	Institution	Roles and Responsibilities
Transboundary	Permanent Indus Commission (PIC)	Commission between Pakistan and India that seeks to implement the Indus Water Treaty and coordinate development and management of hydraulic infrastructure.
	Joint River Commission (JRC)	Commission between Bangladesh and India that implements the Ganges Water Sharing Treaty by coordinating water sharing, irrigation development, and flood control projects.
National	Ministry of Jal Shakti	Established in 2019, manages and develops water resources through national, regional, or state offices. Supports several corporate, statutory, and autonomous bodies, including river boards. There are two departments responsible for bulk management of water resources in river basins and water and sanitation service delivery.
	Central Water Commission (CWC)	Attached office within the Ministry of Jal Shakti. Houses the National Water Development Agency (NDWA), which develops design and feasibility reports for the decades-old national Indian Rivers Inter-link project. Provides technical support to state governments to regulate, conserve, and utilize water resources through flood control projects, irrigation services, and drinking water supply systems. Monitors surface water quality.
	Central Ground Water Authority (CGWA)	Regulates and manages groundwater abstractions and development through permitting.
	Central Ground Water Board (CGWB)	Subordinate office within the Ministry of Jal Shakti. Leads groundwater exploration and mapping, conducts water balance assessments and projections for aquifers, evaluates and proposes groundwater recharge projects, and monitors groundwater quality.
	National Water Resources Council (NWRC)	Executive body that approves model national water policy. Chaired by the Prime Minister and composed of state and national-level ministers.
	Ministry of Housing and Urban Affairs	Lead ministry in charge of water service delivery. Also supports water quality monitoring, water balance studies, and aquifer management.
	The National Water Board (NWB)	Provides technical consultation to the NWRC during the review and approval process of water policy. Led by the Secretary of the Ministry of Jal Shakti and secretaries from related line ministries as well as chief secretaries of states and territories.
	The Ministry of Environment and Forests of India (MOEF)	Houses the Central Pollution Control Board (CPCB), which coordinates the State Pollution Control Boards (SPCB). SPCBs develop and enforce environmental regulations for effluent discharge by issuing discharge permits and monitoring for compliance.
Sub-national	River Boards	Responsibilities are program/project-specific, such as flood control, hydropower generation, and reservoir and hydraulic infrastructure operation and maintenance. Focus on program implementation and infrastructure management within state boundaries.
	State Governments	Wields independent authority to develop state-level water law and policy. National-level water laws and policies are non-enforceable models to guide state laws and policies towards a common vision.
	Water Dispute Tribunals	Judicial bodies that are constituted on demand to adjudicate water disputes among states.
	Water Users Associations (WUA)	Organizations composed of farmers that support operations and management of public irrigation systems to ensure equitable access and sustainability.

References

(1) Jain, M.; Fishman, R.; Mondal, P.; Galford, G. L.; Bhattaral, N.; Naeem, S.; Lall, U.; Singh, B.; DeFries, R. S. Groundwater Depletion Will Reduce Cropping Intensity in India. Sci. Adv. 2021, 7.
(2) World Bank Group. High and Dry : Climate Change, Water, and the Economy; Washington, D.C., 2016.
(3) 2030 Water Resources Group. Charting Out Water Future- Economic Frameworks to Inform Decision-Making; 2009.
(4) Mohanty, M. P.; Mudgil, S.; Karmakar, S. Flood Management in India: A Focussed Review on the Current Status and Future Challenges. Int. J. Disaster Risk Reduct. 2020, 49. https://doi.org/https://doi.org/10.1016/j.ijdrr.2020.101660.
(5) FAO. Aquastat Main Database http://www.fao.org/nr/water/aquastat/data/query/results.html (accessed Jul 8, 2020).
(6) FAO; UN Water. Clean Water and Sanitation - Progress on Level of Water Stress; 2018.
(7) USAID. Climate Risk Profile India; 2018. https://doi.org/https://hdl.handle.net/10568/80457.
(8) Brittanica. Cherrapunji: India https://www.britannica.com/place/Cherrapunji (accessed Sep 17, 2020).
(9) WRIS. River Basin Report Download https://indiawris.gov.in/wris/#/Basin (accessed Sep 16, 2020).
(10) FAO. Ganges-Brahmaputra-Meghna Geography, population and climate http://www.fao.org/nr/water/aquastat/countries_regions/profile_segments/gbm-GeoPop_eng.stm (accessed Sep 16, 2020).
(11) Amarasinghe, U.; Sharma, B.; Aloysius, N.; Scott, C.; Smakhtin, V.; de Fraiture, C. Research Report 83: Spatial Variation in Water Supply and Demand across River Basins of India; Colombo, 2005.
(12) FAO. Country Profile- India; 2015. https://doi.org/10.1787/b0801bd1-en.
(13) ADRI. India Water Facts https://www.adriindia.org/adri/india_water_facts (accessed Sep 18, 2020).
(14) Hongzhou, Z. China-India: Revisiting the 'Water Wars' Narrative https://thediplomat.com/2015/06/china-india-revisiting-the-water-wars-narrative/ (accessed Sep 18, 2020).
(15) The World Bank. The National Ganga River Basin Project https://www.worldbank.org/en/news/feature/2015/03/23/india-the-national-ganga-river-basin-project (accessed Sep 17, 2020).
(16) Central Water Commission (CWC) & National Remote Sensing Centre (NRSC). Brahmaputra Basin Version 2.0; 2014.
(17) Halpert, M.; Bell, G. Climate Assessment for 1996 https://www.cpc.ncep.noaa.gov/products/assessments/assess_96/toc.html (accessed Sep 17, 2020).
(18) Central Water Commission (CWC) & National Remote Sensing Centre (NRSC). Ganga Basin; 2014. https://doi.org/Version 2.0.
(19) Armstrong, R. L.; Rittger, K.; Brodzik, M. J.; Racoviteanu, A.; Barrett, A. P.; Khalsa, S. J. S.; Raup, B.; Hill, A. F.; Khan, A. L.; Wilson, A. M.; Kayastha, R. B.; Fetterer, F.; Armstrong, B. Runoff from Glacier Ice and Seasonal Snow in High Asia: Separating Melt Water Sources in River Flow. Reg. Environ. Chang. 2019, 19, 1249–1261. https://doi.org/10.1007/s10113-018-1429-0.
(20) Maurya, A. S.; Shah, M.; Deshpande, R. D.; Bhardwaj, R. M.; Prasad, A.; Gupta, S. K. Hydrograph Separation and Precipitation Source Identification Using Stable Water Isotopes and Conductivity: River Ganga at Himalayan Foothills. Hydrol. Process. 2011, 25 (10), 1521–1530. https://doi.org/10.1002/hyp.7912.
(21) Srivastava, U.; Desai, D.; Gupta, V.; Rao, S.; Gupta, G.; Raghavachari, M.; Vatsala, S. Inland Fish Marketing in India-Reservoir Fisheries; Concept Publishing Co.: New Delhi, 1985.
(22) Bassi, N.; Kumar, M. D.; Sharma, A.; Pardha-Saradhi, P. Status of Wetlands in India: A Review of Extent, Ecosystem Benefits, Threats and Management Strategies. J. Hydrol. Reg. Stud. 2014, 2, 1–19. https://doi.org/10.1016/j.ejrh.2014.07.001.
(23) CGWB. Aquifer Systems of India; 2012.
(24) Chandra, P. Groundwater of Hard Rock Aquifers of India. In Groundwater of South Asia; Mukherjee, A., Ed.; Springer: Singapore, 2018; pp 61–84. https://doi.org/https://doi.org/10.1007/978-981-10-3889-1_5.
(25) Jha, B.; Sinha, S. Towards Better Management of Ground Water Resources in India. Water E nergy Int. 2009, 67 (1).
(26) Central Ground Water Board (CGWB). Maps http://cgwb.gov.in/Maps.html (accessed May 14, 2021).
(27) Drishti. Different Irrigation Systems https://www.drishtiias.com/to-the-points/paper3/different-irrigation-systems (accessed Sep 21, 2020).
(28) Anwar, S. Canal Irrigation in India https://www.jagranjosh.com/general-knowledge/canal-irrigation-in-india-1448272174-1#:~:text=irrigated by canals.-,The maximum part of the total irrigated area of the,%2C Haryana%2C Punjab and Bihar. (accessed Sep 21, 2020).
(29) Jain, R.; Kishore, P.; Singh, D. K. Irrigation in India: Status, Challenges and Options. J. Soil Water Conserv. 2019, 18 (4), 354. https://doi.org/10.5958/2455-7145.2019.00050.X.
(30) FICCI Water Mission. Water Use in Indian Industry Survey; 2011.
(31) Rao. Filtering Through India's Drinking Water Challenges https://www.waterworld.com/international/desalination/article/16202105/filtering-through-indias-drinking-water-challenges#:~:text=Sources%2C Supply and Distribution of,rural and urban Indian populations.&text=It is estimated that approximately,excess arse (accessed Sep 21, 2020).
(32) Joseph, N.; Ryu, D.; Malano, H. M.; George, B.; Sudheer, K. P. Estimation of Industrial Water Demand in India Using Census-Based Statistical Data. Resour. Conserv. Recycl. 2019, 149, 31–44. https://doi.org/10.1016/j.resconrec.2019.05.036.
(33) International Hydropower Association. India https://www.hydropower.org/country-profiles/india (accessed Sep 21, 2020).
(34) CIA. The World Factbook https://www.cia.gov/library/publications/the-world-factbook/fields/386.html (accessed Sep 21, 2020).
(35) Singh, N.; Singh, O. Role of Water in the Success of Green Revolution in India http://www.millenniumwaterstory.org/Pages/Photo stories/Water & Livelihood/Role of Water in the Success of Green Revolution in India.html (accessed Oct 9, 2020).
(36) Kulkarni, A. A.; Nagarajan, R. Hydrospatial Modelling and Simulations for Assessing the Irrigation Canal Conveyance Losses. Model. Simul. Eng. 2019, 2019. https://doi.org/10.1155/2019/1803748.
(37) Dhawan, V. Water and Agriculture in India Background Paper for the South Asia Expert Panel during the Global Forum for Food and Agriculture; 2017.
(38) Narayanamoorthy, A. Tap drip irrigation to save water https://www.thehindubusinessline.com/opinion/tap-drip-irrigation-to-save-water/article27688289.ece (accessed Oct 9, 2020).
(39) Ministry of Water Resources. National Water Mission under National Action Plan on Climate Change; 2009.
(40) Mukherjee, A.; Bhanja, S. N.; Wada, Y. Groundwater Depletion Causing Reduction of Baseflow Triggering Ganges River Summer Drying. Sci. Rep. 2018, 8 (1), 1–9. https://doi.org/10.1038/s41598-018-30246-7.
(41) Kumari, R.; Banerjee, A.; Kumar, R.; Kumar, A.; Saikia, P.; Khan, M. L. Deforestation in India: Consequences and Sustainable Solutions. In Forest Degradation Around the World; IntechOpen, 2018.
(42) Gartner, T. Watersheds Lost Up to 22% of Their Forests in 14 Years. Here's How it Affects Your Water Supply https://www.wri.org/insights/watersheds-lost-22-their-forests-14-years-heres-how-it-affects-your-water-supply (accessed May 14, 2021).
(43) NITI Aayog. Report of Working Group I Inventory and Revival of Springs in the Himalayas for Water Security; 2018.
(44) CWC. Reservoir Level & Storage Bulletin http://cwc.gov.in/reservoir-storage?page=1 (accessed Oct 9, 2020).
(45) Masih, N.; Slater, J. As a major Indian city runs out of water, 9 million people pray for rain https://www.washingtonpost.com/world/2019/06/28/major-indian-city-runs-out-water-million-people-pray-rain/ (accessed Sep 21, 2020).
(46) Joshi, H. Floods across the country highlight need for a robust flood management structure https://india.mongabay.com/2020/08/floods-across-the-country-highlight-need-for-a-robust-flood-management-structure/ (accessed Sep 21, 2020).
(47) Relief Web. India: Floods and Landslides - Jun 2019 https://reliefweb.int/disaster/fl-2019-000084-ind (accessed Sep 21, 2020).
(48) Padma, T. V. New Recommendations for a Proactive Flood Policy in India https://eos.org/articles/new-recommendations-for-a-proactive-flood-policy-in-india (accessed May 14, 2021).
(49) Murthy, S. L. Land Security and the Challenges of Realizing the Human Right to Water and Sanitation in the Slums of Mumbai, India. Health Hum. Rights 2012, 14 (2).
(50) Ramsar. India https://www.ramsar.org/wetland/india (accessed Sep 22, 2020).
(51) Ramsar. Annotated List of Wetlands of International Importance India; 2019.
(52) Sudhish, N. Escalating salinity upsetting wetland ecosystem in Kerala https://earthjournalism.net/stories/escalating-salinity-upsetting-wetland-ecosystem-in-kerala (accessed Sep 22, 2020).
(53) Verma, R. Water storage in major Indian river basins depleting https://www.downtoearth.org.in/news/water/no-basic-facilities-no-vote-say-residents-of-160-villages-63813 (accessed Sep 21, 2020).
(54) Roy, E. India's latest crisis: 600 million people struggle with drought https://www.lowyinstitute.org/the-interpreter/india-s-latest-crisis-600-million-people-struggle-drought#:~:text=Since 2015%2C India has been experiencing widespread drought conditions.&text=in the future.-,Today millions of farmers hit by drought and crop (accessed Sep 21, 2020).
(55) Ghosh, S. Gangetic river dolphins in the Indian Sundarbans struggle with swelling salinity https://india.mongabay.com/2019/01/gangetic-dolphins-in-the-indian-sundarbans-struggle-with-swelling-salinity/ (accessed Sep 22, 2020).
(56) Aggarwal, D.; Kumar, N.; Dutta, V. Impact on Endangered Gangetic Dolphins Due to Construction of Waterways on the River Ganga, India: An Overview. Environ. Sustain. 2020, 3, 123–138.
(57) CPCB. Consolidated Status Report; 2020.
(58) Times of India. 63% of sewage flows into rivers untreated every day: Central .. https://timesofindia.indiatimes.com/city/agra/63-of-sewage-flows-into-rivers-untreated-every-day-Central-Pollution-Control-Board/articleshow/54531095.cms (accessed Sep 21, 2020).
(59) CPCB. Consolidated Status Report; Delhi, 2020.
(60) CWC. Effect of Time and Temperature on DO Levels in River Waters; 2019.
(61) Chandrashekhar, V. Dying Waters: India Struggles to Clean Up Its Polluted Urban Rivers https://e360.yale.edu/features/dying-waters-india-struggles-to-clean-up-its-polluted-urban-rivers (accessed Sep 21, 2020).
(62) CWC. Status of Trace & Toxic Metals in Indian Rivers; 2019.
(63) Duttagupta, S.; Mukherjee, A.; Bhattacharya, A.; Bhattacharya, J. Wide Exposure of Persistent Organic Pollutants (PoPs) in Natural Waters and Sediments of the Densely Populated Western Bengal Basin, India. Sci. Total Environ. 2020, 717, 137187. https://doi.org/10.1016/j.scitotenv.2020.137187.
(64) Agrawal, A.; Pandey, R. S.; Sharma, B. Water Pollution with Special Reference to Pesticide Contamination in India. J. Water Resour. Prot. 2010, 2, 432–448. https://doi.org/10.4236/jwarp.2010.25050.
(65) National Herald. Plea in Supreme Court seeks to protect Western Ghats as a whole; court issues notice https://www.nationalheraldindia.com/india/plea-in-supreme-court-seeks-to-protect-western-ghats-as-a-whole-court-issues-notice (accessed Sep 22, 2020).
(66) Chatterjee, B. Exclude 15% of Western Ghats ESA for mining, industries: State requests Centre https://www.hindustantimes.com/mumbai-news/exclude-15-of-western-ghats-esa-for-mining-industries-state-requests-centre/story-PrnMTA9DyE4pUQXSnyyiIM.html (accessed Sep 22, 2020).
(67) Chatterjee, B. Take action against mining units without clearances on Western Ghats, Centre tells Maharashtra https://www.hindustantimes.com/mumbai-news/take-action-against-mining-units-without-clearances-on-western-ghats-centre-tells-maharashtra/story-fDTFvYsW4mI1j4iwXEO8fM.html (accessed Sep 22, 2020).
(68) Jain, R.; Kishore, P.; Singh, D. K. Irrigation in India: Status, Challenges and Options. J. Soil Water Conserv. 2019, 18 (4), 354. https://doi.org/10.5958/2455-7145.2019.00050.x.
(69) Gandhi, V.; Bhamoriya, V. Groundwater Irrigation in India Growth, Challenges, and Risks. Geography 2009.
(70) Kapil, S. Nearly 80 per cent Indian households without piped water connection https://www.downtoearth.org.in/news/water/nearly-80-per-cent-indian-households-without-piped-water-connection-67928 (accessed Sep 24, 2020).
(71) Dijk, W. M. van; Densmore, A. L.; Jackson, C. R.; Mackay, J. D.; Joshi, S. K.; Sinha, R.; Shekhar, S.; Gupta, S. Spatial Variation of Groundwater Response to Multiple Drivers in a Depleting Alluvial Aquifer System, Northwestern India. Prog. Phys. Geogr. 2019, 44 (1), 94–119. https://doi.org/https://doi.org/10.1177/0309133319871941.

(72) Fienen, M. N.; Arshad, M. The International Scale of the Groundwater Issue. In Integrated Groundwater Management. Concepts, Approaches and CHallenges; Jakeman, A. J., Barreteau, O., Hunt, R.J., Rinaudo, J.-D., Ross, A., Eds.; SpringerOpen, 2016; pp 21–48. https://doi.org/10.1007/978-3-319-23576-9_2.
(73) Central Ground Water Board. Ground Water Year Book 2019-2020; 2021.
(74) CGWB. Ground Water Resources of Punjab State; 2018.
(75) CGWB. Dynamic Ground Water Resources of India; 2017.
(76) Gideon, V. M. Securing Groundwater Access in Urban India https://science.thewire.in/environment/securing-groundwater-access-in-urban-india/ (accessed May 17, 2021).
(77) Nair, A. S.; Indu, J. Changing Groundwater Storage Trend of India after Severe Drought. Int. J. Remote Sens. 2020, 41 (19).
(78) Mohanavelu, A.; Kasiviswanathan, K. S.; Mohanasundaram, S.; Ilampooranan, I.; He, J.; Pingale, S. M.; Soundharajan, B.-S.; Mohaideen, M. M. D. Trends and Non-Stationarity in Groundwater Level Changes in Rapidly Developing Indian Cities. Water 2020.
(79) Chaudhary, J. Delhi's groundwater plummets https://www.downtoearth.org.in/news/water/delhi-s-groundwater-plummets-60830 (accessed May 17, 2021).
(80) Ali, S.; Fakhri, Y.; Golbini, M.; Thakur, S. K.; Alinejad, A.; Parseh, I.; Shekhar, S.; Bhattacharya, P. Groundwater for Sustainable Development Concentration of Fluoride in Groundwater of India : A Systematic Review , Meta-Analysis and Risk Assessment. Groundw. Sustain. Dev. 2019, 9. https://doi.org/10.1016/j.gsd.2019.100224.
(81) Mohan, V. Across India High Levels of Toxins In Groundwater https://timesofindia.indiatimes.com/india/govt-body-finds-high-levels-of-groundwater-contamination-across-india/articleshow/65204273.cms (accessed Sep 24, 2020).
(82) Adimalla, N.; Venkatayogi, S.; Das, S. Assessment of Fluoride Contamination and Distribution : A Case Study from a Rural Part of Andhra Pradesh , India. Appl. Water Sci. 2019, 9 (94), 1–15. https://doi.org/10.1007/s13201-019-0968-y.
(83) Reddy, K.; Puppala, R.; Kethineni, B.; Reddy, H.; Reddy, A.; Kalyan, V. Prevalence of Dental Fluorosis Among 6–12-Year-Old School Children of Mahabubnagar District, Telangana State, India – A Cross-Sectional Study. Indian Assoc. Public Heal. Dent. 2017, 15 (1), 42–47.
(84) CGWB. Ground Water Quality in Shallow Aquifers of India; 2010.
(85) Krar, P. Parts of Haryana have salty groundwater and rains add to the salt content https://economictimes.indiatimes.com/news/economy/agriculture/parts-of-haryana-have-salty-groundwater-and-rains-add-to-the-salt-content/articleshow/71342070.cms (accessed Sep 24, 2020).
(86) Central Ground Water Board. Ground Water Information Greater Mumbai District Maharashtra; 2013.
(87) Bhattacharya, M.; Shriwastav, A.; Bhole, S.; Silori, R.; Mansfeldt, T.; Kretzschmar, R.; Singh, A. Processes Governing Chromium Contamination of Groundwater and Soil from a Chromium Waste Source. ACS Earth Sp. Chem. 2020, 4, 35–49. https://doi.org/10.1021/acsearthspacechem.9b00223.
(88) Idrees, N.; Tabassum, B.; Abdallah, E.; Hashem, A.; Sarah, R.; Hashim, M. Saudi Journal of Biological Sciences Groundwater Contamination with Cadmium Concentrations in Some. Saudi J. Biol. Sci. 2018, 25 (7), 1365–1368. https://doi.org/10.1016/j.sjbs.2018.07.005.
(89) Ministry of Earth Sciences/ India Meteorological Department. Statement on Climate of India during 2019 https://mausam.imd.gov.in/backend/assets/press_release_pdf/Statement_on_Climate_of_India_during_2019.pdf (accessed Sep 25, 2020).
(90) World Bank Group. Climate Change Knowledge Portal: India https://climateknowledgeportal.worldbank.org/country/india/climate-data-projections (accessed Sep 25, 2020).
(91) Kulkarni, A.; Sabin, T. P.; Chowdary, J. S.; Rao, K. K.; Priya, P.; Gandhi, N.; Bhaskar, P.; Buri, V. K.; Sabade, S. S.; Pai, D. S.; Ashok, K.; Mitra, A. K.; Niyogi, D.; Rajeevan, M. Precipitation Changes in India. In Assessment of Climate Change over the Indian Region; Springer Singapore, 2020; pp 47–72. https://doi.org/10.1007/978-981-15-4327-2.
(92) Aadhar, S.; Mishra, V. Impact of Climate Change on Drought Frequency over India Impact of Climate Change on Drought Frequency over India. In Climate Change and Water Resources in India; Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, 2018; pp 117–129.
(93) INCCA. Climate Change and India: A 4x4 Assessment; 2010.
(94) Mishra, V.; Aadhar, S.; Mahto, S. S. Anthropogenic Warming and Intraseasonal Summer Monsoonvariability Amplify the Risk of Futureflash Droughts in India. Clim. Atmos. Sci. 2021, 4 (1).
(95) Ali, H.; Modi, P.; Mishra, V. Increased Flood Risk in Indian Sub-Continent under the Warming Climate. Weather Clim. Extrem. 2019, 25. https://doi.org/10.1016/j.wace.2019.100212.
(96) BBC News. Uttarakhand dam disaster: Race to rescue 150 people missing in India https://www.bbc.com/news/world-asia-india-55975743 (accessed Feb 18, 2021).
(97) Anand, N.; Terens, C. Explained: How climate change could impact Mumbai by 2050 https://indianexpress.com/article/explained/the-rising-threat-to-mumbai-6160595/ (accessed Sep 25, 2020).
(98) Dhiman, R.; Vishnuradhan, R.; Eldho, T. I.; Inamdar, A. Flood Risk and Adaptation in Indian Coastal Cities : Recent Scenarios. Appl. Water Sci. 2019, 9 (1), 1–16. https://doi.org/10.1007/s13201-018-0881-9.
(99) Sangomla, A. A warming Bay of Bengal may have turned Amphan into super cyclone: Experts https://www.downtoearth.org.in/news/climate-change/a-warming-bay-of-bengal-may-have-turned-amphan-into-super-cyclone-experts-71214 (accessed Oct 1, 2020).
(100) Bhatia, K. T.; Vecchi, G. A.; Knutson, T. R.; Dixon, K. W.; Whitlock, C. E.; Murakami, H.; Kossin, J. Recent Increases in Tropical Cyclone Intensification Rates. Nat. Commun. 2019, 10 (635), 1–9. https://doi.org/10.1038/s41467-019-08471-z.
(101) Neubert, M.; Smith, A. Deadly Cyclone Phailin destroys $4bn worth of crops across area size of Delaware https://www.nbcnews.com/news/world/deadly-cyclone-phailin-destroys-4bn-worth-crops-across-area-size-flna8C11390149 (accessed Oct 1, 2020).
(102) Sud, V.; Rajaram, P. Cyclone Amphan caused an estimated $13.2 billion in damage in India's West Bengal: government source https://www.cnn.com/2020/05/22/weather/cyclone-amphan-damage-intl-hnk/index.html#:~:text=Cyclone Amphan kills dozens and leaves thousands homeless&text=Kolkata%2C India (CNN) The,in the Indian state's government. (accessed Oct 1, 2020).
(103) Mohan, V. National water policy in the pipeline but states still divided https://timesofindia.indiatimes.com/india/national-water-policy-in-the-pipeline-but-states-still-divided/articleshow/73681298.cms (accessed Sep 30, 2020).
(104) Acharyulu, M. The great Indian river question: Three Bills threatening federalism https://www.downtoearth.org.in/news/water/the-great-indian-river-question-three-bills-threatening-federalism-72913 (accessed Oct 1, 2020).
(105) Acharyulu, M. The great Indian river question: Three Bills threatening federalism https://www.downtoearth.org.in/news/water/the-great-indian-river-question-three-bills-threatening-federalism-72913 (accessed Oct 2, 2020).
(106) Pandit, C.; Biswas, A. K. India's National Water Policy : ' Feel Good ' Document , Nothing More India ' s National Water Policy : ' Feel Good ' Document , Nothing More. Int. J. Water Resour. Dev. 2019. https://doi.org/10.1080/07900627.2019.1576509.
(107) Mehrotra, K. Jal Jeevan Mission-Urban: Govt selects 10 cities for survey https://indianexpress.com/article/india/jal-jeevan-mission-urban-govt-selects-10-cities-for-survey-7191861/ (accessed May 17, 2021).
(108) Ahmed, M.; Araral, E. Water Governance in India : Evidence on Water Law , Policy , and Administration from Eight Indian States. Water 2019, 11 (2071).
(109) Department of Water Resources, R. D. and G. R. Annual Report 2019-20; 2019.
(110) Raju, K.; Taron, A.; Change, E. River Basin Organisations in India: An Overview. In IWMI-TATA; International Water Management Institute (IWMI), 2007.
(111) Drishti. Inter-State River Water Sharing Disputes https://www.drishtiias.com/to-the-points/Paper2/inter-state-river-water-sharing-disputes (accessed Sep 30, 2020).
(112) Drishti. Inter-State River Water Sharing Disputes https://www.drishtiias.com/to-the-points/Paper2/inter-state-river-water-sharing-disputes (accessed Oct 6, 2020).
(113) The Economic Times. Lok Sabha passes Dam Safety Bill https://economictimes.indiatimes.com/news/politics-and-nation/lok-sabha-passes-dam-safety-bill/articleshow/70502693.cms (accessed Oct 1, 2020).
(114) The Hindu. 'Bill aims to reduce river water to a commodity' https://www.thehindu.com/news/national/karnataka/bill-aims-to-reduce-river-water-to-a-commodity/article28629395.ece (accessed Oct 1, 2020).
(115) Seth, B. Supreme Court go-ahead for interlinking rivers https://www.downtoearth.org.in/news/supreme-court-goahead-for-interlinking-rivers-36857 (accessed Sep 30, 2020).
(116) Chokkakula, S. The Supreme Court and Interstate River Water Disputes https://www.cprindia.org/projects/supreme-court-and-interstate-river-water-disputes (accessed Oct 1, 2020).
(117) Jolly, A. Why linking rivers won't work https://www.indiatoday.in/magazine/nation/story/20160425-river-linking-narendra-modi-national-green-tribunal-828761-2016-04-14 (accessed Sep 30, 2020).
(118) Hanasz, P. Sharing waters vs. sharing rivers: The 1996 Ganges Treaty https://globalwaterforum.org/2014/07/28/sharing-waters-vs-sharing-rivers-the-1996-ganges-treaty/ (accessed Oct 1, 2020).
(119) Rahman, K. S.; Islam, Z.; Navera, U. K.; Ludwig, F. A Critical Review of the Ganges Water Sharing Arrangement. Water Policy2 2019, 21, 259–276. https://doi.org/10.2166/wp.2019.164.
(120) Sawhney, A. Compliance dilemmas in Indian environmental policy https://www.eastasiaforum.org/2018/10/10/compliance-dilemmas-in-indian-environmental-policy/ (accessed Mar 11, 2021).
(121) CWC. Annual Report 2018-2019; 2019.
(122) Herbert, A.; Kumar, U. Real Time Water Quality Monitoring System (RTWQMS) in Indian Rivers. In National Conference on River Flow Processes Modelling (RFPM-2017); 2017.
(123) CGWB. Annual Report 2018-19; 2019.

ABOUT THIS PROFILE

This profile was produced by USAID's Sustainable Water Partnership activity.

DISCLAIMER