CONNECTING THE DROPS

An Indus Basin Roadmap for Cross-Border Water Research, Data Sharing, and Policy Coordination

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Indus Basin Working Group

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Preface

Decision makers in India and Pakistan will have to overcome a host of overlapping socio-economic, environmental, and political pressures as they endeavor to ensure their countries' future water needs and sustainably manage the resources of the Indus River Basin that both nations share. Continuing population growth will significantly reduce per capita water availability over the coming decades. Increasing industrialization and urbanization are driving important shifts in water use. Climate change will exert additional, chronic strains on water resources, potentially shifting the seasonal timing or shuffling the geographical distribution of available supplies. Increasingly subject to soaring demand, unsustainable consumption patterns, and mounting environmental stresses, the Indus is swiftly becoming a "closed" basin; almost all of the river's available renewable water is already allocated for various uses — with little to no spare capacity.

Scientists, policy makers, and the broader public in both Pakistan and India will need to better apprehend, assess, and act on the links between water resources management, global and regional environmental change, sustainable development, and social welfare in the Indus Basin in order to meet these emerging challenges. Existing analyses and projections, however, are often fraught with important uncertainties and unknowns. The dearth of consistent information at the relevant regional, national, and sub-national scales has in turn impeded efforts to conduct integrated evaluations that would better connect "upstream" assessment of environmental and socio-economic impacts on water resources with "downstream" implications for agricultural production and livelihoods, drinking water supplies and sanitation infrastructure, and hydropower development and industry. Coordination and exchange across national and disciplinary boundaries will be essential to overcoming this science/policy gap and to providing decision makers with holistic perspectives on the multiple risks weighing on the Indus Basin and the consequent policy choices and possibilities facing the riparian nations.

To help build mutual awareness and understanding between India and Pakistan of the common water resource challenges they confront in the Indus Basin, the Stimson Center, the Sustainable Development Policy Institute (SDPI), and the Observer Research Foundation (ORF) partnered to assemble an Indus Basin Working Group gathering twenty-five analysts and practitioners from a diverse range of professional and disciplinary backgrounds. Together, the participants sought to collectively distinguish the critical knowledge gaps facing scientists and policy makers. Asking both "What information can science provide?" and "What information do decision makers need?" the Working Group looked to identify priority questions for research and analysis. From this foundation, participants collaborated to formulate a suite of practical approaches for meeting key research needs and develop potential options to pursue these common knowledge and policy objectives.

Over six months in 2012, the Working Group met for two three-day workshops, supplemented by web-based dialogues. The first workshop was held in June 2012 in Kathmandu, Nepal. In addition to the Working Group members, four experts from the Kathmandu-based International Centre for Integrated Mountain Development (ICIMOD) — including Director General David Molden, Rajan Bajracharya, Samjwal Bajracharya, and Basanta Shrestha — also took part in the workshop. Participants first considered the contexts and objectives of water policy in the Indus Basin and analyzed the challenges facing decision makers and stakeholders in various domains dependent on water management, such as agricultural production, power generation, poverty reduction, environmental impact assessment, and disaster planning and response. The Working Group experts also examined the increasing demographic and socio-economic pressures on water demand, as well as the emerging environmental strains potentially impacting water supplies in the basin.

Building on this base, the Working Group members assessed the knowledge needs of policy makers and stakeholders situated in different fields, including scientists, development specialists, civil society, and diplomats. In each case, the participants strove to map out the information resources and data shortfalls over various sectors — such as hydrology, climate change and the environment, economic development and livelihoods, agricultural production and food security, and diplomacy and international relations — and pinpointed the crucial information that different stakeholders and decision makers require to inform their choices.

The Working Group met for its second session in December 2012 in Bangkok, Thailand. Here, the members turned to crafting strategies and options to enhance the knowledge base for sustainable and integrated water resource management policy in the Indus Basin. The participants considered both research measures and knowledge-building approaches to increase the stock of basic data — such as monitoring and measuring the behavior of glaciers and snowpack — and also developed strategies for capacity building and knowledge management for incorporating sound science into policy formulation and deliberation, including data communication and dissemination, and sharing best practices for adaptation to impending climate changes.

Recognizing that different knowledge-building strategies engage different communities and actors, not all research and policy possibilities can proceed at the same pace. The participants sought to elaborate a coherent array of multiple options from which decision makers can select, ranging from exchanges of data collected nationally, to national research projects developed in parallel, to more comprehensive joint and collaborative programs. In this way, different activities can move forward to the extent possible — ideally building trust and confidence for further steps — without inevitable obstacles in any one area precluding progress in others. The Working Group stressed the need to ensure that national and international institutional architectures and mechanisms that structure and regulate water policy-making within and between India and Pakistan operate as effectively as possible. But stakeholders and decision makers must also develop mechanisms for bringing together appropriate partner institutions on either side of the border, both to perform the necessary studies and to communicate the results to policy makers and the public. Expert scientific organizations must be supplemented and supported by other messengers — especially the media — to reach and sway the larger public. A better informed public ultimately holds the key to better informed policy, as public opinion can generate the political will for policy change.

Connecting the Drops: An Indus Basin Roadmap for Cross-Border Water Research, Data Sharing, and Policy Coordination contains the results of the Working Group's deliberations. In its first section, the *Roadmap* details the manifold socio-economic and environmental stresses on Indus Basin water resources, tracing their potential ramifications and elucidating the resultant looming policy challenges. In the following sections, the *Roadmap* presents a menu of practical steps to bolster Indian and Pakistani capacities to measure, evaluate, and address increasing pressures on the Indus Basin waters. It provides specific recommendations for priority research on water resources issues and offers programmatic orientations to guide future analyses and data sharing, technical exchange, and collaborative knowledge-building. As a *Roadmap*, however, this report does not aim to prescribe one fixed route to reach a predefined destination. Rather, it seeks to illuminate the landscape of policy choices and opportunities and chart many potential pathways forward. By articulating strategies for scientific collaboration and international cooperation to meet the region's collective water security, development, and environmental challenges, the *Roadmap* hopes to aide Indian and Pakistani decision makers in framing water relations in the Indus Basin as a confidence building opportunity for mitigating shared risks and generating mutual benefits.

The text of *Connecting the Drops: An Indus Basin Roadmap for Cross-Border Water Research, Data Sharing, and Policy Coordination*, was prepared by David Michel and Russell Sticklor, drawing on the workshops in Kathmandu and Bangkok and on input papers prepared by the Working Group participants. As such, the *Roadmap* represents a collective effort. It should not be taken necessarily to imply strict unanimity among the participants, however, either concerning the content of the *Roadmap* as a whole or the inclusion of any individual recommendation. Working Group members at times expressed diverging views on certain issues, and further consensus building is ongoing. All Working Group participants served in their individual capacities. The Indus Basin Working Group would like to acknowledge the financial support of the US State Department, Embassy of Islamabad. Any findings, conclusions, or recommendations expressed in this report represent the deliberations of the Working Group members, and do not necessarily reflect the views of the State Department or the US Government. The Working Group also thanks Kerri West, Rebecca Rand, Zachary Weiss, Brendan McGovern, Sreya Panuganti, and Weini Li for their considerable contributions to the project.

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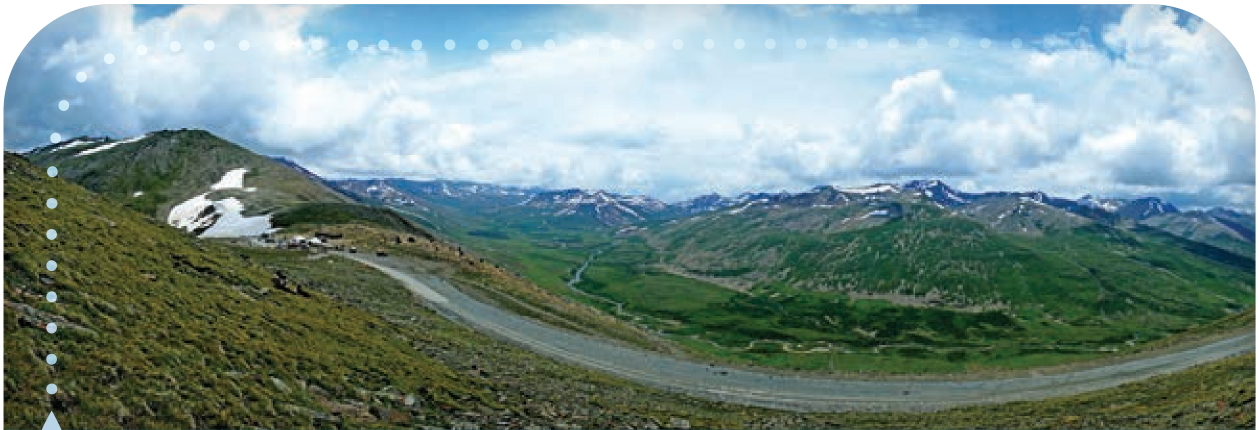
Glossary

CORDEX . . . Coordinated Regional Downscaling Experiment
DLR . . . . German Aerospace Center
ESA . . . . European Space Agency
FAO . . . . Food and Agriculture Organization of the United Nations
GDP . . . . Gross domestic product
GIS . . . . Geographic information systems
GLOF . . . . Glacial lake outburst flood
GRACE . . . . . Gravity Recovery and Climate Experiment
HKH . . . . Hindu Kush Himalaya
IBIS . . . . Indus Basin Irrigation System
ICIMOD . . . . International Centre for Integrated Mountain Development
IFPRI . . . . International Food Policy Research Institute
InSAR . . . . . . Interferometric synthetic aperture radar
IWRM . . . . . . Integrated water resources management
IWT . . . . Indus Waters Treaty
IWMI . . . . International Water Management Institute
IRB . . . . Indus River Basin
MW . . . . Megawatt
NASA . . . . National Aeronautics and Space Administration
NOAA . . . . . . National Oceanic and Atmospheric Administration
OECD . . . . . . Organisation for Economic Cooperation and Development
UN . . . . United Nations
UNEP . . . . United Nations Environment Programme
UNICEF . . . . . United Nations Children's Fund
WAPDA . . . . . Pakistan Water and Power Development Authority
WHO . . . . World Health Organization
WGMS . . . . . . World Glacier Monitoring Service

Figure 1. Map of the Indus River Basin



THE INDUS RIVER BASIN UNDER PRESSURE

The Indus River is one of the most important water systems in Asia. The Indus originates in China on the Tibetan Plateau and runs for 3,200 km across northern India and the length of Pakistan before emptying into the Arabian Sea near the port city of Karachi. While the Indus system counts 27 major tributaries, the six most significant branches — the Chenab, Ravi, Sutlej, Jhelum, Beas, and the Indus itself — flow west through India before crossing into Pakistan. A seventh major tributary, the Kabul River, rises in Afghanistan and flows east into Pakistan. All told, the Indus River Basin encompasses 1.12 million square kilometers (km^2), with 47 percent of this area falling in Pakistan, 39 percent in India, eight percent in China, and six percent in Afghanistan. In turn, 65 percent of the total area of Pakistan, 14 percent of the Indian land mass, 11 percent of Afghanistan, and one percent of China's land area lie within the Indus Basin.[1]

Climate and precipitation conditions vary considerably over the basin. The Upper Indus Basin, in the north, covers a high mountain region with alpine and highland climates. Most of the precipitation occurs in winter and spring, much of it falling as snow, particularly at higher elevations. To the south, the Lower Basin extends over plains exhibiting subtropical arid and semi-arid to temperate sub-humid climates. Here, most of the precipitation falls during the monsoon from July to September. Across the entire Indus Basin, annual average precipitation ranges between 100-500 millimeters (mm) in the lowlands to 2,000 mm and above in the Himalayan foothills and the higher mountains.

The contrasting climate and precipitation profiles between the wetter, cooler north and the hotter, drier south create marked differences in the origins of local stream flows. In the upper sub-basins, flows derive largely or solely from local runoff from the surrounding catchment. In the lower sub-basins, discharges descending from upstream catchments increasingly predominate in the local river flow. In the Indus plains, inflows from upstream catchments represent 81 percent or more of discharge in the lower river. On the whole, the high-altitude catchments comprise net contributors to the basin's water supplies and the lowland catchments constitute net consumers. Even so, all the basin catchments show substantial seasonal fluctuations, with river flows peaking during June-September when the monsoon brings intense rainfall to the Lower Basin and higher temperatures increase snow and glacier melt in the Upper Basin. Observed monthly flows in individual sub-basins can be ten times greater at the height of the summer wet season than during the lean winter months. Large year-to-year variations in annual precipitation induce corresponding variability in the Indus' annual flow.[2]

Today, the Indus supplies the needs of some 300 million people living throughout the basin. Together, India and Pakistan represent almost all of the demand on the river's resources, with Pakistan drawing 63 percent of water used in the basin and India drawing 36 percent. Pakistan depends critically on the Indus, as the country's other rivers run only seasonally and their total flows equal less than two percent of the mean annual inflow entering Pakistan through the Indus system. For India, meanwhile, the Indus furnishes about seven percent of the annual utilizable surface water available nationwide. Crucially, the basin's freshwater resources nourish the agricultural breadbaskets of both countries. Agriculture accounts for 93 percent of water withdrawn from the Indus, while industrial and domestic demands combined make up just seven percent of total use. Pakistan annually abstracts three-quarters of the river's flow into canal systems supporting the world's largest contiguous system of irrigated agriculture, and 95 percent of all the country's irrigation occurs within the basin. Farming in turn employs 40 percent of Pakistan's labor force and generates 22 percent of its GDP, while also delivering critical inputs to industry (notably cotton for the textiles sector). In India, the combined Indo-Gangetic Plain constitutes the most intensely irrigated area on Earth, while agriculture comprises 17 percent of GDP and occupies 55 percent of the economically active population. The Indus Basin, in turn, generates a quarter of Indian grain production, supplying substantial surpluses that offset deficits in other regions.[3] In both countries, the Indus waters help feed and employ significant numbers of people beyond the basin boundaries.

In addition to sharing the Indus' surface waters, India and Pakistan also share important — though inadequately mapped and characterized — transboundary aquifers in the basin.[4] Groundwater constitutes an essential additional source of freshwater for the region. Groundwater and surface water resources in the Indus Basin are closely linked both hydrologically and socio-economically. Hydrologically, seepage from surface sources — such as rivers and irrigation canals — contributes to recharging subterranean aquifers, while groundwater flows similarly enter and augment surface streams. By some assessments, 45 percent of Pakistan's renewable groundwater supply originates in leakage from the canal system, 26 percent comes from irrigation return flows, and six percent derives from river recharge. In India, an estimated one-fifth of the surface water withdrawn from the Indus for irrigation subsequently drains into groundwater aquifers as return flow.[5] Socio-economically, many water users in the basin rely on groundwater to supplement or supplant surface water supplies where these prove inadequate, intermittent, or unavailable. Over 40 percent of the irrigated land area in Pakistan, for example, is irrigated from mixed surface water and groundwater.[6] For many cities in the basin, groundwater is the principal or unique source for municipal water supplies. In India, groundwater abstractions in those states situated wholly or partially within the Indus Basin — Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, and Rajasthan — amount to 62.7 km^3. Pakistan's annual groundwater withdrawals from the basin totaled 61.6 km^3 in 2008, or one-third of all national water use. Across the Indus Basin, groundwater accounts for 48 percent of total water withdrawals.[7]

Growing populations and increasing development, however, are placing mounting pressures on the Indus Basin's water supplies. In Pakistan, total annual water withdrawals have risen from 153.4 km^3 in 1975 to 183.5 km^3 in 2008, while total annual renewable water resources per capita have plunged from 3,385 cubic meters (m^3) in 1977 to 1,396 m^3 in 2011. Over the same period, total annual water withdrawals in India have doubled, leaping from 380 km^3 in 1975 to 761 km^3 in 2010, while annual renewable water resources per capita have tumbled from 2,930 m^3 in 1977 to 1,539 m^3 in 2011.[8] To place these numbers in perspective, hydrologists commonly consider 1,700 m^3 per year the national threshold for filling each person's water requirements for domestic needs, agriculture, industry, energy, and the environment. Annual availability under 1700 m^3 per capita constitutes conditions of "water stress," and less than 1,000 m^3 per capita represents "water scarcity."[9] For the Indus Basin as a whole, the United Nations Environment Programme (UNEP) calculates that per capita annual renewable water availability stands at 1,329 m^3. Another analysis by the International Centre for Integrated Mountain Development (ICIMOD) estimated yearly water supplies in the basin at 978 m^3 per person. Both figures indicate that the basin's inhabitants face severe water stress.[10]

Figure 2. Renewable Water Resources and Withdrawal Levels in the Indus River Basin

Country	India	Pakistan	Total
Average long-term available renewable water supplies in the IRB	97 km^3/year	190 km^3/year	287 km^3/year
Estimated renewable surface water supplies in the IRB	73 km^3/year	160-175 km^3/year	239-258 km^3/year
Estimated renewable groundwater supplies in the IRB	27 km^3/year	63 km^3/year	90 km^3/year
Estimated total water withdrawals in the IRB	98 km^3/year	180-184 km^3/year	257-299 km^3/year
Estimated total surface water withdrawals in the IRB	39 km^3/year	128 km^3/year	
Estimated total groundwater withdrawals in the IRB	55 km^3/year	52-62 km^3/year	

Note: Figures for surface and groundwater supplies may not sum evenly to figures for total renewable water resources because a large fraction of groundwater and surface water resources overlap, so that separate supplies cannot be absolutely distinguished.

Source: Derived from FAO, *Irrigation in Southern and Eastern Asia in Figures: AQUASTAT Survey 2011*, Karen Frenken ed. (Rome: FAO, 2012); A.N. Laghari et al., "The Indus basin in the framework of current and future resources management," *Hydrology and Earth Systems Sciences* 16, no.4 (2012); Bharat R. Sharma et al., "Indo-Gangetic River Basins: Summary Situation Analysis," International Water Management Institute, New Delhi Office, July 2008.

The intensifying strains on the Indus can be read in diminishing river flows and dropping water tables. Water is a renewable resource, but also a finite one. Rainfall, snow and ice melt, seepage between surface waters and groundwater, and return flows from irrigation and other uses ultimately drain to the Indus River and recharge aquifers to varying degrees. For any given source, however, renewals vary over time and place. Natural processes may only recharge underground aquifers over tens, hundreds, or even thousands of years, and the glaciers that nourish many watercourses have accumulated over millennia. Every watershed is only replenished by a certain amount of renewable water every year.

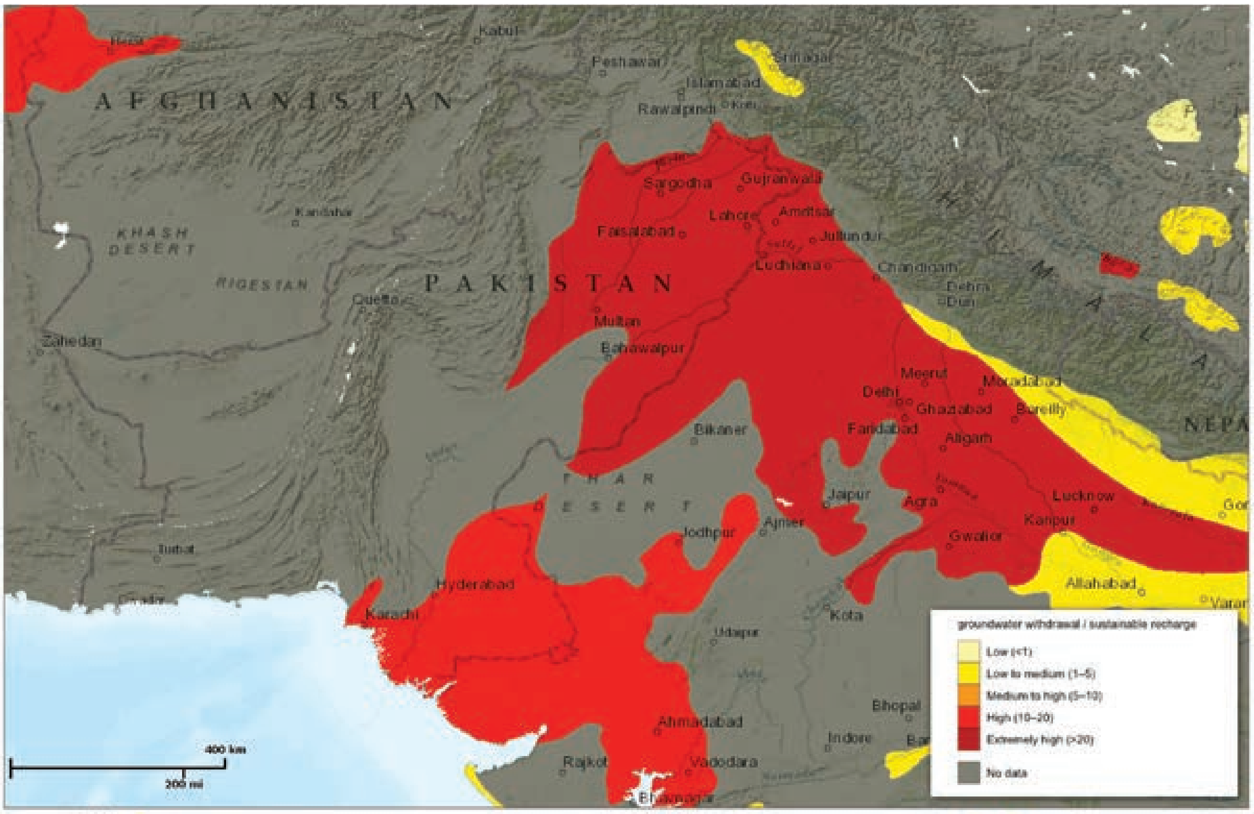
According to various studies, long-term available renewable water supplies in the Indus Basin average 287 km^3 per year, representing 190 km^3 of annual renewable water resources in Pakistan and 97 km^3 in India. Of this total, surface water accounts for around 239-258 km^3, comprising 73 km^3 from India and 160-175 km^3 in Pakistan. Annual renewable groundwater supplies have been estimated at 90 km^3, reflecting resources of 27 km^3 in India and 63 km^3 in Pakistan. (A large fraction of replenishable groundwater reserves and surface water resources overlap, however, so that separate supplies cannot be absolutely distinguished.) Against the basin's renewable freshwater resources, estimates of total annual water demand range from 257-299 km^3. India withdraws about 98 km^3 yearly, with around 55 km^3 of withdrawals coming from groundwater stocks and 39 km^3 from surface sources. Pakistan's annual water demands from the Indus add up to 180-184 km^3, with 128 km^3 from surface water and 52-62 km^3 pumped from groundwater aquifers.[11] Annual averages, though, can camouflage important year-to-year fluctuations in water availability. An assessment of supply and demand on the Indus River by experts at the International Water Management Institute (IWMI) helps frame the importance of such variations. In recent decades (1957-1997), annual flow in the Indus ranged from 120-230 km^3, with a long-term average of 187 km^3. Meanwhile, combined Indian and Pakistani withdrawals from the river now amount to 176.5 km^3.[12]

As the riparians' resource requirements have grown, water removals from the Indus are outpacing natural rates of renewal. Total withdrawals nearly equal or even surpass long-term flow balances and ecosystem needs. Increasingly, the Indus is a "closed" basin. A basin is considered closed when all of its water resources are already allocated to meet various societal and environmental needs, with little to no spare capacity left over, such that supply falls short of demand during part or all of the year.[13] Claims on the Indus have reached the point that some sub-basins, and even the river as a whole, may generate no net runoff (i.e., mean annual discharge from the river is zero percent of mean annual precipitation). In fact, at times the Indus no longer reaches the sea year round.[14]

With human water demands effectively absorbing available supplies, little flow remains to support the natural environment. Hydrologists and environmental scientists recognize that river systems require base "environmental flows" to sustain riverine habitats and ecosystems and maintain ecological functions such as diluting pollution, flushing sediment and nutrients downstream, controlling salinity intrusion, and replenishing wetlands and estuaries. No fixed formula has been found to determine appropriate environmental flows, which will vary from river to river. One preliminary assessment, however, has suggested that environmental water requirements for the Indus River should equal 25 percent of mean annual runoff, or about 46.75 km^3 per year based on the reported long-term average annual flow of 187 km^3.[15] The Indus is not meeting this target. Within Pakistan, the 1991 Water Apportionment Accord between the provinces committed to ensure that annual environmental flows to the Indus Delta below the Kotri barrage would not descend below 12.3 km^3 — so as to check seawater intrusion, maintain the river channel and sediment transport, and support fisheries — but flows since the 1990s indicate the terms of the Accord are not being fulfilled and runoff to the delta has been notably less than 12 km^3 per year.[16]

India and Pakistan are likewise rapidly depleting the basin's groundwater resources. Indeed, abstractions from the Indus aquifers reflect both the most intensive and the most unsustainable levels of groundwater exploitation on Earth.[17] Studies in Pakistan reveal water tables plummeting by two to three meters a year, with groundwater levels falling to inaccessible depths in many wells. Because groundwater salinity in these aquifers typically increases with depth, dropping water tables lead farmers to irrigate with ever more saline water, salinizing the soils and degrading their production potential. Salt-affected soils now afflict 4.5 million hectares, amounting to over 22 percent of Pakistan's irrigated lands.[18] Similarly, a review by India's Central Ground Water Board determined that overdrafts exceeded rates of recharge in 59 percent of the administrative units monitored in Haryana state, 80 percent of units in Punjab, and 69 percent of units in Rajasthan. Around the region, yearly groundwater withdrawals equaled 127 percent of the total renewable supply in Haryana, 170 percent in Punjab, and 135 percent in Rajasthan.[19] As a result, the Indus Basin is literally losing water. Estimates based on satellite data indicate that the basin aquifers lost groundwater at a rate of 10 km^3 per year between April 2002 and June 2008, an annual debit representing more than half the combined capacity of India's six large dams in the Indus system, or almost half the available water storage in all the reservoirs of Pakistan.[20]

Figure 3. Groundwater Stress in the Indus River Basin



Data provided by: WORLD RESOURCES INSTITUTE

AQUEDUCT

Increasing water pollution also burdens the Indus Basin. Natural processes can contaminate water supplies, but poor water quality more often results from human factors.[21] Agriculture, industry, mining, and other activities charge surface and groundwater resources with synthetic chemicals, fertilizers, pesticides, toxic metals, and microbial pathogens that can compromise human health. Human activities also generate heightened levels of nitrogen, phosphorous, and other nutrients, causing eutrophication that chokes waterways with algal blooms, weeds, and toxic bacteria.

Pressures on water quantity and quality interact. Decreasing water quality ultimately can lower effectively available water quantities, as some sources become too degraded for certain uses. Likewise, diminishing water quantities boost the concentration of any pollutants present, eroding water quality. Water quantity and water quality stresses frequently occur together, as demand centers requiring large withdrawals — such as zones of intensive agriculture, urban agglomerations, and industrial concentrations — also generate substantial pollution.[22]

Surface water quality in the upper Indus is high on certain measures, but progressively deteriorates downstream as farms and towns dump untreated agricultural effluents, human waste, and industrial pollutants into the river, canals, and drains. Nitrogen loading, phosphorous loading, pesticide loading, organic loading, and mercury deposition exhibit alarming levels throughout the river's course, and agricultural and industrial pollutants taint almost all shallow groundwater.[23] According to UNEP, farms, cities, industries, and households pour 54.7 km^3 of wastewater into the Indus every year, with 90 percent of these effluents coming from the agricultural sector.[24]

Little of this wastewater is treated. In Indian towns of 50,000 to 100,000 people and cities with populations of 100,000 to one million, wastewater treatment capacities can handle less than one-third of the sewage generated daily. Even in larger metropolitan areas with more than a million inhabitants, installed capacities can treat little more than two-thirds of urban wastewater, and nearly 39 percent of treatment plants tested in 2009 did not conform to discharge standards. A sanitation survey carried out by the Ministry of Urban Development evaluating 423 cities nationwide judged not a single city "healthy," and only four were assessed as "recovering," with none of those four cities in the Indus Basin. Instead, most cities were rated "Needing considerable improvements," and 190 were deemed "Cities on the brink of public health and environmental emergency."[25] Available data on Pakistan suggest that only about eight percent of urban wastewater is treated in municipal plants and 99 percent of industrial effluents are discharged untreated. One five-year national study found that water quality fell below recommended standards for human consumption in 76-96 percent of the samples tested across the country's four provinces.[26]

The consequences for Pakistani and Indian societies are dire. Inadequate sanitation costs Pakistan 343.7 billion Pakistani rupees (USD$5.7 billion) annually in health damages, productivity losses, and work and school absences, a sum equal to over 3.9 percent of GDP in 2006. Meanwhile, inadequate sanitation costs India 2.4 trillion Indian rupees (USD$53.8 billion) annually, equivalent to 6.4 percent of national GDP. More troubling than the economic impacts is the human toll. Water-borne diseases account for 20-40 percent of all hospital patients and one-third of all deaths in Pakistan, and an estimated 200-250,000 Pakistani children die from diarrhea and other water-related illnesses each year. Inadequate sanitation is responsible for 10 percent of all deaths in India and causes more than 30 percent of deaths among children under five. Diarrhea alone killed 395,000 Indian children in 2006.[27]

Reshaping the Basin: Population Growth, Urbanization, and Climate Change

Water managers in the Indus Basin will have to overcome a host of overlapping socio-economic, environmental, and policy pressures as they strive to fulfill their countries' future water needs. Historically, demographic pressures constitute the most powerful driver of regional water stress; the influence of population growth on water shortage has proven about four times more important than the effect of long-term shifts in available water resources due to climate factors.[28] Even absent any other stresses, demographic changes alone will significantly trim per capita water availability over the coming decades. As populations expand, renewable water resources remain finite, reducing available shares per person. The UN expects that India's population will increase by almost a quarter in the next 20 years, topping 1.5 billion in 2030 and approaching 1.7 billion by 2050. Pakistan will witness even more spectacular growth. From 174 million inhabitants in 2010, its population will surge to 234 million in 2030 and near 275 million in 2050.[29] Within the confines of the Indus, one assessment projects that 383 million people will be living in the basin — including populations in Afghanistan and China — by 2050. Annual renewable water availability across the basin would then be under 750 m^3 per capita. Another model evaluation by the International Water Management Institute calculates that total annual availability of renewable water on the Indian portion of the Indus Basin will slip from 2,109 m^3 per capita (in 2000) to 1,732 m^3 in 2050. On the Pakistani portion of the basin, yearly per capita water availability is expected to slide from 1,332 m^3 to 545 m^3.[30]

Economic growth and urbanization will also propel important shifts in water use. The Organisation for Economic Cooperation and Development (OECD) projects that Indian GDP will rise 5.1 percent per annum on average over the next 50 years — more rapidly than any other major economy — boosting per capita income more than sevenfold in 2060. Pakistan aspires to achieve seven percent annual GDP growth, quadrupling per capita income by 2030.[31] Expanding economies will fuel growing industrial sectors,

Figure 4. Water, Economic, and Population Data for India and Pakistan

	India	Pakistan
GDP (2011)[i]	4,503,069,382,752	485,136,390,937
GDP per capita (2011)[i]	3,627	2,745
Human Development Index 2011[ii]	0.547	0.504
Population in 2011 (in thousands)[iii]	1,241,492	176,745
Population in 2050 (in thousands)[iv]	1,692,008	274,875
Percentage of total population using improved drinking water sources, 2010[v]	90	89
Percentage of total population using improved sanitation facilities, 2010[v]	23	34
Total annual renewable water resources, 2011 (10^9 m^3/yr)[vi]	1,911	246.8
Total annual water resources per capita, 2011 (in m^3/person/year)[vi]	1,539	1,396
Total annual water withdrawals, 2005 or most recent year (in 10^9 m^3/year)[vi]	761 (in 2010)	183.5 (in 2008)
Total annual water withdrawals per capita (in m^3/person/year)[vi]	613 (in 2010)	1,038 (in 2008)

i GDP and GDP per capita converted to current international dollars for 2011 using purchasing power parity rates.
Source: World Bank, World Development Indicators, http://databank.worldbank.org/ddp/html

ii The Human Development Index (HDI) is a summary measure of human development.
Source: UNDP, Human Development Report 2011, http://hdr.undp.org/en/data/map/

iii **Source:** World Bank, World Development Indicators, http://databank.worldbank.org/ddp/html

iv Population growth estimates based on the medium-fertility variant.
Source: UN World Population Prospects, the 2010 Revision, http://esa.un.org/wpp/unpp/panel_population.htm

v **Source:** UN Millenium Development Goals Indicators, 2012 Update, http://mdgs.un.org/unsd/mdg

vi **Source:** FAO AQUASTAT, http://www.fao.org/nr/water/aquastat/data/factsheets/aquastat_fact_sheet_pak_en.pdf and http://www.fao.org/nr/water/aquastat/data/factsheets/aquastat_fact_sheet_ind_en.pdf

requiring increasing water inputs. By the same token, the UN anticipates that India's urban population will swell a further 62 percent over the next two decades, and Pakistan's will balloon by 83 percent.[32] City dwellers use more water on average than their compatriots in the countryside, and over the past two decades, municipal water withdrawals have doubled in India and quadrupled in Pakistan. On the Indian side of the Indus, analyses by IWMI conclude that by 2025 both domestic and industrial water withdrawals will double from 2001 levels. Likewise, municipal and industrial demand in Pakistan is expected to grow more than two-and-a-half times over current use.[33]

Larger, wealthier, and more urban populations will need sufficient sustainable water supplies to drink, wash, and cook. But it is the water needed to produce the food that they will eat that will challenge policy makers. International norms established by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) hold that each person requires a minimum of 20 liters of water a day for drinking and basic hygiene.[34] By contrast, to grow a kilogram of wheat — the primary crop cultivated in the Indus — requires 1,827 liters of water on average, while a kilogram of rice takes 1,673 liters. Producing dairy, meat, poultry, and other animal products can be even more water intensive, necessitating appreciable amounts of freshwater to grow feed, provide drinking water, and care for the animals. Raising a kilogram of lamb, for example, demands 10,412 liters of water; a kilogram of eggs uses 3,265 liters; and a kilogram of milk, 1,020 liters.[35] All freshwater inputs considered, it takes 2,000 to 5,000 liters of water per person per day to grow the food to support diets of 2,800 kilocalories daily that the FAO deems the threshold for ensuring food security.[36]

With rising incomes, urban and rural citizens alike discover different dietary possibilities and preferences, deriving less of their daily caloric intake from food grains and more from non-grain crops (fruits, vegetables, oils, and sugar) and animal products (meat, fish, and dairy). Driven by these socio-demographic pressures, experts calculate that Pakistan will need 250 km^3 of water to irrigate its fields in 2025. By the same token, models developed by the International Food Policy Research Institute (IFPRI) anticipate that irrigation water use on the Indian stretches of the Indus will climb some 12 percent above 1995 levels by 2025.[37] (Increased agricultural production and increased irrigation, in turn, suggest that increased amounts of agricultural effluents will drain into Indus water systems. According to models developed by the OECD, as India boosts its crop production by some 50 percent by 2030, annual nitrogen loads in the country's wastewater will soar fivefold and phosphorous loading will more than triple above year 2000 levels.)[38]

Consequently, a growing number of analyses foresee increasing water scarcities striking the Indus Basin. A consortium led by the consulting firm McKinsey & Company and the International Finance Corporation, an arm of the World Bank, recently constructed a baseline for charting emerging global resource challenges by comparing expected future water requirements against actually accessible, reliable, and environmentally sustainable supplies of surface and groundwater. According to this international assessment — assuming that present policy regimes continue and existing levels of efficiency and productivity persist — renewable water supplies will fall 52 percent short of annual demands on the Indian side of the Indus Basin in 2030. The consortium's findings echoed an earlier Indian prognosis concluding that total utilizable freshwater resources in the Indian reaches of the Indus will meet less than half of the basin's requirements in 2050.[39] The situation is equally alarming on the other side of the frontier. There, the World Bank figures that Pakistan has already breached the limit of its available resources. Yet by 2025 the country will require 30 percent more water than today to meet its rising agricultural, domestic, and industrial needs.[40]

The growing danger of climate change compounds the water resource challenges confronting the region. Continuing global warming may shift the seasonal timing or the geographical distribution of water supplies. Extreme weather events are predicted to increase in frequency and degree, with stronger storms, higher floods, and deeper droughts becoming more numerous and severe. Such impacts could significantly alter water availability and damage or degrade the water supply and sanitation infrastructure on which Indians and Pakistanis depend. Regional-scale climate change projections remain clouded by many uncertainties. Nevertheless, ensemble analyses of multiple models suggest that the Indus Basin region will experience increasingly variable precipitation. Winter precipitation is projected to decrease, implying less availability and higher water stress during the lean season. Summer precipitation is expected to increase overall, but with enhanced year-to-year variability in daily rainfall during the monsoon. An anticipated rise in intense precipitation presages more severe monsoon flooding. With more rainwater coming in short sudden

Figure 5. Glaciers in the Major Basins of the Hindu Kush Himalaya Region

Basins	Number	Glaciated area (km^2)	Estimated ice reserves (km^3)	Average area per glacier (km^2)
Amu Darya	3,277	2,566	162.6	0.8
Indus	18,495	21,193	2,696.1	1.2
Ganges	7,963	9,012	793.5	1.1
Brahmaputra	11,497	14,020	1,302.6	1.2
Irrawaddy	133	35	1.3	0.3
Salween	2,113	1,352	87.7	0.6
Mekong	482	235	10.7	0.5
Yangtze	1,661	1,660	121.4	1.0
Yellow	189	137	9.2	0.7
Tarim	1,091	2,310	378.6	2.1
Qinghai-Tibetan Interior	7,351	7,535	563.1	1.0
Total, HKH	54,252	60,055	6,126.8	1.1

Source: Bajracharya, SR (2012) Status of glaciers in the Indus Basin. Kathmandu: ICIMOD
Credit: ICIMOD/Samjwal Ratna Bajracharya

downpours, less will be absorbed by saturated soils and more lost as direct runoff, correspondingly reducing the potential for recharging groundwater.[41]

Climate change will exert additional, chronic pressures on key sources of fresh water supplies in the Indus Basin. The headwaters of the Indus rise in the glaciers of the Himalaya Hindu Kush (HKH). Often called the continent's "water towers," the glaciers of the greater Himalayan range constitute the world's largest body of ice outside the polar ice caps. The glaciers act as massive regional freshwater repositories, seasonally accumulating snow and ice at high elevations and releasing melt water that feeds 10 large river systems across Asia. According to a recent inventory undertaken by ICIMOD, the Indus is by far the most heavily glaciated of the region's major basins. It counts 18,495 glaciers covering 21,193 km^2 and containing an estimated 2,696 km^3 of ice, representing 44 percent of the total ice reserves in the entire HKH region. Snow and glacial melt contribute more than 50 percent of the total flow of the Indus, forming an especially critical source of water during the summer shoulder seasons (before and after the rains from the summer monsoon) when melt water comprises 70 percent of the river's summer flow. In years of feeble or failed monsoons, melt water can avert or alleviate otherwise calamitous drought.[42] As global warming drives up temperatures and shifts precipitation patterns worldwide, however, glaciers in the Himalayas are generally retreating.[43]

Initially, increased glacier melting could boost river flows. This trend could pose risks of its own, however. Rising runoff can heighten the danger of "glacial lake outburst floods" (GLOF) as melt water collects behind natural barriers of ice or debris. Seismic activity, avalanches, landslides, or other triggers can weaken or collapse these retaining barriers, sending sudden waves of water rushing downstream. Historically, some 33 GLOFs have been recorded in Bhutan, Nepal, and the Tibetan Autonomous Republic (China) since the

1930s, some causing loss of life and significant damage to roads, bridges, hydropower plants, and other infrastructure. In some instances, the flooding spread across international borders. ICIMOD has catalogued 16 potentially dangerous glacial lakes just on the Indian tributaries of the Indus in Himachal Pradesh, and a further 52 potentially dangerous lakes in the Pakistani reaches of the basin.[44]

As de-glaciation continues, however, melt water flows will subsequently wane, diminishing the downstream supplies available for drinking, sanitation, agriculture, hydropower, industry, and ecosystems. As melt water contributions to the Indus Basin decline, one set of model projections shows mean water supply decreasing by 8.4 percent on the Indus by 2050. When integrated with assessments of projected irrigation requirements and crop yields, these anticipated shifts in water availability imply a drop in the effective population that can be fed by the basin's water resources. By mid-century, such calculations warn, the Indus Basin will be able to feed 26 million fewer people than it currently supports.[45]

The Challenge and the Opportunity

Left unaddressed, such pressures could sow increasing competition over dwindling water supplies, fueling potentially destabilizing international tensions. Historically, the international boundary that set India and Pakistan apart at independence also set them at odds over water. As the downstream neighbor, Pakistan feared Indian withdrawals or diversions could deprive it of its water supply, posing an existential threat to its agriculture and economy, and undermining its food security. As the upper riparian, India worried that according all of the Indus' flow to Pakistan would curtail possibilities for developing the river for its own benefit. Since 1960, the Indus Waters Treaty (IWT) between the two countries has governed water resource development on the river and its main tributaries. Unlike other water agreements that typically distribute water allowances between riparians — either as absolute amounts or percentages of the river flow — the IWT physically divided the river, allocating use of the three western tributaries that contribute to the main river entirely to Pakistan, and allotting the three eastern tributaries to India. The treaty also controls the type and features of projects that India can establish on its portion of the Indus.

Since its inception, the IWT has stood through three wars and countless lesser clashes. But the accord has no provisions for how the parties should respond to the variations in water flow that climate change could engender. Nor does the agreement contain effectively binding provisions to address water quality or pollution. Similarly, while the two countries share transboundary aquifers as well as surface waters, there are no provisions for managing this key resource, or even for sharing data on groundwater supplies. Yet consumers across the Indus Basin rely on groundwater to supplement or substitute for surface water. As pressures on one source of supply grow, users will of necessity turn to the other.[46]

South Asia's earliest civilizations arose on the banks of the Indus, encompassing sites in both modern day Pakistan and India. Recent archaeological evidence suggests that climatic shifts dried the rivers that once watered the irrigated agriculture on which those Bronze Age cities depended, precipitating the ultimate collapse of Harappan civilization.[47] Today, India and Pakistan again face significant water resource challenges. In 2005, a World Bank assessment judged that India's clashing water supply and demand trajectories offered "a stark and unequivocal portrayal of a country about to enter an era of severe water scarcity." A parallel 2005 World Bank analysis of Pakistan warned that while development of the Indus had transformed one of the world's most arid nations — providing the platform for the country's economy — "the survival of a modern and growing Pakistan is threatened by water."[48] Yet contemporary Indus civilization is by no means destined to suffer the fate of its Bronze Age predecessors. Effective management of the basin's water resources — built on sound scientific data, guided by an integrated knowledge base, and anchored by capacity building and confidence building measures — can promote a sustainable future for both India and Pakistan in the Indus Basin.

POLICY AND RESEARCH RECOMMENDATIONS:
AGRICULTURE AND FOOD SECURITY

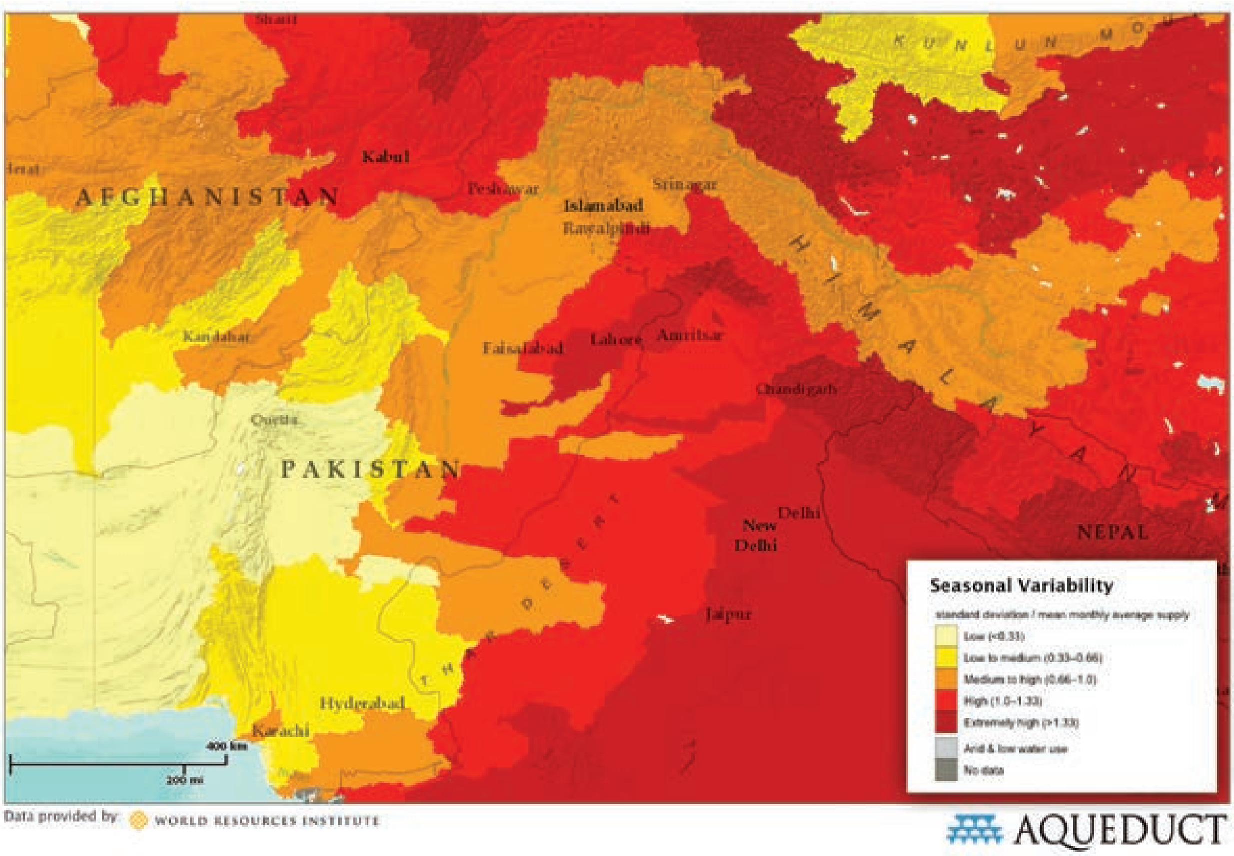
With the introduction of modern irrigation techniques in the mid-19th century, modern-day Indian and Pakistani Punjab transformed themselves into agricultural breadbaskets — a role they continue to fulfill today. Dubbed the “food bowl of India,” Indian Punjab accounts for roughly 12 percent of India’s 234 million tons of food grain, making the state critical to the nation’s food security, despite the fact that the state accounts for less than 1.6 percent of the country’s total land area.[49] Pakistani Punjab, meanwhile — home to nearly 70 percent of the country’s total cropped area — produces 80 percent of Pakistan’s wheat, 97 percent of its fine aromatic rice, 63 percent of its sugarcane, and 51 percent of its maize, in addition to 83 percent of the country’s total cotton.[50]

Vital to the economic stability and food security of both countries, the Punjab region of the Indus Basin, as well as Sindh province in Pakistan and Haryana state in India, face the dual challenges of population growth and climate change. These pressures are taxing soil and water resources in unprecedented fashion by eroding food security, threatening agricultural livelihoods, and heightening competition among water users for increasingly scarce water resources. Erratic seasonal water supply is particularly problematic for Pakistan, where agriculture generates approximately 22 percent of GDP, employs roughly 40 percent of the country’s total workforce, and generates some 80 percent of total Pakistani export revenue.[51] Across the country, some 13 million hectares of arable land now lies untouched due to insufficient water supply, even though Pakistan possesses more than 20 million hectares of arable land.[52] In response to the increased variability of monsoon precipitation across the basin, food producers in both countries frequently resort to groundwater pumping — an almost entirely unregulated practice, which is often encouraged via fuel subsidies — to meet their irrigation needs, resulting in the unsustainable drawdown of vital underground water supplies. Reliance on this resource is driven by the fact that roughly 10 percent of total rainfall within the basin evaporates, while poorly lined canals result in the loss of roughly 41 million acre feet per year due to seepage.[53]

Meanwhile, mounting water scarcity also has long-term implications for food production and livelihoods beyond the two countries’ agricultural heartlands. In the mountainous reaches of the Indian and Pakistani portions of the basin, rural communities adjacent to glaciated areas regularly siphon water directly from the glaciers’ peripheries to irrigate crops. As climate change accelerates glacial melt rates in the Indus headwater regions, these communities face the potential short-term challenge of increased flooding, and the long-term prospect of depleted melt water flows, which will reduce water supply required for local food production.[54]

In addition to population growth, changing lifestyles and diets across the region are also driving intensified water demand for food production. In India in particular, an emerging middle class is showing an increased preference for meat and dairy products, which have a much larger virtual-water footprint than grains and

Figure 6. Seasonal Variability of Water Supply in the Indus River Basin



other agricultural produce due to the water resources needed to raise livestock. Shifting dietary preferences and their attendant impact on water resource allocations threatens to increase tensions and heighten competition between water users in the Indus Basin, particularly between stakeholders in the agricultural and livestock sectors.

Irrigation efficiency in the Pakistani portion of the Indus Basin Irrigation System (IBIS) is roughly 40 percent, with the situation not appreciably better within the Indian portion of the IBIS.[55] Across India, irrigation efficiency in canal systems is generally between 38-40 percent.[56] Such water-use inefficiency in the agricultural sector jeopardizes short-term and long-term food security in the Indus Basin. For decades, funding the maintenance of the vast irrigation network spanning the India-Pakistan border has remained a low priority for government agencies at the state and federal level in both countries. The resulting deterioration of critical water-transport infrastructure has led to substantial water losses, particularly in the form of leakage from poorly-lined canals. Additionally, the continued reliance on flood-based surface irrigation in an increasingly arid basin climate has resulted in major water losses through evaporation. Even for the water that does make it to the crops, poor drainage infrastructure can result in improper distribution of water across farms, oversaturating some plants while leaving insufficient water for others.

To improve agricultural water-use efficiency and enhance food security in the Indus Basin, the Working Group puts forth the following recommendations:

› **Prioritize investment in and institutionalize regular maintenance of canal infrastructure to minimize agricultural water losses.** Public works investments aiming to rehabilitate aging canals represent one of the most likely means of improving water-use efficiency in the Indus Basin. In India, poorly maintained canals lose between 10-40 percent of the water they transport due to seepage.[57] In Pakistan, less than 50 percent of water diverted from rivers for irrigation purposes is ultimately available at the farm gate.[58] To date, rehabilitation of the canals has long been avoided because of cost considerations, and the fact that large-scale agricultural interests in both countries have been able to absorb water losses due to an unregulated supply of irrigation water. Population growth and climate change have changed that equation, however, highlighting the need for improved water-transportation infrastructure to ensure that surface-water withdrawals from the Indus and its tributaries reach their target farmland.

In particular, a comprehensive canal-lining public-works campaign prioritizing rehabilitation of waterways carrying the greatest volume of diverted river flows would enhance water-use productivity by reducing losses due to seepage and evaporation. While such an initiative would necessitate a major public investment, it would serve as a job-creating engine given the labor force needed to execute such a project, and costs would be recouped in the form of heightened agricultural productivity and augmented water security. Pakistan's Water and Power Development Authority (WAPDA) anticipates that upgrading water courses could reduce 2.36 million acre feet worth of water losses, while upgrading the lining of minor canals throughout the basin could generate savings of five million acre feet.[59] Meanwhile, it is estimated in India that enhancing irrigation water-use efficiency by five percent could boost irrigation potential by 10-15 million hectares.[60]

› **Improve cross-border dissemination of hydrological data regarding dry season flow levels and heavy precipitation events to accommodate downstream agricultural interests.** Changing melt rates in the glaciated regions of the Upper Indus Basin and shifting monsoon patterns are not necessarily leading to a net decrease in water availability throughout the basin. However, these changes are altering the traditional patterns of water delivery throughout the basin, resulting in an uneven distribution of water resources that becomes particularly problematic during the shoulder months of the dry season. Given its lower riparian status, Pakistan is particularly dependent on receiving surface water flows of a certain volume during this time, to ensure sufficient supply for power generation, industrial production, and most crucially, crop growth.

To mitigate Pakistan's legitimate sensitivities about water access during such periods, Indian water managers in the higher-elevation portions of the basin could institutionalize a modest exchange of hydrological data on flow levels to better equip Pakistani water managers with the information needed to anticipate future changes in water supply. Disclosing information on abnormally heavy precipitation, prolonged drought, or other major weather-related anomalies in Indian portions of the basin would help Pakistani water managers and farmers plan ahead for reduced water supply, or in the case of pending flooding, allow disaster-management officials lead time to conduct evacuations and mobilize equipment and first responders. If instituted, the sharing of meteorological information could serve as the foundation for greater regional data exchange between water-management agencies at the state/province and federal level in both countries. However, if government involvement proves unfeasible due to bilateral political tensions, third-party meteorological agencies with satellite capability — such as the European Space Agency (ESA), German Aerospace Center (DLR), US National Aeronautics and Space Administration (NASA), or US National Oceanic and Atmospheric Administration (NOAA), among others — could assume the role of primary data provider.

› **Utilize new mapping technologies to build the knowledge base on the status of groundwater supplies in the Indus Basin.** The status and health of groundwater reserves has long been much harder to gauge than surface water supplies, but new technologies are beginning to unearth data on the location and volume of underground aquifers.For example, interferometric synthetic aperture radar (InSAR) satellite data — which reveals changes in land elevation in areas where aquifers have been heavily depleted — is one of a growing number of tools that can be used to gauge the sustainability of groundwater stocks.[61] Other groundwater mapping practices — such as the Gravity Recovery and Climate Experiment (GRACE), pioneered and implemented by the likes of DLR, NASA, and the University of California Center for Hydrological Modeling — also represent a potential starting point for scientific researchers and water managers in both India and Pakistan to better assess depletion rates of the basin's vulnerable groundwater stocks.

Government investment in such technology could prove expensive, but costs could be reduced by enlisting the assistance of third-party scientific agencies with capacity to monitor the health of groundwater supplies via satellite. Existing domestic capacity for monitoring groundwater reserves could also be augmented by bringing hydrological experts experienced in the use of such technology to the region to discuss with their Indian and Pakistani professional counterparts the equipment and logistical capacities needed to map aquifers, and share best practices for accurately mapping groundwater stocks. Developing local water managers' knowledge base and monitoring capabilities will lead to a more comprehensive understanding of groundwater availability, and provide the data needed to inform more efficient and sustainable usage of this vital resource.

› **Promote use of laser land leveling technology on small (subsistence-level) and mid-sized farms.** Laser land leveling is a land intervention process that allows for significant improvements in agricultural water-use efficiency, reducing the amount of irrigation water needed on farms. Alongside zero tillage for wheat crops, laser land leveling has emerged as one the basin's most widely adopted interventions for agricultural water savings. To date, the technology has primarily been implemented by large-scale agricultural operations, with the trend becoming more widespread among these stakeholders in the Punjab around 2005.[62]

Studies suggest the technology can greatly enhance water-use productivity for key crops in the basin such as wheat and rice. Recent studies conducted in the Ganges Basin (in Modipuram, India) and the Indus Basin (in Mona, Pakistan) show that laser land leveling increased irrigation water productivity for those staples by more than 50 percent.[63] The technology's overhead costs are prohibitive for many smaller-scale farming operations — a laser leveling system costs between USD$3,500 and USD$10,000 — and the actual leveling itself can prove expensive as well, particularly if a tractor is used instead of animal power to redistribute soil. However, facilitating small- and mid-scale farmers' access to such technology through equipment loans or financial assistance would likely accelerate the technology's spread. Further, the equipment would only be needed periodically; if plowed and subsequently maintained correctly, laser leveled fields typically need re-leveling only after eight years, and possibly as long as ten years.[64]

Principal challenges to wider adoption of laser leveling technology include the absence of broader public awareness, overhead costs, and insufficient training regarding equipment and best practices for land leveling. Expenses typically vary according to the type and amount of soil being leveled, type of equipment, and geographic contours of the farmland. Despite the associated risks, land leveling technology provides a variety of benefits, including: decreasing weed-removal expenses by some 40 percent; fostering uniform crop growth across a farm by reducing pooling of irrigation water; limiting evaporation rates; and improving drainage so as to help farmland better cope with flooding.[65]

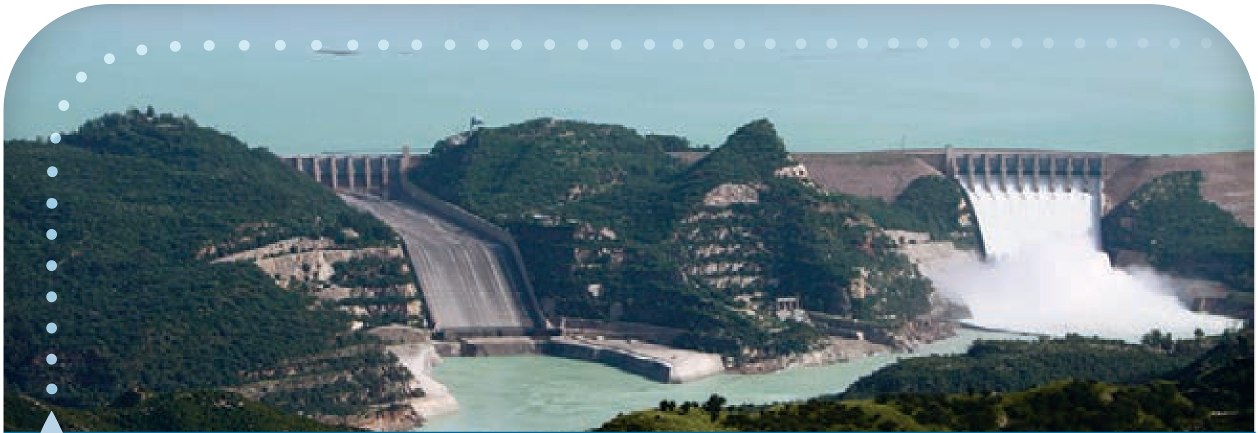
› **Develop cross-border research projects between scientific and agricultural agencies exploring the potential for drip irrigation in the basin; establishing best practices for increased water storage; and identifying alternative crops better suited for growth in the basin's arid climate.**

Farmers installing tensiometers in rice fields in Punjab, India, in July 2012 to enhance soil moisture management.
Source: Columbia Water Center via Flickr

One potential avenue for joint research inquiry might analyze and evaluate the potential impact of drip irrigation in the basin. Despite a relatively high installation cost and unsuitability for certain crops, drip irrigation has shown potential for massive water savings, with some studies documenting water savings of 25-80 percent.[66] The International Water Management Institute further estimates that there exists 0.6 million hectares' worth of cropland suitable for drip irrigation in Indian Punjab, with roughly equivalent areas available in the Pakistani portions of the Indus Basin.[67]

A second joint research study might explore best practices for enhanced water storage in arid environments, a research initiative that would be particularly applicable to Pakistan, which has struggled to cope with both abnormally high and low flow levels in recent years during alternating cycles of severe flooding and drought. Irrigation for the Pakistani portions of the Indus Basin is largely regulated through two major storage dams — the Tarbela Dam on the Indus River, and the Mangla Dam on the Jhelum River, both of which are located in the Upper Indus Basin and fed predominantly by glacier- and snowpack melt water. A joint-research initiative on developing additional water storage infrastructure might analyze: best practices for storing excess water during times of abnormally high flow; how to most effectively store water during the shoulder months of the dry season; how to minimize water loss from evaporation in surface reservoirs; and identify effective and sustainable water-storage interventions utilized in other, similarly arid regions of the globe, such as the American Southwest.

A third joint research initiative might examine the logistics of planting alternative crops in some portions of the basin, with an emphasis on identifying plants that are economically lucrative and more appropriate for the region's increasingly arid environment in terms of water requirements per unit produced. The recommendations emanating from such a project might encounter significant pushback from entrenched agricultural interests that have traditionally used the basin for growing export-oriented, water-intensive cash crops like jasmine rice, which requires fields to be flooded for several months. However, recognizing the increasingly evident truth that some crops irrigated in the basin are ill-suited for the local environment, a transition to new, more heat-resistant and drought-tolerant crop types in certain regions of the Indus Basin Irrigation System could lead to more efficient usage of water resources and bolster food security in the process. One potentially strategic crop worthy of greater research inquiry is moringa, a highly nutritious, antioxidant-saturated plant native to both Africa and Asia that grows rapidly in a variety of environments and boasts high levels of protein and vitamins A, B, and C. Greater reliance on this crop could prove strategically important, as much of it is edible, and the plant can be consumed by livestock and human populations alike.



POLICY AND RESEARCH RECOMMENDATIONS:
ENERGY AND ECONOMIC DEVELOPMENT

Water is an essential input to economic and social development. All people need clean fresh water for drinking, cooking, and washing, while modern civilization depends on reliable water supplies for agriculture and industry, power production, waste elimination, support of fisheries and forests, and maintenance of essential ecosystems. Insufficient water access and inadequate sanitation impose substantial burdens on society. Scarce water supplies and polluted sources can impair farming and food security, compromise industrial production and power generation, endanger public health, jeopardize livelihoods, and hobble economic growth. Indian and Pakistani policy makers at the highest levels increasingly recognize that rising water stresses risk undermining national welfare. Indian Prime Minister Manmohan Singh has repeatedly singled out water supplies as posing a fundamental challenge to the country's continued economic growth. Similarly, the deputy chairman of India's Planning Commission, referring to the looming shortfall between increasing demand and available water resources, has said, "If we are not able to meet this gap, what this means is that GDP growth cannot take place…We will not be able to achieve the improvements in the levels of living that we want unless we can fill this gap."[68] Likewise, Pakistan's Planning Commission identifies scarce supplies as a significant constraint on national GDP growth.[69]

Even so, despite considerable progress achieved in the past two decades, millions of Indians and Pakistanis lack adequate water services. In India, 97 percent of urbanites and 90 percent of rural residents enjoy access to an improved water source. In Pakistan, the figures are 96 percent and 89 percent, respectively. Sanitation services, however, are less widespread. Some 42 percent of urban Indians and 77 percent of their rural compatriots lack access to improved sanitation. In Pakistan, 28 percent of city dwellers and 66 percent of rural residents live without improved sanitation.[70] The public health consequences — counted in disease, deaths, and days of productivity lost — are severe. Unsafe water and inadequate sanitation cost India 2.4 trillion Indian rupees (USD$53.8 billion) annually — equivalent to 6.4 percent of national GDP in 2006 — while water and sanitation shortfalls cost Pakistan 343.7 billion Pakistani rupees (USD$5.7 billion) annually, or over 3.9 percent of GDP.[71]

Just as insufficient water supplies threaten to curb economic productivity, economic growth is also placing new demands on water resources. Worldwide, cities increasingly constitute critical centers and drivers of growth and innovation, drawing in people and investment in search of economic opportunity. By 2030, for example, Indian cities could generate 70 percent of net new jobs, produce 70 percent of GDP, and fuel a fourfold rise in per capita income. Indeed, recognizing cities as engines of economic expansion, Pakistan's Planning Commission proposes placing dense, multi-function city development at the heart of the nation's growth strategy.[72] Rising urbanization, in turn, and the concomitant concentrations of demographic and

Tarbela Dam, Haripur District, Hazara Division, Khyber Pakhtunkhwa, Pakistan.
Source: UN Photo/Mark Garten

economic growth, will shift the locations, intensity, and nature of water demands. Across South Asia, experts project that municipal water demand will surge six-fold and industrial demand will jump sevenfold from 2000 to 2050.

Economic growth will also ripple through water use patterns via rising energy demand. Under the terms of its 12th Plan, India anticipates adding 9,204 megawatts (MW) of hydropower to its generating capacity in the next five years alone. The Central Electricity Authority has identified 33,832 MW of hydropower potential in the Indus Basin, but calculates that only 47 percent of this capacity has been developed or is under construction.[73] Pakistan also nurtures plans for significant additional hydropower development on the Indus. Pakistan's Water and Power Development Authority has identified over 56,000 MW of hydroelectric capacity in various sub-basins of the Indus. With the goal of raising hydro to supply 70 percent of Pakistan's power mix, WAPDA has undertaken studies towards generating an additional 25,000 MW of hydropower by 2020.[74] The amount and type of new hydroelectric infrastructure constructed in both the Indian and Pakistani portions of the basin in the coming years will have major implications for water users throughout the region.

To foster low-impact economic development in the basin, increase water-use efficiency among non-agricultural industries, and improve cross-border communication concerning hydroelectric development, the Working Group puts forth the following recommendations:

Figure 7. Hydropower Potential in the Indus River Basin

Country	Identified capacity as per assessment study	Capacity developed		Capacity under construction	
	Total (MW)	(MW)	(%)	(MW)	(%)
India	33,832	11,113.3*	33.65	4,697*	14.22
Pakistan	59,208	6,516.0	11.01	1,628.76	0.03

*Excludes Small Hydropower installations under 25MW
Sources: Government of India, Central Electricity Authority, "Status of H. E. Potential Development – Basinwise," (As of 31/12/2012) at http://www.cea.nic.in/reports/hydro/he_potentialstatus_basin.pdf; Pakistan Power and Water Development Authority, *Hydro Potential in Pakistan* (Islamabad: Water and Power Develooment Authority, November 2011), pp.3-4, at http://www.wapda.gov.pk/pdf/brohydpwrpotialapril2011.pdf.

› **Initiate a professional exchange program for hydraulic engineers and water managers from each country to jointly identify and expand upon best practices for sediment flushing, water temperature regulation, maintenance of environmental flows, and pollution control as it pertains to hydroelectric infrastructure.** In the absence of direct government-to-government dialogue, Indian and Pakistani research institutions and universities should consider implementing exchange programs bringing together engineers or water managers from both countries to collaborate on a joint research project on environmentally sustainable hydroelectric development. Such a project could analyze and build knowledge on dams' impact on: sediment distribution throughout downstream portions of the basin; erosion rates and flood plain utilization; water temperature fluctuations; health of fresh water fisheries; and geologic stability in seismically active regions. By considering this full range of issues, joint research initiatives could develop a template for more holistic environmental impact assessments that could be applied to new hydroelectric construction in the basin.

In the event that bilateral political tensions prohibit direct person-to-person exchange, participants could use virtual exchange platforms such as Skype to deepen professional linkages. Relevant and interested institutions might also agree on undertaking separate but coordinated research, with results later integrated and synthesized among the cross-border partner institutions. During periods of greater bilateral cooperation, teams sanctioned by the Indus Waters Commission might even consider joint observations of output flow levels from basin dams during winter months (when flows are typically low) and during the monsoon period (when wider dissemination of flow data can help disaster management planners downstream better anticipate pending flood events). Making institutional arrangements for the timely exchange of information on water flows could build confidence and heighten transparency surrounding hydrological data sharing, and mode and speed of data provision could be set between the two coordinating teams.

› **Deepen public understanding on how climate change and shifting precipitation patterns are influencing water availability and impacting the operation and productivity of hydroelectric infrastructure.** Sustained dam construction in Indian-controlled Kashmir over the past several decades has driven Pakistani perceptions that with each additional project, India heightens its capacity to disrupt or delay flows of the Eastern Rivers into Pakistan in the event of conflict between the two countries. This tactic, which may be technically impossible, would theoretically have a major impact on Pakistani crop yields and inflict significant damage on Pakistan's agriculture-dependent economy within weeks. This vulnerability shapes Pakistan's attitudes toward Indian water management in the Indus Basin, but also represents a starting point for building bilateral confidence over both countries' hydroelectric development of the basin.

Indian hydroelectric development — particularly in Kashmir — is one of the most emotive aspects of India-Pakistan water tensions, fueled by misperceptions among downstream water users both about how upstream dams operate on a technical level and how climate change is impacting water inflow rates at the border. The majority of Indian dams are run-of-the-river, meaning they do not feature reservoirs with the capacity to hold back significant volumes of water. However, this is not common knowledge among downstream water stakeholders. Meanwhile, relatively small amounts of water from the Indus, the Jhelum, and Chenab are diverted for local agriculture in Indian-controlled Kashmir. India is required by law to release a certain flow volume to Pakistan throughout the year, an obligation which it honors under the terms set by the Indus Waters Treaty.

Nevertheless, in recent years, India has fed Pakistani threat perceptions by often choosing to initiate dam construction unilaterally, delaying responding to Pakistani objections over projects on the Western Rivers, and providing incomplete data on engineering specifications and the timing and volume of water releases. Civil society actors — chief among them scientific research institutions, universities, and environmental NGOs — in both countries should consider developing joint or coordinated research projects that help dispel misinformation about India's ability to withhold or divert shared basin waters. Joint research initiatives might also analyze the myriad climate change drivers responsible for increasingly erratic precipitation patterns over the basin, highlighting the fact that emerging environmental pressures are largely responsible both for uneven water deliveries from the Indian-controlled parts of the basin into Pakistan and inconsistent hydroelectric production in the two countries' sections of the Indus Basin. Subjecting such research reports to international peer-review would heighten the scientific credibility of the projects, and help insulate them from subsequent politically motivated interference. More generally, civil society actors must use these types of collaborative research efforts to educate decision makers, water managers, journalists, farmers, and the public at large about the science — not the politics — of growing water stress on both sides of the border.

› **Recognizing the growing long-term stresses on basin water supplies, heighten the visibility of research on water recycling innovations and promote policies emphasizing demand-side "water consumption management."** Twentieth century water resource development in the basin focused almost exclusively on building supply-side capacity, a trend that has continued unabated into the 21st century. Pakistani and Indian NGOs or universities might consider jointly identifying research priorities for improving water recycling as a means to achieve greater water-use efficiency. Such an initiative would first and foremost focus on the agriculture sector — which constitutes the lion's share of total water withdrawals in the basin — but would also focus on best practices for wastewater recycling in key industrial sectors as well, including power generation, textiles, manufacturing, and livestock husbandry. Joint research might draw upon lessons learned and best practices from industrial actors situated in river basins in similarly arid climates — such as the Colorado, Jordan, and Nile — and establish best practices for low-impact economic development in the Indus Basin centered on sustainable land-use and enhanced wastewater treatment.

Raising the profile of wastewater recycling among academic and other civil society actors could allow the practice to eventually gain greater scientific acceptance among policy-making bodies and private water managers in the basin. Indeed, it is in the vested self-interest off all basin water stakeholders to

Figure 8. Large Dams and Barrages in the Indus River Basin

Large Dams in the Indus River Basin (2010)

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m³)	Main use
India	Bhakra	Nangal	Sutlej	1963	226	9,620	Irrigation, hydropower
	Nangal	Nangal	Sutlej	1954	29	20	Irrigation, hydropower
	Pandoh	Mandi	Beas	1977	76	41	Irrigation, hydropower
	Pong	Mukenan	Beas	1974	133	8,570	Irrigation, hydropower
	Salal	Reasi	Chenab	1986	113	285	Hydropower
	Baglihar		Chenab	2008		33	Hydropower
						Total: 18,589	
Pakistan	Mangla	Mangla	Jhelum	1968	116	10,150*	Irrigation, hydropower
	Tarbela	Ghazi	Indus	1976	137	11,960	Irrigation, hydropower
	Chashma (barrage)	Mianwali	Indus	1971		870	Irrigation
						Total: 22,980	
						Combined Total: 41,569	

Barrages in the Indus River Basin (2010)

Country	Name	River basin	Year	Main use
India	Rupar	Sutlej		Irrigation
	Harike	Sutlej		Irrigation
	Ferozepur	Sutlej		Irrigation
	Madhopur Headwork	Ravi		Irrigation
Pakistan	Sulemanki & Islam	Sutlej		Irrigation
	Balloki & Sidhnai	Ravi	1965	Irrigation
	Marala	Chenab	1968	Irrigation
	Khanki	Chenab		Irrigation
	Qadirabad	Chenab	1967	Irrigation
	Trimmu	Chenab		Irrigation
	Punjnad	Chenab		Irrigation
	Rasul	Jhelum	1967	Irrigation
	Kalabagh	Indus		Irrigation
	Chashma	Indus	1971	Irrigation
	Taunsa	Indus	1958	Irrigation
	Guddu	Indus	1962	Irrigation
	Sukkur	Indus		Irrigation
	Kotri	Indus	1955	Irrigation
	Mailsi (Siphon)	Under Sutlej	1965	Irrigation

*Includes recent raising of 3.58 km^3

Source: FAO, "Indus river basin," in *Irrigation in Southern and Eastern Asia in Figures: AQUASTAT Survey 2011*, Karen Frenken ed. (Rome: FAO, 2012), page 139, http://www.fao.org/docrep/016/i2809e/i2809e.pdf utilize surface and groundwater resources more efficiency via a heightened emphasis on water reuse, as institutionalizing the practice would help build water-access resiliency during dry periods. Joint studies on potential applications for recycled water resources could emphasize how to gain the greatest economic benefit from multi-functional water sources, including blue and green water.[75]

Lastly, civil society actors should seek to dialogue with policy makers and members of the media and begin to shift the culture of basin water resource management away from installing massive detention reservoirs and large-scale water diversions as a means to improve water security, and instead focus more intensively on water-use efficiency. Indeed, changing the mindset of water managers from supply-side to demand-side could herald a sea change in the availability of basin water supplies. Research initiatives into demand-side water management should begin with the agriculture sector, but encompass industry and domestic water usage as well. In addition to researching new pathways toward improving demand-side water efficiency — such as developing experimental models for water pricing and creating potential financial incentives for more efficient water resource utilization across industries — joint research efforts might also consider the revival of traditional water storage techniques (including large-scale and small-scale rooftop water harvesting), which improves water users' ability to trap precipitation and distribute it evenly across the drier months to sustain water supply. Looking at water resources from a demand-side perspective as opposed to a supply-side perspective is an effort that may ultimately unfold across several generations, but universities, think-tanks, and other NGO actors can begin to lay the foundation for this shift by supplying new research initiatives and building the region's knowledge base.

› **Explore the potential for newly established protected wildlife reserves to stimulate the local ecotourism industry on both sides of the border.** Cooperative efforts between Indian and Pakistani ecotourism operators could help jumpstart an already rapidly expanding industry, while also raising the public profile of environmental preservation efforts. The Indus and its tributaries support a wide range of habitats, flora, and fauna, all of which have faced progressive degradation over recent decades due to population growth, water diversions, and industrial and agricultural pollution.

To improve the basin's ecological health and spur development of a new set of ecotourism-based livelihoods, state/province or federal agencies in either Pakistan or India might consider environmental restoration efforts in targeted sections of their portion of the basin. Strengthening wetland protections or conducting afforestation campaigns, for example, could boost resiliency against flooding by restoring natural flood barriers and flood plains, while the establishment of new nature reserves dedicated to ecosystem restoration could provide new revenue streams for local entrepreneurs in the ecotourism sector. Whether ad hoc or institutionalized, cross-border exchange between ecotourism operators would represent a confidence-building measure in and of itself, by developing person-to-person connections at the civil society level.

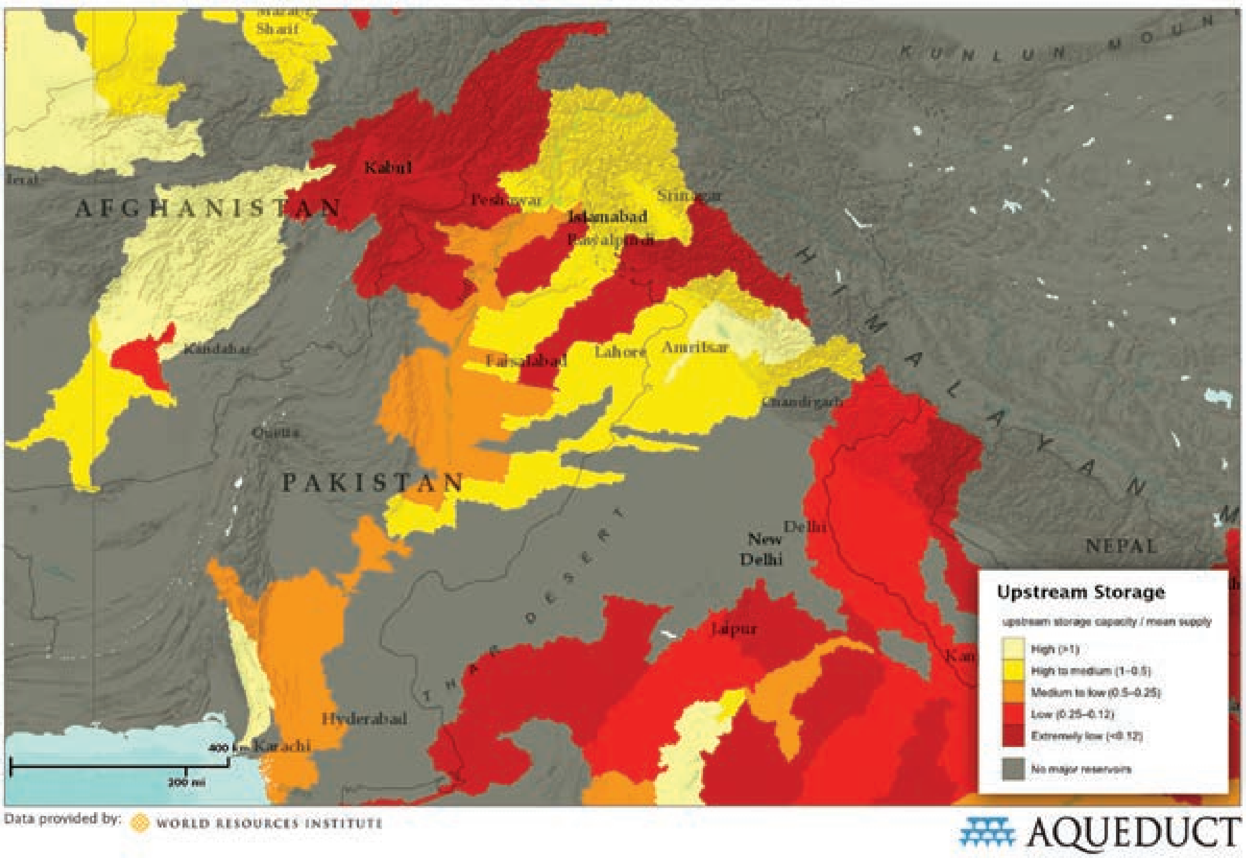
POLICY AND RESEARCH RECOMMENDATIONS:
CLIMATE CHANGE AND ENVIRONMENTAL PRESSURES

Impacts of a changing climate are increasingly evident throughout the Indus Basin. From rising temperatures and accelerating melt rates in the glaciated upper reaches of the basin to intensified cycles of drought and flooding at lower elevations, shifts in the typical rhythms of water delivery into the basin are fundamentally reshaping the basin's hydrology. These changes have major implications for the region's environmental, economic, and human security, with serious implications for the quality of life of the roughly 300 million people that the Indus Basin supports. Population growth rates are soaring throughout the basin and economic and agricultural expansion and increasing urbanization are placing elevated pressure on available water supplies. India and Pakistan cannot disentangle themselves from one another, and climate change poses a shared and urgent threat to the viability of key agricultural breadbaskets in the Indus Basin, particularly in Sindh province and Punjab province in Pakistan, and Punjab state in India.

One of the most pronounced aspects of climate change across South Asia has been variation in the timing and intensity of monsoon rains, which has significantly impacted agricultural production and weakened food security, often driving tensions between the two countries over water access during the dry periods between rainy seasons. Indeed, leading Indian meteorologists announced at a February 2012 meeting in Pune, Maharashtra state, that monsoon precipitation across the country had fallen 4.5 percent between 1979 and 2009.[76] The health and sustainability of basin water supplies has been further eroded by a variety of human-induced causes including: agricultural and industrial pollution of surface water courses and groundwater stocks; large-scale water withdrawals for irrigation that often leave rivers without the minimal environmental flow volumes needed to provide continuous ecological services; cascades of hydroelectric dams that collectively block sediment flows, degrade freshwater fisheries, and erode rivers' ecological health; and the commercial development and residential settlement of vulnerable low-lying flood plains that place human populations at risk and decrease rivers' natural ability to absorb heightened flows during periods of heavy precipitation.

There is growing consensus within the region that these environmental pressures are contributing to increased strain on basin water supplies. In India's portion of the Indus Basin, per capita water availability is projected to drop by nearly 50 percent during the first half of the 21st century, falling from 2,109 m^3 in 2000 to 1,132 m^3 in 2050; in Pakistan's portion of the basin, per capita water availability is expected to drop from 1,332 m^3 in 2000 to 545 m^3 in 2050.[77] Public awareness of these critical water security issues must be heightened in order to better understand and cope with these challenges, and address popular perceptions within certain segments of Pakistani society that India is diverting more than its fair share of water from its

Figure 9. Upstream Storage Capacity in the Indus River Basin



portion of the Indus Basin. Although a contentious political relationship has prevented a meaningful and progressive dialogue on the shared risk that both countries face from climate change and human-induced environmental pressures, it is in the enlightened self-interest of both India and Pakistan to jointly respond to these issues in the decades ahead.

The basin's hydrology pays no attention to national boundaries. Given that the causes and effects of mounting environmental pressures are interrelated and transcend specific sectors of society and industry, policy makers within India and Pakistan must recognize that only a collaborative, holistic approach to responding to these challenges will bolster the resiliency of the basin's human, environmental, and economic security. The absence of increased cooperation will simply lead to the continuation of the status quo of water management within the basin, a situation that is marked by highly inefficient usage of available water supplies on both sides of the border, and little to no communication between water managers in the two countries. This situation is becoming more untenable with each passing year in the face of growing population and soaring water demand. In short, the status quo is no longer an option.

Even in light of ongoing bilateral political tensions, several pathways exist for interested parties at the government and civil-society levels to engage with one another to deepen the knowledge base on emerging climate change impacts and environmental pressures, and develop reformed water management policies at the national and basin-wide level that can bolster economic productivity within the basin while institutionalizing greater safeguards for the ecological health of the Indus and its tributaries.

To develop a comprehensive knowledge base on emerging climate change impacts and mounting environmental pressures on the basin's hydrological health, and create a cooperative framework for safeguarding the region's ecological health, the Working Group puts forth the following recommendations:

› **Conduct a joint research study evaluating the cumulative environmental impact of multiple dams on a single waterway and develop the knowledge base on the relationships between dam cascades, river basin hydrology, and climate change.** Dam construction across the Indus Basin over the past 50 years has resulted in fundamental transformations to the hydrology of the Indus and its tributaries. While new hydroelectric infrastructure is subject to environmental impact assessment, contemporary and past environmental assessments of hydroelectric infrastructure conducted by the Indian government, Pakistani government, or third parties such as the World Bank or Asian Development Bank, have typically focused on the potential downstream environmental impacts of a single dam project. Rarely have these assessments taken a broader, more holistic approach that analyzes the potential cumulative environmental impact of multiple dam construction on the same river and taken into account the wide sweep of human security impacts that dam cascades entail, and no studies to date have thoroughly evaluated the subject. Given that the net impact of a cascade of dams upon a river's ecological health is far more intensive than the impact of a single dam, the subject deserves greater attention from policy makers, water managers, and energy developers in the Indus Basin.

  A joint or coordinated study between Indian and Pakistani universities, NGOs, or scientific bodies might assess the pressures that dam cascades on the Eastern Rivers impose upon the local environment, and highlight the relationship between dam-related ecological degradation, food security, livelihoods, and economic productivity. Such collaboration could establish a mutual methodology for environmental impact assessments and create data sets documenting the impact of dam cascades on: sediment flows and distribution through the Indus Basin; soil fertility in agricultural areas adjacent to rivers; biodiversity conservation; natural flood barriers and wetland preservation; and water quality and water flow volume. Nurturing a cross-border dialogue between civil society actors on this subject will help develop a knowledge base that can eventually provide policy makers and water managers with a better platform to assess the various environmental, economic, and human security impacts that multiple-dam construction has upon the basin. These holistic environmental assessments may then enter into the policy-making dialogue, potentially influencing the design of new hydroelectric infrastructure and informing policy-making decisions regarding dam operation to ensure sufficient water levels within the Indus and its tributaries to maintain minimum environmental flows. Establishing a mutually agreed upon baseline level for minimum flow volume in dammed rivers would need to take into account the shifting volume requirements of the dry and wet seasons, but would ultimately help water managers ensure the continuous delivery of waterways' ecological services.

  A subsidiary area for joint research inquiry on the subject might encompass the cumulative impact of multiple hydroelectric projects on freshwater fisheries. Across the Indus Basin, freshwater fisheries constitute a small yet important part of diets and local livelihoods. Heavy development of the basin threatens or destroys spawning grounds and migration routes, endangering fish populations and reducing their role in local economies and diets. Dams' impact on fisheries remains understudied, and represents a common starting point for Indian and Pakistani hydrologists and wildlife management officials to deepen research ties and build knowledge on the subject.

› **Increase the knowledge base on monsoon variability trends to improve outcomes for rainfall-dependent agriculture.** Despite the extensive irrigation network spanning Indian and Pakistani Punjab, a significant portion of arable land in the basin — particularly in Pakistan — is partially or wholly dependent on direct rainfall for irrigation. With climate change driving erratic delivery of monsoon rains, food security and livelihoods in these sections of the basin are jeopardized, particularly among smaller-scale farmers whose land is not linked to broader irrigation networks. Joint research studies might be executed by relevant government agencies, universities, or civil society actors within India and Pakistan to analyze the nature of evolving monsoon trends using available data. Researchers also can draw upon hydrological and meteorological data supplied by third-party scientific agencies such as the NOAA (US) and ICIMOD (Nepal) to deepen understanding of current and projected future precipitation changes, and analyze how such shifts will impact the hydrological health of the Indus and its tributaries. Based on of this data, a range of models illustrating water availability scenarios for rainfall-dependent agriculture can be developed for use within the policy-making community.

A secondary focus of a research initiative on evolving monsoon trends might evaluate the potential human security impacts of precipitation variability, particularly as it pertains to disaster preparedness. Anticipated changes in snowfall include reduced snow and increased winter rain at elevations close to the present winter snowline, with increased snowfall during extreme precipitation events at higher elevations. For populations inhabiting high-altitude regions of the basin, increased frequency of high precipitation events such as cloud bursts can trigger flash flooding and avalanches, which in turn damage or destroy communication and transportation infrastructure.

› **Use multimedia tools to raise public awareness of climate change within India and Pakistan.** Despite mounting evidence that climate change is contributing to water supply issues within the Indus Basin, the causes behind shifting patterns of water availability remain poorly understood within civil society. In addition to lack of awareness, a principal driver of misperceptions is inaccurate media coverage of water-related issues, with scientifically inaccurate and often purposefully inflammatory reporting fueling political tensions between the two countries. One approach to combat such media inaccuracies — and to raise awareness and foster informed public discussion about environmental pressures in the region — would be the creation of a high-impact documentary on climate change in the Indus Basin, produced in the vein of "An Inconvenient Truth," the award-winning 2006 climate change documentary.

Funding such a film project represents one of the principal challenges, although financial backing could be secured from foundations and the private sector, both inside and outside of South Asia. The key toward ensuring maximum public impact for such a documentary would be the presence of prominent Indian and Pakistani scientific and environmental experts on screen — side by side — discussing the shared threat both countries face from climate change, and making clear the likely results for South Asian security if inaction on the issue persists. In addition to crafting a visually arresting case for climate change's impact on food production and water availability, a film would allow for the creation of a narrative on climate change that features informed commentary, which could be used to bolster civil society awareness on key issues including glacial melt trends and monsoon variations. Experts and well-known authoritative figures featured in the film could emphasize the mutual economic and political benefits of taking joint action on climate change adaption and mitigation, highlighting that it is in the self-interest of both countries to collaborate on such measures instead of remaining mired in a cycle of perpetual conflict over shared water resources. Commenters from both countries could also present scientific evidence illustrating that declining river flows, intensified droughts, and changing rainfall patterns are natural phenomena symptomatic of climate change, and not evidence that evidence that upstream users are unfairly withholding water from downstream consumers.

Flood damage in Sindh Province, Pakistan, October 2010.
Source: United States Marine Corps via Flickr

Without heightened public understanding, there can be no political will at the state/province and federal government levels to implement appropriate policy interventions dealing with climate change. However, using the documentary medium to directly correct misperceptions on water supply variability and educate media consumers on climate change issues would ensure the message is not inappropriately filtered or altered via government channels or biased media coverage. From a practical standpoint, given the growing prevalence of Internet and satellite-television access across the basin, a documentary could reach its target audiences relatively easily, and be rebroadcast indefinitely across traditional media channels as well as social media. Media outlets including the British Broadcasting Corporation, *National Geographic*, and the Discovery Channel have a track record of developing original, high-quality educational programming on climate change issues and environmental trends, and might be enlisted to participate in the production of the film. The ultimate goal of the project is to help reshape public perceptions of climate change and drive home the message that there must be political will on both sides to jointly address the issue of long-term sustainable water resource management, emphasizing that cooperation on the issue is now a matter of survival for both countries.

› **Develop a digitized online model of the Indus Basin to foster regional network building and deepen hydrological modeling capacities.** Short of direct and sustained government-to-government collaboration at the state/province and federal levels, continuing to deepen and institutionalize relationships between Indian and Pakistani NGOs, universities, and other relevant civil society actors will prove critical in creating an atmosphere conducive to bilateral cooperation on climate change issues. While travel restrictions and visa issues can and often do prohibit direct meetings between these parties, the growing prevalence of high-speed Internet connectivity allows for greater interaction between

Flood relief efforts in Mingora, Khyber-Pakhtunkhwa, Pakistan in August 2010.
Source: Giro555 via Flickr

hydrological experts and environmental generalists on both sides of the border via virtual exchange to boost the role of science diplomacy in encouraging joint responses to shifting water availability.

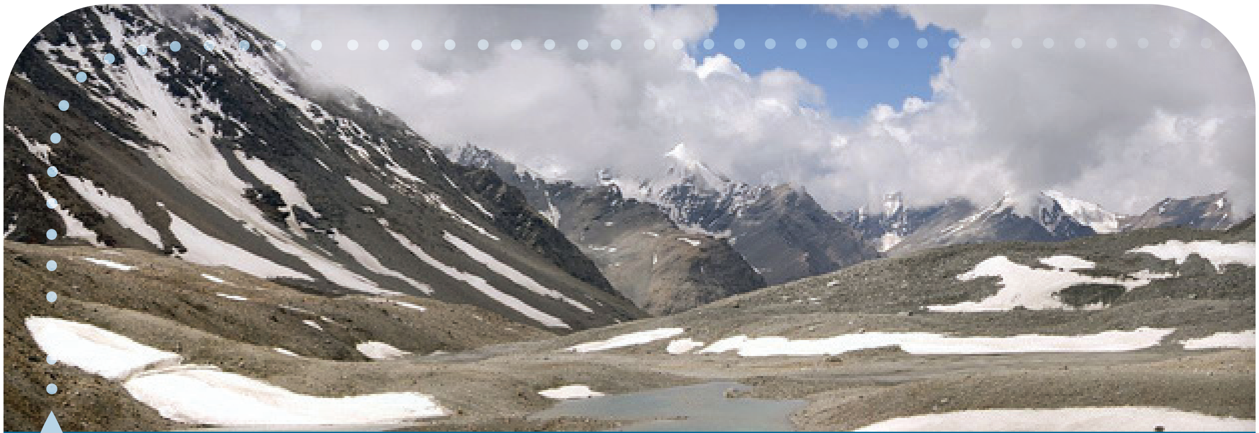
One pathway toward greater joint analysis of potential climate change impacts on water availability in the Indus and its tributaries would be the development of a digitized, Internet-based model of the basin that utilizes geographic information systems (GIS) data to allow online users to run various hydrological modeling simulations. In recent years, such models have already been developed in other river basins, such as the Yellow River in China, which can provide a useful template for creating an Indus-specific modeling platform. Developing a GIS-based version of the basin would allow scientists, hydrologists, and water managers in both countries to accurately model water flow levels; develop new theoretical scenarios for water availability that incorporate shifting precipitation patterns; and easily share data and models with one another. Further, once the modeling platform has been designed and established online, it can be operated at minimal cost, while providing significant informational benefits to water researchers and other water stakeholders in both countries.[78]

› **Explore pathways for improved data sharing on precipitation trends and meteorological forecasting to better infuse scientific data into the water policy-making process.** Both countries should seek to institutionalize a heightened degree of hydrological data-sharing, with the aim of enhancing policy makers' ability to anticipate future changes in water supply and design appropriate interventions. To advance this exchange of data, parties in both India and Pakistan should jointly categorize the best existing sources — both inside and outside the South Asia region — of satellite photography and remote-sensing data documenting current and projected future environmental and meteorological changes in the Indus Basin. Priority information repositories will include those populated with data on short-term and long-term shifts in the timing, duration, and intensity of monsoon precipitation, as well as those documenting past (or anticipating future) glacial- and snowpack melt trends in the two countries' Himalayan headwater regions. Once the information landscape of existing hydrological data in the Indus Basin has been mapped, a joint research project could outline a sequence of concrete measures needed to move this information out of existing online databases and into the hands of Indian and Pakistani water planners, taking into account the realities and nuances of the water policy-making sectors in each country.

Another venue for enhanced bilateral cooperation on climate change research is the Coordinated Regional Downscaling Experiment (CORDEX) program. CORDEX, sponsored by the World Climate Research Program, has a dedicated South Asia program that helps generate multi-model simulations and assessments of regional climate change. These research outputs, which are subsequently archived online, are meant to help develop the capacity of India, Pakistan, and neighboring countries to understand and effectively address climate shifts. Between 2013 and 2015, CORDEX is planning a series of science-oriented workshops across South and Southeast Asia to further bolster the region's knowledge base on emerging climate change trends.

› **Conduct joint research to better understand the role agricultural and industrial pollution play in limiting water availability, shaping public health outcomes, and weakening rivers' ability to deliver ecological services.** Improper disposal and insufficient treatment of industrial and agricultural wastewater, coupled with depleted flow volumes, has a major impact on water availability in the Indus and its tributaries, with downstream water users most seriously impacted. Rampant pollution of waterways also erodes biodiversity, threatening fresh water fisheries, and the flora and fauna that drive the economically lucrative ecotourism sector.

A potential joint study on water pollution throughout the basin might examine: best practices for low-tech, low-cost wastewater treatment interventions; the extent to which untreated wastewater impacts agricultural water availability; the interplay between surface pollutants and groundwater contamination; the passage of pollutants throughout the basin system, so as to monitor how hydroelectric infrastructure impacts their movement; and the extent to which pesticide and fertilizer run-off enters municipal and rural drinking water supplies. Developing the region's knowledge base on these issues will help inform more sustainable policies on wastewater treatment and disposal, and allow government officials to better gauge the potential public health threat that contaminated water supplies pose. In executing such research initiatives, particular attention should be paid to pollution of waterways during the dry season, when contaminants' environmental impact is exacerbated due to low flow volumes.



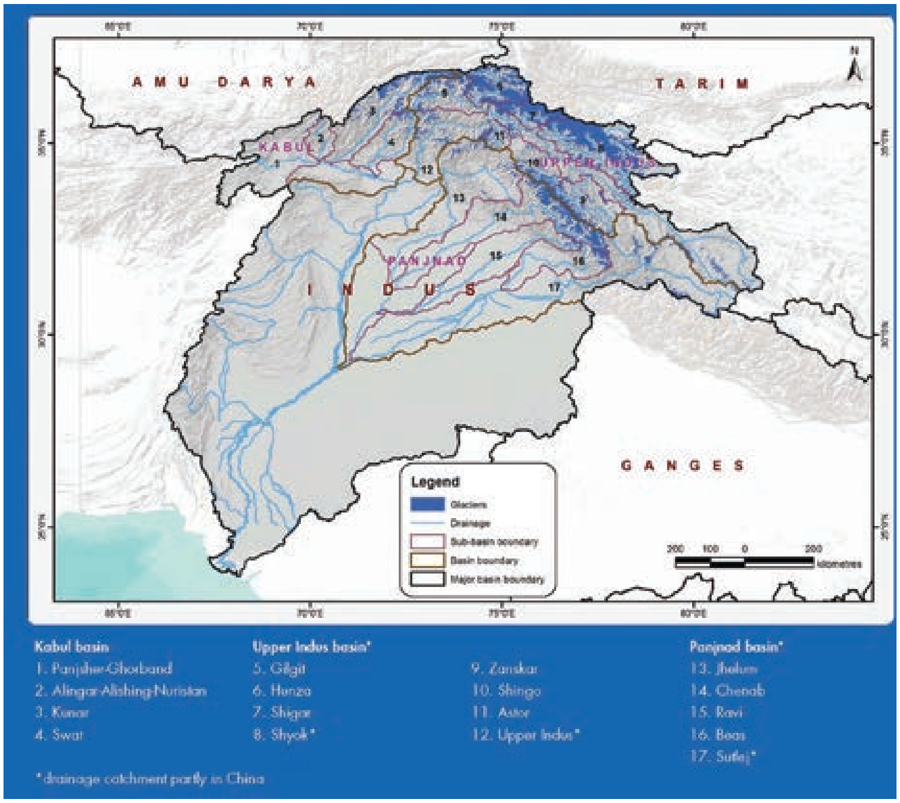
POLICY AND RESEARCH RECOMMENDATIONS:
GLACIOLOGY

Glaciers of the Hindu Kush Himalayan (HKH) region affect the hydrological regimes of 10 of the largest river systems in Asia. These glaciers help regulate water flows, control the regional and global climate systems on several time and spatial scales, and help sustain the livelihood of more than 1.3 billion people. The Indus Basin is uniquely dependent on these glaciers — snowpack- and glacial melt account for more than 50 percent of the Indus' annual average flow volume, and melt waters constitute roughly the same portion of flow volume for the river's primary tributaries. The arrival of snowpack- and glacial melt waters is particularly vital to downstream water users during the spring and fall shoulder months that come before or after the westerly monsoons, when these waters account for a significant portion of the base flow volume of the Indus and its tributaries.[79]

Within the Indus Basin portion of the HKH, roughly 3.8 percent of the land is glaciated, covering approximately 21,200 km^2. The vast majority of the 18,495 glaciers in the Indus Basin remain unstudied or understudied. These glaciers collectively hold estimated ice reserves of 2,696 km^3, more than twice the reserves of the next most heavily glaciated river basin, the Yarlung Tsangpo/Brahmaputra.[80] Indus Basin glaciers are understudied in part due to the rough physical topography of the region — much of the glaciated Upper Indus Basin sits 5,000 meters or more above sea level, making glacial monitoring difficult due to the region's inaccessibility. The other primary reason these critical water reserves are understudied is the lack of technical capacity and funding to execute such efforts. Without better data on glacial and snowpack melt trends, policy makers in downstream portions of the Indus Basin are left unequipped to understand the important climate change–driven hydrological changes now taking place in the glaciated regions, and are subsequently unable to design and implement effective measures for coping with the attendant future changes on downstream water availability.

Given the key role of glacial and snowpack melt in the Indus Basin, it is crucial to bolster India and Pakistan's knowledge base on HKH glaciology. Improved understanding of change dynamics in glaciated regions has significant implications for weather forecasting, managing river flows, irrigation, livelihoods, biodiversity conservation, and power generation in downstream portions of the basin. Glaciers are very sensitive to meteorological conditions; study of their mass balance and dynamics yields important data on climate change impacts, such as shifting precipitation patterns and warming temperatures in high-altitude regions. Increased study of the glaciated reaches of the upper Indus Basin would also provide more comprehensive information on the accumulation of black carbon aerosols on glacial surfaces, a byproduct of industrial activity that accelerates melt rates and may influence the timing and volume of water delivery to downstream populations in the long term.

Figure 10. Distribution of Glaciers in the Indus River Basin



Source: Bajracharya, SR (2012) Status of glaciers in the Indus Basin. Kathmandu: ICIMOD

Various studies have confirmed that the glaciers of the northwestern Himalaya were largely in a state of retreat during the 20th century, with glacial recession rates appearing to have accelerated between 1970 and 2000. Changing snow accumulation and ablation patterns, coupled with ongoing glacial melt trends, may have a significant effect on the hydrology of the Indus. Discharges of water from the glaciated Indus headwater regions are likely to increase in near future as a result of enhanced melting, but on a longer time scale, these discharges are likely to decrease as glaciers' contribution to the waters of the Indus Basin gradually lessens over time. The extent of glacial melt has not been uniform, however. The larger glaciers appear to have receded at a comparatively slower rate than smaller length glaciers, and there are certain transverse or tributary glaciers (also known as 'surging glaciers') in the Karakoram Himalaya showing abnormal rates of advancement. Nevertheless, glaciers in the Indus Basin are generally considered to be in a state of retreat, with variations in glacier length appearing to be influenced by increasing average air temperatures during the 20th century and into the 21st century. Between 1906 and 2005, average air temperatures across the region increased by 0.74°C, with more than half of the increase — 0.44°C — occurring between 1980 and 2005. Temperatures are almost certain to continue increasing in the short term, with an anticipated further increase of 4°C over current average temperatures by 2050.[81]

To deepen knowledge of glacial melt trends and better understand their implications for water stakeholders in the Indus Basin, the Working Group puts forth the following recommendations:

Figure 11. Characteristics of Glaciers in the Indus River Basin

Basin	Sub-basin	Number of glaciers	Glacier area (km²)	Estimated ice reserves (km³)	Highest elevation (m a.s.l.)	Lowest elevation (m a.s.l.)	Largest glacier area (km²)
Kabul	Panjsher-Ghorband	88	14.6	0.4	5,242	3,857	2.5
	Alingar-Alishing-Nuristan	37	5.8	0.2	5,284	4,162	1.5
	Kunar	1,149	1,573.9	176.8	7,578	3,114	189.5
	Swat	327	127.4	5.3	5,580	3,772	4.9
	Total	**1,601**	**1,721.7**	**182.7**	**7,578**	**3,114**	**189.5**
Upper Indus	Gilgit	968	938.3	71.3	7,730	2,703	61.8
	Hunza	1,384	2,753.9	310.6	7,749	2,409	345.7
	Shigar	439	2,374.1	601.9	8,566	2,774	631.5
	Shyok	3,357	5,937.7	981.7	7,803	3,231	925.9
	Zanskar	1,197	975.5	82.1	6,368	3,997	62.6
	Shingo	882	612.7	42.9	7,027	3,656	46.3
	Astor	372	239.6	16.9	8,032	2,991	31.0
	Upper Indus	2,814	1,230.0	66.1	7,820	2,760	51.9
	Total	**11,413**	**15,061.7**	**2,173.5**	**8,566**	**2,409**	**925.9**
Panjnad	Jhelum	733	222.8	9.0	6,285	3,404	6.8
	Chenab	2,039	2,341.2	210.7	7,103	3,001	109.3
	Ravi	217	113.6	5.5	5,824	3,276	9.2
	Beas	384	416.6	31.8	6,196	3,079	29.0
	Sutlej	2,108	1,315.0	82.9	6,652	3,606	49.6
	Total	**5,481**	**4,409.2**	**339.9**	**7,103**	**3,001**	**109.3**
	Total	**18,495**	**21,192.6**	**2,696.1**	**8,566**	**2,409**	**925.9**

Source: Bajracharya, SR (2012) Status of glaciers in the Indus Basin. Kathmandu: ICIMOD
Credit: ICIMOD/Samjwal Ratna Bajracharya

› **Enlist third-party scientific agencies with satellite-based remote-sensing capacity to disseminate non-politicized, reliable, and timely hydrological data documenting glacial melt trends to water policy makers and the general public in both countries to enhance transparency.** Outlining a consortium of multilateral and nongovernmental bodies with the technological capability to gather (and a willingness to distribute) accurate information on glacial- and snowmelt trends in the Indus Basin represents a first step toward heightening transparency between the two countries vis-à-vis transboundary water resource management. Equipping Indian and Pakistani policy makers with scientific data supplied by neutral third parties — such as the Nepal-based International Centre for Integrated Mountain Development (ICIMOD), the European Space Agency (ESA), or the US National Oceanic and

Atmospheric Administration (NOAA) and US National Aeronautics and Space Administration (NASA) — would establish a baseline for both countries to analyze hydrological changes in the upper Indus Basin and better understand and prepare for evolving climate change impacts in the region. Building the knowledge base of each country via third-party data dissemination will also mitigate suspicions concerning the source and accuracy of the data.

In terms of starting points for such collaboration, ICIMOD — which receives funding from both the Indian and Pakistani governments — has conducted a thorough remote-sensing analysis of the Indus Basin's glaciers in recent years, based on geo-spatial data points including slope, hypsometry, debris cover, elevation range, and latitude/longitude, among others. Similar work has been undertaken by the World Glacier Monitoring Service (WGMS), a multilateral organization that counts both India and Pakistan among its 30+ country membership. Streamlining Indian and Pakistani policy makers' access to state-of-the-art data from such organizations would provide both countries with the information needed to monitor glaciated areas of the upper Indus Basin, and proactively plan for the looming water supply challenges that shrinking glaciers and snowpack present.

› **Devise joint research projects to increase understanding of emerging climate impacts in the Upper Indus Basin.** While India and Pakistan's political relationship warms and cools in cycles, collaboration on science-based research initiatives at the university- or civil-society level has the potential to withstand these shifts. Scientific diplomacy in the form of joint glaciology research projects can serve as a foundation for broader bilateral confidence-building, particularly among academic institutions and civil society groups, by allowing these parties to better understand and appreciate the water supply challenges faced by their neighbor.

  Projects coordinated between NGO organizations in each country, or between other elements of civil society, could help identify common ground between the two countries based on the shared threat that increased glacial and snowpack melt rates poses to water users in both countries. Initiatives analyzing the anticipated short-term and long-term water supply challenges that climate change will impose on the basin could also draw lessons learned from issues faced in contentious transboundary river basins reliant on glacial and snowpack melt waters, such as the Amu Darya and the Yarlung Tsangpo/Brahmaputra. Research projects could alternatively identify best practices implemented by policy makers in climate change–impacted river basins in other parts of the world, with an emphasis on highlighting policy interventions that bolster resiliency to water supply disruptions, such as enhanced water storage.

› **Improve mutual disaster preparedness regarding the threat posed by glacial lake outburst flooding.** Melting glaciers and snowpack significantly increase the risk of catastrophic flooding in the form of GLOFs, which can be found in the Shyok, Indus, and Yarkhand valleys, among others. These unstable lakes in high-altitude regions can breach their banks with little warning, sending powerful torrents of mud and water downstream that sweep away people and homes, and destroy power and transportation infrastructure. While difficult to predict, the GLOF risk faced by populations in both countries can be mitigated through increased cross-border sharing of data on seismic activity, heavy precipitation events, and the location of potential GLOFs, as well as the development and deployment of early warning systems. Improved monitoring of GLOFs is particularly important as glaciers shrink because remnantal, terminal, and lateral moraines exposed due to glacier recession have led to increased incidences of rock fall, as well as the formation of unstable moraine-dammed lakes in some locations. Enhanced coordination between India and Pakistan in addressing the mutual GLOF threat represents a relatively attainable means of bolstering disaster preparedness in the basin, and offers a strategic opening for

Melting ice in the Indus River, Gilgit-Baltistan, Pakistan.
Source: meemainseen via Flickr

institutionalizing a modest exchange of hydrological information between disaster management agencies at the federal and state/province level in each country.

› **Invest in the educational infrastructure needed to train the next generation of Indian and Pakistani glaciologists.** To date, India possesses a more robust academic and professional institutional infrastructure to support the study of glaciology than Pakistan. This imbalance can begin to be corrected through a heightened emphasis within Pakistan's institutes of higher learning on glaciology in particular, and earth sciences more broadly. Developing specialized curriculum specifically geared toward training glaciologists at the undergraduate and graduate levels would help Pakistan achieve parity with India vis-à-vis glaciology-related academic infrastructure. Such academic programs must secure funding to be sustainable, and young scientists choosing to specialize in glaciology must be reassured that there will be jobs available in research and policy-making circles once they have completed their studies. Nevertheless, bolstering the long-term capacity for each country to provide specialized academic training and heightening the profile of glaciology studies will prove critical in training a new cadre of young Indian and Pakistani science professionals, equipping them with the skills needed to build domestic capacity within their home countries for understanding and addressing the implications of glacial melt trends.

› **Heighten cross-border sharing of best practices and technical resources for on-the-ground glacier monitoring.** Building India and Pakistan's knowledge base on glacial and snowpack melt trends and heightening each country's technical capacity to document such changes from the ground will be crucial during the coming decades. Ground-based measuring equipment — although vulnerable to periodic flash flooding — helps fill in important gaps of data generated via satellite photography or remote-sensing. When combined, ground-based data and aerial imagery provide a more holistic and complete picture of the status of glaciers and snowpack. To date, India also has installed more glacier monitoring stations in its portion of the basin than Pakistan. To rectify this imbalance and help Pakistan achieve a similar capacity, Indian glaciologists could share best practices with their Pakistani counterparts for installing such stations.

The development of joint glacier-monitoring stations in glaciated border regions would also help in this regard, by not only providing water policy makers in both countries with accurate data on melt rates, but also more broadly serving as a means to enhance hydrological information sharing in the basin. Development and installation of a single glacier monitoring station costs roughly USD$100,000, a figure which does not include maintenance costs. Funding such infrastructure represents a principal challenge, but costs could potentially be mitigated through third-party financial assistance. Short of installing joint monitoring stations or having a direct exchange of glaciologists traveling between the two countries, progress could still be made in the form of Indian and Pakistani glaciologists communicating via online channels to either discuss the technology needed to measure glacial movements from ground-based monitoring stations, or devising and executing coordinated research projects on climate change impacts in the two countries' portions of the glaciated Upper Indus Basin.

POLICY AND RESEARCH RECOMMENDATIONS:
INSTITUTIONS, GOVERNANCE, AND DIPLOMACY

The international boundary that set India and Pakistan apart at independence also set the two nations at odds over water. The 1947 line of Partition divided the Indus Basin, cutting across long-established irrigations systems, and separating downstream Pakistan from the sources of the water supplies on which it had relied for centuries, which now ran first through Indian territory. Following several years of negotiations brokered by the World Bank, Pakistan and India signed the 1960 Indus Waters Treaty (IWT).[82] Under the provisions of the IWT, Pakistan receives unrestricted use of the waters of the three Western Rivers: the Jhelum, the Chenab, and the Indus itself. India must let these waters flow unhindered, except for restricted uses and defined amounts related to domestic and agricultural uses and for limited hydropower generation. The IWT allots to India the waters of the three Eastern Rivers: the Sutlej, Beas, and Ravi. Pakistan must refrain from impeding the flow of any tributaries of the Ravi and the Sutlej that traverse its territory before the tributaries join these rivers in India. When the Eastern Rivers ultimately enter Pakistan, they become available for Pakistan's unrestricted use.

To oversee the accord, the IWT also established institutional arrangements, creating the Permanent Indus Commission composed of one Commissioner from each country. The Treaty provides for the two Commissioners to meet annually and for periodic exchanges of visits to ensure cooperative implementation of the Parties' obligations and to resolve differences that may arise. (If the Commissioners cannot reach agreement, the matter may be referred first to the two governments, then to a Neutral Expert, and finally to a Court of Arbitration.) Importantly, the IWT also mandates the regular exchange of data on river flows and water utilization, and calls upon each country to inform the other if it undertakes engineering works on the tributaries that could affect the other party and to provide any requested data. Further, Article VII of the agreement records the Parties' declared intention to potentially undertake future cooperation to install hydrological and meteorological observation stations, carry out drainage works, and collaborate on engineering works.

Since 1960, the IWT has stood through the 1965, 1971, and 1991 wars between the two countries and survived numerous lesser clashes. Yet marked dissatisfaction with the IWT exists in both India and Pakistan. A significant body of opinion in India regards persistent Pakistani objections to planned Indian infrastructure projects on the Western Rivers as unfairly stalling India's legitimate development programs. Many in Pakistan, in turn, fear that — though individual Indian proposals may abide by the technical letter of the IWT — erecting multiple structures on the rivers may generate substantial cumulative impacts downstream. In the wake of continuing controversies, voices in both countries have suggested revisiting the IWT terms — or even scrapping the accord and starting over. Ultimately, some future mutually agreed alterations to the

IWT might improve the scope for effective international cooperation and integrated resource management across the basin. Presently, however, moves to renegotiate the IWT would almost certainly prove more contentious than current confidence levels between the parties could bear.

Nevertheless, despite its historical success at avoiding water conflicts between India and Pakistan, the current treaty alone provides little response to several emerging threats to the Indus Basin's water supplies. The accord has no provisions for how the parties should respond to variations in water flow that climate change could engender, for instance. Nor does it adequately address water quality — beyond hortatory declarations of intent to prevent pollution where practicable — though deteriorating quality increasingly cuts into available quantities as sources become too degraded for many uses. And while consumers across the basin rely on groundwater to supplement or substitute for surface water, there is no agreement for sharing supply or even sharing data on shared groundwater resources.

India and Pakistan must strive to ensure that the IWT institutions that govern their international water relations operate as effectively as possible. But decision makers and stakeholders at all levels across the basin must also work to strengthen other existing mechanisms and to forge new spaces for collaboration. Successful cross-border cooperation will require not only identifying the right issues for joint knowledge building and research, but also identifying the right actors and institutional arenas amenable to developing and enacting effective collaboration in specific issue areas.

To fully utilize and effectively empower the institutional arenas and governance mechanisms that shape water policy-making within and between India and Pakistan, the Working Group puts forth the following recommendations:

› **Explore potential means to strengthen the Article VI "Exchange of Data" and operationalize the Article VII "Future Cooperation" provisions of the IWT and consider options to enhance the advisory capacities of the Permanent Indus Commission.** Powerful new technologies, such as satellite-based remote sensing and GIS mapping that have been developed since the signing of the IWT in 1960, now enable increasingly comprehensive environmental monitoring and measuring capabilities coupled with possibilities for non-intrusive real-time data collection and exchange. Interpreted together, Articles VI and VII prospectively lay the foundations for joint monitoring stations and telemetry platforms, potentially integrated to form a collective Indus Basin Earth Observation system. Such a system could in turn supply data inputs, calibration, and validation for constructing joint hydrological and climate models and scenarios for the basin. On the ground, both India and Pakistan suffer from power shortages and insufficient water storage capacities that might be mutually addressed via agreed activation of Article VII provisions for cooperative engineering works. Joint water resources data and models for the basin could then inform common decisions about optimal siting, construction, and operation of such facilities for storage, hydropower, flood control, habitat maintenance, and environmental flows, as well as trade-offs between these objectives.

  The advisory capacities and dispute resolution capabilities of the Commission could be expanded by the addition of Assistant Commissioners or other professional staff so as to endow the Commission with supplementary breadth and depth of expertise. Drawing on the mediating role played by the World Bank in the original drafting of the IWT, the Commission could also be augmented with an independent office of neutral experts from outside South Asia charged to execute transboundary environmental assessments and promote sustainable development and cooperative water management under the IWT. Such an independent office could provide oversight or actively manage the initial establishment of joint monitoring and observation systems so as to defuse mistrust on data exchange.

- **Leverage technical expertise and capitalize on the structured forums for policy deliberation, data exchange, collaborative research, and sharing of best practices offered by regional organizations and associations such as the International Centre for Integrated Mountain Development (ICIMOD), the International Water Management Institute (IWMI), the South Asia Association for Regional Cooperation (SAARC), and the Global Water Partnership (GWP).** ICIMOD and IWMI operate as international knowledge hubs. ICIMOD conducts research on mountain climate, environment, and communities, while IWMI conducts research on water resources and management policies. Both generate and distribute data and knowledge resources through training, publications, and web-based portals. Both represent internationally recognized sources of scientific expertise on which Indian and Pakistani decision makers can draw for "neutral" information and analyses. Both additionally represent potential "third party" nodes for implementing data exchanges or cooperative research in settings possibly less susceptible to bilateral secrecy, suspicion, and mistrust.

  SAARC, an eight-member intergovernmental organization, offers another possible arena for defusing potentially acrimonious bilateral zero-sum dynamics by embedding consideration of regional, basin-wide water resource challenges in a multilateral setting. (Indeed, SAARC's charter precludes treatment of purely bilateral issues among the member states.) Although questions do surround the organization's real efficacy, SAARC has moved to adopt a Convention on Environmental Cooperation calling for regional policy collaboration and sharing of knowledge and policy experience. It has also established a number of joint research centers — including the SAARC Disaster Management Centre, a SAARC Meteorological Research Center, the South Asia Forum, and the new South Asian University — that could host or carry out collaborative projects linking Pakistani and Indian scientists and students. Beyond supporting such collective scientific efforts, with some investment of political energy, SAARC's ministerial meetings and gatherings of Heads of State could be made a high-level stage for exploring and enacting a degree of policy cooperation.

  GWP was founded in 1996 to foster integrated water resources management (IWRM), defined as the coordinated development and management of water, land, and related resources in order to maximize economic and social welfare without compromising the sustainability of vital environmental systems. Pakistan and India are both members of the NGO's South Asia Regional Water Partnerships. The Regional Partnerships especially function to promote water sharing across national boundaries and broad, inclusive stakeholder dialogue. NGOs such as GWP can furnish an alternative forum to official intergovernmental organizations in which to convene potentially different sets of stakeholders. However, at the same time, entities such as GWP — like ICIMOD or IWMI — can prove highly effective at designing solutions tailored to local conditions, and at identifying, collecting, and conveying good practices from one community to others across the network.

- **Recognize and promote possibilities for knowledge building and exchange — and for policy learning and collaboration — between India and Pakistan, and within India and Pakistan at the subnational state/province, city-to-city, local, and civil society levels.** Many of the sharpest tensions over shared water supplies in the Indus Basin occur at the subnational level, between neighboring states, provinces, and communities. In Pakistan, disputes over the disposition of Indus water resources particularly divide Punjab and Sindh, for example. In India, Punjab and Himachal Pradesh contest the resources of the Ravi. These internal frictions can render local communities all the more sensitive in the face of perceived cross-border threats to shared water supplies. Reducing this domestic strife could simultaneously contribute to alleviating international discord on the Indus.

Between India and Pakistan, cross-border water diplomacy has concentrated at the level of the nation state. But some neighboring jurisdictions in the basin have managed a modicum of local cooperation in other issue areas that might serve as a model for exploring subnational collaboration on the Indus. Cross-border bus service and trade has linked the two sides of Jammu and Kashmir. Pakistani and Indian Punjab have signed a memorandum of understanding to boost trade over the frontier, backed by local business communities who have also pushed the central governments to loosen the visa regime to facilitate economic ties.[83] City governments could also play a significant role paving the route to more international cooperation and exchange. Sharing many of the same water management challenges for providing municipal water and sanitation, city governments on both sides of the border are especially well placed to share best practices and policy lessons, backed by growing support networks for city-to-city initiatives.[84] For example, the multi-city association Local Governments for Sustainability (ICLEI) links hundreds of cities in 84 countries. ICLEI provides information, delivers training, organizes conferences, facilitates networking and city-to-city exchanges, carries out research and pilot projects, offers technical services, and provides software and tools to help local governments achieve their sustainable development goals regarding climate change, energy, infrastructure, and urban water supply. Over 40 Indian cities are members, although no Pakistani cities currently are.

In addition to such institutional networking opportunities, state/province and municipal governments could supply the structures for organizing joint parliamentary committees, staff studies, and site visits by the legislators whose constituencies are most at risk from water scarcity. City and state/province legislator groups could also constitute important focal points for establishing broad-based local, regional, and national cross-border civil society forums or networks of institutions and individuals from both India and Pakistan, drawing on their collective knowledge and policy assets to promote cooperative initiatives that can be tailored to specific communities and contexts, or adapted and replicated to scale at the regional or basin level.

Annex A:
Indus Basin Working Group Member Biographies

Arshad Abbasi

Advisor on Water and Renewable Energy, SDPI, Islamabad, Pakistan.

Arshad Abbasi is currently an advisor at the Sustainable Development Policy Institute, an organization which works to help public officials and stakeholders respond to the challenges posed by climate change.

Ghazanfar Ali

Head, Water Section, Global Change Impact Studies Center, Islamabad, Pakistan.

Ghazanfar Ali holds a Master's degree in Geography (Major in Snow & Ice Hydrology) from Wilfrid Laurier University, Canada and has more than 35 years of research experience with Water and Power Development Authority (WAPDA), Pakistan in the field of Snow and Ice Hydrology focusing on spatial and temporal variations in snow and ice accumulation and its melting pattern, glacier movement, and mass balance studies in the Upper Indus Basin, Northern Pakistan. Since 2006, he is associated with the Global Change Impact Studies Centre (GCISC) as Head Water Resources & Glaciology Section. His current research interests include assessment of climate change impacts on the dynamics of snow, glaciers, and runoff over the rivers of the Indus River System and their consequent implications for the water and food security of Pakistan. Such information will be used to assist national planners. Ghazanfar Ali is National Correspondent from Pakistan for the World Glacier Monitoring Services in Switzerland and has been a Member of the Glaciology Group Task Force on Climate Change, Planning Commission of Pakistan.

Dr. Mahendra Bhutiyani

Head, Hazard Assessment and Forecasting Division, Snow and Avalanche Study Establishment, Chandigarh, India.

Dr. Bhutiyani began his career as a lecturer at the Science College, Karad, and became Head of the Department of Geology in the College of Military Engineering, Pune, where he taught Engineering Geology and Remote Sensing for more than 18 years. Dr. Bhutiyani is a two-time awardee of the Engineer in Chief's Commendation Card for his work in the field of snow, avalanches, glaciers, and climate change in the Northwest Himalayas, and has published over 50 research papers on the subject. Dr. Bhutiyani has been regularly invited to deliver guest lectures at various institutions both in India and abroad, such as the Parliamentarians for Global Action, the Chief Ministers' Conclaves, and the Swiss Federal Institute of Technology. Dr. Bhutiyani has both graduate and post-graduate degrees in Geology and a doctorate in Environmental Science from the University of Pune.

Ambassador Salman Haidar

Former Indian Foreign Secretary.

Ambassador Haidar was Foreign Secretary of India from 1995-1997. Among his many other diplomatic positions he served as the Indian ambassador to the United Kingdom, China, and Bhutan, and as first secretary and deputy to the ambassador in Afghanistan. He also served as head of the Diplomatic Service, Secretary East, and spokesman for the Ministry of External Affairs and later chief of protocol. From

1977–1980, Ambassador Haidar was the minister/deputy permanent representative of India at the United Nations in New York. Since 2000, Ambassador Haidar has written a weekly column on political affairs for *The Statesman*. Ambassador Haidar received a Bachelor of Arts (with honors) in English from Delhi University and a Bachelor of Arts (with honors) in English from Cambridge University.

Syed Iqbal Hasnain

Consultant, Environmental Security Program, Stimson Center, Washington, DC, United States.

Mr. Hasnain serves as Chairman of the Glacier and Climate Change Commission established by the State Government of Sikkim. Mr. Hasnain is also a member of the United Nations Environment Programme Committee on Global Assessment of Black Carbon and Troposphere Ozone, and the International Mid-Term Review Committee. Between 2002-2006, Mr. Hasnain served as a vice-chancellor (President) of the University of Calicut, India. Previously, he held the post of Professor of Glaciology, Jawaharlal Nehru University, India. Mr. Hasnain has published a book as well as research papers in peer-reviewed journals, including the *Journal of Glaciology* and the *Journal of Hydrology*. Mr. Hasnain was awarded the Padma Shri in 2009 by the President of India for his contributions to advancing the science of glaciology in India.

Dr. Akmal Hussain

Distinguished Professor of Economics, Forman Christian College University, Lahore, Pakistan.

Dr. Hussain is a Professor of Economics at Forman Christian College University. He is also a member of the Governing Board of the South Asia Center for Policy Studies, and is a Senior Fellow of the Pakistan Institute of Development Economics. He has helped establish such organizations as the Pakistan Poverty Alleviation Fund and the Punjab Rural Support Program, both of which aim to overcome poverty in Pakistan. Dr. Hussain has authored three books on development policy, and has co-authored twenty-seven other books on poverty, peace, and development.

Muhammad Idrees

Director, Disaster Risk Management, National Disaster Management Authority, Islamabad, Pakistan.

Mr. Idrees has served as the NDMA's Director of Disaster Risk Management since 2010. Previously, he served as a diplomat in the Embassy of Pakistan in Hanoi, Vietnam between 2005 and 2009, where his work focused on political, economic, military, and cultural affairs. Mr. Idrees has also held the position of Deputy Director of Policy Planning at the Ministry of Foreign Affairs (Islamabad). He holds a Master's Degree in International Relations from the University of Peshawar.

Ambassador (Ret.) Shafqat Kakakhel

Shafqat Kakakhel is a retired Pakistani diplomat and former UN Assistant Secretary General/Deputy Executive Director, United Nations Environment Programme (UNEP). Shafqat Kakakhel's diplomatic assignments included postings in Pakistan missions in Lebanon, Egypt, Saudi Arabia, Germany, India (as deputy head of mission), and Nairobi (as High Commissioner to Kenya). During his tenure as No. 2 of UNEP (1998–2007) Shafqat Kakakhel was responsible for overseeing the preparation, negotiation, and implementation of the Programme's work program and budget, program management and coordination, guiding the work of UNEP's activities in the regions and outposts, consultations with Governments, UN agencies and NGO's, organizing global negotiations and meetings of UNEP's governing council, human resource development and resource mobilization. Since voluntary retirement from the UN, Shafqat Kakakhel has been serving on the Executive Board of the UNFCCC Clean Development Mechanisms. He has been a member of Pakistan's Task Force on Climate Change and is a member of the Advisory Group on climate change and sustainable development. He is a member of boards of directors of several think tanks and institutions including the Sustainable Development Policy Institute (SDPI) and the Mountain Glacier Protection Organization. He has been actively contributing to efforts for promoting cooperation in climate change and environmental issues between Pakistan and India and among south Asian countries. Mr. Kakakhel has been taking part in the annual conferences of parties of UNFCCC and Kyoto Protocol as a member of Pakistan's delegation.

Simi Kamal

Chairperson of Hisaar Foundation, Karachi, Pakistan.

Simi Kamal is the founder of several non-profit and for-profit organizations in Pakistan, including Hisaar Foundation, and of several initiatives and networks across South Asia. Her experience and expertise covers water, food, environment, women's rights and social development. She currently leads the Gender Equity Program of Aurat Foundation in Pakistan, supported by USAID. A geographer educated at Cambridge University, she is the author and co-author of about 430 research reports, consulting reports, papers, articles, book chapters and presentations, and has served on a number of commissions, boards, task forces, and committees in Pakistan and globally, including six years on the Technical Committee of the Global Water Partnership. She is also an associate of the Water for Food Institute, University of Nebraska.

Ambassador Aziz Khan

High Commissioner to India (2003-2006).

Ambassador Aziz Khan joined Pakistan's Foreign Service in 1969, serving in Buenos Aires, Brasilia, Maputo, Vienna and Lisbon. He was appointed Deputy Chief of Mission at New Delhi, Consul General of Los Angeles, and served as High Commissioner to Malaysia from 1995-1996; Ambassador to Afghanistan from 1996-2000; and as Additional Foreign Secretary from 2000-2002. Khan acted as Spokesperson of the Ministry of Foreign Affairs from 2001-2003. He was Director General of the Foreign Service Academy from 2002-2003. Most recently, Khan has acted as a consultant to the National Defense University in Islamabad from 2007-2008. Ambassador Khan is currently honorary Vice President of Jinnah Institute, an independent think tank.

Dr. Iqrar Ahmad Khan

Vice Chancellor, University of Agriculture in Faisalabad, *Pakistan.*

Dr. Khan is Professor of Horticulture at the University of Agriculture in Faisalabad, where he established the Center of Agricultural Biochemistry and Biotechnology. He also founded a USAID-funded Center for Advanced Studies and co-founded the International Center for Development and Decent Work funded by DAAD (Germany). Dr. Khan has established more than 20 international academic linkage programs that include ACIAR-funded linkages with Australian universities and academic programs sponsored by the US National Academy of Sciences. He has also worked with UNESCO's International Hydrological Programme. Dr. Khan received his PhD from the University of California, Riverside.

Professor Mahendra P. Lama

Founding Vice Chancellor of Central University of Sikkim, India.

Professor Lama is Vice Chancellor of Central University of Sikkim. Previously, he was Professor of South Asian Economies and also Chairman of the Center for South, Central, Southeast Asia and Southwest Pacific studies in the School of International Studies at the Jawaharlal Nehru University. From 2000-2007 he served as the Chief Economic Adviser to the Government of Sikkim in the Cabinet Minister rank, He has also served as a Member of the National Security Advisory Board of the Government of India. Prof. Lama has worked extensively on energy, water, trade, investment, and cooperation and integration issues in South Asia and has been presently nominated by the Government of India as a Member of the Steering Committee of the *South Asia Forum* established by the SAARC Summit in 2010.

Dr. Chandan Mahanta

Assistant Professor of Civil Engineering, Indian Institute of Technology, Guwahati, India.

Dr. Mahanta is an Assistant Professor in the Department of Civil Engineering at the Indian Institute of Technology. Dr. Mahanta's area of specialization is in Environmental Engineering and Engineering Geology. Some of his current projects include formulating a joint collaborative project with the Utah Water Research Laboratory on transboundary water management of the Brahmaputra River. His research interests include water quality, sediment dynamics in fluvial systems, environmental geo-informatics, and environmental impact, risk assessment and management.

Samir Mehta

Director of the South Asia Program at International Rivers, Mumbai, India.

Mr. Mehta works with regional partners to campaign against the construction of destructive dams in the Himalayas. He supports social movements and provides advocacy support to South Asian communities and NGOs. Prior to joining International Rivers in 2010, Mr. Mehta worked with the Bombay Environmental Action Group for over 17 years. He was appointed by the Bombay High Court to a Committee which assesses impacts of development on the tidal movement of a coastal river in Mumbai. He has served on several Federal and State appointed Committees. Mr. Mehta has a Bachelor Degree in Statistics from the University of Bombay, and has a Master's Degree in Public Administration from Harvard University.

David Michel

Director, Environmental Security Program, Stimson Center, Washington, DC, United States.

David Michel is a Senior Associate and Director of the Environmental Security Program at the Stimson Center. He has advised the US National Intelligence Council and the Departments of Defense, Energy, and State on environmental governance, water security, and climate policy issues. Prior to joining Stimson in 2008, Michel served as senior associate with the Center for Transatlantic Relations at The Johns Hopkins University School of Advanced International Studies. Michel holds a BA in Political Science from Yale University, a MA in Social Sciences at the École des Hautes Études en Sciences Sociales in Paris, and did his doctoral studies at The Johns Hopkins University's School of Advanced International Studies (SAIS).

Sonali Mittra

Junior Fellow, Observer Research Foundation, New Delhi, India.

Ms. Mittra is a Junior Fellow at the Observer Research Foundation (ORF). Her work is centered around transboundary water issues and management in South Asia. She has been a part of flagship water projects in ORF: Mekong-Ganga Dialogue (M-POWER), Waging Peace (Atlantic Council) and Inter-Ganga Initiative (Asia Foundation). She has recently co-edited a book: "*Perspectives on Water, Constructing Alternative Narratives*" (Academic Foundation). She has been writing editorial columns/commentaries in a weekly journal (Energy News Monitor) on issues of hydropower development and renewable energy in India. Ms. Mittra received her Bachelor of Science in Botany (with honors) from Delhi University, and Master's Degree in Environmental Impact Assessment and Management from University of Manchester, U.K. Currently, she is pursuing a post graduate course in Environmental Law and Management from Indian Law Institute, India.

Khalid Mohtadullah

Senior Advisor and Director, IWMI-Pakistan, Lahore, Pakistan.

Mr. Mohtadullah has over 45 years of experience in the field of civil engineering and water resource management. Currently, he is the Senior Advisor and Director of the International Water Management Institute's Pakistan Office. He also works as a senior consultant to the Global Water Partnership and the United Nations Development Programme. In the past, he has advised the Chinese government on water related issues, and was a member of Pakistan's Water and Power Development Authority. Mr. Mohtadullah received a Bachelor of Science in Civil Engineering from Peshawar University, a Master of Science in Civil Engineering from the Massachusetts Institute of Technology, and completed the Advanced Management Program at the Harvard Business School.

Lydia Powell

Head, Center for Resources Management, Observer Research Foundation, New Delhi, India.

Ms. Powell has been with the Observer Research Foundation (ORF) for over eight years, working on policy issues in energy and climate change. She has represented ORF at multiple conferences on India's energy policy and climate change, and has also authored a number of reports on these same topics. Ms. Powell was a Congressional Fellow with a three-month residency at the East-West Center in Washington, DC, and has worked in the private sector for Norsk Hydro ASA and Orkla, two of Norway's largest industrial enterprises. Powell has three post-graduate degrees; two from the Norwegian School of Management Oslo on Energy, and one on Solid State Physics from Cochin University of Science and Technology.

Shakeel Ramay

Senior Research Associate, Climate Change Study Center, SDPI, Islamabad, Pakistan.

Mr. Ramay is a Senior Research Associate at the Sustainable Development Policy Institute. His research has focused primarily on the environment, agricultural development, food security, and the impacts of climate change. Mr. Ramay is currently leading research studies on the environment in the Central Karakoram and the potential for renewable energy within Pakistan. He has been an Executive Board Member of the Climate Action Network South Asia, a member of the core team on climate change at the Ministry of Environment, and has been part of Pakistan's official delegation at the UNFCCC negotiations in Copenhagen and in Cancun. Having completed a Master of Science (with honors) from the University of Agriculture in Faisalabad, Mr. Ramay received his post-graduate degree in Agriculture Economics.

Ahmad Raza Sarwar

Director General, National Disaster Management Agency, Islamabad, Pakistan.

Mr. Sarwar is the Director of Recovery and Rehabilitation at the National Disaster Management Agency (NDMA). The NDMA is supported by the national government to take measures for the prevention of disaster, the mitigation, and the preparedness and capacity building for dealing with disaster situations. Prior to serving in the NDMA, Mr. Sarwar served as the Director General of the Livelihoods Sector at the Earthquake Reconstruction and Rehabilitation Authority.

Akhilesh Sati

Program Manager, Observer Research Foundation, New Delhi, India.

Mr. Sati has been with ORF since 2004, where he specializes in energy-related issues. In his present capacity, he assists ORF's Senior Research Fellows by collecting, interpreting, and furnishing reliable data and information on energy development. He has a MSc (Statistics) from Ramjas College.

Russell Sticklor

Research Analyst, Environmental Security Program, Stimson Center, Washington, DC, United States.

Russell Sticklor is a Research Analyst with the Stimson Center's Environmental Security Program. Prior to joining Stimson, he worked at the Woodrow Wilson International Center for Scholars' Environmental Change and Security Program, where his work focused on water scarcity and demographic change in South Asia, the Middle East, and North Africa. A journalist by trade, Russell's work has also appeared in *World Politics Review*, *Outdoor America*, *Diplomatic Courier*, and various US government publications. He holds an MA in International Affairs with a concentration in Asian Studies from George Washington University.

Brig. Gen. (Ret.) Krishnaswamy Srinivasan

Establishment Director, Centre for Security Analysis, Chennai, India.

A graduate of Defence Services Staff College and College of Defence Management, during his active army career of 35 years, Srinivasan held several important commands, instructional, and planning assignments. At the Centre for Security Analysis (CSA), he guides and supervises the work of research fellows. His area of work includes conflict resolution and peace building, terrorism, disaster management, and the role of civil society in conflict situations. He has been an active member of the working group on Disaster Management and Water Security convened by the Strategic Studies Network set-up by NESA Center, National Defense University, Washington, DC.

B.G. Verghese

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As a journalist, Verghese worked with the *Times of India* in both Bombay and Delhi from 1948-66, and was editor of the *Hindustan Times* (1969-75) and *Indian Express* (1982-86). Verghese also served as Information Adviser to the Prime Minister (1966-68) and as Information Consultant to the Defense Minister in 2002. Verghese was a recipient of the Magsaysay Award for Journalism in 1975, has served on several boards and committees, is Chairman of the Commonwealth Human Rights Initiative , and has been a member of several Indian dialogue groups engaged with Bangladesh, Nepal, Pakistan and China.

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Dr. Wani received his MSc in Agricultural Economics from GND University, Amritsar, and his PhD in Agricultural Economics from C.S. Azad University of Agriculture and Technology, Kanpur. Prior to his current position, Wani has 26 years of experience as Senior Technical Assistant, Assistant Professor, Associate Professor, Chief Scientist in the area of agricultural economics. Dr. Wani served as Professor & Head, Division of Agricultural Economics and Marketing at SKUAST-K. He has published two books and has to his credit more than 55 research papers published in peer reviewed Indian and international journals. Under the Rajiv Gandhi Chair, Dr. Wani is working on a number of projects including the agricultural economy of the cold-arid regions of Ladakh; the impact of climate change on agricultural development and productivity; economic valuation of various ecosystem services (lakes, rivers, and forests); and diversification of existing agricultural systems in the frame of attainment of livelihood and food security. He is an executive member of Indian Society of Agricultural Economics and joint secretary of the Agricultural Economics Research Association (India).

Annex B:
Indus Basin Working Group Partner Organizations

Stimson Center
Washington, DC, United States.

The Stimson Center is a nonprofit, nonpartisan institution devoted to enhancing international peace and security through a unique combination of rigorous analysis and outreach. The Stimson Center's work is focused on strengthening institutions for international peace and security, building regional security, and reducing weapons of mass destruction and transnational threats. Stimson's approach is pragmatic — geared toward providing policy alternatives, solving problems, and overcoming obstacles to a more peaceful and secure world. Through in-depth research and analysis, the Stimson Center seeks to understand and illuminate complex issues. By engaging policy makers, policy implementers, and nongovernmental institutions as well as other experts, the Stimson Center crafts recommendations that are cross-partisan, actionable, and effective.

Sustainable Development Policy Institute (SDPI)
Islamabad, Pakistan.

A non-profit, public policy think tank, the Sustainable Development Policy Institute's research concentrates on food security, natural resources, and water management across South Asia. To facilitate the region's transition to sustainable economic and environmental development practices, SDPI provides vital research, policy recommendations, and training programs targeting the government-, private-, and civil society sectors of Pakistani society. SDPI promotes its agenda by participating in collaborative advocacy activities with like-minded institutes at the national and international level.

Observer Research Foundation (ORF)
New Delhi, India.

The Observer Research Foundation is a private, non-profit think tank that provides an independent forum for examining critical security issues facing India and developing coherent policy responses suited to a rapidly changing regional and global environment. Supported by many of India's leading intellectuals, academics, public figures, social activists, business leaders and institutions of higher learning, ORF is known among policy makers both in India and abroad for its innovative public policy research in the fields of economic development, environmental sustainability, and regional security.

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Indus River delta, Pakistan, as seen from space (**NASA** via Flickr).