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Water Challenges and Cooperative Response in the Middle East and North Africa

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For the ninth annual U.S.-Islamic World Forum, we returned once again to the city of Doha. The Forum, co-convened annually by the Brookings Project on U.S. Relations with the Islamic World and the State of Qatar, serves as the premier convening body for key leaders from government, civil society, academia, business, religious communities, and the media. For three days, Forum participants gathered to discuss some of the most pressing issues facing the relationship between the United States and global Muslim communities.

Each year, the Forum features a variety of different platforms for thoughtful discussion and constructive engagement, including televised plenary sessions with prominent international figures on broad thematic issues of global importance; morning "breakfast" sessions led by experts and policymakers focused on a particular theme; and working groups which brought together practitioners in a given field several times during the course of the Forum to develop practical partnerships and policy recommendations. This year, the Forum also featured a signature event, "The Long Conversation," in which all participants came together in an off-the-record and town hall style format discussion on the evolving relationship between the citizen, religion, and the state. For detailed proceedings of the Forum, including photographs, video coverage, and transcripts, please visit our website at http://www.brookings.edu/about/projects/islamic-world.

Each of the four working groups focused on a different thematic issue, highlighting the multiple ways in which the United States and global Muslim communities interact with each other. This year's working groups included: "Compassion: An Urgent Global Imperative," "Between Interference and Assistance: The Politics of International Support in Egypt, Tunisia, and Libya," "Water Challenges and Cooperative Response in the Middle East and North Africa," and "Developing New Mechanisms to Promote the Charitable Sector."

We are pleased to share with you the fourth of our four working group papers, "Water Challenges and Cooperative Response in the Middle East and North Africa." Please note that the opinions reflected in the paper and any recommendations contained herein are solely the views of the authors and do not necessarily represent the views of the participants of the working groups or the Brookings Institution. All of the working group papers will also be available on our website.

We would like to take this opportunity to thank the State of Qatar for its partnership and vision in convening the Forum in partnership with us. In particular, we thank the Emir of Qatar, HRH Sheikh Hamad bin Khalifa Al-Thani; the Prime Minister and Foreign Minister of Qatar, HE Sheikh Hamad bin Jassim bin Jabr Al-Thani; H.E. Sheikh Ahmed bin Mohammed bin Jabr Al-Thani, the Minister's Assistant for International Cooperation Affairs and the Chairman of the Permanent Committee for Organizing Conferences; and H.E. Ambassador Mohammed Abdullah Mutib Al-Rumaihi for their collective support and dedication to the Forum and the Project on U.S. Relations with the Islamic World.

Sincerely,

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Abstract

For thousands of years, managing water has been fundamental to the development of human societies in the Middle East and North Africa. In the cradle of civilization, the legal codes governing the cities of ancient Mesopotamia—recorded in the Code of Ur-Nammu (ca. 2100 BCE) and the Code of Hammurabi (ca. 1750 BCE) —prescribed obligations for the proper use and maintenance of common water works.[1] In classical antiquity, the Greek historian Herodotus described Egypt as the gift of the Nile's floods and flows.[2] In the 14th century, the great Tunis-born statesman and scholar Ibn Khaldun first sought to decipher a pattern in the cycles of human political and social organization. He maintained that dynasties endure by establishing cities, ensuring urban life as the highest form of civilization, and named the provision of fresh water as one of the few critical requirements for siting cities, blaming the failure to adequately secure this natural necessity for the ruin of many Arab towns.[3]

Today, the countries of the Middle East and North Africa (MENA) region still depend on effective water resource management for their continuing welfare and future prosperity. The people of the Arab world now live in the most water-scarce region on Earth. In the coming decades, as populations grow, demand rises, and global climate change looms, per capita water availability in the region is projected to drop in half by mid-century.[4] Meeting these challenges will require both enhanced innovation and reform within the water policy communities and economies of the MENA countries and increased cooperation, data sharing, knowledge and capacity building between them.

On May 29-31, 2012, the Stimson Center convened a workshop on Water Challenges and Cooperative Response in the Middle East and North Africa as a component of the 2012 US-Islamic World Forum held in Doha, Qatar. Participants included scientists, academics, policy analysts, and practitioners from several MENA countries, as well as US and European experts. The interdisciplinary working group identified the principal water resource issues facing decision makers and stakeholders in the region, assessed the MENA states' existing governance capacities and resources to address these emerging pressures, and recommended priority areas and

[1] J.J. Finkelstein, "The Laws of Ur-Nammu," *Journal of Cuneiform Studies* 22, nos.3-4 (1968/1969); L. W. King, trans. *The Code of Hammurabi*, The Avalon Project Documents in Law, History and Diplomacy, Lillian Goldman Law Library (New Haven, CT: Yale University, 1915/ 2008).

[2] Herodotus, *The History*, trans. David Greene (Chicago: University of Chicago Press, 1987), p.133.

[3] Ibn Khaldun, *The Muqaddimah: An Introduction to History*, ed. N.J. Dawood, trans. Franz Rosenthal (Princeton: Princeton University Press Bollingen Series, 1967), pp.267-269.

[4] World Bank, *Making the Most of Scarcity: Accountability for Better Water Management Results in the Middle East and North Africa* (Washington, DC: World Bank, 2007), p.xiii.

approaches for advancing international and intersectoral cooperation and for identifying and strengthening intellectual and technical resources, tools, lessons, and best practices that could be shared, applied, or adapted across the region.

This report first provides a brief overview of available water resources in the MENA region. It then discusses the salient socio-economic and environmental stresses and trends that will drive and condition water supply and demand over the coming decades. Next, the report sketches prevailing water management approaches that are being developed or might be brought to bear. With this foundation in place, the report then seeks to illuminate the water governance policy options and obstacles confronting the region by examining three case studies: the Tigris-Euphrates basin, the Nile basin, and a side-by-side consideration of water stewardship in Yemen and Oman. Finally, the report concludes by presenting some recommendations suggesting strategies for the MENA countries to build their water management capabilities and bolster collaborative alternatives to managing scarce water resources at both the domestic and regional levels.

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Time magazine prominently featured Hasnain's work in its December 14, 2009 article, "Climate Change: The Tragedy of the Himalayas." Professor Hasnain was awarded the Padma Shri in 2009 by the President of India for his contributions to advancing the science of glaciology in India.

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INTRODUCTION

Societies across the Middle East and North Africa (MENA) have long balanced the competing water demands of households, industry, and agriculture.[5] Careful management of water resources has been an absolute necessity in this region where annual renewable water supplies average about 623.8 billion cubic meters (BCM), compared to Africa's 3,950 BCM, Asia's 12,009 BCM, and the world total of 43,764 BCM.[6]

Recent developments that have imposed substantial stress on societies and challenged policymakers, scientists, engineers, and planners alike include population growth, migration, industrialization, urbanization, pollution, and global warming and other environmental change. Today, growing water demand, decreasing water availability, and deteriorating water quality affect environmental quality, food security, municipal infrastructure, economic development, and overall human security in most societies of the MENA region. Transboundary tensions threaten international peace and stability. These strains pose serious challenges to regional prosperity and social order. It is no exaggeration to say that water policy and water security are as central a determinant of the future well-being of the MENA countries as is governance or ideology.

Home to more than 7 percent of the world's population, the region is endowed with less than 1.5 percent of the world's renewable freshwater supply. Yet some parts of the region (namely the more prosperous members of the Gulf Cooperation Council) have some of the highest *per capita* water consumption rates in the world. How quickly and in what manner non-renewable resources are drawn down—and the manner in which renewable resources are used—are critical policy issues within and between nations. Changes in the types and pace of water usage also have significant impacts on local water endowments.

Issues of water scarcity and choices about water policies affect farming (crop choice, growing seasons, and pests), fisheries, forestry, and livestock, hydropower, and industry, all of which have an impact on agricultural production, food security, and rural and urban livelihoods. The quantity and quality of available water supplies create and constrain management choices for direct human consumption, sanitation, and commercial and industrial development. All these uses are critical to livelihoods, public health, and economic development, each of which is crucial to maintaining social and political stability. Transboundary water issues complicate

[5] For the purposes of this paper, the MENA region includes the following states and territories: Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Syria, Sudan, Tunisia, Turkey, United Arab Emirates, and Yemen.

[6] Regional total for the 20 MENA countries and territories derived from FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations, accessed 30 July 2012. World, Africa, and Asia figures from FAO, *Review of World Water Resources by Country* (Rome: FAO, 2003), p.20. 1 BCM = 1 cubic kilometer (km^3).

all of these elements. To date, various mitigation or management approaches have been adopted by societies in the region. Some strategies to increase supply—such as desalinization and dam construction—have side-effects that pose additional environmental, economic, and social stresses. Other strategies, such as Integrated Water Resource Management (IWRM), have been lauded as models of prudent stewardship.

Much of the MENA region relies upon transboundary resources for its water supplies. Between nations, the uses of shared waters can lead to competition, conflict, or cooperation. These dynamics affect not only relationships among Arab countries, but also between these countries and non-Arab states. Two-thirds of the Arab world's surface water supplies originate outside the region.[7] Roughly 90 percent of the Euphrates's annual flow, for instance, and half of the Tigris's water supply rises in Turkey.[8] Across the region, more than half of Iraq's renewable water originates outside the country; Sudan and Syria receive some three quarters of their water from beyond their borders; and Bahrain, Egypt, and Kuwait depend on external sources for more than 95 percent of their renewable freshwater.[9]

Aquifers containing both renewable and fossil water will be critical to the environmental futures of the region. Several Arab countries derive one-third or more of their water supplies from underground reservoirs. But many states are depleting their groundwater at an unsustainable clip. Annual withdrawals exceed 108 percent of renewable resources in Iran, 350 percent in Egypt, 800 percent in Libya, and 954 percent in Saudi Arabia.[10] When these water sources cross political boundaries, they too can become sources of conflict within and between nations. Significant transboundary aquifers in the region include the Nubian Sandstone Aquifer beneath Egypt, Libya, Chad, and Sudan; the North-Western Sahara Aquifer System underlying Algeria, Libya, and Tunisia; and the Basalt Aquifer shared by Jordan and Saudi Arabia. The key role that underground water resources—and in particular fossil water reserves—will play in the water security of the region over the next fifty years remains largely underappreciated, mostly because those resources are so poorly characterized and understood. States will need to better map and assess their groundwater resources, negotiate policies for extracting this water, and address contentious issues such as sustainable management of underground water resources and equitable allocation of water from shared aquifers.

Countries and territories in the MENA region can be largely divided into two groups: (1) those that have low levels of renewable water resources, such as flowing rivers, and must rely on groundwater and desalination for most of their supply, and (2) those that get much of their water from river systems they share with other countries. The former group includes, among others, Bahrain, the Gaza Strip, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates (UAE), and Yemen, while the latter group consists of Egypt, Iraq, Iran, Jordan, Lebanon, the West Bank, Sudan, and Syria.

Today, factors such as rapid urban and population growth, increased water withdrawals for irrigation, municipal uses, and energy production, along with the proliferation of energy-intensive lifestyles, are placing an unprecedented strain on the MENA region's limited water resources. Water experts typically consider annual water availability of less than 1,700 m^3 per capita to pose a significant constraint on socio-economic development. Taken together, the MENA countries possess annual renewable water resources of 1,274 m^3 per capita, making the region the most water stressed in the world.

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[7] World Water Assessment Programme, *World Water Development Report 4: Managing Water Under Uncertainty and Risk*, vol.1 (Paris: UNESCO, 2012), p.210.

[8] M.L. Kavvas et al., "A study of water balances over the Tigris-Euphrates watershed," *Physics and Chemistry of the Earth* 36, nos.5-6 (2011).

[9] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations, accessed 30 July 2012.

[10] WWAP, *World Water Development Report 4*, p.210; Mark Giordano, "Global Groundwater: Issues and Solutions," *Annual Review of Environment and Resources* 34 (2009), p.158.

Individually, annual renewable water supplies in most Arab countries are considerably less, amounting to 794 m^3 per inhabitant in Egypt, 462 m^3 in Tunisia, 161m^3 in Jordan, 33 m^3 in Qatar, and just 7.3 m^3 in Kuwait. With limited rainfall, several countries pump more water from rivers, lakes, and underground aquifers than nature replenishes. All told, Egypt's yearly freshwater withdrawals amount to 94 percent of its actual annual renewable water resources, while Libya withdraws an unsustainable 609 percent, Saudi Arabia 936 percent, and Kuwait 2,075 percent.[11] Many of the region's water sources are over-exploited. Numerous river basins, including the Nile and the Tigris-Euphrates, are considered "closed" or nearly so; all of their renewable flows are already being used to meet various human demands or to fulfill environmental requirements for maintaining vital ecosystems, with little to no spare capacity left over.[12]

Within countries, sizable populations suffer from inadequate access to water services. While urban coverage from improved drinking water systems tops 90 percent in most countries, piped water may only flow for a limited number of hours a day. Rural areas are frequently less well served than cities and towns. Only 61 percent of rural inhabitants in Morocco, 56 percent in Iraq, and 47 percent in Yemen enjoy improved drinking water sources. Meanwhile, one-in-three rural Iraqis, nearly half of rural Moroccans, and two-thirds of rural Yemenis have no access to improved sanitation.[13]

For MENA countries, the repercussions from such shortfalls in water services provision are substantial. Insufficient or unsafe water supplies can constitute critical risks to public health and social welfare. The World Bank calculates that the economic costs of degraded water supplies—including health damages, lost productivity, etc.—amount to some 1 percent of gross domestic product (GDP) in Egypt, Jordan, Lebanon, and Morocco, and nearly 3 percent of GDP in Iran.[14] Improving water services in the region would carry considerable benefits. According to a study by the bank HSBC, achieving universal access to improved water and sanitation would bring the MENA countries $5 billion in annual economic gains. While the initial investments necessary would be large, so would the returns, with each dollar spent generating more than four dollars in benefits.[15]

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[11] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations, accessed 30 July 2012. The FAO calculates annual freshwater withdrawals to exclude uses of desalinated water and reuse of treated wastewater that are included when figuring total annual water withdrawals.

[12] Vladimir Smakhtin, "Basin Closure and Environmental Flow Requirements," *International Journal of Water Resources Development* 24, no.2 (2008); WWAP, *World Water Development Report 4*, pp.124-126.

[13] UN Millennium Development Goals Indicators, 2012 update, at http://mdgs.un.org/unsd/mdg/, accessed 31 July 2012.

[14] WWAP, *World Water Development Report 4*, p.95.

[15] Frontier Economics, "Exploring the links between water and economic growth," HSBC Holdings, London, June 2012, p.3.

Key Trends

Socio-demographic and environmental trends will exert increasing stresses on regional water resources in coming decades. The Middle East and North Africa is one of the most arid areas on the planet. Even so, the MENA countries have not always been water short relative to their needs. Over the past two millennia, the physical availability of water appears to have declined about 8 percent in the Middle East, but increased about 8 percent in North Africa, essentially due to climatic factors. Rather, demographic forces have largely driven water pressures in the region. Prior to 1800, historical analyses indicate that only small zones in North Africa experienced water shortages on a per capita basis. As populations rose through the 20th century, strains on water resources mounted. Still, only in 1960 did the Middle East reach the point where per capita water availability fell below 1700 m^3/year for 20 percent of the region's inhabitants. By 2005, with regional population growth rates continuing above 2 percent per year, 81 percent of North Africa's population and 76 percent of the Middle East's population had passed this threshold. Between demography and hydrology, population effects on water scarcity have proven about four times as large as physical availability.[16]

Expanding populations will continue to squeeze regional water resources for years to come. From 489.7 million in 2010, the combined population of the twenty MENA countries and territories is projected to climb 57 percent by 2050, to 771.2 million.[17] More than the water these additional 281.5 million people will need to drink, wash, and cook, it is the water they will need to eat that will challenge policymakers. International norms established by the World Health Organization and UNICEF hold that each person requires a minimum of 20 liters of water a day for drinking and basic hygiene.[18] By contrast, to grow a kilogram of wheat requires, on average, 1,827 liters of water; a kilogram of barley takes 1,423 liters; a kilogram of olives, 3,015 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 beef demands 15,415 liters of water on average, while a kilogram of lamb needs 10,412 liters; a kilogram of eggs uses 3,265 liters; and a kilogram of milk, 1,020.[19] 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

[16] Matti Kummu et al., "Is physical water scarcity a new phenomenon? Global assessment of water shortage over the last two millennia," *Environmental Research Letters* 5 (2010) 034006.

[17] UN Population Division, *World Population Prospects: The 2010 Revision*, at http://www.un.org/esa/population/, accessed 31 July 2012. Medium variant projections.

[18] UNDP, *Human Development Report 2006. Beyond Scarcity: Power, Poverty, and the Global Water Crisis* (New York: UNDP, 2006), p.34.

[19] M.M. Mekonnen and A.Y. Hoekstra, "The green, blue and grey water footprint of crops and derived crop products," *Hydrology and Earth System Sciences* 15, no.5 (2011); Mesfin M. Mekonnen and Arjen Y. Hoekstra, "A Global Assessment of the Water Footprint of Farm Animal Products," *Ecosystems* 15, no.3 (2012).

daily that the UN Food and Agriculture Organization deems the threshold for food security.[20]

Agriculture constitutes far and away the largest driver of water demand across the region, accounting for more than 80 percent of total water withdrawals in Egypt, Libya, Morocco, Oman, Saudi Arabia, Syria, and the UAE, and 90 percent or more in Iran, Yemen, and Sudan (compared to a world average of about 70 percent).[21] Even so, the MENA countries are already the world's largest net food importers. Most Arab countries buy 50 percent or more of the calories they consume from abroad. This strategy has helped curb domestic water usage by easing agricultural requirements, but it has also rendered the importing countries vulnerable to global price fluctuations of staple crops and export restrictions imposed by other countries. Following the global food crisis of 2007-08, for example, many countries across the region saw the cost of basic food items skyrocket, draining public budgets to support food subsidies while contributing to popular disaffection that ultimately led to the Arab uprisings. Because they are so import dependent, Arab countries are especially vulnerable to such price shocks. In Egypt for example, the World Bank has calculated that a 30 percent jump in food prices results in a 12 percent increase in poverty.[22]

In addition to becoming more populous, the MENA countries will also be increasingly urban. Propelled by rapid rural-to-urban migration, the region's urban population has nearly quadrupled in the past forty years, surging from 69 million in 1970 to 259 million in 2010, and will double again to 506 million in the next forty.[23] Many MENA countries now figure among the most urbanized in the world with four-fifths or more of their people living in cities. Cities are sources of wealth and innovation, representing important engines of economic development. But this urban demographic and economic growth also fuels greater water demand for businesses and households. (Urbanization also affects agricultural water demand as richer, more urban populations possess different dietary preferences and possibilities from their rural neighbors, typically consuming more meat and dairy products, for instance.) Given the region's population trends and anticipated rise in both national GDP and GDP per capita, experts estimate that annual domestic water demand in the MENA countries will more than triple from 28 km^3 today to 88 km^3 in 2040-2050, while industrial demand will double from 20 km^3 to 41 km^3 over the same period.[24]

Rapid urban expansion increasingly risks overburdening existing infrastructure and outpacing local capacities to expand service. In Amman, Jordan, for example, public tap water is rationed to a few hours on one day a week. Meanwhile, across the Mashreq, water losses in urban systems from leakage and theft top 35-50 percent. By the same token, urban systems generate substantial wastewater. One fifth of domestic effluents in Egypt, half in Jordan, and 95 percent in Lebanon go untreated.[25] Degraded water quality, in turn, can effectively diminish available water quantities, as some sources become too polluted for certain uses. Finally, spreading urban areas also increasingly encroach on surrounding spaces, leading to conflicts between urban and rural constituencies over water resources and scarce arable land. All told, water needs in the MENA countries are

[20] World Water Assessment Programme, *United Nations World Water Development Report 3: Water in a Changing World* (Paris/London: UNESCO/Earthscan, 2009), p.107.

[21] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations, accessed 30 July 2012.

[22] World Bank, *Improving Food Security in Arab Countries* (Washington, DC: World Bank, 2009), p.12.

[23] UN Population Division, *World Urbanization Prospects: The 2011 Revision*, at http://www.un.org/esa/population/, accessed 31 July 2012. Medium variant projections for Northern Africa and Western Asia.

[24] Walter Immerzeel et al., *Middle-East and Northern Africa Water Outlook* (Wageningen, NL: FutureWater, April 2011), p.74; P. Droogers et al., "Water resource trends in Middle East and North Africa towards 2050," *Hydrology and Earth System Sciences* 16, no.9 (2012), p.3109. These papers employ an alternative definition of the MENA region from this report. They exclude Turkey and Sudan, and add Djibouti, Israel, and Malta.

[25] UN Habitat, *The State of Arab Cities 2012: Challenges of Urban Transition* (Nairobi: UN Habitat, 2012), pp.2, 61, 63.

expected to balloon over the coming decades. The Water Resources Group, a consortium led by the International Finance Corporation and the consulting firm McKinsey & Company, projects that annual water demand across the region will rise 47 percent from 2005 to 2030. Under business-as-usual scenarios (holding present policy regimes and rates of efficiency improvements constant and maintaining climate conditions within historical variability), many basins could face substantial shortfalls between expanding demands and available supplies. In Sudan, for example, the projected gap between expected demand and practically accessible renewable water resources could approach 75 percent.[26] Even with more optimistic assumptions, the region's water picture remains sobering. A "Resource Efficiency" scenario developed by the Organisation for Economic Cooperation and Development, supposing a 15 percent improvement in irrigation efficiency over the next forty years and 30 percent improvements in domestic and industrial uses, still anticipates that significant populations in the MENA countries will suffer severe water stress in 2050.[27]

Global climate change will exacerbate the challenges confronting policymakers. According to a 2007 assessment from the Intergovernmental Panel on Climate Change (IPCC), much of the MENA region will likely face hotter and drier weather over the course of the 21st century. Further, projections reveal stark differences in how changing climates will affect the region. For instance, runoff levels across northern Africa and the eastern Mediterranean are projected to drop by 10 to 50 percent or more, encompassing an area that includes the headwater regions of the Euphrates and Tigris river systems. Parts of eastern Africa and the southern Arabian Peninsula, however, are projected to experience heightened runoff up to 50 percent greater than current levels.[28] The MENA countries' underground aquifers could also be affected by global warming. With changing precipitation, evaporation, and surface water flows, shifts in the hydrological cycle could disrupt groundwater recharge. One global examination of several model scenarios figured that by the period 2041-2070, groundwater recharge could tumble 30 to 70 percent (relative to 1961-1990) through large swathes of coastal North Africa, the eastern Mediterranean, and—in some scenarios—parts of the Arabian Peninsula. Iran, Saudi Arabia, Jordan, Morocco, and Tunisia were judged especially vulnerable due to their pre-existing water scarcity and heavy reliance on groundwater sources. (The same study, however, also projected that interior regions of the Sahel and the Arabian Peninsula could experience significant increases in groundwater recharge.)[29] Climate change could also degrade important coastal groundwater sources as sea level rise drives saltwater intrusions into freshwater aquifers.

The combined pressures from population growth, economic development, and climate change will sorely strain water resources availability in all the MENA countries. A recent evaluation undertaken for the World Bank integrated assessments of these socio-economic drivers with hydrological models and scenarios derived from nine different general circulation models (GCMs) of climate change. The resultant analyses suggest that the region will suffer dire gaps between annual demand and freshwater resources in 2050. While the models anticipate that total demand will climb some 50 percent, from 261 km^3 today to 393 km^3 by mid-century, they also indicate that annual available water supplies will decline by 12 percent under the average climate change projection, from 219 to 194 km^3, creating

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[26] Water Resources Group, *Charting our Water Future: Economic Frameworks to Inform Decision-Making* (Water Resources Group, 2009), pp.45, 49. At the time of publication, Sudan included the now independent state of South Sudan.
[27] OECD, *OECD Environmental Outlook to 2050* (Paris: OECD, 2012), pp.244-245. The OECD study defines severe water stress as existing when the ratio of total average annual water demand compared to total annual available water exceeds 40 percent.
[28] M.L. Parry et al. eds., *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2007).
[29] Petra Döll, "Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment," *Environmental Research Letters* 4, 035006 (2009).

a shortfall of 199 km^3. Under dryer climate change scenarios, the supply deficit could reach 283 km^3. Hydrological responses to climate change will vary considerably around the region, but most MENA countries' renewable water resources could fall substantially, plunging 33 percent in Morocco, 36 percent in Saudi Arabia, 46 percent in Oman, and 98 percent in Jordan by 2050.[30]

Absent marked improvements in water management, unmet demand could near 4 km^3 annually in Algeria, hit 20 km^3 in Saudi Arabia, and top 31 km^3 in Egypt, 39 km^3 in Iran, and 54 km^3 in Iraq by 2050. Crucially, though climate change will significantly stress regional water supplies, socio-economic factors account for 78 percent of the projected water shortages, placing a premium on both adaptation and governance strategies. Depending on the climate change scenario, the costs to overcome the predicted water shortages range from $27 billion to $212 billion per year for the entire MENA region in 2050. Here, too, sizeable variations exist from country to country, with annual adaptation costs under the average climate change scenario ranging from $17 million in Tunisia and $363 million in Lebanon, to $3.l billion in UAE, $5.9 billion in Yemen, $13.1 billion in Morocco, and a colossal $39.6 billion a year in Iraq.[31]

If such models hold, the effects of climate change will push countries into uncharted territory, as far as water usage and water sharing are concerned. It will be critical to manage that transition with as few bumps as possible to ensure that water does not aggravate other elements of the region's delicate political balance.

[30] Immerzeel et al.; Droogers et al.

[31] Droogers et al., p.3110; Immerzeel et al., pp.86, 90.

Water Management Choices and Challenges

To date, international and domestic responses to water scarcity issues have largely focused on bolstering supply rather than reducing demand via measures that encourage or mandate greater water conservation. Augmenting supply allows governments to at least partially circumvent various political and ethnic tensions that often accompany water access. Focusing on conservation and greater water-use efficiency, meanwhile, has a much higher potential to trigger grievances, particularly among politically influential actors in the agricultural sector who may have become accustomed to unrestricted surface water and groundwater pumping for irrigation.

Integrated Water Resources Management strategies seek more balanced consideration of both supply and demand dynamics, coordinating between multiple uses, stakeholder claims, and ecosystem needs, as well as across geographic areas.[32] Policymakers increasingly view the approach as not only a better way to manage water, but also as a more effective means to spur cooperation between riparian states. IWRM is based on the philosophy that all uses of water are interdependent, and that water exists both as a social and economic good. For instance, agricultural runoff can pollute aquifers and rivers, leading to poor-quality drinking water and environmental degradation. Conversely, limiting agricultural water withdrawals for ecological reasons—such as sustaining fisheries—can result in disappointing crop yields. These issues can have security ramifications when they create or add to intrastate or interstate instability.

The private sector can play a significant role in water conservation and demand management. The public water-management sectors in many MENA countries suffer from poor management and/or inadequate investment in the water sector. Participation of private for-profit enterprises is now widely discussed as a means of improving productivity and efficiency in water management and public sanitation. Societies in the region have weighty choices to make about the optimal public-private balance for local needs, capacities, and circumstances. Even partial privatization of water raises the thorny issue of what balance should be struck between water as a public resource and as a privately traded commodity. Another challenge is that MENA governments will have to demonstrate the political will to raise water tariffs to cover costs and develop the regulatory arrangements that would give private sector firms confidence that they can generate the desired rate of return on their investments, while at the same time providing for basic water consumption of the poorest citizens and for other important public purposes. Good governance is imperative on both sides. While many governments are currently contemplating reforms that would make private

[32] For an overview of IWRM in the MENA region, see Hamed Assaf, "Integrated Water Resources Management," in *Arab Environment: Water – Sustainable Management of a Scarce Resource*, Mohamed El-Ashry et al. eds. (Beirut: Arab Forum for Environment and Development, 2010).

participation in water and sewerage possible, only a few countries in the MENA region have succeeded to date in actually achieving private sector participation. Even scarcer are reliable models that balance private incentives and public interest.[33]

The belief that water management has social, economic, environmental, and security ramifications began to gain mainstream attention in the 1990s. At the 1992 International Conference on Water and the Environment (ICWE) in Dublin, participants proposed guiding principles for an integrated, more holistic approach to water stewardship. Known as the Dublin Principles, these steps highlighted the following subject areas:

- Water management requires a holistic approach that links social and economic development with ecosystem protection. Water management policies should also consider land use in the vicinity of the water source.

- A participatory approach to water management is needed, which includes raising awareness among both policymakers and the general public, as well as involving water stakeholders at all levels.

- As primary providers and users of water domestically, women need to play a pivotal role in water management.

- Water is an economic good, and as such should be managed efficiently and equitably, with special attention to conserving and protecting water resources.

These principles were presented at the United Nations Conference on Environment and Development (UNCED) later that year. Echoed at the first and second World Water Forums in 1997 and 2000, respectively, they came to undergird more structured formulations to guide integrated water resources management.[34] At the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, targets were set to develop national IWRM and water efficiency plans by 2005. At the fourth World Water Forum in Mexico in 2006, Yemen, Tunisia, Palestine, Morocco, Jordan, and Egypt were recognized as the most successful MENA countries and territories to formally incorporate IWRM into their national water policies. Algeria, Kuwait, Iraq, Oman, and Qatar meanwhile, were judged to be the least successful in meeting the Johannesburg goals.[35]

The primary challenge for most states in the MENA region has been accepting that sustainable water management entails more than just resource exploitation for purposes of development and modernization. Part of this process has involved moving toward recognition that water resources are limited, and that water policy must focus not only on exploiting current sources and finding new ones, but also on educating water users regarding conservation techniques and demand management. In addition to optimizing human use of water, such awareness and education must encompass the stewardship of so-called "in-stream" water resources. (Maintaining appropriate ecological water flows to sustain important environments—such

[33] Globally, empirical studies of the impact of private sector participation on access to water services and the efficiency of provision have found mixed results. See, e.g., Herath Gunatilake and Mary Jane F. Carangal-San Jose, *Privatization Revisited: Lessons from Private Sector Participation in Water Supply and Sanitation in Developing Countries* (Manila: Asian Development Bank, 2008); Edouard Pérard, "Water supply: Public or private? An approach based on cost of funds, transaction costs, efficiency and political costs," *Policy and Society* 27, no.3 (2009); José Esteban Castro, "Private-Sector Participation in Water and Sanitation Services: The Answer to Public Sector Failures?" in *Global Change: Impacts on Water and Food Security*, Claudia Ringler et al. eds. (Berlin: Springer-Verlag, 2010).

[34] See Global Water Partnership – Technical Advisory Committee (GWP-TAC), *Integrated Water Resources Management*, TAC Background Paper no.4 (Stockholm: GWP, 2000).

[35] World Water Council/National Water Commission of Mexico, *Regional Document: Middle East and North Africa*, Fourth World Water Forum, Mexico City, March 2006, pp.35-37.

as marshes and river deltas—is essential to ensuring other collective goods and ecosystem services such as biodiversity, nutrient cycling, groundwater recharge, etc.) Additionally, before being able to effectively implement IWRM policies, many MENA countries had to contend with highly fragmented control over water management, characterized by overlapping responsibilities among different institutions and water-using sectors. Other countries in the region had to surmount the opposite institutional challenges stemming from rigid, over-centralized control of water resources that had become entrenched through decades of rapid economic development and large water infrastructure projects.

To overcome these hurdles, many countries were forced to make difficult decisions and restructure institutions involved in water governance. To encourage better management and conservation, many countries moved to situate water management responsibilities in one national-level ministry, while engaging water stakeholders at the municipal and community levels. (To its credit, Egypt has been particularly successful in adopting such changes.) On the whole, the MENA countries have made significant strides in adopting IWRM approaches over the past decade. Even so, recent regional and global status reports reveal that many envisaged reforms have yet to be fully implemented, while progress in particular areas such as environmental monitoring and integration, climate change adaptation, stakeholder participation, knowledge sharing programs, and sustainable financing is not as advanced.[36]

Today, several regional institutions are dedicated to encouraging IWRM cooperation in the region. One is the Arab Integrated Water Resources Management Network (AWARENET), which seeks to foster regional communication on how to best incorporate IWRM into national policies. Similarly, the Arab Water Council, established in 2004, focuses on developing a multidisciplinary approach to water management and increasing the sharing of scientific information, such as hydrological data, within and between countries. Bilateral agreements in the MENA region are also beginning to reflect a greater acceptance of IWRM. IWRM-based agreements provide states that share water resources with many potential benefits, including:

- *Cooperation*. Cooperation between fellow riparians can improve stewardship of shared surface waters, increase agricultural production and energy generation, and facilitate preparedness for disasters, such as floods and droughts.

- *Reduced costs*. Costs for water management can be shared between countries, thus reducing cross-border tensions and lowering conflict potential.

- *Security*. Cooperation in the management of water resources can lead to improved political and economic relations between countries.

More broadly, IWRM can play an important role in fostering scientific diplomacy, sharing lessons learned, and building domestic and cross-border institutional infrastructure that might help anchor regional stability—as far as environmental security is concerned—in the coming decades.

To illuminate some of the water governance policy options and obstacles confronting the region, this paper will consider three case studies: the Tigris-Euphrates basin, the Nile basin (focusing especially on the downstream riparians), and a side-by-side examination of water stewardship in Yemen and Oman.

[36] AMCOW, *Status Report on the Application of Integrated Approaches to Water Resources Management in Africa* (African Ministers' Council on Water, 2012); UNEP, *The UN-Water Status Report on the Application of Integrated Approaches to Water Resources Management* (Nairobi: UNEP, 2012).

CASE STUDY #1

Dividing Conflict Zones New and Old: The Tigris-Euphrates Basin

Both the Tigris and Euphrates rise in the mountains of eastern Turkey. The annual flow of the Tigris-Euphrates fluctuates significantly. Combined discharges over 84 km^3 (1 km^3 = 1 BCM) occurred in the mid-1970s, while drought plunged annual flows below 30 km^3 in the 1960s. Analysis of the base years 1957-1969, before major dam construction altered flow patterns, found average annual flow volumes in the Tigris of 49 km^3 and 35 km^3 in the Euphrates. On average, Turkey provides 90 percent of the water running in the Euphrates and Syria provides the remaining 10 percent. Turkey furnishes about half the flow of the Tigris, while Iraq supplies two-fifths, and Iran the remainder.[37] Both Iraq and Syria are highly reliant on the Tigris-Euphrates for their water supplies. Iraq's "dependency ratio" on external water flows is 53.5 percent and Syria's is 72.3 percent. Turkey's dependency ratio, by contrast, is 1 percent.[38]

As early as the 1950s, Turkish leaders had discussed harnessing the waters of both rivers to drive national economic development and bolster domestic energy production. The resulting project, GAP—from its Turkish name *Güneydoğu Anadolu Projesi*, or the Southeastern Anatolia Project—was launched in the 1980s, with plans for twenty-two dams and nineteen hydroelectric power plants. Upon completion, this massive infrastructure project is expected to eventually divert enough water to irrigate 1.8 million hectares of land and provide 27 billion kilowatt-hours (kWh) of electricity. The project enables the continued economic development of the politically restless Kurdish southeast corner of the country where unemployment remains high and which, given the sentiments of separatist Kurds, Ankara is eager to bring closer under its wing.[39]

The GAP plans sparked considerable concern among Turkey's neighbors. Using the project's own figures, one calculation concluded Turkey's irrigation intentions would imply withdrawing 9 to 10 km^3 of water from the Euphrates and 3.7 to 5.6 km^3 from the Tigris annually. Other experts suggested the project could entail using roughly half the flows of both the Tigris and the Euphrates when fully implemented. Adding to the impacts expected downstream—because some of the waters diverted by Turkey for irrigation would subsequently drain

[37] Kavvas et al.

[38] FAO, *Iraq: Country Profile* (Rome: FAO AQUASTAT, 2008); FAO, *Syria: Country Profile* (Rome: FAO AQUASTAT, 2008); FAO, *Turkey: Country Profile* (Rome: FAO AQUASTAT, 2008).

[39] Republic of Turkey, *Southeastern Anatolia Project Action Plan 2008-2012* (Southeastern Anatolia Project Regional Development Administration, May 2008); A. Akpinar and K. Kaygusuz, "Regional sustainable water and energy development projects: a case of Southeastern Anatolia Project (GAP) Turkey," *Renewable and Sustainable Energy Reviews* 16, no.2 (2012).

back from the fields—analysts anticipated that agricultural runoff would pollute 40 percent of the flow entering Syria from Turkey and 25 percent of the Tigris waters running from Turkey into Iraq.[40]

With construction of GAP projects underway, the three riparians in 1983 established the Joint Technical Committee for Regional Waters (JTC) to address all water issues in the Tigris-Euphrates Basin. Yet from the outset, the parties have espoused contrary perspectives on water distribution in the basin. Thus, in 1984, Turkey put forward a plan for joint development of the rivers based on a complete inventory of the basin's land and water resources. Proposed projects would then be compared across the basin as a whole, and those judged most beneficial implemented. At the same time, however, Turkey claims absolute rights to utilize the waters originating within its borders, asserting that it shares the rivers with its neighbors without any legal obligation to accommodate them. In the words of then Prime Minister Suleyman Demirel, "Water resources are Turkey's and oil is theirs. Since we do not tell them, 'Look, we have a right to half your oil,' they cannot lay claim to what is ours."[41] Insisting on this right of territorial sovereignty, Turkey figures as one of only three states to have voted against the 1997 UN Convention on the Law of Non-Navigational Uses of International Watercourses (versus 103 votes in favor). Syria and Iraq, by contrast, ground their claims to the Tigris-Euphrates waters on customary principles of equitable and reasonable utilization and acquired historical rights. They argue that Turkey's appeal to territorial sovereignty violates the obligation not to cause harm and deem the proposed 1984 framework for centralized basin development a ploy designed to favor allocating basin waters to irrigation and hydropower projects in Turkey.[42]

With little direct leverage over Turkey's upstream water projects, downstream Syria and Iraq resorted to outside issue linkages to influence Ankara. Syria in particular long wielded support for the Kurdistan Workers Party (PKK) and its guerrilla activities against Turkey as a counterweight to Ankara's potential ability to manipulate flows in the Euphrates. In 1987, for example, the two countries signed dual protocols by which Turkey guaranteed Syria an annual average minimum flow of 500 m^3/s on the Euphrates, while Damascus pledged to curtail its support for the PKK. Nevertheless, Turkey frequently failed to comply and Syria soon renewed its backing of the Kurdish group, precipitating serial political crises and military showdowns. In 1990, Turkey halted the Euphrates' flow for a month during the filling of the Atatürk Dam reservoir. In 1998, Syria's ongoing assistance to the PKK animated Ankara to accuse the Assad regime of waging an "undeclared war" in Turkey's southeast. Under threat of armed intervention, Damascus then ceased its support for the separatist movement, expelling rebel leader Abdullah Öcalan and concluding the 1998 Adana security agreement, banning the PKK as a terrorist organization.[43]

Iraq and Syria have also clashed over the waters of the Tigris and Euphrates. In 1973 Syria began impounding water behind the Tabqa Dam on the Euphrates to fill Lake Assad behind the dam. Iraq accused its neighbor of withdrawing one-third of the river's flow, complaining to the Arab League that Syria was abusing its role as an upper riparian, and threatened to bomb the offending structure. Syria abandoned negotiations and closed its airspace to Iraq in May 1975. Soon, the two countries were amassing troops at their borders in preparation for conflict, averted only when Saudi Arabia brokered

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[40] Peter Beaumont, "Restructuring of Water Usage in the Tigris-Euphrates Basin: The Impact of Modern Water Management Policies," *Yale Forestry and Environmental Studies Bulletin* 103 (1999), p.172; Marwa Daoudy, "Asymetric Power: Negotiating Water in the Euphrates and Tigris," *International Negotiation* 14, no. 2 (2009), p. 370.

[41] Murat Metin Hakki, "An Analysis of the Legal Issues Concerning Turkey's Southeastern Anatolia Project (GAP)," *World Affairs* 169, no.4 (2007), p.176.

[42] Ali Çarkoğlu and Mine Eder, "Domestic Concerns and the Water Conflict over the Euphrates-Tigris Basin," *Middle Eastern Studies* 37, no.1 (2001); Hakki; Daoudy.

[43] Serdar Güner, "The Turkish-Syrian War of Attrition: The Water Dispute," *Studies in Conflict & Terrorism* 20, no.1 (1997); Joost Jongerden, "Dams and Politics in Turkey: Utilizing Water, Developing Conflict," *Middle East Policy* 17, no.1 (2010).

a pact in which Damascus agreed to guarantee that 60 percent of the flow of the Euphrates would reach Iraq.[44]

Since that time, Turkey has shifted its stance somewhat on territorial sovereignty, emphasizing instead the possibility of sharing joint benefits through coordinated water management and more openness to environmental cooperation. In 2001-2002, Turkey and Syria issued a Joint Communiqué and Implementing Document committing to common research and training programs. From 2005, the Track II Euphrates and Tigris Initiative for Cooperation has gathered academic analysts and former officials from Turkey, Syria, and Iraq for multilateral discussions. And in March 2008, the three countries officially established a joint water institute.[45]

Nevertheless, despite various bilateral arrangements between them, no trilateral agreement governs river flows or water allocations among the three riparians. Though unfinished, the GAP remains contentious inside and outside of Turkey. Within Turkey, the government—and many Kurds as well—judge the project essential to the socio-economic welfare and integration of one of the country's least developed regions. Yet the multiple dam projects so far completed have flooded nearly 400 villages and displaced almost 200,000 people, most of them Kurds.[46] Outside of Turkey, Iraq and Syria both blame withdrawals by their upstream neighbor for recurring water shortages while also accusing Turkey of contaminating what little river flow reaches them. Indeed, many experts cast doubt on the long-term political and environmental viability of completing the GAP. The existing diversions and engineering projects have already pared average annual flow volumes in the Tigris-Euphrates from 80 km^3 in the period 1965-1973 to 50 km^3 in 1989-1998. According to one study, finishing all of the GAP installations would further trim annual flow volumes by 5 km^3 while shrinking the marshes by an additional 550 km^2.[47] Another analysis simulating the water demands from the full array of planned irrigation and hydroelectric projects concluded that completing the GAP design would cut outflows in the Tigris and Euphrates by 25 percent and 32 percent respectively, rendering Turkey unable to meet its commitment to guarantee minimum flows downstream 25 percent of the time.[48]

Global climate change could place additional strains on the basin's water resources. Spring and summer snowmelt in the mountains of eastern Turkey accounts for 60 to 70 percent of total annual river runoff. Yet climate change may substantially diminish the winter snows that nourish the Tigris-Euphrates Basin. Climate model runs reviewed by Turkey's Ministry of Environment and Forests suggest that snowfalls in eastern Anatolia could decline by up to two meters (snow water equivalent), implying considerable subsequent changes in stream flows.[49] Other models suggest substantial declines in spring and summer runoff in the Upper Euphrates by 2100. One high-resolution model of the region projects that summer stream flow in the Euphrates could dip to less than 12 percent of its current levels during the peak month of June, while the river's total annual discharge could plummet 29 to 73 percent by the end of the century.[50]

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[44] Kevin Freeman, "Water Wars? Inequalities in the Tigris-Euphrates River Basin," *Geopolitics* 6, no.2 (2001); Daoudy.

[45] Aysegul Kibaroglu et al., "Cooperation on Turkey's Transboundary Waters: Analysis and Recommendations," in *Turkey's Water Policy*, Aysegul Kibaroglu et al. eds. (Berlin: Springer-Verlag, 2011); Daoudy.

[46] Leila M. Harris, "Water and Conflict Geographies of the Southeastern Anatolia Project," *Society and Natural Resources* 15, no.8 (2002); Jongerden.

[47] C. Jones et al., "Hydrologic impacts of engineering projects on the Tigris-Euphrates system and its marshlands," *Journal of Hydrology* 353, nos.1-2 (2008).

[48] A. Tilmant, J. Lettany, and R. Kelman, "Hydrological Risk Assessment in the Euphrates-tigris River Basin: A Stochastic Dual Dynamic Programming Approach," *Water International* 32, no.2 (2007).

[49] Republic of Turkey, *First National Communication of Turkey on Climate Change* (Ankara: Ministry of Environment and Forestry, January 2007), p.165; A. Arda Şorman et al., "Modelling and forecasting snowmelt runoff process using the HBV model in the eastern part of Turkey," *Hydrological Processes* 23, no.7 (2009).

[50] Akio Kitoh et al., "First super-high-resolution model projection that the ancient 'Fertile Crescent' will disappear in this century," *Hydrological Research Letters* 2, no.1 (2008); A.G. Yilmaz and M.A. Imteaz, "Impact of climate change on runoff in the upper part of the Euphrates basin," *Hydrological Sciences Journal* 56, no.7 (2011).

Model and statistical analyses by the U.S. National Oceanic and Atmospheric Administration suggest that climate change forcing accounts for half of the increased drying trend already observed around the eastern Mediterranean region over the past century (1902-2010).[51] As the effects of climate change alter the timing of snowmelt and precipitation, tensions could easily flare throughout the basin. Abnormally low precipitation levels in the basin's Turkish headwaters, for instance, might cause Ankara to withhold water behind Turkish dams as a reserve to generate hydroelectricity and irrigate crops, to the detriment of downstream water users that rely on the same water to grow food and drive economic activity.

The long-term ecological integrity of the famed Mesopotamian Marshes of southern Iraq remains threatened by huge canals and earthworks constructed to re-route the Tigris's and Euphrates's waters around the marshes they once nourished, and channel these rivers' waters directly into the Gulf instead. The end result was catastrophic from an environmental standpoint, with 93 percent of the lower basin's original marshlands wiped out by 2002. Marsh Arabs' traditional livelihoods and ways of life were also marginalized to the point of non-existence, fulfilling Baghdad's intention to consolidate government influence in the region. (The UN imposed strict sanctions as a result, requiring Baghdad to pay compensation for war damages and environmental damage. These sanctions, however, restricted Iraq's ability to restore key social services and infrastructure, with feedbacks to the river system. At the Al-Rustamiyah wastewater treatment plant in Baghdad, for instance, it proved impossible to import spare parts to rehabilitate the plant, resulting in the discharge of 300,000 cubic meters per day of untreated sewage into the Tigris.) To date, little more than a third of the original Marshlands area has been restored.[52]

Today, Iraq's water infrastructure and usage patterns leave little room for optimism. Urban water supply and sewage systems have fallen into disrepair from years of neglect and lack of maintenance, suffering damage from war, looting, and power cuts. Water loss rates to seepage and wastage hover between 50 to 60 percent, owing to leaky water-distribution networks and pipe ruptures. Meanwhile, many newly developed areas in city suburbs are not served with any potable water. Instead, the population depends entirely on raw, low-quality water provided by private vendors. According to the Ministry of Water Resources, on current trends Iraq's available water supply could fall to 43 km^3 in 2015, far short of the 66.85 km^3 the country is then projected to need.[53]

The economic stability of Iraq and Syria depends fundamentally on Ankara's water management policies as well as their own. Water-related human insecurity in any of the basin countries could reverberate between them via contending claims on water supplies or potential pathways, such as the possibility of increased migration from water-scarce areas. During the drought of 2007 to 2009, for example, precipitation levels across much of the Fertile Crescent dove 60 to 80 percent below normal, while water levels in the Tigris-Euphrates and other water bodies fed by the rivers—such as Lake Tharthar, Iraq's largest lake—also plunged, causing shortages of irrigation water. Cereal production in Iraq and Syria slumped. From 2006 to 2008, the wheat and barley crops in both countries slid by half or more.[54] In Syria, the UN estimated that 1.3

[51] Martin Hoerling et al., "On the increased frequency of Mediterranean drought," *Journal of Climate* 25, no.6 (2012).

[52] Hassan Partow, "Environmental Impact of Wars and Conflicts," in *Arab Environment: Future Challenges,* Mostafa K. Tolba and Najib W. Saab eds. (Beirut: Arab Forum for Environment and Development, 2008), pp.164, 165; UN Integrated Water Task Force for Iraq, *Managing Change in the Marshlands: Iraq's Critical Challenge* (New York: UN, 2011), p.8.

[53] UN/World Bank, "Joint Iraq Needs Assessment Working Paper: Water and Sanitation," October 2003, p.5; UN in Iraq, "Press Release: On the occasion of the 2011 World Water Day, the UN Calls for Improved Water Resource Management, Policies and Governance for All," Baghdad, 22 March 2011; UN Assistance Mission for Iraq/UN Country Team in Iraq, "Water Resources Management White Paper," June 2010, pp.8,15.

[54] Ricardo M. Trigo et al., "The intense 2007-2009 drought in the Fertile Crescent: Impacts and associated atmospheric circulation," *Agricultural and Forest Meteorology* 150, no.9 (2010).

million people were affected, losing over 90 percent of their income on average, and driving 65,000 families to leave their homes. In Iraq, an estimated 100,000 migrants left stricken areas in the predominantly Kurdish northeast of the country. At the height of the drought in May 2009, the Iraqi Parliament moved to compel the government to demand a greater share of water from Turkey, passing a resolution requiring any agreement signed with Ankara to include an article ensuring that Iraq receive an equitable water supply from the Tigris-Euphrates.[55] With Syria experiencing significant internal unrest and Iraq recovering from two decades of sanctions and war, water resource management capacities in both countries are considerably diminished. Turkey must also tread carefully in its water-rich southeastern region. Without sufficient consultation or involvement of the region's Kurdish leadership, hydroelectric developments in the region could end up agitating Kurdish separatist factions.

A comprehensive agreement on the Tigris-Euphrates basin remains elusive, despite several decades of promising technical cooperation and bilateral agreements among the three riparian countries. The prevailing Syrian and Iraqi views are that the basin's waters are a common good, to be shared equally and fairly. Turkey views the headwaters as its sovereign domain, with the freedom to utilize those water resources as it sees fit. Commanding the literal high ground has allowed Turkey great influence over the basin's hydrology. Ankara has signaled its intention to improve water-sharing relations on the river, declaring its willingness to work with downstream riparians to ease tensions over basin disputes, although substantive actions have not yet been taken. All the pressures described above will complicate water-sharing relationships between the three countries unless new frameworks are devised to take into account the heightened water-supply variability that may become increasingly commonplace.

[55] UN, *Syria Drought Response Plan 2009-2010 Mid-Term Review* (New York: UN, February 2010); Robert A. McLeman, "Settlement abandonment in the context of global environmental change," *Global Environmental Change* 21, Supplement (2011), p.115; Jongerden, p.138.

CASE STUDY #2

Enduring Challenges: The Nile River and the Nile Basin Initiative

The Nile River Basin is shared by eleven (now including South Sudan) countries. It is home to 200 million people, and covers a drainage area that extends over 10 percent of Africa's landmass. The Nile River as a whole (including its tributaries the White Nile, Blue Nile, and Atbara) has mean annual flow of 80 billion m^3 (BCM).[56] In addition to providing an indispensable lifeline for the commercial sectors of each basin country, the river has served as the foundation for some of the world's oldest civilizations and continues to be an integral part of its dependents' political, economic, and social identities. But the Nile Basin is also characterized by extreme disparities: nearly 100 million residents within the Basin countries live on less than a dollar a day; 98.7 percent of its irrigated lands fall in either Egypt or North Sudan; and, for half of the Nile's journey through the Basin, it flows through countries that have no effective rainfall, making those countries overwhelmingly reliant on the Nile for every aspect of daily life.[57]

Environmental degradation and mismanagement is rife throughout the basin, leading to regular power shortages, severe drops in water levels of the river and connected lakes, and serious disruptions in ecological systems that are vital to the health of the river and its flora and fauna.[58] In an effort to ensure a common legal and institutional foundation to meet these challenges and pursue equitable and cooperative development of their shared water resources, the then ten Nile basin riparians spent much of the past two decades negotiating the Nile River Basin Cooperative Framework Agreement through the Nile Basin Initiative. Since the conclusion of these negotiations in 2010, however, disagreements have persisted among the states, even as the Agreement opened for signature. Six upper riparians—Burundi, Ethiopia, Kenya, Rwanda, Tanzania, and Uganda—have now signed the treaty, though none as yet has ratified it. Egypt and Sudan continue to reject the Agreement. Egypt, in particular, objects that the accord fails to adequately guarantee its water security against adverse impacts. Even so, all of the riparians have so far maintained their commitment to cooperation within the overarching Nile Basin Initiative. Further, most international funding agencies, such as the multilateral development banks, will refuse to back projects on international waterways without basin-wide assent. Nevertheless, other funders, such as China, may prove less reticent, and the upper riparians, facing

[56] FAO, *Synthesis Report: FAO-Nile Basin Project* (Rome: FAO, 2011), p.4. An estimated 370 million people live within Nile riparian countries.

[57] Ashok Swain, "Mission Not Yet Accomplished: Managing Water Resources in the Nile River Basin," *Journal of International Affairs* 61, no. 2 (2008); M. El Fadel et al., "The Nile River Basin: A Case Study in Surface Water Conflict Resolution," *Journal of Natural Resources and Life Sciences Education* 32 (107) 2003, p. 108.

[58] See "Hydropower Resource Assessment of Africa," Ministerial Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate Change, Sirte, Libyan Arab Jamahiriya, 15-17 December 2008.

their own development pressures, may not always refrain from pursuing projects on their stretches of the Nile.[59]

The case of the Nile is somewhat different from that of the Tigris and Euphrates. Unlike the Tigris-Euphrates basin—where upstream Turkey is the dominant geopolitical power—in the Nile basin, it is downstream riparians Egypt and Sudan that feel they have dominant claim to the river's waters (despite the fact that the river passes through eleven countries, and some nine-tenths of the Nile's waters originate in the highlands of Ethiopia).[60] Egypt and Sudan typically receive far less rainfall than riparians in the higher reaches of the Nile basin. Consequently, both countries count heavily on the Nile for irrigation. Given this need, it has largely been Egypt and Sudan that have determined who has priority over the river. Together, the two countries use about 94 percent of the river's water.[61] Egyptian and Sudanese water rights are outlined in the 1959 Nile Waters Agreement, which allots 18.5 BCM per year to Sudan and 55.5 BCM per year to Egypt.

Of the Nile basin countries, Egypt and Sudan will largely determine the river's hydropolitics in the coming decades. Egypt's land is 97 percent desert, and the 4 percent of the country's arable land is almost exclusively dependent on the Nile for its food, water, and power. The Nile contributes 10 percent of Egypt's electricity via hydropower, almost all of which is generated by the High Aswan Dam, which uses the manmade Lake Nasser as its reservoir.[62] Using the water allotted by the 1959 Nile Waters Agreement (along with 0.5 m^3/year of internal water resources), Egypt has become both a North African and Nile Basin hegemon and has been able to continuously improve its citizens' access to services and employment opportunities. The use of water-intensive crops, the proliferation of inefficient traditional abstraction methods, and massive environmental degradation, however, have combined to endanger Egypt's already strained water resources. Egypt's total annual renewable water resources currently stand at 706m^3 per capita, which qualifies as a state of "water poverty," and it is estimated that that figure might drop to as little at 550 m^3 per capita by 2025.[63]

Despite continuous conflict, political instability, and food insecurity, Sudan has evolved its water management policies over the years to take better advantage of its significant water resources. The agricultural sector, the most dominant in Sudan's economy, relies heavily on the Nile and contributes 90 percent of Sudan's non-oil export earnings. Overall, Sudan is home to the largest irrigated land area of any sub-Saharan African country.[64] The White Nile, the Blue Nile, the Nile mainstream, and Atbara are all dammed once they enter Sudan, and hydropower accounts for 48 percent of Sudan's electricity production.[65] Despite the fact that north Sudan receives virtually no rainfall, Khartoum has become one of the fastest-growing cities in Africa.

Egypt and Sudan have a mixed track record when it comes to management of transboundary water resources. They have enjoyed some success in water diplomacy over the past twenty years, including the signing of a 1992 agreement detailing water-sharing in the Nubian Sandstone Aquifer. Not yet under significant stress, this and other aquifers could play

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[59] Anja Kristina Martens, "Impacts of Global Change on the Nile Basin: Options for Hydropolitical Reform in Egypt and Ethiopia," IFPRI Discussion Paper 01052, International Food Policy Research Institute, Washington DC, January 2011; Abadir M. Ibrahim, "The Nile Basin Cooperative Framework Agreement: The Beginning of the End of Egyptian Hydro-Political Hegemony," *Missouri Environmental Law and Policy Review* 18, no.2 (2011).

[60] FAO, *Synthesis Report*, pp.53ff.

[61] Swain.

[62] Energy Information Administration, *Egypt: Country Analysis Brief* (Washington, DC: EIA/USDOE, July 2012).

[63] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations, accessed 30 July 2012; Musa N. Nimah, "Water Resources," in *Arab Environment: Future Challenges*, Mostafa K. Tolba and Najib W. Saab eds. (Beirut: Arab Forum for Environment and Development, 2008), p.65.

[64] FAO, *Sudan: Country Profile* (Rome: FAO AQUASTAT, 2005).

[65] International Energy Agency, *Statistics and Balances* Database, "Electricity/Heat in Sudan in 2009," at http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=SD, accessed 1August 2012.

an important role in fortifying each country's water security. Recent efforts to map Africa's aquifers suggest that Egypt may possess 36,000–130,000 km^3 of groundwater storage and Sudan 37,100–151,000 km^3 (compared to annual flows in the Nile of 80 km^3), though much may lie in non-renewable fossil aquifers and not all may be practically available for abstraction.[66]

The two countries' relations on the Nile, however, have often been fraught. When Sudan gained independence in 1956, the country's first prime minister immediately requested that all previous agreements between the two countries be revised, while objecting to Egypt's plan to build the Aswan High Dam. Egypt responded in kind, withdrawing its support for Sudan's reservoir project at Roseires on the Blue Nile. In a subsequent escalation, after Sudan's announcement that it would not adhere to any past agreements, Egypt amassed troops on the border. The two countries eventually signed the Agreement for the Full Utilization of the Nile Waters (Nile Waters Treaty) in 1959, but only after a military takeover in Sudan resulted in the installation of a government friendlier to Cairo.

Egypt has also clashed with other riparians over water rights. Ethiopia, according to the 1959 treaty, is entitled to none of the billions of cubic meters of Nile waters that flow through its territory each year. In 1970, Egypt threatened war against Ethiopia over the proposed construction of a dam on Lake Tana on the Blue Nile. Indeed, Egypt's military hegemony has allowed it to enforce the status quo: In June of 1979, there were 50,000 Egyptian troops stationed in Sudan in order to "secure the flow of the waters of the Abbay/Blue Nile." And in 1994, when Ethiopia announced plans to build dams on the Blue Nile, Egyptian President Hosni Mubarak threatened to bomb Ethiopian dam infrastructure.[67] More common and consequential than this overtly violent rhetoric has been Egypt's diplomatic moves: In 1990, Egypt successfully blocked an African Development Bank loan to Ethiopia for dam construction.[68]

Egypt's water-resource development in the basin has also contributed to significant environmental degradation in the lower Nile. The 1962 construction of the Aswan High Dam in southern Egypt, near the Sudanese border, entrapped large volumes of sediment in Lake Nasser, resulting in significant erosion to the Nile delta. Sediments that would typically replenish the delta also became diverted by dense irrigation networks and drainage channels. Since the completion of the dam, sediment loads have fallen to 15 million tons annually compared to 60-180 million tons previously. Indeed, scrutiny of Landsat (satellite) images reveals that between 1964 and 2006, the promontory of Rosetta at the outlet of the Nile's Rosetta branch retreated more than 4 kilometers inland on the western side of the river mouth and more than 5 kilometers on the eastern side.[69] The delta is also highly vulnerable because of the potential sea level rise associated with climate change. Sea level rise of one meter would flood an estimated 34 percent of the densely populated delta's land. Major cities such as Alexandria, Idku, Damietta, and Port-Said would be threatened. Such an outcome could conceivably force about 8.5 percent of the country's entire population to eventually relocate to the southern edge of the Nile delta, creating ever greater population densities and placing ever greater pressure on physical and institutional infrastructure.[70]

Until the 1990s, the Egyptian government's priority was "balancing" water supply and demand through

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[66] A.M. MacDonald et al., "Quantitative maps of groundwater resources in Africa," *Environmental Research Letters* 7, 024009 (2012).

[67] Yacob Arsano, *Ethiopia and the Nile: Dilemmas of National and Regional Hydropolitics* (Zurich: Center for Security Studies, Swiss Federal Institute of Technology, 2007), pp.91-92, 224.

[68] Dina Zayed, "Egypt asserts right to block upstream Nile dams", *Reuters*, 18 May 2010, at http://af.reuters.com/article/topNews/idAFJOE64H0MP20100518.

[69] M. Torab and A. Azab, "Modern Shoreline Changes Along the Nile Delta Coast as an Impact of Construction of the Aswan High Dam," *Geographia Technica* 2 (69) 2007.

[70] Eman Ghoneim, "A Remote Sensing Study of Some Impacts of Global Warming on the Arab Region," in *Arab Environment: Climate Change*, Mostafa K. Tolba and Najib W. Saab eds. (Beirut: Arab Forum for Environment and Development, 2009), p.40.

supply augmentation, including increased exploitation of groundwater. Significant investments were made in water supply, drainage, and rehabilitation of irrigation infrastructure. Still, by the late 1990s, the need for a more integrated approach became apparent due to continued deterioration of water quality, a growing demand-supply gap, intensification of intersectoral and interregional water allocation problems, inadequate government funds to sustain new investments, and poor operational performance of water agencies. Over the past decade, government policy has shifted in the direction of integrated water quality and quantity management.[71]

In January 2005, the Egyptian Ministry of Water Resources and Irrigation issued a National Water Resources Plan based on IWRM concepts. The first part of the plan aims to conserve current water resources, rather than tapping or creating new supplies. Sustainable use of existing water resources in Egypt has also involved (1) adjusting operational practices at the massive Lake Nasser reservoir to reduce evaporation, (2) mining fossil water in the Western Desert with an eye toward conserving the aquifers for future generations, (3) harvesting rainfall, and (4) deploying desalination technology.

On the demand side, Egypt's plans include provisions for improving irrigation techniques to minimize waste. Particularly in the West Delta area, Egypt has instituted a design, build, and lease (DBL) system for farmers involving the construction of three major channels to deliver irrigation water. The hope is that local stakeholders will be more likely to conserve water if they feel they have an ownership stake in the water-delivery mechanism.

Looking at the Nile basin more broadly, many riparian countries have experimented with IWRM policies with the view of promoting regional cooperation. The nine original signatories to the 1999 Nile Basin Initiative (NBI)—Uganda, Tanzania, Sudan, Rwanda, Kenya, Ethiopia, Egypt, the Democratic Republic of Congo, and Burundi—agreed on a pact "to develop the water resources of the Nile Basin in a sustainable and equitable way to ensure prosperity, security, and peace for all its peoples."[72] NBI-sanctioned projects tend to include environmental protection, stakeholder education, and increased efficiency in agricultural water usage. Incorporating both the economic and the security ramifications of water management, the NBI reveals an impressive shift in regional thinking about water resources.

Yet building pressures on the Nile will pose persistent challenges to maintaining and deepening cooperative efforts in the basin. While conflict over access to the Nile's waters has been held in check by the Nile Basin Initiative, new demographic and political variables may change historical water access dynamics. Population growth throughout the Nile basin is leading to speculation that transboundary agreements governing water use in the Nile and its tributaries may need to be renegotiated to take into account both current and future demographic realities. Egypt and Sudan, the two lower riparians, are projected to see their current populations grow by 1.5 and 2 times, respectively, over the next four decades. Sudan's population by mid-century is projected to jump from the current 43.6 million to 90.9 million, while Egypt's will increase from 81.1 million to 123.5 million by 2050.[73]

Upstream, Ethiopia's demographic and development outlook could place it in greater competition with Sudan and Egypt for the basin's waters. Rapid population growth in Ethiopia in the coming decades could even shift the basin's geopolitical power balance southward. According to the UN, the country's population is expected to rise from 83 million to roughly 145 million by 2050, heightening local demand for water resources.[74] Further,

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[71] See S. Luzi, "Driving forces and patterns of water policy making in Egypt," *Water Policy* 12, no.1 (2010).

[72] Council of Ministers of Water Affairs of the Nile Basin States, *Nile Basin Initiative Shared Vision Program: Socio-Economic Development and Benefit Sharing* (Entebbe: Nile Basin Initiative Secretariat, March 2001), p.4.

[73] UN Population Division, *World Population Prospects: The 2010 Revision*, at http://www.un.org/esa/population/, accessed 31 July 2012.

[74] UN Population Division, *World Population Prospects: The 2010 Revision*, at http://www.un.org/esa/population/, accessed 31 July 2012.

limited access to safe drinking water poses a serious threat to Ethiopia's public health and social welfare, with only 44 percent of the population using improved drinking water sources (compared to 99 percent in Egypt).[75] Further, only 17 percent of the population has access to electricity.[76] Ethiopia intends to draw on the Nile to develop both its water and its power resources. Thus, in 2011, Addis Ababa announced construction of the 6,000 megawatt Grand Renaissance dam, Africa's largest hydroelectric project. Ethiopia maintains the project will also benefit its neighbors, generating power for sale to Egypt and Sudan as well. Some Egyptian authorities, though, including the former water minister, contend the dam will spawn water and power shortages downstream, raising the specter of economic and political instability. Ethiopia, Egypt, and Sudan have since formed a tripartite technical committee to assess the dam's impact, but Ethiopia has not halted the project in the interim.[77]

Other emerging challenges may be more political. With the birth of independent South Sudan in January 2011, the Nile basin counts an additional riparian country. Some 23 BCM of water, representing 28 percent of the Nile's flow, enters Sudan from South Sudan and then crosses into Egypt. The newly sovereign country possesses virtually no power infrastructure, but has announced plans to build a handful of hydropower plants to capitalize on the Nile's energy potential.[78] Longstanding but as yet unrealized canal projects to conserve the nearly 20 BCM of water, 50 percent of the White Nile's flow, that evaporates in three enormous African swamps now also fall in South Sudan's territory. During the negotiations leading to independence, the Sudan People's Liberation Movement purposely avoided making an issue of the Nile. As the still contentious deliberations on the NBI go forward, however, the disputing original parties will likely court and pressure South Sudan to ally with them.[79] Historically, too, rapid institutional changes within a river basin, such as the introduction of new national actors, have constituted the most salient indicators for future water conflict.[80]

The effects of climate change stand to push current environmental problems in the Nile Basin into even more dangerous circumstances. One comparative set of climate simulations deploying multiple climate models suggest that stream flow will initially rise throughout the Basin during the next thirty years (2010-2039) due to increased rainfall, and will then increasingly decline during the mid- (2040-2069) and late (2070-2099) 21st century due to diminished precipitation and higher evaporation. If so, the models imply that the water available for irrigation from Egypt's High Aswan Dam would fall by about one-sixth by 2100, while the water available for hydropower would also wax and then wane with the stream flow trend.[81]

Yet very sizable uncertainties continue to cloud climate impact projections for the basin. While most studies anticipate temperatures will increase some 2-5^{o}C by the end of the century, model analyses disagree on both the size and direction of precipitation changes, generally ranging from drops of about 15 percent to increases of 15 percent relative to historic baselines. Predictions at smaller, sub-basin and tributary scales have proven even more difficult.[82] Moreover, no empirical work has yet rigorously in-

[75] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012.
[76] World Bank, World DataBank, at http://databank.worldbank.org/Data/Home.aspx, accessed 31 July 2012.
[77] Katrina Manson, "Nile dam: Water wars averted for now," *Financial Times*, 19 June 2012.
[78] Hereward Holland, "South Sudan's 'ministry of darkness' eyes hydropower," *Reuters*, 21 March 2012.
[79] Salman M.A. Salman, "The new state of South Sudan and the hydro-politics of the Nile Basin," *Water International* 36, no.2 (2011).
[80] Shira Yoffe et al., "Conflict and Cooperation Over International Freshwater Resources: Indicators of Basins at Risk," *Journal of the American Water Resources Association* 39, no.5 (2003).
[81] Tazebe Beyene et al., "Hydrologic impacts of climate change on the Nile River Basin: implications of the 2007 IPCC scenarios," *Climatic Change* 100, nos.3-4 (2010).
[82] Declan Conway, "From headwater tributaries to international river: Observing and adapting to climate change in the Nile Basin," *Global Environmental Change* 15, no.2 (2005); Giuliano di Baldasserre et al., "Future hydrology and climate in the Nile basin: a review," *Hydrological Sciences Journal* 56, no.32 (2011).

tegrated the full chain of interrelated impacts from climate forces to hydrological models through resident vegetation and cropping systems and on to the potential ramifications for livelihoods, water, and food security in basins. And, in fact, these forces will not act in isolation, as the same basins will also experience additional socio-economic, technological, political, and environmental changes and adaptations.[83] Inevitably, the very uncertainties surrounding climate impacts compound water managers' challenges. Policy strategies that may be effective under some projected scenarios might prove counterproductive under others. Adaptive measures taken upstream (building dams for water storage, erecting embankments for flood protection) could have maladaptive consequences elsewhere (e.g., disrupting river flows downstream, channeling flood surges onto the neighbors, etc.).

[83] Mark Mulligan et al., "The nature and impact of climate change in the Challenge Program on Water and Food (CPWF) basins," *Water International* 36, no.1 (2011).

CASE STUDY #3

Successes and Failures: Integrated Water Resources Management on the Arabian Peninsula

At the southern end of the Arabian Peninsula, neighbors Oman and Yemen offer an intriguing snapshot of two countries seeking to manage scarce water resources. Unlike other areas of the MENA region, Oman's and Yemen's water resources are entirely internal. Estimates by the UN Food and Agriculture Organization (FAO) conclude that both countries possess dependency ratios of zero, meaning they derive no transboundary surface water or groundwater flows from beyond their borders. Both countries also crucially rely on underground aquifers for their water supplies.[84] While Oman is in a difficult position regarding water availability, it is well-off compared to Yemen—a state now considered one of the most water-stressed in the world, with no indications that the situation will improve substantially anytime soon.

Despite the warning signs that the region is facing daunting and relatively immediate security challenges stemming from water availability, Yemen and Oman furnish insights into how water might be more sustainably and efficiently managed over the coming decades. Oman's and Yemen's experiences speak to a larger reality across the Middle East and North Africa: the region's water-scarce states are reconsidering how they manage and interact over water. The approach that the two countries have embraced—integrated water resource management—explicitly incorporates the human, ecological, and economic aspects of water management, whereas other approaches to water management tend to focus on bolstering water supply for increasing consumption, with often insufficient regard for potential adverse impacts in other sectors. The conservation philosophy that IWRM embodies is perhaps most important for countries on the Arabian Peninsula, which draw most of their water from aquifers, reservoirs, treated wastewater, and desalination plants (Saudi Arabia, for example, has the largest desalination capacity in the world). These countries' greatest water challenge is that they are meeting current demands by tapping non-renewable sources, which one day will run out. Saudi Arabia suffers the biggest gap between renewable supply and demand: it has only 2.4 cubic kilometers per year of renewable water resources, yet manages to use 23.67 cubic kilometers per year.[85] An examination of water practices in Yemen and Oman offers the possibility that improved water management might mitigate potential water crises to some degree.

[84] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012.
[85] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012.

Yemen's water outlook appears especially daunting. Total annual water withdrawals of 3.6 km^3 surpass the country's annual renewable water resources of 2.1 km^3 by 71 percent, while per capita water supplies amount to just 87 m^3 a year.[86] Yemen's population of 24 million is expected to increase 2.5 times by mid-century, pushing past 61 million in 2050.[87] Such explosive population growth will place significant strain on domestic water supplies. One recent analysis projects that Yemen's total annual water demand will soar past 11.5 km^3 in 2050, while another estimates it will approach 12.9 km^3.[88]

Continuing global climate change further darkens Yemen's water future. A paucity of reliable meteorological and water resources data over time and at finer scales hampers the calibration, application, and validation of computer generated model projections for Yemen. Nevertheless, multi-model comparisons generally agree that average temperatures will climb steadily and rainfall will likely grow more variable and intense, with negative ramifications for the country's agriculture. Analyses undertaken by the World Bank suggest that, under a possible "Warm and Wet" scenario of moderate temperature rises and higher rainfall, Yemen's agricultural yields might actually improve, though the projected benefits trail off over time. Under a "Mid" range scenario, however, crop production bumps up only slightly in 2050, before declining 6.3 percent by 2080, while a "Hot and Dry" scenario of stronger temperature rises and diminished rainfall projects crop production could slip 10.7 percent by 2030 and more than 27 percent in 2080. Indeed, climate variability will likely increase, complicating adaptation planning and response. Continuing unpredictability and uncertainty argues for strategies to enhance data collection and sharing, knowledge-building for public awareness, and forecasting and early warning programs, as well as integrated preparation and management across water resources and sectors at all levels.[89]

Over the past decade, Yemen has attempted to incorporate IWRM into its national water policy. In 2003, the newly created Yemeni Ministry of Water and Environment issued the IWRM-based National Water Sector Strategy and Investment Program, 2005–2009 (NWSSIP), updated in 2010. Plans included involving farmers in water management by introducing cost-sharing investments in new irrigation techniques that conserve water, while simultaneously reducing government subsidies for the diesel fuel traditionally used to power groundwater pumps. To further encourage conservation, Yemen's Sana'a University began offering a Master's of Science degree in IWRM in 2005, with classes on the environment, the gender dynamics of water management, and the economics of water resources. (Of all IWRM objectives, recognizing the primary role of women in the use and allocation of water at the local level has received little attention, and it is significant that gender considerations were incorporated into the university's MSc degree coursework.)[90] By the time of the fourth World Water Forum in Mexico in 2006, Yemen nominally figured among the MENA region's most advanced adherents of IWRM.[91]

Behind Yemen's notional commitment to IWRM, however, implementation has been wanting. In many cases, relevant agencies simply lack the human and technical capacities to effectively administer and enforce water policy. One study counted just 6 to 7 staff in the Ministry of Water and Environment assigned to the entire Sana'a Basin Catch-

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[86] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012.

[87] UN Population Division, *World Population Prospects: The 2010 Revision*, at http://www.un.org/esa/population/, accessed 31 July 2012.

[88] Jean G. Chatila, "Municipal and Industrial Water Management," in *Arab Environment: Water – Sustainable Management of a Scarce Resource*, Mohamed El-Ashry et al. eds. (Beirut: Arab Forum for Environment and Development, 2010), p.75; Droogers et al., p.3110.

[89] World Bank, *Yemen: Assessing the Impacts of Climate Change and Variability on the Water and Agricultural Sectors and the Policy Implications* (Washington, DC: World Bank, April 2010).

[90] R.W.O. Soppe et al., "Capacity Building in IWRM: The IWRM MSc Curriculum at the Water and Environment Centre, Republic of Yemen," EMPOWERS Regional Symposium, 13-17 November 2005, Cairo, Egypt.

[91] World Water Council/National Water Commission of Mexico.

ment Area, home to 1.5 million people.[92] In other cases, government interventions undertaken without adequate planning and consultation have set communities at odds, as when small dams erected to capture and store sporadic seasonal runoff have diverted flows from villages downstream. Perverse subsidies—on diesel fuel for well pumps, for example—have abetted the rampant expansion of groundwater irrigation. Many tubewells are drilled illegally. At the same time, powerful vested interests in the Yemeni state and society frequently oppose IWRM-based approaches. Large landowners and agricultural users resist water demand management strategies as threatening their unhindered irrigation of high-value cash crops such as bananas and *qat*. State agencies such as the Ministry of Agriculture and Irrigation perceive measures to reform current water use practices as menacing their power and elite constituencies. As water tables drop and wells run dry, the social and economic impacts of water scarcity are unevenly distributed. Reported conflicts are rising between well owners and farmers, between rural and urban consumers, between upstream users and downstream, increasingly resulting in violence that could threaten social stability.[93]

Feeble and fragmented governance institutions combine with the weak legal environment to impair efforts to improve efficiency and restrain over-exploitation of the country's scarce water resources. Critically, groundwater supplies 70 percent of total water withdrawals and groundwater irrigation accounts for two thirds of the value of crop production, but Yemen is now depleting its aquifers two to four times faster than nature can replenish them. At that rate, a 2010 World Bank assessment concluded that, irrespective of climate change, Yemen will essentially exhaust its groundwater reserves by 2025-2030. Groundwater withdrawals would then necessarily fall to no more than the natural recharge, potentially driving down Yemen's agricultural production by 40 percent or more.[94] While Yemen's NWSSIP formally embodies IWRM in principle, in practice the country stands on the brink of water crisis.

Oman, Yemen's neighbor on the southern Arabian Peninsula, has fared comparatively poorly in terms of explicitly incorporating IWRM policies into its national water plan. A careful examination of Omani water policies, however, reveals the limitations of formulaic adoption of IWRM as the international standard of water management. Oman also highlights a virtually ignored aspect of water policy—the importance of cultural and religious values in water management policies, laws, and institutions.[95]

Oman relies on precipitation for most of its renewable water resources. In the north and center of the country, most rain falls during mid- and late-winter, while a summer monsoon waters the south. Annual average rainfall ranges from less than 20 millimeters a year on the coast and interior plains, to over 300 millimeters a year in Oman's mountainous north. In Oman's arid climate, most precipitation rapidly evaporates. Much of it runs down *wadis* (gullies that are usually dry) in the form of seasonal floods. Some of this water is caught in a series of recharge dams constructed since 1985 and retained in surface reservoirs, but these bodies of water also have high evaporation rates. Another portion of the rainfall seeps underground to replenish aquifers. Oman also possesses significant fossil aquifers that receive scant if any natural recharge. With little perennial surface water, groundwater constitutes nearly 92 percent of the Sultanate's total annual water withdrawals.[96]

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[92] Jackson Morill and Jose Simas, "Comparative Analysis of Water Laws in MNA Countries," in *Water in the Arab World: Management Perspectives and Innovations*, N. Vijay Jagannathan et al. eds. (Washington, DC: World Bank, 2009), p.286.

[93] Christopher Ward, "Water Conflict in Yemen: The Case for Strengthening Local Resolution Mechanisms," in *Water in the Arab World: Management Perspectives and Innovations*, N. Vijay Jagannathan et al. eds. (Washington, DC: World Bank, 2009); Mark Zeitoun et al., "Water demand management in Yemen and Jordan: addressing power and interests," *The Geographical Journal* 178, no.1 (2011).

[94] FAO, *Yemen: Country Profile* (Rome: FAO AQUASTAT, 2008), p.6; World Bank, *Yemen* (2010).

[95] The following section draws substantially on Kendra Patterson, "Water Management and Conflict: The Case of the Middle East," in *Transnational Trends: Middle Eastern and Asian Views*, Amit Pandya and Ellen Laipson eds. (Washington, DC: The Stimson Center, 2008). See also Morill and Simas.

[96] FAO, *Oman: Country Profile* (Rome: FAO AQUASTAT, 2008); FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012.

Desalination augments the natural freshwater supply, now furnishing some 80 percent of Oman's potable water. But desalination cannot so readily be greatly expanded because of the hefty expense involved. Building and running desalination installations is highly capital and energy intensive. The unit capital costs for a seawater desalination plant amount to $1000 to $2000 per cubic meter/day of installed treatment capacity. Depending on the desalination technology employed, energy usage accounts for 50 to 75 percent or more of operating costs, even in plants that cogenerate water and electricity. (Raw materials for building desalination plants, such as steel and cement, are also expensive.) Desalination plants also have a significant impact on the local environment—including the discharge of brine that contains decaying organisms caught during in-flow, and chemicals and heavy metals introduced during the desalination process. And because of their energy requirements, desalination facilities generate considerable greenhouse gas emissions.[97] These effects can entrain appreciable financial costs, and cleanup campaigns and construction of more environmentally friendly plants are likely to make desalination even more expensive.

The star of Oman's water management system has been, and to some extent remains, its *falaj* system ("aflaj" in plural). Aflaj are water channels that take advantage of the Earth's gravity and topography to deliver water from underground sources. With a history spanning thousands of years in the region, they currently deliver one-third of renewable water resources for irrigation, while wells supply the rest. Shares of aflaj water can be either owned or rented, and they are traditionally measured by complex calculations based on seasonal variations in the length of the day and night and the position of the stars.
Conserving its aflaj has been a key part of Oman's modern water policies. In 1997, the Sultanate established the National Aflaj Inventory Project, which counted 4,112 aflaj in the country, of which about 74 percent were then in operation.[98] The Sultanate takes responsibility for the maintenance of both aflaj and wells—a parallel Well Inventory Project was initiated in 1992—and continues to fund research on desalination and other water-sourcing technologies, such as fog collection.

Oman is an absolute monarchy governed by Sultan Qaboos bin Said Al Said, who exercises substantial influence over policymaking in the country. To his credit, Sultan Qaboos has striven to establish proactive management of the country's water resources. In 1984, he created the Ministry of Regional Municipalities, Environment, and Water Resources, which placed responsibility for water and environment issues at the municipal-government level, and made Oman the first Arab state to have a ministry dedicated to environmental issues. In 1986, he strengthened these links by consolidating the councils responsible for environmental resources and water resources into the Council for the Conservation of the Environment and Water Resources. These steps recognized the relationship between local governance, environmental stewardship, and water management and reflect a strategy of maintaining a strong overarching national authority that is not fragmented among various ministries while decentralizing water management to better involve stakeholders at the local levels. These were concepts that would only enter the international discourse some years later, at the Dublin Conference in 1992 and then again at UNCED in 2002 in Johannesburg, South Africa.

The objectives of the water resources sector of the Ministry of Regional Municipalities, Environment, and Water Resources include many of the same targets as plans formally incorporating IWRM, including a focus on sustainable use, demand management, environmental protection, and public outreach through educational initiatives. The primary objectives are (1) supplying sources of potable water and creating a balance between water utilization and renewable resources, (2) enhancing water

[97] FAO, *Oman*, p.5; Adil A. Bushnak, "Desalination," in *Arab Environment: Water – Sustainable Management of a Scarce Resource*, Mohamed El-Ashry et al. eds. (Beirut: Arab Forum for Environment and Development, 2010), pp.129-143.
[98] Patterson, p.222.

resources and protecting them against depletion and pollution, (3) rationing water consumption, (4) establishing principles of water preservation, and (5) increasing awareness of the importance of conserving water resources.

Still, viewed in a broader context, Oman lags behind other countries in the region in formally adopting international IWRM standards and targets. Oman has not developed a national plan that incorporates IWRM concepts and terminology, like Yemen's NWSSIP. Nevertheless, Oman has incorporated IWRM-like policies into its water management for decades. The Sultan's twenty-first National Day speech in November 1991 perhaps best indicates his integrated view of water management, including its importance to both regional and global security:

"Of all the gifts with which God has blessed us, water is the greatest…. If extravagance is forbidden by Islam, it is even more applicable to water. Indeed, Islam emphasizes in its teaching that it is our duty to conserve it. We cannot stress too strongly the need to observe the conservation measures laid down by Government in this respect. The use of this vital resource throughout the world can have a great impact on future development strategies, and indeed could become a decisive factor in political tension and thus, world security. Our Government has plans to increase our country's water resources to meet our national requirements without arduously affecting the demands of conservation."[99]

Oman's emphasis on maintaining traditional religious and cultural values as the country undertakes modernization efforts sets it apart, in its view, from other water-scarce states on the Arabian Peninsula. As the Sultan's speech indicates, modern water management and traditional values are not incompatible. Indeed, water conservation and equitable distribution are core values in Islam. The Qur'an stresses the importance of not wasting water, even when supplies are plentiful. It also teaches that water belongs to everyone and cannot be owned—of the three people Allah will ignore on the day of resurrection, one is the man who had more water than he could personally use and refused to share it with travelers. Further, the IWRM principle of involving all water stakeholders in decision-making is echoed in the Islamic principle of *shura*, which states that decisions that affect a community should be made through group consultation and consensus within the community, as well as by tribal norms of collective decision-making.[100] Oman's approach of integrating traditional values with sustainable water management techniques ought to be noted by policymakers, water managers, and environmental experts across the region.

Like Oman, other countries in the Middle East have used traditional principles to formulate approaches to water management. In 1978 Saudi Arabia's Council of Leading Islamic Scholars (CLIS) issued a *fatwa* on reused wastewater, to address water purity. Since in a water-poor country like Saudi Arabia treated wastewater represents an important water source, the *fatwa* stated, in part, that "impure wastewater can be considered as pure water and similar to the original pure water, if its treatment using advanced technical procedures is capable of removing its impurities with regard to taste, color, and smell, as witnessed by honest, specialized, and knowledgeable experts. Then it can be used to remove body impurities and for purifying, even for drinking."[101] Jordan has used Islamic principles in its IWRM-based public awareness campaigns about water conservation for years, a fact that was ignored in the fourth World Water Forum report acknowledging Jordan's success in implementing IWRM.

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[99] "Speech of His Majesty Sultan Qaboos bin Said on the occasion of the 21st National Day," 18 November 1991, at http://www.omanet.om/english/hmsq/royalspeechese/royalspeeches21.pdf.

[100] See Naser I. Faruqui, "Islam and Water Management: Overview and Principles," in *Water Management in Islam*, Naser I. Faruqui et al. eds. (Tokyo: United Nations University Press, 2001).

[101] Cited in Bahadar Nawab et al., "Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan," *Journal of Environmental Psychology* 26, no. 3 (2006).

Oman, Saudi Arabia, and Jordan provide examples of how traditional values and Islamic discourse can complement modern integrated water policies. Indeed, it is important not to use international IWRM standards exclusively when judging a country's progress in achieving integrated water management. In particular, Oman demonstrates the importance of examining a nontraditional security concern—such as water scarcity—from a perspective that takes into account how the resource is viewed within the context of that region's culture.

Conclusions and Recommendations[102]

Demographic trends, rapid urbanization, political uncertainty, and shifting climate patterns are collectively pushing the MENA region into uncharted territory for water resource management. The increasing competition for water resources in the face of significant population growth means that the possibilities for conflict over water are also elevated—among old adversaries and new water-using actors alike. But despite dire (and controversial) warnings about looming water wars in the MENA region and elsewhere, growing water scarcity also provides potentially productive pathways toward intrastate and interstate cooperation. With so many governments in flux across the MENA region, given the effects of the Arab Spring protests, cooperation on environmental security concerns—water access chief among them—could be an entryway to cooperation between countries in transformation.

Despite their considerable diversity, the MENA countries share many common water challenges. At the same time, these issues represent possible opportunities for knowledge-building and collaboration—both among sectors and stakeholders within countries, and across sectors and stakeholders between countries. Significant areas for prospective policy innovation, mutual capacity-building, sharing of data and best practices, joint benchmarking and standard setting, and technical cooperation include:

- *Prioritizing conservation and demand management, especially in the agricultural sector.* Annual water withdrawals exceed total annual renewable resources in nine of the twenty MENA countries considered in this report. In another three countries, annual withdrawals range from two-thirds to nine-tenths of renewable supplies. Yet in the world's most water-scarce region, water policies do little to contain demand and consumers receive little signal to conserve. (Across the Middle East and North Africa, water tariffs are estimated to cover just 35 percent of the average cost of supply.)[103] Instead, to meet the needs of growing populations over the past fifty years, countries planned and developed large-scale infrastructure programs to source, control, and deliver water. These projects—such as dams, desalination plants, and river diversions—focused almost entirely on the supply side of water management. While large supply-oriented projects were meant to alleviate conflicting demands, they can entail

[102] This section reflects the discussions of participants in the Working Group on Water Challenges and Cooperative Response in the Middle East and North Africa at the 2012 US-Islamic World Forum.

[103] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012; Hussein Abaza et al. eds., *Arab Environment 4. Green Economy: Sustainable Transition in a Changing Arab World* (Beirut: Arab Forum for Environment and Development, 2011), p.57.

significant environmental consequences and have often triggered domestic tensions among different water users and sectors as well as international frictions between states that share transboundary waters. They are also frequently more expensive than conservation and efficiency measures that can increase net water availability at net cost savings as well.[104] Refocusing from supply to demand-side strategies, marked water savings could be found in agriculture. Agriculture remains the dominant claimant on water use, accounting for 75 percent of total withdrawals on average across the MENA countries. Yet irrigation efficiencies are low, at 35-40 percent, and irrigation water losses are considerable for most of the region. Agriculture can also impact available water quantity indirectly via water quality, since pesticide and fertilizer runoff can contaminate surface and groundwater stocks, rendering them too polluted for some uses, and irrigation upstream can increase salinity for irrigators downstream.[105]

- *Mitigating unchecked groundwater pumping.* Many MENA countries are rapidly depleting their groundwater aquifers. Governments are often complicit in the act, as they tend not to charge agricultural and urban users for water withdrawals at the full cost of provision. On the contrary, all of the MENA countries pursue various policies that create perverse incentives for excessive groundwater overdrafts, such as subsidized credit for drilling wells, subsidized energy to fuel well pumps, and domestic price supports and external import barriers that favor agricultural products dependent on irrigation. These practices have led to abuse of the resource, highly inefficient usage, and unsustainable withdrawal rates that have placed many pockets of the MENA region on the verge of serious water shortages. In the short run, groundwater pumping supports livelihoods and economic activities that contribute to GDP. In the longer run, however, over-abstraction contributes to sharpened resource competition and depletes national assets. The World Bank estimates the lost wealth from excessive groundwater depletion equals 1.2 percent of GDP in Tunisia, 1.4 percent in Yemen, and 2.1 percent in Jordan.[106]

- *Recognizing the impact of ongoing urbanization and increasing urban water demands, and implementing water-management policies accordingly.* The MENA region is rapidly urbanizing, changing the way water resources are utilized by public and private interests. For example, according to the United Nations, Saudi Arabian cities experienced a 34-fold increase in population from 1950 to 2010, while the country's rural population barely doubled in the same time frame. During the same period in Egypt, rural populations grew by 213 percent, while urban populations swelled by 412 percent. In Syria, meanwhile, rural populations grew by 282 percent, while urban populations expanded by 986 percent.[107] Rapid urbanization is frequently outpacing the extension, operation, and maintenance of the attendant water and sanitation infrastructures. In an effort to ensure basic public goods to the poor, many municipal systems supply water to consumers at subsidized prices well below the cost of provision. Some 58 percent of utilities in the region apply tariffs too low to meet their operating and maintenance costs. But without adequate funding, utilities skimp on maintenance and defer network expansions, undermining service quality and reliability. The share of nonrevenue water—water that is pumped into the distribution system but then is either lost to leak-

[104] Fatma El-Gohary, *Incorporation of Environmental Dimension in Integrated Water Resources Management* (Cairo: UNDP Water Governance Program in the Arab States, March 2010); Water Resources Group, pp.8ff.

[105] FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012; Ayman F. Abou-Hadid, "Agricultural Water Management," in *Arab Environment: Water – Sustainable Management of a Scarce Resource*, Mohamed El-Ashry et al. eds. (Beirut: Arab Forum for Environment and Development, 2010), p.60.

[106] World Bank (2007), pp.13, 19-21.

[107] UN Population Division, *World Urbanization Prospects: The 2011 Revision*, at http://www.un.org/esa/population/, accessed 31 July 2012.

age or unauthorized consumption – amounts to about 25 percent in Casablanca and Rabat; 36 percent in Sana'a; 40 percent in Beirut; 50 percent in Algiers, Alexandria, and Cairo; and 60 percent in the West Bank. At the same time, citizens in urban areas who are unserved or underserved by utilities must seek out alternative sources, often paying private vendors for water at prices many times higher than the utility's tariffs.[108]

- *Building public and policymaker awareness of the prevalence and impacts of increasingly water-intensive lifestyles.* Public demands and attitudes toward water change with increasing prosperity. In the MENA region, the thriving Gulf states have some of the highest per capita domestic water consumption rates in the world—between 300 and 750 liters per person per day. (By comparison, the UNDP reports that the average per capita daily use in the United States is 575 liters, 200-300 liters in most European nations, and less than 50 liters in many sub-Saharan African states.)[109] Under business-as-usual scenarios, these rates are not sustainable. Yet sizable publics in many high-consumption countries—and beyond—do not consider water supply an important environmental problem. According to a 2006 regional opinion survey, 64 percent of respondents in Bahrain, 52 percent in Tunisia, 41 percent in Qatar, 35 percent in Oman and Kuwait, and 31 percent in UAE deemed water either not a major problem or not a problem at all. (Interestingly, across the Arab world, 71 percent of respondents judged that weak awareness of environmental problems itself poses a significant threat.)[110]

- *Pursuing research and development in desalination and wastewater reuse while appreciating that these technologies will not offer a panacea.* The MENA region is home to some 2800 plants producing 27 million cubic meters of freshwater a day (9.9 km^3/year). This represents about 38 percent of global desalination capacity, but just 3.2 percent of these countries' annual freshwater withdrawals.[111] Desalination can help mitigate certain water scarcity challenges such as domestic and industrial supply in coastal population centers. For deep-pocketed but water-scarce energy producers like Kuwait, Saudi Arabia, and the United Arab Emirates, the technology is hugely important. The revenues—and fuel—derived from their hydrocarbon resources allow them to pay for and power desalination facilities to meet demand for potable water. But the technology does not represent a silver bullet. Desalination is expensive. While production costs have fallen to about $0.5 per cubic meter of freshwater supplied in the most modern large-scale plants, typical market prices of $1-2/m^3 make desalination the priciest supply option in most circumstances. Desalination is also energy intensive. One quarter of Saudi oil and gas production now goes to power local electricity and water production, and Saudi officials anticipate that share will rise to 50 percent by 2030. Across the region, electricity demand for desalination is projected to triple by 2030. The practice also has environmental costs. Desalination and power plants generate 48 percent of the industrial effluent volume discharged into the Gulf each year.[112] Technical progress,

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[108] World Bank (2007), pp.85-87, 111, 157.

[109] Abaza et al., p.64; UNDP (2006), p.34.

[110] Mostafa K. Tolba and Najib Saab, "Arab Public Opinion & the Environment Conference: Report of 18-Country Survey," Beirut, 16-17 June 2006, at http://www.afedonline.org/en/inner.aspx?contentID=88.

[111] Mirei Isaka, *Water Desalination Using Renewable Technology*, IEA – ETSAP and IRENA Technology Brief 112 (Abu Dhabi: International Renewable Energy Agency, March 2012); FAO, AQUASTAT database, 2012, Food and Agriculture Organization of the United Nations (FAO), accessed on 30 July 2012. The figures reflect the MENA regional designation employed by the International Energy Agency, which includes the 20 countries and territories in this report minus Palestine, Sudan, and Turkey.

[112] Isaka, p.13; Bushnak, p.131; Mahmoud Khamis El Sayyed, "Marine Environment," in *Arab Environment: Future Challenges*, Mostafa K. Tolba and Najib W. Saab eds. (Beirut: Arab Forum for Environment and Development, 2008), p.85.

especially in the use of renewable energy to run desalination plants, will help alleviate some of these problems. But such advances largely remain in the early development stages, while the current production costs for various renewable alternatives range from a daunting $1.3-6.5/m^3$ for solar stills to a prohibitive $10.4-19.5/m^3$ for solar membrane distillation. Even as these prices fall, the projected growth of desalination will furnish but a fraction of rising demand and offset only a portion of potential shifts in availability due to global warming, while those countries most vulnerable to climate change are also those least able to afford desalination.[113]

In the years and decades ahead, it will be in the region's self-interest to pursue collaborative approaches to managing scarce water resources, at both the domestic level and regionally. These aims can be advanced through multiple strategies including, (1) sharing of technical data and policy learning from best water management practices, (2) strengthening networks of MENA water experts, (3) building broader and deeper cooperative relationships among MENA experts with water experts in other areas of the world, (4) demonstrating an awareness of cultural contexts and an openness to incorporating Islamic values and traditional knowledge to promote efficient and sustainable use of surface and groundwater resources, and (5) identifying and advancing intellectual and technical tools to foster greater transparency in water management, such as stakeholder dialogues and participatory consultations, joint research and field data collection and dissemination, regional-scale climate change modeling, and remote-sensing data.

Many of these strategies are explicitly knowledge intensive. The collection and dissemination of comprehensive, accurate hydro-meteorological information, basin and sub-basin water balances, groundwater mapping, and water-use data are essential for sustainable and equitable water-resource policymaking in general, and for transboundary rivers and aquifers in particular. Integrated Water Resource Management approaches rely and capitalize on participatory interactions between sectors and stakeholders at multiple levels to formulate, legitimate, and implement policy measures. To most effectively craft policy options, weigh policy choices, and execute policy interventions, decision-makers require an accurate—and broadly accepted if not completely uncontested—knowledge base to inform and orient their collective deliberations. At the moment, however, water data acquisition in the MENA region faces many challenges, including: inadequate coverage and poor maintenance of hydrometeorological networks due to insufficient funding and in some states poor governance in general; low human-resource capacity (at the professional as well as technical levels) within national hydrological services; incompatible water data and information systems among riparian states; and distrust of data monitoring and theft of monitoring equipment.

To promote and facilitate the establishment and maintenance of sustainable hydro-meteorological data and information systems, policy interventions should be implemented that develop public awareness programs regarding the importance of data sharing, strengthen national-level hydro-meteorological institutions, build scientific expertise at the professional and technical levels, and support the development of data dissemination systems across the MENA region. Water research and water science organizations in the Arab world now struggle with multiple burdens; they are too often underfunded, understaffed, usually unsupported by larger national science and technology policy agendas, and largely unconnected to national policy-making institutions or to the wider international research and policy communities. All of the MENA countries must work to improve their investment in and institutionalization of the science-policy con-

[113] Isaka, pp.14, 16; Khairy Al-Jamal and Manuel Shiffler, "Desalination Opportunities and Challenges in the Middle East and North Africa Region," in *Water in the Arab World: Management Perspectives and Innovations*, N. Vijay Jagannathan et al. eds. (Washington, DC: World Bank, 2009).

nection by 1) strengthening training and retention of qualified scientists and technicians; 2) forging the institutional environments necessary to support these researchers and advance their endeavors; and 3) building and sustaining the international networks necessary for MENA water researchers to draw on and contribute to each other and the global community in an increasingly interconnected world.[114]

"Research [and information] can contribute to better governance in at least three ways: by encouraging open inquiry and debate, by empowering people with the knowledge to hold governments accountable, and by enlarging the array of policy options and solutions available to the policy process."[115] Importantly, if undertaken collaboratively, such science capacity-building and diplomacy may help circumvent some of the potentially divisive political, religious, and cultural baggage that can accompany other forms of state-to-state interaction. Greater scientific exchanges across the region could fulfill many objectives by bolstering understanding and preparedness of current and future climate change impacts, and by establishing cooperative frameworks for jointly responding to changes in water availability.[116] Further, identifying knowledge gaps and bolstering communication about key water resources in the region—particularly transboundary sources such as the Nile and Tigris-Euphrates basins—could serve as important and relatively attainable confidence-building measures in the years ahead. If achieved, greater cooperation in the realm of water governance could spill over to increase transparency, accountability, and collaboration in other areas of national policy and bilateral and multilateral relations, to the benefit of the MENA region as a whole.

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[114] Hammou Laamrani and Abdin M.A. Salih, "Linking Water Research and Policy," in *Arab Environment: Water – Sustainable Management of a Scarce Resource*, Mohamed El-Ashry et al. eds. (Beirut: Arab Forum for Environment and Development, 2010); David Michel, Amit Pandya, and Corey Sobel, *Scientific, Intellectual, and Governance Cooperation on Emerging Environmental Challenges in the Muslim World* (Washington, DC: Brookings Institution, June 2010), pp.17ff.

[115] Laamrani and Salih, p.190.

[116] Jeannie Sowers et al., "Climate change, water resources, and the politics of adaptation in the Middle East and North Africa," *Climatic Change* 104, nos.3-4 (2011).

Country Name	GDP[I]	GDP per capita	Human Development Index 2011[II]	Population in 2010 (in thousands)	Population in 2050 (in thousands)[III]	Percentage of total population using improved drinking water sources, 2010[IV]	Percentage of total population using improved sanitation facilities, 2010	Total annual renewable water resources, 2010 (in 10^9 m^3/yr)[V]	Total annual water resources per capita, 2010 (in m^3/person/year)	Total annual water withdrawals, 2005 or most recent year (in 10^9 m^3/yr)	Total annual water withdrawals per capita, 2005 or most recent year (in m^3/person/year)	Projected total annual water demand (in 2041-2050) for average climate change scenario (in 10^9 m^3/yr)[VI]	Projected annual water shortage (in 2041-2050) for average climate change scenario (in 10^9 m^3/year)
Algeria	297,771,410,462	8,395	0.698	35,468	46,522	83	95	11.67	329	6.161 (in 2000)	195.9 (in 2000)	12.366	3.947
Bahrain	29,893,198,778	23,690	0.806	1,262	1,801	100 (urban pop.)	100 (urban pop.)	0.116	91.92	0.3574 (in 2003)	386 (in 2003)	0.391	0.383
Egypt	499,103,310,305	6,153	0.644	81,121	123,452	99	95	57.3	706.4	68.3 (in 2000)	973.3 (in 2000)	87.681	31.648
Iran	839,571,868,205	11,479	0.707	73,974	85,344	96	100	137.5	1859	93.3 (in 2004)	1306 (in 2004)	97.107	39.939
Iraq	113,579,971,204	3,546	0.573	31,672	83,357	79	73	75.61	2387	66 (in 2000)	2616 (in 2000)	83.803	54.860
Jordan	35,231,197,174	5,826	0.698	6,187	9,882	97	98	0.937	151.4	0.941	166	2.276	2.088
Kuwait	138,574,464,055	50,635	0.76	2,737	5,164	99	100	0.02	7.307	0.9132 (in 2002)	441.2 (in 2002)	1.216	0.801
Lebanon	59,207,841,311	14,005	0.739	4,228	4,678	100	98 (in 2005)	4.503	1065	1.31	316.8	1.869	0.891
Libya	105,554,599,321	16,855	0.76	6,355	8,773	54 (in 2001)	97	0.7	110.1	4.326 (in 2000)	796.1 (in 2000)	5.982	3.65
Morocco	152,376,781,883	4,691	0.582	31,951	39,200	83	70	29	907.6	12.61 (in 2000)	428.1 (in 2000)	24.223	15.414
Oman	75,841,259,966	27,257	0.705	2,782	3,740	89	99	1.4	503.2	1.321 (in 2003)	515.8 (in 2003)	1.709	1.143
Palestine	-	-	0.641	4,039	9,727	85	92	0.837	207.2	0.418	112.1	1.022	0.925
Qatar	136,247,051,447	77,466	0.831	1,759	2,612	100	100	0.058	32.97	0.444	376.9	0.395	0.246
Saudi Arabia	625,554,760,306	22,790	0.77	27,448	44,938	90 (in 1999)	-	2.4	87.44	23.67 (in 2006)	928.1 (in 2006)	26.633	20.208
Sudan	97,807,011,620	2,246	0.408	43,552	90,962	58	26	64.5	1481	37.14 (in 2000)	1037 (in 2000)		
Syria	107,583,894,070	5,262	0.632	20,411	33,051	90	95	16.8	823.1	16.76	867.4	21.337	7.111
Tunisia	99,617,685,500	9,443	0.698	10,481	12,649	94 (in 2009)	85 (in 2009)	4.595	438.4	2.85 (in 2001)	295.8 (in 2001)	4.452	0.837
Turkey	1,136,131,803,310	15,616	0.699	72,752	91,617	100	90	213.6	2936	40.1 (in 2003)	572.9 (in 2003)		
United Arab Emirates	353,094,699,912	47,006	0.846	7,512	12,152	100	98	0.15	19.97	3.998	739.5	3.389	3.189
Yemen	63,346,789,378	2,634	0.462	24,053	61,577	55	53	2.1	87.31	3.565	162.4	12.889	8.449

I. GDP converted to current international dollars for 2010 (2009 for Iran, Libya) using purchasing power parity rates. Source : World Bank, World Development Indicators.

II. The Human Development Index (HDI) is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: a long and healthy life (health), access to knowledge (education) and a decent standard of living (income). Data availability determines HDI country coverage. To enable cross-country comparisons, the HDI is, to the extent possible, calculated based on data from leading international data agencies and other credible data sources available at the time of writing. Source: UNDP, Human Development Report 2011.

III. Source: UN World Population Prospects, the 2010 Revision. Population growth estimates based on the medium-fertility variant.

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

V. Source: FAO, AQUASTAT database.

VI. Source: P. Droogers et al., "Water resources trends in Middle East and North Africa towards 2050," Hydrology and Earth Systems Sciences 16, no.9 (2012).

About the Brookings Project on U.S. Relations with the Islamic World

The Project on U.S. Relations with the Islamic World is a major research program housed within the Saban Center for Middle East Policy at the Brookings Institution. The project conducts high-quality public policy research, and convenes policy makers and opinion leaders on the major issues surrounding the relationship between the United States and the Muslim world. The Project seeks to engage and inform policymakers, practitioners, and the broader public on developments in Muslim countries and communities, and the nature of their relationship with the United States. Together with the affiliated Brookings Doha Center in Qatar, it sponsors a range of events, initiatives, research projects, and publications designed to educate, encourage frank dialogue, and build positive partnerships between the United States and the Muslim world. The Project has several interlocking components:

- The U.S.-Islamic World Forum, which brings together key leaders in the fields of politics, business, media, academia, and civil society from across the Muslim world and the United States, for much needed discussion and dialogue;
- A Visiting Fellows program, for scholars and journalists from the Muslim world to spend time researching and writing at Brookings in order to inform U.S. policy makers on key issues facing Muslim states and communities;
- A series of Brookings Analysis Papers and Monographs that provide needed analysis of the vital issues of joint concern between the U.S. and the Muslim world;
- An Arts and Culture Initiative, which seeks to develop a better understanding of how arts and cultural leaders and organizations can increase understanding between the United States and the global Muslim community;
- A Science and Technology Initiative, which examines the role cooperative science and technology programs involving the U.S. and Muslim world can play in responding to regional development and education needs, as well as fostering positive relations;
- A Faith Leaders Initiative which brings together representatives of the major Abrahamic faiths from the United States and the Muslim world to discuss actionable programs for bridging the religious divide;
- A Brookings Institution Press Book Series, which aims to synthesize the project's findings for public dissemination.

The underlying goal of the Project is to continue the Brookings Institution's original mandate to serve as a bridge between scholarship and public policy. It seeks to bring new knowledge to the attention of decision-makers and opinion-leaders, as well as afford scholars, analysts, and the public a better insight into policy issues. The Project is supported through the generosity of a range of sponsors including the Government of the State of Qatar, The Ford Foundation, The Doris Duke Charitable Foundation, and the Carnegie Corporation.

The Project Conveners are Stephen R. Grand, Fellow and Director of the Project on U.S. Relations with the Islamic World; Martin Indyk, Vice President and Director of Foreign Policy Studies; Tamara Cofman Wittes, Senior Fellow in and Director of the Saban Center; Kenneth Pollack, Senior Fellow in the Saban Center; Bruce Riedel, Senior Fellow in the Saban Center; Shibley Telhami, Nonresident Senior Fellow in the Saban Center and Anwar Sadat Chair for Peace and Development at the University of Maryland; and Salman Shaikh, Fellow in and Director of the Brookings Doha Center.

About the Saban Center for Middle East Policy at Brookings

THE SABAN CENTER FOR MIDDLE EAST POLICY was established on May 13, 2002 with an inaugural address by His Majesty King Abdullah II of Jordan. The creation of the Saban Center reflects the Brookings Institution's commitment to expand dramatically its research and analysis of Middle East policy issues at a time when the region has come to dominate the U.S. foreign policy agenda.

The Saban Center provides Washington policymakers with balanced, objective, in-depth and timely research and policy analysis from experienced and knowledgeable scholars who can bring fresh perspectives to bear on the critical problems of the Middle East. The center upholds the Brookings tradition of being open to a broad range of views. The Saban Center's central objective is to advance understanding of developments in the Middle East through policy-relevant scholarship and debate.

The center's foundation was made possible by a generous grant from Haim and Cheryl Saban of Los Angeles. Ambassador Martin S. Indyk, Vice President of Foreign Policy at Brookings, was the founding Director of the Saban Center. Tamara Cofman Wittes is the center's Director. Within the Saban Center is a core group of Middle East experts who conduct original research and develop innovative programs to promote a better understanding of the policy choices facing American decision makers. They include Daniel Byman, a Middle East terrorism expert from Georgetown University, who is the center's Director of Research; Kenneth M. Pollack, an expert on national security, military affairs and the Persian Gulf; Bruce Riedel, a specialist on counterterrorism; Suzanne Maloney who focuses on Iran and economic development; Michael Doran, a specialist in Middle East security issues; Khaled Elgindy, an expert on the Arab-Israeli conflict; Natan Sachs, an expert on Israeli domestic politics and the Arab-Israeli conflict; Stephen R. Grand, Fellow and Director of the Project on U.S. Relations with the Islamic World; Salman Shaikh, Fellow and Director of the Brookings Doha Center; Ibrahim Sharqieh, Fellow and Deputy Director of the Brookings Doha Center; Shadi Hamid, Fellow and Director of Research of the Brookings Doha Center; and Shibley Telhami, who holds the Sadat Chair at the University of Maryland. The center is located in the Foreign Policy Studies Program at Brookings.

The Saban Center is undertaking path breaking research in five areas: the implications of regime change in Iraq, including post-war nation-building and Gulf security; the dynamics of Iranian domestic politics and the threat of nuclear proliferation; mechanisms and requirements for a two-state solution to the Israeli-Palestinian conflict; policy for the war against terrorism, including the continuing challenge of state sponsorship of terrorism; and political and economic change in the Arab world, and the methods required to promote democratization.

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