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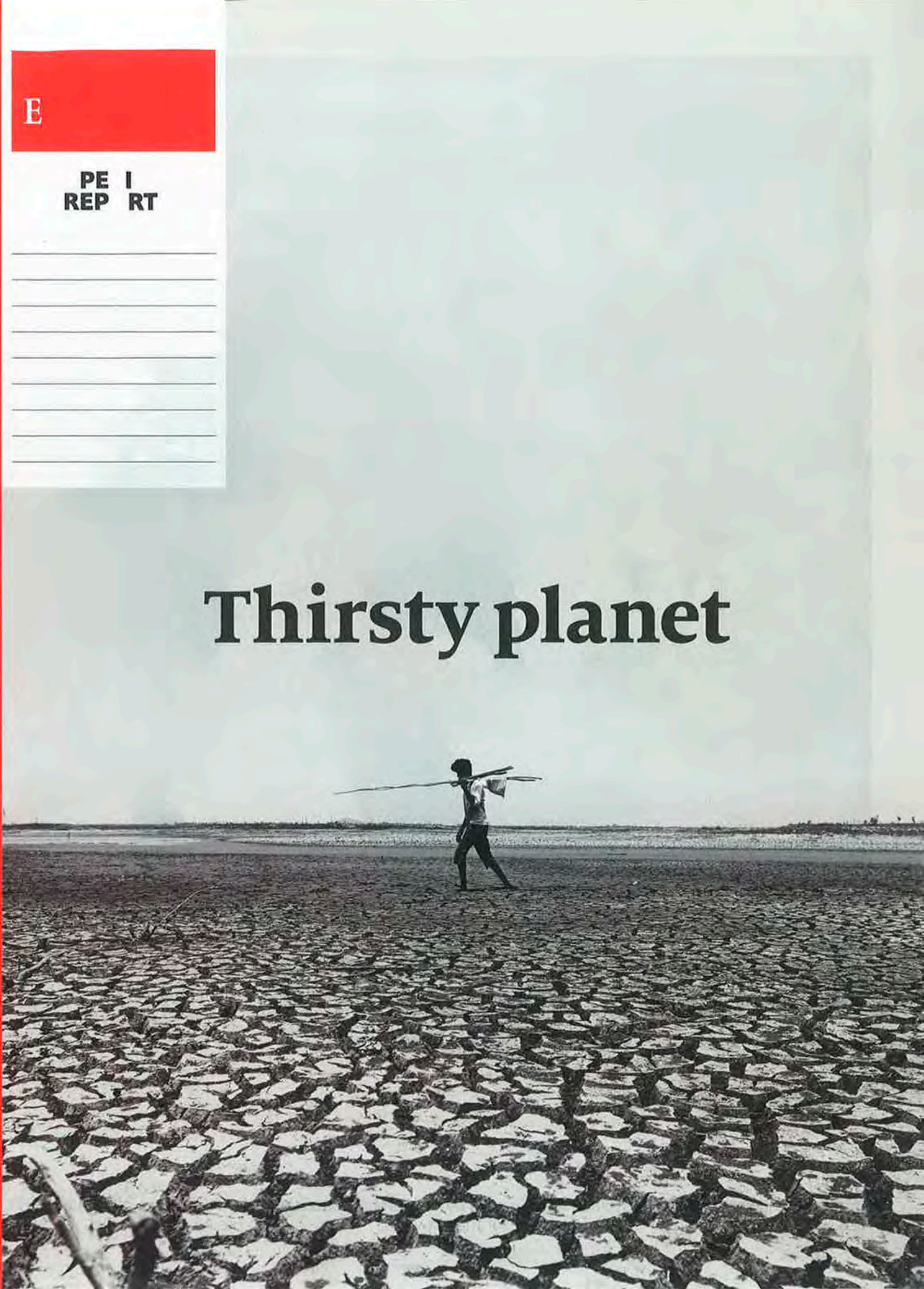
Thirsty planet



Thirsty planet

Climate change and population growth make the world's water woes more urgent, says Simon Long

As it scours the universe for signs of extraterrestrial life, NASA has a motto-cum-mission-statement: "Follow the water". About 70% of the human body is made up of water, it says, and 70% of Earth's surface is covered in the stuff. "Water creates an environment that sustains and nurtures plants, animals and humans, making Earth a perfect match for life in general."

If water is a proxy for life itself, it is perhaps not surprising that worries about the health and availability of supplies here on Earth can take on apocalyptic overtones. A scorching, arid future marked by a fierce, bloody struggle for a few drops of water is a standard theme of dystopian fiction and film-making. This report will examine how close such nightmares are to reality. It will look at the state of the world's freshwater and at the increasing demands on it, and consider the ways they can be met.

The first thing to recognise is that the 70% figure is largely irrelevant to the debate. The sea it represents is salty, accounting for 97.5% of all the water on Earth. A further 1.75% is frozen, at the poles, in glaciers or in permafrost. So the world has to rely on just 0.75% of the planet's available water, almost all of which is subterranean groundwater, though it is from the 0.3% on the surface that it draws 59% of its needs (see chart on next page). This report will argue that misuse of water may indeed lead to a series of catastrophes. But the means to dodge them are already known, and new technologies are constantly evolving to help.

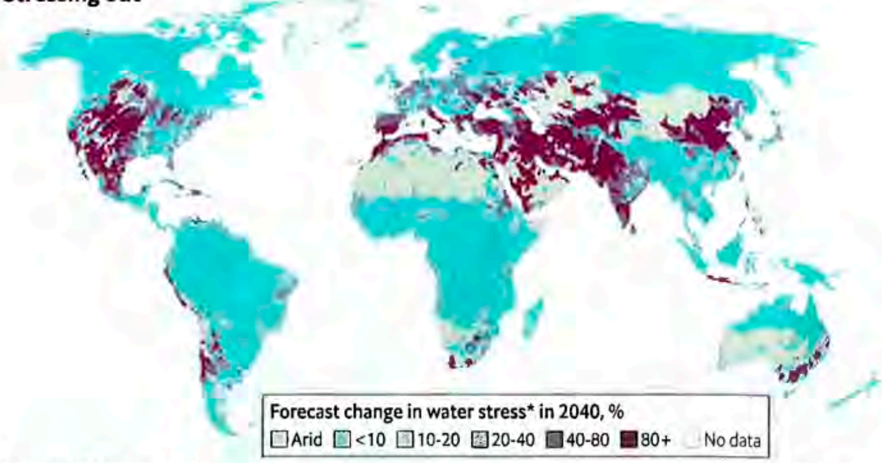
The fundamental problems, however, are neither the resource itself, since water is likely to remain abundant enough even for a more populous Earth, nor technical. They are managerial, or, more precisely, how to withstand economic, cultural and political pressures to mismanage water. In the harsh words of Asit Biswas, a water expert at the Lee Kuan Yew School of Public Policy in Singapore: "Lack of money, scarcity, and so on—they're all excuses. The problem everywhere is bad management." Or, as Jean-Claude Juncker, president of the European Commission, put it in an entirely different context: "We all know what to do, we just don't know how to get re-elected after we've done it."

Even governments not facing the vexatious business of winning over voters struggle to institute sensible water policies. People regard access to water as a fundamental human right and hence as something that should be available on the basis of need, rather than the ability or willingness to pay. That makes it hard to charge a proper price for it, which in turn encourages profligate use. Even those who would be willing to curb their consumption for the benefit of generations to come may not be aware how much they are using. They consume it mostly not through drinking or washing, but through the water that has gone into the food they eat and the clothes they wear.

In any event, water seems an infinitely renewable resource. Used in a bath, it can be reused—to water plants, for example. Rainwater can be "harvested" or may seep into the ground to replenish an aquifer. Water that evaporates from lakes, swimming pools and reservoirs, or "transpires" in the photosynthetic process whereby water passes into the leaves of plants, joins the atmosphere and will eventually be recycled. Over 60% of the rain and snow that falls is returned in this way through "evapotranspiration". But, like water that has run into the sea, it cannot be used again until nature has recycled it.

The present-day world provides ample examples of environmental devastation that serve as a warning that water usage has its ▸▸

Stressing out



Source: World Resources Institute

*The ratio of water withdrawal to supply

natural limits. Boats are stranded aground in the middle of nowhere, amid the vanished waters of what was once the world's fourth-largest saline lake, the Aral Sea, between Uzbekistan and Kazakhstan. Last year Cape Town in South Africa averted only narrowly the unwanted prize for being the first of the world's big cities to run out of water. By the time rain finally broke a three-year drought, water levels in the reservoirs supplying the city had fallen to below 20%, and officials were discussing the feasibility of towing an iceberg from Antarctica to provide meltwater to drink. Four years earlier, it had been São Paulo in Brazil that had teetered on the brink, with reservoirs reduced to 5% of capacity.

Even the sober assessment of the UN's latest annual world "water development report" smacks of a kind of desperation. Already, it notes, more than a quarter of humanity—1.9bn people, with 73% of them in Asia—live in areas where water is potentially severely scarce (up, other studies suggest, from 240m, or 14% of the world's population, a century ago). The number facing shortages almost doubles if you count those at risk at least one month a year. Meanwhile, global water use is six times greater than it was a century ago—and is expected to increase by another 20-50% by 2050. The volume of water used—about 4,600 cubic kilometres a year—is already near the maximum that can be sustained without supplies shrinking dangerously. A third of the world's biggest groundwater systems are in danger of drying out. So the numbers living under severe water stress are expected to climb to as many as 3.2bn by 2050, or 5.7bn taking seasonal variation into account. And they will not just be in poor countries (see map). Australia, Italy, Spain and even America will endure severe water shortage.

Three main factors will drive the continued growth in demand: population, prosperity and climate change. In 2050 the number of people in the world is expected to increase to between 9.4bn and 10.2bn, from just under 8bn now. Most of the increase will come in parts of the world, in Africa and Asia, that are already short of water. People will be leading more water-intensive lifestyles and move into cities, many of them in places at great risk of water shortage.

The biggest uncertainty in projecting future demand lies in estimating how much will be needed for agriculture, which currently accounts for about 70% of water withdrawals, mostly for irrigation. Some forecast a big increase in demand, as food production has to rise to feed a growing population. Others, such as the OECD, have predicted a small decline in water use in irrigation thanks to a reduction in wastage and a rise in productivity.

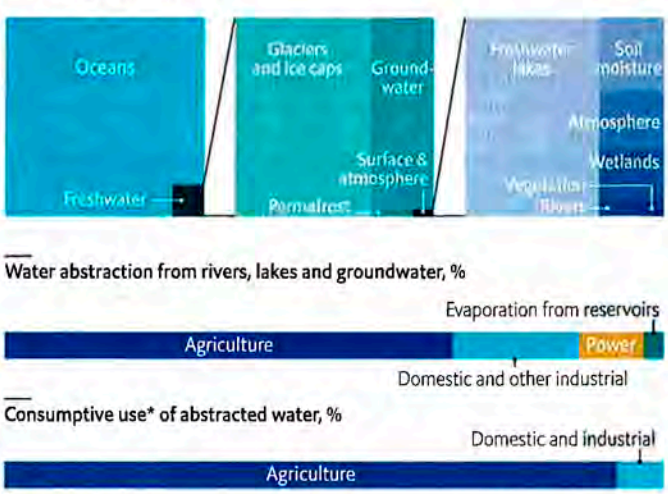
Still less predictable is the impact of climate change. The scientific consensus.is that, in the words of Henk Ovink, the Dutch government's special envoy on water matters, the process will be "like a giant magnifying glass, making all our challenges more extreme". Wet places will become wetter and dry places drier. The world's water endowment is already highly unequal—just nine countries account for 60% of all available fresh supplies. China and India have about 36% of the world's people, but only about 11% of its freshwater. Climate change will exacerbate this inequity. And rainfall, such as the South Asian monsoons, on which much of subcontinental economic life hinges, will become more erratic.

The most dramatic short-term effects have been the increasing number of extreme weather events. Over the past two decades these have affected on average about 300m people every year. Last September's almost simultaneous storms—Hurricane Florence in the east of America, and super-Typhoon Mangkhut in East Asia—were linked by scientists to rising levels of greenhouse gases, warming oceans and changing climate. Measurements of sea temperatures down to 2,000 metres show a steady rise since the 1950s, to new records. Climate models have long forecast that warmer oceans will lead to more intense, longer-lasting storms. The rising temperatures are accompanied by rising sea levels—at a rate of about 3mm a year—as the warmer water expands, and as ice at both poles melts. Higher seas bring storm surges that can reach farther inland. And warmer air temperatures mean the atmosphere can hold more moisture that eventually falls as precipitation.

In the long run, however, the bigger problem from climate change will not be too much water but too little. As a report by the World Bank puts it: "The impacts of water scarcity and drought may be even greater, causing long-term harm in ways that are poorly understood and inadequately documented." Of course, a lot depends on how much the climate changes and how fast. ▸▸

Mostly salt

Global water resources, %



Source: World Bank

*Water unavailable for further use in the system

Last October the Intergovernmental Panel on Climate Change published a report comparing the consequences of restraining global temperature rises to 1.5°C above pre-industrial levels as opposed to 2°C. It concluded "with medium confidence" that, with a 2°C rise, an additional 8% of the world's population in 2000 will be exposed to new or aggravated water scarcity by 2050. With a 1.5°C rise, that falls to 4%. There would be considerable regional variation. For example, it cited research showing that, in the Mediterranean region, a 1.5°C rise in temperatures would lead to statistically insignificant changes in the mean annual flow in its rivers and streams. A 2°C rise, however, would bring decreases of 10-30%.

Decreasing streamflow is a worldwide phenomenon. Some of it results from declining rainfall. But much is the direct result of human intervention—the damming and diversion of rivers for flood control, water-storage and irrigation. And, where rivers still flow, the water in them is often unsafe to drink or even bathe in. In surveying the Earth, surface water is an obvious place to start. As throughout this report, examples will be drawn worldwide, but especially from two countries with very contrasting experiences: Israel, which is sometimes held up as a model of sensible water management; and India, which almost never is. ■

Rivers and lakes

Surface tension

Poisoned and over-exploited, many rivers are in a parlous state

THE RIVER VIEW HOTEL on the banks of the Yamuna river at Okhla, on the outskirts of Delhi, lives up to its name. But the view is not uplifting. Rubbish is strewn along the water's edge. As elsewhere in India, industrial pollution, untreated sewage and the still widespread practice of open defecation make this stretch of the Yamuna a toxic soup teeming with bacterial infection. According to India's Central Pollution Control Board (CPCB), in 2016 the water contained at times 1.6bn faecal coliform bacteria per 100ml—more than 3m times the CPCB's "desirable" bathing limit of 500 per 100ml.

About 600km (373 miles) downstream from Okhla the sacred Yamuna joins an even holier river, the Ganges, or Ganga, at Prayagraj (formerly Allahabad), site from January to March this year of the six-yearly *kumbh*, a Hindu festival that is expecting 150m devotees—perhaps the largest human gathering ever held anywhere. They have waited for days for the chance to cleanse their souls, if not their bodies, by taking a short dip (limited to 41 seconds, in an effort to avert stampedes) in the blessed waters. The river there is considerably less toxic. In December the CPCB ordered state governments to stop "grossly polluting units"—distilleries, paper mills and textile factories—discharging effluent into the river. The Tehri dam upstream released more water to ensure it flowed just fast enough to wash away sins but not sinners.

Even farther downstream, the Ganges reaches Varanasi, Hinduism's holiest city and the parliamentary constituency of India's Hindu-nationalist prime minister, Narendra Modi. Year-round, devotees visit to bathe or drink the waters, or to cremate their dead on the ghats, the series of broad stone staircases that line the southern bank. One of Mr Modi's first and most fervent pledges in office was to clean up the Ganges, to ensure its "purity and uninterrupted flow". He renamed the Ministry of Water Resources by adding to its title "River Development and Ganga Rejuvenation".

But the water remains polluted and dangerous to health, and the Ganges' flow is weakening, in part because of the hydroelectric dams on its upper reaches. A study in 2018 found its flow in some stretches may have fallen by 50% since the 1970s. Climate change has actually encouraged the damming of the river. By one reckoning about 70% of the Ganges' flow is contributed by meltwater from the Himalayan glaciers from where it springs. Engineers had assumed that, as temperatures rise, more ice would melt, increasing the river's flow and hence its hydroelectric potential. In fact, it has declined in the past few years, because the aquifers supplying Himalayan rivers have been shrinking as winter precipitation drops. In the long run, however, the fate of the glaciers might doom the great rivers. A study published in February by the International Centre for Integrated Mountain Development, a think-tank in Nepal, warned that even on relatively benign forecasts of global warming, more than a third of Himalayan glaciers will have melted by 2100, with river flows declining from the 2060s.

The state of the holy river is worth dwelling on. Some 400m people—5% of humanity—live on its plains. But it may also be the most powerful symbol anywhere of the sheer difficulty of managing freshwater supplies. As Victor Mallet, a British journalist, asks in his book on the Ganges, "River of Life, River of Death", "Why do Indians and their governments tolerate for even a week the over-exploitation of their holy river—sometimes to the point of total dehydration—by irrigation dams and its poisoning by human waste and industrial toxins?" After five years of government under Mr Modi, that question remains unanswered.

The clean-up effort has two main elements. The first involves a nationwide campaign, known as *swachh bharat* (clean India) to end open defecation, in which India in 2014 led the world, with ▸▸

Anyone for a dip?

600m open defecators out of a global total of 1bn. Thanks to subsidies for the construction of 92m toilets (mostly simple twin-pit arrangements that turn faecal sludge into harmless compost), the government says the "ODF" (open-defecation free) rate has risen from 39% in 2014 to 99% now. Many scoff at such hyperbole, but, at the very least, in many places to venture at dawn through the Indian countryside is no longer to intrude on a mass latrine.

The second aim, building treatment plants, has been beset by disagreements over the design of the scheme. Private companies are to bid for treatment contracts, with payment partly based on sensors tracking the water they produce. They are handicapped by the lack of sewers in much of India, so in many cases they will have to block discharges with weirs to divert them for treatment.

If such a sacred source is so hard to rescue, what hope for other ravaged rivers and lakes, in India and elsewhere? For his book "When the Rivers Run Dry", published in 2006 and recently updated, Fred Pearce, a British writer, visited dozens of countries around the world and writes of river after river under seemingly life-threatening stress. Three of the rivers have, since Mr Pearce's first visit, become test-cases for different approaches to solving surface-water problems: large-scale infrastructure to bring water from elsewhere; flow-management through digital monitoring; and the use of economic levers.

India in 2014 had 600m open defecators out of a global total of 1bn

In Israel, the state of its famous sources of surface water—the River Jordan and the Sea of Galilee (in fact, a freshwater lake)—is also a national preoccupation. After five years of its worst drought in nearly a century, the level of the Sea had sunk late last year to alarming levels. Heavy rains in December and January ended the crisis, but Israel's supply of natural freshwater remains precarious, according to Uri Schor of Israel's water authority.

For much of Israel's history, Galilee supplied most of its drinking water. Under the British mandate over Palestine, economists used to worry that immigration into the territory would overwhelm its available water resources. In 1939, 834,000 people lived there. The upper limit was seen as 2m. Israel now has 8.7m inhabitants, with another 5m people living in the occupied territories. They no longer rely on the Sea of Galilee for water. More than half the water Israel uses is man-made, from desalinated seawater (see page 8) and treated effluent. So during the drought the 400m cubic metres that used to be pumped annually from the Sea was cut, to less than 70m in 2018. Now Israel plans to replenish it with desali-

Water fights

Disputes over water will be an increasing source of international tension

IT HAS BECOME a cliché of doom-mongering: future wars will be over water. The forecast is old enough to face a sceptical backlash. Whatever happened, people ask, to the water wars? One answer emphasises the role water has played in past conflicts. In his autobiography, Ariel Sharon, who before becoming Israel's prime minister had been a commander in the six-day war of 1967, wrote that it "really started on the day Israel decided to act against the diversion of the Jordan...The matter of water diversion was a stark issue of life and death."

Another answer is that, though many conflicts involve water, it is rarely their sole motivation. That will remain true. But it also seems likely that water will be an aspect of ever more conflicts. A chronology maintained by the Pacific Institute, a think-tank in Oakland, California, of water-linked conflicts, shows a startling increase in their number in just the past few years (see chart).

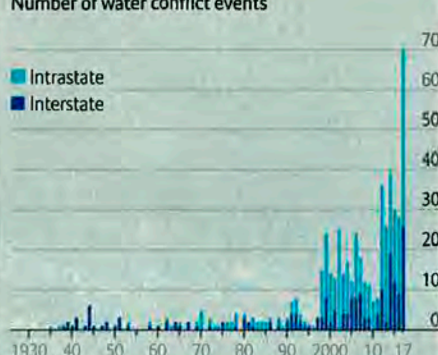
The institute distinguishes between three types of violence. Sometimes water itself can be used as a weapon, as when China in 1938 breached dykes along the Yellow River to repel the Japanese army, or, just last year al-Shabaab, a terrorist group, diverted water from the Jubba river in Somalia, causing a flood that forced opposing forces to move to higher ground where they were ambushed.

Sometimes water is the trigger, as last year when conflicts over pasture land and water led to violence in both northern Kenya, and central Nigeria, where 11 people were killed in an attack by Fulani herdsmen on a farming community. Finally, water installations can also be the target of military action, as in 2006 when Hezbollah rockets damaged a wastewater plant in Israel, which mounted retaliatory attacks on water facilities in Lebanon. Last year, during ethnic strife in the populous Oromia region of Ethiopia, dozens of water systems were attacked.

Most water conflicts will be sub-national disputes. But transboundary tensions are also likely to intensify. A study last year by the Joint Research Centre, a think-tank under the European Commission, used computer modelling to rank the rivers where these are most likely to flare up. Its scientists listed five: the Nile, Ganges-Brahmaputra, Indus, Tigris-Euphrates and Colorado.

Controlling the sauce

Number of water conflict events



Source: P. Gleick, Pacific Institute, Water Conflict Chronology, 2018

In all these instances, downstream nations fear or resent the effect on their waters of the actions of upstream countries. Egypt worries about the Grand Renaissance Dam that Ethiopia is building on the Blue Nile, about 40km from the Sudanese border. India and Bangladesh fear that China's water-diversion ambitions might one day turn towards the Brahmaputra as a source for China's thirsty north. South-East Asian nations are concerned, too. Pakistan and India, in turn, squabble over the treaty they concluded in 1960 (to which the World Bank was also a signatory) on sharing the waters of the Indus.

In contrast, no treaty regulates the Tigris and Euphrates rivers where dam construction in Turkey has reduced flow in Iraq and Syria. The Colorado river is shared by seven US states and two in Mexico. After a 19-year drought, water flow has dropped by nearly 20%. In Mexico, the river that created the Grand Canyon and fed a vast marshy delta has, for two decades, been almost completely dry.

nated water so it will form a strategic water reserve.

For now, though, the Sea of Galilee is probably more important to tourists and pilgrims. They can also survey the River Jordan, which runs south into the Dead Sea, the fast-evaporating saltwater lake at Earth's lowest point on dry land (430 metres below sea-level). The Jordan has long disappointed visitors expecting to see the "deep and wide" waterway from which Michael rowed his boat ashore. In places it can be crossed with a standing jump.

The Yellow River in China, the world's seventh-longest at 5,500km, now counts as a success story. It gets its colour, and name, from the loess-soil sediment it carries downstream. Its fertile basin was the cradle of Chinese civilisation and, in an epithet often given the river, its "sorrow". A build-up of sediment changed the river's course 26 times before 1949. But the sediment also raises the river above the surrounding plains, so that it has to be contained by dykes. Often it has flooded, catastrophically. The risk of floods remains, but a massive dam at Xiaolangdi in Henan province enables engineers to release water to flush the sediment downstream, reducing the danger.

By 2015 this system had also more than doubled the channel's capacity. But it was still only two-thirds what it had been 50 years before. Indeed, in recent years the river's drying out has been as big a concern as its flooding. By 1997 it was so overused that it only reached the sea 139 days in the year. At that stage 40% of its waters were too polluted even for irrigation. The quality has much improved but by 2017 water in one-tenth of samples taken from the Yellow River was still deemed unfit for farming. Since then digital centralised controls over the release of water from dams have been introduced. Billed as the world's most advanced water-rationing system, this has kept the flow to the sea uninterrupted. Environmentalists, however, complain that the dams have harmed the river's ecosystem, and that pressure has shifted from the river itself to its increasingly polluted tributaries and underground aquifers, which are shrinking alarmingly.

In Australia, the Murray river, with its main tributary, the Darling (known as the Murray-Darling basin), drains one-seventh of the country, a region the size of France and Spain combined. It irrigates farms, and supplies cities in the east. When Mr Pearce visited the region in 2006 drought had already lasted more than a decade, yet he was shocked to find local farmers insouciant about squandering water, using wasteful flood irrigation, for example, when the water was available. Since the 1970s enormous farms growing thirsty crops such as cotton and nuts had spread across the basin.

That disastrous drought prompted government action to restore the river—if not to its heyday, when paddle-steamers plied it, then at least to levels where it could sustain the farms and people that rely on it. Australia already had an elaborate system for trading water rights, allowing farmers to buy or sell entitlements according to their need in any given season. An index compiled by Aither, a consultancy, tracks a weighted price for these entitlements in the Murray-Darling basin, and showed a 96.1% rise in the ten years from July 2008. The government's plan aimed to reduce water consumption by at least 2.75 cubic km a year, or about a fifth, either by purchasing water licences from farmers who were willing to offload them, or by financing projects that would save water (eg, through more efficient irrigation).

Water usage was cut by two-thirds of this target, recovering 2.1 cubic km of the surface water. In 2016 the state of South Australia saw its highest flows since 1993. Yet by last year the river was again low, with hundreds of kilometres running dry, entitlement prices rising fast and fish dying in huge numbers. Scientists concluded the basin as a whole was yet to show real improvement. ■

In places, the River Jordan can be crossed with a standing jump

Groundwater

Subterranean blues

Underground water has helped feed the world, but in many places it is dangerously depleted

IN 2004, WHEN Danmanti Devi was four years old, her mother took her to see a doctor because of pains in her legs. The doctor wrongly diagnosed polio. He could do no more than prescribe painkillers. Danmanti's legs are now deformed. Many others in Churaman Nagar, her 140-household hamlet of mud huts and a few "pukka" brick houses in rural Bihar, one of India's poorest states, also hobble on the knock knees or bow legs characteristic of a condition known as skeletal fluorosis. She is one of millions of Indians to suffer this, and to have contracted it merely from drinking water containing dangerous levels of fluoride. She is a victim of the over-exploitation of India's groundwater.

Fluoride, like arsenic, is present naturally in groundwater. It is harmless (or even beneficial) in small concentrations. The World Health Organisation (WHO) suggests a limit of 1.5 milligrams per litre. In Churaman Nagar, the water that comes from standpipes overseen by the local *panchayat* (village council) has 16mg.

The hamlet's inhabitants are among India's most downtrodden. They are *dalits*, once called "untouchables", at the bottom of the Hindu caste system. They eke a living as wage labourers in nearby brick kilns or by distilling moonshine.

In being poisoned by their drinking water, however, they are sadly typical. The most obvious danger—bacterial pollution—is a "second-order problem", says V.K. Madhavan, chief executive in India for WaterAid, a British charity. More fundamental is contamination by arsenic, nitrates, salinity and fluoride. Some of this is natural, some a consequence of industrial effluent, and of seepage from landfills, septic tanks, leaky underground gas tanks and the overuse of fertilisers and pesticides. But the most intractable difficulty is the pumping of groundwater from ever deeper below the surface. The deeper the water, the more likely it is to be contaminated by chemicals such as arsenic seeping downwards.

As long ago as 2002, the WHO called the effects of arsenic con- ▸▸

tamination of groundwater in Bangladesh "the largest mass poisoning of a population in history". Tens of millions are at risk in neighbouring India, too. Efforts to save people from the bacterial diseases carried by surface water leave them condemned to longer-term dangers hidden in the groundwater. Arsenic has been linked to cancers of the skin, gallbladder and lungs.

In the scheme of things, the extraction of groundwater for drinking and bathing by India's poor, like those in Churaman Nagar, is a minor cause of its over-exploitation. Far more important is irrigation. Almost 60% of India's irrigation needs are now met from groundwater. The Green Revolution which, in the 1970s, transformed India's ability to feed itself and turned it into a big food exporter, relied on tube wells, powered by electric pumps.

It also turned India into the world's biggest extractor of groundwater. The five largest such users, which include America, China, Iran and Pakistan, account for 67% of total extractions worldwide. In India, the water is free. A law from 1882 gives every landowner the right to collect and dispose of all water on and under his land. The cost of the electricity needed to pump it ever farther to the surface is one constraint. But Indian politicians love to lavish cheap or free electricity on rural voters when elections loom (as, in India, they often do). The Green Revolution saw agriculture's share of total energy use climb from 10% in 1970 to 30% by 1995.

This freed many farmers from the fickle monsoon—India usually receives more than 70% of its annual rainfall in the annual downpours from June to September. In Churaman Nagar, and elsewhere in Bihar, residents believe the rains are weaker than they were, though scientists have so far measured only a tiny decline in the rains in recent years.

In India and elsewhere the easy availability of groundwater has encouraged the cultivation of thirsty crops in water-stressed areas. Starting under British rule, irrigation canals and groundwater-extraction turned the arid lands of Punjab into India's agricultural powerhouse. Similarly, in China, the dry plains of the north-east now produce 60% of the country's wheat and 40% of its maize on an area with 4% of its water resources.

As Sunil Amrith, a historian at Harvard University, notes in his new book, "Unruly Waters", the half-century since the 1960s has reversed a centuries-old pattern in which agrarian wealth lay where rains were most abundant. Instead, Israel, Punjab and Manchuria have actually become net exporters of water, if you include what hydrologists call "virtual" water used in the production of a crop or good. In other words, they sell more water in the form of crops and products than they import in that form or extract from their own sources of water. Mr Amrith notes the "most bitter of ironies" in this agricultural miracle: intensified production means that more land is planted with crops, which reflect more solar radiation than forests. The land becomes cooler, weakening the temperature differences with the sea that drive the circulation of the monsoon. So measures taken to protect farmers from the vagaries of the monsoon have in fact themselves helped make the rains more fickle.

This phenomenon is not confined to India. Across the world, the need for more food production encourages deforestation and the use of more land for agriculture. That in turn will increase demand for irrigation which, as precipitation becomes more erratic and surface water is over-used, will probably rely ever more on groundwater. The long-term impact of this is uncertain. Research led by Mark Cuthbert, of the School of Earth and Ocean Sciences at Cardiff University, found that groundwater systems are likely to take far longer fully to respond to differences induced by climate change than does surface water. Only half the world's groundwater flows are likely to find a new equilibrium within 100 years. The arid regions where water is scarce are often where response times are longest. So the full impact of withdrawals now may not be felt for decades, or much longer in some cases. ■

Desalination

Worth its salt?

Manufactured water can supplement the natural stuff, but never replace it

THE SOREK desalination plant, about 15km south of Tel Aviv, is eerily unpopulated. This is the largest such plant in the world, producing as much as 230m cubic metres of desalinated water a year—about one-fifth of Israel's domestic water supply. Yet only 20 staff are needed at any time to operate it. Seawater is piped in from over a kilometre out at sea. It is given a preliminary clean in a series of large tanks where it is filtered slowly through sandbeds before being pumped through "reverse osmosis" membranes (pictured).

These are based on a design first patented in the early 1960s by Sidney Loeb, an American scientist who moved to Israel and saw his invention eventually oust competing methods and become the dominant desalination technology not just in his new homeland, but around the world, accounting for 69% of the output of desalinated water. They certainly seem effective. The water is absolutely tasteless. Indeed, what it lacks—calcium and magnesium, for example—causes more worries than pollutants.

But these are minor quibbles, easily fixed: at first sight, desalination seems the answer to the world's water needs. Seawater is not going to run out. Indeed, sea levels are already rising because of climate change. To be sure, desalination is catching on. A recent synthesis of available data by Manzoor Qadir, of the Institute for Water, Environment and Health at the UN University (UNU), and other scholars, found that 15,906 plants are in operation worldwide, producing 95m cubic metres a day of desalinated water. Israel already has five plants and is planning another two. The country has a target of increasing annual production from 600m cubic metres a year now to 1.1bn in 2030. In global league tables, however, Israel remains a relatively small producer, with a 2% global share, ▸▸

Singapore goes one better: it drinks its treated sewage

compared with Saudi Arabia (15.5%), the United Arab Emirates (10.1%) and Kuwait (3.7%). Nearly half (48%) of global production is, not surprisingly, in the Middle East and north Africa. China and America also have large capacities (see chart below). Eight countries (the Maldives, Singapore, Qatar, Malta, Antigua, Kuwait, the Bahamas and Bahrain) produce more desalinated water than they withdraw from natural sources.

That breakdown of where desalination is used hints at two reasons it is not a panacea. One is geography. If the sea is the feedstock it will be too costly to transport desalinated water long distances inland—to western China, for example. Secondly, even for coastal regions, desalination is very expensive, which explains why two-thirds of existing facilities are located in high-income countries. The expense comes partly in the capital cost of the plants. Sorek required a total investment of about $400m. In Israel the desalination industry marks a departure from one of the cardinal principles of its water-management policies—that all water is a public good. From the moment a raindrop leaves a cloud it is the state's property. However, four out of the five desalination plants are privately owned.

The second big reason for the expense is the energy they use—typically between one-half and two-thirds of the cost of desalinated water. Israel has managed to achieve relatively good energy efficiency, partly through the use of innovative membranes. The price of Sorek's water is $0.50-0.55 a cubic metre, down from $0.78 for water from the first Israeli plant built on the public-private model at Ashkelon, which opened in 2005.

The UNU paper concentrated on a third drawback to desalination: what happens to the salty sludge (known as brine) left behind by the pristine, desalinated water. At Sorek, as is typical, it is taken out by a pipe and discharged nearly 2km out at sea. Around the world, desalination plants produce nearly 50% more brine (141.5m cubic metres a day) than freshwater.

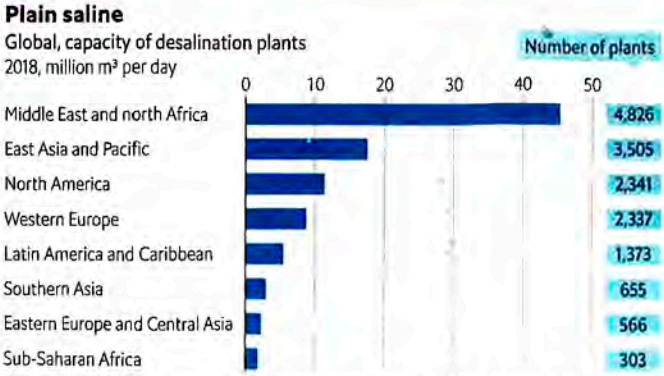
The researchers worry about the threat that uncontrolled discharge of brine could cause to marine life. At the very least it raises the salinity of the surrounding seawater, depleting the dissolved oxygen. But in some places it may be accompanied by toxic chemicals used in the treatment process. More optimistically, they also point to opportunities to use reject brine, for example, in aquaculture, where it has achieved increases in fish biomass of 300%.

The sea is not the only source of manmade water in Israel. It also treats and reuses 86% of its waste water. In this it claims to be far ahead of the rest of the world—with the next-highest recycler being Spain, with just 20%. This is cheaper than desalinated water and is primarily used for agriculture (which accounts for 52% of Israel's water usage), with about 10% returned to "nature" (eg, to increase river flow), or used for putting out fires. That leaves the expensive stuff to flow out from the taps in people's houses. In this area Singapore even goes one better: it drinks its treated sewage. "NEWater" is reclaimed wastewater treated with advanced membrane technologies and ultra-violet disinfection. Its four plants can meet up to 30% of Singapore's needs—three times as much as its local catchment.

All of this costs money. Both Israel and Singapore are unusual in trying to recoup the full cost from the consumer, though Singapore subsidises lower-income users. Pricing is a reminder to consumers in both places of water's importance to national security, and of the truth of an observation made by Mr Schor of the Israeli water authority: "Desalination is the most expensive way to produce a cubic metre of water. The cheapest way is to save it." ■

Plain saline

Global, capacity of desalination plants
2018, million m³ per day



Source: "The state of desalination and brine production: A global outlook", by E. Jones et al.

Saving water

Waste not, want not

The best way to solve the world's water woes is to use less of it

IF THE WORLD is to reduce its use of water, the most obvious area in which to look for savings is where most water goes: agriculture. How much water this accounts for varies enormously from country to country. In Britain, which is a huge importer of embedded or "virtual" water (that consumed in producing any crop or product) accounting for as much as two-thirds of its water needs, it is relatively little. In Egypt it is about 84%, and in India as much as 90%. Viewed more broadly, as a global water "footprint"—a concept developed by Arjen Hoekstra, a Dutch scientist—including not just the direct uses of water in agriculture, but the indirect ones all the way along the chain from field to fork, agriculture accounts for 92%.

Much of this is wasted. "Flood" irrigation systems, where water is released to inundate fields or furrows, lose water to evaporation, or to percolation (ie, to the soil itself before it can be absorbed by the crop's roots). A common estimate is that flood-irrigation squanders 50% of the water it releases. Sprinkler systems can help with efficiency. But these, too, are imprecise, vulnerable to the wind and to loss of water through evaporation.

Far more effective are "drip" irrigation systems introduced in Israel in the 1960s and since spread around the world. As the name suggests, these direct limited amounts of water to the plants themselves, so that they get enough but not too much. Avi Schweitzer, chief technology officer of Netafim, an Israeli company that sells drip-irrigation equipment and technology in 110 countries, says that, by minimising both evaporation and percolation, it manages to achieve 95-97% efficiency in delivering the water to the photosynthetic process.

This saves large amounts of water and increases yields. Precise amounts of nutrient and crop-protection chemicals can be added to the irrigation water. And the new generation of systems employ remote sensors that can monitor weather, soil and plant conditions and calibrate how much water is delivered. Mr Schweitzer, however, concedes that, for now, the high capital cost precludes the use of drip irrigation in much of the world, and limits its use to cash crops. The goals for the future are to reduce costs for commodity crops such as grains, and to improve precision even more. The market will expand. Climate change is likely to mean that more rain-fed farmland—at present estimated to make up about 80% of the world's total—will be irrigated. ▸▸

Greater efficiency, however, comes with risks of its own: that farmers persist in planting thirstier crops than is rational in an arid climate, or switch to more water-intensive ones. Even in Israel, just south of the shrinking Sea of Galilee, swathes of irrigated land are covered in plastic-draped banana plantations.

So reducing the water consumed by agriculture will depend not just on improving efficiency, but on rationalising crop-planting. And that in turn will depend on demand and hence on changes in diet and even fashion. A foretaste of controversies to come was a furore that arose last year over avocado-eating—criticised by many as an emblem of selfish millennial hipsterdom. Avocado consumption in America increased by 300% (to about 4.25bn avocados a year) from 2010 to 2015. Farmers scrambled to meet demand, including in very dry places, such as some parts of Chile and in Mexico, where the craze was blamed for a surge in deforestation. A kilo of avocados can need up to 2,000 litres of water, so local sources were strained, and activists mobilised to campaign against the culinary fashion.

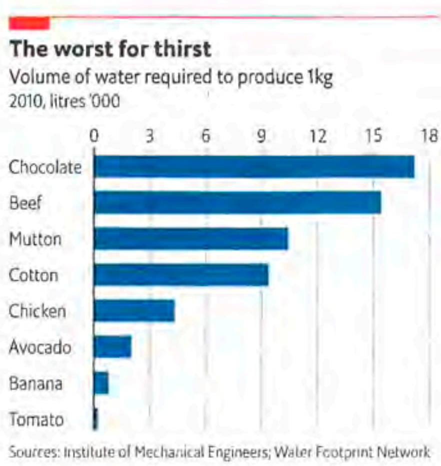
In future, people around the rich world at least are likely to be made more aware of the water footprint of what they eat (and wear: the global average water requirement for producing a kilo of cotton is 9,359 litres). Avocados may need more water than tomatoes (214 litres) but they are far more frugal in their water needs than meat—chicken takes 4,325 litres per kg, mutton 10,412 and beef 15,415 (see chart). Globally, however, the trend is not towards a low-water diet. On the contrary, as countries such as China grow richer, meat-eating is on the increase. Over the past 50 years, global meat production has quadrupled.

Another way in which water is used inefficiently in agriculture is in waste or loss of food, which adds up to as much as a third of global production. In countries such as India, the inadequacies of the cold chain and logistical hurdles mean that much never reaches the shops. Even in rich countries, food shops and consumers end up discarding vast amounts of uneaten food.

A new report by the World Economic Forum, a think-tank, emphasises technological fixes to this problem. Sell-by and use-by dates could be replaced, it argues, by remote sensor technologies, such as near-infrared spectrometers and hyperspectral imaging, capable of evaluating the perishability of individual items. It looks forward to the day when the imaging technology is available on shoppers' smartphones.

A less visible but perhaps more shocking waste is in the form of "non-revenue water"—that is, water supplied by utilities but never paid for. Some is diverted and stolen; much is simply lost through leakage. The lost revenue often leads to a vicious circle. Money is too short to maintain and repair the system, leaks increase, prices rise and theft becomes more widespread. The problem is most obvious in poor countries. Delhi's water board, for example, reported in 2011 that 53% of the water it distributed was non-revenue. In Hanoi that figure was 44%. But even in the rich world, where pipes and other infrastructure may be old, rates can also be staggering. London, for example, reported 28% and Montreal 40%. Again, technology is helping. Sensors and smart valves that use the water itself to send a pulse, which alters when there is a leak, can make it easier to pinpoint trouble-spots.

In almost every aspect of water usage the scope for using less is enormous. It is a question of incentives. Optimists point to signs that this is changing. Some governments still use the availability of cheap and plentiful water as a lure to foreign investors. But some businesses are seeing water-efficiency as both an economic goal in itself and as an important part of their image-building. In the Canadian province of Ontario, for example, the local arm of Nestlé, a Swiss food-and-drinks giant that is one of the world's biggest sellers of bottled water, has found itself embroiled in a lawsuit between First Nations representatives and the provincial government, which has led to a moratorium on issuing new bottling permits.



Read it and weep

Elsewhere, Nestlé is making much of its efforts to save water, aiming to reduce usage in every product category between 2010 and 2020 (a target it says is already within touching distance). In some countries, for example, such as America, Brazil and South Africa it makes baby milk in "zero-water" factories, reclaiming water evaporated from cow's milk used in the manufacturing.

Unilever, another multinational, also has set "sustainability goals". One is to keep the water used in its manufacturing processes to 2008 levels, despite greatly increased production. Already, it says, it has cut water use per tonne of production by 39% since 2008 in seven water-scarce countries representing half the world's population. Less successful has been its drive to reduce the amount of water its customers use—by making products, such as detergents, for example, that need less water. Since 2010, per-consumer use has fallen only by 2%. ■

Conclusion

Hard and soft solutions

Water, the original solvent, can provide its own solutions

AFTER RATTLING into the hillside outside Jerusalem for 7km, the little three-carriage railway reaches the end of the line, some 300 metres underground. The diminishing speck of light at the tunnel's opening has long vanished altogether. This, for now, is as far as it goes. The German-Austrian contractor will eventually bore about 13.5km. But progress is fitful, depending on the rock being drilled through and whether it will need some artificial strengthening. The drill has already negotiated one large cave, complete with stalactites, which had to be reinforced with concrete. More such obstacles are expected. The contractor works non-stop, but the average progress made by Isabel, as their "double gripper" boring machine has been named, is just 22 metres a day. As its jaws grind into the wall of rock ahead, conveyor belts carry the rubble out to the tunnel's opening.

The tunnel will accommodate a tube 2.6 metres wide, the deepest potable-water pipe in the world, that will pump (mostly desalinated) water through 30km of tunnel from sea-level to an elevation of 860 metres to supply much of Jerusalem's drinking-water needs. In a country famous for its ambitious water-supply schemes, this is the biggest since the 1960s. It was in 1964 that Israel inaugurated its National Water Carrier, a public-works project to bring water from the north of the country down to the Negev desert in the south. It was an emblem of the young country's determination to survive. And it is a dominant theme in water policy to this day. In a dramatic symbol of a determination to shape the natural order to human needs, the direction of water-flow in the national carrier is to be reversed, to give clean, desalinated water back to "nature" in the north of the country.

Water "megaprojects" are not unique to Israel. Humanity has long embraced what Peter Gleick, a scientist who co-founded the Pacific Institute, a think-tank in California, calls "the hard path" to solving its water problems: one that relies "almost exclusively on centralised infrastructure to capture, treat and deliver water supplies". When water has been short, the solution has been to find a new source, or to bring it from somewhere else, in ancient times using large amounts of human labour.

Ancient Sumerians in southern Mesopotamia dug canals. More than 4,000 years ago Egyptian farmers relied on the Nile—traces of their irrigation systems survive today. Throughout the Roman Empire cities were supplied by manmade aqueducts. High in the Andes in present-day Peru the Incas and their predecessors built cisterns and irrigation canals, and carved terraces into the hillsides.

Modern technology means that megaprojects now are on a scale the ancients could only dream of. China's are the grandest. The Three Gorges Dam on the Yangzi river, which went into full operation in 2012, involved the flooding of hundreds of villages and the displacement of 1.2m people. The reservoir it created is 600km long. Besides providing energy for one of the world's biggest power stations, the project was touted for improving navigation and preventing floods. Ever since it was first mooted as an idea a century ago, however, the dam has been controversial, with worries about its impact on biodiversity, cultural heritage and even seismology.

Environmentalists are also leery of another proud boast of modern Chinese hydraulic engineering: its south-to-north water-diversion project (pictured overleaf), by some measures the most expensive infrastructure project in the world. It counts as the largest transfer of water between river basins in history. It recognises that, for all China's well-publicised struggles with air pollution, a shortage of water is its biggest environmental problem. That shortage is acute in the north, where 11 provinces have less than 1,000 cubic metres of water per person per year, the usual international measure of water stress. Those provinces include four of China's five biggest agricultural producers.

So, since 2014, two-thirds of the tap water and one-third of the total water supply in Beijing, in the arid north, has come by canal and pipeline from a reservoir 1,400km to the south, fed by a tributary of the Yangzi. China hails the project as an unqualified success, supplying more than 50m people in its early years of operation. And it is part of an even bigger project that will see up to 45bn cubic metres of water a year transferred—7% of Chinese consumption. Environmentalists and water experts at home and abroad are more sceptical, however. Mr Biswas at the Lee Kuan Yew School in Singapore says the project gives China at best "a few years' grace". The worry is that it is a distraction from more pressing and important policy changes—cutting demand for water—and may actually encourage wasteful use. As elsewhere, the authorities fear that charging users for the true cost of their water might provoke protests and threaten social stability.

Similar doubts surround India's scheme to "interlink" 37 rivers through a network of 15,000km of canals, the ultimate aim being, as in China, to move water from well-endowed regions—such as some of the Himalayan foothills in the north—to areas of scarcity. The plan has been discussed for decades. The current government has tried to give it fresh impetus. But even if it forges a political consensus in Delhi behind the plan, it would be hard to realise be- ▸▸

South to north, Chinese-style

cause of tensions between different states over water.

With so many cities around the world facing an acute need for water, "the hard path" will not be abandoned. It will always seem easier to bring water in, or to exploit a new source, than to move tens of millions of people, or completely redraw the map of agricultural production. The scale of the problem was suggested by research published in 2014 by The Nature Conservancy, an American charity. Its list of water-stressed cities was dominated by places in India and China—with Delhi second, Shanghai fourth and Beijing fifth. Mexico City came third. But top of the list was Tokyo. Other rich-world cities were also high up, including Los Angeles (eighth) and even London (15th).

Few, however, would disagree with Mr Gleick that the hard path alone is no longer enough and that it needs to be complemented with a "soft" one that seeks to improve the way water is used, rather than to find new sources of supply. That means spending on local facilities, efficient technologies and education and training.

How to do this is already known. In water-scarce regions where people—usually women—have to spend hours each day fetching water from a distant source, it may mean building pipes or borewells and training people to maintain them. In places with heavy seasonal rain followed by long dry seasons it means building (or in many cases restoring) storage systems, ideally in places where evaporation will be low. (In Bermuda, with abundant year-round rain, domestic water needs are met by harvesting rainwater from the islands' roofs, which building regulations stipulate must make room for storage tanks.) And to ensure that the water people drink does not kill them, the discharge of untreated effluent has to be stopped, and people have to use toilets.

Waste water, as Israel and Singapore have shown, can be treated as a resource to exploit rather than a problem to dispose of. As the UN's Sustainable Development Goals (SDGs), the targets for 2030 adopted in 2015, acknowledge, water-management has to be "integrated", that is co-ordinated both between the various bodies responsible for different bits of the water cycle and other policies that have an impact on water. At times this will entail cross-border co-operation. It will always require community involvement.

None of this is rocket science, which helps explain a paradox of most conversations with scientists, ecologists and charity-workers who have devoted their lives to solving the world's water problems. Most are full of horror stories about how woefully the world is misusing and wasting its water. Yet most will profess cautious optimism about the long-term future.

The World Bank has even sought to cost the water-related SDGs. It estimated that, to "achieve universal and equitable access to safe and affordable drinking water for all" and "achieve access to adequate and equitable sanitation for all and end open defecation" would need $114bn a year, 69% of it spent on sanitation. So to provide access to drinking water for the whole world would cost not much more than $30bn a year, or roughly the size of the defence budget in, say, Italy or Brazil.

The total of $114bn would amount to just 0.39% of the GDPs of the 140 countries the World Bank studied. That would, however, be 0.27 percentage points more than is currently spent globally. It would require a massive reallocation of resources. For that to be realised, three issues need to be tackled: ownership; price; and political priorities. On ownership, India and Israel represent two extremes. In India it may be hard to repeal the British-era law giving landowners the right to all the water on and under their property. But it should be possible to mitigate some of its effects by, for example, penalising the over-extraction of groundwater. Israel's nationalisation of all water supplies has helped "integrate" policy, but may not be replicable elsewhere. In many countries water rights are less clear and subject to litigation. America, for example, still suffers from tension between two different doctrines adopted in the early days of the modern nation: a "riparian" one in the east, giving rights to those near to a body of water, and the "prior-appropriation" one in the west, giving rights to the earliest users.

Pricing will be even harder. Few utilities in the world charge consumers the full cost of the water they use. And even in countries where they do, a water subsidy may be included in the cost of the goods people buy in shops. To persuade people to recognise and pay for the water-intensity of their lifestyles may require concerted campaigns of the type that have helped cut smoking rates in many places. But because they will affect the entire population, it will be even harder. On the other hand, as experience in some unlikely places has shown—Phnom Penh, the capital of Cambodia, for example—poor people will pay for a clean, reliable source of water. After all, in much of the world, they already pay over the odds for dirty, dangerous and erratic supplies.

Poor people will pay for a clean, reliable source of water

Finally, even if the world is cajoled into using water more sustainably, that will still leave questions of allocation. On the global level, it is easy to see where the priorities should lie: in the hundreds of millions who do not yet have access to safe and adequate drinking water and sanitation. At the national and subnational level, there will always be powerful interests lobbying for their own needs, whereas those without access to clean water are, almost by definition, the powerless. So, as Jonathan Farr, senior policy analyst at WaterAid, puts it, water management—however sustainable, progressive and integrated—has first to concentrate on access. Money is not the binding constraint. Nor is technology. It is a political choice. ■

ACKNOWLEDGMENTS A list of acknowledgments and sources is included in the online version of this special report

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