Water conflicts

Water, like energy, is a fundamental human need, but water is not evenly available over the surface of the Earth. Population growth, economic development and rising standards of living all increase the demand for water. In many parts of the world, the rise in demand is outstripping supply. This is having serious consequences for human **wellbeing**. It is also a potential source of conflict between water users, as well as between those countries and regions with water deficits and those with surplus supplies. If the world is to ensure future water supplies it will need to develop management strategies to resolve these conflicts. Achieving more sustainable use of scarce water resources is another priority.

The geography of water supply

What is the geography of water supply and demand?

By the end of this section you should:

- *know the physical factors affecting the supply of freshwater*
- *be aware of the growing mismatch between water supply and demand, and the resulting stresses*
- *understand how human activities affect water availability*
- *appreciate how access to water is related to wealth and levels of economic development*

The familiar model of the hydrological system makes use of the terms **inputs**, **stores**, **outputs** and **flows** to explain how water moves through the environment. Within this framework, we are able to identify important elements such as precipitation, groundwater, evapotranspiration and surface runoff. Figure 2.1 shows the relative importance of these elements and introduces the concept of blue and green water flows. **Blue water flow** is the visible part of the system, namely water running on the surface and supplying rivers or travelling underground, recharging aquifers. This water is potentially available and recyclable. **Green water flow** involves either the interception and transpiration of water by vegetation or its evaporation from a variety of surfaces. These processes have important ecological as well as hydrological functions.

Water supply

Global water supplies are linked to three main physical factors: climate, river systems and geology.

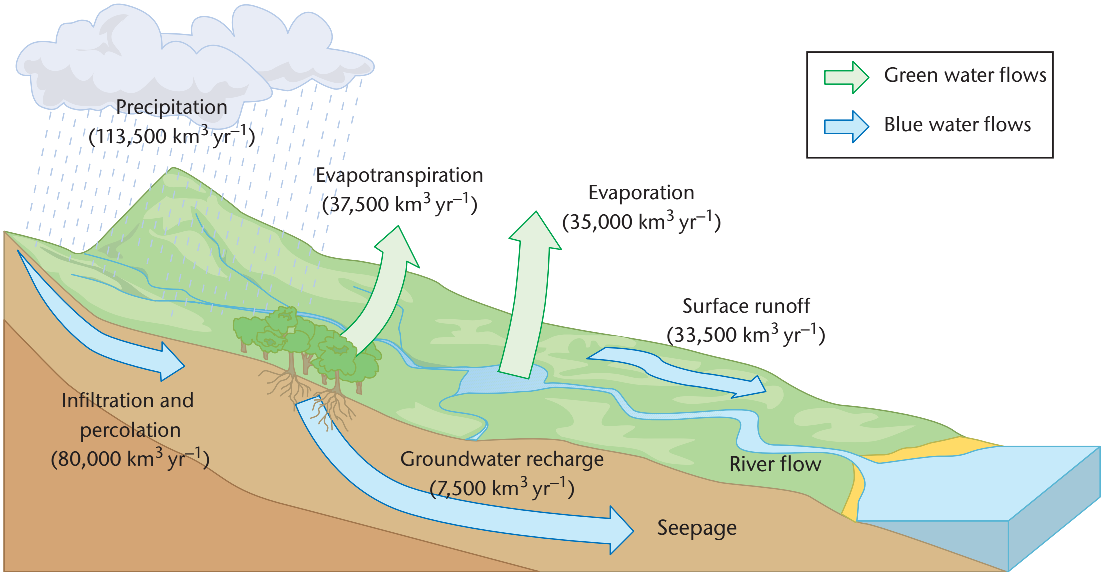


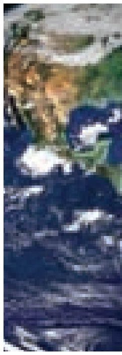
Figure 2.1 The hydrological system (global values)

Climate

The distribution of water globally is related to the Earth's climatic zones. For example, regions near to the equator receive high levels of annual precipitation, while some tropical areas suffer recurring drought. Rainfall may also vary with the seasons. Equatorial areas such as the Amazon lowlands have two distinct periods of wet weather per year, whereas the monsoon lands of southeast Asia have one very distinct wet season (Photograph 2.1). High mountains with snowpack hold vast reserves of water, some of which is released in late spring and during the summer.

Photograph 2.1 The monsoon in India

TopFoto



River systems

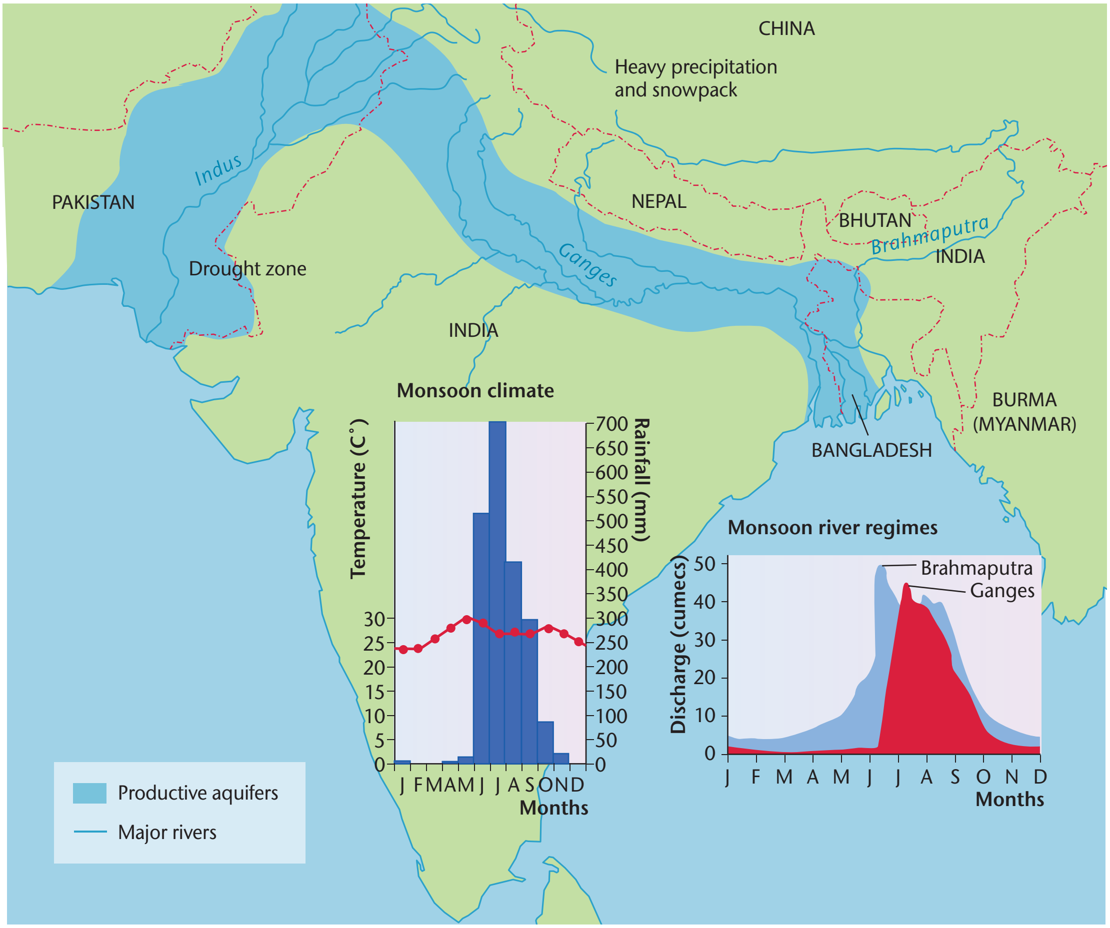
The world's major rivers store large quantities of water and **transfer** it across continents. The Amazon, for instance, produces an average **discharge** of 219,000 $m^3 s^{-1}$ from a catchment area of 6,915,000 km^2. This is 20% of all the river water entering the world's oceans. River flow generally increases downstream as tributaries feed into the main river, though high temperatures can lead to considerable water loss by evaporation. Seasonal changes in climate can also create significant variations in discharge and produce distinctive **river regimes**.

Geology

Where the rocks underlying a river basin are **impermeable**, water will remain on the surface as runoff, creating a high **drainage density**. Permeable soils and rocks such as limestone may allow water to pass into underground drainage systems. **Aquifers** such as chalk and porous sandstones can store vast quantities of water underground. The Ogallala aquifer, in the High Plains region of the USA, is one such water source. Groundwater may create springs or provide the baseflow of rivers.

Figure 2.2 shows how these factors apply in the Indian subcontinent.

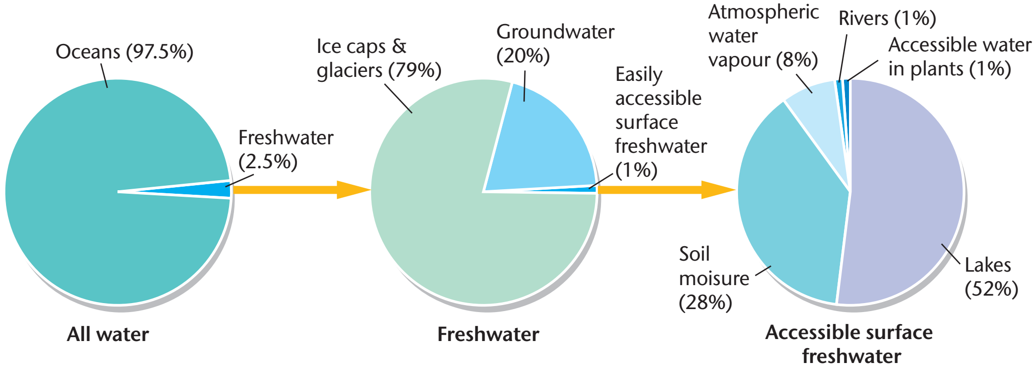
Figure 2.2 Factors affecting water supply in India



Finite resource

A fundamental issue for water supply is that the amount of water available is finite. The world's oceans hold an estimated 1,386 million km^3 of water, and this accounts for 97.5% of the global water store (Figure 2.3). So only 2.5% of the store is potentially available as freshwater, and almost 80% of that is trapped in ice, snow and permafrost. Most of the remaining 20% is groundwater. Only 1% is easily accessible freshwater held in lakes, ecosystems, the atmosphere and rivers.

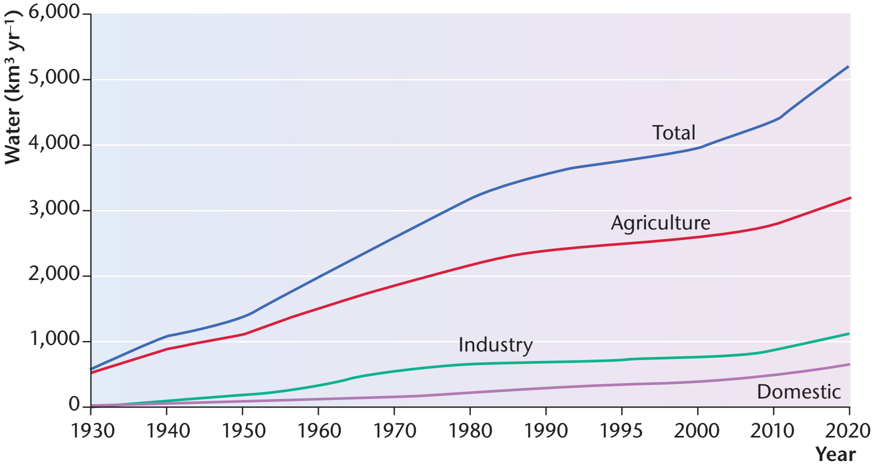
Figure 2.3 The availability of the world's water

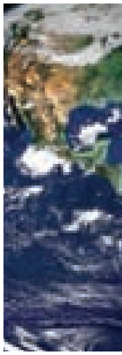


Water stress

As the global population grows and the demand for water increases, there will be less water per person. For water-rich countries such as Canada or Brazil this decrease is not a serious worry, but elsewhere it can be life-threatening. Globally, half a billion people – most of them living in Africa and the middle east – are chronically short of water. There are insufficient renewable supplies of water in China and parts of Europe, while India looks set to suffer considerable water stress in the future. Even in the USA, where water is relatively abundant, availability will have halved between 1955 and 2055, most obviously in the dry southwest.

Figure 2.4 The growing demand for, and use of, water, 1900–2025





At present, more than one-third of the world's population is short of water, and it is estimated this will reach 45% by 2025. The United Nations Food and Agriculture Organisation (FAO) expects water demand to reach 5,235 km^3 per year by 2025. Figure 2.4 shows the rising demand for water for agriculture, industry and domestic uses.

Agriculture

Agriculture is the major user of water, particularly as we struggle to increase food supplies for a growing global population (Figure 2.4). Currently, agriculture uses 69% of the world's 4,430.7 km^3 a year freshwater supply. Some forms of agriculture are less water-efficient than others. A kilogram of beef, for example, is ten times more 'water-costly' to produce than a kilogram of rice. At present, 17% of the global area devoted to growing crops is irrigated (Photograph 2.2). While water storage and irrigation systems do make agriculture more productive, they can also be wasteful of water. Poor management of such systems can lead to problems of evaporation, seepage, salinisation and fertiliser pollution.

Industry

The proportion of water used globally by industry (21%) rose relatively slowly during the twentieth century, mainly in the developed countries of Europe, Russia, Canada and the USA. Estimates for the coming decade suggest a more rapid global rise, driven by large-scale industrialisation in countries such as India and China.

Hydroelectric power (HEP) continues to use huge amounts of water, but this water is available to other users once it has passed through the turbines. Industry is generally a much more efficient user of water than agriculture, but there are

Corbis

Photograph 2.2 Irrigation of crops by spraying

some significant exceptions: paper manufacturing, for example, is one of the most extravagant users of water on the planet. Industry has also caused significant water pollution problems.

Domestic

Figure 2.4 shows that water usage in homes (labelled 'domestic' on the graph) is the smallest category of consumption, using only 10%. The amount used, however, varies enormously from country to country. Most developed countries need at least 100,000 litres of water per person per year, while in most African countries the figure is less than 50,000 litres. Global domestic demand seems to be doubling every 20 years and it is arguably only the poor access in Africa that is limiting growth in demand there. The quality of the water involved also varies considerably.

Water sources

Our water supply comes essentially from two sources: surface water and underground aquifers.

Surface water

Rivers, lakes and reservoirs provide large amounts of surface water for a wide variety of uses. So called 'mega-dams' are found on most of the world's major rivers. Half of all the world's dams (around 50,000) are in China, the USA, India and Japan, and their reservoirs account for a quarter of the global freshwater supply. The construction of reservoirs brings short-term economic gains in terms of water supply, hydroelectric power and flood control, but these must be measured against their longer-term environmental and social impacts. Large-scale river-water diversions and wetland drainage programmes also have costs and benefits.

Aquifers

Underground supplies from aquifers are the sole source of drinking water for about a quarter of the world's population. Three-quarters of Europe's drinking water comes from groundwater, while Bangladesh and India use most of their groundwater for irrigation. In many countries, for example the USA, China and India, as well as in much of the middle east, water is being abstracted from aquifers faster than it is being replaced. The long-term costs of this **over-abstraction** are dwindling supplies, falling water tables and seawater contamination.

Pressure on water supplies

In many parts of the world there is a growing mismatch between water supply and demand. This can be seen locally and across whole regions (see Figure 2.5).

Water stress is the term used when the annual supply of water per person falls below 1,700 m^3. When this figure drops below 1,000 m^3, the term used is **water scarcity**. There are two types of water scarcity:

- **Physical scarcity** occurs when more than 75% of a country or region's river flows are being used. A quarter of the world's population lives in such areas, which include parts of the USA and Australia.

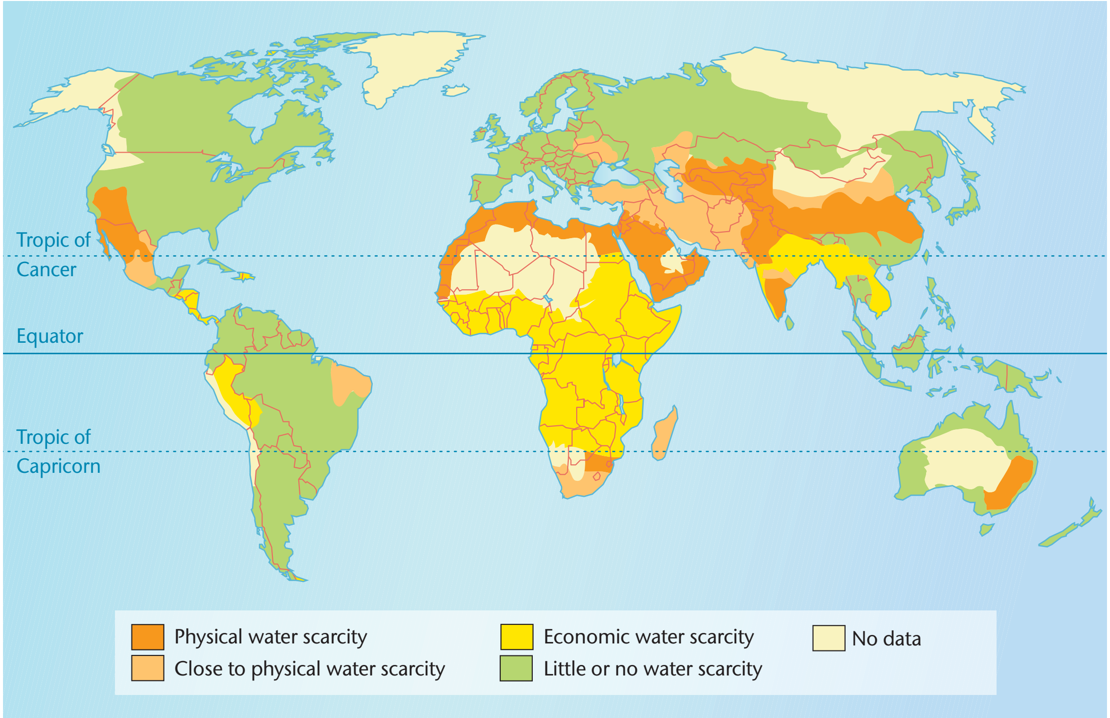


Figure 2.5 Water stress and scarcity

➤ **Economic scarcity** occurs when the development of blue water flow sources is limited by human and financial capacities. More than 1 billion people, in areas such as sub-Saharan Africa, use less than 25% of the river resources available.

Rapid economic growth in India and China is putting enormous pressure on water supplies.

India

India has 4% of the world's freshwater, but 16% of its population. Demand will probably exceed supply by 2020, as urban water demand is expected to double and industrial demand to triple. Hydrologists calculate that 43% of precipitation never reaches rivers or aquifers, and water tables are falling rapidly as 21 million wells abstract water.

China

China has 8% of the world's freshwater but must meet the needs of 22% of the world's population. Two-thirds of Chinese cities do not have enough water all year round, and national water supplies are likely to reach stress levels by 2030. China uses irrigation to produce 70% of its food, mostly in the north and northeast, where the Yellow River and major aquifers are running dry. Huge engineering projects will soon transfer vital water to this area from the water-rich south. An interactive map showing water issues in China can be found at **www.pbs.org/kqed/chinainside/nature/waterissues.html**

Case study: The water problems of the Beijing–Tianjin region

Beijing, China's capital, may soon run out of water. Each year, the gap between water demand and supply widens, wells dry up, groundwater and rivers become polluted and ground subsidence worsens.

Why is this happening?

The causes of this deteriorating situation are both physical and human. Northeast China, where Beijing is located, is prone to floods and, in recent years, droughts. Most precipitation falls between July and September, sometimes more than half of it within 3 days. Several wet years can be followed by several dry years. The capital's population of 16 million makes it the second largest city after Shanghai. On the coast, not far from Beijing, is China's third largest city, Tianjin (population 11 million), a major port with heavy industry, commerce and developing services. Beijing's annual population growth rate is stabilising at about 2.5% as a result of efforts by the government to restrict family size, but rural–urban migrants continue to arrive. The situation in Tianjin is similar.

Water supply

Beijing draws 60% of its water supply from aquifers. These are overexploited, but the water quality is still acceptable. In the late 1970s and early 1980s, a series of droughts led to increased demands for irrigation water. This lowered the water table in some areas by as much as 40 m, and some wells were pumped down to the bedrock. Much of Beijing has subsided by between 0.5 m and 1 m per year because of all this abstraction. Tianjin relies on groundwater for about 30% of its water supply, but **salt water incursion** makes the water brackish.

Surface water supply in the region depends on five major rivers which enter the Hai He river system. Upstream withdrawals and contamination of these rivers have a negative effect on downstream cities, and Beijing also makes Tianjin's water problems worse by the scale of its abstractions and pollution.

An aqueduct 2,500 km long has been built, the first phase of a scheme to divert water from the Three Gorges Dam to the Beijing–Tianjin region. Projects to improve water quality and conserve water have also been implemented.

Demand for water

Water demand in the Beijing–Tianjin region is currently 4.9 billion m^3 per year and continues to rise. Of this, agriculture accounts for about 65%, although the use of water-saving technologies means irrigation demands are levelling off. Industrial output in the region has increased more than sixfold in the last 20 years. Water demand has not risen as fast as this as industries have become more water-efficient and recycle their waste water and there has been a shift from heavy to high-tech industry. The fastest rate of increase is in domestic water use: consumption has risen tenfold in the last 50 years and now averages 240 litres per person per day.

Human impacts on water availability

Human activity can have a negative effect on the water environment (Figure 2.6). Pollution caused by human activity and excessive abstraction of water supplies can further increase water stress.

Pollution of groundwater is much less obvious than surface-water pollution, but is no less a problem:

- Sewage disposal in developing countries is expected to cause 135 million deaths by 2020 (World Health Organization). Diseases such as hepatitis, typhoid and cholera are common in areas with polluted water. In the UK we add 1,400 million litres of sewage to our rivers daily, though most of it has been treated.
- Chemical fertilisers used by farmers contaminate groundwater as well as rivers

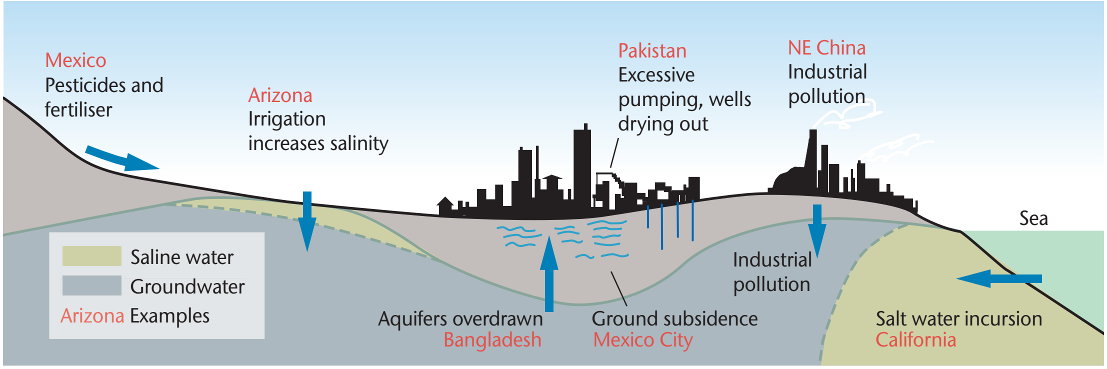
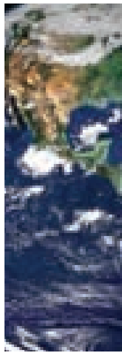


Figure 2.6 A model showing some human impacts on water supply and quality



and water supplies. In Yucatan, Mexico, the level of nitrate in the groundwater is 45 mg l^{-1}. Sewage and fertilisers add nutrients to the water and increase the growth of algae downstream. The algae remove oxygen from the water, for example along the shores of the Gulf of Mexico.

- Each year the world generates 400 billion tonnes of industrial waste, much of which is pumped untreated into rivers, oceans and other waterways. Heavy metals such as lead, cadmium and mercury also become concentrated in rivers. Chemical waste includes toxic and widely banned polychlorinated biphenyls (PCBs).
- Big dams trap sediment in reservoirs, which reduces floodplain fertility and the flow of nutrients from rivers into seas. This may damage coastal fish stocks and prevent beach formation, which in turn can expose coasts to greater erosion. Sediment disturbance during dam construction can also block the gills of river fish and suffocate them.

Abstraction

Removing water from rivers and groundwater sources, whether for drinking water or for irrigation, can have unintended consequences:

- Worldwide, water is being extracted from aquifers faster than it is being replaced. In arid areas, rainfall can never recharge these underground stores.
- The removal of freshwater from aquifers in coastal locations can upset the natural balance of saline and fresh groundwater and lead to **salt water incursion** and salinisation of wells, boreholes and wetlands.

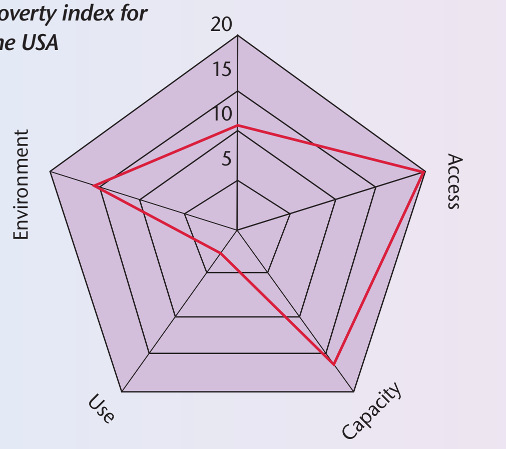
Access to water

Water insecurity means not having access to sufficient, safe water. Despite efforts to improve supplies and sanitation ($30 billion is spent each year worldwide), there are 1.2 billion people without access to clean water, many of whom live in the 20 or so developing countries classified as 'water scarce'. Typically in these countries the poor are most water insecure, with few opportunities to escape from poverty and access the benefits of economic development. The problems of water insecurity are related to:

- *availability* – having a water supply and a distribution network

- *access* – freedom to use or income to buy water in a particular location
- *usage* – entitlement to, and understanding of, water use and health issues

Figure 2.7 Water poverty index for the USA



The water poverty index

In 2002 the British Centre for Ecology and Hydrology published the first **water poverty index** (WPI). The index uses five parameters:

- *resources* – the quantity of surface and groundwater per person, and its quality
- *access* – the time and distance involved in obtaining sufficient safe water
- *capacity* – how well the community manages its water (and health)
- *use* – how economically water is used in the home and by agriculture and industry
- *environment* – ecological sustainability (green water)

Each of the parameters is scored out of 20, to give a maximum possible score of 100 (see Figure 2.7).

Poverty

Poverty and water poverty go hand in hand (Figure 2.8), but they are part of a wider equation. Lack of water hampers attempts to reduce poverty and encourage development. Improved water supply and sanitation can increase food production, bring better health and provide higher standards of wellbeing. Water wealth in developed countries brings cheap water, irrigation, energy and economic growth. Some commentators have dubbed water 'the lubricant of development'.

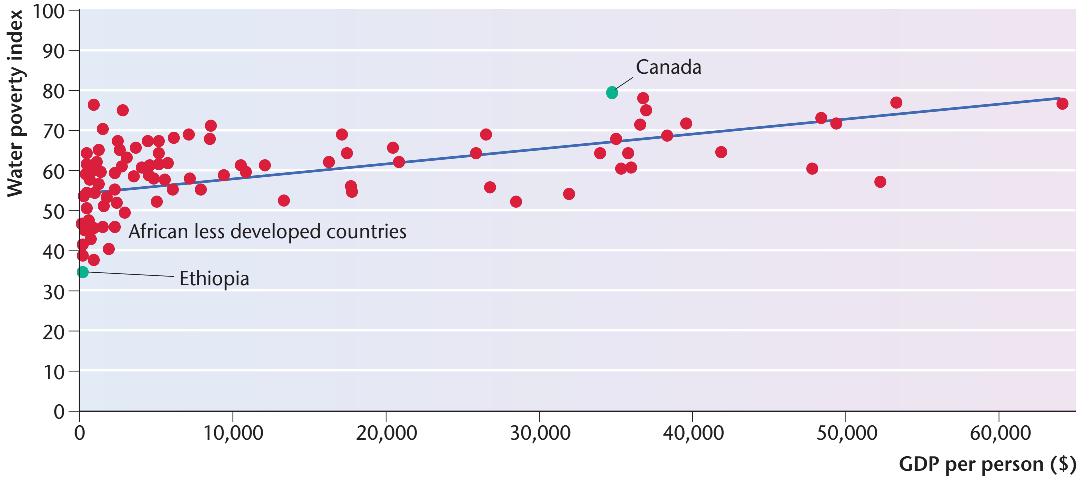
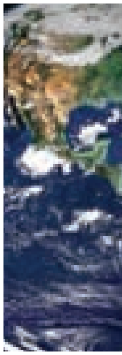


Figure 2.8 Water and wealth



Case study: Contrasting water extremes

Canada and Ethiopia represent the two extremes of the water and development **spectrum**. Canadian households use 800 litres per person per day to 'wash, cook and flush'. Water is also used for lawns, gardens, parks and swimming pools. Problems here are about rising water bills and leakages.

In Ethiopia the water consumption is 1 litre per person per day, much of it fetched daily from a shared source. This water has to meet all needs. Since Ethiopia is a poor country, its water problems relate to water shortages, pollution and the risk of disease. The fact that the population is concentrated in widely dispersed rural villages and overpopulated urban slums aggravates the problems.

Table 2.1 helps to explain the worsening water supply difficulties faced by Ethiopians, compared with the situation their Canadian counterparts are in.

Water indicators	Canada	Ethiopia
Water poverty index	78	45
Surface water resources (km^3)	2,892	110
Groundwater resources (km^3)	370	40
Renewable water resources in 2000 (m^3 per person per year)	92,646	1,749
Renewable water resources by 2050 (m^3 per person per year)	70,520	590
Water use: agricultural (%)	12	93
Water use: industrial (%)	69	6
Water use: domestic (%)	20	1
Access to improved water (% of population)	100	24
Access to improved sanitation (% of population)	100	12
Development indicators		
GNI ($ per person)	33,170	170
Population in 2000 (millions)	30	62.9
Estimated population in 2050 (millions)	42.3	169.4
Urban population (%)	77	18
Agriculture (% of GDP)	2	47
Industry (% of GDP)	35	14

Table 2.1 Water and development indicators for Canada and Ethiopia

The price of water

As demand begins to overtake supply in the global market, water costs look set to follow oil and food prices upwards. Who pays most for their water may surprise you. Homeowners in Washington DC (USA) pay about $350 for a year's water (72 cents per m^3). In many developing countries, water is free in rural areas, but it often needs to be carried daily over long distances and is likely to be contaminated. In the largest cities, slum dwellers may have to buy water

Table 2.2 Costs (US cents per m^3) of water supplies in selected cities

City	Tap connection	Informal vendor
Jakarta (Indonesia)	16	31
Dhaka (Bangladesh)	8	42
Karachi (Pakistan)	14	81
Ulaanbaatar (Mongolia)	4	151
Phnom Penh (Cambodia)	9	164
Manila (Philippines)	11	474

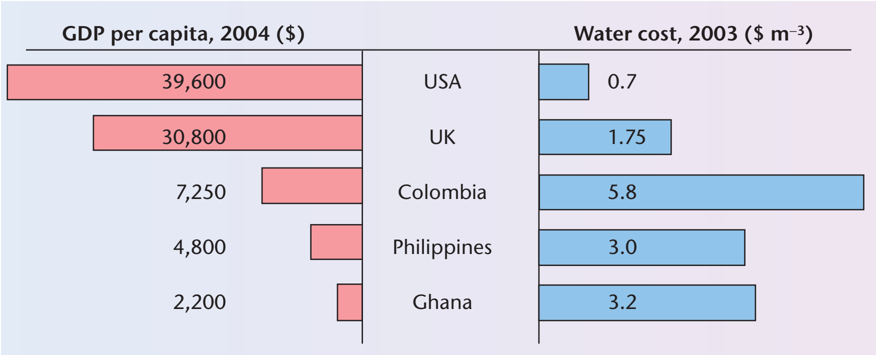


Figure 2.9 Water prices and GDP in selected countries

from private vendors whose prices often exceed $1 per m^3. This can be many times the price of tap water elsewhere in the city (Table 2.2).

Figure 2.9 shows some interesting relationships between national water prices and GDP.

The price of freshwater depends upon transport costs and the level of demand, less any subsidy.

- Californian cities import water over hundreds of kilometres from the Colorado basin. Lifting water from depth and moving it over hills by pumps is energy-expensive.
- Water prices in Australia's markets peaked at nearly 75 cents per m^3 in December 2006, having increased twentyfold in the year as a result of prolonged drought.
- In India, water scarcity has prompted some farmers to profit by selling their abstracted water instead of using it themselves for irrigation.
- Water subsidies can be large. In the city of Delhi, they make up 80% of the cost of providing municipal water. Farmers in California use roughly one-fifth of the state's water, yet pay only 1 cent per m^3 for it.

The risks of water insecurity

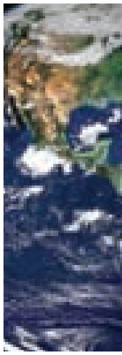
What are the potential implications of an increasingly 'water insecure' world?

By the end of this section you should:

- *be aware that water availability affects human welfare and economic growth*
- *understand how the need for water can lead to tensions and conflict*
- *have some grasp of the politics of water supply and the role of agreements and treaties*
- *know the environmental and political risks of transferring water*

Water supply problems

Secure water supplies are essential to economic development. They are needed to support irrigation and food production, manufacturing and energy generation.



However, the development, extraction and use of water resources can lead to environmental and supply problems, and can have negative impacts on both economic activity and human welfare. During its 'Green Revolution' programme to increase food production, India put 45 million hectares of land into irrigation. The negative consequences of this were depletion of underground aquifers and salinisation of the soil. Perhaps the most severe example of damage inflicted by irrigation programmes can be seen in the large-scale diversion of rivers which once flowed into the Aral Sea (see case study).

Case study The Aral Sea

Once the world's fourth largest inland sea (68,000 km^2), the Aral Sea has been steadily shrinking since the 1960s. In the late 1950s the Soviet government diverted much of the water from the rivers Amu Darya and Syr Darya, which fed into the Aral Sea, for irrigation of agriculture. By 2007 the sea had declined to just 10% of its original size and split into separate lakes, and its level had fallen by up to 40 m (Figure 2.10). This is an environmental catastrophe.

An interactive map and satellite photographs can be seen at: **http://visearth.ucsd.edu/VisE_Int/aralsea/aral_map.html**

The Aral Sea crisis has involved several stakeholders:

- *The former Soviet government*. Communist leaders began an ambitious irrigation scheme designed to develop fruit and cotton farming in what had been an unproductive region and create jobs for millions of farm workers.
- *The fishing community*. A once prosperous industry that employed 60,000 people in villages around the lakeshores has collapsed. Unemployment and economic hardship are everywhere. Ships lie useless on the exposed seabed (Photograph 2.3).

Figure 2.10 Map showing location of the Aral Sea

TopFoto

Photograph 2.3 Abandoned fishing boats on the Aral seabed

- *Local residents*. Health problems are caused by wind-blown salt and dust from the dried-out seabed. Drinking water and parts of the remaining sea have become heavily polluted as a result of weapons testing, industrial projects, and pesticide and fertiliser runoff. Infant mortality rates are among the highest in the world, with 10% of children dying in their first year, mainly of kidney and heart failure.
- *The Uzbekistan government*. The irrigation schemes based on the Aral Sea allow this poor country, with few resources, to remain one of the world's largest exporters of cotton. It also hopes to discover oil deposits beneath the dry seabed.
- *Scientists*. Only 160 of the region's 310 bird species, 32 of the 70 mammal species and very few of the 24 fish species remain. The climate has changed too, making the area even more arid and prone to greater extremes of temperature.
- *Kazakhstan farmers*. Irrigation has brought the water table to the surface, making drinking water and food crops salty and polluted.
- *International economists*. People in the region may no longer be able to feed themselves, because the land has become so infertile. Up to 10 million people may be forced to migrate and become environmental refugees.
- *Water engineers*. Inspections have revealed that many of the irrigation canals were poorly built, allowing water to leak out or evaporate. The main Kara Kum Canal, the largest in central Asia, allows perhaps 30 to 75% of its water to go to waste.

Water conflicts

'If we do not act, the reality is that water supplies may become the subject of international conflict in the years ahead,' said UK Minister for International Development Gareth Thomas in 2008. When the demand for water overtakes supply and several stakeholders wish to use the same resource, there is a potential for conflict. Competing demands for water for irrigation, power generation, domestic use, recreation and conservation can also create tension both between and within countries.

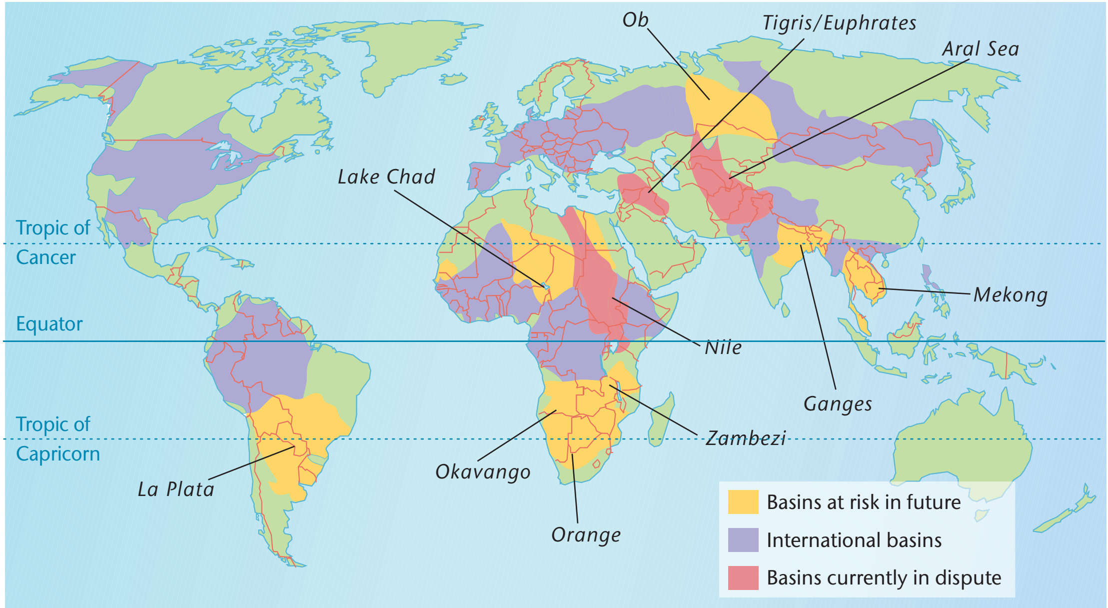


***Figure 2.11** International conflicts over water in major river basins*

Conflict is perhaps more likely where developing countries are involved. Water is vital as they struggle to feed their growing populations and promote industrial development, and often they have to cope with a legacy of poor water management.

Just as oil resources have caused growing international tension over the last 50 years, many people see water resources as the next flashpoint. UN reports suggest there are around 300 potential water conflicts around the world as rivers, lakes and aquifers struggle to provide sufficient supplies for neighbouring countries (Figure 2.11). It should be noted that politicians and government map-makers have not always helped these situations, creating boundaries and borders which do not easily fit with the natural features of river catchments.

Case study: The middle east water conflicts

The middle east is already an area of significant conflict. The fact that it has relatively low seasonal rainfall and growing population is the root cause of the tensions over water resources (Figure 2.12).

- In the western part of this region, Israelis, Syrians, Jordanians, Lebanese and Palestinians are in dispute over shrinking water supplies. Security of water supplies was not the cause of the Arab–Israeli war in 1967, but was a contributory factor. Water in this region comes primarily from two sources: the River Jordan (and its lakes) and three important aquifers. The division of these water resources between the neighbouring states is an ongoing challenge. A detailed account can be found at **www.mideastweb.org/Mew_water95.pdf**
- In the eastern part of the region, Turkey plans to build dams to store and use water in the headwaters of the Tigris and Euphrates Rivers. This is strongly opposed by Syria and Iraq, where reduced water supplies threaten to hold back economic development and food production.

Figure 2.12 Water conflicts in the middle east

Case study: Tensions between India and Bangladesh

For much of its 2,500 km length, the Ganges flows through India. But the last part of its course takes it through Bangladesh, where it is known first as the Padma River. It is joined later by the Jamuna River, the largest distributary of the Brahmaputra, and takes on the name Meghna before flowing out into the Bay of Bengal. In 1974 India opened the huge Farakka Barrage, just 11 km from the Bangladeshi border. Further upstream, a series of dams divert water into irrigation systems and many of India's largest cities use the river to carry wastewater from domestic and industrial sources. So Bangladesh is effectively a double loser. It is being deprived of much-needed water and has to suffer the effects of India's pollution of the river. Although an agreement was signed in 1990 by the two countries about sharing the waters of the Ganges, India is very much in control of the situation. To make matters worse for Bangladesh, India now has plans to make greater use of the Brahmaputra, which also flows through India before reaching Bangladesh (see Figure 2.2, page 35).

Bangladeshi grievances include the following:

- reduced flow of the river is affecting irrigation and food production

- fish stocks and the fishing industry are declining
- navigation and water-borne trade are becoming harder because of lower river levels
- lower river flows are increasing salinisation
- the delta is eroding because less silt is being carried and deposited
- seawater incursion is increasing as the delta dries out

Water geopolitics

As countries compete for water resources international agreements and treaties have to be drawn up on how best to manage shared water supplies. Pacts about water supply, distribution and use are in place along many major rivers. However, as the political situation changes, these can flare up into disputes (**hydropolitics**).

As water resources take on a greater significance, new treaties may need to be negotiated using what might be called **water diplomacy**. Unfortunately, international law does not provide a clear solution to transboundary river disputes, except where navigable waterways are involved. In fact, present international law tends to make matters worse. Upstream countries usually assert their right of territorial sovereignty (it is our water, so it is our decision how it is used). Downstream countries claim territorial integrity (it is our right to receive the same amount and quality of water as we have in the past).

Sharing water

Under the **Helsinki Rules** there is general agreement that international treaties must include concepts such as 'equitable use' or 'equitable share' and be applied to whole drainage basins, not single countries. Ideally, the criteria for water sharing should be based upon the following:

- *natural factors* – rainfall amounts, water sources, share of drainage basin
- *social and economic needs* – population size, development and welfare
- *downstream impacts* – restricting flow, lowering water tables, pollution
- *dependency* – are alternative water sources (other rivers or aquifers) available to the country?
- *prior use* – the tricky question of existing (past) or potential (future) use
- *efficiency* – avoiding waste and mismanagement of water

In reality, of course, agreements are rarely equitable because the country with the greatest political, economic and even military power gets the better deal. This is true in the middle east, in many parts of southeast Asia, and arguably even between states in the USA (see case study of the Colorado River).

Case study: The Colorado River

The basin of the Colorado River is the most heavily used source of irrigation water in the USA. Water rights between states were allocated by the Colorado Compact in 1922. Over the next 60 years a series of treaties were agreed between the seven US states with a direct interest in the river, and between the USA and Mexico. A 'giant plumbing system' has come into being, involving more than ten major dams to serve the water needs of 30 million people (Figure 2.14 and Photograph 2.4).

Figure 2.13 The Colorado basin

The 1920s 'Law of the River', based on the Colorado Compact, established the division of water between the upper basin states of Colorado, Wyoming, Utah and New Mexico and their responsibility to supply the lower basin states of Arizona, Nevada and California, together with Mexico, where the river meets the sea. Initial agreements allocated California the largest proportion of water because of its large population and considerable political power. This has since been reduced by new developments and legal challenges.

The 1920s, when these agreements were drawn up, was a period of higher rainfall and water surpluses. As demand and populations increase and less water is available they are a growing challenge for the states and players involved. The stakeholders include the following:

- *Farmers*. Agriculture has always done well out of the Colorado River, receiving some 80% of the water allocation. This is because the farmers and ranchers got there first. In addition, to encourage agricultural development, the federal government

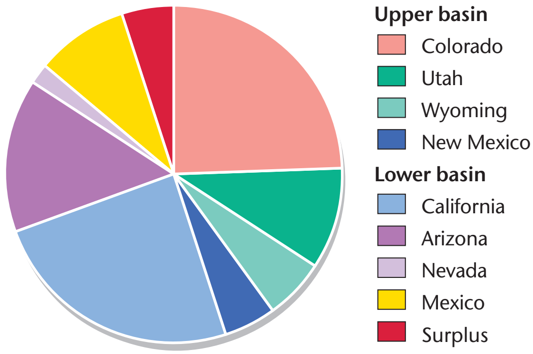


Figure 2.14 Water allocation from the Colorado River

supplied the water to farmers at low cost – as low as one-twentieth of the price in nearby cities. Much of this water is wasted in flood irrigation and inappropriate choices of crop (cotton and rice which need a lot of water). The sale of water rights by farmers to others is controversial.

- *City dwellers*. The southwest states have become increasingly urbanised. California is accused of using water that other states may need in the future. In recent years, against the background of a 5-year drought and continuing population growth, the conflict has become even angrier. In 2007, for the first time, Arizona began to take its full share of water for the cities of Phoenix and Tucson. To make up for this, California is squeezing farmers in the Imperial Valley to supply Los Angeles and San Diego.
- *Environmentalists and recreationalists*. The recreational development of lakes is of increasing concern to environmental groups which would prefer to see lower levels of recreational activity in wilderness and wetland areas. The heavy use of Lake Powell by tourists, for example, is threatening the lakeshore areas.
- *Indigenous groups*. Native Americans along the Colorado River have claims to water rights based on treaties and agreements made between their tribes and the federal government in the 1880s. They are engaged in prolonged legal battles over these claims.
- *Mexican people*. The Colorado River is used so heavily that it no longer reaches the sea – 90% of its water is extracted before it reaches Mexico. The wetlands that once existed in the river's delta are now a vast expanse of barren mudflats. Most of the local Cucupa fishermen have been forced to move elsewhere. The delta has reduced in size as water and sediment have been retained by the huge dams on the Colorado.

TopFoto

Photograph 2.4 The Hoover dam on the Colorado River

- *US federal government*. This is under pressure from its own politicians not to change water allocations. Plans to line the canal which carries water to California's Imperial Valley with concrete seem a sensible water conservation project. However, seepage from the canal tops up groundwater along the border, so any change would reduce supplies in Mexico. On the other hand, it seems that Mexico is taking more than its allotted share from the Rio Grande. These water issues could affect US–Mexican relations on other matters, such as curbing cross-border drug smuggling and controlling illegal immigration from Mexico into the USA.

The measures taken to control the River Colorado in order to prevent floods, generate electricity and provide water for homes and agriculture were an engineering marvel at the time of their construction. There is a view now, however, that it has been a costly, inefficient, divisive and environmentally damaging operation (Table 2.3).

Table 2.3 Colorado River: the benefits and costs

Benefits	Costs
Flood control	Water loss through evaporation and seepage
Power to pump the water	Salinisation as a result of irrigation
Domestic water supply	Groundwater overdraft
Irrigation for agriculture	Water waste
Industrial development	Environmental damage
Sediment control	
Recreation opportunities	
Wildlife protection	

Water transfers

Many regions and countries faced with increasing populations are finding themselves short of water. One solution to water shortages is to divert water from one drainage basin to another. Large-scale **transfers** of water can be achieved by diverting a river or by constructing a large canal to carry available water from one basin to another. Two very different case studies illustrate the environmental and political risks of water transfer. The Snowy Mountains Scheme in Australia has followed a traditional path, while the Turkey/Israel case study shows how international proposals are easily derailed by environmental and political change.

Case study: The Snowy Mountains Scheme

The Snowy Mountains Scheme in the Kosciuszko National Park is the largest engineering project in Australia and one of the most complex hydroelectric schemes in the world, with 16 major dams, seven power stations and a network of tunnels, pipelines and aqueducts. The scheme collects and diverts water so that it can be used by the power stations to create electricity. The water then flows west into the Murray and Murrumbidgee Rivers to irrigate farms and provide water for communities in New South Wales, Victoria and South Australia (Figure 2.15). Work began in 1949 and finished in 1974.

A number of negative consequences have gradually emerged. The creation of storage lakes, such as Lake Eucumbene, has destroyed valuable wildlife habitats, and in some places the Snowy River flow

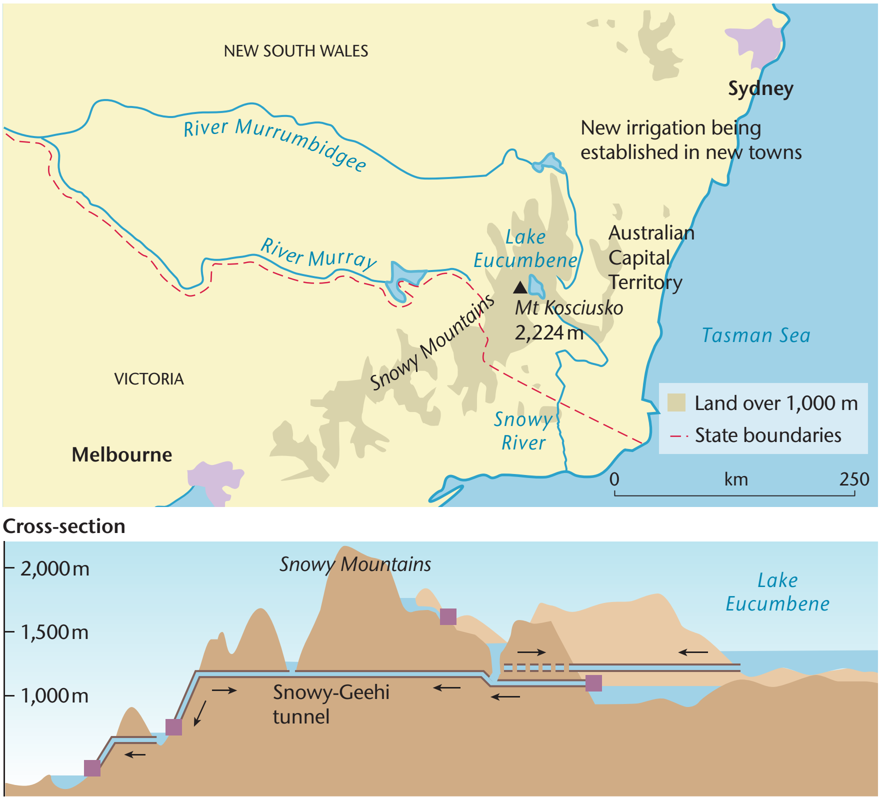


Figure 2.15 The Snowy Mountains Scheme

has fallen to only 1% of its original discharge. Groundwater overdraft and salinisation problems resulting from this low flow and irrigation have adversely affected farming in the Murray lowlands. Water scarcity has set farmers against city dwellers as they compete for supplies. The political fallout has forced the governments of New South Wales and Victoria to restore some of the flow in the Snowy River and to invest in water-saving projects. The aim has been to protect farmers from the worst effects of water shortages. Record droughts in Australia in recent years triggered by El Niño events have all but used up the water allocations of the Snowy Mountains Scheme.

A useful reference is: **www.cultureandrecreation.gov.au/articles/snowyscheme**

Case study Water transfers, Turkey to Israel

Israel's Hydrological Service has warned that the country's water reserves are being severely stretched as aquifers become salinised and water levels in the Sea of Galilee fall. Demand currently stands at 1.5 billion m^3 per year. Turkey appears to have surplus water that could be taken from the Mangavat River and sold to Israel. The following chronology illustrates how the water transfer might be achieved:

- *December 2001* – Israel and Turkey plan an undersea water pipeline link via Northern Cyprus.
- *August 2002* – Israel begins talks with Turkey to import 50 million m^3 of treated water each year using tankers.
- *July 2004* – Syria objects to Turkish plans because

Turkey has built reservoirs that retain water along the Tigris and Euphrates.

- *May 2005* – Israel and Turkey discuss once again the possibility of an undersea pipeline.
- *April 2006* – the water pipeline deal is scrapped as fears of terrorism grow and the costs of desalinating seawater fall.
- *June 2007* – Turkey proposes a 'peace bridge' overland pipeline to link all middle east states.
- *July 2008* – Official figures suggest Turkey is experiencing increasing drought and water shortages of its own, the outcome of global warming and poor management.

So how will Israel's water shortages be met – by water transfer or desalination?

Water conflicts and the future

What are the possible conflicts and solutions to increasing demands for water?

By the end of this section you should:

- *understand the uncertainties that surround future trends in water supply and demand*
- *be aware of the role of various players in decisions about water*
- *have investigated alternative strategies for water management*
- *have explored the role of technology in water supply and water security*

Trends in water demand

We have already looked at the current and forecast trends in global water supply and demand (Figures 2.4 and 2.5). By 2025, water withdrawal is projected to reach 5,235 km^3 per year, and this is likely to have considerable impact on food production, human welfare and the natural environment. Any predictions are tentative as they involve uncertain factors such as climate change.

Three alternative futures

In 2002 the International Food Policy and Research Institute used a computer model to examine the implications of three alternative futures for global water (and food) supply and demand. These futures calculated for 2025, are shown in Table 2.4. Clearly the business as usual scenario will be unsustainable in the long term. The most worrying scenario is that of water crisis, which shows how mismanagement of water resources or climate change could threaten our water and food supplies and lead to wider geographical problems including conflict. Some features of this scenario may be beginning to occur already.

Climate change

The impacts of global warming on water supply are easier to examine if we focus on the two most obvious features of current climate change – higher global temperatures and increasingly extreme weather events.

- Increases in mean annual temperature are already leading to earlier snowmelt in mountain areas and this is causing increase in spring discharge in major river basins. This water will be lost to the oceans or evaporated, as present water

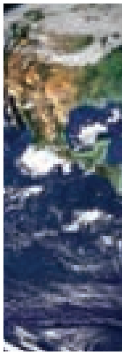


Table 2.4 Alternative scenarios for water by 2025

Scenario	Water changes by 2025	Wider impacts
Business as usual	Water scarcity will reduce food production Consumption of water will rise by over 50% Household water use will increase by 70% (mostly in developing countries) Industrial water demand will increase in developing countries	Developing countries will become reliant on food imports and experience increased hunger and malnutrition. In sub-Saharan Africa, grain imports will more than triple. In parts of western USA., China, India, Egypt and north Africa, water will be pumped faster than aquifers can recharge
Water crisis	Global water consumption will increase, mostly for irrigation Worldwide, demand for domestic water will fall Demand for industrial water will increase by 33% over business as usual levels, yet industrial output will remain the same	Food production will decline and food prices, especially cereals, will increase rapidly. In developing countries malnutrition and food insecurity will increase. Dam building will decline and key aquifers in China, India and north Africa will fail. Conflict over water between and within countries will increase
Sustainable water	Global water consumption and industrial water use will have to fall considerably. Environmental flows could be increased dramatically compared to other scenarios Global rain-fed crop yields could increase due to improvements in water harvesting and use of sustainable farming techniques Agricultural and household water prices might double in developed countries and triple in the developing world	Food production could increase slightly and shifts occur in where it is grown. Prices could fall slowly. Investment in crop research, technology and water-management reforms will increase. Unsustainable pumping of groundwater should end. Governments could delegate farm management to community groups

management cannot store or use it effectively. Snowfields in the Andes are already disappearing as rainfall replaces snowfall – this means the loss of a primary source of water. Melting of Himalayan glaciers could threaten water supplies of nearly half the world's population in Asia.

- Cyclones and monsoon events threaten water supplies intermittently, but it is the shortages of water brought about by the increased frequency and intensity of drought that will have the most devastating impacts. Dried-up rivers, irrigation failure and depleted aquifers threaten the lives of millions of people in Asia and sub-Saharan Africa.

Water players and decision makers

A range of **players** are involved in any issue relating to water resources and their use. There are supporters and opponents, villains and victims, 'Davids' and 'Goliaths'. However, for almost all players, the conservation and **sustainable development** of water resources is an increasingly important priority.

The process of weighing up the motivations and perceptions of players is called **values analysis.** It is an important factor in the evaluation of issues and in decision-making.

Many of the issues examined in this chapter involve a range of specific players who are identified in particular case studies. Table 2.5 identifies and illustrates the more general categories of player.

Table 2.5 Some of the players involved in water issues

Category	Players
Political	International organisations (e.g. UN), government departments (e.g. DEFRA), regional and local councils, lobbyists and pressure groups
Economic (business)	World Bank, governments, developers, utility companies (e.g. Thames Water), agriculture, industry (esp. chemicals and food), TNCs and businesses (including energy companies)
Social (human welfare)	Individuals, residents, indigenous groups, landowners, farmers, consumers, health officials, scientists and NGOs (e.g. Water Aid)
Environmental (sustainable development)	Conservationists, scientists, planners, international organisations (e.g. FAO) and NGOs (e.g. WWF and People & Planet)

Case study: Water futures for India and its neighbours

The Indian subcontinent has an insecure water future because:

- it has considerable supplies of water provided by three of the world's major rivers, but its monsoon climate creates extremes of flooding and drought
- rapid population growth and urbanisation, the existence of a large rural population and recent industrialisation are creating an unsustainable demand for water (see Table 2.6)
- the political division of some of its major drainage basins does not help water management, and disputes with neighbouring countries over water are ongoing

Table 2.6 Current water-related projections

	1995	2025
Rural access to piped water (% of population)	11	47
Irrigated rice (million hectares)	18	22.5
Irrigated cereals (million hectares)	37.8	47.1
Rice yield (tonnes per hectare)	2.5	3.8
Ganges water used (km^3)	141	147
Domestic water used (km^3)	21	41

Figure 2.16 illustrates some of the pressures in the region.

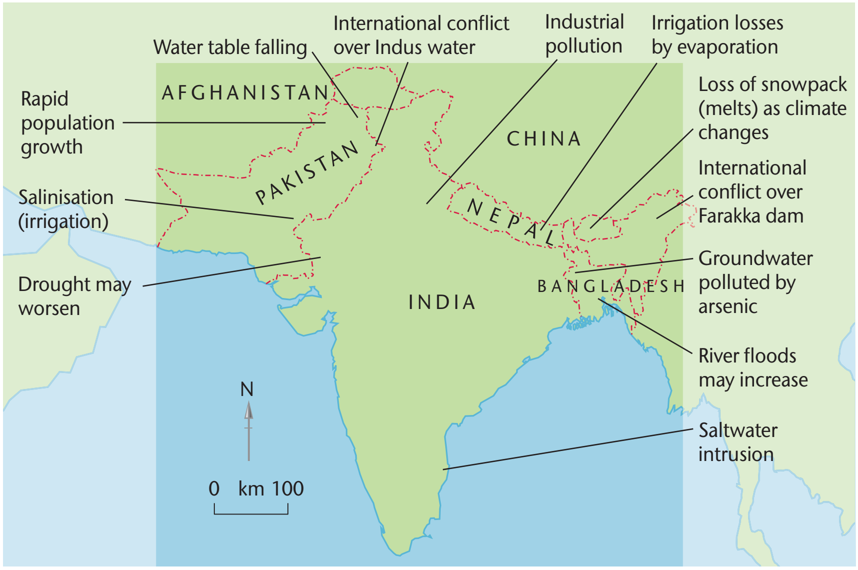


Figure 2.16 Human pressures in south Asia

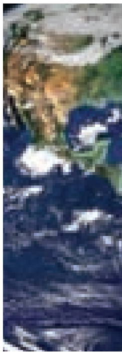
Case study: The Ebro River in Spain

In July 2001 the Spanish government approved a scheme to divert water from the lower Ebro valley to supply cities, farmers and tourists in the parched southeast of the country (Figure 2.17). Three years later, the newly elected government cancelled the diversion project and replaced it with cheaper, more localised schemes, including desalination plants.

This decision was the outcome of a hotly contested debate between players in favour of and opposed to the diversion project.

- *The case for.* Big international investors were concerned because they had marketed the south-east of Spain as the 'new Florida'. Vast tourist developments between Alicante and Almeria costing billions of euros, many based on new golf courses, were to be sited in areas supplied with Ebro water. People in Murcia and Almeria saw the Ebro scheme as the beginning of a new future, allowing the development of holiday homes, golf resorts and Europe's biggest tourism complex at Cabo Cope. The head of the Murcia regional government claimed desalination was unproven and expensive. EU funding was available, but may not be in the future.
- *The case against.* Environmentalists in the north protested that the diversion scheme was a misuse of a scarce resource and that it would have a drastic impact on the Ebro and its fragile delta. The Environment Minister claimed that the desalination plants would provide the same amount of water sooner and more cheaply. The new national government also promised to improve water recycling and make irrigation systems more efficient. Environmentalists claimed that the aquifers of the Ebro basin were already drying out because of over-extraction. They, and other critics, felt that the subsidies offered to farmers for irrigation encouraged the use of unsuitable land.

Figure 2.17 Diversion of the Ebro River



Responses to rising demands

Managing future water supplies will require action at a variety of levels, ranging from large-scale projects funded by governments down to changing consumers' attitudes to water use at a local level. Likely actions include:

- hard engineering projects to increase water storage and transfer, as for example in China's Three Gorges Project and its South–North Transfer Project (page 63)
- **restoration** of lost, mainly rural, water supplies, for example in the Aral Sea 'rescue' (see case study on page 60)
- water conservation in urban areas, involving such actions as rainwater harvesting and water recycling

The advantages and disadvantages of some of these actions have been discussed already. As demands for water rise tension is likely to increase. Major engineering projects will become too costly and their environmental impacts too great. Privatisation of water supply and sanitation services, together with the use of new **technology**, will change the economics of water use. People's concerns and priorities will change over time, as will their views of costs and benefits. There is the likelihood that water insecurity and water poverty will fuel major conflicts.

Case study: The Three Gorges Project

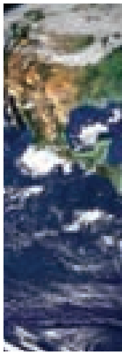
China's Three Gorges Project along the Yangtze River, the world's largest hydroelectric scheme, is due to come fully on stream during 2009. Given its current reliance on coal-fired power stations (70%), China sees hydroelectric power as clean energy with which to support its rapid industrial growth. However, the social and environmental costs of using this source of energy are already apparent, well before the economic benefits are reaped.

Benefits

- The 18,000 MW of water-generated electricity could save 50 million tonnes of coal each year.
- The project will supply water to a region responsible for 22% of China's GDP.
- Flood protection could save many lives and cut the financial losses created by flood damage.
- Navigational improvements could help open up the interior region of China to development.

TopFoto

***Photograph 2.5** An aerial view of the dam at Yichang*



Benefits ($ billion)		Costs ($ billion)	
Economic growth	82	Construction	50
Power generation	31	Archaeological loss	15
Clean power – benefit of energy switch to HEP	17	Resettlement	12
Flood control	5	Organisational costs	5
Navigational improvements	3	Dam failure risks	3
		Downstream effects	3
		Fishery loss	0.7
		Tourism loss	0.4
		Land inundation	0.2
Total	138		89.3

Table 2.7 A possible cost–benefit analysis

Costs

- The dammed waters will drown 100,000 hectares of arable land, 13 cities, many smaller settlements and 1,500 factories.
- Some 1.9 million people will be displaced from their homes and lose their land.
- Dam failure, earthquakes, heavy rains and even terrorism pose serious safety risks.
- The ecological impacts on fisheries, biodiversity and habitats are considerable.
- Pollution will increase as abandoned mines and factories are flooded.
- Important archaeological and other heritage sites will be lost.
- The river has the world's fifth largest sediment load. Sediment could damage turbines and become trapped behind the dam, raising water levels and reducing soil fertility downstream.

Table 2.7 shows a cost–benefit analysis of the scheme. This gives a simple **benefit–cost ratio** of 138/89.3 = 1.55. This sort of value is considered a positive one in civil engineering proposals. Figure 2.18 suggests that after initial losses due to construction this project will return to profitability after 25 years.

The wider issues of China's South–North Transfer Project are considered in the final part of this chapter.

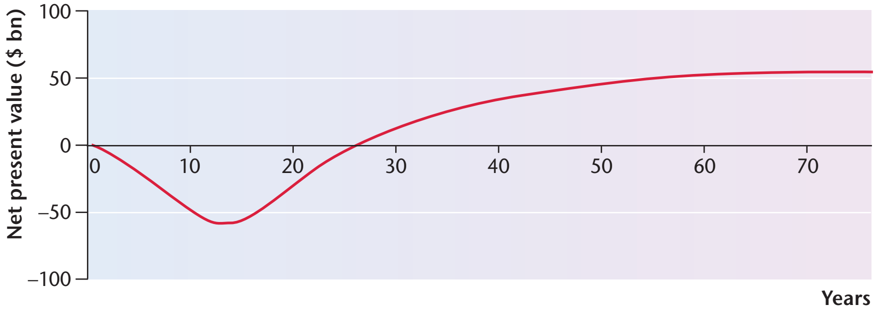


Figure 2.18 A cumulative net present value graph for the Three Gorges Project

Hard engineering

Most major dam construction in the future is likely to be limited to developing countries. Current global dam-building costs are between $22 and $31 billion each year. Half the world's large dams were built primarily for irrigation (contributing up to 16% of world food production). Hydroelectric power, flood control and domestic water supply are other benefits. But what are the real costs of such schemes? The World Commission on Dams report (November 2000) (to be found at www.dams.org) has some answers:

- *Economic costs*. The construction of large dams seems to overrun projected costs by an average of 50%. Water sales rarely cover the costs of water supply in developing countries. Even in the long term, multi-purpose schemes often fail in financial terms. The total global investment in dams between 1950 and 2000 was estimated at around $146 billion.
- *Ecological costs*. Dams, inter-basin transfers and water withdrawals for irrigation have fragmented 6% of the world's rivers, disrupting floodplain agriculture, fisheries, pasture, forestry and ecosystems. Many of these ecological impacts were not anticipated before the dams were built. Environmental impact assessments (EIAs) are relatively new.
- *Social costs*. During the construction phase local communities are starved of development and welfare investment. Communities and their livelihoods are severely disrupted. Construction of dams in India and China alone is reported to have displaced 58 million people in the last four decades.

River, lake and wetland restoration

A number of management strategies are being used to return water environments to their natural state. At a local scale, this can involve restoring meanders, replanting vegetation and using sustainable methods to manage watercourses for people and the environment. A good example is provided by the River Restoration Centre in the UK. It began its work on the rivers Cole and Skerne and has since tackled similar projects throughout the UK (for more information visit www.therrc.co.uk/rrc_case_studies_list.php).

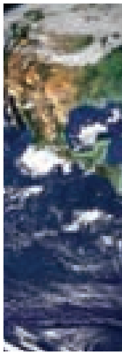
On a larger scale, the US Army Corps of Engineers has begun restoring the Kissimmee River in Florida. When restoration is complete in 2011, more than 100 km^2 of floodplain ecosystem will be restored, including 8,000 ha of wetlands and 75 km of river channel. Restoration on an even grander scale is being planned in the Lower Danube basin, but perhaps the largest project currently being considered is the restoration of the Aral Sea.

Case study: Restoring the Aral Sea

Since the breaking up of the Soviet Union the northern part of the Aral Sea is in Kazakhstan and the southern part in Uzbekistan. In 2007 the Kazakhstan government secured a $126 million loan from the World Bank to help save the northern part of the Aral Sea (see the case study on page 45). It is an ambitious project aimed at reversing one of the world's worst environmental disasters.

The Kazakhstan government used an earlier $68 million loan to build a dam that has split the sea into two parts (Figure 2.19). Officials claim that the northern sea is already filling up, now that water from the Syr Darya is once again flowing into the Aral. The new loan will be used to build a second dam to bring the water back to the deserted port of Aralsk. Communities in the area are already feeling the impact. The fishermen are back in their boats, rain has returned and the future no longer looks hopeless. See http//:news.bbc.co.uk/2/hi/asia-pacific/7479760.stm

However, the actions taken so far have not solved the problem on the Uzbek side of the border. The



southern part of the sea is still shrinking, and many experts believe it is too late to save it. The waters of the Amu Darya, which should be feeding into the sea, are desperately needed for growing cotton. The economy of Uzbekistan is heavily dependent on this cash crop. An additional problem with both this river and the Syr Darya is that their headwaters are controlled by other countries. Even worse is the fact that this is a part of the world where sensitive water developments could easily trigger conflict.

For a more radical proposal to solve the Aral Sea problem using major diversions of the Volga and Ob rivers, see www.ecoworld.com/home/articles2.cfm?tid=354

Figure 2.19 The shrinking Aral Sea

Water conservation

Water conservation involves reducing the amount of water used (i.e. demand) rather than trying to increase water supplies. In a world where the supply is finite, this is an important strategy.

Water conservation can be applied in a variety of situations. In agriculture, it can involve more efficient irrigation. In industry, water can be treated or recycled for further use. Domestically, water savings and water harvesting are beginning to move from a DIY basis to a more commercial footing.

In some places, efforts are being made to conserve wetlands, as part of a wider challenge to store water and develop a more eco-hydrological view of water resources and their management. At home, measures such as raising water prices and introducing water meters make consumers more careful about their consumption of water.

Effective use of water for food production is of crucial importance, and irrigation is a key area in this. In the past, flood irrigation has proved to be wasteful of water as it leads to high evaporation and seepage losses. Modern spray technology is more controllable, and the more advanced 'drip' irrigation, though expensive, is more effective. Fertigation, which uses small quantities of fertiliser with fine water sprinklers, has proved to be effective in Israel and the USA. For more information on the issues of water, agriculture, food security and poverty in developing countries, visit the FAO Water website 'Water at a glance' (**www.fao.org/nr/water/art/2007/flash/glance/gallery1.html**).

Conservation of industrial and domestic water is about recycling and re-use. Potable water is crucial for some purposes but grey water can be used for others. Water can be treated using filters or chemicals, but sewage and polluted water require strict disposal strategies. In and around the home, there is much that can be done to conserve water (Figure 2.20).

How many of these are part of your home action plan? Ten ways to save water...and money

In the bathroom

1 Fit a low-flush toilet, or put a water-filled plastic bottle in your toilet tank – saves 1,300 litres a month.
2 Shorten your showers by 1 or 2 minutes – saves up to 3,000 litres a month.
3 Don't waste water by waiting for hot water to reach the shower or sink. Catch the cold water in a container to use on your outside plants – saves 900 to 1,300 litres a month.
4 Turn off the water while brushing your teeth or shaving – saves 13 litres a day.

In the kitchen

5 When washing dishes by hand, don't leave the water running for rinsing – saves 900–2,000 litres a month.
6 Run only full loads in the washing machine and dishwasher – saves 1,300–1,800 litres a month.
7 Keep a bottle of drinking water in the fridge instead of running tap water to cool it for drinking – saves 900–1,300 litres a month.

Outside

8 Water the garden during the cool parts of the day.
9 Try water harvesting – catching rainwater from roofs in butts or ponds.
10 Drive your car onto the lawn to wash it: the rinse can help water the grass.

Figure 2.20 Water conservation at home

Water technology

The final part of this chapter focuses on the role of technology in managing and conserving future water supplies. Technology can help increase both water supply and access. Water transfer is now commonplace as civil engineering skills and construction technology continue to improve. The dams and canals of the Colorado Project, once the wonder of the world, are now dwarfed by developments in China and Brazil and on the Indian subcontinent. China's plans are both spectacular and controversial (see case study below).

Case study: China's South–North Transfer Project

The south of China is rich in water resources but the north is not. To redistribute these resources and to even out the availability of water, a gigantic south–north water diversion project was begun in 2003. It is expected to take 50 years to complete and will cost $62 billion. The project involves building three canals which run 1,300 km across the eastern, middle and western parts of China and link the country's four major rivers: the Yangtze, Yellow, Huai and Han (Figure 2.21). The scale of engineering involved in this scheme is awesome. It will transfer a total of 44.8 billion m^3 of water per year. Central government will provide 60% of the cost of the scheme, with the rest coming from local authorities, which, in turn, will charge domestic and industrial users. Water conservation, improved irrigation, pollution treatment and environmental protection are included in the plans.

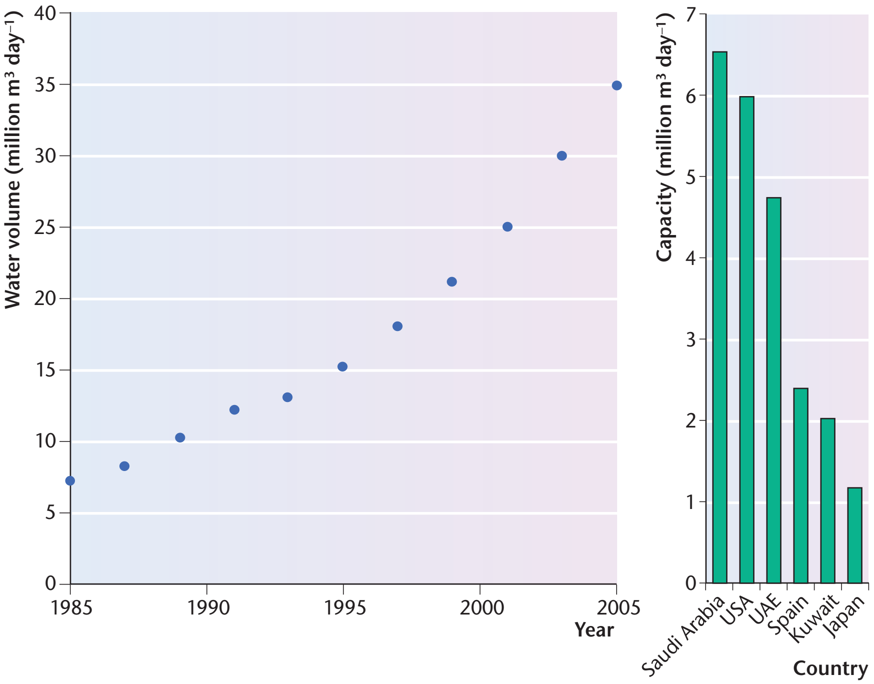
Critics are concerned about the uncertainties and risks associated with the project. These include the likelihood of significant ecological and environmental impacts along the waterways, resettlement issues and worsening water quality. The pollution of the Yangtze River is already at alarming levels. Untreated industrial and city wastewater is being mixed unchecked with agricultural runoff containing pesticides and fertilisers. The Huai River is already severely polluted and the water of the Yellow River is undrinkable. Some experts fear an ecological disaster.

Figure 2.21 China's South–North Transfer Project

Desalination

The process of **desalination** (also known as desalinisation) is the removal of excess salt and other minerals from water. It produces freshwater suitable for human consumption or irrigation. For a long time, desalination was a technological success that failed to deliver in economic and environmental terms. However, as water costs and demand have increased, more countries are turning to desalination as part of their future water strategy (Figure 2.22).

Figure 2.22 The global growth of desalination



Many of the countries or states involved are relatively well off, technologically developed and increasingly water stressed. In the middle east, Saudi Arabia, the United Arab Emirates (UAE) and Kuwait use cheap energy to distil freshwater from seawater.

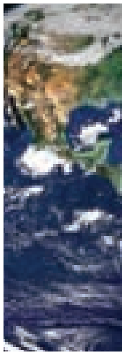
In the USA, California and Florida lead the list of states using reverse osmosis membrane technology to filter salt from brackish water and rivers. Recent newcomers to this technology include Spain, China, Australia and Israel.

The costs of desalination are difficult to calculate, as subsidies are often involved. Cheaper processing and larger plants make it cheaper but the process uses a lot of energy so rising oil costs are increasing the price. The water produced is of a high quality, although chemically different (in terms of minerals) from rainwater. Water intake and outflow processes have ecological effects, not least because concentrated brine is a by-product of desalination. The costs of desalinated water in California offer some interesting comparisons (see Table 2.8)

Remember that **water technology** includes not just desalination technologies, but also those associated with the diversion, transfer, storage, conservation and

Source	Lowest cost (cents per m^3)
Desalination of seawater	95
Desalination of river/brackish water	60
Treated runoff	38
Untreated runoff	29
Subsidised water for agriculture	2

Table 2.8 Supply costs of water in California



restoration of water. The hope for a 'water-hungry' world free from water conflicts lies in a sensible, balanced and sustainable use of all these technologies.

Review questions

1 Examine the factors which can create water stress in some parts of the world.
2 Explain the links between (a) economic growth and water demand, and (b) water insecurity and water poverty.
3 Using examples, show how disputes over water can create tensions between countries.
4 Examine the risks associated with water transfer schemes.
5 Explain why there is so much uncertainty about future water demand and supply.
6 Evaluate the view that reducing water demand is better than trying to increase water supply.
7 Using examples, evaluate the economic and environmental benefits of different types of water technology.