WATER CONFLICTS

THE GEOGRAPHY OF WATER SUPPLY

Water supply is controlled by physical factors, such as climate, geology and surface processes; supply can be from surface or groundwater sources; fresh water supply is a finite resource.

Physical factors

Climate is the main factor: uneven distribution of rainfall globally means there are areas of water deficit and surplus. For example, equatorial regions have more rain than temperate or arctic regions. At high altitudes, spring snows are often the source of large rivers. However, high rates of evapotranspiration reduce the water supply if the water is not captured and stored immediately.

Drought in the Sahel region of Africa

- The Sahel region has been suffering from drought on a regular basis since the early 1980s. The area naturally experiences alternating wet and dry seasons.
- Human activities such as overgrazing, overcultivation and the collection of firewood can lead to desertification, especially when combined with drought conditions.
- Drought leads to crop failure, soil erosion, famine and hunger. People are less able to work when their need is greatest.
- In Niger in 2004, the drought situation was made worse when a plague of locusts consumed the remaining crops.
- Food aid is unsustainable in the long term, so development aid, which involves educating the local community in farming practices, is the better option.

Drought in 2012

- The USA faced its worst drought in 50 years. It is the world's largest producer of wheat, soybean and corn, 40% of which is used to make biofuels. Crop yields fell and prices increased.
- In the Horn of Africa, between 50,000 to 100,000 people died, more than half of them children under 5. The drought affected 13 million people through the destruction of livelihoods, livestock and local markets. A full scale response was launches a year after emergency signs appeared, causing widespread criticism of the response effort.
- In England, 17 counties faced water shortages. The South West and Midlands moved into official drought status after two dry winters left rivers and groundwater depleted. Hosepipes were banned and the Environment Secretary stated that is was "everyone's responsibility to save water".

Seasonality is also very important for water supply as precipitation patterns vary throughout the year. Vancouver, on the west coast of Canada, receives about 1,100mm of precipitation per year, but this falls mainly between October and March. In summer, higher temperatures increase evaporation, and plant growth during spring and summer increases rates of transpiration.

The Edwards aquifer and drought

- In November 2011, there had been a drought for 14 months, causing significant depletion of the aquifer. Stage 2 drought restrictions were put in place. The aquifer held at 649 feet.

- In May 2014, storm rains brought by El Niño raised the level of the aquifer but did not break one of the worst long-term droughts in Texas' history.
- In September 2014, the area moved into stage 4 drought restrictions, so all users in San Antonio had to cut pumping by 40%.
- In October 2014, the San Antonio City Council approved the 142-mile Vista Ridge pipeline that will import up to 72 million m^3 annually from the Carrizo-Wilcox aquifer.

Geology is another factor that greatly influences water supply. Rivers will form on impermeable rocks, such as granite or clay. Permeable rocks such as chalk or limestone store water underground in what are known as aquifers e.g. the chalk aquifer underneath London, the limestone Edwards aquifer in Texas and the Nubian Sandstone Aquifer System.

Sources of water

Water can be found in many sources. Surface stores are lakes, springs and rivers that are very easy to abstract water from. Aquifers are groundwater stores in areas of porous or permeable rock, such as the London Basin and the Ogallala aquifer in the USA. Mexico City was built on an aquifer. Reservoirs behind artificial dams store water that is fed to water treatment plants and then to homes.

While the amount of water available will determine the ecology of an area, people have the technology to overcome the physical challenges of living in hostile environments, but this is limited by their ability to afford the required technology. Some of the areas that are most pressured in terms of water availability are also home to many poorer people and here people are much more reliant on seasonal rainfall and suffer greatly when these rains fail to arrive.

Key words

Actual evapotranspiration: the quantity of water that is actually removed from a surface due to evaporation and transpiration.

Arid conditions: where rainfall is less than 250mm of precipitation per year.

Drought: a prolonged period of abnormally low rainfall, leading to a shortage of water.

Potential evapotranspiration: the amount of evaporation (from soil, rock and surface stores) that can occur given a sufficient supply of water.

Semi-arid conditions: where rainfall is less than 500mm per year.

There is often a growing mismatch between water supply and demand, which can lead to water stress either locally, or across whole regions e.g. economic growth in the RICs such as China and India.

Uses of water

Water is most often used for irrigation and other agricultural uses, with 67% of the world's water going to the agriculture sector in 2005. 9% of water use was by households, such as for white goods. Less than a quarter of water was used in industry. However, demand for water differs greatly in different parts of the world. Agriculture uses 88% of water in Africa compared with only 33% in Europe where industry consumes more than half the supply. The amount of water that people use depends not only on basic needs and how much water is available but also on levels of urbanisation and economic development.

Water in reservoirs can be used in the following ways:

- Hydro-electric power generation e.g. the Three Gorges Dam
- Irrigation e.g. the Aswan Dam and the Hoover Dam
- Flood control e.g. the Aswan Dam
- River regulation e.g. Kielder Water
- Recreation e.g. the Hoover Dam

Population and economic development are driving a steadily increasing demand for new water supplies; in the last 70 years, the global population has tripled while water withdrawals have increased six times. As poorer countries develop, the volume of water used by industry is rising and, as the world becomes more urban, the demand for potable water for municipal use is exceeding the capacity of local water companies to supply it. Agriculture, industry and the domestic sector use most of the water abstracted from rivers, lakes and aquifers, but larger volumes are being taken from finite sources and maintaining supplies to meet demand is becoming increasingly difficult. Large quantities of water are used for agricultural and industrial processes. The additional indirect water use is known as 'virtual water'.

Water use is measured in terms of the volume of water consumed and/or polluted per unit of time and the consequent water footprint is divided into three elements:

- Blue water is freshwater taken from surface water and groundwater resources.
- Green water is freshwater taken from rainwater stored in the soil as soil moisture.
- Grey water is polluted water, calculated as the volume of water that is required to dilute pollutants so that the quality of water is above agreed water quality standards.

Water stress

Water stress is measured as annual water supplies below 1,700m^3 per person. This involves the deterioration of freshwater resources in terms of quantity (aquifer depletion or dry rivers) and quality (eutrophication, pollution or saline intrusion). Water scarcity occurs when the shortage of freshwater threatens food production and damages ecosystems. This is measured as annual water supplies below 1,000m^3 per person.

Water scarcity may be divided into the following categories:

- Physical water scarcity: more than 75% of river flows are allocated to agriculture, industries or domestic purposes (accounting for recycling of return flows). This definition of scarcity – relating water availability to water demand – implies that dry areas are not necessarily water-scarce, e.g. Mauritania.
- Approaching physical water scarcity: more than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.
- Economic water scarcity: water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists. These areas could benefit by development of additional blue and green water, but human and financial capacity are limiting.
- Little or no water scarcity: abundant water resources relative to use. Less than 25% of water from rivers is withdrawn for human purposes.

India and China

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 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 transfer water to this area from the water-rich south.

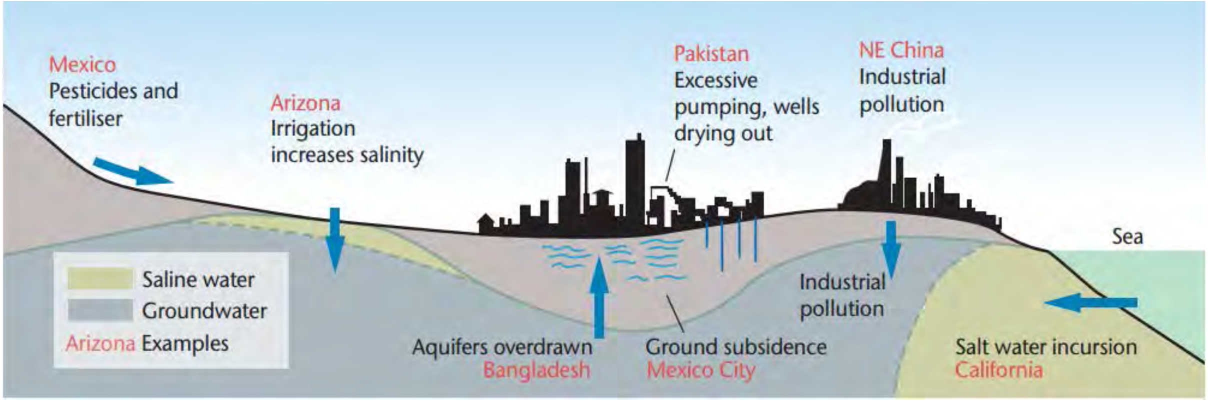
Keywords

Virtual water: the amount of water used in the production of a good or service.

Water scarcity: the lack of sufficient water resources to meet the demands of water usage within a region.

Water stress: a situation where the availability of water is a major constraint on human activity. Also the availability of water less than 1,000m^3 per person per year.

Human activity can affect water availability, through processes such as pollution of supply, over abstraction and salt-water incursion; this can exacerbate water stress.



MDG7

Humans must drink potable water. In HICs water can be purified, for example in the Lea Valley, London, where wastewater is cleaned and used to recharge aquifers. Contaminated water carries diseases such as cholera, which is one of the diseases responsible for the high infant mortality rates in LICs. The 7^{th} Millennium Development Goal (MDG7) aims to reduce by half the proportion of people without sustainable access to safe drinking water. This goal can be achieved through reliable supplies and waste treatment technology.

With a warmer climate, droughts and floods could become more frequent, severe and long-lasting. Droughts can have devastating effects on agriculture, livestock and water supplies, causing famine, malnutrition and the displacement of populations from one area to another. The land may become starved of nourishment or contaminated with mineral salts, so that even when it does rain the ground cannot support much vegetation growth. With climate change expected to reduce rainfall in some places and cause drought in others, some regions could become 'economic deserts', of no use to people or agriculture.

Droughts can be classified in different ways:

- Meteorological drought: a prolonged period with less than average precipitation.
- Hydrological drought: water reserves in aquifers, lakes and reservoirs fall below average levels.
- Agricultural drought: a reduction in precipitation levels, but also may occur when inappropriate agricultural activity causes a shortfall in water available to crops.

Some of the most dramatic examples of water shortages in 2008 included:

- Lake Faguibine in Mali, on which 200,000 mostly nomadic people depended, dried up.
- Fatal clashes occurred over drying boreholes in northern Kenya.
- 25 million people were affected by the drought in Ethiopia.
- California declared a state of emergency over water shortages.
- Australia spent billions of dollars to cope with drought.
- Governments in Europe had to ship in water to prevent communities running dry.

Pollution of supply

The Pearl River in China is highly polluted.

- The Delta, which accounts for 10% of China's GDP, has undergone rapid urbanisation. The rapid growth of cities has contributed to environmental degradation in the Delta.
- Polluted water is killing crops in the Pearl River Delta.
- Cities are rich enough to treat the water but they do not allow farmers to use the treated water, so people are forced to drink the polluted water. Those who do fall sick.
- 9,000 tonnes of heavy metals, 66,000 tonnes of nitrates and ammonia and 60,000 tonnes of petrol are deposited into the sea every year by the river.
- The World Bank has approved a US$96 million loan to reduce water pollution.
- Guangzhou has built 30 water treatment plants which aim to cut sewage by 85%.

Pollution of aquifers in the USA is a growing problem.

- In California's Silicon Valley, electronic industries store their waste solvents in tanks underground.
- When local water authorities conducted an inspection they found 85% of tanks were leaking.
- 60% of the US's liquid hazardous waste is injected directly into the ground, including solvents, heavy metals and radioactive material.
- Even though waste is injected deep below drinking water sources, the waste has leaked and entered aquifers affecting many states including Florida, Texas, Ohio and Oklahoma.
- It puts the Ogallala aquifer at risk.

Over abstraction

Mexico City's over abstraction of the aquifer is causing problems with subsidence.

- The city is built on layers of clay and sand that easily compress when water is abstracted. The inelastic compression is not reversible.
- Water is being taken from the Mexico City Aquifer provides 72% of water supply in the city.
- Subsidence occurs at 1-3" per year. It has caused damage to infrastructure, including building foundations, wells, streets and sewers. 40% of water loss is from leaky pipes.
- Flooding is a problem as the city now lies 6 feet below nearby Lake Texoco.

The abstraction of water from the Aral Sea has caused severe local problems.

- Soviet engineers began diverting water from the two rivers that sustain the Aral Sea, the Amu Darya and the Syr Darya, after Soviet central planners had calculated that the rivers were worth more if they were used to grow crops in the desert.
- By 2005, the Aral Sea had lost 80% of its water.
- Most of the fish and 60,000 fishing jobs disappeared.
- 3 million people in the area suffered from high rates of cancer, respiratory ailments and anaemia due to millions of tonnes of salt and toxic dust exposed on the sea bed.

Thailand’s salt industries over-abstract local groundwater sources.

- In January 2010 sink holes 10 metres in depth and 20 in width opened up on a tapioca farm in the village of Nong Rang.
- Geologists conducted inspections of the area and showed that the sinkholes were the product of over abstraction of the underground aquifer, and blame was put on the salt factories around the area that used lots of water for the production of salt.
- The provincial chief of primary industry and mines division is going to strictly control or ban the abstraction of salt factories to prevent the overuse of underground water.

Salt water incursion

Saline intrusion is occurring on the coast of Spain.

- 60% of aquifers are experiencing saline intrusion due to irrigation and overuse by tourism.
- La Plana de Castellon is an aquifer mostly used for irrigation in farming. The increase in demand for water due to the increase in agriculture has placed stress on the aquifer. This has caused the aquifer to deplete, allowing salt water to intrude into the aquifer.

Israel also suffers from salt water incursion.

- Israel has two water supplies. The first is the West Bank Aquifer, which is shared with Palestine. The other is the Crystal Plain Aquifer, which is located in the Gaza Strip.
- The Crystal Plain Aquifer contributes to Israel’s commercial drip irrigation. Israel has depleted the aquifer to below sea level and mismanagement has caused the aquifer to become contaminated by nitrates, salt and seawater.
- 20% of the water in the Crystal Plain aquifer cannot be used. The damage is irreversible.

Misuse of water supply

In Yemen there is a severe misuse of water.

- Yemen imports most of its food as there is too little water for it to feed itself.
- Much of the remaining water goes to growing khat, a non-essential crop that can induce mild euphoria, excitement and hallucinations when chewed.
- Khat is becoming increasingly popular as half of the people live on less than US$2 per day and there is little other amusement to be had.
- Growing khat earns farmers 20 times more than potatoes, but 40% of the country’s water goes in irrigating khat. Production is increasing 15% per year.
- The basin around Sana’a, the capital city, is depleted 10 times faster than it is replenished.

Key words

Potable water: water that is safe for human consumption.

Access to water is often related to and controlled by wealth and poverty, especially in developing and emerging economies.

Access to water

Unsustainable use is threatening the future of water supply in many areas. Demand has risen as the global population has tripled in the last 70 years and water withdrawals have increased six-fold. There is increased competition for available water as living standards rise and groundwater reserves are abstracted faster than they are recharged. In some countries, urban populations are rising rapidly while, in others, old water mains and sewers are no longer fit for purpose. Pollution from urban, industrial and agricultural sources had affected water quality, and over-extraction in many places has reduced the ability of supplies and suppliers to meet demand. The threat of climate change, affecting the amount and reliability of rainfall in many parts of the world, compounds this unsustainable situation. There is also an environmental obligation to maintain fragile wetlands and water courses.

In the Pearl River Delta in China, access to cleaned water is unequal.

- Polluted water is killing crops in the Pearl River Delta.
- Cities are rich enough to treat the water but they do not allow farmers to use the treated water, so people are forced to drink the polluted water. Those who do fall sick.

Players in water supply and demand

The people whose activities affect water supply and demand are the players: they control access to water or are affected by others' control of the water supply. Vulnerable populations stand to suffer the most because access to water is controlled by those with wealth and power, especially in the developing and emerging economies where the lack of access to clean drinking water is a vital issue.

THE RISKS OF WATER INSECURITY

The development, extraction and use of water sources can lead to environmental and supply problems e.g. in the Middle Eastern or India/Bangladesh, with severe implications for human welfare and economic activity.

Sources of water

The development of water resources depends on the availability of easily accessible reserves. There are several sources of water for human use: these include surface stores, groundwater stores and rainwater. Surface stores in springs, streams, rivers and lakes are the most accessible sources, provided that the water is sufficiently clean to use. Narrow valleys in upland areas may be dammed to create reservoirs to store water and control flooding. Springs emerging directly from ground sources are generally potable. Other water courses may contain pollutants from adjacent natural and human land uses and need to be treated prior to use.

Groundwater sources are stored in aquifers usually within sandstones and limestones. Confined aquifers are those sandwiched between layers of impermeable rock called aquicludes. Wells are sunk to extract water from aquifers but they have been over-exploited in some places and removal of the water is lowering water tables. The Ogallala aquifer lies under the central states of the USA from South Dakota to Texas and supplies water for agriculture, but the water is being pumped out faster than it is recharged and in places the water table is falling by over a metre per year. Most of the water in this aquifer is thought to have collected when the glaciers melted 15,000 years ago and it is described as fossil water, meaning that it is now recharged at a much slower rate.

Environmental and supply problems

The Coca-Cola plant in Kerala, India was closed for over-abstracting from the local aquifers.

- Coca-Cola used 309 billion litres of water globally in 2009. 2.7 litres of water are used to make one litre of product.
- The Plachimada bottling plant opened in 1998 in Kerala.
- The company was accused of putting thousands of farmers out of work by draining well water and poisoning the land with waste sludge they claimed was fertiliser.
- Water supplies had to be brought in daily by the government, and farmland (coconut plantations) was abandoned.
- Coca-Cola has achieved 90% wastewater recovery at the Wakefield plant in the UK, showing that progress has been made in this respect.

Modification of the ground water system can have long-lasting consequences. Lowering the water table by abstracting water faster than it is replenished causes wells to dry up. This can lead to subsidence as the previously water-bearing sediments may become compacted and the added weight of buildings can increase this effect. Near coasts, saltwater seeps naturally into permeable rocks. Normally freshwater in the ground floats on the denser saltwater but, when too much water is taken from the groundwater store, saltwater can be drawn up towards the well, contaminating the supply. Also, as water is taken from a wall, a cone of depression in the water table is formed around the well.

Groundwater is vulnerable to pollution from landfill sites, to leakage from underground storage tanks and sewerage and to surface pollution spills where the ground above is permeable. Residues from agro-chemicals leach into groundwater stores. In some areas, such as East Anglia, Nitrate Sensitive Areas have been set up, restricting the use of nitrates to protect water supplies. Pollution is increasingly damaging the supply of freshwater; almost two million tonnes of waste are dumped daily into lakes, rivers and streams.

Water conflicts

The Middle Eastern water conflicts are exacerbated by low seasonal rainfall and growing population sizes.

- 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, but was a contributory factor. Water in this region comes 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.
- 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.

The above diagram details water conflicts in the Middle East.

At the heart of tensions between India and Bangladesh is the water supply from the River Ganges.

- For most of its 2,500km length, the Ganges flows through India, but the last part of its course takes it through Bangladesh before passing into the Bay of Bengal.
- In 1974 India opened the huge Farakka Barrage, just 11km 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.
- Bangladesh is being deprived of much-needed water and has to suffer the effects of India's pollution of the river.
- The 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, which are also increasing salinization. The delta is eroding because less silt is being carried and deposited. Seawater incursion is increasing as the delta dries out.

Key words

Fossil water: ground water that collected thousands of years ago and is now regenerated at a much slower rate.

There is potential for water conflict where demand exceeds supply, and where several players use the same water system.

Supplying clean water

While industries such as power generation may use untreated water, river water needs to be treated prior to domestic use. Water purification involves a series of physical, chemical and biological processes including settling, coagulation, disinfection, filtration through sand and aeration to encourage benign bacteria. Industry and agriculture may release waste water directly into rivers but this is strictly controlled in HICs to ensure that pollution is minimised. Waste water, cleaned of all significant pollutants, is returned to rivers or in some places, such as the Lea Valley in North London, used to artificially recharge an aquifer.

Access to a clean water supply is fundamental to human health with vital implications for human welfare. The minimum requirement is about five litres per day to prevent dehydration, but 30 litres per day is regarded as the minimum needed for cooking and cleanliness as well as drinking. In many poorer countries up to 25 litres of water may be carried for several kilometres. It is the female members of the community who normally collect the water and it can take more than half their time, causing young girls to give up formal education. Carrying water over long distances is a health hazard, especially during childhood and pregnancy. In urban areas water may be bought from private water-carrying services or from public standpipes.

Contaminated water is a major health risk in developing countries; water-borne diseases cause around 2 million deaths a year, mainly of children in poorer countries where there is inadequate or non-existent public sanitation. About 1 billion people do not have access to safe water and 2.5 billion people do not have access to adequate sanitation. Water-related diseases prevent many people from leading healthy lives and undermine development efforts. Around 2.3 million people suffer from diseases caused by protozoa, viruses, bacteria and intestinal parasites acquired from water. In developing countries, diarrhoea is the leading cause of childhood death. Providing clean water and ensuring proper sanitation facilities would save millions of lives by reducing the prevalence of water-related diseases, so finding solutions to these problems should become a high priority for developing countries and aid agencies.

Water conflicts

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.

Several players using the same water system

There are several stakeholders involved in in the Aral Sea.

- *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.
- *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 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 build, allowing water to leak out or evaporate. The main Kara Kum Canal, the largest in Central Asia, allows between 30 to 75% of its water to go to waste.

In Kenya, there is growing conflict over dwindling resources.

- Most conflicts are at a local level. There is often tension and violence over water.
- 50 people are killed each year over water.

Increasingly water supply is a geopolitical issue; often with a trans-boundary dimension e.g. water trading along the Colorado between states of the USA, the rise in water treaties, and the political power associated with these.

The politics of water

UNEP has calculated that enough rain falls on Africa to supply the needs of 13 billion people and has called for a continent-wide programme of rainwater harvesting. UNESCO has suggested that globally the volume of water available per person will decrease by 30% by 2025.

Water supply is increasingly a geopolitical issue. Water politics have emerged internationally as a series of treaties, and agreements have been made between states and countries sharing water resources. Several major river systems cross international boundaries and tensions canaries over the use of the water as demand for water increases.

Water is a strategic resource and increasingly an important feature of many political conflicts. Some have suggested that water will become a tradable commodity as important as oil, benefiting water-rich countries such as Greenland, Canada and Colombia. Those who hold vital resources also hold power over those who do not have access to those resources. Where water resources cross international or state boundaries, the challenges for integrated watershed management are compounded and political cooperation may be compromised. The potential for conflict is high: water and its use may strain relations between and within countries. The authorities responsible for the sources and major upstream tributaries of river systems are able to control the flow downstream, possibly depriving other states and nations of valuable water resources. It has been calculated that there are 261 international rivers, covering 45.3% of the earth's land surface. Nineteen basins are shared by five or more riparian countries.

International treaties

The River Danube is a trans-boundary source, but international agreement has stopped conflicts.

- The Danube flows through 17 countries, and rises in the Black Forest Mountains in Germany and flows for 2,850km to the Black Sea.
- It provides drinking water for 10 million people and the International Commission for the Protection of the Danube River, comprising 13 member states and the EU, was set up in 1998 to promote and coordinate sustainable and equitable water management, including conservation, improvement and rational use of the water of the river, its tributaries and groundwater sources.

The River Nile is over-used, so conflict in the near future is likely.

- The Nile flows through 10 countries for 6,700km, draining more than 3 million km^2, about one-tenth of the entire African landmass, and is formed by three major tributaries, the White Nile, the Blue Nile and the Atbara.
- The primary problem facing the Nile and the countries has to do with the scarcity and over-use of the water.
- Before dams were built on the river, the discharge at Aswan varied widely throughout the year.

The River Jordan is being over-exploited.

- The Jordan is 320km long and flows to the Sea of Galilee and then to the Dead Sea, which is about 40m below sea level and has no outlet. It is formed from three tributaries: the Hasbani which flows from Lebanon, and the Banias and the Dan which both flow from Mount Hermon whose summit is on the border of Syria and Lebanon, while the southern slopes have been in Israeli control since 1967. Two more tributaries join from the east: the Yarmouk and the Jabbok.
- In 1964, Israel began operating a dam that diver water from the Sea of Galilee and Jordan constructed a channel diverting water from the Yarmouk. Syria has also built reservoirs that catch the Yarmouk's waters.
- Now 70-90% of the water is used for human purposes and the flow is so reduced that the Dead Sea is shrinking.

The Colorado River

The Colorado River basin is about 630,000km^2 in area. The Colorado River has its source about 4,000m high in the Rocky Mountains of Colorado and flows south-west for 2,300km to the Gulf of California in Mexico. The Colorado and its tributaries drain south-western Wyoming and western Colorado, parts of Utah, New Mexico and California, and almost all of Arizona.

The use of water from the Colorado is a controversial issue, and there is much conflict between the potential users. These include:

- Those who live in the upper part of the basin.
- Those who live in the lower part of the basin, including Arizona, whose population increased by 40% in the 1980s.
- Farmers, who want water for irrigation.
- The native Indian population who claim rights to the water.
- Neighbouring settlements such as Las Vegas, Nevada, which are in dry areas but have a high demand for water.
- Settlements that need water to generate electricity by hydro-electric power.

After a number of treaties established by the government between 1922 and 1948, water was allocated to the various users in different parts of the basin.

Many additional dam projects have been completed since the Hoover Dam. In the mid-1960s, Glenn Canyon Dam was completed, creating Lake Powell. This dam was controversial, and opposition to its construction helped to shape policy more towards concepts of water management and environmental policy.

In 1963 a decision by the US Supreme Court prompted funding of the Central Arizona Project, completed in the 1980s. The project comprises a mountain tunnel through which water from the southern end of Lake Havasu is pumped up and into an aqueduct that flows southward to the two cities of Phoenix and Tucson. A lot of the water is lost due to evaporation because temperatures are high for much of the year and the aqueduct is not covered due to the high cost of the extra infrastructure.

The biggest loser is Mexico, as 90% of water has been abstracted from the river before it reaches the international border. Irrigation water extracted from the river is supposed to be put back in to maintain flow in Mexico. However, this water is very saline and unsuitable for Mexican farmers to use. About 20% of farmland is not cultivated for this reason. The government has also had to build an expensive desalination plant near the border at Yuma.

Environmentalists are unhappy, because the reduced flow at the mouth has led to a loss of habitats for birds such as the egret and fish such as the totoaba.

Mexico has also objected to the lining of the All American Canal, which runs near its border and takes water to California. Previously, a lot of water leaked out of the canal and into the Mexical aquifer. Lining the canal has stopped leakage and the aquifer is now holding less water.

The increasingly severe competition for whatever small quantities remain in the Colorado River keeps the basin tied up in legal disputes and controversy. Water projects must now undergo thorough environmental-impact studies in accordance with US environmental protection laws.

The above diagram shows the Colorado River basin and all neighbouring states.

Key words

International river basins: river basins that are shared by 2 or more countries. The river is a transboundary resource.

Riparian countries: countries situated on a river bank.

Strategic resource: a resource that is considered to be essential to the maintenance of an economy.

There are environmental and political risks of developing pathways between areas of water surplus and of deficit nationally (e.g. in Australia) and internationally (e.g. between Israel and Turkey).

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 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.

International water transfer schemes

Israel's Hydrological Service has warned that the country water reserves are being severely stretched. Turkey appears to have surplus water that could be taken from the Mangavat River and sold to Israel.

- December 2001: Israel and Turkey plan an undersea water pipeline via Northern Cyprus.
- August 2002: Israel begins talks with Turkey to import 50 million m^3 each year using tankers.
- July 2004: Syria objects to Turkish plans because Turkey has built reservoirs that retain water along the Tigris and the Euphrates.
- May 2005: Israel and Turkey discuss once again the possibility of an undersea pipeline.
- April 2006L 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 Eastern states.
- July 2008: official figures suggest Turkey is experiencing increased drought and water shortages of its own, the outcome of poor management and global warming.

National water transfer schemes

Kielder Water, owned by Northumbrian Water, is a river-regulating reservoir in the UK.

- Holds 200 billion litres of water, and is the largest reservoir in the UK.
- The reservoir releases water into the North Tyne River, which joins the Tyne near Hexham.
- It regulates the Derwent, Wear and Tees Rivers in the North-east of England.
- Pumping stations at Riding Mill, Frosterly and Eggleston allow for the transfer of water between the rivers to regulate the water levels.

- The reservoir serves Tyneside, Wearside and Teesside, three large conurbations in the north-east.

South-North Water Transfer Scheme

- The project cost 140 billion yuan (US$120 billion) and is 1400km long.
- It brings 1 billion litres of water to Beijing every year. 2/3 of Beijing's water comes from the south. Beijing pays US$60 billion yearly for the water. It's largest water treatment plant can clean 1.7 million m^3 of water daily. This improves living standards in Beijing.
- The Transfer Scheme moves 45 billion m^3 of water from Danjiangkou to 19 cities in the north.
- However, many people were displaced by canal construction, and the canals cross high risk areas such as an earthquake belt. There was environmental damage caused by building the Transfer Scheme.
- It is needed as there is currently a massive drought in the north, meaning that they have to grow wheat instead of rice as it is less water intensive. However, if Beijing had conserved more of its water and increased water prices, the Transfer Scheme would have been made redundant.
- There is currently also a water shortage in the south due to climate change and urban development, both of which were not factored in when the project was first approved in the 1950s.

WATER CONFLICTS AND THE FUTURE

Trends in water demand (improved standards of living, economic growth in industry and agriculture) and supply suggest an increasingly insecure water future for many regions, such as the Indian subcontinent. Climate change may have a significant impact in some areas.

Predictions

Population growth, urbanisation, economic development, industrialisation and migration have increased water demand to unsustainable levels. There are rising trends in water demand, driven by improving standards of living and economic growth in industry and agriculture. But future projections are based on uncertainties:

- Climate change is occurring but its exact impact cannot be predicted.
- Continued economic growth is not inevitable as the 'credit crunch' has shown.
- Population growth is slowing due to lower birth rates and higher death rates.
- Political and religious conflicts can create severe shocks demographically and economically.

The supply of water in agriculture in developing countries will need to increase in order to meet the MDG to halve the proportion of people who suffer from hunger between 1990 and 2015. To reduce hunger, agricultural output must increase and thus water use must increase. All the indicators suggest an increasingly insecure water future for many regions. By 2025 there could be 3.5 billion people living in water-stressed countries. By then it has been predicted that the USA will have lost its status as the world's most dominant nation as the rise of the BRICs is changing the balance of the global economy. The demand for water is growing rapidly in these nations, and in similar smaller developing countries, but each country faces its own unique challenges.

India, for example, will need to accommodate:

- Continuing rapid population growth.
- Economic development raising living standards and expectations.
- A reduction of input from melting Himalayan glaciers as climate change causes their retreat.
- Declining water tables as thirsty industrial process abstract too much water from aquifers.
- The extension of irrigation schemes for agricultural expansion to feed the growing population.

More than 21 million Indian farmers use private pumps to tap underground reservoirs to water their crops. This water took thousands of years to accumulate and is now rapidly running out as the rate of fall in the levels of these fossil aquifers is about 3 metres a year. To combat the insecurity of water supply, rainwater storage capacity is being increased to catch the rainwater brought by the annual monsoon storms.

In 2007 the UK Meteorological Office provided advice to senior defence officials on likely flashpoints around the world where resource issues could be driven or exacerbated by climate change. Shortages of food and water may get worse as populations grow and weather patterns change so the impact of climate change could exacerbate inequalities in health systems, as well as access to adequate food, clean water and other resources. Rainfall patterns in Africa are moving away from the continent's interior to its coasts, leaving millions of people inland without enough water for consumption or food production. Long-term drought is causing migration and this is likely to increase. The areas most likely to suffer water shortages include western Asia, the Middle East, Central America, and the Mediterranean and Amazon basins.

Millions of people live without access to adequate or clean water now with little hope that their situation will improve as global water shortages increase, Mathematical analysis that combines climate model outputs, water budgets and socio-economic data suggests that a large proportion of the world's population is already suffering from water stress and that rising water demands greatly outweigh climate change in determining the state of global water systems by 2025.

Different players and decision makers have key roles to play in determining the future water security; their aims may conflict (water companies, environmentalists, individual, government).

Stakeholders and decision-makers

The potential for conflict is widespread where human activity disrupts water regimes, over-utilises resources and degrades water quality. Water wars are already a reality in many parts of the world and are likely to become more common in the future. Different players and decision-makers have key roles to play in securing future water supplies, but their aims may conflict. Developing management strategies to ensure supply will require the cooperation of these players as well as changes in the way in which water is valued and used.

The actions taken to supply water are influenced by the economic and political structure of a country. There is also a distinction to be made between top-down and bottom-up (grassroots) actions. Sustainability may be developed from the top or the bottom but it is more likely to succeed with community involvement. The people and groups involved are the players or stakeholders and each has a different amount of power and authority in any decision-making situation.

There are many individuals, pressure groups and political movements, governments, businesses, charities and agencies involved in monitoring and managing water resources. Each puts a different value on these economic, social and environmental terms and they meet at forums, conferences and conventions to discuss and plan the management of water at local, national and international levels.

Water companies

TNCs such as Viendi and Suez (owns Thames Water, American Water Works) are companies that provide technological fixes. Water companies control the price of water and can choose not to supply certain areas with water if they feel they will not profit.

Environmentalists

WWF and Friends of the Earth campaign for the full Environmental Impact Assessments of major projects likely to damage the environment. This group will include many scientists and researchers. At a local scale NIMBY groups will campaign against projects.

Individuals

Individuals that abstract their own water are relatively self-sufficient, however they do have to conform to drought restrictions placed by governments in order to increase the security of supply in the future by reducing over-abstraction.

Individuals that depend on the supply brought to them by water companies can cause water TNCs to increase supply by increasing demand, however this may reduce supply to other areas. Although consumers can form pressure groups, these do not tend to have a great power over governments or water companies.

Water NGOs

Play a large role in securing water supplies in the rural areas of LICs. However, they have little input in HICs as there is no requirement for their services. Have a small footprint compared to governments and water TNCs but have a huge positive impact on communities.

WaterAid has funded more than 50 water and sanitation projects in Ethiopia, giving 1.2 million people access to clean water. They work with regional governments, technical experts and other stakeholders.

Intergovernmental Organisations

The World Bank funds megaprojects to improve supply. It has become more environmentally conscious. The IMF often makes privatisation of water supply a condition for the receipt of financial aid, which can severely disrupt supply to rural areas.

The G8 summits have increased the focus on water and the amount of aid reaching LICs to help achieve the MDGs. They highlighted the need for more integrated management of water resources.

Governments

Governments play a key role in securing water supplies for citizens as they can back and fund large and small projects that increase water security. They are also pivotal to the implementation of international treaties. They are also able to provide water companies with licences to abstract water from aquifers as well as build dams. They can take part in funding IGOs. Lack of regulation can lead to unsustainable extraction of water. Governments decide whether the water network is nationalised, which can have an impact on water prices. Tariffs and taxes on water can also be implemented by governments.

Water privatisation

The regional water authorities in England and Wales were privatised in 1989. The entire infrastructure was sold to private companies with the responsibility to run the water supply and sewerage systems, regulated by the Office for Water Service (Ofwat). There are currently over 20 companies supplying water in England and Wales. Other countries have copied the UK model and the World Bank and IMF have made privatisation a condition of finance for water projects. Although the privatised water industry accounts for only a small part of global water utilities, business is growing. Mergers and takeovers have led to the creation of a small number of influential global companies such as Veolia and Suez, French companies that are responsible for over two-thirds of the private water market with contracts in Brazil and China, for example.

Many organisations actively criticise the actions of water companies for being motivated primarily by profit rather than public welfare and they think that it exposes people to exploitation. There are also enthusiastic supporters of the private sector; they advocate deregulation, the opening up of markets, and the establishment of public-private partnerships in major water supply schemes. But water companies have sometimes encountered resistance as they have increased prices to cover the costs of investment. Some companies have been forced out of countries, others have left voluntarily, and some people may have to wait for clean water projects are abandoned due to opposition to privatised projects.

Integrated management

Managing water is an integral part of land use management, development and agricultural policy; it involves a careful balance between supplying personal needs, economic demands and the conservation of the natural environment. These demands need to be met within the framework of sustainable development and there needs to be integrated management:

- Of resources: surface and groundwater, quantity and quality, upstream and downstream basins.
- Of resource development and water purification and treatment.
- Of supply: renewable natural resources, non-renewable resources, unconventional resources.
- Of resource uses (including the management of aquatic environments).

There are 240 transboundary aquifers worldwide but they are difficult resources to manage as they flow across the boundaries. The quantity of water available for one country may be significantly diminished by over-pumping in a neighbouring country or water quality may be affected by transboundary pollution. It is hard to define and enforce private property rights over groundwater. Assigning ownership to the land overlying the aquifers does not solve the problem as any abstraction will affect the entire aquifer, not just the part that is owned. It is much easier to focus on the control and use of surface water. Management of water in Africa is complex: the collective ownership of water is recorded in oral tradition and not in written documents, handed down through generations, but national boundaries were largely determined during colonial rule, producing difficult political and cultural relations.

The international principles governing transboundary aquifers have developed from agreements that focused on surface water. There are three fundamental principles in determining and implementing states' rights and duties with respect to transboundary aquifers:

- The principle of equitable and reasonable utilisation of shared watercourses.
- The duty not to cause injury to countries sharing the same rivers.
- The duty to cooperate with other states sharing the same aquifer.

The first agreement on the regulation of international watercourses was in 1911 since when there have been many treaties, agreements and protocols.

The UN Convention on the Law of Non-Navigational Uses of International Watercourses is intended to prevent and resolve disputes between states. It was approved by the UN General Assembly in 1997 and passed by an overwhelming majority. However, it does not become legally binding until it is ratified by 35 countries and, so far, too few countries have signed the treaty. The Convention includes measures to protect, preserve, and manage water and covers issues such as flood control, water quality, erosion, sedimentation, saltwater incursion and living resources. The representatives of some countries felt there was a lack of balance between the rights and obligations of the upstream and downstream riparian states, but a basin state may not deny a reasonable supply of water to another state in the same basin by storing water for future use and must not pollute the water.

There are a range of responses to current and projected demands for water such as diverting supplies and increasing storage, for example China and Brazil; or water conservation; or restoration of lost supplies, for example the Aral Sea or Long Island.

One of the greatest challenges of the 21st century is to supply sufficient clean water for all. New strategies are needed to manage water supplies and responses to the growing demand for water include diverting supplies, increasing storage, restoring lost supplies, and water conservation.

Diverting supplies

Inter-basin transfers are used to redistribute water from areas of water surplus to those experiencing a shortage. In the UK, a national water grid has been considered; this would allow water from well-stocked parts of the country, such as Northumberland, to be piped to areas where there are shortages, such as the South East. So far this plan has been ruled out because of the costs of the infrastructure and the energy needed to pump the water. Smaller interregional schemes have been set up such as the Kielder Project, drawing water from the Kielder Reservoir in Northumberland to the River Tees, and, in 1996, Yorkshire Water announced its decision to develop a £50 million water transfer scheme from the River Tees to the River Ouse in Yorkshire.

The Essex Transfer Scheme.

- Parts of Essex receive less than 500mm of rainfall per year, and in a dry year, up to a third of its water needs are supplied by the Ely Ouse to Essex Transfer Scheme.
- The scheme transfers water from the Great Ouse River in Norfolk via pipelines and pumping stations to the headwaters of Stour and Blackwater Rivers.
- Another 20% of water in Essex is provided by raw water bulk transfer from the Lea Valley reservoirs to the Chigwell treatment works before supply to customers.

While there is growing interest globally in developing water transfer schemes to meet water demands, there is considerable concern that such projects may cause serious environmental and social impacts. Continuous use may cause long-term changes to local and regional hydrological conditions, possibly increasing flood risk, and change the natural character of the river ecosystem by damaging fish stocks, spreading disease and introducing alien species into river environments. Long-distance water transfer projects are under construction in the Maghreb, Libya, Egypt and Senegal despite the high energy costs of their operation. The south-to-north water diversion project in China is probably the most ambitious of them all.

Increasing storage capacity

At least 84,500 dams and 5,000 megadams have been constructed to meet energy or water demand, about half principally to supply irrigation and nearly half of the world's rivers now have at least one large dam. Supporters of dams highlight the social and economic development benefits such as irrigation, electricity from HEP, flood control and water supply, but large dams have had negative social and environmental impacts: opponents refer to debt burden, cost overruns, the displacement and impoverishment of people, destruction of important ecosystems and fisheries, and the inequitable sharing of costs and benefits.

Globally, there are many dam projects at various stages of planning and development:

- The countries with the most large dams under construction are Turkey, China, Japan, Iraq, Iran, Greece, Romania and Spain, and countries in the Paraná basin in South America.
- The river basins with the largest dams under construction are the Yangtze with 38, the Tigris and Euphrates with 19 each, and the Danube with 11.

In North America and Europe most technically attractive sites have already been developed. Their value is now called into question as an appropriate response to water supply needs. More water evaporates from reservoirs than people use and, despite the potential for multipurpose use, there are ongoing maintenance costs, such as the need to dredge the sediment to maintain volume.

The Wold Commission on Dams, reporting in 2000, concluded that the outcome that any project achieves must be the sustainable improvement of human welfare. This means a significant advance of human development on a basis that is economically viable, socially equitable and environmentally sustainable. A large dam should only be built if it achieves these aims better than other options.

Overall the Commission judged that large dams generally did not achieve their water supply and irrigation targets and have delivered poor economic returns, and it recommended better management systems to improve the efficiency of existing large dams.

Small dams against medium and large dams.

- Ethiopia, which is typical of many sub-Saharan African countries, has a storage capacity of $38m^3$ per person.
- Australia has almost $5,000m^3$ per person, yet even this may be insufficient with the impacts of climate change.
- Whilst there will be a need for new large and medium-sized dams, the construction of small dams for single villages or farms may prove to be a more sustainable solution.

The UK also needs more reservoirs to store water but they take years to build, even once permission has been granted. Thames Water hopes to create a reservoir near Abingdon, Oxfordshire, but the earliest it could be completed is 2020. It plans a twin-track approach to maintaining water supplies: reducing demand by tackling leakage and encouraging people to use less water; and finding new sources of water, including collecting and storing water when it is available.

Restoring lost supplies

Rapid population growth and economic development combined to increase water use several times over during the 20th century. Surface and groundwater stores were in some places substantially reduced and measures are now being taken to replenish some of these stores.

The North London Artificial Recharge Scheme is the only one of its kind in the UK.

- It stores water for use in times of shortage by pumping water into the chalk aquifer that lies beneath London.
- Water abstraction from this aquifer in the past has lowered the water table, creating space for water to be stored. Drought conditions in 2005 brought this store into use, enabling water to be abstracted from boreholes located in Enfield, Haringey, Walthamstow, Tottenham and Chingford.

Long Island, New York, contains a series of sand and gravel aquifers.

- Fed by precipitation, which takes from 25 to 1,000 years to percolate.
- All of New York's water supply comes from these underground water reserves.
- Almost 4 million gallons are abstracted each day for the resident population; most homes are on a municipal water system but there are still many homes with their own wells.
- Development has lowered and contaminated the groundwater to the extent that any new development must build recharge basins, proportional to the size of the development, to collect runoff via sumps and storm water drainage.
- As about half of precipitation is lost to evapotranspiration, it makes sense to capture as much as possible from impermeable surfaces.

Water conservation

Leakage before and after water treatment can be minimised; around 22% of water does not meet the end user due to leakage in the UK and it is the responsibility of the water companies to repair the ageing water mains. When drought threatens water supplies, hosepipe and sprinkler band are common. Water conservation includes reducing consumption, recycling, and technological and policy options that promote the efficiency of water at the user end of the supply chain. Methods of reducing domestic consumption include:

- Installing water meters in every home.
- Reducing the amount of water used in lavatory cisterns.
- Planting drought-resistant species in 'water-wise' gardens.
- Using grey water to flush the lavatory or water the garden.

In industry, water is used in many manufacturing processes and companies have installed more efficient systems to reduce their water costs. Almost all manufacturing uses water at some stage for washing, diluting, cooling, or incorporating water into a product.

In agriculture, the efficiency of irrigation systems varies. There are three broad types of crop irrigation: surface, sprinkler and micro. Surface irrigation through small channels or surface flooding are the least efficient due to wastage in runoff, a high level of evaporation and increased salinity. Sprinklers have high energy costs and require careful monitoring; those that throw water into the air are also prone to evaporation losses. Micro-irrigation techniques are the most efficient, using mini-sprinklers or drip-irrigation from tubes with many holes that can be laid on the surface, suspended from wires or buried beneath the soil surface. Modern control systems, using automation and remote control, for water supply and demands in irrigation networks also substantially reduce the volume of water used.

Half of Israel's land is desert, so Israel has founded innovative techniques to reduce water stress.

- Water conservation is supported as water is very expensive in Israel.
- Israel recycles much of its waste water and uses it for irrigation. Drip-feed irrigation is the preferred choice by farmers as it uses as little water as possible.
- Desalination plants clean seawater to make it potable.

Technology may play a role in increasing water supply, for instance water transfer schemes and desalinisation, although this is likely to have environmental costs.

Technology has an important role to play in improving water supply and reducing water insecurity, despite the associated financial and environmental costs. The MGD7 aim to provide sufficient clean water for everyone presents complex challenges for governments, water managers and NGOs, but there are sustainable solutions.

Large projects may not be sustainable as they require large amounts of energy therefore have large carbon footprints. They often displace people and habitats are greatly impacted. These projects are also very costly, and countries may not be able to afford to build or maintain them. If the country decides to loan the necessary money from the World Bank or the IMF, the conditions may cripple the economy. In the future, climate change will mean that water supply will change, and there may not be enough water.

Technological solutions

Desalination

More than half of seawater desalination capacity is in the Middle East and it provided 70% of Saudi Arabia's water. Desalination is the most expensive option for water supply due to its energy use. The unit in Jersey uses 6.8kWh of electricity per cubic metre of freshwater produced. The Ashkelon plant in Israel uses osmosis membranes to remove salt from water. In California, a desalination plant was introduced due to the drought. It uses the brackish water from underground, and although energy intensive, a new process has been introduced that uses 30% less energy than conventional methods.

Transfer schemes

Developments to reduce losses through evaporation from natural bodies of water, such as the Jonglei Canal transferring White Nile water around the Sûdd swamps in Sudan, have increased water supply, but such schemes have environmental impacts.

Treatment plants

Treatment plants are used to make water potable, and are necessary even for reservoirs. For example, there are 4 water treatment plants that are supplied with water from the Kielder Water reservoir. Plants in the Lea Valley, London, are used to recharge the chalk aquifers to prevent subsidence and increase the volume of water stored in case of a drought.

Intermediate technology

In most less economically developed countries, not only are high-tech industries too expensive to develop, they are usually inappropriate to the needs of the local people and to the environment in which they live. An appropriate technology can contribute to a more sustainable way of life for people who are rich or poor, living in places which may be developed or developing. If the place is developed and industrialised and its inhabitants are well-off, then the appropriate technology is more likely to be high-tech. If the place is underdeveloped and its inhabitants are poor, then alternative forms of technology should be adopted. These alternative forms may include:

- Labour-intensive projects: with so many people likely to be unemployed or underemployed, replacing existing workers with machines is of little value.

- Encouraging technology that is sustainable and fully utilises the existing skills and techniques of the local people.
- Using tools designed to take advantage of local knowledge and resources.
- Developing local crafts and industries by using local natural resources and, where possible, recycling materials.
- Low-cost schemes using technologies that people can afford and manage.
- Developing projects that are in harmony with the environment.

Gravity-fed schemes

In Nepal, Multiple Use Water Systems have been built, supported by the NGO Practical Action. They use local materials and simple technology to bring water to where it is needed by gravity and a system of pipes. Water is moved from springs and streams to supply agriculture and people/, providing families with 1,000 litres of water per day for many uses.

Hand-dug wells

Hand-dug wells are the most common method of getting water in LICs. However, traditional hand-dug wells often dry out as they are too polluted as the sides are not lined and the top is uncovered. Without proper drainage, pools of water can form around the wells and these can act as breeding grounds for disease-carrying insects like mosquitoes. New technology combines tradition with additional features to prevent these problems. Hand-dug wells are usually 1.2 metres in diameter to allow sufficient digging space. Depths vary, from shallow wells at 5 metres to deep wells over 20 metres, but all are deep enough to ensure the water table can still be reached during the dry season. They are lined with concrete to prevent pollution and make them more stable.

Rainwater harvesting

Falling rainwater is some of the cleanest naturally occurring water available and where it falls regularly there is scope to collect it, before evaporation takes place and before it becomes contaminated. Water is generally collected from cleaned roofs, where it runs down a gutter into a storage tank.

Tubewells and boreholes

Tubewells are small diameter holes drilled by hand-power. Although hand-dug wells can retain more water, tubewells can be built quickly and cheaply, require less maintenance, can reach greater depths and are safer to construct. Hand pumps can be used to draw water from tubewells. Where there are harder rocks and the water table is very low, engine powered drills are necessary to cut through the earth to depths of 100 metres or more. These are called boreholes and the water then has to be pumped to the surface using diesel or electric engines. The water is then usually stored in large tanks before being piped to tap stands in surrounding villages. The diesel or electric pumps are expensive to maintain.

Future policies

Future policies will have much more community involvement, especially in developing countries. There will be increased accountability and less corruption. Aquifer monitoring will increase, looking especially at pollution and water table levels. More research and solutions will be needed to reduce water usage, and GM crop use will increase to reduce the amount of water essential food crops need in order to meet increasing demands for food while reducing stress on water resources.