The human impact

How human activity can modify the natural hydrological cycle

By changing the operation of the natural system (inputs, stores, flows and outputs) in a drainage basin, human activity can have a significant impact on the way that the drainage basin operates.

By affecting the nature and amount of precipitation, evapotranspiration and river discharge, people can increase or decrease the impacts of river floods.

Direct human modification of the drainage basin system usually involves:

- changing the amount of precipitation entering the river's drainage basin
- storing water within the drainage basin by building dams or by groundwater recharge
- changing the channel characteristics of the river so that the speed of flow is affected
- transferring water between drainage basins
- **abstracting** water from the river for industrial, domestic and agricultural use.

Indirect human modification of the drainage basin system usually involves changing the nature of the drainage basin itself through:

- deforestation or afforestation
- changing the agricultural land use
- urbanisation - building towns and cities.

Precipitation

Cloud seeding involves adding artificial particles to clouds so that large water droplets form around these **condensation nuclei** and raindrops then fall. Silver iodide and dry ice are commonly used and this cloud seeding has led to local increases in rainfall in Australia and the USA of between 10-30 per cent. There is only a limited amount of water in the atmosphere, so increasing rainfall in one place can lead to less rainfall elsewhere.

Cities produce air pollution, which includes particles of soot from vehicle exhausts, domestic fires and industrial chimneys. These extra condensation nuclei, together with the heat island effect (which produces warm, rising air and atmospheric turbulence), can produce up to 10 per cent more rainfall in cities than in nearby rural areas.

Human-induced climate change (global warming) also has an effect. Warmer seas produce more evaporation. More water vapour in the atmosphere leads to more rainfall. Heat is energy, so a warmer atmosphere moves faster. Weather systems that produce rainfall, e.g. temperate depressions and tropical cyclones, could become more frequent as a result.

Water storage

Dams have been built on rivers throughout the world. A large dam is defined as a dam over 15 metres high. Worldwide there are over 48 000 of these large dams. Dams store water and have a major impact on river discharge. They are built to:

- provide water for irrigation, for homes and for factories
- produce hydro-electric power (HEP)
- control flooding.

15. (a) What is meant by 'irrigation' and why do many farmers use this technique?

(b) Make a list of all the ways that water can be used in the home.

(c) How is water used in factories?

Large dams can even out the flow of water in a river, ensuring that river levels remain high enough for water abstraction but stopping river levels rising above the bankfull stage, thereby reducing flooding. Significant amounts of water evaporate from large reservoirs. The Aswan dam in Egypt has reduced the annual flooding on the River Nile in Egypt but up to 30 per cent of the Nile's water is lost by evaporation from Lake Nasser, the reservoir created by the building of the dam. Because water abstraction from the River Nile downstream of the dam has increased, hardly any Nile water now reaches the Mediterranean Sea.

RESEARCH Make a list of the advantages and disadvantages of the building of the Aswan Dam for the people and economy of Egypt.

Artificial groundwater recharge is used to store water in underground aquifers. At times of high discharge, water is pumped from rivers into the ground via boreholes. This maintains or increases the height of the water table and boosts the discharge in streams fed by springs flowing from the aquifer. This stops the streams drying up during a dry spell. Water can also be extracted for human use, using the same boreholes used for the recharge. Artificial groundwater recharge is a strategy used in southern England, for example, where water is often in short supply during the summer months.

Changing the nature of the river channel

Large rivers are often straightened and deepened in order to make them easier to navigate by barges. This is called

canalisation and it tends to increase the hydraulic radius of the river channel. These straight, deep channels move water more efficiently and this can lead to shorter lag times and increased flood peaks. The River Rhine has been extensively canalised and the flood surge, which used to take five days to move from Switzerland to the Netherlands, now takes only three days.

In urban areas, rivers are often confined to concrete channels or underground drains. This can lead to increased levels of flooding in nearby buildings.

Transferring water between drainage basins

In north-east England there are three large industrial cities: Newcastle-upon-Tyne, Sunderland and Middlesbrough. They each have a high demand for water. A huge reservoir has been built on the **headwaters** of the River Tyne at Kielder and this supplies water, via the River Tyne, to Newcastle. Kielder can hold far more water than is needed by Newcastle, so a series of pipelines have been built to transfer water from the River Tyne into the River Wear (for Sunderland) and into the River Tees (for Middlesbrough). One large reservoir in a very sparsely-populated area is therefore supplying water to three large urban/industrial areas, allowing all three cities to develop their economy. The natural discharge of all three rivers has been changed as a result.

Abstracting water from the river

River water is in demand for three main uses:

- Agriculture: in many parts of the world, rainfall is low and farmers need to irrigate their fields so that crops can grow.
- Industrial use: industry can use huge amounts of water for manufacturing (e.g. papermaking) or for cooling (e.g. power stations).
- Domestic use: in HICs people use large amounts of water each day for drinking, washing, flushing toilets, watering gardens and even washing cars. In LICs people use much less water, mostly for drinking.

16. Suggest why people in LICs use less water than people in HICs.

It is important that the use of water is sustainable - water use should not exceed water supply. If too much water is used, river levels fall and wetland areas dry out. This can have an impact on wildlife because habitats are reduced or destroyed.

Centre-pivot irrigation

Centre-pivot irrigation is a modern technology that has the potential to use water in a very unsustainable way. A borehole is drilled down to groundwater held in an aquifer. Water is pumped from the aquifer and sprayed onto crops via a long, wheeled boom that slowly rotates around the central borehole. This produces circular areas of cultivation in what might otherwise be a dry, brown landscape.

Near Lubbock, Texas, this technique has lowered the water table by about a metre a year since its introduction in the 1960s. This suggests that the use of groundwater in this way is unsustainable because water is being used up faster than it is being replaced. In Libya, there are many aquifers that filled with water when the Sahara desert was a rainy place. The Sahara became a desert around 7000 years ago and very little rain now falls there. Centre-pivot irrigation in Libya is also an unsustainable use of groundwater because here the groundwater is, in effect, a non-renewable resource. The same is true of centre-pivot irrigation schemes in other dry parts of the world.

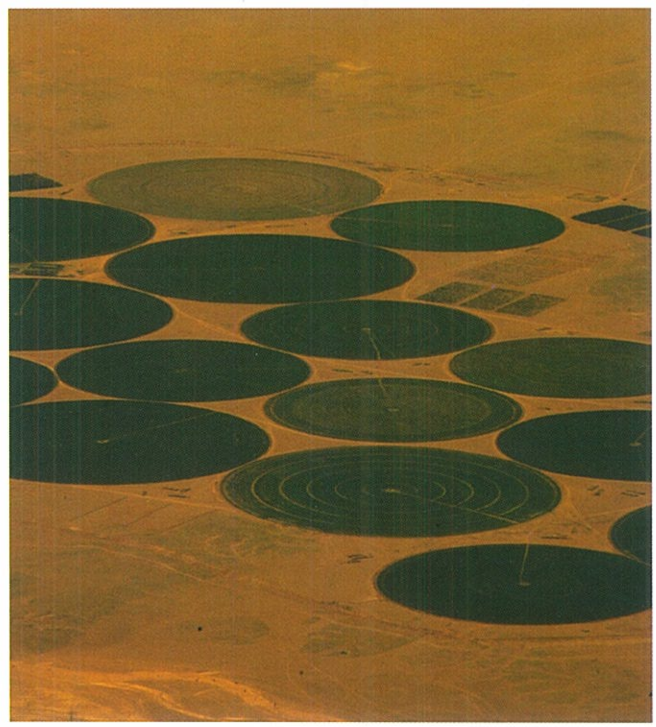


Fig. 1.42 Centre pivot irrigation circles in the Jordanian desert

Although water use per person is much greater in HICs than in LICs, water shortages can occur anywhere. Water is a renewable resource but when water use exceeds supply, long-term water shortages can result. This can have an impact on local people and on the potential for economic development. This leads to competition for the use of the available water resources and water has to be carefully managed. This can be an issue within one country or between countries.

Case study: Water management issues within one country: south-west USA

In Nevada, USA, there is a large lake called Pyramid Lake. It is an important source of water in this semi-arid area. There is intense competition for the water from Pyramid Lake:

- The farmers around Fallon, Nevada, need water to irrigate their crops of alfalfa.
- The residents of Reno, a tourist city similar to Las Vegas, need water for domestic use. The city is growing and demand for water is increasing rapidly.
- Pyramid Lake is a nature reserve, much valued by the local Native Americans who believe they are spiritually connected to a rare fish species that lives in the lake. Water is needed to allow the fish spawning runs each year. Without the spawning runs the fish will become extinct.

Competition between the different **stakeholders** was so intense that legal action was taken. The federal authorities ruled that the Native Americans and the residents of Reno should have priority and the Fallon farmers lost their water supply, resulting in their fields drying out.

Case study: International water management issues: the River Euphrates

The River Euphrates rises in Turkey, flows through Syria and Iraq and empties into the Gulf. Between 1983 and 1990, Turkey built the Ataturk Dam on the river in order to generate electricity and irrigate crops in Turkey. Despite previous agreements on the use of water, Turkey stopped the flow of the river for a month in 1990 to allow the reservoir behind the dam to fill. Syria and Iraq both protested because their water supplies had been disrupted. Turkey allowed the flow of water to resume but water use in Turkey means that the flow of the Euphrates below the dam is one-third less than it used to be. The reduction in water supply has had a bad effect on Syria and Iraq, reducing their potential for economic development.

17. (a) What is meant by a 'stakeholder'?

(b) Did the federal authorities make the right decision about the use of water from Pyramid Lake? Justify your answer.

18. Water wars are predicted in several parts of the world during the 21^{st} century. Why might a country feel that it has to go to war to protect its water supplies?

Deforestation and afforestation

Forests growing in a river basin tend to reduce the discharge of the river. Increased interception and increased transpiration mean that evapotranspiration can become a more important output from the drainage basin than river discharge. Forests also encourage infiltration and throughflow rather than overland flow, reducing the speed at which rainfall reaches the river. **Flood peaks** are lower in a basin that is forested. If the forest is removed, much more water goes into the river, increasing the discharge and the flood risk.

Population growth in Nepal, in the Himalayas, has led to pressure to cut the trees down to provide fuelwood and terraced fields on the steep hillsides. Over-grazing of the deforested land has led to soil erosion. The local rivers are tributaries of the Ganges which has received more discharge and more sediment as a result. The sediment clogs up the river channels and leaves less room for the water. Increased levels of river flooding in Bangladesh, where the Ganges reaches the sea, have been blamed on deforestation in Nepal.

Devastating floods on the River Chang Jiang (Yangtze) in China in 1998 (see page 29) prompted the authorities to institute an afforestation programme in the upper reaches of the river. The province of Yunnan used to be heavily forested but many of the forests were removed in the 1960s because of the need for land to produce food for the growing population. As on the Ganges, this led to increased flooding on the Chang Jiang. The afforestation programme has met resistance from some local people in Yunnan but it is going ahead. It will be several years before the growing trees have a significant effect on reducing river discharge and flood peaks.

Changing agricultural land use

Land uses that create impermeable surfaces or reduce vegetation cover tend to increase overland flow and river discharge. Pasture land allows rainfall to soak into the ground but has less evapotranspiration than the forest it may have replaced. Floodplains tend to be fertile and are often used for arable farming. Ploughing increases infiltration because it loosens the surface soil but in HICs, arable farming can also reduce infiltration because the use of heavy machinery for cultivation and harvesting squashes the soil, so there is more overland flow and flood peaks increase. This was a significant factor in the flooding on the River Rhine in 1995.

Urbanisation

Covering large areas in concrete, tile and tarmac leads to an increase in overland flow, therefore floods are more likely, especially in places downstream of the urban area. The concrete drains and sewers of urban areas allow water to reach the river quickly, replacing natural throughflow with a much more rapid process. This reduces lag times and increases flood peaks. Building on a floodplain means that there is less room for the water when the river floods. The floodwaters will rise higher as a result.

River flooding – recurrence intervals and the prediction of flood risk

River flooding occurs when a river's discharge exceeds the capacity of the river channel. The river overflows its banks. River flooding is a significant hazard that affects many parts of the world. It is important that people are aware of the risk of flooding in the place where they live and work. It is also important to be able to give them accurate and reliable flood warnings.

Flood risk analysis

In the UK the Environment Agency is responsible for flood risk analysis and for issuing flood warnings. Flood risk analysis is important because it tells homeowners and tenants what flood risk their property faces. Owners of high-risk properties need to be especially alert for flood warnings.

The Environment Agency works out the flood risk at a place by using 'magnitude and frequency analysis'. A scatter graph is produced using historical flood data from that place. The **magnitude** (size) of the flood is plotted against the **recurrence interval** of the flood, i.e. how often, on average, that size of flood is likely to occur. This is done on special semi-log graph paper and a straight best-fit line can be drawn. Using the **best-fit line** the size of the 5-year flood, 50-year flood, 100-year flood, 500-year flood, etc., can be calculated. An example is shown Fig. 1.43. The vertical scale is arithmetic but the horizontal scale is logarithmic, making this a semi-log graph.

As can be seen from Fig. 1.43, the magnitude and frequency analysis deals in probabilities. The '10-year flood' is the size of flood that can be expected every 10 years on average and there is a 10 per cent chance of a flood of this size happening in any one year. This means that once the 10-year flood has happened, there is no guarantee that it will be 10 years before it happens again. However, the use of recurrence intervals is useful when planning flood defences and when drawing flood risk maps.

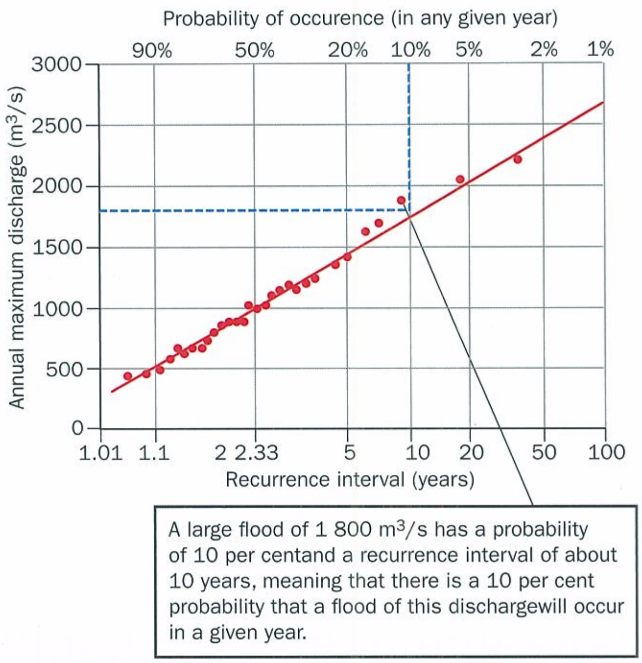


Fig. 1.43 Magnitude and frequency analysis of flood risk

Current advice in the UK is that densely-populated urban areas should be protected against floods up to the height of the 100-year flood. The 'magnitude and frequency analysis' graphs can show the Environment Agency how high to build the walls and embankments in order to do this. This means that there will occasionally be floods that will come over the top of the defences. The Dutch have recently rebuilt the flood defences on the River Rhine to cope with the 1000-year flood, but this has cost a lot of money. Politicians in the UK have decided to pay for the damage caused by very rare floods rather than pay for very expensive flood defences to protect people from them. It's a question of what is cheapest over the long term. However, climate change could be making big floods more frequent. What is currently the 100-year flood might soon become the 20-year flood. This adds another level of uncertainty to flood risk analysis and planning.

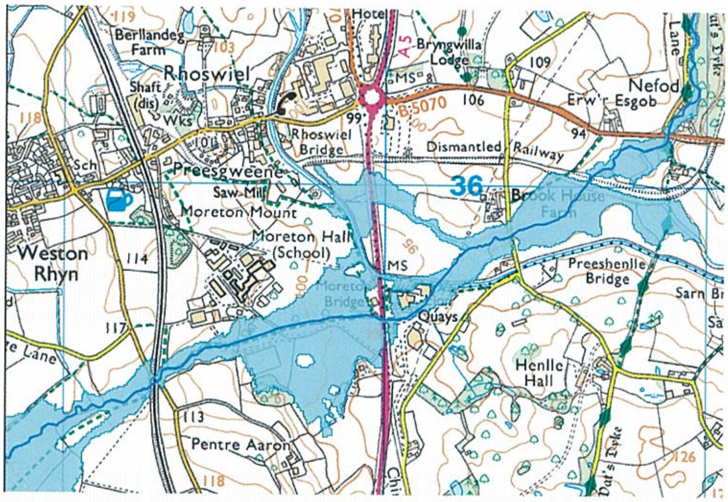
Flood risk maps

On the Environment Agency's website it is possible to obtain flood risk maps for most places in the UK.

This flood risk map is very reassuring for most of the people who live in the area shown. Very few buildings are at risk. Some low-value agricultural land could be flooded but if the farmer gets sufficient warning, any grazing animals can be moved to higher ground and safety.

Flood predictions and warnings

In the UK, the Environment Agency monitors rainfall and river levels and is able to produce flood warnings as a result.



A Key:
■ = significant flood risk (1–75 year flood)
■ = moderate flood risk (76–200 year flood)

Fig. 1.44 Flood risk at Moreton Hall, Shropshire, UK

The details are as follows:

- Rainfall radar can plot the approach of depressions and other rain-bearing weather systems. These data are fed into the Agency's computer system.
- Tipping rain gauges throughout the drainage basin monitor the actual amount of rain falling and feed this information into the system.
- Along the river, automatic river discharge gauges monitor the rising river levels and this is added to the system data.
- The system's database includes a model of the way the drainage basin behaves at different times of the year and with different inputs of rainfall. This is based on past flood events, i.e. a whole series of past storm hydrographs.
- As a result the computer system can continuously compare the incoming data with past events and produce predictions of river levels at different points along the river. It can predict how high the flood peak will be and when it will reach different places.
- On the basis of these predictions the Environment Agency issues detailed flood warnings. People are then given time to prepare for the flooding.

River flooding – the causes, impacts and management of river flooding

River flooding causes death, damage and disruption (both economic and social). Because of this, people try to manage the flood hazard. Management involves a combination of prediction, prevention and amelioration. For management to be successful we have to fully understand the causes of flooding.

The causes of river flooding

River floods are caused when rates of overland flow exceed the river's capacity to hold the water it is supplied with. The natural factors affecting overland flow have been dealt with earlier in this chapter but can be summarised as:

- heavy, persistent and/or intense rainfall
- rapid snowmelt
- impermeable soil and bedrock
- a lack of vegetation in the drainage basin
- cold temperatures which reduce evapotranspiration.

In addition, human activities can make flooding worse. These activities include:

- deforestation
- urbanisation
- mechanised farming
- **acid rain** (which destroys forests)
- global climate change.

The impacts of river flooding

As with all natural hazards, the impacts of river flooding are:

- death – of people and animals
- damage – to buildings, infrastructure and farmland
- disruption – to people's lives. Disruption can be social (e.g. people are made homeless), or it can be economic (e.g. damage to businesses or factories which means that people are unable to continue making a living).

The impacts of river floods vary from country to country. As a general rule, in HICs the *economic cost* of the flooding is higher than in LICs but the *death toll* is usually higher in LICs than in HICs.

19. Suggest why the cost of flooding is greater in HICs but the death toll is higher in LICs.

The management of river flooding

How well the flood hazard is dealt with depends on:

- The level of economic development of the place. This influences factors such as emergency service provision, infrastructure and the ability to recover from the flood.
- The willingness of the local people and their governments to spend money on flood preparation and alleviation.

→ The accuracy and length of any warnings that are given.

Flood management strategies can be grouped into three main categories:

→ *Forecasts and warnings which allow the adoption of behavioural strategies* - people adjusting their lifestyles and taking personal responsibility for the hazard risk.

→ *Hard engineering solutions* - these usually involve building something.

→ *Soft engineering strategies* - working with nature rather than trying to dominate it.

Forecasts and warnings which allow the adoption of behavioural strategies

→ Make sure people understand the flood forecasting and warning service. This gives them time to move animals, move furniture and carpets, and evacuate people.

→ Have an emergency plan, so that people know what to do once the warnings are given and once the flooding takes place. Each household needs to have its own plan and the whole town needs an overall plan.

→ Organise at-risk houses so that they have tiled floors, moveable mats, drains in the floor, cupboards above flood level, plug sockets above flood level, wide stairs and space for storage upstairs.

→ Take out insurance. A householder pays a set amount per year to the insurance company. If there is no flood, the insurance company keeps the money. If there is a flood, the insurance company pays the householder to repair the damage. The amount that has to be paid by the householder will depend on the level of the flood risk.

Hard engineering strategies

→ Dams and reservoirs can be built upstream. As long as they are not already full, the reservoirs can store some of the floodwaters.

→ Platforms can be built on the floodplain before any buildings are constructed. This raises the buildings above flood level (but still reduces the room for water on the floodplain).

→ Build embankments along the river. They are effective but they are expensive and don't always look very nice. Temporary flood barriers are an alternative solution but the preparatory work is permanent.

→ Dredge the river. This lowers the bed and makes more room for water in the river channel. It is very expensive and cannot be a permanent solution as the river deposits fresh silt over time.

→ Straighten the river. This allows the water to flow faster and so prevents the build-up of flood waters. It does cause bigger floods further downstream, however.

→ Retention basins can be built. These are areas surrounded by an embankment into which floodwaters are diverted at times of crisis. The land-use within the retention basin is severely restricted as a result. These have been built beside the River Rhine near Strasbourg in an attempt to reduce flood levels downstream.

→ Flood relief channels. Artificial channels can be built around a town to take away excess water and prevent the town flooding. Once again, it causes worse flooding downstream.

Fig. 1.45 A hard engineering solution to flood risk. This is an artificial river channel in Nerja, southern Spain. The photo was taken during the summer dry season. The small inner channel is designed to cope with the normal winter flow of the river. The larger outer channel is designed to cope with extreme rainfall events which could cause flash floods, for which very little warning can be provided. The vegetation growing in the flood channel could be a problem as it takes up space and makes less room for the floodwaters

Soft engineering strategies

→ Floodplain zoning. Only use the floodplain land for things that will not be affected too much by floods, e.g. sports pitches. Don't build houses in high-risk floodplain areas.

- → Rely on 'washlands'. The land upstream is allowed to flood. This acts as a safety valve and protects the town. On the River Chang Jiang, Dongting and Poyang lakes serve this purpose.
- → Plant trees in the upper part of the drainage basin. Trees encourage interception, evapotranspiration and infiltration. Forested areas have fewer floods.
- → Wetland and riverbank conservation schemes. This involves protecting the natural floodplain areas which still remain. It gives the floodwaters a place to go and protects disappearing wildlife habitats, enhancing species diversity.
- → River restoration schemes. This returns the river and its floodplain to its natural state providing sustainable environmental gain – but there is often an economic cost. In the Netherlands, some river floodplains have been returned to their original state and nature reserves have replaced farmland. Flood protection has been enhanced. The Netherlands is a rich country that can afford to do this and the farmers have been compensated.

Case study: River flooding on the River Chang Jiang, China

China is one of the largest countries in the world, both in terms of population size, land area and economic power. Its economic growth since 1980 has been phenomenal but the country is threatened by a variety of natural hazards which include earthquakes, typhoons and flooding.

China has many large rivers with the Chang Jiang (Yangtze) being the third longest in the world at 6380 km. Every year the summer monsoon rains, combined with snowmelt from the Himalayas, cause the river to rise to very high levels. Despite embankments, flooding is common.

Fig. 1.46 The location of the Chang Jiang River in China

Flooding on the Chang Jiang has caused many problems. Its valley is home to 400 million people. It floods annually but in 1931, 1934, 1954 and 1998 the floods were particularly catastrophic. 300 000 people died from its floods during the 20th century. The worrying trend is that the floods seem to be getting worse and the 1998 flood set new records.

Physical causes of flooding on the Chang Jiang

Flooding on the Chang Jiang is an annual event, caused by snowmelt in the Himalayas and the summer monsoon rains. In 1998 the rains lasted a month longer than usual and the 'El Niño' effect was blamed for this.

RESEARCH Find out what the El Niño effect is and how it can lead to increased rainfall in China and other areas on the west side of the Pacific Ocean.

Human causes of flooding on the Chang Jiang

As on most rivers, human activities have made the impact of the floods worse:

- China's urban population has been growing rapidly. Many of the cities are sited beside the river. More people and more property are at risk than in the past.
- To counteract the pressure for rural-to-urban migration, factories have been built in the village communes to provide jobs for the country folk. Many of these factories are on the floodplain and are not as well protected from floods as those in the cities. These factories and the workers' houses are at risk.

- More buildings on the floodplain mean less room for the floodwater so the flood levels rise higher.
- Deforestation in the headwaters of the river in the 1960s means that there is less interception, less evapotranspiration and less infiltration. This leads to more surface run-off and bigger flood peaks.
- Mismanagement of the deforested land, e.g. overgrazing, has led to soil erosion and more silt being washed into the river channel. There is, therefore, less room for the water.
- Canalisation of the river to improve river transport has straightened the river, speeding up the flow, reducing the lag time and increasing the flood peak.
- Flood protection embankments have constrained the river. This means that the river can hold more water but when the banks break the flooding is rapid and more deadly – people have less time to escape.
- In the old days, Dongting and Poyang Lakes near Wuhan acted as safety valves. Floodwater from the river was diverted into the lakes, reducing the potential flood peak. More recently, farmers have been reclaiming **polders** from the lakes to create new farmland. This means the lakes are much smaller and there is less room in the lakes for the floodwaters. Flood peak levels are increased.
- Global warming could have resulted in more rainfall in China.

The impacts of the 1998 Chang Jiang floods

The Chang Jiang floods of 1998 were some of the worst floods on this river in the last one hundred years. The monsoon rains were not more intense than normal but lasted for a month longer. At one time the river was 45 metres high. What were the impacts of these devastating floods?

- 240 million people in seven of China's provinces were affected by the floods in some way.
- 4000 people were drowned.
- Thousands of farm animals died.
- Huge areas of crops were destroyed. These included food crops such as rice and industrial crops such as cotton.
- To protect Wuhan, the largest city in the area, many of the river's flood protection embankments had to be deliberately breached. Large areas of the countryside were flooded as a result, destroying houses and factories in the village communes.
- 14 million people were homeless for months until their houses could be repaired or replaced.
- People were out of work for months while factories were repaired.
- Great thicknesses of sticky clay were deposited onto the fertile fields. This clay had to be removed before farming could re-commence.
- The total cost to China's economy was enormous.

Management of flooding on the Chang Jiang

Several schemes have been developed to reduce flooding on the Chang Jiang. These include both 'hard' and 'soft' engineering projects.

The Three Gorges Dam: a hard engineering solution

Downstream of the city of Chongqing, the Chang Jiang flows through a deep, narrow section of its valley known as the 'Three Gorges'. This is an ideal site for a dam because the reservoir is very big but is contained in the narrow valley and does not spread out over a huge lowland area. The dam has been built at Sandouping and the reservoir is 660 km long and 1 km wide, extending upstream almost as far as Chongqing.

The Three Gorges dam is the largest hard engineering project ever undertaken on a river. Construction started in 1994 and the dam was completed in 2006. The project was finally completed in 2009 when the reservoir completely filled up. The dam is 2.3 km long and almost 200 metres high. A series of gigantic ship locks has been built at the north-east end of the dam and an 18 000 megawatt H.E.P. station has been built inside the southwest end of the dam. It has cost in excess of US$ 38 billion to build.

What are the benefits of the scheme?

- At least 50 million people have been protected from the sort of catastrophic flooding that occurred in 1998, including those living in the mega-cities of Wuhan and Shanghai.
- Millions of hectares of farmland have been protected from flooding *and* provided with guaranteed irrigation water. This will raise grain and oil-seed production.

- Water supplies to the 13 million people living in Shanghai are now secure.
- It is generating 10 per cent of China's electricity, equivalent to 15 nuclear power stations. This is clean HEP and its production will not contribute to air pollution or to climate change. The power produced will boost economic growth, especially in central and eastern China, including the cities of Wuhan and Shanghai.
- The Chang Jiang is now navigable by ships of up to 10 000 tonnes, as far upstream as Chongqing. There is expected to be a 500 per cent increase in river traffic and this will also boost economic growth.

What are the disadvantages of the scheme?

- The reservoir has flooded 150 towns and cities and 1300 villages. 1.2 million people have been resettled in new settlements close to their old homes but the compensation did not cover the cost of their new homes.
- The reservoir is heavily polluted by toxins from flooded mines and factories. This has damaged the river's fragile ecosystem and species such as the White Flag River Dolphin and the Siberian Crane are endangered.
- The landscape itself could be a problem. As the water seeps into the rocks of the steep valley sides, landslides are expected. This is also an earthquake region and if the dam were to break the resulting flood would be unbelievably devastating.
- The Chang Jiang is laden with silt. This will be deposited in the reservoir, reducing its capacity. It will have to be dredged or flushed out on a regular basis. In the past, farmland downstream was fertilised with a thin layer of silt each year. This has been lost and more chemical fertilisers are needed.
- Over 1000 cultural and archaeological sites have been flooded, including the Zhang Fei temple.

Afforestation: a soft engineering solution

Upstream of Chongqing, the Chang Jiang runs through a hilly area on the borders of Yunnan and Sichuan provinces. This used to be heavily forested but many of the trees were cut down in the 1960s for fuel, timber and farm land. The new fields are used to grow crops like buckwheat but the terraces are poor and soil erosion is a problem. Animals are grazed here too. There is a now a big programme to get the local people to replant the trees wherever possible. The advantages are:

- Trees encourage interception, evapotranspiration and infiltration. This will help to reduce flooding, both locally and downstream.
- Forested areas have less soil erosion. This will be good for the local area and will reduce the amount of silt further down the river. This also reduces flooding and will reduce the rate of sedimentation in the Three Gorges reservoir.
- Trees can be harvested for food, fodder, fuel and timber.

However, the disadvantages are that the local farmers are losing their arable and grazing fields. Many of the trees planted are fast growing conifers which are less useful than the natural forest and do not stimulate biodiversity.

20. 'The Three Gorges Dam has caused more problems than it has solved'. To what extent do you agree with this statement?

Key concepts

The key concepts listed in the syllabus are set out below. For each one a summary of how it applies to this chapter is included.

Space: the drainage basin is an excellent example of the concept of space. The inputs, flows and outputs of the drainage basin system all operate within and across the space provided by the drainage basin. The nature of the drainage basin space determines the way in which the system operates to influence the functioning of the streams and rivers in the drainage basin. The river landscape is another example of the concept of space. The different river landforms are arranged logically throughout this space, from the upper valley to the lower valley of the river.

Scale: spatial scale is an important concept when studying rivers and their landscapes. Individual landforms are found at the local scale while drainage basins occupy the regional scale and the hydrological cycle operates at the global scale. The timescale is important when considering how quickly water moves through a drainage basin, how changes that are made to the drainage basin can affect these timescales and how these changing timescales can modify the nature and magnitude of river floods.

Place: distinctive river landforms are found in similar places within drainage basins. The source of a river is usually in a hilly place while the mouth is often beside the sea. Floodplains are places which provide people who live on them with opportunities and challenges.

Environment: rivers are part of the natural environment and they interact with people in a variety of ways. Water abstraction needs to be managed sustainably to ensure that supplies do not run out. Flood risk is a challenge which needs to be managed sensibly, considering the whole drainage basin and not just one place.

Interdependence: the water cycle operates at a range of scales and its interaction with human systems at each of these scales is complex. People need to understand the processes and links that operate in each drainage basin system if they are to successfully exploit the opportunities that it provides to them and manage the threats that it presents.

Diversity: every drainage basin and river landscape has its own distinctive character but they all obey overarching physical laws. Despite this, the human response to the opportunities and challenges that rivers provide is variable. This variation is often to do with the level of economic development of the country or society concerned.

Change: river basins and the landforms in them are constantly changing. This change is not only a response to the physical processes operating there (e.g. erosion, transportation and deposition) but also to the human activities going on there (e.g. water abstraction and flood risk management). Geographers should aim to understand the physical processes, the human activities and the way that the interaction between them leads to change.

Exam-style questions

1 Study Fig. 1.47 which shows the annual hydrograph of the River Severn at Bewdley.

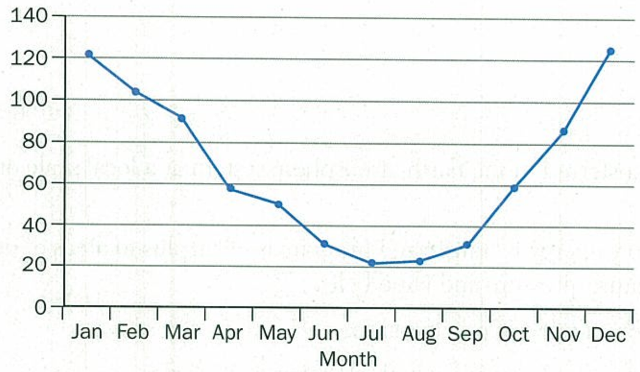


Fig. 1.47

(a) Using Fig. 1.47, identify the:

(i) Mean monthly discharge of the River Severn in October? [1]

(ii) The lowest mean monthly discharge of the River Severn and the month in which it occurs. [2]

(b) Briefly describe the pattern of the annual discharge of the River Severn. [3]

(c) Suggest how seasonal changes in evapotranspiration could cause the variations in river discharge shown in Fig. 1.47. [4]

2 (a) (i) Define the terms overland flow and throughflow as they apply to the movement of water in a drainage basin. [4]

(ii) Briefly explain how the shape of a storm hydrograph can be affected by overland flow. [3]

(b) Explain how vegetation type can affect the flows and stores of water in a drainage basin. [8]

(c) With the aid of examples, assess the extent to which human activities can increase the impact of river floods. [15]