12 Inland water — dammed, diverted and drained

12.1 Overview

TO COME

12.1.1 Introduction

Water makes life on Earth possible — rivers are like blood running through the veins of a body. Over time we have dammed, diverted and drained our water sources, and this has brought about significant environmental change. Careful stewardship of our water resources will help ensure a sustainable future.

Resources

eWorkbook	Customisable worksheets for this topic
Video eLesson	Drained away (eles-1709)

LEARNING SEQUENCE

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12.7 The impacts of drainage and diversion
12.8 **SkillBuilder**: Reading topographic maps at an advanced level (online only)
12.9 Putting water back — managing the Murray–Darling
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12.11 **Review** (online only)

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12.2 Wet and wonderful — inland water

12.2.1 What is inland water?

Have you ever stopped to think that the water flowing down a river or rippling across a lake is our life-support system? The rivers, lakes and wetlands that make up our inland water then supply our domestic, agricultural, industrial and recreational water use. They also provide important habitats for a wide range of terrestial and aquatic life.

Inland water systems cover a wide range of landforms and environments, such as lakes, rivers, floodplains and wetlands. The water systems may be **perennial** or **ephemeral**, flowing (such as rivers) or standing water (such as lakes) (see **FIGURE 1**). There are interconnections between surface water and **groundwater**, and between inland and coastal waters. Inland water is an important link in the water cycle, as water evaporates from its surface into the atmosphere. In return, rainfall can be stored in rivers and lakes, or soak through the soil layers to become groundwater.

FIGURE 1 The Parana River floodplain in northern Argentina shows a variety of different types of inland water.

12.2.2 Why is inland water important?

Inland water provides both the environment and people with fresh water, food and habitats. It provides environmental services; for example, it can filter pollutants, store floodwater and even reduce the impacts of climate change. The economic value of these services cannot easily be measured. Their importance, however, can be taken for granted and not appreciated until the services are lost or degraded.

12.2.3 What are the threats to inland water?

Inland water is extremely vulnerable to change. It has been estimated that in the last century, North America, Europe and Australia have lost over 50 per cent of their inland water (excluding lakes and rivers). Those systems remaining are often shrunken and polluted. This loss is largely a result of human-induced environmental changes. **TABLE 1** illustrates some of the reasons for changes to inland water systems, and their possible impacts on the environment and people. As water is such a valuable resource, much of our inland waterways have been dammed, diverted or drained to meet the needs of people.

TABLE 1 Threats to inland water

Cause of change to inland water systems	Environmental functions threatened	Impacts of change
Increasing population and increasing demand for water across space	Most services (e.g. fresh water, food and biodiversity) Regulatory features such as recharging groundwater and filtering pollutants	Increased withdrawal of water for human and agricultural use Large-scale draining of wetlands to create farmland
Construction of infrastructure including dams, weirs and levee banks, diverting water to other drainage basins	Services supporting the quality and quantity of water Biodiversity, habitat, river flow and river landforms	Changes to the amount and timing of river flow. The transportation of sediment can be blocked and dams can restrict fish movements.
Changing land use (e.g. draining of wetlands, urban development on floodplains)	Holding back floodwaters and filtering pollutants Habitats and biodiversity	Alters run-off and infiltration patterns Increased risk of erosion and flood
Excessive water removal for irrigation	Reduced water quantity and quality Less water available for groundwater supply	Reduced water and food security Loss of habitat and biodiversity in water bodies
Discharge of pollutants into water or on to land	Change in water quality, habitat Pollution of groundwater	Decline in water quality for domestic and agricultural use Changes ecology of water systems

FIGURE 2 Wetlands are an example of inland water systems that are vulnerable to human-induced damage.

12.2 ACTIVITY

Make a simplified sketch of FIGURE 1 and clearly label an example of each of the following features: *main channel, tributary, anabranch, meander, oxbow lake (or billabong), floodplain*

Classifying, organising, constructing

12.2 EXERCISES

Geographical skills key: GS1 Remembering and understanding **GS2** Describing and explaining **GS3** Comparing and contrasting **GS4** Classifying, organising, constructing **GS5** Examining, analysing, interpreting **GS6** Evaluating, predicting, proposing

12.2 Exercise 1: Check your understanding

1. **GS2** Match the following terms with their correct definition in the table below. You may need to use a dictionary to help. *main channel, tributary, anabranch, meander, oxbow lake (or billabong), floodplain*

Term	Definition
	A smaller stream that flows into a larger stream
	A bend in the river
	An area of relatively flat, fertile land on either side of a river
	A main river
	A cut-off meander bend
	Where a river branches off and joins back into itself

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5. <content to come – leave 2 lines>

12.2 Exercise 2: Apply your understanding

1. **GS6** Suggest two short-term and two long-term examples of human-induced ***changes*** that could have an impact on the wetland in FIGURE 2.
2. **GS5** The Parana River is 4880 kilometres long, making it the second longest river in South America. The river flows from the south-east central plateau of Brazil south to Argentina. FIGURE 1 is a small section of this river. What evidence is there to suggest that this river frequently floods?
3. **GS5** Refer to FIGURE 1. The brown shading visible in the water and on the land represents the river's muddy sediment. This is material such as sand and silt carried and deposited by a river.
   (a) Where has this sediment come from?
   (b) How does the sediment get onto the floodplain?
   (c) If the river is dammed upstream, what ***changes*** are likely to happen to the sediment carried and to the floodplain?
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Try these questions in learnON for instant, corrective feedback. Go to www.jacplus.com.au.

12.3 Damming rivers — the pros and cons

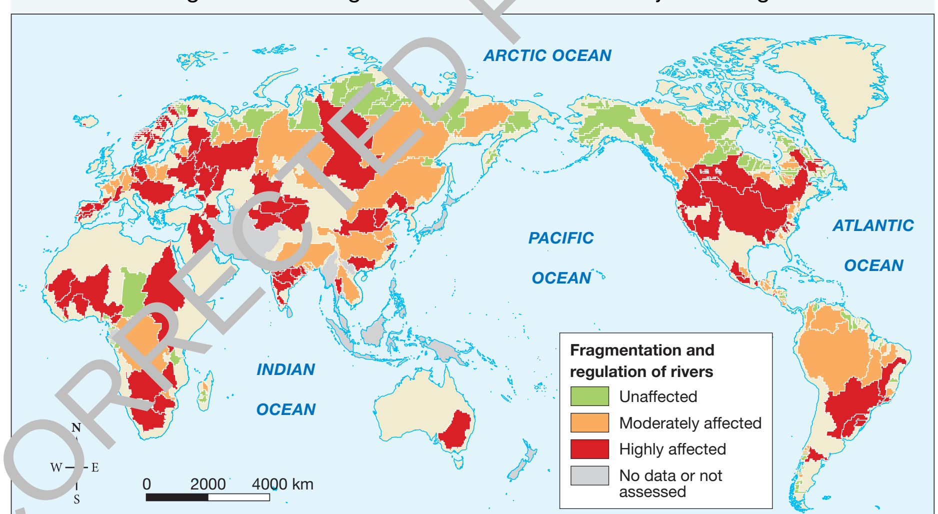
12.3.1 Why dam rivers?

Are dams marvelous feats of modern engineering or environmental nightmares? Without them, we would not have a dependable supply of water or electricity, nor would we feel relatively safe from floods. For many decades, dams have been seen as symbols of a country's progress and economic development. But increasingly, the social, economic and environmental costs are emerging.

A reliable water supply has always been critical for human survival and settlement. The global demand for water has increased by 600 per cent in the last century — more than twice the rate of population growth. If this rate continues, global water demand will exceed supply by 2030. Water is also unevenly distributed across the globe. Some places suffer from regular droughts, while others experience massive floods. As a result, people have learned to store, release and transfer water to meet their water, energy and transport needs. This could be in the form of a small-scale farm dam or a large-scale multi-purpose project such as the Snowy River Scheme. Constructing dams is one of the most important contributors to environmental change in river basins. Globally, over 60 per cent of the world's major rivers are controlled by dams.

FIGURE 1 shows the degree of **river fragmentation**, or interruption, in the world's major drainage basins. River fragmentation is an indicator of the degree to which rivers have been modified by humans. Highly affected rivers have less than 25 per cent of their main channel remaining without dams, and/or the annual flow pattern has changed substantially. Unaffected rivers may have dams only on tributaries but not the main channel, and their discharge has changed by less than 2 per cent. Forty-eight per cent of the world's river volume is moderately to severely affected by dams today.

FIGURE 1 Degree of river fragmentation in the world's major drainage basins

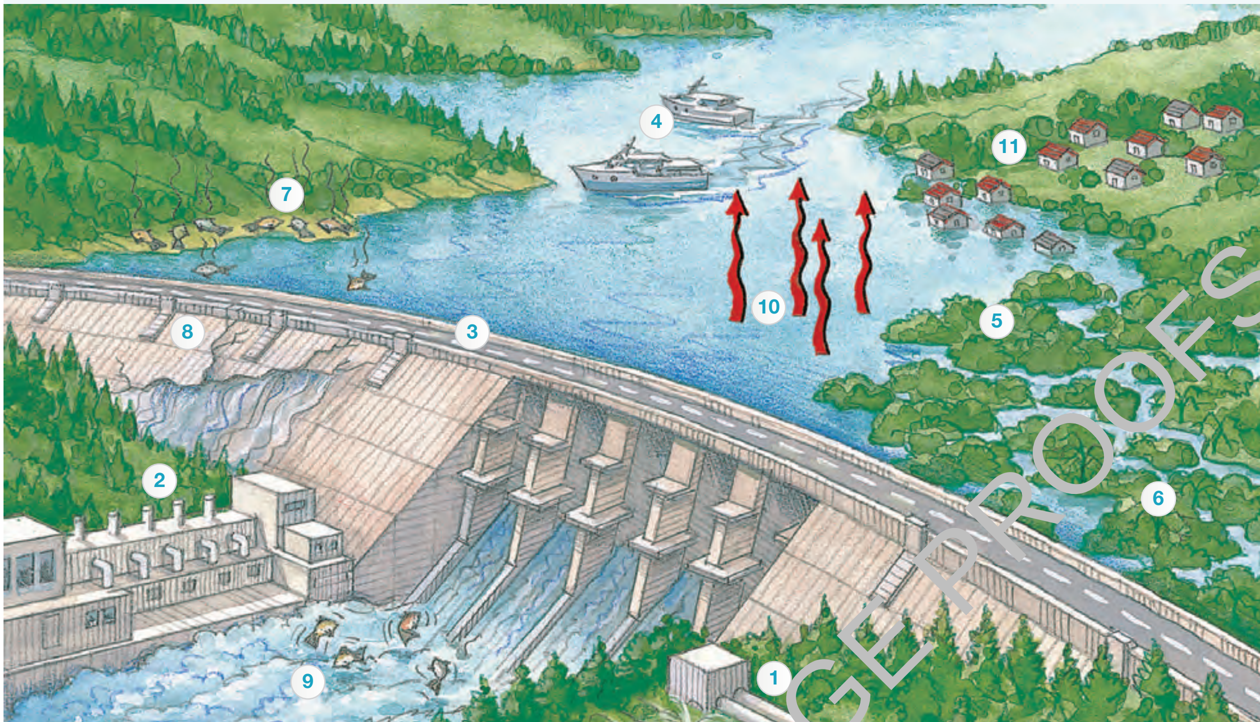


Source: Made with Natural Earth. University of New Hampshire UNH/Global Runoff Data Centre GRDC http://www.grdc.sr.unh.edu/ Map by Spatial Vision

Dams, **reservoirs** and **weirs** have been constructed to improve human wellbeing by providing reliable water sources for agricultural, domestic and industrial use. Dams can also provide flood protection and generate electricity.

However, while there are many benefits, large-scale or mega dams bring significant changes to the environment and surrounding communities, both positive and negative, as shown in **FIGURE 2**.

FIGURE 2 The advantages and disadvantages of large-scale dams



Positive changes

1 A regular water supply allows for irrigation farming. Only 20 per cent of the world's arable land is irrigated, but it produces over 40 per cent of crop output.

2 Released water can generate hydro-electricity, which accounts for 16 per cent of the world's total electricity and 71 per cent of all renewable energy.

3 Dams can hold back water to reduce flooding and even out seasonal changes in river low.

4 Income can be generated from tourism, recreation and the sale of electricity, water and agricultural products.

Negative changes

5 Large areas of fertile land upstream become flooded or inundated as water backs up behind the dam wall. Alluvium or silt is deposited in the calm water that previously would have enriched floodplains.

6 Initially, flooded vegetation rots and releases greenhouse gases.

7 The release of cold water from dams creates thermal pollution. Originally the Colorado River had a seasonal fluctuation in temperature of 27 °C. Today, temperatures average 8 °C all year. The water is too cold for native fish reproduction, but is ideal for some introduced species.

8 Some dams are constructed in tectonically unstable areas, which are prone to earthquakes.

9 Dams block the natural migration of fish upstream. Since 1970, the world's freshwater fish population has declined by 80 per cent.

10 Over 7 per cent of the world's fresh water is lost through evaporation from water storages.

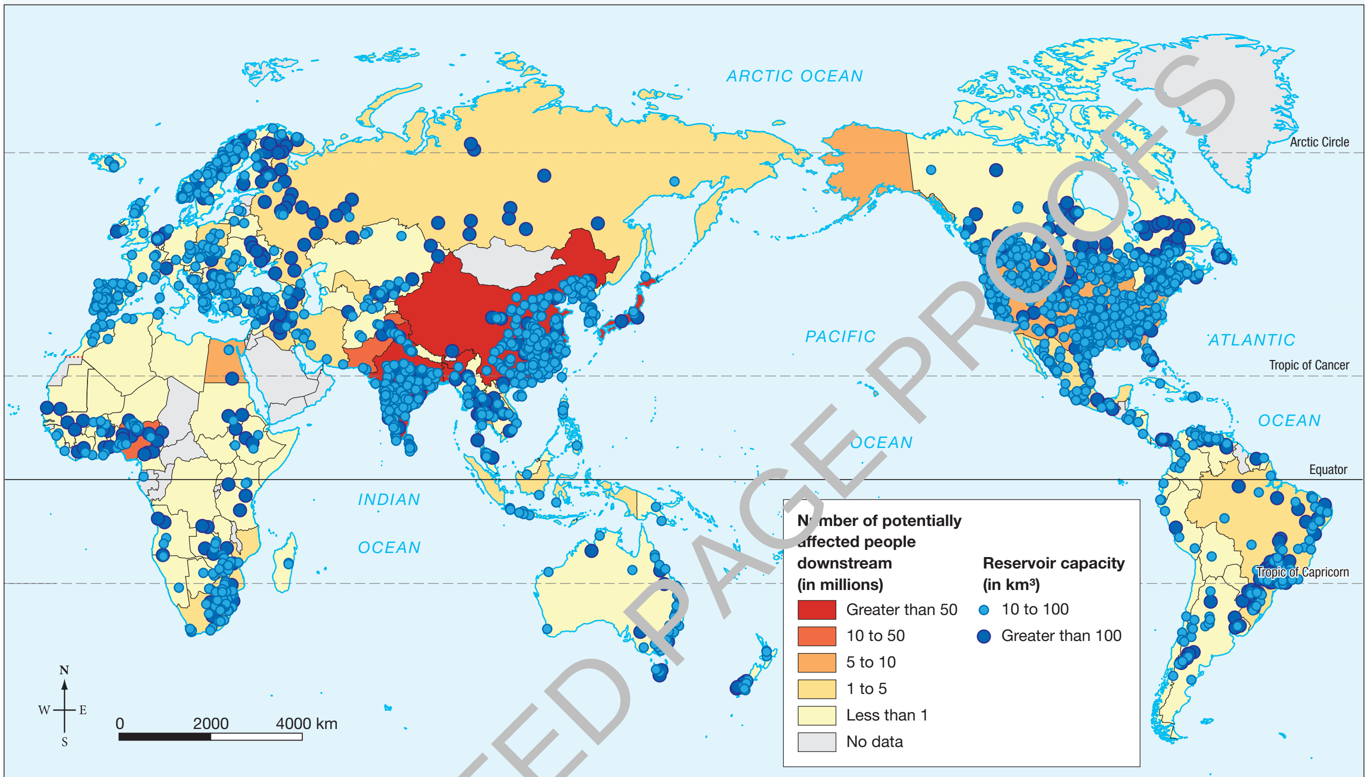
11 A conservative estimate has stated that dams have negatively affected 472 million people worldwide. Tens of millions have been relocated from dam sites while other communities both upstream downstream have lost their livelihoods or had their land flooded.

12.3.2 Why should a river flow?

Traditionally, water flowing out to sea was seen as a waste. If it could be stored, then it could be used. Little thought was given to the health of the river and the importance of keeping water in a stream. Governments around the world have favoured damming rivers to make use of water resources. But is this the only solution to our growing water needs?

Large-scale or mega dams have been linked to economic development and improvement in living standards. Only in recent times have people questioned the real cost of these schemes: environmentally, economically and socially. **FIGURE 3** shows the number of downstream communities in each country that have the potential to be affected by the construction of mega dams.

FIGURE 3 Distribution of downstream communities affected by large dams



Source: Lehner et al.: High resolution mapping of the world's reservoirs and dams for sustainable river flow management. Frontiers in Ecology and the Environment. GWSP Digital Water Atlas (2008). Map 81: GRanD Database (V1.0). Available online at http://atlas.gwsp.org.

There is also the concern that multi-purpose dams have conflicting aims. To generate hydro-electricity you need to release a large volume of stored water. To provide **flood mitigation** you need to keep water levels low. To use water for irrigation you need a large store. So, what do you do?

More than one billion people worldwide lack access to a decent water supply, yet it has been estimated that only 1 per cent of current water use could supply 40 litres of water per person per day, if the water was properly managed. The problem is not so much the quantity or distribution of water resources but the mismanagement of it. During the twentieth century, over $2 trillion was spent on constructing more than 50 000 dams. The emphasis now is to switch from *controlling* river flow to *adapting* to river flow. In other words, shifting from a human-centred to an earth-centred approach. This means building small-scale projects that promote social and environmental sustainability (see subtopic 12.4). In many regions of the world, there are ongoing community protests against the need for mega dams in preference to smaller schemes that benefit local people directly.

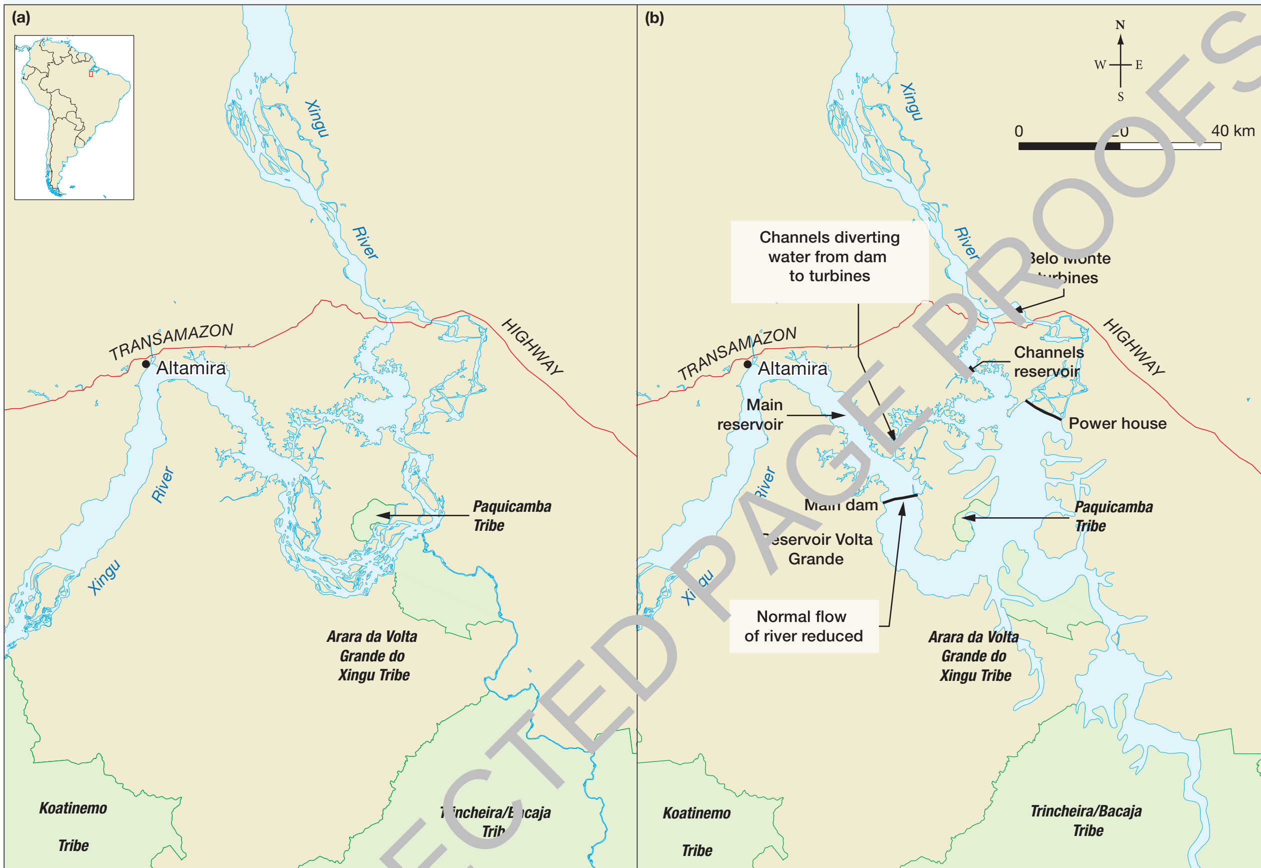
12.3.3 People versus power?

Across the globe, from Africa to Asia to South America, there has been a growing movement of community and environmental groups challenging the construction of mega dams in terms of location, sustainability and the potential social, economic and environmental impacts. Organisations such as International Rivers work with local groups to help restore justice to dam-affected communities, find better alternatives and promote the restoration rivers through better dam management.

12.3.4 CASE STUDY: Belo Monte Dam, Brazil

For over 20 years, there has been an ongoing protest over the construction of the Belo Monte Dam in Brazil. The original design called for five huge dams on the Xingu River, but after large-scale local and international protests by indigenous groups and environmentalists, the scheme was scaled back to one large dam — the world's third largest (see **FIGURE 4**).

FIGURE 4 (a) Location of the Belo Monte Dam and (b) the related environmental changes



Source: Spatial Vision

Belo Monte was designed to divert more than 80 per cent of the flow of the Xingu River, drying out over 100 kilometres of river, known as the Big Bend (see **FIGURE 5**). As a result, over 516 km^2 of rainforest was flooded, and between 20 000 and 40 000 indigenous people were displaced from their homelands.

Construction was delayed and battles fought in court over the legality of the **environmental impact assessment**, which was done after work had already started on the project. For the indigenous people, diverting water from the river channel meant a reduction in fish populations. Additionally, because there were few roads in the region, river trading was essential, but has now been reduced. The loss

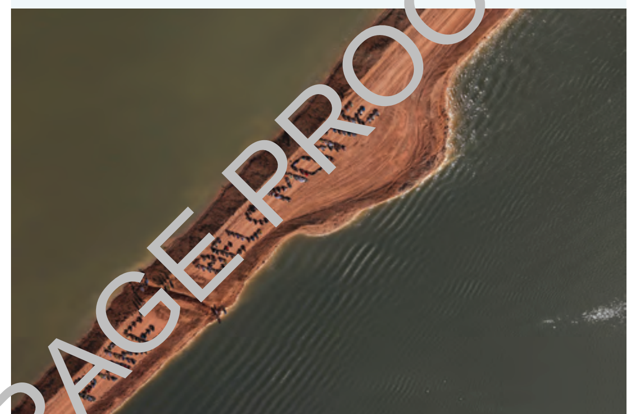
FIGURE 5 First stages of the construction of the Belo Monte Dam

of rainforest, lowering of watertables and drying out of soils are further predicted impacts. Traditional livelihoods and cultures based on small-scale fishing, floodplain farming and forest management have been threatened.

While the government claimed the dam will provide **green energy**, the amount of greenhouse gases released from drowned and rotting vegetation behind the dam wall will contribute to global warming for some years. River flow in the region is seasonal, so hydro-electricity can be generated at peak flow for only a few months of the year. During the dry months, only 1000 MW of a potential 11 000 MW will be generated. There is a distinct possibility that another dam will need to be built upstream to supply a more even and continual flow of water for power generation.

Downstream, the small town of Altamira (shown in **FIGURE 4**) rapidly expanded during the three-year construction period, when 60 000 labourers flooded in looking for construction work. Land prices skyrocketed, the cost of living rose, and crime rates soared to create the most dangerous town in the country. Once construction was halted, workers left as jobs disappeared.

FIGURE 6 Protesters at the dam site cut a channel through earthworks to restore flow in the Xingu River. The wording translates as 'Stop Belo Monte'.



In early 2016 the project was suspended and the owners, Norte Energia were fined $317 000 for failing to provide promised protection for local communities. A two-year 'emergency program' established in 2011 was designed to compensate people for the schools and clinics that were promised but not supplied. Each village was allocated 30 000 reais (around $12 500) per month for two years. After centuries of living a subsistence life, local tribes were introduced to the modern world. Fishing and hunting was replaced with supermarket fast food, alcohol and sweets. Motorbikes and outboard motors replaced canoes, and the role of the tribal Elders was pushed aside by younger people who could speak Portuguese with the construction workers. Traditional social activities were replaced by televisions, and plastic and other garbage accumulated as no-one knew what to do with it.

For nearly three decades the Juruna tribe have fought the dam construction and much of their traditional lifestyle activities have been replaced by meetings with government and company officials, environmental activists and journalists. Attitudes towards the native communities have changed, as one dam employee noted, 'In the old days you just gave the Indians a mirror and they were happy. Now they want iPads and four-wheel drives'.

Scientists are now questioning whether large-scale infrastructure projects can balance economic benefits with environmental and social costs. With the increasing threat of climate change and recent drought, which has reduced flow along the Xingu River, the Belo Monte dam may never meet its promised economic or energy-producing goals.

In 2018, the Brazilian government announced that they would cease constructing mega dams in the Amazon. Brazil has the potential to generate 50 gigawatts of energy by 2050 if they built all the dams under design, but 77 per cent of these would to some extent impact indigenous land or federally protected areas. It appears that the ongoing resistance of indigenous peoples and environmentalists, combined with other political and economic influences have led to a hard-won change in policy.

DISCUSS

Does a large company such as Norte Energia have obligations to the people dislocated by such a large-scale scheme? Before deciding, carefully consider the consequences of the company being deemed responsible or not responsible. **[Ethical Capability]**

Resources

Interactivity Dam it (int-3292)

eWorkbook Controversial dams

12.3 ACTIVITIES

1. Using your atlas, compare a map of world population distribution with **FIGURE 1.** What do you notice about the ***interconnection*** between population concentration and moderately to highly fragmented rivers? **Comparing and contrasting**
2. Complete the **Controversial dams** eWorksheet to learn more about other dam projects around the world and the impact of dams on people and the environment. **Examining, analysing, interpreting**
3. Research one other controversial dam site around the world and compare it with the Belo Monte dam in terms of (a) size, (b) purpose and (c) impacts. **Examining, analysing, interpreting**

12.3 EXERCISES

Geographical skills key: GS1 Remembering and understanding **GS2** Describing and explaining **GS3** Comparing and contrasting **GS4** Classifying, organising, constructing **GS5** Examining, analysing, interpreting **GS6** Evaluating, predicting, proposing

12.3 Exercise 1: Check your understanding

1. **GS1** What human activities are responsible for ***changing*** or fragmenting rivers?
2. **GS2** Using **FIGURE 1**, describe the location of ***places*** with rivers that are largely unaffected by river fragmentation.
3. **GS2** Suggest the ways that native fish can be affected by large dams.
4. **GS1** Traditionally, why has water flowing out to sea been considered a waste? Is this a human-centred or earth-centred viewpoint?
5. **GS1** What is the primary aim of an ***environmental*** impact assessment?
6. **GS1** Why won't the Belo Monte Dam be able to generate maximum electricity all year round?
7. **GS2** Refer to **FIGURE 5.** Describe the landscape in this image.
8. **GS2** Refer to **FIGURE 4 (a) and (b)** to describe the ***environmental changes*** brought to the Xingu River by the dam.

12.3 Exercise 2: Apply your understanding

1. **GS4** Using information from FIGURE 2 and the text in this subtopic, construct a table with the following headings to classify the impacts of dam building.

Positive effects for people	Negative effects for people
Positive effects for the environment	**Negative effects for the environment**

2. **GS5** Refer to **FIGURE 3**.
   (a) Which countries in the world have the greatest number of people affected by large dams? Suggest a reason why.
   (b) Where are the world's largest (over 100 km^3) dams?
   (c) In what ways would they be affected?
   (d) Would people and ***environments*** upstream of large dams be affected by the dams? Give reasons for your answer.
3. **GS6** Suggest reasons why large-scale dam projects were seen as indicators of development and progress in countries.
4. **GS6** Suggest reasons that make a place suitable for a large dam. Consider landforms, climate, soil and rock type.

5. **GS6** Is there a ***sustainable*** future for mega dam projects such as the Belo Monte Dam? Justify your answer.
6. **GS6** 'The positive impacts of large dam building projects on people outweigh the negative impacts on the environment.' Do you agree or disagree with this statement? Give reasons for your point of view.

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12.4 Alternatives to damming

12.4.1 How can water be saved?

Traditionally, managing water has been focused on exploiting resources rather than conserving them. However, there are viable alternatives to dams that are often cheaper and have fewer social and environmental impacts. The focus has to be, first, on reducing demand for water and, second, on being using existing water more efficiently.

Agriculture

Globally, more than 70 per cent of fresh water is used for agriculture. In many expanding economies; for example, India, farming uses more than 85 per cent of available water. Irrigation is often very inefficient, with over half of the water applied not actually reaching the plants. High rates of evaporation and leaking **infrastructure** waste water. Often governments subsidise and encourage farmers to grow water-thirsty crops, such as cotton, in semi-arid regions. Poorly designed and managed irrigation schemes can become unsustainable if they develop waterlogging and salinity problems. Industrial and domestic users of water pay up to $3 per cubic metre, while agriculture users pay only $0.10. Such low costs can act as a disincentive to improving efficiency.

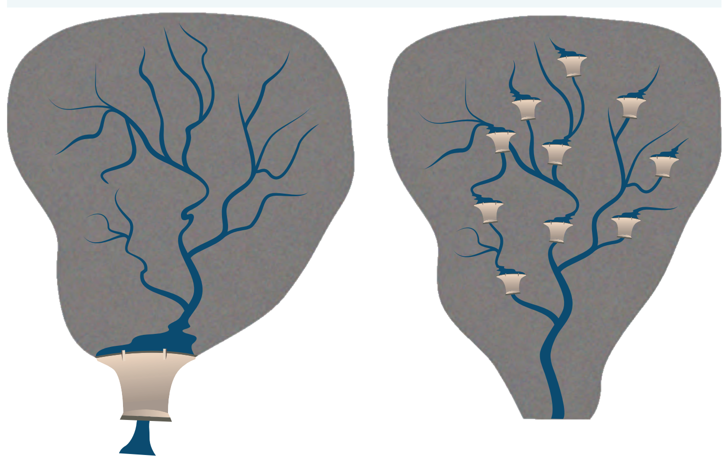
We could save vast amounts of water by improving irrigation methods, switching to less water-consuming crops and taking poor quality land out of production. Pakistan; for example, has one of the most wasteful water systems in the world. With the same quantity of water and an efficient system, Israel produces 70 per cent more food. Globally, if the amount of water consumed by irrigation was reduced by 10 per cent, water available for domestic use could double.

Urban use

Researchers state that 30 per cent of all clean drinking water is said to be lost through leaking pipes. The United States of America loses 8 trillion litres of water each year through deteriorating infrastructure. Countries could make savings by:

- reducing leaking pipes and improving water delivery infrastructure
- encouraging the use of water- and energy-efficient appliances and fixtures
- changing the pricing of water to a 'the more you use, the more you pay' system
- offering incentives to industry to reduce water waste and recycle
- harvesting rainwater, collecting rainwater off roofs, recycling domestic wastewater and other efficiency schemes. For example, 40 per cent of Singapore's water needs are met using treated wastewater.

FIGURE 1 Research in India has shown that 10 micro dams with one-hectare catchments will store more water than one dam of 10 hectares.



Small-scale solutions

Currently, researchers estimate it will cost US$114 billion per year to meet the United Nations' goal of achieving universal access to clean water and adequate sanitation. Hence the growing awareness of investing in small-scale technologies. Rather than one large, expensive dam, smaller projects that benefit local communities can be more desirable. These are often constructed and maintained by people who benefit directly from control over their own resources, at a minimal cost (see **FIGURE 1**).

12.4.2 How can we reduce the need for dams?

As many countries are actually running out of suitable places to locate large dams, we need to find alternatives. **Rainwater harvesting** schemes, as illustrated in **FIGURE 2 (a)** and **(b)** can be used for storing water. **Micro hydro-dams** (see **FIGURE 3**) can be used for generating electricity. Both of these schemes are easier and cheaper to build than large dams, and have lower environmental impacts.

FIGURE 2 Two methods for water harvesting: (a) rainwater tank and (b) groundwater recharging

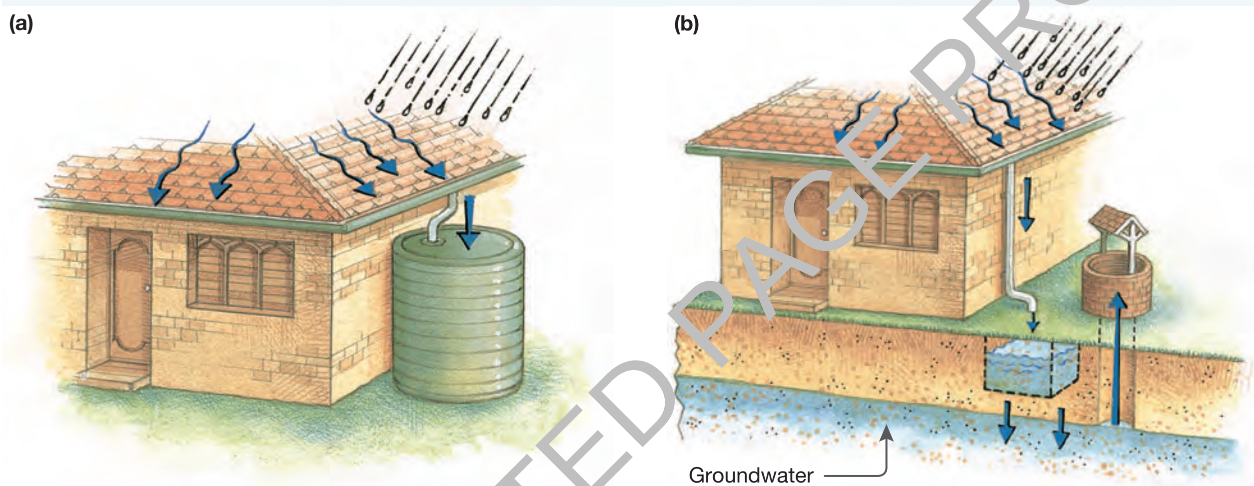


FIGURE 3 Water collected from a stream uphill rushes down the pipe and drives a small turbine in the hut to generate electricity for a local community in the Philippines.

12.4.3 CASE STUDY: Traditional water harvesting in India

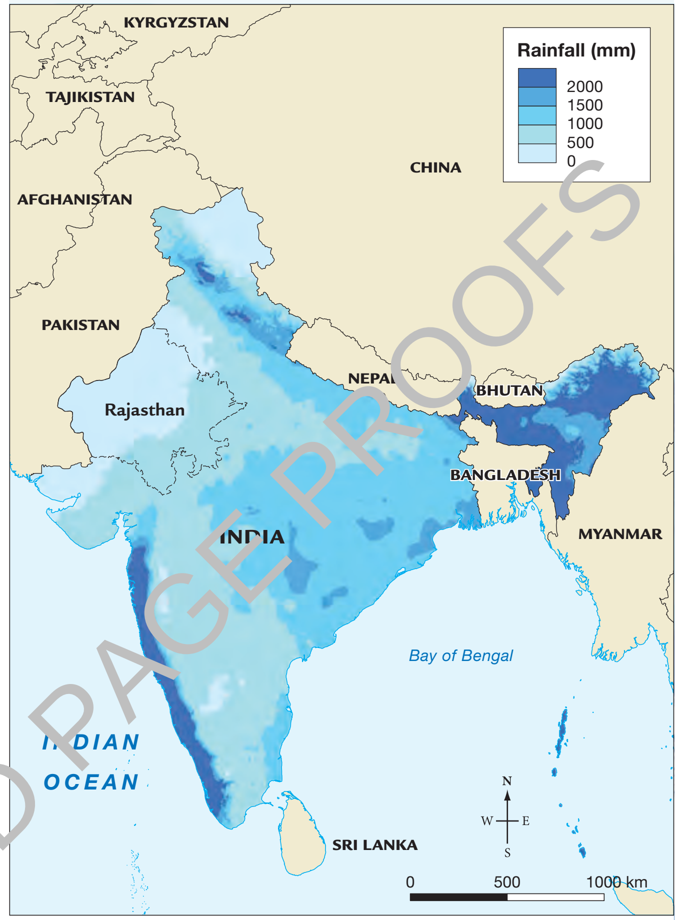
The state of Rajasthan is located in the arid north-west of India (see **FIGURE 4**). The region has only 1 per cent of the country's surface water and a total **fertility rate** of 2.4, compared to the national average of 2.2 (and compared to Australia's 1.74). Rajasthan adds more than 1 million people to its population every year; by comparison, Victoria added 120 000 people to its population between 2017 and 2018. The largest state in India faces both water scarcity and frequent droughts. Continual pumping of groundwater has seen underground water supplies dropping.

Traditionally, forests, grasslands and animals were considered property to be shared by all, local communities managed them carefully with a strict set of rules. Resources were used sustainably to ensure regeneration of plants and trees to enable farming to continue each year. However, by the mid twentieth century, government initiatives had taken control of local resources and promoted excessive mining and logging in the area. Large-scale deforestation resulted in severe land degradation, which increased the frequency of flash floods and droughts. There was little motivation for villages to maintain traditional water systems, or *johads*, and so there was a gradual decline in people's economic and social wellbeing.

Tarun Bharat Sangh (TBS) is an aid agency that was established in the mid-1980s. It set about trying to re-establish traditional water management practices. The basic principle is to capture, hold and store rainfall whenever it occurs, to be used during dry periods. TBS focused its attention on constructing and repairing some 10 000 *johads* in over 1000 villages. *Johads* are often small, dirt embankments that collect rainwater and allow it to soak into the soil and recharge groundwater **aquifers** (see **FIGURE 5**).

Another *johad* design features small concrete dams across gullies that would seasonally flood, trapping the water and allowing

FIGURE 4 Distribution of rainfall in India. The state of Rajasthan is highlighted.



Source: World Climate – http://www.worldclim.org/ Made with Natural Earth. Map by Spatial Vision.

FIGURE 5 A *johad* or traditional small water harvesting dam in India

it to infiltrate. Water, stored in aquifers, can later be withdrawn when needed via wells. The benefits have been remarkable and the estimated cost calculated to be an average of US$2 or 100 rupees per person. This is compared to over 10 000 rupees per head for water supplied from the Narmada River Dam Project.

What have been the benefits?

Environmental benefits

- Groundwater has risen from depths ranging 10–120 metres up to 3–13 metres below the surface.
- Five rivers that flowed only after the monsoon season now flow all year (fed by **base flow**).
- Revegetation and agroforestry schemes have increased forest cover by from 7 to 40 per cent, which helps improve the soil's ability to hold water and reduce evaporation and erosion.
  - The area under single cropping (one crop grown per year) has increased from 11 to 70 per cent and the area under double cropping (two crops per year) has increased from 3 to 50 per cent.
  - The water is shared among the villagers, and farmers are not allowed to use it to grow water thirsty crops.

Social benefits

- More than 700 000 people across Rajasthan have benefited from improved access to water for household and farming use.
- There has been a revival of traditional cultural practices in constructing and maintaining *johads*.
- The role of the village council (Gram Sabha) is promoted for encouraging community participation and social justice.
- With a more reliable water supply, communities became more economically viable.

12.4 ACTIVITIES

1. Complete the **Water harvesting** eWorksheet to learn more about traditional water harvesting schemes.
Examining, analysing, interpreting
2. Investigate the different methods of irrigating crops, such as flood, furrow and drip irrigation.
   (a) What are the advantages and disadvantages of each in terms of water use and waste?
   (b) Which irrigation method would:
      i. be the most economically viable
      ii. have the most ***environmental*** benefit?
Examining, analysing, interpreting

Resources

eWorkbook Water harvesting

12.4 EXERCISES

Geographical skills key: GS1 Remembering and understanding **GS2** Describing and explaining **GS3** Comparing and contrasting **GS4** Classifying, organising, constructing **GS5** Examining, analysing, interpreting **GS6** Evaluating, predicting, proposing

12.4 Exercise 1: Check your understanding

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12.4 Exercise 2: Apply your understanding

1. **GS5** Study the information in **FIGURE 4.** Explain why Rajasthan has water issues. Use data in your answer.
2. **GS6** Some ***places*** in India can receive up to 2500 mm of rainfall per year, but this can all fall in 100 hours. Suggest possible repercussions of this for local communities.
3. **GS6** Have small-scale water management schemes in Rajasthan been successful? Why or why not?
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5. <content to come – leave 2 lines>

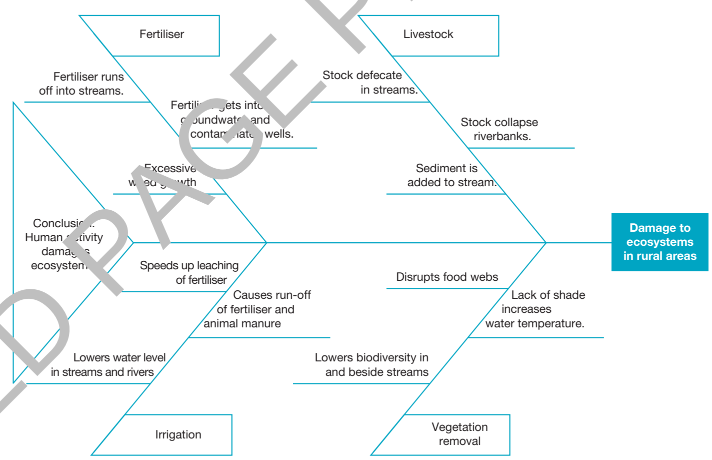
Try these questions in learnON for instant, corrective feedback. Go to www.jacplus.com.au.

12.5 SkillBuilder: Creating a fishbone diagram

online only

What is a fishbone diagram?

Fishbone diagrams are useful to help visualise a problem or effect, and to show the causes of that problem. Bones above and below the central line are used to identify causes, while the 'head' of the diagram gives the problem or effect. Each major category of cause then flows to other causes and even sub-causes. These are all linked to convey the interconnection of ideas.



Select your learnON format to access:

- an overview of the skill and its application in Geography (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

Video eLesson Creating a fishbone diagram (eles-1748)

Interactivity Creating a fishbone diagram (int-3366)

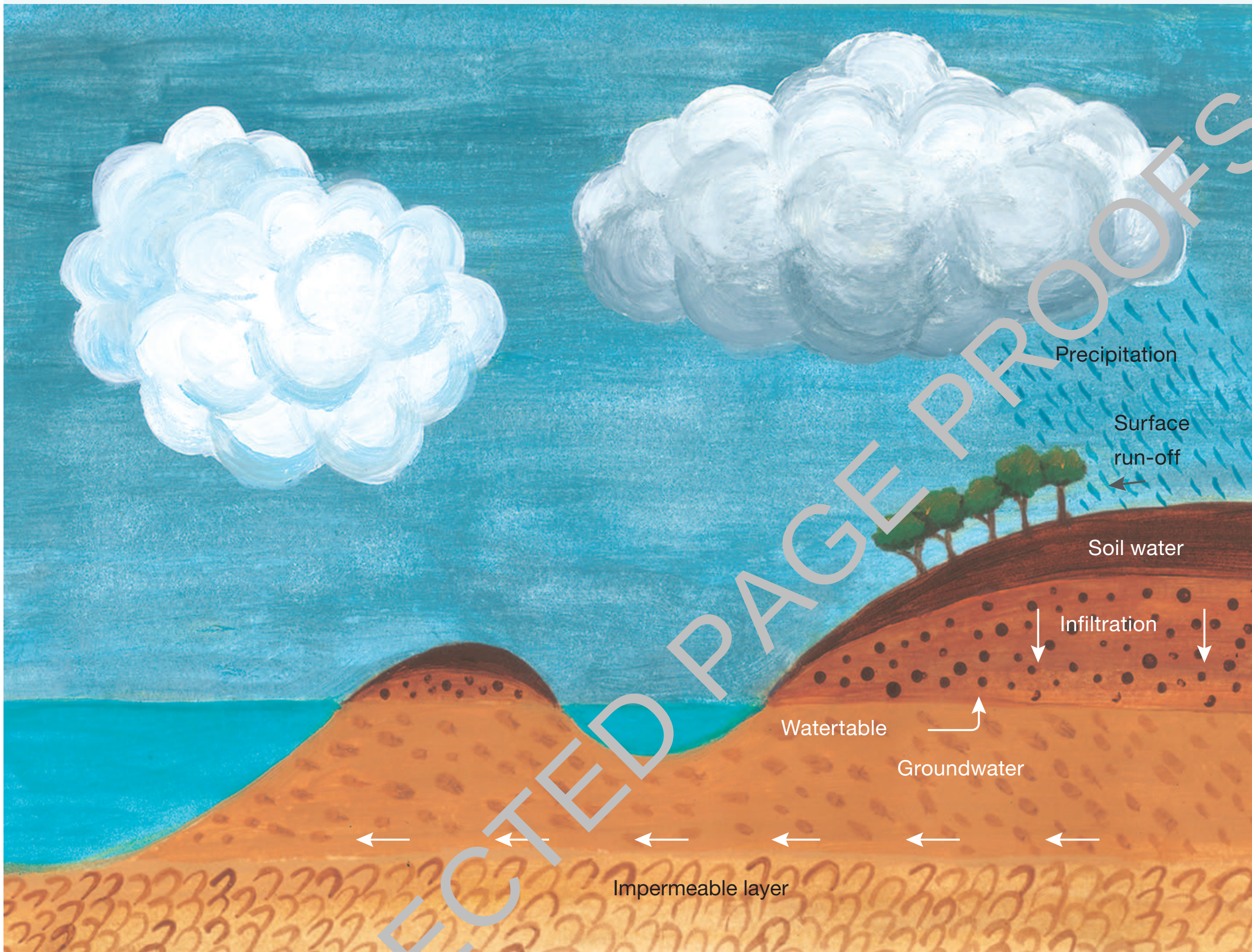
12.6 Using our groundwater reserves

12.6.1 What is groundwater?

Of all the fresh water in the world not locked up in ice sheets and glaciers, less than 1 per cent is available us to use — and most of that is groundwater. More than two billion people use groundwater, making it the single most used natural resource in the world. It is also the most reliable of all water sources. Fresh water stored deep underground is essential for life on Earth.

Groundwater is one of the invisible parts of the water cycle, as it lies beneath our feet. Rainfall that does not run off the surface or fill rivers, lakes and oceans will gradually seep into the ground. **FIGURE 1** shows where groundwater is stored in porous rock layers called aquifers. Water is able to move through these aquifers and can be stored for thousands of years. Unlike most other natural resources, groundwater is found everywhere throughout the world.

FIGURE 1 Diagram showing groundwater



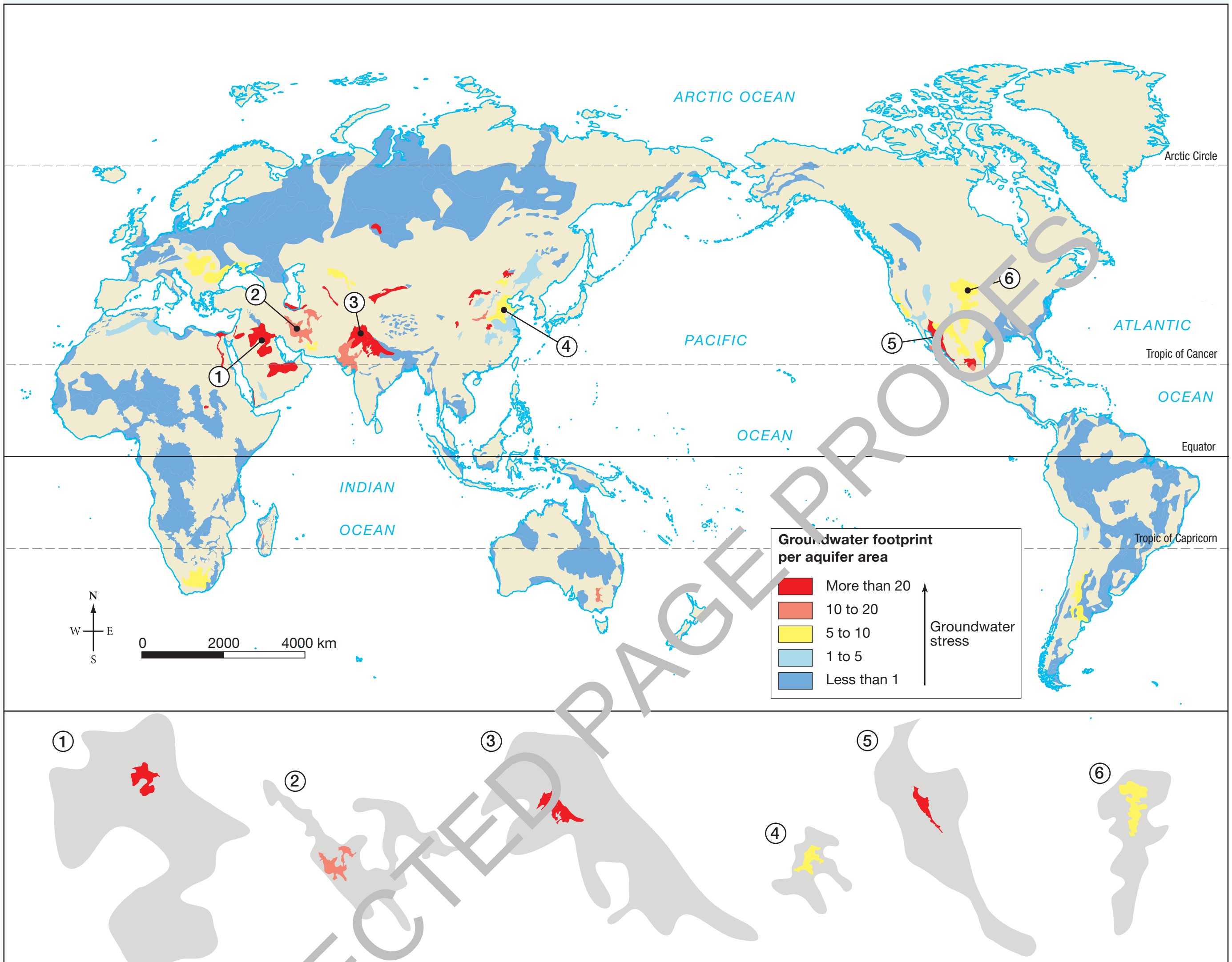
12.6.2 What are the advantages of using groundwater?

Since the mid-twentieth century, advances in drilling and pumping technology have provided people with an alternative to surface water for meeting increasing water demands. Groundwater has many advantages:

- It can be clearer than surface water.
- It is less subject to seasonal variation and there is less waste through evaporation.
- It requires less and cheaper infrastructure for pumping as opposed to dam construction.
- It has enabled large-scale irrigated farming to take place.
- In arid and semi-arid places, groundwater has become a more reliable water supply, which has led to improved water and food security.

If groundwater is removed unsustainably, that is, at a rate that is greater than is being replenished naturally by rainfall, run-off or underground flow, then **watertables** drop and it becomes harder and more expensive to pump. In areas of low rainfall there is very little **recharge** of groundwater so it may take thousands of years to replace. Over-extraction of groundwater can result in wells running dry, less water seeping into rivers and even land **subsidence** or sinking. **FIGURE 2** identifies those places in the world most at risk of groundwater depletion. Many of these are important food bowls for the world.

FIGURE 2 The world's use of groundwater



Note: The red area is the aquifer. The grey area is the size of the area that would be required to catch enough rainfall to replenish that aquifer.

Source: BGR & UNESCO 2008: Groundwater Resources of the World 1 : 25 000 000. Hannover, Paris. Map by Spatial Vision

12.6.3 Can we improve our use of groundwater?

In the past, we had limited knowledge of the interconnection between groundwater and surface water. As agriculture is the biggest user of groundwater, any improved efficiencies in water use can reduce the demand to pump more water. Improved irrigation methods and the re-use of treated effluent water are all methods that could reduce our unsustainable use of groundwater. Many countries share aquifers, so pumping in one place can affect water supplies in another. There is a need for more international cooperation and management of the aquifer as a single shared resource.

12.6.4 CASE STUDY: Why is China drying up?

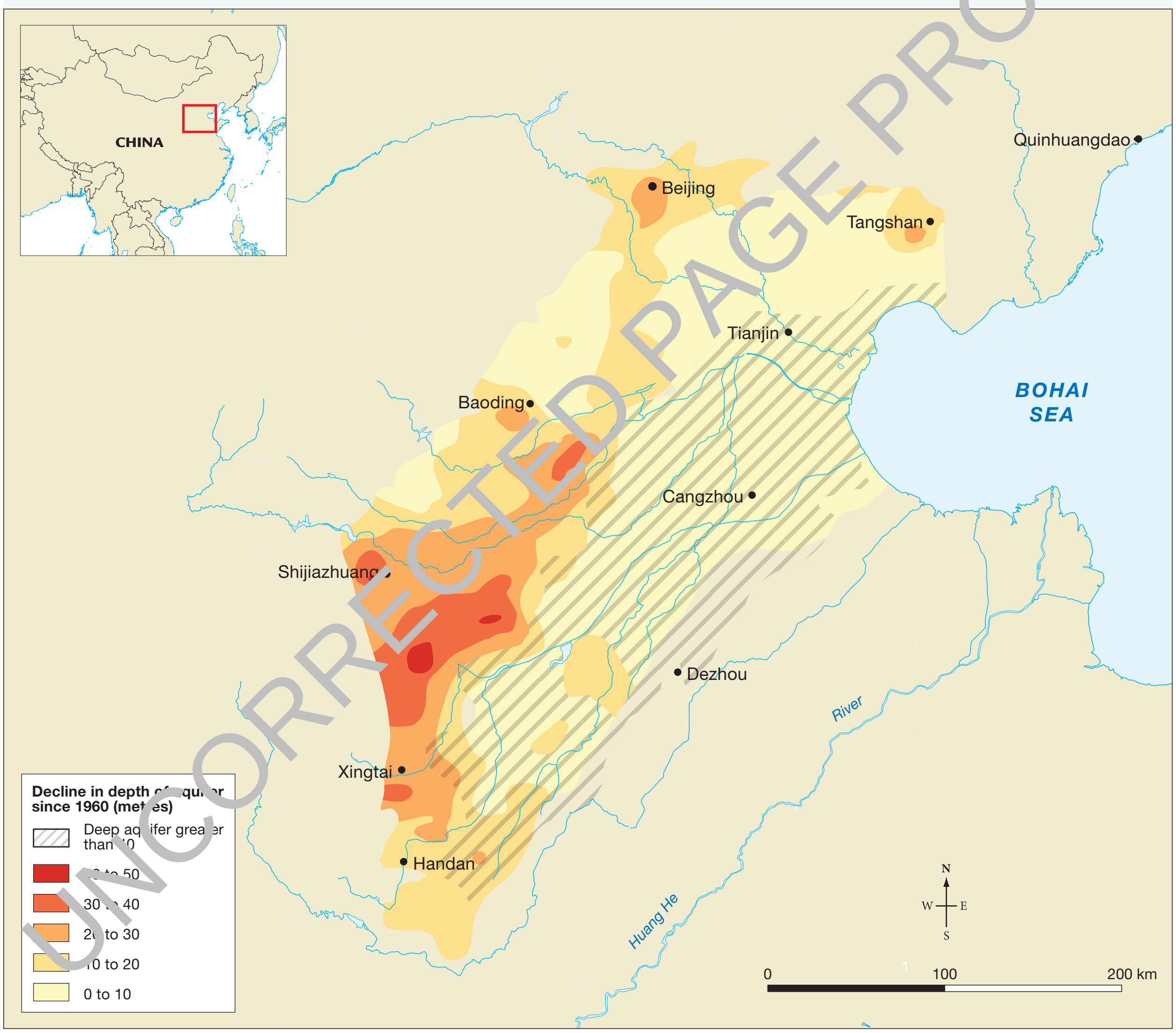
What is happening to groundwater in China?

What do you do if you don't have access to a reliable water source? You do what hundreds of millions of people do around the world every day. You dig for it. Beneath our feet lie vast quantities of fresh water that may have taken thousands of years to slowly work its way deep into rock layers. Since ancient times, people have used groundwater to provide for their water needs.

Rapid growth in both population and irrigated agriculture, combined with increasing demand for water, has seen the increased pumping of groundwater in northern China. As a consequence, the watertable around Beijing has been dropping by 5 metres per year. Groundwater supplies more than 70 per cent of the water needs for over 100 million people living on the North China Plain (see **FIGURE 3**).

The northern regions of China receive only 20 per cent of the country's rainfall. The southern regions, home to about half the population, receive the other 80 per cent. Eleven provinces in the north have less than 100 cubic metres of water per person per year, which officially classifies these places as being 'water stressed'. Eight other provinces in the north have less than 500 cubic metres of water per person per year. To date, management of water resources has been poor and unsustainable. The emphasis has always been on meeting an increasing demand for water using large-scale engineering 'fixes', rather than looking at ways of using water more efficiently, slowing down demand by increasing the cost, reducing irrigation wastage and improving the catchment areas to recharge the aquifers.

FIGURE 3 Decline in the aquifer under the North China Plain



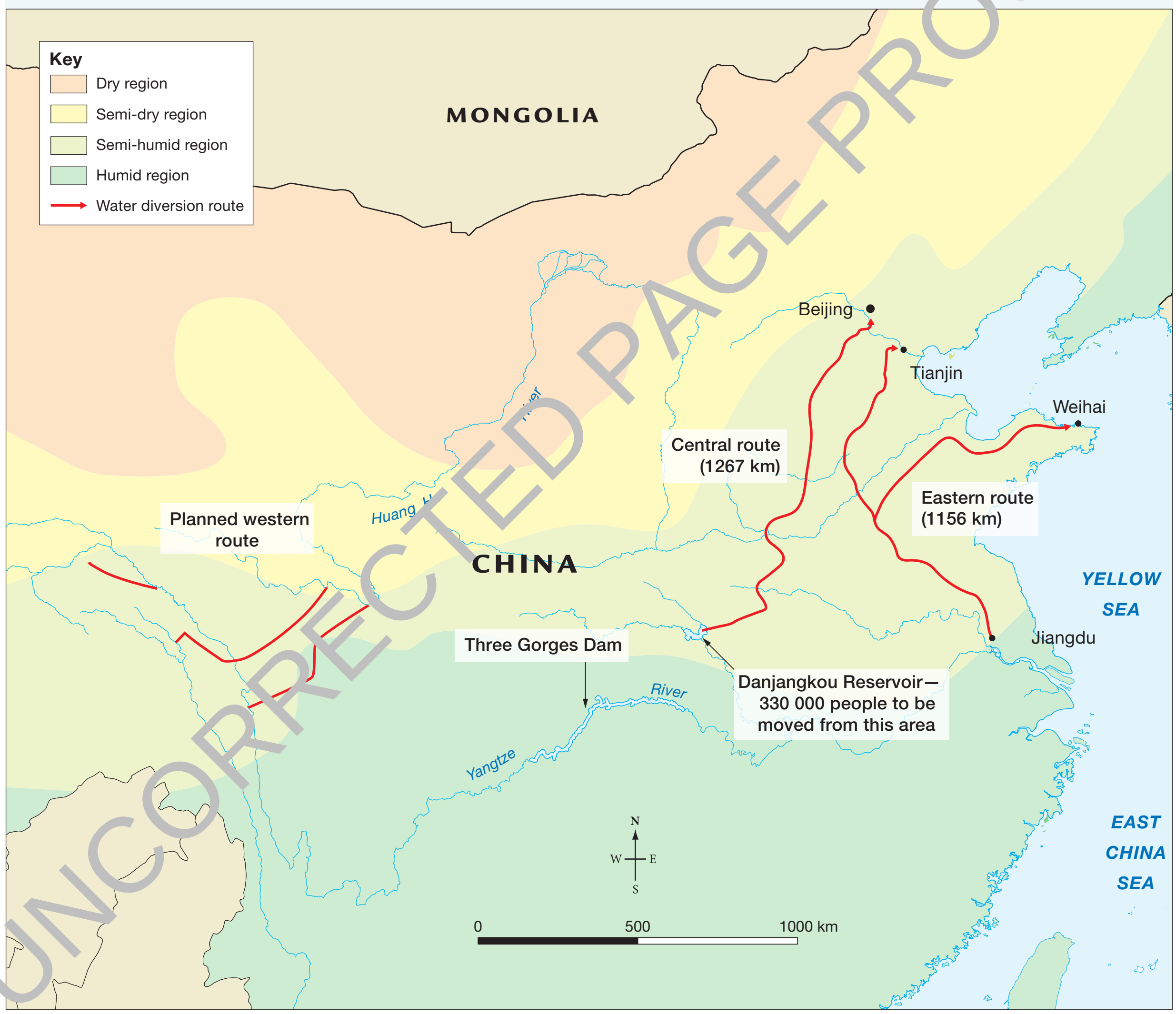
Source: UNEP Global Environmental Alert Service GEAS. Map by Spatial Vision.

After extensive flooding in the 1960s, the government set about building dams and canals to reduce flood impacts and provide water to rapidly growing cities. Farmers were encouraged to increase grain production by drawing on groundwater to irrigate a second crop each year. As cities continued to expand, they too began to pump unsustainable amounts of groundwater for domestic and industrial use. Scientists now also believe that climate change has reduced rainfall in the region, which will only make the situation worse.

The South–North Water Transfer Project

In 2002, an ambitious 50-year project was started to effectively 're-plumb' the country: the South–North Water Transfer Project. At an estimated cost of US$62 billion, over 44.8 billion cubic metres of water per year will be diverted north from the Yangtze River via three canals into the Huang He River Basin in the north of the country (see **FIGURE 4**). Before the transfer project development, the Yangtze River, on average, released 960 billion cubic litres of fresh water into the sea each year. Construction of the central and eastern sections has been completed, but the western route is still being planned. The completed central section now supplies 73 per cent of the Beijing's tap water, to provide for its population of 21.5 million people. The water transfer has reduced the exploitation of groundwater by 800 million cubic metres. As the extra surface water filters into the ground, the watertable has started to rise, with levels increasing by around half a metre.

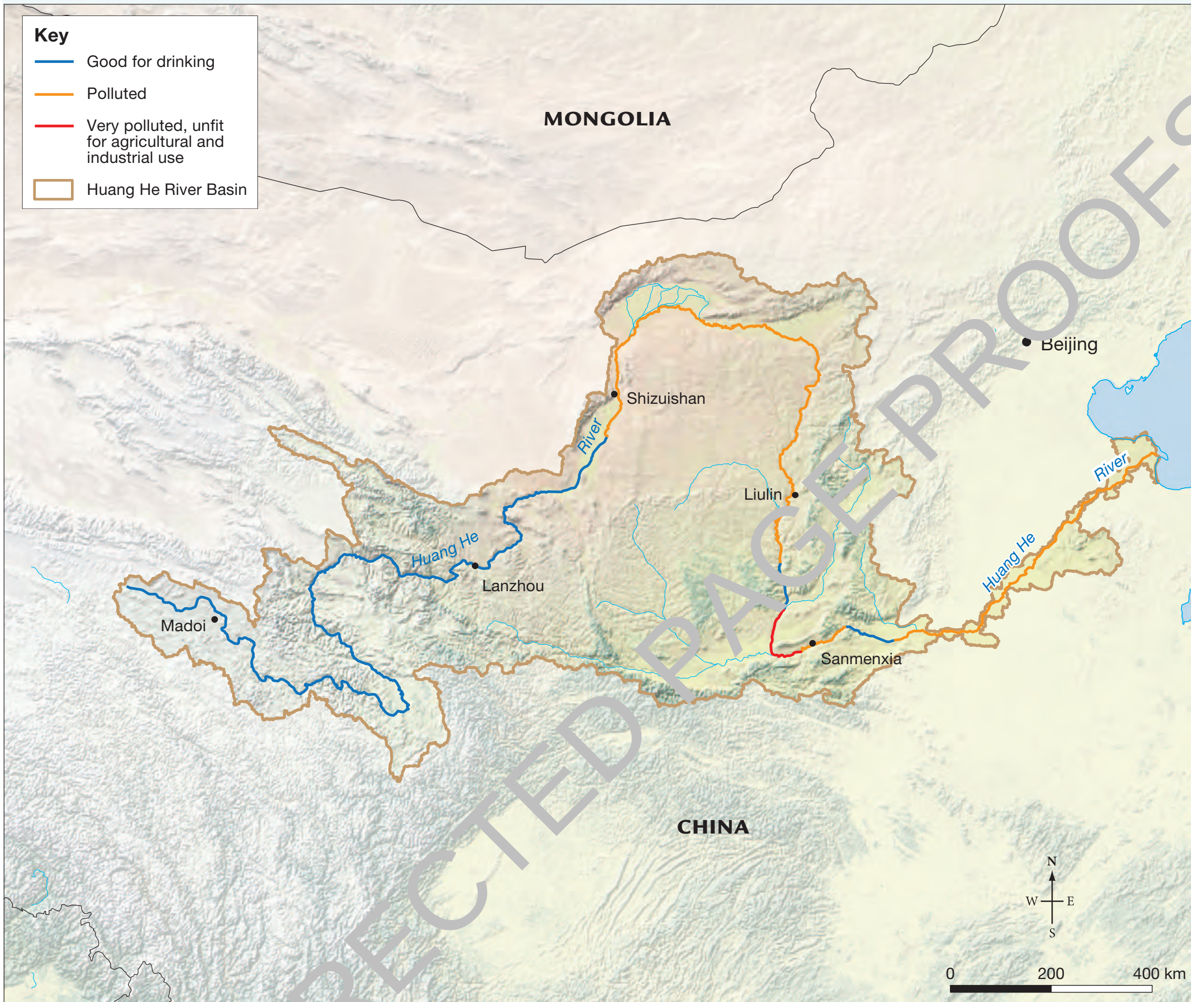
FIGURE 4 South–North Water Transfer Project for transfer of water from the Yangzte River in the south to the Huang He River in the north



Source: BBC News, http://news.bbc.co.uk/2/hi/8545321.stm

The project's water will largely go to expanding industries and cities such as Beijing and Tianjin. Little of the water will be directed towards food production. Irrespective of the cost and relocation of hundreds of thousands of people, the biggest ongoing concerns of the scheme will be about water quality. The Huang He River collects over 4.29 billion tonnes of waste and sewage each year (see **FIGURE 5**), and over 40 per cent of China's total waste water is dumped in the Yangtze River (see **FIGURE 6**). This figure is likely to increase as more and more industry moves close to new water sources. With less water to flow downstream, there will be less water available to dilute the polluted water. This will affect river environments and it is possible that the water reaching the north will be too polluted for human or even agricultural use.

FIGURE 5 Levels of pollution along the Huang He River



Source: Map by Spatial Vision.

The government has pushed hard to maintain water quality for the Danjiangkou Reservoir and its canal system (see FIGURE 4), spending over $3 billion on wastewater management and soil and water conservation systems. The most controversial strategy has been to ban two high-polluting industries from practising in the catchment: cage aquaculture (fish farming) and turmeric (a yellow spice) processing. While this may reduce polluted run-off it will also affect the livelihoods of hundreds and thousands of people who work in the industries.

The South–North Water Transfer Project is by far the most ambitious water transfer project in the world, in all taking 50 years and potentially well over the initial $62 billion estimated cost to construct a network of pipes, canals and tunnels that would stretch in a straight line from Melbourne to Fiji. Is it sustainable? Beijing consumes more than 3.6 billion cubic metres of water each year, supplied partially by its own traditional surface and groundwater sources and, increasingly, by the transfer scheme. Predictions are that its needs will soon outstrip the new scheme's capacity to supply. Scientists are already questioning the 'big scheme' approach rather than the use of water recycling, desalination and harvesting more rainwater as more environmentally friendly and sustainable methods of supplying water.

FIGURE 6 Polluted water flows into the Yangtze River.

Resources

Interactivity That sinking feeling (int-3293)

eWorkbook Water transfer

12.6 ACTIVITIES

1. Using an atlas, find a map of world food production and compare this with any three ***places*** from **FIGURE 2** in section 12.6.2. Conduct research to determine the following:
   (a) What types of food are produced in those regions of the world where watertables are severely depleted?
   (b) What are the future implications for ***sustainable*** food production in these regions?
   Examining, analysing, interpreting
2. Complete the **Water transfer** eWorksheet to learn more about the South–North Water Transfer Project.
   Examining, analysing, interpreting

12.6 EXERCISES

Geographical skills key: GS1 Remembering and understanding **GS2** Describing and explaining **GS3** Comparing and contrasting **GS4** Classifying, organising, constructing **GS5** Examining, analysing, interpreting **GS6** Evaluating, predicting, proposing

12.6 Exercise 1: Check your understanding

1. **GS2** What are the advantages and disadvantages of using groundwater for domestic and agricultural purposes?
2. **GS2** Refer to **FIGURE 1**.
   (a) What is the difference between groundwater and the watertable?
   (b) Describe how water can move vertically and horizontally through the ground.
   (c) What is the ***interconnection*** between atmospheric, surface and groundwater?

3. **GS2** Refer to **FIGURE 2.** Describe the location of ***places*** in the world that have the highest groundwater stress. (You may wish to refer to your atlas.)
4. **GS2** Looking at **FIGURE 2,** explain the ***scale*** of the area needed to replenish the most stressed aquifers.
5. **GS1** Using **FIGURE 3,** describe the location of the North China Plain. Use distance, direction and place names in your answer.

12.6 Exercise 2: Apply your understanding

1. **GS1** Refer to **FIGURE 4.** Suggest a reason why northern China uses groundwater to supply over 70 per cent of its water needs.
2. **GS6** Suggest possible sources for the pollution you can see entering the river in **FIGURE 6.**
3. **GS6** Is the South–North Water Transfer Project nothing but a pipe dream? Is a human-centred rather than earth-centred viewpoint the best option for water management in northern China? Write a paragraph outlining your views.
4. **GS4** There is often talk about transferring water from the wetter regions of northern Australia to the water-hungry regions further south. What would you need to know before planning a project similar to the one in China? Thinking geographically, write a list of 10 questions you would like to ask before designing such a project.
5. **GS6** Who owns groundwater? How can we manage the resource ***sustainably***? Write a paragraph expressing your viewpoint.

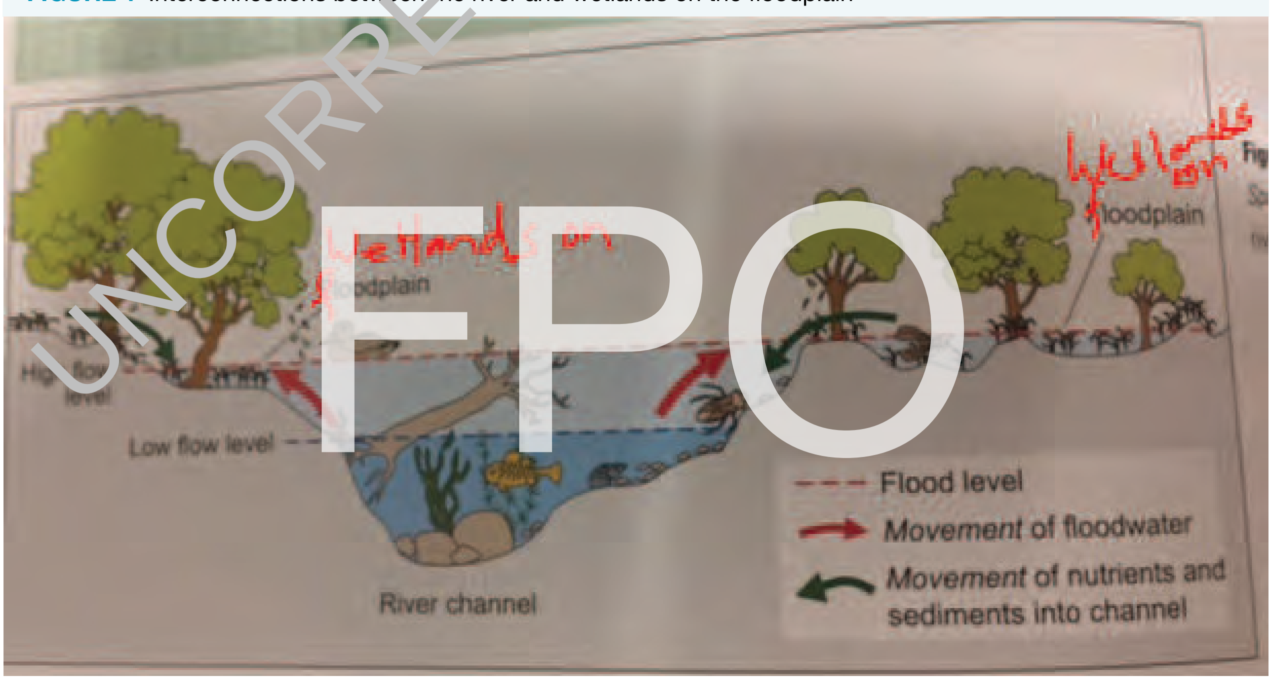
Try these questions in learnON for instant, corrective feedback. Go to www.jacplus.com.au.

12.7 The impacts of drainage and diversion

12.7.1 What are wetlands?

Often referred to as the area where 'earth and water meet', **wetlands** are one of the most important and valuable biomes in the world. Wetlands are areas that are covered by water permanently, seasonally or ephemerally and can include fresh, salty and brackish waters. They include such things as ponds, bogs, swamps, marshes, rice paddies and coastal lagoons. Wetlands are intricately connected to other elements in the landscape, especially rivers and floodplains as water, nutrients and sediments move between them (see **FIGURE 1**).

FIGURE 1 Interconnections between the river and wetlands on the floodplain



The importance of wetlands

Wetlands perform many important functions. They purify water — much of Melbourne's sewage water is filtered through a series of lagoons and wetlands at the Western Treatment Plant in Werribee, producing high-quality recycled water. Wetlands located along river floodplains reduce the impact and speed of floods by holding vast quantities of flood water and then slowly releasing it back into the river system. Water in wetlands also infiltrates the soil and to help recharge groundwater reserves. In addition, wetlands provide habitat and breeding grounds for 40 per cent of the world's species, such as aquatic fish, insects, reptiles and birds. Globally more than one billion people rely on wetlands for a living, for their water and food supply, and for tourism and recreation (see **FIGURE 2**).

FIGURE 2 A wetland in Queensland. What features in this image would be typical for a wetland?

12.7.2 What are the threats to wetlands?

The degradation and loss of wetlands and the species that inhabit them, have been more rapid than any other ecosystem, in fact, they are disappearing three times faster than forests. It has been estimated that between 1970 and 2015, the world lost 35 per cent of its wetlands. Competition from other land uses and increasing populations have contributed to the decline.

- Agricultural expansion is the largest contributor to wetland loss and degradation globally. Farming often requires the draining of wetlands to create more land, reducing biodiversity. In addition, the water run-off from agriculture is often polluted with fertilisers and pesticides and increased pumping from aquifers depletes groundwater resources.
- Dams alter seasonal floods and block supply of sediment and nutrients onto the floodplain and deltas. Often, damming means little water and sediment reaches the mouths and deltas of large rivers.
- Loss of wetlands affects populations and the migratory patterns of birds and fish. The introduction of invasive species results in changed ecosystems and loss of biodiversity. For example, 70 per cent of amphibian species are affected by habitat loss.
- Clearing for urban growth, industry, roads and other land uses replaces wetlands with hard **impervious** surfaces, which reduces infiltration and leads to polluted run-off and increased impacts of flooding.
- While wetlands can naturally filter many pollutants, excessive amounts of fertilisers and sewage causes algal blooms and **eutrophication (excessive amounts of nutrients)**, depriving aquatic plants and animals of light and oxygen.
- Climate change is expected to increase the rate of wetland degradation and loss.

Wetlands, like all other water resources are prone to over-exploitation and need to be managed carefully to ensure sustainable use.

12.7.3 Why is water diverted?

Because populations and water sources are distributed unevenly, we often need to transfer or divert large amounts of water. This means piping or pumping water from one drainage basin to another; for example, in Australia, water from the Snowy River is diverted into the Murray and Murrumbidgee rivers. Diverting water can alleviate water shortages and allows for the development of irrigation and the production of hydro-electricity. Diversions, however, are not always the most sustainable use of water resources.

Many of the world's greatest lakes are shrinking, and large rivers such as the Colorado, Rio Grande, Indus, Ganges, Nile and Murray discharge very little water into the sea for months and even years at a time. Up to one-third of the world's major rivers and lakes are drying up, and the groundwater wells for 3 billion people are being affected. The overuse and diversion of water is largely to blame.

12.7.4 CASE STUDY: A dying lake in Iran

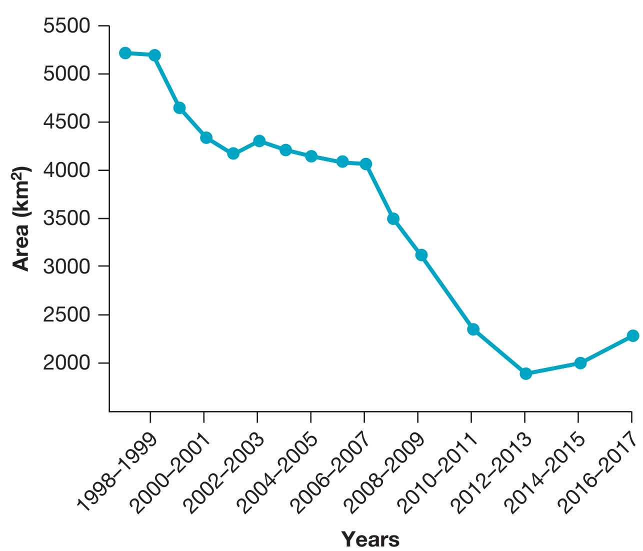
The largest lake in the Middle East and one of the largest salt lakes in the world is drying up. Since the 1970s, Lake Urmia in northern Iran has shrunk by nearly 90 per cent. In 1999, the lake's volume was 30 billion cubic metres; by 2018, this had reduced to 2 billion cubic metres, exposing extensive areas of salt flats (see **FIGURES 3 (a)** and **(b)**).

FIGURE 3 Lake Urmia (a) in 1998 and (b) in 2016

The lake was declared a Wetland of International Importance by the Ramsar Convention in 1971, and a UNESCO Biosphere Reserve in 1976. The lake and its surrounding wetlands serve as a seasonal habitat and feeding ground for migratory birds that feed on the lake's shrimp. This shrimp is the only thing, other than plankton, that can live in the salty water.

Lake Urmia is a **terminal lake**: the rivers, some permanent and some ephemeral, that flow into the lake bring naturally occurring salts. Because of the arid climate, high evaporation causes salt crystals to build up around the shoreline. **FIGURE 4** shows the rapid decline in the surface area of Lake Urmia from 2006 to 2013.

FIGURE 4 Surface area of Lake Urmia



Why is the lake drying up?

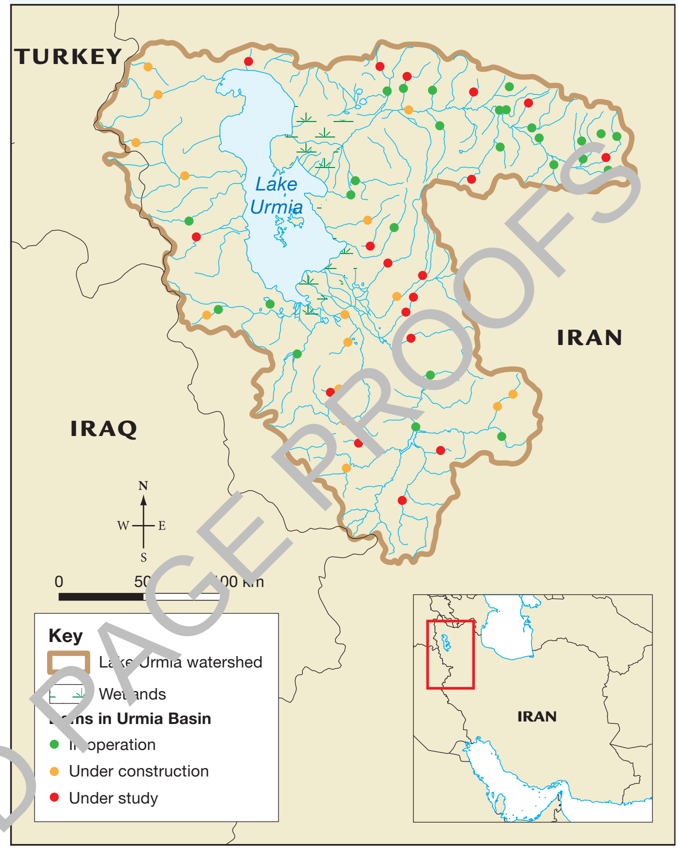
A combination of environmental, economic and social factors has been blamed for the large-scale changes in Lake Urmia. Prolonged drought and the illegal withdrawal of water by farmers who do not pay or who take more than their allocation are minor contributors to the problem.

Researchers have found that 60 per cent of the decline can be attributed to climate changes (increased frequency of drought and higher temperatures) and 40 per cent of the decline relates to water diversions and the increased demand for water in the region as the area under agriculture has tripled and the population has risen. The result is a form of 'socioeconomic drought' — a man-made drought caused when the demand for water is greater than the available supply.

Impacts of this man-made drought include:

- increased salinity of the shallow lake due to high evaporation (rates of between 600 mm and 1000 mm per year) and reduced freshwater flowing in via rivers (salt levels have increased from 160 g/Litre to 330 g/Litre)
- collapse of the lake's ecosystem and food chain (salt levels over 320 g/Litre are fatal to the shrimp which form the basis of its food chain)
- loss of habitat as surrounding wetlands dry up, which then reduces tourism to view wetland wildlife
- over 400 km^2 of exposed lakebed around its shores is nothing but salty deserts, unable to support native vegetation or food crops
- salt storms occuring as wind blows salt and dust from the exposed, dry lakebed; the storms damage crops and are also a potential health hazard
- less water available to produce food crops.

FIGURE 5 Distribution of dams, existing and under construction, in the lake's catchment area. This level of diversions is unsustainable.



Source: United Nations Environment Programme. Vector Map Level 0 Digital Chart of the World.

The lake is divided in two by a causeway and bridge constructed to improve access across the lake (the bridge can be seen in **FIGURE 3(b)**). However, there is concern that the nearly 1.5 km-long bridge does not allow sufficient mixing of water between the north and south sections of the lake. The bridge, completed in 2008, is already rusting as a result of the highly saline water.

The current situation

Lake Urmia and surrounds is an important region supporting a growing population of six million and its associated agricultural industries. Essentially, more water is required to flow into the lake to increase the water level, dilute the salt and maintain an ecological balance. This would require doubling the current water level.

In 2017, the government pledged an annual budget of US$460 million to help restore the lake and its surrounding wetlands. However only about US$5 million has actually been available. Other programs in place include:

- a water transfer scheme is now in place moving water from the Little Zab basin through tunnels and channels

- engineering works to help clear sediment clogging many of the rivers that feed into the lake
- releasing water from dams to flow into the lake
- the construction of 13 treatment plants in the region to treat wastewater from urban areas and deliver it to the lake
- a development plan launched in 2017 to reduce consumption of potable water by 30 per cent by 2021 and to use desalinated water to meet 30 per cent of the water demands in South Iran
- trials of planting vegetation to reduce wind speed and salt being blown
- eighty-five per cent of the water in the region is used for agriculture, hence, there is an emphasis on helping farmers by promoting water-saving techniques and planting less water-thirsty crops, such as olives and saffron, instead of water-intensive sugar beet.

Water levels in recent years have started to increase but any further progress is limited by a lack of funding. In addition, the lake can only support 300 000 hectares of farmland in the region while currently there are 680 000 hectares.

on Resources

Interactivity Wetland wonderlands (int-3294)

eWorkbook Wetland mapwork

12.7 ACTIVITY

Conduct some online research and investigate the decline of either Lake Chad in Africa, Owens Lake in the United States or the Aral Sea in Kazakhstan. Use the following as a research guide for elements to include in your investigative report:

- location
- original size and appearance of the lake/sea
- original uses of the lake/sea and surrounding area
- causes and rate of decline
- ***changes*** that have taken place
- impacts on people and the ***environment***
- possible solutions.

Include annotated images, maps and data where possible.

12.7 EXERCISES

Geographical skills key: GS1 Remembering and understanding **GS2** Describing and explaining **GS3** Comparing and contrasting **GS4** Classifying, organising, constructing **GS5** Examining, analysing, interpreting **GS6** Evaluating, predicting, proposing

12.7 Exercise 1: Check your understanding

1. What are wetlands?
2. In what ways are wetlands important?
3. Outline three major threats to wetlands.
4. Why is it sometimes necessary to divert water?
5. Lake Urmia is a terminal lake. What does this mean?

12.7 Exercise 2: Apply your understanding

1. Explain eutrophication, its causes, and the impact it has on wetland biomes.
2. <content to come – leave 2 lines>
3. <content to come – leave 2 lines>

4. <content to come – leave 2 lines>

5. <content to come – leave 2 lines>

Try these questions in learnON for instant, corrective feedback. Go to www.jacplus.com.au.

12.8 SkillBuilder: Reading topographic maps at an advanced level

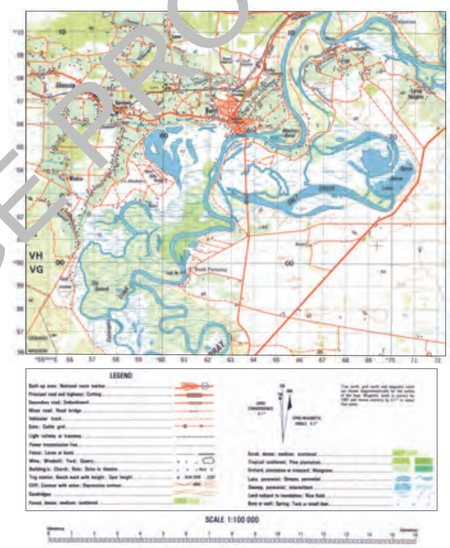
online only

What is reading a topographic map at an advanced level?

Topographic maps are more than just contour maps showing the height and shape of the land. They also include local relief and gradients and allow us to calculate the size of various areas. Reading this information requires more advanced skills.

Select your learnON format to access:

- an overview of the skill and its application in Geography (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.



Source: Map supplied by MAPLAND, Environmental and Geographic Information, Department for Environment and Heritage, South Australia

on Resources

Video eLesson Reading topographic maps at an advanced level (eles-1749)

Interactivity Reading topographic maps at an advanced level (int-3367)

12.9 Putting water back — managing the Murray–Darling

12.9.1 Where has the water gone?

The rivers, lakes and wetlands of the Murray–Darling Basin (see **FIGURE 1**) make it Australia's most important inland water body. Decades of continually diverting water from its rivers and prolonged periods of drought have brought significant changes to the rivers, surrounding floodplains and surrounding wetlands. The amount of water taken out of the river system has increased five-fold over the past century. In addition, 90 per cent of floodplain wetlands in the Murray–Darling Basin have been lost because of human-induced changes to **river regimes**. The floodplains of the Murray River are now flooded once every 10–12 years compared to 3–4 years out of every five a century ago. Reduced flow has also meant that the mouth of the river blocks regularly, preventing the flushing out of pollutants and affecting the Lower Lakes wetlands.

FIGURE 1 Key features of the Murray–Darling Basin

Source: © Commonwealth of Australia Geoscience Australia 2013. Murray Darling Basin Commission. Map by Spatial Vision.

12.9.2 Declining river health

One of the difficulties in managing the water resources of the Murray–Darling Basin has been the fact that there are four states and one territory that all use and manage the water in their own way. In the twentieth century, the management of the river switched focus from using the river for transport to expanding agriculture. This period saw a rapid rise in the amount of water withdrawn and a decline in the health of river ecosystems. Consequently, 20 out of 23 catchments within the Basin have 'poor' to 'very poor' ecosystem health. Contributing factors include:

- extensive clearing of native vegetation in the catchments
- introduction of exotic weeds and animals
- run-off of pollutants
- draining of wetlands.

In the twenty-first century we are now working towards a more sustainable approach to managing water, with a greater emphasis on balancing the competing needs of the community and river environments. In essence, it means improving the health of the rivers and wetlands and keeping more water in the system.

12.9.3 Attempts to restore the balance

There have been a number of government initiatives put in place over the years to reduce the amount of water being harvested from the river:

- *The Living Murray Program*. In an effort to try to improve the health of rivers, the Murray–Darling Basin Authority (MDBA) concentrates on maintaining the health of six **icon sites** (see **FIGURE 1**) by providing them with additional water from **environmental flows**. Water 'savings' have to be made elsewhere through improvements in water storage, distribution and irrigation methods. **FIGURES 2 (a), (b)** and **(c)** show the effects of an environmental flow on a stressed wetland.

FIGURE 2 Wanganella Swamp (Deniliquin, New South Wales) (a) before, (b) during and (c) after an environmental flow

- *The Basin Plan*, passed into law in 2012, allows the Federal Government, rather than four states and one territory to be responsible for the overall management of the Murray–Darling Basin. The Plan's aim is to 'increase the amount of water for the environment of the Murray–Darling Basin and ensure sufficient water for all users'. Thus, the Basin Plan aims to balance out social, economic and environmental demands on the water resources across the entire basin. Central to this aim is the need to provide sufficient water for the health of the river first, and then allocate water for other uses. The following were to be implemented to achieve this aim:
  - limits to the amount of water that could be withdrawn from the river system each year — 10 873 GL, compared with 13 623 GL extracted in 2009 (1 gigalitre equals 1000 Olympic-sized swimming pools)

  - a reduction (of between 27 and 45 per cent) in the amount of water allocated to different regions
  - a limit of 3334 GL of groundwater to be withdrawn each year
  - the establishment of an environmental watering plan to restore and protect the river and wetlands.
- Water is being saved through buying back farmer's water entitlements and through improved storage, distribution and irrigation methods. Long term, the goal is to allow sufficient movement of water to keep the mouth of the river open 90 per cent of the time.

12.9.4 How is the Basin Plan working?

The Basin Plan was formalised in 2012 but it took until 2017 for all state and federal governments to agree to the terms of how environmental water will be returned to the river system. An additional 450 GL (plus the original 2750 GL stated in the Plan) is to be returned to the environment, providing that it does not have a negative socio-economic impact on river communities. It may take up to a decade for large-scale environmental changes to be noted from the improved flow. It is extremely difficult for water managers to balance the need for natural river flows as well as protecting farmers' water needs and preventing large floods.

Menindee Lakes fish kill

The summer of 2019 saw more than one million fish killed by extremely poor water quality in the Menindee Lakes storage system (see **FIGURE 3**). Water levels in the lakes were extremely low and the system had stopped flowing. On average 4000 GL flows into the Barwon–Darling river system and then into the lakes where it can be released to flow downstream into South Australia. The lakes are very shallow and between 20 and 30 per cent of water evaporates each year. Management tries to avoid this by releasing water in a 'use it or lose it' mindset.

FIGURE 3 Fish killed at the Menindee Lakes

High temperatures and calm warm water provided ideal conditions for the growth of blue-green algae, which smothered the water surface turning it quite green. A cold front moved across the region, dropping water temperatures, which served to kill off the algal bloom. The rapid growth of bacteria that feeds off dead algae used all the oxygen in the water, causing the fish to suffocate. Essentially insufficient water was available in the system to provide environmental flow.

Calculating how much water can be diverted from the river system is usually based on 'full rivers'; little planning is done to manage flow in times of drought. Current water licenses are also based on the height of a river. If one person leaves water in the river, the next person downstream can take more.

In 2018, in the wake of ongoing concerns about the management of the Basin, a Royal Commission was held to investigate the operations and effectiveness of the Murray-Darling Basin Plan. The Commission report, released in January 2019, contained 111 findings and 44 recommendations to overhaul the Plan, including adjusting the balance between irrigation and environmental flows, to give more water back to the environment. The nearly 750-page report highlighted the complexities and challenges of balancing environmental, social and economic needs in relation to a water source on which millions of people depend.

12.9 EXERCISES

Geographical skills key: GS1 Remembering and understanding **GS2** Describing and explaining **GS3** Comparing and contrasting **GS4** Classifying, organising, constructing **GS5** Examining, analysing, interpreting **GS6** Evaluating, predicting, proposing

12.9 Exercise 1: Check your understanding

1. **GS1** What are the factors that have contributed to the poor health of the Murray–Darling Basin?
2. **GS2** Describe how the management of water resources has ***changed*** over time.
3. **GS2** Refer to **FIGURE 1**.
   (a) What are icon sites and why are they important?
   (b) Where are they located?
4. **GS2** Why is there a need for ***environmental*** flows in the Murray–Darling Basin?
5. **GS2** Compare the three photographs in **FIGURE 2**. Describe the ***changes*** in the appearance of the wetland before, during and after an ***environmental*** flow.

12.9 Exercise 2: Apply your understanding

1. **GS6** Suggest why both the amount and timing of ***environmental*** flows is important for a healthy river.
2. **GS5** What would be one advantage and one disadvantage of the Federal Government taking control of the management of the Murray–Darling Basin over the individual states?
3. **GS6** What steps could an irrigation farmer take to adapt to a reduced allocation and more ***sustainable*** use of water?
4. **GS2** Explain how both natural events and human activities contributed to the Menindee Lakes fish kill.
5. **GS6** Suggest one way that water managers could try to prevent a fish kill occurring again.

Try these questions in learnON for instant, corrective feedback. Go to www.jacplus.com.au.

12.10 Thinking Big research project: Menindee Lakes murder! news report

online only

SCENARIO

As a reporter for a city newspaper, you have been sent to the small town of Menindee to investigate the recent massive fish kills in the Menindee Lakes. What caused this horrific event and what can be done to stop it happening again? It's your job to uncover the truth!

Select your learnON format to access:

- the full project scenario
- details of the project task
- resources to guide your project work
- and assessment rubric.

Resources

projectsPLUS Thinking Big research project: Menindee Lakes murder! news report (pro-xxxx)

12.11 Review

online only

12.11.1 Key knowledge summary

Use this dot-point summary to review the content covered in this topic.

12.11.2 Reflection

Reflect on your learning using the activities and resources provided.

on Resources

Interactivity Inland water — dammed, diverted and drained crossword (int-xxxx)

eWorkbooks Reflection (doc-xxxxx)

Crossword (doc-xxxxx)

KEY TERMS

aquifers layers of rock which can hold large quantities of water in the pore spaces
base flow water entering a stream from groundwater seepage, usually through the banks and bed of the stream
environmental flows the quantity, quality and timing of water flows required to sustain freshwater ecosystems
environmental impact assessment a tool used to identify the environmental, social and economic impacts, both positive and negative, of a project prior to decision-making and construction
ephemeral describes a stream or river that flows only occasionally, usually after heavy rain (e.g. Todd River, Alice Springs)
eutrophication a process where water bodies receive excess nutrients that stimulate excessive plant growth
fertility rate the average number of children born per woman
flood mitigation managing the effects of floods rather than trying to prevent them altogether
green energy sustainable or alternative energy (e.g. wind, solar and tidal)
icon sites six sites located in the Murray–Darling Basin that are earmarked for environmental flows. They were chosen for their environmental, cultural and international significance.
impervious a rock layer that does not allow water to move through it due to a lack of cracks and fissures
infrastructure the basic physical and organisational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society
Micro hydro-dams produce hydro-electric power on a scale serving a small community (less than 10 MW). They usually require minimal construction and have very little environmental impact.
perennial describes a stream or river that flows permanently
rainwater harvesting the accumulating and storing of rainwater for re-use before it soaks into underground aquifers
recharge the process by which groundwater is replenished by the slow movement of water down through soil and rock layers
reservoirs large natural or artificial lakes used to store water, created behind a barrier or dam wall
river fragmentation the interruption of a river's natural flow by dams, withdrawals or transfers
river regimes the pattern of seasonal variation in the volume of a river
subsidence the gradual sinking of landforms to a lower level as a result of earth movements, mining operations or over-withdrawal of water
terminal lake a lake where the water does not drain into a river or sea. Water can leave only through evaporation, which can increase salt levels in arid regions. Also known as an endorheic lake.
watertables level below which the rock layer is fully saturated with water
weirs walls or dams built across a river channel to raise the level of water behind. This can then be used for gravity-fed irrigation.
wetland an area covered by water permanently, seasonally or ephemerally. They include fresh, salt and brackish waters such as rivers, lakes, rice paddies and areas of marine water, the depth of which at low tide does not exceed 6 metres.