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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Scholarship 2005
Geography

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RESOURCE BOOKLET

Flood, Sweat and Tears

River Flooding – Causes and Responses

Refer to this booklet to answer the questions for Scholarship Geography 93401.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.

A – An overview of river flooding

A1: How we see river flooding

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A2: Global natural disasters – 10 largest death tolls 1900–2005

Disaster type	Location	Year	Number killed

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Source : NBC News

A3: New Zealand – Insurance payouts of over $50 million from natural disasters

1968–2004 (figures adjusted to 2004 $ values)

Disaster type	Location	Year	Insurance payments ($ millions)

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Source : www.civildefence.co.nz

A4: Flooding in the news, New Zealand 2004–2005

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B – Causes and nature of river flooding

Physical causes of flooding

The main influences on the amount of water flowing in a river are the intensity and duration of precipitation, vegetation type and cover, landforms and soil. These influences are shown in diagram B1.

Diagram B1: The River Basin Hydrological Cycle

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River regimes (seasonal fluctuation in the volume of water in a river) have great natural variations that are both temporal and spatial (see Diagrams B2 and B3). Flooding occurs when the capacity of the river channel is exceeded, and water overtops the riverbanks. Overland water flow can also cause flooding. Overland flow occurs when the amount of water exceeds the infiltration capacity of the ground. Overland flow and rivers escaping their channels generally result from climate related factors:

- intense rainfall when a huge downpour occurs over a short period. The lag time (time gap between rainfall peak and flood peak) is short (see Diagram B4) and the infiltration capacity of the ground and the river channel are quickly exceeded. This is usually the cause of flash flooding.
- prolonged rainfall resulting in soil saturation and overland flow. Overland flow is most likely when the soil has low permeability (like with a clay soil) or if the soil is already saturated. River levels rise quickly when large amounts of overland flow enter the river channels.
- rapid snowmelt. This adds to water volume. Where the underlying ground remains frozen restricting infiltration, snowmelt is especially likely to cause overland flow and flooding.

Human contribution to flooding

Human activity can increase the chance of flooding or make flooding worse. Catastrophes like a dam collapse will make the news, but it is urban expansion and deforestation that are the two human activities that most increase the likelihood of flooding.

Urban expansion makes more of the land surface impermeable. This increases volume and speed of water run-off. Urban expansion consequently alters the shape of the storm hydrograph, reducing lag time and increasing the peak flow discharge (see diagram B4). The changes that urban area expansion brings to hydrology are due to:

- removing topsoil and compacting the ground surface with heavy machinery.
- creating vast concrete and asphalt surfaces. These surfaces allow little water infiltration to occur.
- building gutters and drains that quickly transfer rainwater to the rivers.
- straightening river channels and lining them with concrete in urban areas. This leads to a faster delivery of water downstream and increases the risk of flooding in these areas.

Diagram B2: Temporal variations in river discharge (changes over time)

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Diagram B3: Spatial and seasonal temporal variations in river discharges

Hydrographs of river regimes in different world locations

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Diagram B4: Hydrographs (a time plot of the amount of water flowing in a river)

The response of rivers to a rainstorm:

Diagram B5: Run-off levels in the Maraca rainforest

Factors affecting a flood hydrograph:

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The removal of trees reduces evapotranspiration and interception resulting in increased run-off and soil erosion. The eroded material ends up in the river channel where it aggrades the river bed. This reduces the channel capacity thereby increasing the likelihood of flooding. The Royal Geographical Society carried out research into the effects of deforestation in the Maraca rainforest in Brazil. Run-off was measured in areas of virgin rainforest, in areas with partial tree clearance and in areas completely cleared of trees. As diagram B5 shows, tree removal resulted in a large increase in run-off volumes.

C – River flooding: two case studies

Case Study 1: River flooding in a rich country:
River Derwent, England – local scale flooding

"We know this area can flood but we cannot understand why no one could do anything to stop it becoming so bad" said residents of the town of Malton in Yorkshire in the north of England as they mopped up their homes when the floods finally subsided. "We had plenty of warnings, but the water just kept rising and everyone seemed helpless. You do not expect that in a developed country at the end of the 20th century".

Flooding across the United Kingdom in 1999 was widespread. The flooding in the twin towns of Malton and Norton was the worst in living memory. Homes and businesses were swamped and the damage clean up and repair cost around $30 million. The psychological and emotional costs of the experience are immeasurable. In 2000 and 2001 the towns were flooded again!

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The natural landscape and its modification – the history behind the flood

Stage 1: 2 million–10 000 years ago

The valley where the towns of Malton and Norton were built, was shaped by a river flowing from a large lake dammed by an ancient ice sheet. The towns are located in an old glacial overflow channel.

Stage 2: 10 000 BC–to the present

Land use in the basin of the River Derwent has been changed. This has increased the flood risk lower down the valley. In the past in the river headwaters above Malton, spongy peat soils and forest covered the higher land. They soaked up rainfall and slowed down run-off. In the lower land above Malton, the rivers meandered and flowed slowly across a floodplain where any floodwater would spread out. Natural storage stopped floodwaters from rushing down the valley to Malton. Farmers in the Bronze Age cut down most of the upland forest. This increased both run-off speed and erosion of the peat soil. In the 19th century, people using the uplands for grouse shooting regularly burnt old vegetation to stimulate new growth to feed the birds. This led to further destruction of the peat soil.

Farmers on the lowlands from the Middle Ages onwards drained the floodplain to allow crop farming. The aim was to get rainfall off the land and into the rivers as quickly as possible: many water drainage channels were dug. Alongside the river upstream of Malton, earth embankments (levées) have been built to reduce flood risk. In the past 50 years, farmers have been paid grants to drain the land. Floodplain and marshland have been turned into crop land.

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East Yorkshire after the last Ice Age

Stage 3: the past 2000 years of human settlement

The Romans established a town at Malton 2000 years ago. The location was chosen by the Romans as the site to bridge the River Derwent. Since then Malton developed as a nodal point. In the 17th and 18th centuries, corn, wood and textile mills developed alongside the river and its local tributaries. The mills used the rivers as their source of power. Workers' houses were built close to the factories on the river floodplain. In the mid-1800s, a railway was built along the valley on the Norton side of the river.

Stage 4: developments since 1960

Flooding has always occurred in the Malton area. The old bridge across the river had narrow arches which got blocked by branches and other debris as the river rose after heavy rain. This was the reason that there had been little building upstream of the bridge between Malton and Old Malton. To allow for housing development in Malton and Norton, many of the smaller streams were piped beneath the houses and roads. The environmental protection agency also encouraged willow growth along the river banks to reestablish a natural habitat and encourage wildlife.

Stage 5: February–March 1999: the storm event

A strong anticyclone developed over the European mainland. The anticyclone blocked the eastward movement of depressions coming from the Atlantic. The stalled depressions and fronts dumped huge amounts of snow and then warm rain onto the North of England. The higher land around Malton and Norton where the River Derwent had its headwaters received 125 mm of rainfall in 48 hours in early March. The average rainfall for the whole of March in this area is 87 mm. This 48 hour total was a 100-year record. In these heavy rains, the 'stream pipes' became blocked with leaves and branches, forcing run-off water to bypass them. The main River Derwent also ponded upstream of the main town bridge, and the bankside trees slowed the return of floodwater to the river. Severe flooding of Malton and Norton occurred.

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Weather systems in early March

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Weather systems on 4 March

Topographic map and oblique aerial photograph of Malton and Norton

Malton. Reproduced from the 1997 1:50 000 Ordnance Survey map

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Photo taken from the air above 791717 on map. The camera was pointing south.

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B – culvert where a stream pipe normally ends at the River Derwent
M – site that became the centre for the clean up operation **S** – 1960s housing area in Norton
X – Hotel / tavern **Y** – Car showroom **Z** – Clothing factory

Case Study 2: River flooding in a poor country
Bangladesh – national scale flooding

In 1998, river flooding in Bangladesh made international headline news. The flood was unprecedented in terms of magnitude, duration and outcomes. 68% of the country was flooded, some places for more than 70 days. In places, only the tops of trees and buildings could be seen above the floodwaters. Parts of the capital city Dhaka, including the international airport, were under 2 metres of water. With the airport out of action, and railways, roads and bridges swept away, aid distribution was impossible.

Bangladesh 1998 – headline news and background

Flooding is an annual event in Bangladesh. Monsoon rains cause rivers such as the Brahmaputra and Ganges to overflow their banks between July and August. Most of Bangladesh's 140 million inhabitants live on the floodplains of these rivers. For most of them, the seasonal flood is essential for their survival, as it brings water in which to grow their main crops of rice and jute, as well as silt to fertilise their fields. Flooding of 20% of the country is considered beneficial for crops and the ecological balance. Less than this can result in food shortages, more can lead to loss of life, ruin crops and seriously damage property. The photos show the results of flooding in both urban and rural areas.

Results of river flooding in Bangladesh

Inundated floodplain *This river floodplain in Bangladesh is largely under water during flood. Villages occupy the higher ground of the natural levees bordering the river channel.*

Bangladesh – flood results and causes

Flooding in Bangladesh, 10 September 1998
(map adapted from a radar-satellite image)

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Causes of Bangladesh Floods

Annual summer monsoon rains are the main cause. This seasonal rain is heaviest in the Himalaya Mountains where the rivers that flow through Bangladesh have their headwaters. Rainfall totals of over 10 000 mm a year are common. The rains in 1998 were exceptionally heavy.

Most of Bangladesh is low, flat floodplain and delta land. 70% of the country is less than 5 metres above sea level with much of that less than 1 metre above sea level. This land is home for 140 million people, and the country is one of the world's most densely populated. Once rivers overflow, the water spreads vast distances covering roads, farms and homes.

Spring and summer ice and snow melt in the mountains adds to the peak water flow in the rivers. Global warming may be increasing the speed of the melt and also increasing rainfall intensity.

Rapid urban growth in Bangladesh with more hard surface cover has led to increased peak river flow and reduced lag times, creating favourable conditions for intense flooding. Once flooding occurs, elevated roads and stopbanks prevent an easy return flow of floodwater into the rivers.

Deforestation in the Himalayan foothills has been rapid. In Nepal, 50% of the forest cover that existed in 1950 has been removed. Scientists suspect that river hydrology in the upper river basin areas outside of Bangladesh has been altered: the speed of water run-off into the rivers has increased, and the rivers get more silt deposits because of increases in landslides, soil erosion and overland flow. This causes higher peak water flows into Bangladesh and a raising of the river bed as more silt gets deposited in the river channels in the lowlands of Bangladesh. The water-carrying capacity of the rivers is reduced.
Deep soil ploughing by farmers in Bangladesh also causes more topsoil to be washed into the rivers, and this results in further river bed aggradation and hence adds to the flood risk.

D – Management of river flooding

There are different schools of thought about how best to approach managing and responding to river flooding.
On page 14 are the voices of a range of people.
On this page the diagrams show rivers in two different states: natural and controlled.

- *Diagram D1 shows rivers as part of a complex ecological balance. It suggests flooding should be seen and allowed as a natural event. The river is part of a natural system*
- *Diagram D2 shows a controlled and managed river. The river is part of an environment used and settled by people.*

Diagram D1: River in a natural state – the Mississippi River in the past

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Diagram D2: A controlled river – the Mississippi River today

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D3: Voices – views about flood hazard and flood management

What we are seeing is a climate change. Annual rainfall is not increasing much in total, but the intensity of one or two rainfall events is. We need to revise our estimates upwards of the 'one in one hundred year flood'. More and greater future flooding is inevitable. What I cannot predict is exactly when and how severe it will be. – ***climate scientist***

Flooding does not occur for one particular reason, a number of processes are responsible. Solutions to flooding need to be proactive rather than reactive. Coherent and integrated whole catchment management that fulfills sustainability objectives is needed. – ***Howe and White, Geography April 2002***

It is unfortunate that most of today's planning decisions that affect the sustainability of communities and regions of the world rarely take into consideration risks associated with climate variability and change. This may be because the risks of hurricanes, floods, storms, and drought are uncertain and difficult to quantify or to manage structurally. Climate hazards profoundly affect the socio-economic status and sustainability of communities and regions. The inclusion of climate risks in the design and implementation of development initiatives is a necessary first step in the reduction of vulnerability and hazard impact prevention. – ***Greg O'Hare, Geography July 2002 (adapted)***

Council and government help is needed to reduce the flood risk. Families have lived and farmed here for generations. They don't want to leave the area. But if another flood comes they face financial ruin. Insurance companies are refusing cover for any future flood damage. – ***chairperson of local residents' association***

The council has hazard zone areas identified and mapped. Property development in these areas is not permitted – planning regulations prevent it. The problem we face is what to do with the developments that have already taken place in these areas. Millions of dollars of property and livelihoods are at risk. – ***local council planner***

Waitakere City Council has spent about $6 million buying thirty-one properties after years of flooding. Twenty families were evacuated from their homes in May last year when the Opanuku Stream again burst its banks after heavy rain. Properties were waist-deep in water. The council met residents and offered to buy the flood-prone sites. "Many of the homes will have to be moved or demolished, creating an uninhabitable flood zone" said the council spokesperson – ***Western Leader, April 26, 2005***

Hard engineering solutions are available. River banks and levées can be strengthened and heightened. Concrete banks can be built in the urban areas most at risk from the floodwaters. River channels can be dredged and deepened. The issue is one of cost: who pays? Government help will be needed, as the local councils will not be able to meet the enormous financial commitment involved for construction and ongoing maintenance of the building schemes. – ***drainage basin controlling authority***

More people in England and Wales are becoming prone to flood hazard, not so much because of recent record heavy winter rainfalls, but because of increasing settlement in the river floodplains themselves.
Solutions to flood problems are not easy. Floodplain management is a complex and multidimensional problem, that has been ill-served in the past by short-sighted non-sustainable technical engineering strategies resulting in a bias towards structural (flood defence) solutions. Removing this bias and moving towards more adaptive strategies, including local flood defences, better cultivation techniques, not developing in vulnerable places, waterproofing buildings, educating people about flood risk, insurance and government support will go some way towards creating a more comprehensive and sustainable floodplain management system. – ***Greg O'Hare, Geography July 2002 (adapted)***

Monitoring, forecasting and modelling have been improved. River hydrology is well understood. Early warnings of river floods can be given with some accuracy today – especially in developed countries. However none of this really helps. It is the increased development of property and people living in flood prone areas that leads to the increasing catalogue of flood damage. Deaths can be prevented or at least minimised, but the damage to buildings and infrastructure and the disruption caused to daily life is a huge and growing financial and social cost of flooding. – ***civil defence worker***

Hard engineering schemes have been relied upon too much in the past. They have given people a false sense of security. People are not above nature. Modern approaches involve clearance of bankside vegetation and other obstructions that restrict water flow. On the other hand tree and bush planting in the upper catchments can reduce run-off speed, increase lag time and even out peak flow. Flood control is possible by the use of these soft engineering solutions. 'Prevent first, restore second, and work with nature' is a good principle to follow in flood risk management. – ***environmental agency report***

The situation in Bangladesh is unique. Despite all the flood control measures put in place, flooding likelihood has increased. Most of the country is densely populated low-lying delta and floodplain. The rivers that flood have most of their drainage basins in neighbouring countries: India and Nepal. Controlling and regulating water flow in these rivers requires action by neighbouring countries. The outcomes of political negotiations will determine whether any such action is taken. Heavy seasonal monsoon rain is a feature of this part of Asia. Flood prevention schemes like the building of embankments alongside the rivers are costly and also ineffective in the worst floods. They can bring a false sense of security. Some commentators argue that allowing natural floodplain processes to occur with mitigation of flood damage, rather than flood prevention, is the best approach. This would help maintain soil fertility, fish production and local ecosystems. There is a delicate balance between the disadvantages that river flooding creates, such as death and destruction, and the advantages that the river floods can bring to crop and fish production and to export earnings. Better forecasting, flood warnings, building emergency shelters, and having emergency services ready to help flood victims would reduce the hardship when flooding occurred. This approach would make use of more appropriate technology, and be in keeping with the knowledge, skills and finances of local communities. It would be a sustainable approach to flood management.
– report into flooding in Bangladesh, Daily Star (Bangladesh) May 2004

A new flood shelter in Bangladesh. *Some shelters have been designed to be used as schools in normal times, but in a flood emergency can provide shelter for the whole village.*

D4: River basin management strategies

Acknowledgements

Page 2 Adapted from: www.civildefence.co.nz, www.peopleandplanet.net*, The Guardian* (UK) Dec–Jan, 1999–2000, www.thinkquest.org, *NZ Herald* June 10 and June 18, 2005

Page 3 (see page 3)

Page 4 *Weekend Herald*

Page 5 Diagram B1: *Advanced Geography*, p 61, G Nagle, OUP, UK, 2000

Page 6 Diagram B2: *AS Level Geography*, pp 12, 15, A Bowen and J Pallister, Heinemann, UK, 2000
Diagram B3: *AS Level Geography*, p 3, A Bowen and J Pallister, Heinemann, UK, 2000
Diagram B4: *GCSE Geography in focus*, p 101, J Widdowson, John Murray, London, 2001
Diagram B5: *AS Level Geography*, p 33, 15, A Bowen and J Pallister, Heinemann, UK, 2000

Page 7 *GCSE Geography in focus*, pp 48–49, J Widdowson, John Murray, London, 2001

Page 8 East Yorkshire map: *GCSE Geography in focus*, p 53, J Widdowson, John Murray, London, 2001
Weather systems maps: *GCSE Geography in focus*, p 56, J Widdowson, John Murray, London, 2001

Page 9 Malton map: *GCSE Geography in focus*, p 50, J Widdowson, John Murray, London, 2001
Malton photo: *GCSE Geography in focus*, p 51, J Widdowson, John Murray, London, 2001

Page 10 Headlines: *A New Introduction to Geography*, p 37, K Flinders, Hodder & Stoughton, UK, 2001
Bangladesh material: *The New Wider World*, pp 288–289, David Waugh, Nelson Thornes, UK, 2003

Page 11 Floodplain photo: *Physical Geography*, p 489, A Strahler, J Wiley and Sons Inc, USA, 2002
Street photo: *AS Level Geography*, p 5, 15, A Bowen and J Pallister, Heinemann, UK, 2000

Page 12 Bangladesh map, *AS Level Geography*, p 36, 15, A Bowen and J Pallister, Heinemann, UK, 2000
Diagram: *Advanced Geography*, p 244, P Guiness & G Nagle, Hodder & Stoughton, UK, 1999

Page 13 Geography – An Integrated Approach, p 90, David Waugh, Nelson Thornes, UK, 2002

Page 15 Flood shelter: *A New Introduction to Geography*, p 39, K Flinders, Hodder & Stoughton, UK, 2001
Management strategies: *AS Level Geography*, p 39, 15, A Bowen and J Pallister, Heinemann, UK, 2000