

**Drayton Manor High School**

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| Exam Question |
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| (a) | Study Figure 1. Analyse the changes in infiltration and surface run-off over time shown on the graph. *(3 marks)* |

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| (b) | Explain the physical and human factors that influence the response of a storm hydrograph to a rainstorm. *(6 marks)* |

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| (c) | Explain the physical and human factors that can cause flooding. *(8 marks)* |

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| (d) | Study Figure 2. Use it to help you assess the role that volcanic outgassing plays in the long-term geological carbon cycle. *(12 marks)* |

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| (e) | Evaluate the extent to which the alternatives to fossil fuels can help reduce global emissions of carbon. *(20 marks)* |

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| **Total:** 49 marks |

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| Source |
| **Figure 1: Precipitation and duration of rainfall****Figure 2: Negative feedback regulating the geological carbon cycle** |

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| Mark scheme |
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| (a) | 3 marks (AO1 = 2 marks, AO2 = 1 mark)You gain 2 marks for analysing the graph and showing how the two transfers change over time: • Infiltration rates start high then fall off. • Surface run-off starts lower then rises.You gain 1 mark for making the connection between the two transfers. • Over time, infiltration rates fall as the soil store becomes full with water. As infiltration is occurring at its maximum rate, any additional rain that falls is more likely to travel by surface run-off.**Hints and tips**Outline the changes and make a clear connection between them. |

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| (b) | 6 marks (AO1 = 6 marks)**AO1 Demonstrating your knowledge and understanding**Storm hydrographs show how a river’s discharge varies in response to a rainstorm. • At first, discharge remains largely unchanged, before rising quickly to a peak, then falling back to its original level. • The response can be flashy (short lag time and a higher peak discharge) or flat (longer lag time and lower peak discharge) depending on a range of physical and human factors. • Physical factors include basin size, relief, shape, soil type and geology. • Human factors include urbanisation, agriculture and afforestation.**Answers to this question will be given a mark within a level bandLevel 1 (1–2 marks):** You show limited geographical knowledge and a narrow understanding of the physical and human factors. Part of your answer may be inaccurate or lack detail.**Level 2 (3–4 marks):** You show mostly relevant geographical knowledge and understanding of the physical and human factors. Some parts of your answer are not fully developed.**Level 3 (5–6 marks):** You show accurate and relevant geographical knowledge and understanding of the physical and human factors. Your answer is detailed and fully developed. **Hints and tips**Identify a range of physical and human factors and link them clearly to the processes at work in the drainage basin.  |

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| (c) | 8 marks (AO1 = 8 marks)**AO1 Demonstrating your knowledge and understanding***Physical factors* • Rainfall: intense storms can lead to flash flooding as the large amounts of rainfall exceed infiltration capacity; seasonal variations in rainfall, for example the Indian monsoon, can produce large quantities of rain during parts of the year. • Snowmelt: snow acts as a seasonal store of precipitation, allowing it to build up. When spring arrives and temperatures rise, then this releases large amounts of stored water which can lead to flooding.*Human factors* • Land-use change: deforestation reduces interception and evapotranspiration, resulting in more water in the drainage basin and more surface run-off of that water, increasing the flood risk. • Hard engineering strategies can fail, increasing the magnitude of the flood event.**Answers to this question will be given a mark within a level bandLevel 1 (1–2 marks):** You show limited geographical knowledge and a narrow understanding of the physical and human factors. Part of your answer may be inaccurate or lack detail.**Level 2 (3–5 marks):** You show mostly relevant geographical knowledge and understanding of the physical and human factors. Some parts of your answer are not fully developed.**Level 3 (6–8 marks):** You show accurate and relevant geographical knowledge and understanding of the physical and human factors. Your answer is detailed and fully developed.**Hints and tips**Show good depth of understanding of both factors through the use of examples to illustrate your points.  |

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| (d) | 12 marks (AO1 = 3 marks, AO2 = 9 marks)**AO1 Demonstrating your knowledge and understanding** • Volcanic outgassing is one of the processes whereby geological carbon is released into the atmosphere. • Outgassing occurs at: subduction zones and ocean ridges; hot spots with no current volcanic activity such as Yellowstone Park; fractures in the lithosphere.**AO2 Applying your knowledge and understanding**When this carbon is released, a negative feedback loop can occur. • In the short term, the extra carbon in the atmosphere results in an enhancement of the greenhouse effect, resulting in rising temperatures. • This extra atmospheric energy causes more global precipitation. • This in turn causes more chemical weathering and erosion of rocks, depositing ions on ocean floors, where it is absorbed into the geological store once more. • This whole cycle takes hundreds of thousands of years.Therefore, we can see that, although volcanic outgassing causes short-term variations in climate through the release of carbon into the atmosphere, in the longer term, because of the negative feedback loop, it ultimately balances out this emission by contributing to the geological sequestering of carbon.**Answers to this question will be given a mark within a level bandLevel 1 (1–4 marks):** You show only a limited geographical knowledge and understanding of the role played by volcanic outgassing. You make limited connections between aspects of your answer and support your interpretations with limited evidence. You draw unbalanced conclusions based on the material in your answer.**Level 2 (5–8 marks):** You show mostly relevant and accurate geographical knowledge and understanding of the role played by volcanic outgassing. You make mostly relevant connections between aspects of your answer as appropriate and support your interpretations with some evidence. You draw conclusions based on the material in your answer but your conclusions may be limited or unbalanced.**Level 3 (9–12 marks):** You show relevant and accurate geographical knowledge and understanding of the role played by volcanic outgassing. You make sound connections between aspects of your answer as appropriate and support your interpretations logically with evidence. You draw balanced and logical conclusions based on the material in your answer.**Hints and tips**Remember to weigh up the various elements relevant here to come to an overall assessment at the end, based on the argument you have presented.  |

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| (e) | 20 marks (AO1 = 5 marks, AO2 = 15 marks)**AO1 Demonstrating your knowledge and understanding** • There are three broad categories of alternatives to fossil fuels: renewables/recyclables, biofuels and radical technologies. • Renewables are growing globally and meeting an ever-increasing proportion of global energy demands. • Biofuels are also growing, especially in countries such as Brazil and the USA. • As technology advances, new ways of capturing carbon are being found.**AO2 Applying your knowledge and understanding** • Despite the positive signs of the growth of global use of renewables, there are concerns about energy accessibility — not all countries have the same local access to the renewables. • There are also social and environmental consequences to the use of renewables, including visual pollution, methane emissions from hydroelectric power (HEP) reservoirs, and social impacts such as the displacement of people. • It is unlikely that most countries will be able to meet their energy needs through renewables alone, so some are turning to nuclear power as an option. • Nuclear power has many benefits: low carbon emission, limited air pollution, reliability; but there are also concerns — safety, security and disposal of waste. • Biofuels are also lower emitters of carbon and the market for biofuel for transport is growing. However, there remain concerns, especially related to the displacement of other farming activities as the land needed for biofuels expands. If this land involves the clearing of forests, then are biofuels really carbon neutral? • Alternative technologies include carbon capture. New technologies are being developed that make this increasingly effective and efficient. But concerns exist, including about the extra energy required at the power plants to actually capture the carbon — does this offset the benefits of capturing it in the first place? • Hydrogen fuels also are an alternative form of technology. They are currently in the early stages of development, but they are non-polluting and there is optimism about the role they might play in meeting energy needs in the future.**Answers to this question will be given a mark within a level bandLevel 1 (1–5 marks):** You include isolated points of geographical knowledge and understanding of the merits of the alternatives to fossil fuels and their connection with global emissions, with some errors and inaccuracies. You have not made connections from the question to points made. Your answer is incoherent and lacks relevant evidence to support ideas. Your argument is limited, with unbalanced points. Points that you make are concluded in a general manner, if at all.**Level 2 (6–10 marks):** You make some points showing geographical knowledge and understanding of the merits of the alternatives to fossil fuels and their connection with global emissions, some of which may be relevant. You make some inaccurate points. You apply some of your knowledge but your ideas are not developed or may not be linked directly to the question. You use some evidence to support statements, which may answer only part of the question. You make a conclusion but this is drawn from often unbalanced ideas.**Level 3 (11–15 marks):** You make generally relevant points showing geographical knowledge and understanding of the merits of the alternatives to fossil fuels and their connection with global emissions. Your ideas are mostly accurate and some connections are made between ideas. You interpret the question well in general but there may be some gaps in the use of evidence to support points. You draw a conclusion that links to the arguments made but is not fully supported by evidence.**Level 4 (16–20 marks):** You show good use of geographical knowledge and understanding of the merits of the alternatives to fossil fuels and their connection with global emissions. You make a range of relevant points to create a coherent argument supported by appropriate evidence. You apply your knowledge well throughout. All points you make are linked to the question. You draw a good, well-balanced conclusion that links clearly to the evidence presented.**Hints and tips**Consider and weigh up the various alternatives, and come to an overall conclusion based on the argument you outline.  |

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| Student Response A |
| (a) | The graph shows that infiltration rates start higher but then quickly they start to fall off quite steeply, until they begin to level off to a lower and more constant rate. At the same time, the rate of surface runoff starts off lower and more constant, before starting to rise as the infiltration rate levels off.These two flows are linked. The rate of infiltration starts to fall as the soil store is filling up with water. As it fills, the infiltration capacity of the soil drops. At the same time, surface run-off starts lower as most of the precipitation that falls is infiltrating. However, as the infiltration capacity falls over time, less water infiltrates and so it travels by surface run-off.

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| **Examiner comment**The student clearly identifies the trends in the graphs and successfully links the two flows in a clear and effective explanation. 3 marks. |

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| (b) | Storm hydrographs show how river discharge varies in response to a storm. As the rainstorm begins, the discharge rises very slowly. There is little initial change during the rainstorm as most rain does not fall directly into the river. Soon, the rising limb of the discharge rises steeply towards its peak discharge. After reaching its peak, the falling limb falls and the discharge returns to its original level.This hydrograph can be affected by various physical and human factors, making it either a flashy hydrograph (which has a short lag time and a high peak discharge) or a flat hydrograph (with a longer lag time and lower peak discharge).First, the physical factors. In smaller basins, the precipitation has less distance to travel before it reaches the mouth, so the hydrograph will be shorter and steeper. Basin shape has an influence. Shorter, more rounded basins are more likely to be flashy as the water from the basin tends to arrive more quickly at the mouth. In a longer, thinner basin, the water that falls near the source has much further to travel and so it will produce a flatter hydrograph. Relief is important too. In steeper basins, under the influence of gravity, water will make its way to the mouth more quickly.Soil type is another factor. Clay soils have much smaller pore spaces and so do not allow for much infiltration. As a result, overland flow is more likely and so the water reaches the channel quickly. The opposite is the case for sandy soils. When it comes to geology, some rocks, such as basalt, are impermeable and less infiltration occurs. This produces flashier hydrographs. More permeable rocks, such as chalk, allow infiltration and produce flatter hydrographs.Second, human factors. Some land uses produce flashy responses. In urban areas, the impermeable surfaces increase run-off, and the drains and sewers are designed to take the surface water to the river quickly. Where vegetation is removed for agriculture, it leaves bare soil. This reduces interception and so the water gets to the channel more quickly.Other land uses produce flatter responses. For example, afforestation increases interception and thus slows down the speed at which the water reaches the channel. Furthermore, increased interception results in more evaporation, so the total amount of water reaching the channel is reduced, lowering the peak discharge.

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| **Examiner comment**A wide series of relevant factors are outlined and explained in detail. Level 3, 6 marks. |

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| (c) | Flooding occurs when the discharge of a river overflows its banks. This is a perfectly natural process, and can occur as a result of various physical factors. One of these is rainfall. There are places in the world with very seasonal rainfall, such as the monsoon which affects the Indian sub-continent. For example, the River Indus flooded badly in 2010 following a very intense monsoon. In July, the north-west region of Pakistan had 60 hours of continuous rainfall producing over 200 mm of rain. As a result, a huge flood peak of discharge started to travel south down the Indus into central Pakistan. River flow peaked at 32,000 m3/s. In addition to seasonal rain, there can be intense storms that lead to flash flooding. For example, the river flooding of the Mississippi in 2011 was caused in part by a series of four intense rainstorms in April in the Ohio River basin, which produced six times the average monthly rainfall for the area. This sent a flood peak down this tributary towards the confluence of the Ohio with the Mississippi at Cairo, Illinois.A second physical cause of flooding is snowmelt. If snow falls onto high mountains, it can be stored there over the winter, only to be released again in the following spring as temperatures start to rise. Snowmelt contributed to the Mississippi flood of 2011. In the upper Mississippi and Missouri tributaries to the north-west of the Mississippi Basin, the snowfalls of winter 2010/2011 were record-breaking, with the snow being around 600 mm deeper than average. When snowmelt occurred in April, this meant that there was a higher quantity of water entering the river system. This raised the peak discharges and sent a flood peak down these tributaries that peaked at 15 m in Illinois.Although it is a natural process, flooding can be made worse by human activities. One of these is changing land use. The Mississippi again illustrates this. There has been extensive deforestation in the Mississippi Basin since European settlers began to arrive in the eighteenth century. Fewer trees meant that there was less interception of rain when it fell, causing peak discharges to rise more quickly to higher levels. Furthermore, lack of trees meant that less of the water was taken up and outputted via transpiration, increasing the overall volume of water in the drainage basin. This increased the scale of the 2011 flood. A second human factor is urbanisation. The increase in urban areas increased surface run-off, resulting in faster and higher peak discharges, and reduced the storage capacity of the river basin, increasing the total volume of discharge in the river.

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| **Examiner comment**This extensive answer shows a detailed understanding of a wide range of relevant geographical factors throughout. Level 3, 8 marks. |

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| (d) | Volcanic outgassing is one of the processes whereby geological carbon is released into the atmosphere and is part of the long-term geological carbon cycle. Volcanic outgassing occurs at various tectonically active places, for example, at tectonic plate margins, including subduction zones. One such volcano is Mount Pinatubo, which erupted in 1992, emitting 42 million tonnes of carbon dioxide into the atmosphere that had been brought to the surface in magma from its store in the asthenosphere below. The volcanic activity at constructive margins in mid-ocean ridges tends not to be as explosive and so does not emit as much carbon as in subduction zones. That said, given the extensive distribution of these margins, they still emit around 80 million tonnes of carbon dioxide per year, a significant proportion of the 200 million tonnes emitted annually by all volcanic activity.However, the diagram shows that, over a long enough time period, volcanoes are part of the loop of the carbon cycle. This is because of a negative feedback loop set up by these carbon emissions. In the short term, the extra carbon in the atmosphere results in an enhancement of the greenhouse effect, resulting in rising temperatures — this extra atmospheric energy causes more global precipitation. The additional rain helps with chemical weathering, as the carbon dioxide mixes with the rainwater to form a weak carbonic acid. When this rain reacts with rocks, it dissolves them and produces calcium ions. These are then transported by rivers and deposited in layers elsewhere on ocean floors. The carbon is stored in these layers; in fact, over time, they can form into sedimentary rocks — calcite sediment forms into limestone.Therefore, we can see that, although volcanic outgassing causes short-term variation in climate through the release of carbon into the atmosphere, in the longer term, because of the negative feedback loop, it ultimately balances this emission out by contributing to the geological sequestering of carbon. However, over even longer time spans of millions of years, this rock can experience subduction and be carried into the asthenosphere, from where it can rise with magma into the lithosphere and be outgassed once again at volcanoes, starting the feedback loop over again once more.

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| **Examiner comment**The student shows good detailed and relevant geographical knowledge throughout. In addition, they use the figure well and combine that with their understanding to explain in detail the processes involved in the negative feedback loop. The conclusion is detailed and follows naturally and coherently from the earlier part of the answer. Level 3, 11 marks. |

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| (e) | There are three main categories into which you can put the alternatives to fossil fuels.The first is renewable (wind, solar, geothermal, tidal and hydroelectric power (HEP)) and recyclable energy (nuclear). There is already widespread and increasing use of renewable energy. It is estimated that just over 10\_f the world’s global energy consumption comes from renewable sources. In 2015, nearly US$290 billion was invested in renewable technologies. There is some evidence of success in the uptake of renewable sources. For example, much of China’s energy supply for its economic development has come from the burning of coal which emits high levels of carbon dioxide. However, in recent years, China has been moving away from the use of coal. In 2015, its coal production and coal-fired energy production both fell by 3nd the government banned the development of new coal mines for 3 years. At the same time, low-carbon energy production sources increased by more than 20\_n China. Stories like this have led some people to be optimistic about the future of renewables. In 2011, a projection by the International Energy Agency suggested that solar energy could produce most of the world’s electricity by 2060. Energy generation from renewables is certainly growing. In 2015, for the first time, renewable energy sources made up the majority of all new power capacity (54\_However, others are less hopeful. Renewables like solar may well be growing and may well in the future supply considerable amounts of energy. That said, there remain issues with it — most notably related to physical availability of solar power: not all countries have enough hours of sunshine to locally generate sufficient power from solar energy. Indeed, not all countries have enough tectonic activity to generate geothermal energy. Not all countries have coastlines that will allow for tidal power. Consequently, it is unlikely that most countries will be able to rely on renewables alone to replace their current power needs. There are also environmental concerns with the use of some renewables. These include the visual pollution associated with wind farms (although some people do not mind these). Additionally, there are issues with the reservoirs needed for HEP dams. Reservoirs need to be large enough to store sufficient water to smooth out the annual variations in river regimes. This means that they can flood large areas, disrupting natural habitats found there. Some reservoirs in tropical areas can generate significant amounts of methane (a potent greenhouse gas) from rotting vegetation. One study has suggested that reservoirs can give off more greenhouse gases than an oil-fired power station if the trees have not been cleared before the valley was flooded. In addition, there are issues of efficiency (reservoirs can experience siltation as sediment is deposited there, reducing their efficiency) and the social impacts can be negative (the Three Gorges Dam in China displaced 1.24 million people).Given the challenges that still exist with renewables, some countries look to recyclable energy in the form of nuclear power to meet their energy mix. On the positive side, nuclear power generates very limited carbon outputs, between 50 to 80 times less than fossil fuel power plants. Globally, around 11\_f electricity generated comes from nuclear power plants. The plants emit virtually no localised emissions, so there are no issues of air quality around them. They can generate recyclable and reliable energy to supply the baseload demands of a country (unlike some renewables). However, nuclear power is very controversial and comes with various risks. There can be nuclear accidents, such as with the Fukushima plant in Japan which was damaged by the 2011 tsunami, causing nuclear contamination to be spread into the surrounding countryside and ocean. There are concerns about terrorism and plant security. There are issues with the disposal of the radioactive waste. Finally, cost — nuclear power plants are expensive and so may not be a realistic option for the poorest countries.This brings us to the second category: biofuels. In 2010, 3\_f the world’s transport fuel was from biofuels. In the USA, nearly all of the petrol sold is mixed with 10\_thanol, and car companies such as Ford and GM have developed flex-fuel vehicles that can run on petrol containing up to 85\_thanol. Brazil has also made extensive use of biofuels. Around 90\_f all new passenger vehicles sold in Brazil have flex-fuel engines. The push for biofuel development here has meant that Brazil now is one of the leading exporters of sugar cane and ethanol, with the area of sugar cane cultivation expected to double between 2003 and 2018. However, there are issues related to this expansion of cropland, as it has displaced other farm uses, especially cattle pasture. As a result, this has put pressure on rainforest land for cattle pasture instead. Deforestation not only contributes directly to carbon emissions (as the trees are often burnt to clear the land) but also removes part of the vital carbon store of the global carbon cycle. Thus, the environmental benefits of biofuels may be counteracted by these environmental losses.The final category is the use of radical technologies, including carbon capture. The aim of carbon capture is to collect carbon dioxide from sources of emission (such as power stations) and transport it elsewhere where it can then be put into terrestrial stores or sinks so that it remains there rather than entering the atmosphere. The carbon dioxide is dissolved in water and injected into deep rock stores where it reacts with the rock to form carbonates.One report suggests that there is capacity in North America for 900 years of carbon storage, based on current usage levels. In the UK, the depleted oil and natural gas fields in the North Sea could be used for carbon storage. In 2016 in Iceland, new technological approaches led to the solid carbonates forming in 2 years (compared with the hundreds of years that had previously been predicted). This has led the Icelandic government to aim to bury 10,000 tonnes of carbon dioxide per year.However, there remain concerns about the possibility that the carbon dioxide may leak back out into the atmosphere, perhaps in the more worrying form of methane. In addition, there are considerable extra energy costs involved in carrying out the capturing of carbon. For example, for coal-based power stations, the extra power needed ranges from 24\_o 40\_significantly increasing the amount of fuel needed to produce the same amount of power.In conclusion, it is clear that, although alternative energy sources are a vital part of transforming our global energy consumption away from an over-reliance on fossil fuels, each of the alternatives comes with its own issues and much careful management is needed to get the maximum benefit from them at the minimum economic, social and environmental cost.

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| **Examiner comment**The student does not only show very sound geographical knowledge throughout, with extensive and effective use of examples and figures, but also draws out relationships between positives and negatives, weighing them up against one another. A substantial and credible conclusion is reached. Level 4, 20 marks. |

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| Student Response B |
| (a) | The infiltration rate on the graph starts high but then quickly falls off, dropping steeply. It then levels out to a lower and more constant rate. Meanwhile, the rate of surface run-off starts low and more constant and then rises as the infiltration rate levels out.

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| **Examiner comment**The student clearly identifies the trends in the graphs but does not link the two flows to provide an explanation. Read the question carefully and answer precisely what is asked. 2 marks. |

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| (b) | A storm hydrograph shows how the river discharge varies in response to a storm. A hydrograph can be either flat (with a short lag time and a high peak discharge) or flashy (with longer lag times and lower peak discharges) depending on various physical and human factors.

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| **Examiner comment**The student mixes these two up. Mistakes like this can happen in the exam when under pressure, but the student should be careful not to make careless mistakes so that the answer can earn maximum marks. |

Relief is an important physical factor. For example in steeper basins, the influence of gravity means the water makes its way to the mouth of the river more quickly. The hydrograph will be shorter and steeper in smaller basins, as the precipitation has less distance to travel before it reaches the mouth. Soil type is another physical factor. Overland flow is more likely with clay soils as they have much smaller pore spaces which doesn't allow for much infiltration, and so the water reaches the channel quickly.Human factors also affect storm hydrographs. A flashy response is seen with some land uses, for example urban areas. Impermeable surfaces here increase run-off and the drains and sewers take the surface water to the river quickly. On agricultural land, bare soil is left when vegetation is removed, interception is reduced and so water gets to the channel more quickly.A flatter response is caused by other land uses such as afforestation. Interception is increased here, slowing down the speed at which the water reaches the channel. The peak discharge is lower as increased interception also results in more evaporation, so the total amount of water reaching the channel is reduced.

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| **Examiner comment**Overall, there are some relevant factors. But the student makes one error in understanding and the factors need to be developed more for a top-level response. Level 2, 3 marks. |

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| (c) | Flooding can occur due to different physical factors, such as rainfall. There are places in the world with very seasonal rainfall, such as the monsoon which affects the Indian sub-continent. The monsoon affects this region in the summer months and can drop significant amounts of rainfall in a few short months, overwhelming the river banks. You can also have flooding that follows intense rainstorms in the UK. For instance in 2015, a very intense rainstorm over Cumbria caused significant flooding there, flooding nearly 5,000 homes. The intense rain means that the infiltration capacity is exceeded and more surface run-off occurs.Flooding can also be caused by snowmelt. For example, the Indus River in Pakistan is fed by seasonal melting of the glaciers and snowpack. This is one of the reasons for the devastating flood there in 2010.Human factors also cause flooding. For example, land use change. Again in the Indus River, there has been extensive deforestation — the country’s forest cover will be reduced to half of its 1995 level by 2020. With the trees removed, there was less interception of the rains, meaning that both the volume and speed of water reaching the rivers increased, contributing to the exceptionally high flood peak levels. Hard engineering can also contribute to flooding. The levees built up beside the Indus to reduce the flood risk actually made it worse. By cutting the river off from the floodplain, the levees meant that sediment was kept in the channel and deposited on the river bed, raising its level. The levees then failed during the flood and the waters spilled out onto the floodplain.

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| **Examiner comment**The student refers to a range of physical and human factors and makes good use of examples to illustrate their answer. It could be improved by showing a fuller understanding of exactly how these factors link to flooding. For instance, in the first paragraph, these connections are not made as clearly as they might be. Level 2, 6 marks. |

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| (d) | Volcanic outgassing happens at various tectonically active places, such as tectonic subduction zones. For example, Mount Pinatubo, which erupted in 1992, emitted significant amounts of carbon dioxide, that had been brought to the surface in magma, into the atmosphere. The volcanic activity at constructive margins in mid-ocean ridges tends not to be as explosive and so does not emit as much carbon as in subduction zones. Outgassing also occurs at hot spots such as Hawaii and at places like Mount Etna, a collision zone on Sicily. This clearly adds carbon into the atmosphere.However, this carbon can set in motion a negative feedback loop which ultimately acts to return carbon to the geological store, when measured over the timescale of hundreds of thousands of years. It happens like this. The extra carbon in the atmosphere initially leads to an enhancement of the greenhouse effect. In the short term, this first of all leads to an increase in precipitation. But this precipitation mixes with the carbon dioxide to produce weak carbonic acids. These react with the rocks on the surface, causing chemical weathering, releasing ions from the rocks. These are then carried away by the rivers and deposited on ocean floors. This way, the carbon is taken back into the geological store.So we can see how, though outgassing releases carbon in the short term, over longer timescales it can bring carbon back into the geological carbon store via this negative feedback loop.

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| **Examiner comment**The student shows good knowledge and understanding, but could be more detailed in places to earn more marks. For example, more details on the places and examples referred to could be given. In addition, the conclusion is reasonably coherent, but again more detail would show a deeper understanding of the longer-term outgassing cycle. Level 2, 8 marks. |

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| (e) | The first alternative to fossil fuels is renewable and recyclable energy. There is already widespread and increasing use of renewable energy. For example, much of China’s energy supply for its economic development has come from the burning of coal which emits high levels of carbon dioxide. However, in recent years, China has been moving away from the use of coal. In 2015, its coal production fell and low-carbon energy production sources increased by more than 20\_Stories like this have made some more positive about the future of renewables. An estimate by the International Energy Agency suggested that solar energy could produce most of the world’s electricity by 2060.Not everyone is as positive, though. For example, there are issues with solar power. Not all countries have enough hours of sunshine to locally generate sufficient power from solar energy. Indeed, not all countries have coastlines that will allow for tidal power. Consequently, it is unlikely that most countries will be able to rely on renewables alone to replace their current power needs. There are also environmental concerns with the use of some renewables. These include the visual pollution associated with wind farms (although some people do not mind these). This is known as NIMBYism (Not In My Back Yard). If there are proposals to locate a wind farm nearby, then people may often protest. There were plans to put an offshore wind farm near the AONB at the Giant’s Causeway, Northern Ireland, but these were dropped after opposition from environmentalists.Some countries are also using recyclable energy including nuclear power. This power source emits very little carbon and it is reliable and can help meet the baseload needs of a country. But there are concerns about nuclear power. There can be nuclear accidents, such as with the Fukushima plant in Japan which was damaged by the 2011 tsunami. There are concerns about terrorism and plant security. There are issues with the disposal of the radioactive waste. Finally, cost — nuclear power plants are expensive and so may not be a realistic option for the poorest countries.Biofuel is another alternative to fossil fuels. Brazil has made extensive use of biofuels and is now one of the leading exporters of sugar cane and ethanol. The area of sugar cane cultivation in the country is expected to double between 2003 and 2018. However, there are issues related to this expansion of cropland, as it has displaced other farm uses, especially cattle pasture. This has put pressure on rainforest land for cattle pasture instead. Deforestation removes part of the vital carbon store of the global carbon cycle.Radical technologies can also be used. One of these is carbon capture. The aim of carbon capture is to collect carbon dioxide from sources of emission and transport it elsewhere where it can then be put into terrestrial stores or sinks so that it remains there rather than entering the atmosphere. It is thought that there is capacity in North America for 900 years of carbon storage. In the UK, the depleted oil and natural gas fields in the North Sea could be used for carbon storage. On the other hand, carbon capture is expensive and uses more energy in the process of capturing it. Hydrogen fuel cells are another alternative technology. These cells are non-polluting as they only emit electricity, heat and water. It can be used to power cars and seems to have a good future ahead of it.Overall, there are some positives and some negatives in the use of alternatives to fossil fuels.

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| **Examiner comment**This student covers a range of alternatives with relevant material. More marks could be gained by making more connections between parts of the answer. For example, the reason why some countries are exploring the use of recyclable energy is due to issues with the effectiveness of renewables — this link could be made more explicit in the paragraph about nuclear power. Also, the conclusion is too brief and not really informed by the discussion that came before it. Level 3, 11 marks. |

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