



EARTH AND ENVIRONMENTAL SCIENCE

ATAR course examination 2021

Marking key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

Section One: Multiple-choice

15% (15 Marks)

Question	Answer
1	a
2	c
3	c
4	b
5	c
6	b
7	a
8	d
9	d
10	b
11	d
12	a
13	b
14	c
15	a & c

Section Two: Short answer

55% (110 Marks)

Question 16

(16 marks)

- (a) Name **three** factors related to the Earth's orbital motion that affect distribution of solar radiation. (3 marks)

Description	Marks
Change in the orientation of the Earth's axis over time (precession)	1
Orbital plane (axial tilt/obliquity)	1
Shape of the Earth's orbit (elliptical orbital path or eccentricity)	1
Total	3
Accept other relevant answers.	

- (b) Net solar energy input is the sum of radiant energy received by and emitted from the Earth at a given location. Explain, with the use of a diagram, why net solar energy input varies with latitude. (3 marks)

Description	Marks
Relevant diagram showing sun's rays spread over a narrow (equatorial) and wide (polar) area	1
Relevant answer related to tropical latitudes	1
Relevant answer related to polar latitudes	1
Total	3

Answers could include:

Tropical latitudes

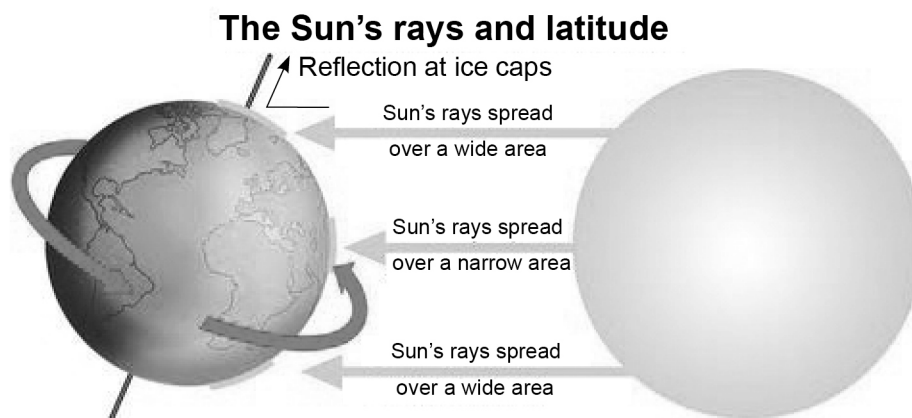
- sun's rays are overhead – strike vertically
- insolation concentrated over a smaller area
- darker forests absorb energy

Polar Latitudes

- polar ice caps are highly reflective
- sun's angle in the sky decreases
- rays are spread over a wide surface
- more energy is lost to reflection and absorption

Sample diagram:

- must refer to sun's rays spread over a narrow and wide area



Accept other relevant answers.

Question 16 (continued)

- (c) Draw a labelled diagram showing how a La Niña event affects oceanic and atmospheric circulation and rainfall between South America and Australia. (4 marks)

Description	Marks
Wind direction towards Australia	1
Warm surface water off the eastern coast of Australia	1
Upwelling of water off South American coast and surface water movement in a westerly direction	1
High rainfall on eastern coast of Australia	1
Total	4

Sample diagram:

Accept other relevant answers.

- (d) Identify **three** typical consequences of a La Niña event for weather conditions in eastern Australia, and outline how each of these conditions is produced by the atmospheric and/or oceanic circulation patterns described in part (c). (6 marks)

Description	Marks
For each of three ways (2 marks each)	
Identifies a consequence of La Niña for weather conditions in eastern Australia	1
Outlines how the climatic condition identified is related to the relevant atmospheric and/or oceanic patterns	1
Total	6

Answers could include:

- increased number of cyclones caused by warmer waters to the north of Australia
- increased rainfall/flooding caused by stronger equatorial trade winds
- cooler daytime temperatures south of the tropics caused by stronger equatorial trade winds
- increased cloud cover caused by higher evaporation rates.

Accept other relevant answers.

Question 17

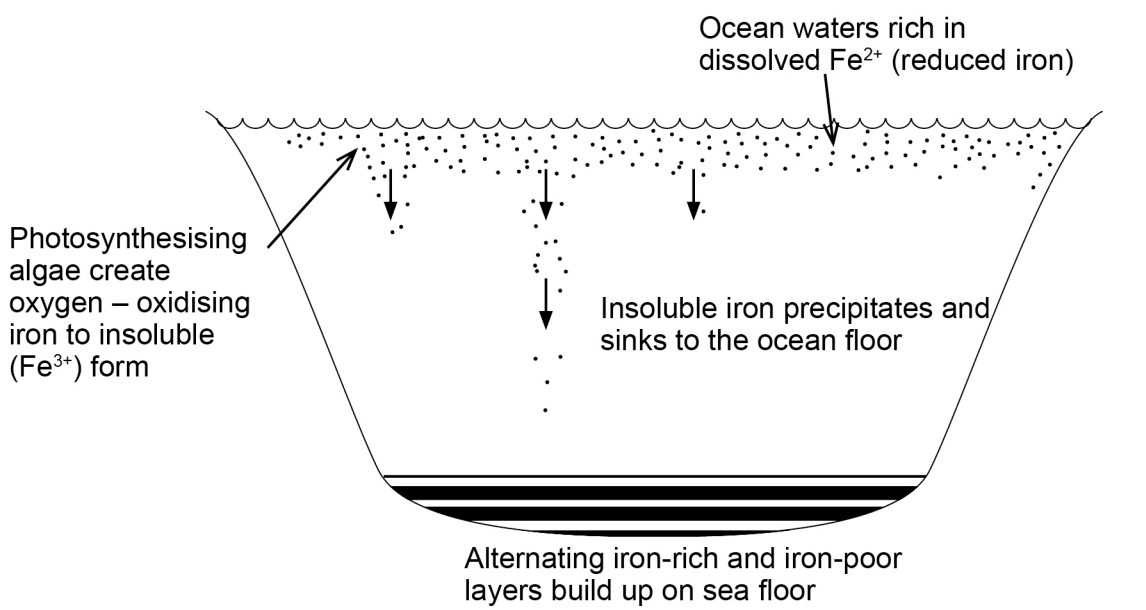
(12 marks)

(a) With the aid of a diagram, explain how banded iron formations are created. (5 marks)

Description	Marks
Diagram	
Diagram clearly illustrates the development of banded iron formations	1
Subtotal	1
Explanation	
Original enrichment of anoxic water with soluble iron (Fe^{2+})	1
Oxygen produced by bacteria oxidises iron to insoluble form (Fe^{3+})	1
Cyclical blooming and death of cyanobacteria forming silicate or carbonate rich layers	1
Alternating iron-rich and iron-poor sedimentary deposits create banded iron formations	1
Subtotal	4
Total	5

Sample explanation for three marks:
 Early atmosphere and oceans were un-oxygenated, so any iron weathered out of rocks was in the reduced form. This form is highly soluble, leading to high levels of dissolved iron building up in the oceans. When photosynthesising cyanobacteria (blue-green algae) evolved, these began to produce oxygen in the oceans. As oxygen levels increased, dissolved iron became oxidised, precipitating out of solution to form minerals such as magnetite and hematite, which sank to the seafloor forming an iron-rich layer. Cyclical blooming and death of cyanobacteria produced alternations of these iron-rich and silica or carbonate rich layers. Over time, this cyclical layering produced banded iron formations. Eventually oxygen built up to excess in the atmosphere, preventing the further build-up of dissolved iron and stopping the process.

Sample diagram:



Question 17 (continued)

- (b) Banded iron formations require substantial additional concentrations of iron to reach grades high enough to form an economic ore body. Explain **one** process that can produce this secondary enrichment. (3 marks)

Description	Marks
Identifies an appropriate process	1
Describes the process	1
Explains how the process eliminates the non-economic material	1
Total	3
Answers could include:	
<ul style="list-style-type: none">• supergene enrichment, where weathering of banded iron formations in the surface environment dissolves out large volumes of silica and/or carbonate, leaving insoluble iron minerals behind and thereby further concentrating the iron• weathering and erosion of banded iron formations, concentrating heavy and insoluble iron minerals in river channels to form channel iron deposits.	
Accept other relevant answers.	

- (c) Outline **two** environmental considerations that are important in the extraction of iron ore from ore bodies. (4 marks)

Description	Marks
For each of two considerations (2 marks each)	
Identifies an environmental consideration	1
Outlines the main features of the consideration for the environment	1
Total	4
Considerations could include:	
<ul style="list-style-type: none">• vegetation clearing• topsoil removal• local water contamination• dust management• hazardous areas requiring fencing• mine dewatering• disposal of mine waste.	
Sample answer for two marks: Mining of iron ore requires the clearing of large areas of vegetation to access the ore and develop the necessary mine infrastructure. This may have a substantial impact on local ecosystems, the impact of which might be increased if endangered species are present.	
Accept other relevant answers.	

Question 18

(14 marks)

- (a) Identify **three** characteristic features that you would expect to see in a sample of schist. For each feature identified, outline how that characteristic could be used to distinguish schist from one or more other metamorphic rock types. (6 marks)

Description		Marks
For each of three features (2 marks each)		
Identifies a characteristic feature of schist		1
Outlines how the identified characteristic distinguishes schist from other metamorphic rock type(s)		1
Total		6
Answers could include:		
Characteristic feature of schist	How this feature distinguishes schist from other metamorphic rock type(s)	
Fine to medium grained	Coarser grains than phyllite Finer grains than gneiss	
Mica grains visible to the naked eye	Phyllite has a micaceous sheen on foliation surfaces but individual grains are not visible	
Foliated	Contact metamorphic rocks are not foliated	
Alternating bands of lighter and darker minerals	Lower grade metamorphic rocks (phyllite and slate) do not have this segregation	
Accept other relevant answers.		

- (b) The igneous rock shown in the illustration below has metamorphosed one of the units it is in contact with.

Name the metamorphic rock you would expect to see at location A and state **two** characteristics of this rock. (3 marks)

Description		Marks
Identification		
Correctly names the rock as quartzite		1
Subtotal		1
For each of two characteristics (1 mark each)		
Characteristics could include:		1
• non-foliated or granular		
• large crystals		
• quartz is the only mineral present.		
Subtotal		2
Total		3
Accept other relevant answers.		

Question 18 (continued)

- (c) The chart below shows a number of minerals commonly used to determine the grade of metamorphism a rock has undergone.

Explain why pyroxene is considered useful as a metamorphic index mineral whereas muscovite is not. (2 marks)

Description	Marks
Identifies that pyroxene has a restricted range of stability so its presence in a rock is indicative of metamorphic conditions within that range	1
Identifies that muscovite has a broader range of stability that extends to surface conditions, so its presence in a rock is less informative as to metamorphic conditions	1
Total	2
Accept other relevant answers.	

- (d) The metamorphic rock illustrated below consists of alternating bands of coarsely crystalline light-coloured and dark-coloured minerals.

- (i) Give an appropriate name for this metamorphic rock. (1 mark)

Description	Marks
Gneiss	1
Total	1

- (ii) On the basis of your knowledge of this rock type and the indicator mineral chart shown in part (c), suggest **two** minerals you would expect to find in the light-coloured layers, and **two** minerals you would expect to find in the dark-coloured layers. (2 marks)

Description	Marks
Any two relevant minerals found in the light-coloured layers	1
Any two relevant minerals found in the dark-coloured layers	1
Total	2
Relevant light-coloured minerals could include: <ul style="list-style-type: none"> • quartz • feldspar (can accept individual feldspar types e.g. plagioclase, orthoclase, but candidates will not be awarded marks for both specific and generic feldspar answers) • muscovite (mica would not be acceptable as other forms of mica are key minerals in dark segregated layers). Relevant dark-coloured minerals could include: <ul style="list-style-type: none"> • amphibole • pyroxene • biotite (mica would not be acceptable as muscovite is a key mineral in the light-coloured segregated layers) • garnet • chlorite. 	
Accept other relevant answers.	

Question 19

(17 marks)

- (a) Describe a benefit of having a measuring station for atmospheric CO₂ in a remote location. (2 marks)

Description	Marks
Identifies a benefit	1
Describe how/why it is a benefit	1
Total	2
Sample answer: Because of the remoteness of the station, data is not influenced by local traffic or industrial pollution. This means a more accurate insight is provided into underlying atmospheric character.	
Accept other relevant answers.	

- (b) Describe the cause of the monthly fluctuation in CO₂ levels seen in the Keeling curve graph. (2 marks)

Description	Marks
Identifies the cause of monthly fluctuation – seasonal	1
Describes the change in vegetation cover due to imbalance in seasonal change in northern and southern hemispheres	1
Total	2
Sample answer: The variation shown in the graph is due to seasonal change in vegetation cover. During winter, deciduous trees lose their leaves. Because the northern hemisphere has a much larger land area than the southern hemisphere in temperate zones where deciduous trees dominate, this effect causes relative CO ₂ build up in the northern hemisphere winter.	
Accept other relevant answers.	

- (c) Explain why the ratio of ¹⁸O to ¹⁶O in oceanic sediments is highest during periods of cooler global climate. (4 marks)

Description	Marks
¹⁸ O is heavier than ¹⁶ O	1
¹⁶ O is preferentially evaporated	1
¹⁶ O is then locked in ice sheets/glaciers during cooler times	1
¹⁸ O is higher in abundance in oceans and therefore ocean sediments	1
Total	4
Sample answer: The oxygen isotope ¹⁸ O is heavier than the ¹⁶ O isotope. This means that evaporation preferentially affects water containing ¹⁶ O, leaving a higher ¹⁸ O concentration in the remaining seawater. During periods of cool climate ¹⁶ O-enriched precipitation becomes locked up in ice sheets, driving a progressive intensification of the ¹⁸ O enrichment in the oceans. This enrichment is reflected in marine carbonates formed in these ocean waters and accumulated as sediments.	
Accept other relevant answers.	

Question 19 (continued)

- (d) Other than the methods named above, describe **one** way of recording climate change on each of the historical and geological timescales. (4 marks)

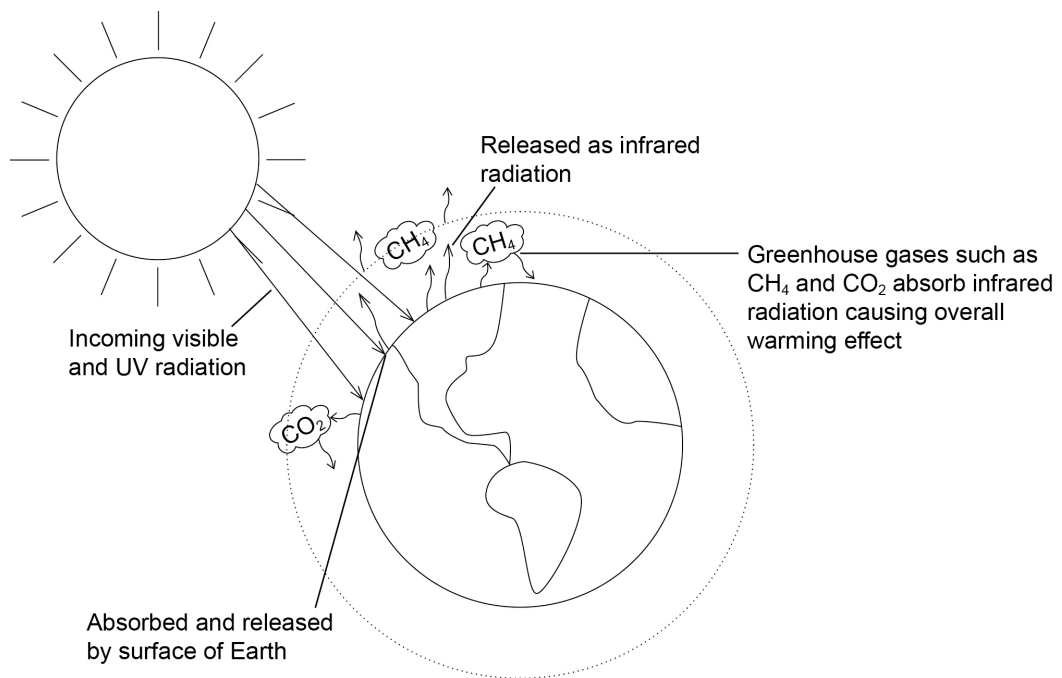
Description	Marks
Identifies historical method of measuring climate change (active measurement of change over time in the current era is an accepted form of historical measurement in this context)	1
Identifies how historical method indicates climate change	1
Identifies geological method of measuring climate change	1
Identifies how geological method indicates climate change	1
Total	4
<p>Answers could include:</p> <p>Historical</p> <ul style="list-style-type: none"> • ocean current monitoring • historic shipping records recording weather • changing distribution of ice sheets • species distribution • tree rings <p>Geological</p> <ul style="list-style-type: none"> • pollen analysis • fossil distribution • ice cores • rock type. <p>Sample answer: Fossils are evidence of the types of organisms that lived in the past. When we observe changes in the fossil record it can be suggested that the removal of a certain species from the fossil record indicates that climate changed and is no longer suitable. Ocean currents help regulate and distribute heat around the globe. Increased heating of the surface water will create a greater temperature difference between surface and deep water that results in faster convection of ocean water. This leads a stronger ocean current.</p> <p>Accept other relevant answers.</p>	

- (e) Explain, with the aid of a diagram, how substances such as carbon dioxide and methane influence the enhanced greenhouse effect. (5 marks)

Description	Marks
Diagram	
Diagram is clear and relevant	1
Subtotal	1
Explanation	
Incoming energy occurs in the form of visible and UV radiation (short-wave)	1
Outgoing energy occurs in the form infrared radiation (long-wave)	1
Greenhouse gases such as CH ₄ (methane) and CO ₂ (carbon dioxide) absorb this radiation	1
This results in increased heat being retained in the atmosphere, resulting in an enhanced greenhouse effect	1
Subtotal	4
Total	5

Sample answer:
 Energy enters the atmosphere from the sun as visible UV radiation. CH₄ (methane) and CO₂ (carbon dioxide) absorb infrared energy (heat) released from the Earth's surface and atmosphere. As the energy is absorbed it causes the lower atmosphere's temperature to rise. Some of the heat is transferred back to the Earth's surface. As the volume of greenhouse gases increases, the heating effect in the atmosphere also increases.

Sample diagram:



Accept other relevant answers.

Question 20

(11 marks)

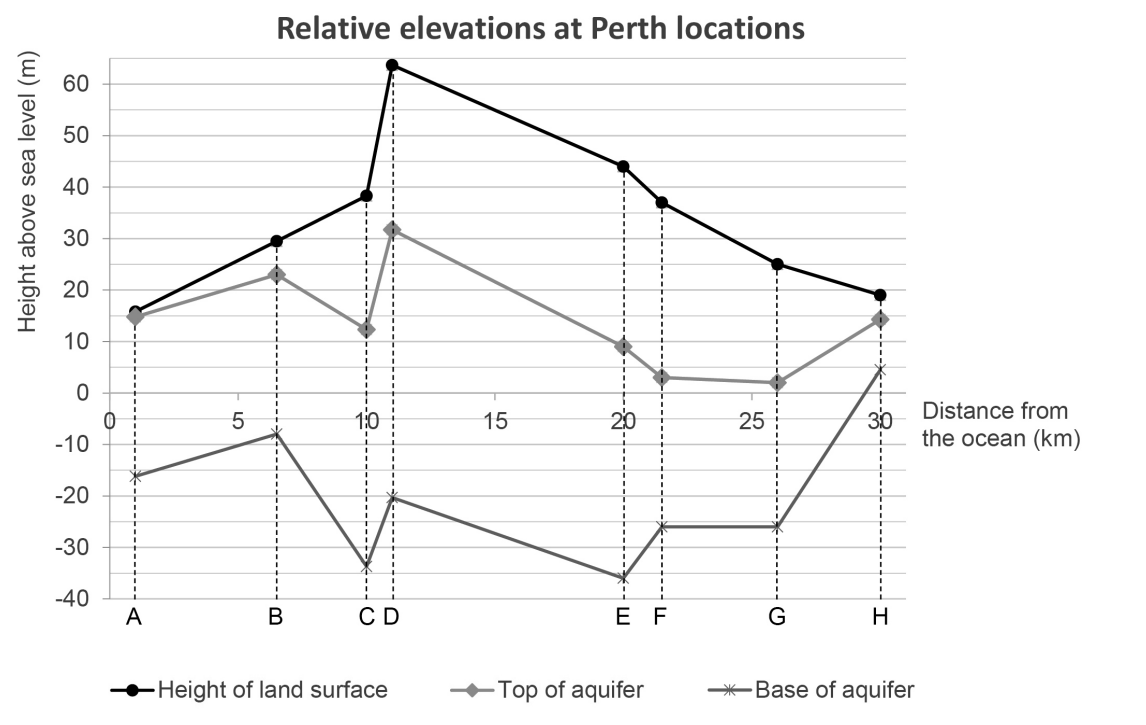
- (a) Show how this can be determined using values from the table. (1 mark)

Description	Marks
$A = 15.8 - 1 - 31 = -16.2$ (16.2 m below sea level)	1
Total	1

- (b) Show the relative elevations of the base of the aquifer at each location in the table on the graph provided on page 18. (2 marks)

Description	Marks
Correctly plots at least four relative heights of the base of the aquifer	1
Correctly plots all relative heights of the base of the aquifer	2
Total	2

Sample answer:



- (c) Identify the location where

- (i) the aquifer is the thickest. (1 mark)

Description	Marks
Location D	1
Total	1

- (ii) the top of the aquifer is the deepest. (1 mark)

Description	Marks
Location G	1
Total	1

- (d) Describe **one** way in which human activity might negatively affect aquifer recharge. (2 marks)

Description	Marks
Identifies a human activity that might affect aquifer recharge	1
Describes how this negatively affects aquifer recharge	1
Total	2
Answers could include: <ul style="list-style-type: none"> • industrial development – water demand for industrial activities affect recharge • agricultural activities – land tillage alters runoff and water infiltration, affecting recharge • agricultural activities – crop irrigation affects runoff/groundwater pumping affect recharge • urban development – pollutants, including fertilisers from gardens, enter stormwater drains and affect recharge • paving large areas – blocks surface recharge • land clearance – promotes runoff at the expense of infiltration of water. 	
Accept other relevant answers.	

- (e) Describe **one** benefit of a managed aquifer recharge system. (2 marks)

Description	Marks
Identifies a benefit	1
Describes how/why this is a benefit	1
Total	2
Benefits could include: <ul style="list-style-type: none"> • increases ability to store water to meet the needs in times of higher demand such as summer. Lowers the impact on residents for water restrictions • reduces the risk of saltwater intrusion. If saltwater intrusion occurs, aquifer is contaminated and unable to be used • increases water availability for commercial and environmental use. Recreational areas such as parks and gardens do not die off in warmer months (social benefit). 	
Accept other relevant answers.	

- (f) Desalination might also be used to increase the availability of fresh water for a region. Describe **one** advantage of desalination over managed aquifer recharge. (2 marks)

Description	Marks
Identifies an advantage of desalination	1
Describes how/why this is an advantage over managed aquifer recharge	1
Total	2
Advantages could include: <ul style="list-style-type: none"> • desalination is independent of climate • fresh water production by desalination can be scaled up or down arbitrarily • desalination is not vulnerable to pollution • salt water is readily available. 	
Sample answer: Managed aquifer recharge relies on treatment and reuse of another freshwater source. Supply of water for desalination is not limited by other freshwater sources.	
Accept other relevant answers.	

Question 21

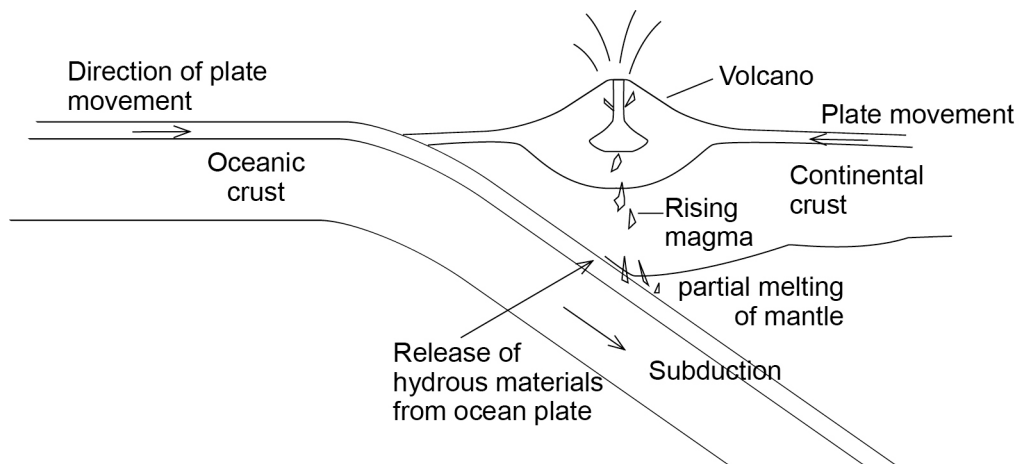
(14 marks)

(a) In the space below, draw a labelled diagram of a convergent continental-oceanic plate boundary, explaining how volcanic landforms are created at this location. (5 marks)

Description	Marks
Identifies tectonic plates are moving towards one another (convergent)	1
Identifies that the oceanic plate will be subducted under the continental plate	1
Identifies volcano is formed on the continental plate	1
Describes partial melting of the mantle due to dehydration of the subducted oceanic crust	1
The magma produced rises through mantle to the surface to form a volcano	1
Total	5

- Volcanic landform creation:
- two plates collide, where the denser oceanic crust is subducted beneath the less dense continental plate
 - subducted plate is metamorphosed, releasing water
 - water lowers melting point of the overlying mantle, causing partial melt
 - melt rises and erupts at surface, forming volcano.

Sample diagram:



Accept other relevant answers.

- (b) Tsunamis are produced by the sudden displacement of a large volume of water. Explain **one** way in which interactions between tectonic plates can create such a disturbance and generate a tsunami. (3 marks)

Description	Marks
Stress builds up at the plate boundary contacts as the plates try to move past one another	1
Release of this stress at the plate boundary during an earthquake creates sudden movement between the plates	1
A tsunami is generated when an earthquake disrupts the ocean floor	1
Total	3
Sample answer: Tectonic plates are in constant motion, moving at different speeds and in different directions to one another. At times when these plates move past each other, sections of the plates collide, preventing or resisting the opposing movement. When this occurs, the kinetic energy is stored. The release of this energy is an earthquake. When these interactions disrupt the sea floor, water is displaced to produce a tsunami.	
Accept other relevant answers.	

- (c) Monitoring can be used to establish early warning systems for both tsunamis and volcanic eruptions. Describe **one** strategy used to provide warning of an approaching tsunami and **one** strategy used to warn of an imminent volcanic eruption. (4 marks)

Description	Marks
Identifies a monitoring strategy used to warn of an approaching tsunami	1
Describes a monitoring strategy used to warn of an approaching tsunami	1
Identifies a monitoring strategy used to warn of imminent volcanic eruption	1
Describe a monitoring strategy used to warn of imminent volcanic eruption	1
Total	4
Tsunami behaviour: <ul style="list-style-type: none"> tsunamis are preceded by a large earthquake or other seismic event and it takes time for the wave to travel outwards from the event location. Monitoring seismic events in oceanic areas allows scientists to give advance warning of the possible arrival of a tsunami at different locations buoys located in oceanic areas known to be susceptible to tsunamis. Monitoring can detect the displacement of the tsunami wave, allowing scientists to warn adjacent areas that a wave may be on the way Volcanic eruption: <ul style="list-style-type: none"> monitoring the composition and volume of gases released from an active volcano can change in the lead-up to an eruption, providing warning seismic monitoring of volcanic activity can detect earthquakes caused by magma ascending, warning of a volcanic eruption. 	
Accept other relevant answers.	

Question 21 (continued)

- (d) Describe how the period of warning provided in advance of either a tsunami **or** a volcanic eruption can be used to reduce the risk to nearby human populations. (2 marks)

Description	Marks
Recognises an increased length of warning provides opportunity to reduce risk to human populations	1
Describes how the warning period can be used to reduce risk to nearby human populations	1
Total	2
Sample answer: Early warning of a tsunami allows sufficient time for an alarm to be sounded, alerting the coastal population of the danger and warning them to move to higher ground immediately before the wave arrives. Warning of a volcanic eruption can be days to weeks, allowing for appropriate emergency response plan to be implemented. Livestock and human populations can be moved to safe regions.	
Accept other relevant answers.	

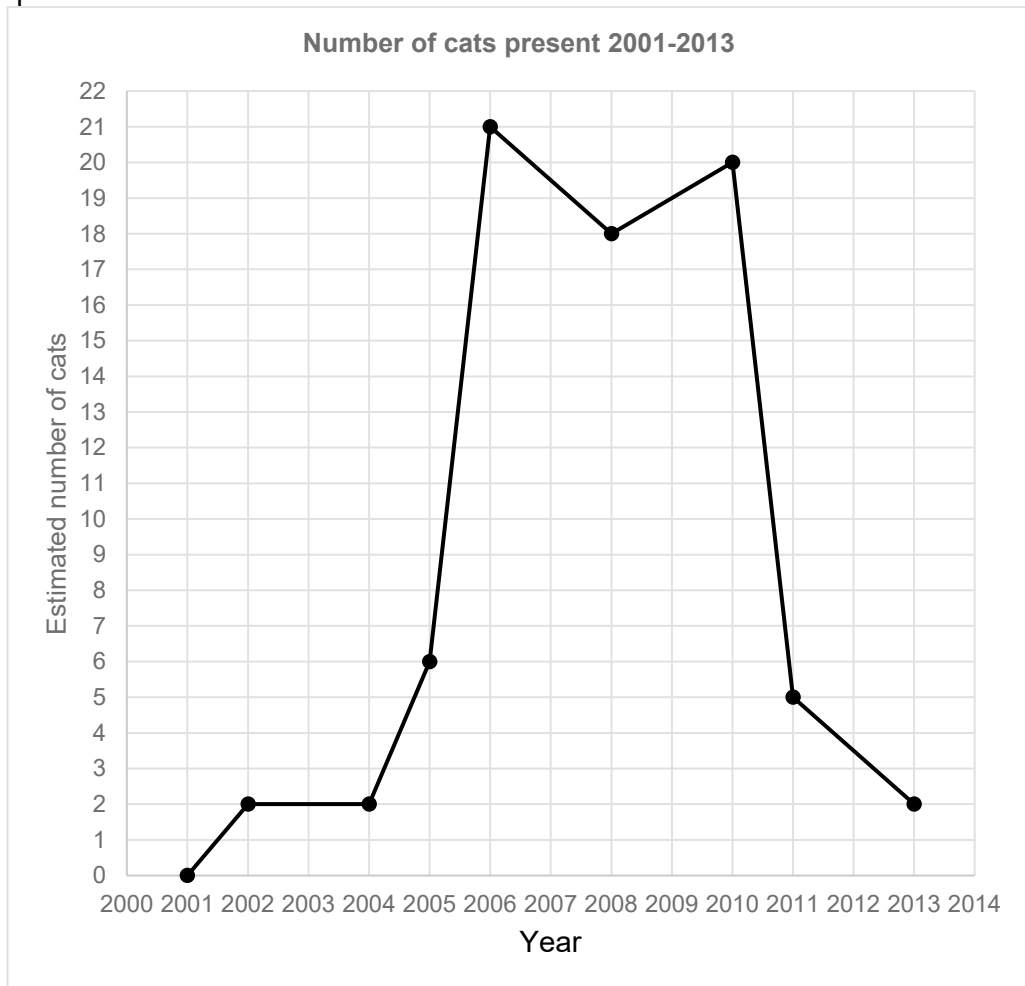
Question 22

(14 marks)

- (a) Using the grid provided on the next page, draw a line graph of the data shown in the table. (5 marks)

Description	Marks
Plotted as a line graph	1
Appropriate title for graph	1
Cat population figures plotted correctly and joined by straight lines	1
X-axis plotted in years and scaled appropriately	1
Y-axis labelled as number of cats and scaled appropriately	1
Total	5

Sample answer:



- (b) Suggest a reason why cat numbers remained stable from 2002 to 2004. (1 mark)

Description	Marks
States a valid reason that could account for stable numbers	1
Total	1

Answers could include:

- both cats are male (or female), so they are unable to breed
- one cat, or both cats, has been sterilised or is otherwise infertile
- natural predation or loss is keeping numbers steady.

Accept other relevant answers.

Question 22 (continued)

- (c) No active control measures were ever implemented to reduce cat numbers, but in 2010 the organisation stopped shooting wild dogs in the area. Identify **two** features observed in the number of cats from 2010 onward. (2 marks)

Description	Marks
Numbers drop sharply from 2010 to 2011	1
Numbers continue to decrease between 2011 and 2013, but at a slower rate	1
Total	2
Accept other relevant answers.	

- (d) Explain the relationship these population numbers imply between wild dogs and feral cats in the local ecosystem. (2 marks)

Description	Marks
Recognises a valid relationship between wild dog and feral cat numbers	1
Provides a plausible reason for the identified relationship	1
Total	2
<p>Relationships could be:</p> <ul style="list-style-type: none"> as wild dog numbers increased, the feral cat numbers decreased (inverse relationship) <p>Valid reasons could include:</p> <ul style="list-style-type: none"> dogs actively predate the cats dogs and cats compete for food sources and the dogs are more successful dogs chase the cats away from the local area. <p>Sample answer: Dogs are highly territorial and will chase cats and other competing predators away from their range, so as wild dog numbers recover cats are driven away.</p>	
Accept other relevant answers.	

(e) State the relationship you would expect between each of the following, and provide a probable reason for this relationship.

(i) Brushtail possum numbers and feral cat numbers (2 marks)

Description	Marks
Makes a plausible statement about the relationship	1
Provides a probable reason for the relationship	1
Total	2
Statements and probable reasons could include: <ul style="list-style-type: none"> • inverse relationship because possums decrease as cat numbers increase • predator-prey relationship because cats are efficient predators and able to climb trees, and therefore would be expected to predate the possums. Accept other relevant answers.	

(ii) Brushtail possum numbers and wild dog numbers (2 marks)

Description	Marks
Makes a plausible statement about the relationship	1
Provides a probable reason for the relationship	1
Total	2
Statements and probable reasons could include: <ul style="list-style-type: none"> • no direct relationship because possums are tree dwellers and dogs cannot climb, so the two will rarely interact • positively correlated because the dogs drive off or kill the cats that predate on the possums. Accept other relevant answers.	

Question 23

(12 marks)

- (a) Produce a cross-section of the region along the line A–A' on the section line provided below. Show the actual or inferred distribution of all lithologies cutting this section line to an elevation of 200 m below sea level. Note: to assist you in transcribing data locations you may remove page 45 by tearing along the perforations. (5 marks)

Description	Marks
Accurate plotting of topography	1
Lithological contacts transferred accurately to section line	1
Anticline structure illustrated by units dipping outwards	1
Conglomerate and sandstone shown as horizontal units	1
Basalt shown as vertical dike cutting other lithologies	1
Total	5

Sample diagram:

- (b) Imagine you were going to drill a hole at point Y on the map. List the first **three** lithologies you would encounter as you drilled deeper. (3 marks)

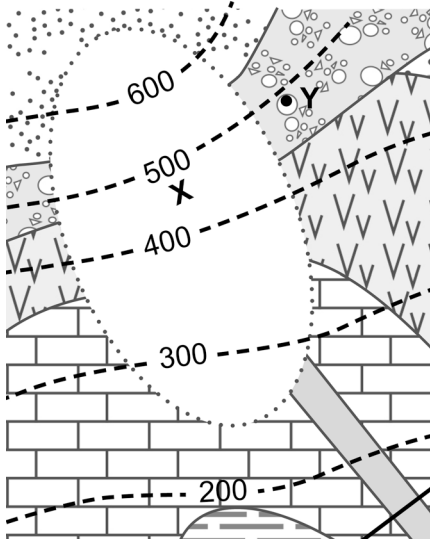
Description	Marks
First lithology encountered is conglomerate	1
Second lithology encountered is volcanics	1
Third lithology encountered is limestone	1
Total	3

- (c) Identify the oldest unit in the mapped area. (1 mark)

Description	Marks
Shale	1
Total	1

- (d) It is not known whether the basalt dyke is older or younger than the conglomerate unit, and the part of the area where this relationship could be tested has not been mapped. Mark on the map with an **X** where you predict the contact between the basalt and conglomerate might be exposed. (1 mark)

Description	Marks
Marks X on the map at a point where the basalt and conglomerate might reasonably be inferred to meet	1
Total	1

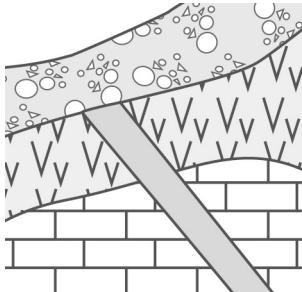


- (e) If this contact is exposed, describe or sketch the relationship you would see between the basalt and the conglomerate if

- (i) the basalt is older than the conglomerate. (1 mark)

Description	Marks
Response shows or describes the basalt being truncated by erosion and overlain by the flat-lying conglomerate	1
Total	1

Sample diagram:



Question 23 (continued)

(ii) the basalt is younger than the conglomerate.

(1 mark)

Description	Marks
Response shows or describes the basalt cutting vertically through the conglomerate	1
Total	1
Sample diagram: 	

Section Three: Extended answer

30% (30 Marks)

Question 24

(15 marks)

- (a) Describe **three** ways in which scientists can identify regions at risk from earthquakes. (6 marks)

Description	Marks
For each of three ways (2 marks each)	
Outlines an earthquake risk analysis method	1
Describes how this information can be applied in a scientific manner to identify regions at risk from earthquakes	1
Total	6
Relevant methods could include: <ul style="list-style-type: none"> • identification of plate tectonic boundaries and/or geological setting • analysis of historic earthquake occurrence • geological investigation of history of fault movement and shaking intensity • modelling of earthquake behaviour. Sample answer: By assessing historic records of earthquake activity, scientists can predict the frequency of earthquakes and the typical magnitude of earthquakes likely to occur in a given area. This can be used to predict any areas that might be at risk of potentially damaging earthquakes.	
Accept other relevant answers.	

- (b) State how the magnitude of an earthquake and distance from the earthquake's epicentre affect the intensity of ground shaking experienced. (2 marks)

Description	Marks
The higher the magnitude of the earthquake, the higher the intensity of ground shaking	1
The intensity of the ground shaking will decrease away from the epicentre	1
Total	2
Accept other relevant answers.	

Question 24 (continued)

- (c) Use labelled illustrations to demonstrate the way in which **two** different structural designs limit the amount of damage that occurs to a building during an earthquake. (4 marks)

Description	Marks
For each of two methods (2 marks each)	
Diagram accurately shows structural design	1
Identifies how design resists or absorbs ground movement	1
Total	4
<p>Answers could include:</p> <ul style="list-style-type: none"> • base isolation • cross bracing • pendulum seismic isolators. <p>Sample diagram:</p> <div style="text-align: center;"> <p>Building is positioned on rollers or suspension spring system that absorbs ground movement</p> </div>	
Accept other relevant answers.	

- (d) Outline **three** social and/or economic factors that might influence the design choices applied to construction in earthquake-prone areas. (3 marks)

Description	Marks
For each of three factors (1 mark each)	
<p>Relevant factors could include:</p> <ul style="list-style-type: none"> • cultural preference for one style of architecture over another • cultural preference for certain building materials • relative wealth – inhabitants being unable to afford complex engineering solutions • potential for corruption preventing enforcement of building and engineering codes • population density requiring high-rise living. 	1
Total	3
Accept other relevant answers.	

Question 25

(15 marks)

- (a) On the basis of the information provided, state a mineral resource that might be present in the area, and explain with the use of a labelled diagram how this type of resource forms. (4 marks)

Description	Marks
Correctly identifies a possible mineral resource formed at this location	1
Mechanism for alteration/resource formation identified	1
Mechanism for resource concentration/enrichment identified	1
Diagram clearly illustrates the chosen process, and is labelled appropriately	1
Total	4

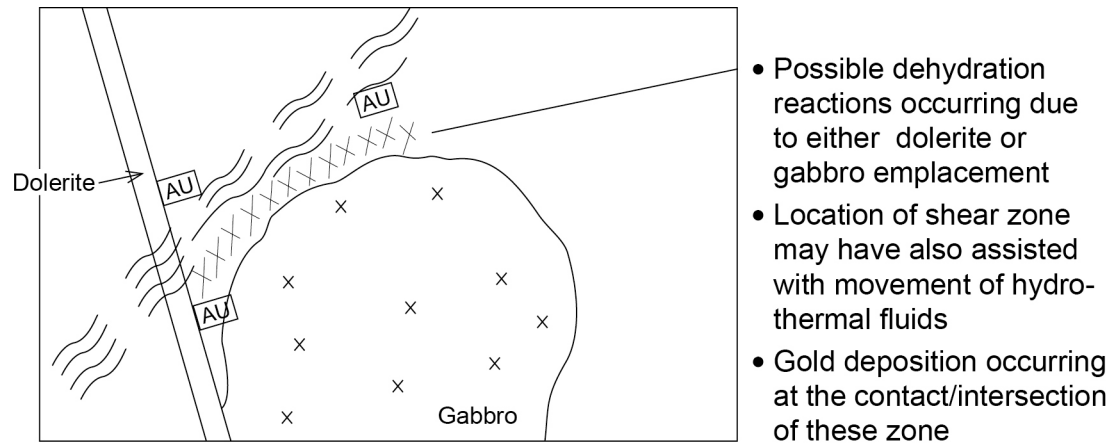
Viable resources could include:

- gold
- nickel
- copper

Sample answer:

- The resource target that this exploration program will investigate is gold mineralisation.
- The interaction between igneous intrusions and structure zones such as shear/fault zones or possibly the intruded dolerite may have driven hydrothermal fluid circulation leading to alteration of surrounding rocks. This could have resulted in formation of a hydrothermal gold deposit.

Sample diagram:



NB: drawn location or structural features/subsurface geological interpretation is not on assessable part, provided the explanation is geologically sound.

Note: A diagram by itself might be acceptable for full marks if it adequately delivers explanatory information as described above.

Accept other reasonable answers.

Question 25 (continued)

- (b) State, or label clearly on your diagram, **two** aspects of the local geology that lead you to believe this mineral resource identified in part (a) may be present in the area. (2 marks)

Description	Marks
For each of two aspects (1 mark each)	
Identifies an aspect of the geology shown in the map and drill logs that could be reasonably associated with the resource model defined in part (a)	1
Total	2
Answers could include: <ul style="list-style-type: none"> • diamond core samples illustrate gabbro and shear zones cross-cutting one another • geological map shows complex relationship between gabbro and shear zones cross-cutting one another • apparent trend in linear NW features possibly suggest a possible mechanism for hydrothermal fluid movement • a number of significant WA gold deposits are formed through the interaction of igneous material. 	
Accept other relevant answers.	

- (c) Provide a detailed exploration plan, working within the budget provided and involving **three** exploration techniques from the table.

Your plan should:

- include your target mineral
- state the order in which the chosen techniques would be applied
- describe how each technique should be undertaken and how the results would indicate whether the targeted resource type was likely to be present. (9 marks)

Description	Marks
Proposal does not exceed budget of \$3 000 000	1
Overall order and logic of exploration plan described	1
Chooses appropriate exploration methods for target mineral	1
Subtotal	3
For each of three exploration techniques (2 marks each)	
Describes how the exploration technique is undertaken	1
Describes and/or illustrates the response based on properties of the ore	1
Subtotal	6
Total	9
<p>Target resources could include:</p> <ul style="list-style-type: none"> • gold • nickel • copper-gold (VMS) <p>Exploration techniques: (must describe how the technique should be undertaken, no marks for naming technique)</p> <ul style="list-style-type: none"> • Remote sensing: Airborne craft are used to create a digital map of the land surface. It can be used for mapping mineral distribution. • Seismic surveys: These can be carried out by aircraft or on land. It involves the use of soundwaves being reflected off subsurface geology. It can be used to map the subsurface geology or geological structures. • Electromagnetic survey: Measures the electrical conductivity of a subsurface. Mostly used for nickel, copper, oil or gas exploration. • Gravity survey: Gravity surveys detect the differences in the pull of gravity caused by materials of differing density within the Earth. This technique is useful in structural geological mapping, gold, oil and gas exploration. • Magnetic survey: Magnetic surveys can be conducted on foot or by air depending on the scale needed. These surveys contrast the magnetic susceptibilities of target materials against the Earth's magnetic field. Mostly used for geological mapping, iron ore, gold and nickel exploration. • Radiometric survey: Airborne or ground surveys are used to detect the natural gamma radiation from Earth elements such as uranium. Useful tool for geological mapping. • Geological mapping: This exploration technique is used to gain a detailed understanding of the geology of the area. Geologist physically map the area to identify any smaller scale changes or influences in the rock types of the area. • Stream sampling: Sediment samples are collected from the main channel areas throughout the exploration area. Samples are analysed for trace amounts of ore minerals. Significantly less expensive than geochemical sampling. Can be used for most ore deposits. • Geochemical sampling: Mostly used for base metal or gold deposits. This technique takes samples of rock subsurface, generally across a grid like pattern of the exploration area. Used to map the subsurface zones of mineralisation. 	

Question 25 (c) (continued)

Sample answer:

Exploration techniques required:

1. Geological mapping: \$500 000
2. Gravity survey: \$1 000 000
3. Geochemical sampling (diamond): \$1 500 000

Total cost: \$3 000 000

Resource target:

- The resource target that this exploration program will investigate in gold mineralisation.
- The interaction between igneous intrusions and structure zones such as shear/fault zones or possibly the intruded dolerite may have been a mechanism for hydrothermal fluid and subsequent alteration of surrounding rocks. This could have resulted in a hydrothermal gold deposit forming.

Exploration techniques requested:

1. Gravity survey:

- In most cases this survey is conducted by aircraft flying over the exploration area. The aircraft has devices to detect the differences in the pull of gravity of materials within the Earth.
- In the area a gravity survey was chosen to study the subsurface interactions between Gabbro and shear zones. These areas could be a possible location for the gold mineralisation.

2. Geological mapping:

- A team of geologists will traverse the exploration area, mapping the geological boundaries. They will record rock type information and structural data such as dip and strike of rock units to enable them to create detailed geological cross sections of the target area.
- The geological mapping will focus on the contacts between the gabbro and the shear zones. The purpose of this is to understand the subsurface relationships of these rock units.
- After completing the mapping and gravity survey, the exploration team will be better placed to understand the potential controls on mineralisation. If the shear zones dip to the East (towards the gabbro), gold mineralisation is more possible.

3. Geochemical sampling:

- The process of diamond drilling cuts cylindrical, continuous length of solid bedrock (core samples). These sections are placed into core trays for geologists to log (mark geological contacts and features). Samples of this core will be then sent to a processing lab to determine if it contains any ore material.
- This drill program will be planned to investigate areas where the shear zone and gabbro intersect.
- Geochemical analysis of the core samples will indicate if mineralised material containing high concentrations of gold is present. A 3D model can be created of any zones of mineralisation.

Accept other relevant answers.

Question 26

(15 marks)

- (a) Using the information provided and your own knowledge, compare the relative geological suitability of the three locations proposed for a radioactive waste storage facility. (6 marks)

Description	Marks
For each of three locations (2 marks each)	
Outlines the suitability of the location	1
Justifies suitability of location based on information provided	1
Total	6
Answers could include: <ul style="list-style-type: none"> • Location B is not suitable as it is located along a major active fault structure so is prone to earthquakes • Location C is not suitable as igneous rocks are relatively impermeable and so nominally suited to storage of nuclear waste, but in this case the environment is still volcanically active, and prone to erosion, so site is at risk of disturbance • Location A is the most suitable as it is the most geologically stable of the options. Accept other relevant answers.	

- (b) For the location you identify as the most suitable, identify a property of this site that presents a potential risk for radioactive waste storage, and outline **two** techniques that could be used to mitigate this risk. (3 marks)

Description	Marks
Identifies a property of the chosen location that presents a potential risk for radioactive waste storage	1
Clearly outlines up to two techniques that could mitigate the risk identified	1–2
Total	3
For the expected answer of location A, properties posing potential risk could include: <ul style="list-style-type: none"> • permeable nature of some local sedimentary rocks could allow groundwater to penetrate the facility • boundaries between different lithologies might act as fluid pathways • sediments might host groundwater aquifer that could be exposed to radioactive waste • varied sediments might include weak lithologies that present a risk of failure. Potential mitigation techniques could include: <ul style="list-style-type: none"> • for potential rock strength issues, conduct a detailed geological survey which may include geotechnical surveys to determine the stability of the underlying formation. • aerial photography to identify local-scale geological features such as minor faults or stress zones • engineering works to strengthen the walls of the storage facility and/or create impermeable barriers to prevent ground water interacting with the waste. Sample answer: Location A is in a region of varied sedimentary strata that could include weak horizons that would be at risk of failure. This risk could be mitigated by (1) conducting detailed geological surveying of the proposed site to evaluate the local sediments and ensure the facility was sited within a relatively strong and impermeable lithology, and (2) planning strengthening works for the walls of the facility to ensure the rock walls were stable and able to accommodate expected stress levels.	
Note: Alternative answers will be assessed on the logic of the arguments presented.	

Question 26 (continued)

- (c) Outline **two** social or political factors that may be relevant to the location of a radioactive waste storage facility. (2 marks)

Description	Marks
For each of two factors (1 mark each)	
Outlines a social or political factor relevant to the location of a radioactive waste storage facility	1
Total	2
<p>Answers could include:</p> <p>Social factors</p> <ul style="list-style-type: none"> • proximity to ecologically or culturally significant area • close to human population <p>Political factors</p> <ul style="list-style-type: none"> • most suitable location may be in a neighbouring state and/or country • political influence on the location of the waste material. 	

- (d) Other than issues connected with the waste disposal, state **two** advantages and **two** disadvantages of using nuclear power over fossil fuels as a source of electricity. (4 marks)

Description	Marks
For each of two advantages (1 mark each)	
States an advantage of using nuclear power over fossil fuels	1
Subtotal	2
For each of two disadvantages (1 mark each)	
States a disadvantage of using nuclear power over fossil fuels	1
Subtotal	2
Total	4
<p>Answers could include:</p> <p>Relative advantages of using nuclear power</p> <ul style="list-style-type: none"> • lower greenhouse emissions • less disruptive to the environment • lower cost per unit production of power • higher energy density – lots of energy from relatively little fuel • more sustainable than fossil fuels due to rate of replenishment <p>Relative disadvantages of using nuclear power</p> <ul style="list-style-type: none"> • higher initial set-up cost • more politically sensitive • risk in transporting nuclear fuel in built-up areas • more vulnerable to catastrophic failure. <p>Accept other relevant answers.</p>	

ACKNOWLEDGEMENTS

Question 16(b) Adapted from: Guerin, L. (2013). *The sun's rays & latitude* [Diagram]. Retrieved September, 2021, from https://dr282zn36sxxg.cloudfront.net/datastreams/f-d%3A768b0173ecea16504f4d5dce5bc41fc6bb39c96b0c596ed9efb015da%2BIMAGE_THUMB_POSTCARD_TINY%2BIMAGE_THUMB_POSTCARD_TINY.1
Used under a Creative Commons Attribution-NonCommercial 3.0 Unported licence.

This document – apart from any third party copyright material contained in it – may be freely copied, or communicated on an intranet, for non-commercial purposes in educational institutions, provided that it is not changed and that the School Curriculum and Standards Authority is acknowledged as the copyright owner, and that the Authority's moral rights are not infringed.

Copying or communication for any other purpose can be done only within the terms of the *Copyright Act 1968* or with prior written permission of the School Curriculum and Standards Authority. Copying or communication of any third party copyright material can be done only within the terms of the *Copyright Act 1968* or with permission of the copyright owners.

Any content in this document that has been derived from the Australian Curriculum may be used under the terms of the Creative Commons [Attribution 4.0 International \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) licence.

An *Acknowledgements variation* document is available on the Authority website.

*Published by the School Curriculum and Standards Authority of Western Australia
303 Sevenoaks Street
CANNINGTON WA 6107*