Government of **Western Australia**
School Curriculum and Standards Authority

ATAR course examination, 2021

Question/Answer booklet

EARTH AND ENVIRONMENTAL SCIENCE

Please place your student identification label in this box

WA student number: In figures

In words

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Multiple-choice answer sheet

Number of additional answer booklets used (if applicable):

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: protractor, drawing compass, mathomat, up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

2022/5844
Web version of 2021/61808

Ref: 21-023

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Multiple-choice	15	15	20	15	15
Section Two Short answer	8	8	100	110	55
Section Three Extended answer	3	2	60	30	30
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2021: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. Do not use erasable or gel pens. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer booklet.

3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

5. The tear-out page is not to be handed in with your Question/Answer booklet.

See next page

Section One: Multiple-choice **15% (15 Marks)**

This section has **15** questions. Answer **all** questions on the separate Multiple-choice answer sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. Do not use erasable or gel pens. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 20 minutes.

---

1. Which of the following is **not** an ecosystem regulating service?

   (a) nutrient cycling
   (b) water purification
   (c) pollination of crops
   (d) dispersal of seeds by wind

2. Which of the following statements is correct, according to the table below?

	Monthly streamflow in gigalitres (GL)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2016	0.11	0.14	0.22	0.52	2.02	4.25	9.18	25.5	35.3	44.1	47.2	48.1
2017	0.81	1.75	1.95	2.66	3.86	6.3	19.6	66.7	85.4	93.4	96.9	98.4
2018	1.77	2.21	3.14	3.68	5.53	11.7	40	105	122	131	134	136
2019	0.51	0.64	0.69	0.95	0.95	4.95	13.9	22.7	39.3	42.9	43.7	44.4
2020	0.7	0.7	0.7	0.7	0.7	4.33	4.33	13.8	27.5	31.2	34.9	35.6

   (a) The median streamflow for August was higher than the median streamflow for December.
   (b) The mean streamflow for 2018 was lower than the mean streamflow for 2019.
   (c) The median streamflow for May was 2.02 GL.
   (d) The mean streamflow for August was 25.5 GL.

3. Which of the following lists is composed entirely of actively managed renewable resources?

   (a) dairy farming, coal mining, geothermal energy
   (b) geothermal energy, solar energy, wind energy
   (c) wheat farming, timber harvesting, commercial fishing
   (d) timber harvesting, bioenergy, wave energy

See next page

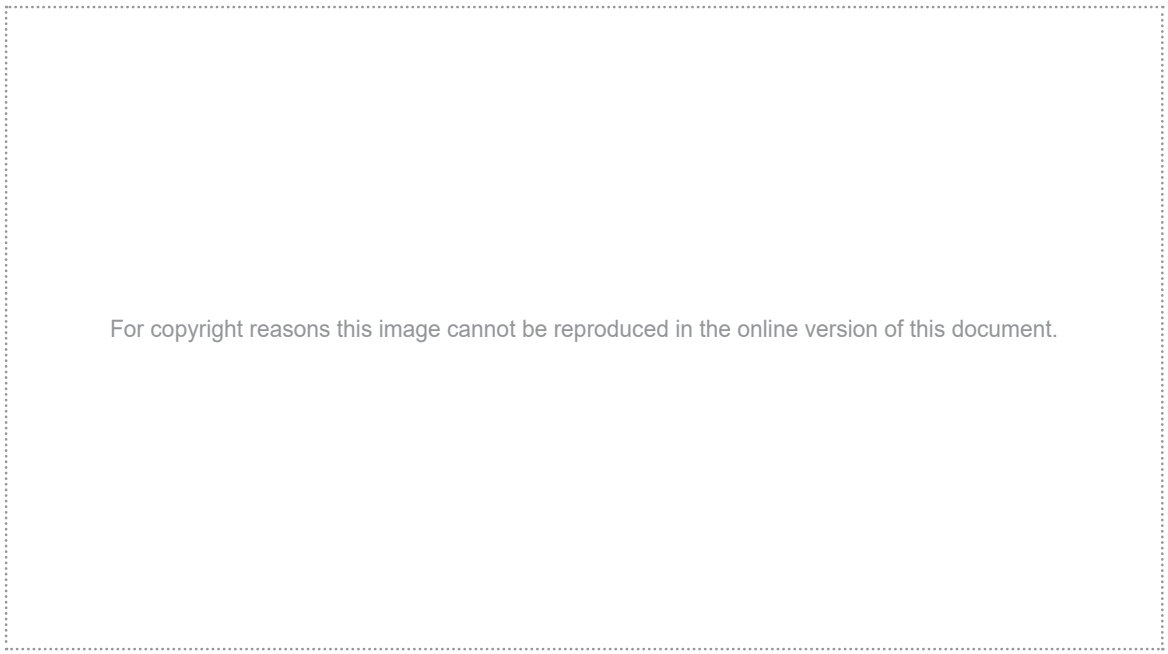
4. A method used to prevent the contamination of a local water resource from a tailings dam is to

   (a) actively monitor bore holes.
   (b) line the dam with clay.
   (c) surround the tailings facility with trees.
   (d) bring in water from a different source by tanker.

5. The characteristics of an ideal groundwater aquifer include

   (a) high porosity and low permeability.
   (b) low porosity and high permeability.
   (c) high porosity and high permeability.
   (d) low porosity and low permeability.

6. Tectonic plates move slowly across the surface of the Earth. Plate boundaries form where these plates meet and create earth hazards such as volcanic eruptions and earthquakes.



Earthquakes
S Shallow-focus earthquakes
M Medium-focus earthquakes
D Deep-focus earthquakes

—— Plate boundary
⟶ Direction of plate movement

The earthquake pattern shown in the diagram above illustrates that

   (a) medium-focus earthquakes occur only on continental landmasses.
   (b) deep-focus earthquakes occur only at convergent plate boundaries.
   (c) the depth of an earthquake is not associated with plate boundary interaction.
   (d) shallow-focus earthquakes occur only at divergent plate boundaries.

See next page

7. Tropical cyclones form due to

(a) heating of the sea surface, resulting in strong vertical movement of water vapour-laden air.
(b) heating of the sea surface, resulting in strong horizontal movement of dry air.
(c) cooling of the sea surface, resulting in powerful storms.
(d) areas of low pressure air moving toward islands.

8. The four primary greenhouse gases are

(a) ozone, nitrous oxide, carbon dioxide and propane.
(b) water vapour, methane, carbon dioxide and nitrogen.
(c) water vapour, ozone, carbon monoxide and chlorofluorocarbons.
(d) methane, carbon dioxide, nitrous oxide and water vapour.

9. Which of the following **best** describes the ecological footprint of a wheat farm?

(a) the physical land area that is occupied by the crop
(b) the native ecosystem that has been replaced by the wheat crop
(c) the amount of CO_2 emissions created by the cultivation and processing of the crop
(d) all resources used to produce, harvest, transport and process the crop

10. An El Niño event affecting eastern Australia is likely to cause increased

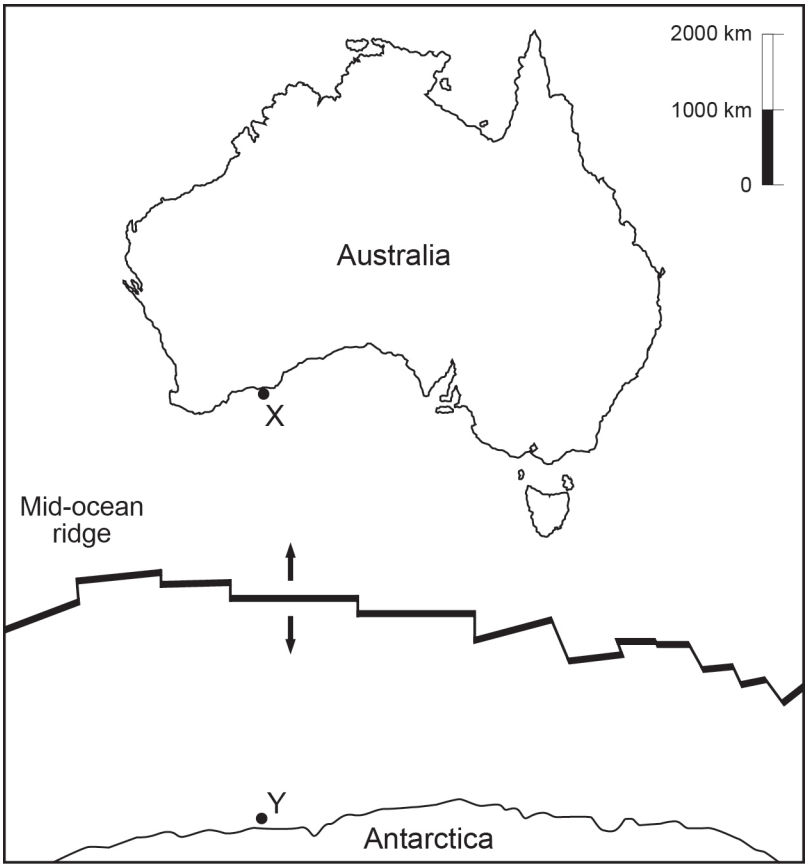
(a) trade winds.
(b) number and/or severity of bushfires.
(c) flooding.
(d) number of tropical cyclones.

11. Australia has experienced an increase in the area affected by saline soils since the 1800s. Which of the following is responsible for this increase?

(a) evaporation of inland water bodies
(b) use of fertilisers on crops
(c) transportation of salt from the oceans to inland areas
(d) clearing of trees and irrigation of crops

See next page

12. The image below shows the coastlines of Australia and Antarctica and the mid-ocean ridge between them.



The age of the oceanic crust at locations X and Y is approximately 80 million years. If the rate of movement between these two continents has remained constant, how fast are the two moving **apart**?

(a) 7 cm/year
(b) 14 cm/year
(c) 70 cm/year
(d) 140 cm/year

13. The **most** likely climatic impact of a major episode of flood basalt volcanism is

(a) increased rainfall, due to water vapour being emitted during the eruption.
(b) warming, due to the release of gases such as carbon dioxide into the atmosphere.
(c) cooling, due to lahar flows followed by a period of warming due to volcanic bombs.
(d) a period of warming, due to ash circulating above the eruptive vents.

See next page

14. The ‘global ocean conveyor’ system of currents cycling water within the Earth’s oceans is driven primarily by

(a) the warm pool of water in the central Pacific Ocean.
(b) global wind systems.
(c) differences in the temperature and salinity of ocean waters.
(d) the melting of sea ice in the Northern Hemisphere.

15. Tectonic movement has resulted in the Earth’s landmasses being joined into a single supercontinent several times during the Earth’s history. The geological records of such periods show that supercontinent formation causes

(a) large areas of desert.
(b) the evolution of flowering plants.
(c) the growth of ice sheets at the poles.
(d) an increased frequency of earthquakes.

End of Section One

See next page

Section Two: Short answer **55% (110 Marks)**

This section has **eight** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 100 minutes.

Question 16 **(16 marks)**

All activity within the atmosphere and life on Earth relies on energy from the Sun. The orientation of the Earth and ocean currents contribute to the distribution of this energy and the global heat budget.

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

One: _____

Two: _____

Three: _____

(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)

Australia experienced a La Niña event in 2020 and continues to be affected by La Niña conditions in 2021.

(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)

(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)

One: _____

Two: _____

Three: _____

See next page

Question 17 **(12 marks)**

Iron ore extracted from banded iron deposits accounts for over half of Western Australia's combined mineral and petroleum exports by value each year.

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

See next page

(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)

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

One:

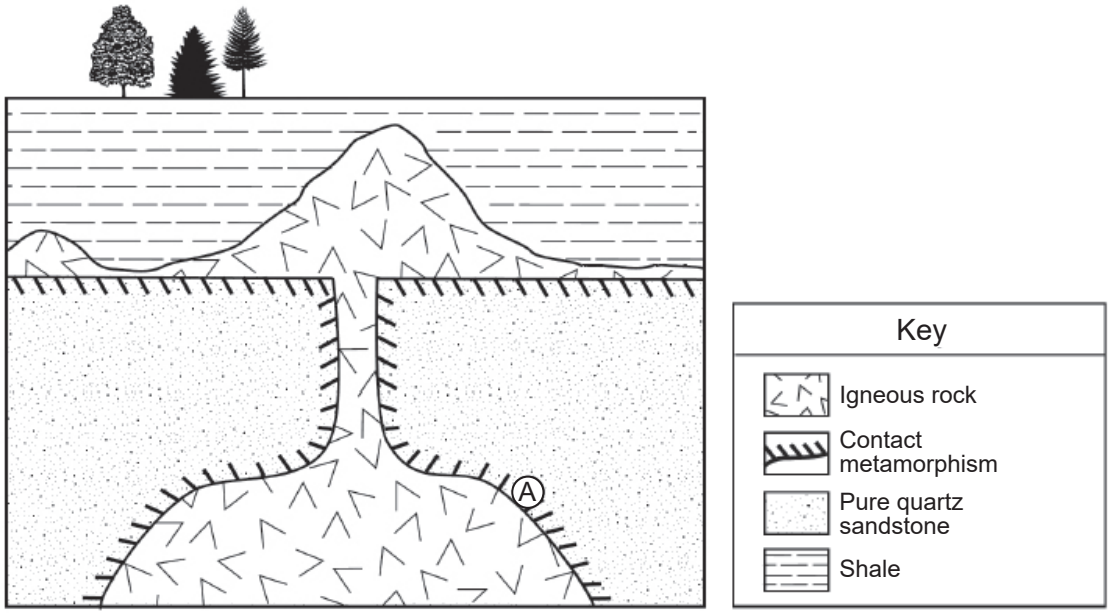
Two:

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)

Characteristic feature of schist	How this characteristic distinguishes schist from other metamorphic rock type(s)

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



See next page

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

Metamorphic rock: _____

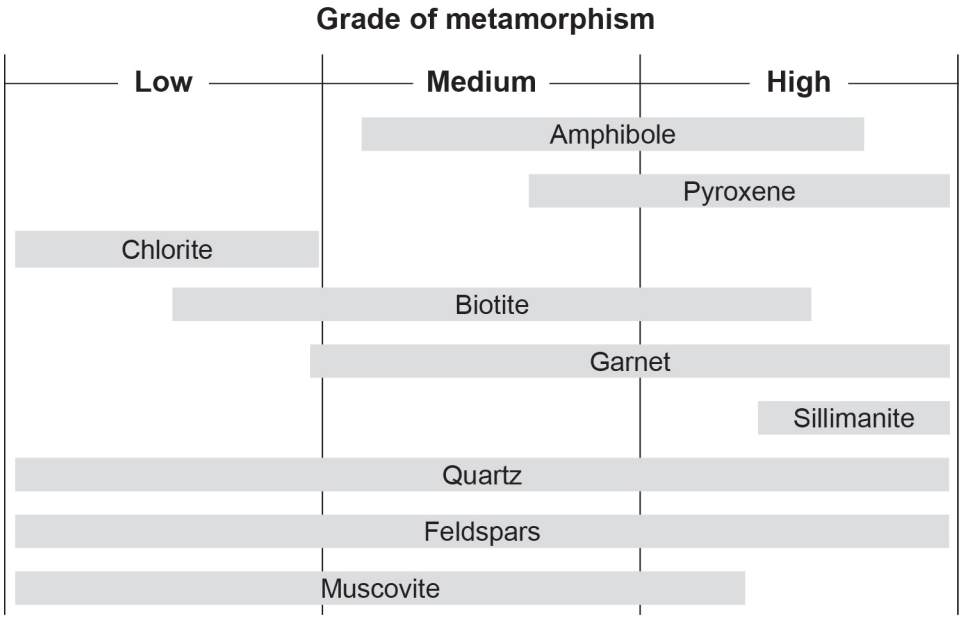
One: _____

_____

Two: _____

_____

(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)

_____

_____

_____

_____

Question 18 (continued)

(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)

_____

(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)

Light-coloured layers: _____

_____

Dark-coloured layers: _____

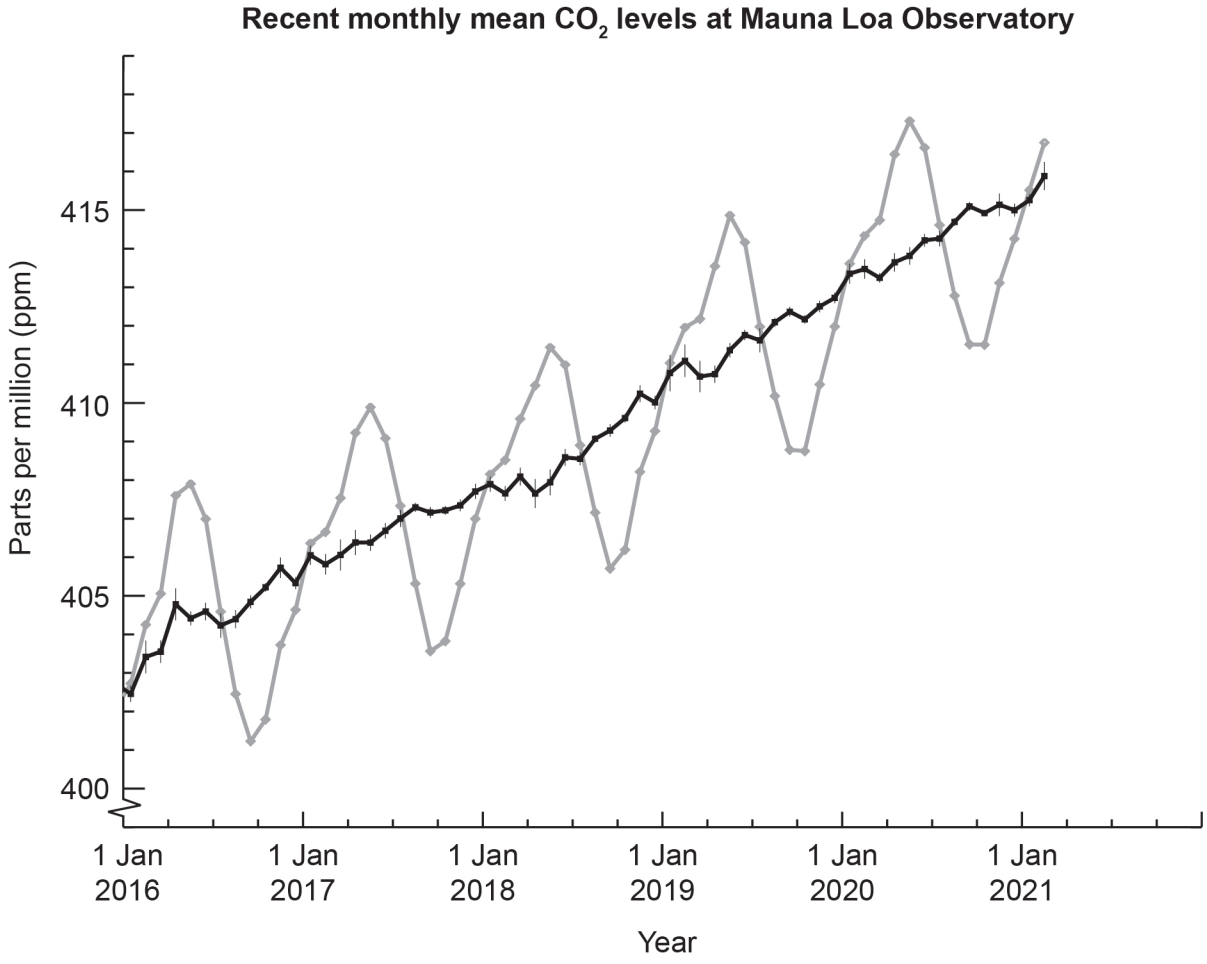
_____

See next page

Question 19 **(17 marks)**

Both the geological record and historic measurements contribute to our understanding of climate fluctuation over time. The Mauna Loa Observatory is a remote monitoring station located on the Big Island of Hawaii where atmospheric carbon dioxide levels have been recorded continuously since 1958.

The Keeling curve, shown in the graph below, is a record of carbon dioxide measurements at this observatory.



The grey curve represents monthly mean values of CO_2 measurements, and the black curve represents the same data corrected by removal of the average seasonal cycle of variation.

(a) Describe a benefit of having a measuring station for atmospheric CO_2 in a remote location. (2 marks)

See next page

Question 19 (continued)

(b) Describe the cause of the monthly fluctuation in CO_2 levels seen in the Keeling curve graph. (2 marks)

Scientists gather longer-term records of changing climate through measuring the relative proportions of different isotopes of oxygen in marine sediments.

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

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

Historical timescale:

Geological timescale:

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

See next page

Question 20 **(11 marks)**

Western Australia's managed aquifer recharge system aims to protect human health and the environment by injecting recycled water into selected aquifers.

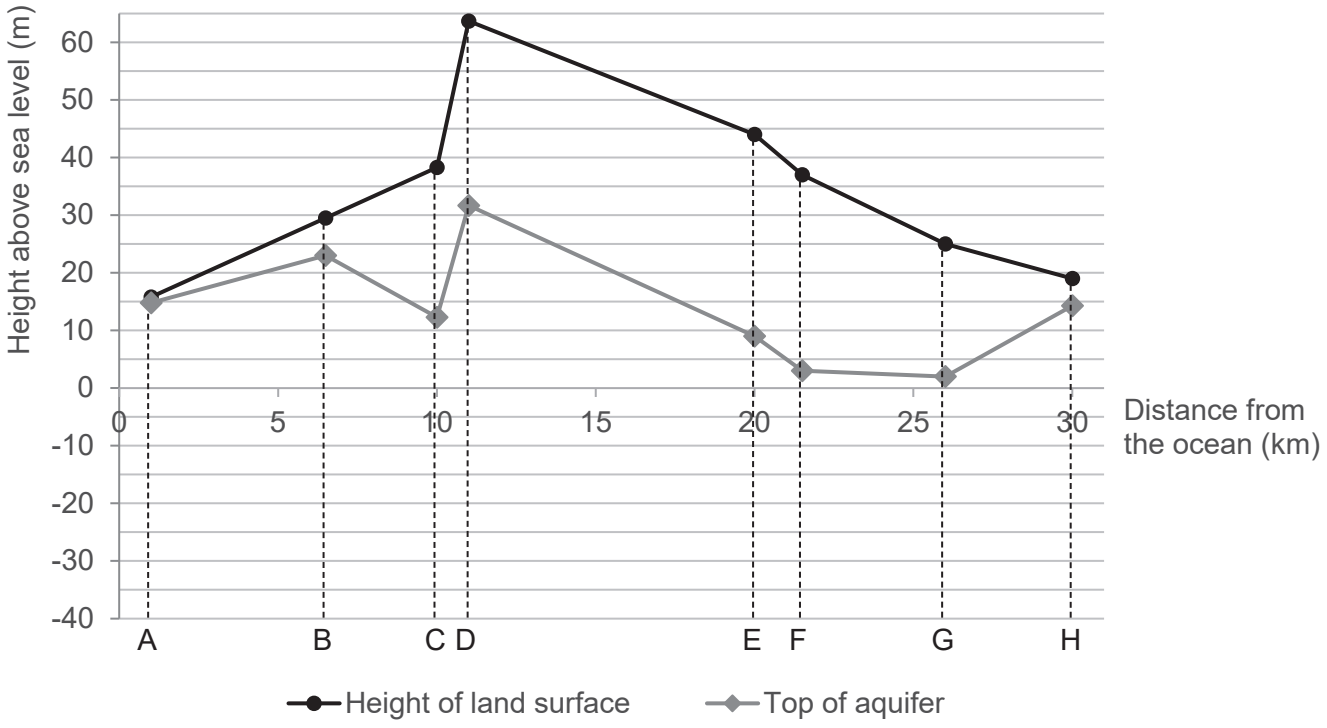
Depth of water table below the surface at selected locations across Perth

Location	Height of land surface above sea level (surface topography)	Depth to water table from surface	Thickness of aquifer
A	15.8	1	31
B	29.5	6.5	31
C	38.3	26	46
D	63.7	32	52
E	44	35	45
F	37	34	29
G	25	23	28
H	19	4.7	9.8

Note: All measurements in the table are recorded in metres (m).

The graph below shows the relative elevations of the height of land surface and the top of the aquifer at each location in the above table.

Relative elevations at Perth locations



See next page

The base of the aquifer at location A is 16.2 metres below sea level.

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

(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)

(c) Identify the location where

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

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

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

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

(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)

See next page

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)

(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)

See next page

(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)

Tsunami: _____

Volcanic eruption: _____

(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)

See next page

Question 22 **(14 marks)**

An environmental organisation is working to rehabilitate an area of degraded brushtail possum habitat in the Pilbara region. As part of its ongoing work, it monitors the populations of a number of key native and introduced species, including wild dogs and feral cats.

Feral cats were not present in the area when the organisation began its work in 2001, and were first identified in faunal surveys in 2002, when two cats were believed to be present.

The table below shows the estimated population of feral cats in the area from 2001 to 2013.

Year	2001	2002	2004	2005	2006	2008	2010	2011	2013
Estimated number of cats present	0	2	2	6	21	18	20	5	2

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

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

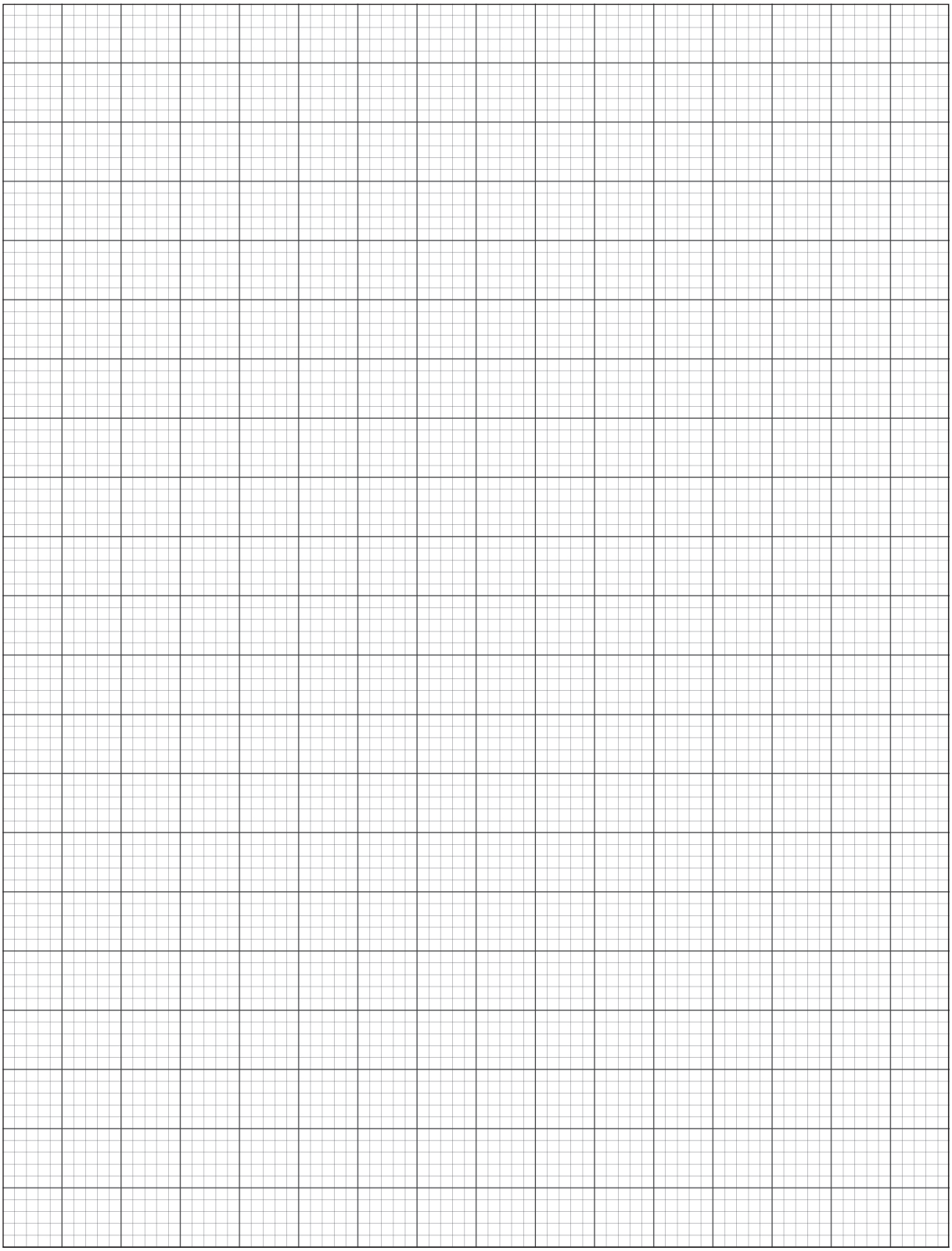
(c) No active control measures were ever implemented to reduce cat numbers, but in 2010 the organisation stopped shooting wild dogs in the area. Identify **two** features observed in the number of cats from 2010 onward. (2 marks)

One:

Two:

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

See next page



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

See next page

Question 22 (continued)

A brushtail possum is a small tree-dwelling marsupial.

(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)

Relationship: _____

_____

Reason: _____

_____

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

Relationship: _____

_____

Reason: _____

_____

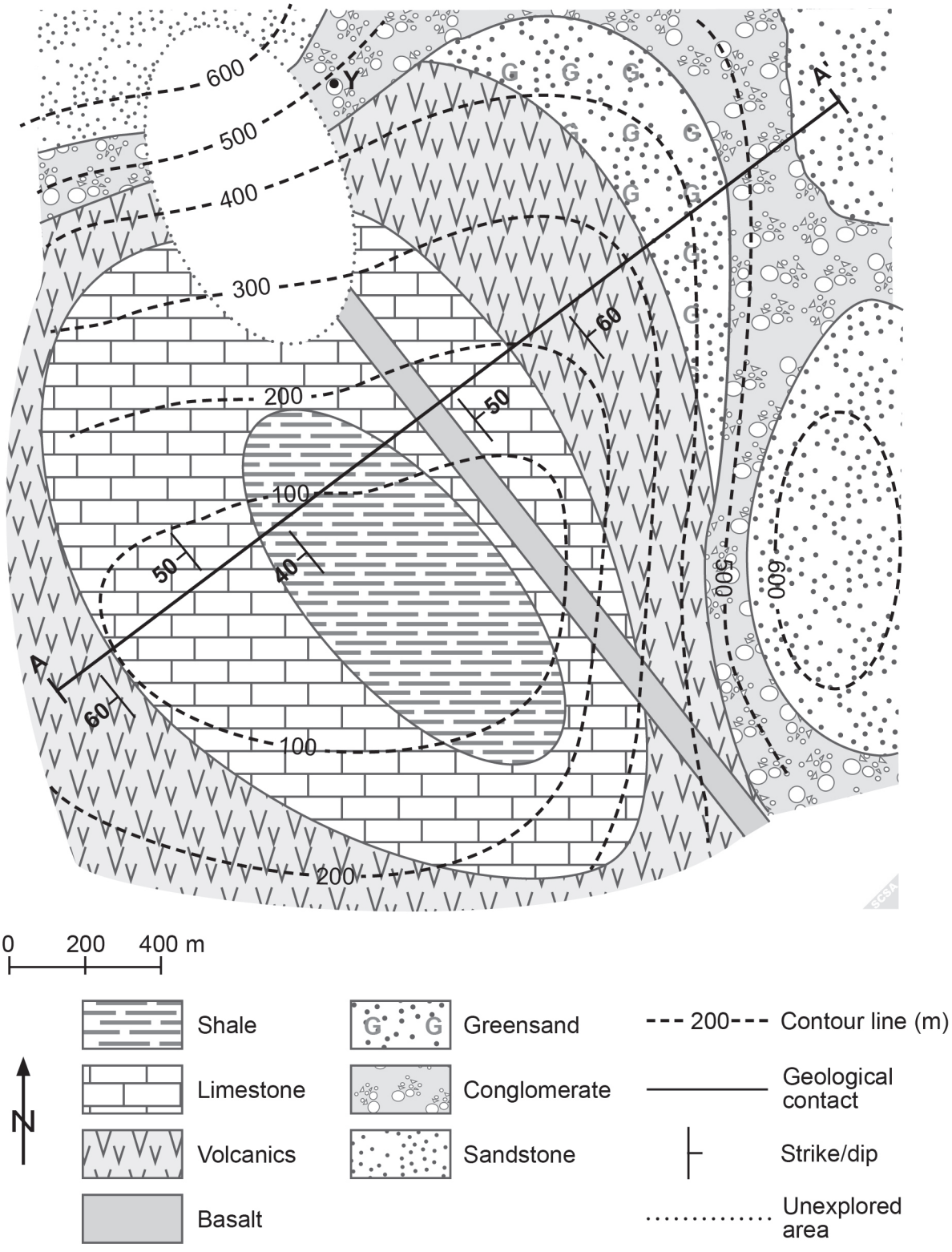
See next page

This page has been left blank intentionally

See next page

Question 23 **(12 marks)**

The accompanying map displays the known geology for an area you are investigating. Use this to answer the following question parts.



See next page

(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)

A spare section line is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare section line.

(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)

First lithology: _____

Second lithology: _____

Third lithology: _____

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

_____

(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)

See next page

Question 23 (continued)

(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)

(ii) the basalt is younger than the conglomerate. (1 mark)

End of Section Two

See next page

Section Three: Extended answer **30% (30 Marks)**

This section contains **three** questions. You must answer **two** questions: the compulsory question (Question 24) and one of the other questions (Question 25 or Question 26). Write your answers on the pages provided following Question 26.

If you use a page for planning, indicate this clearly at the top of the page.

Suggested working time: 60 minutes.

Question 24 **(15 marks)**

Intense ground shaking caused by earthquakes creates substantial hazards to human life and infrastructure. Advances in scientific research and engineering have led to the development of a range of techniques that can help protect communities against these hazards.

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

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

(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)

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

See next page

Question 25 **(15 marks)**

As the senior geologist, your company has provided you with a budget of up to $3 000 000 for a new exploration plan. The geological map and two historical drill logs on page 31 are the only information currently available for this region. The table below lists the projected costs of applying a range of different exploration techniques.

(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)

(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)

(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)

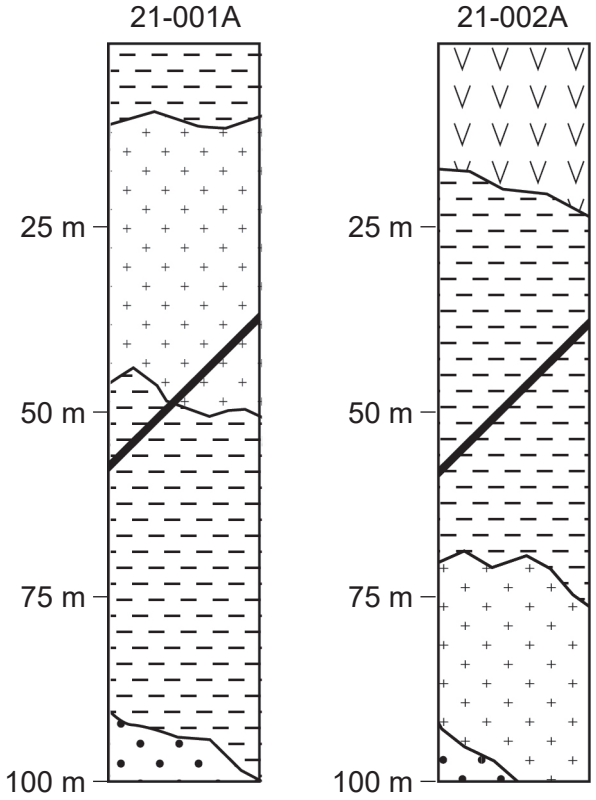
Exploration costs

Exploration technique	**$**
Remote sensing	500 000
Seismic surveys	1 500 000
Electromagnetic survey	1 000 000
Gravity survey	1 000 000
Magnetic survey	1 000 000
Radiometric survey	1 000 000
Geology mapping	500 000
Stream sampling	500 000
Geochemical sampling	
RC drill sampling	1 000 000
Diamond drill sampling	1 500 000

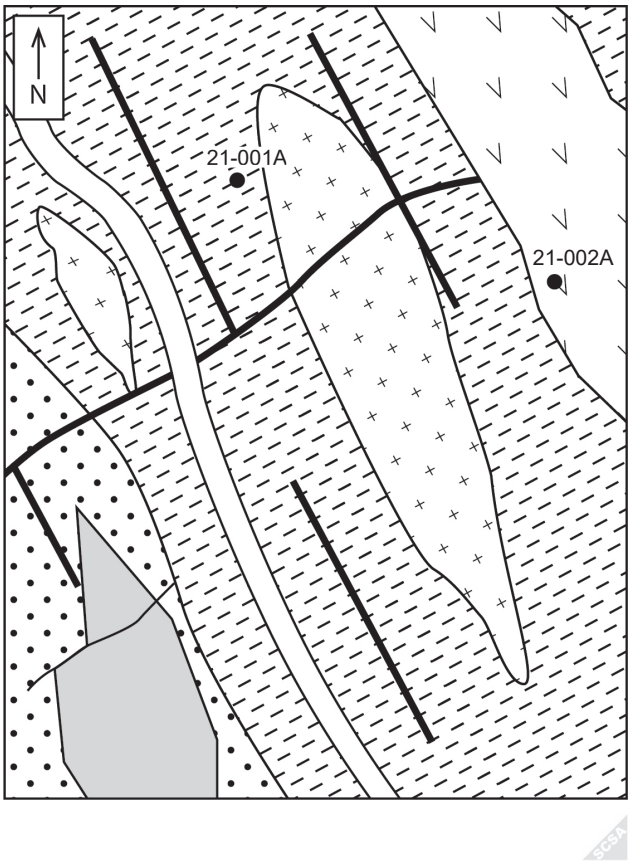
Project budget = $ 3 000 000

See next page

Diamond drill logs



Geological map



Map key

- Gabbro
- Basalt
- Dolerite
- Shale
- Siltstone
- Sandstone
- Shear zone (fault)
- Drill hole location

Scale 0 500 m 1000 m

or

See next page

Question 26 **(15 marks)**

Radioactive waste is produced around the world in nuclear reactors used to generate electricity. This waste needs to be processed into a stable form and then transferred to a final storage destination.

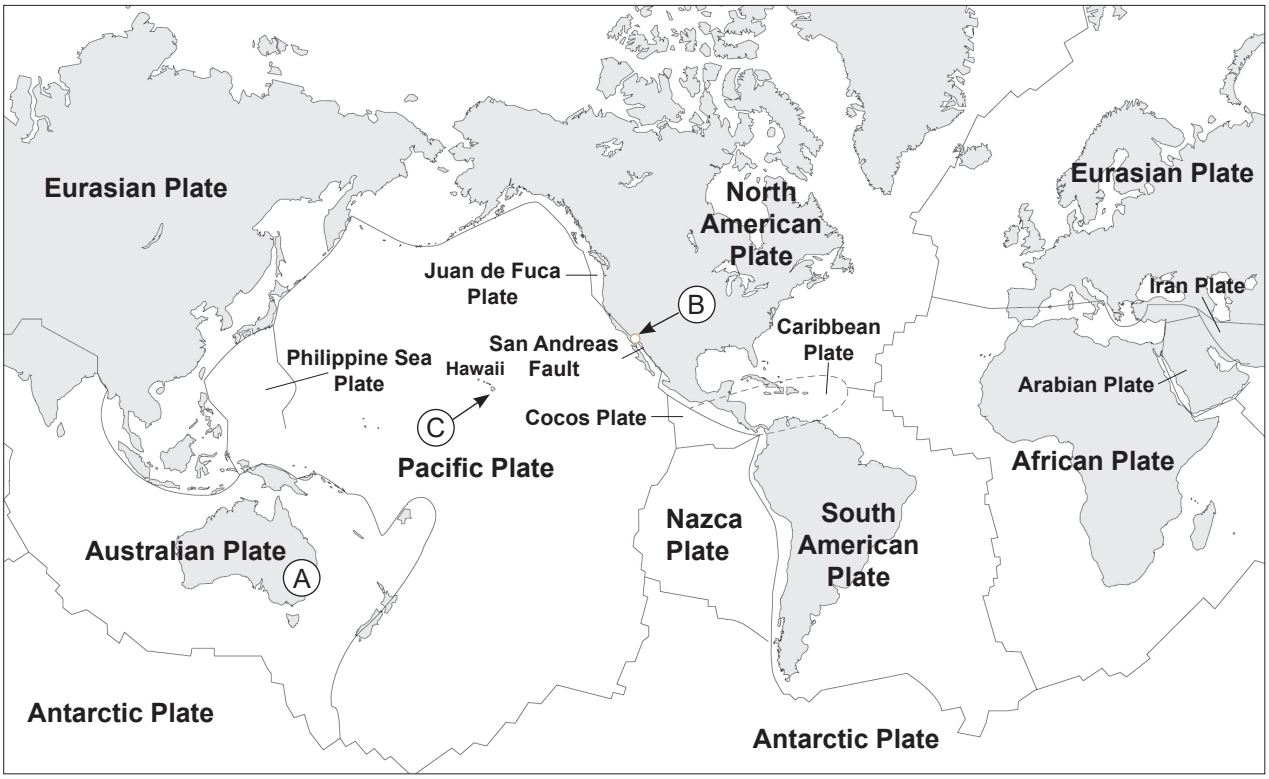
The preferred characteristics of storage locations for radioactive waste include the following:

- deep below the surface
- within a geologically stable environment
- within a rock formation of low permeability, such as granite, welded tuff, basalt, salt or clay
- where surrounding rock is able to dissipate heat and contain any radiation leaking out
- within a coherent stratigraphic unit at least 100 m thick
- somewhere water will not enter the vessel in which the waste is stored.

Potential radioactive waste storage locations

Location	A	B	C
Elevation above sea level	155 m	2692 m	4207 m
Tectonic setting	Eroded margin	Plate boundary	Active volcanism
Rock type	Sedimentary	Sedimentary	Igneous
Rock formation	Sandstone Quartz-rich sandstone Siltstone	Sandstone Siltstone	Basalt

Global tectonic map showing the location of proposed radioactive waste storage sites



See next page

(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)

(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)

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

(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)

End of questions

Question number: _____

Question number: _____

Question number: _____

Question number: _____

Question number: _____

Question number: _____

Question number: _____

Question number: _____

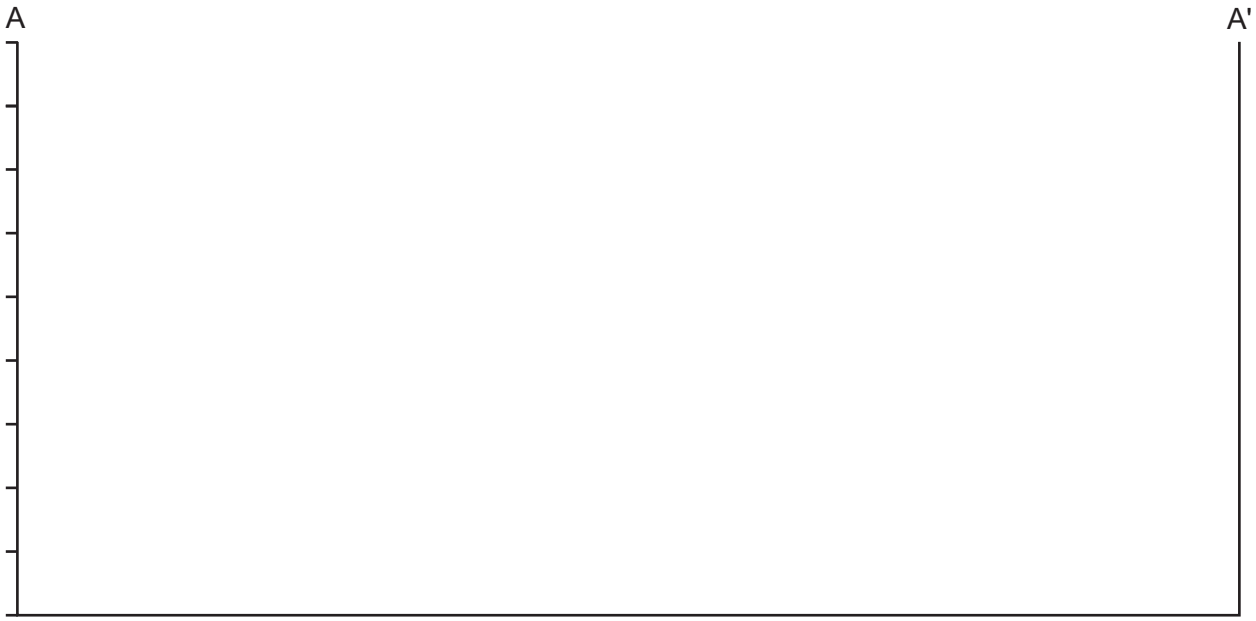
Supplementary page

Question number: _____

Supplementary page

Question number: _____

Spare section line



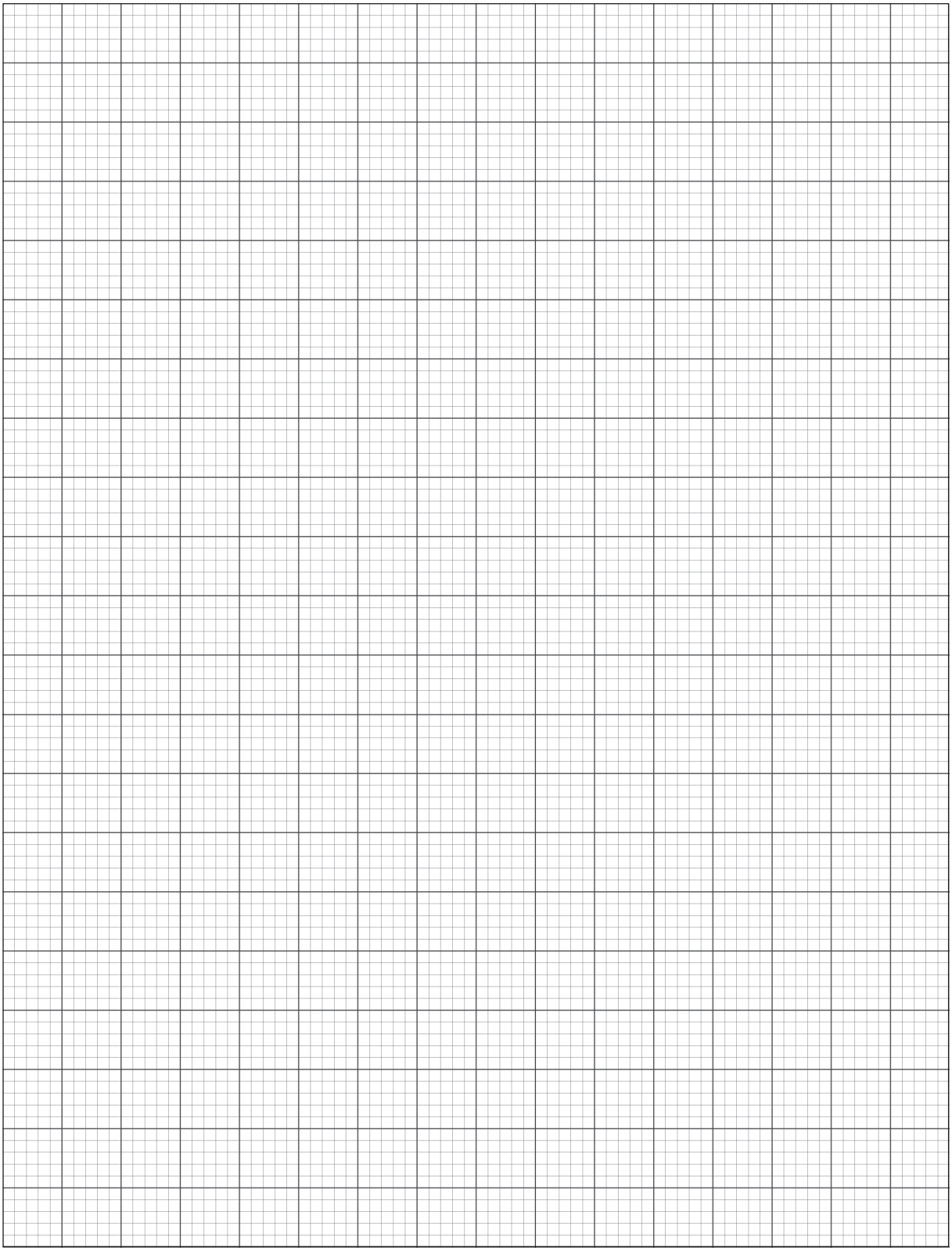
You may tear along the perforations to use this page (to transcribe strata locations for Question 23).

This page is to be used for transcribing strata locations only

You may tear along the perforations to use this page (to transcribe strata locations for Question 23).

This page is to be used for transcribing strata locations only

Spare grid



ACKNOWLEDGEMENTS

Question 2 Data adapted from: Water Corporation. (2021). *Streamflow* [Data]. Retrieved May, 2021, from https://www.watercorporation.com.au/Our-water/Rainfall-and-dams/Streamflow

Question 6 Adapted from: Almberg, L., Batt, G. E., Cahill, M., et al. (2016). Fig. 5.13: Approximate rate of plate movement and directions based on GPS measurements [Diagram]. *Exploring earth and environmental science*. Earth Science Western Australia, p. 108.

Question 18(b) Adapted from: HMXEarthScience. (2013). [Diagram of cross section of metamorphic rock formation]. *Practice questions: Metamorphic rocks*. Retrieved May, 2021, from https://hmxearthscience.com/Sammartano/METAMORPHIC/Teacher%27s%20Copy.pdf

Question 18(d) Adapted from: [Diagram of metamorphic rock]. (n.d.). Retrieved May, 2021, from https://hmxearthscience.com/Sammartano/METAMORPHIC/Teacher%27s%20Copy.pdf

Question 19 Adapted from: NOAA Global Monitoring Laboratory. (2021). *Recent monthly mean CO_2 at Mauna Loa observatory* [Graph]. Retrieved May, 2021, from https://gml.noaa.gov/ccgg/trends/

Question 20 Data from: Water Corporation. (2021). *Groundwater report* (Various suburbs: Depths). Retrieved May, 2021, from https://maps.water.wa.gov.au/Groundwater/

Question 26 Adapted from: USGS (U.S. Geological Survey). (n.d.). [Diagram of tectonic plates on world map]. Retrieved May, 2021, from https://mynasadata.larc.nasa.gov/lesson-plans/modeling-plate-tectonics-and-volcanoes

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