

EARTH AND SPACE SCIENCES

Wednesday, August 19, 2026 — 8:30 to 11:30 a.m., only

Student Name _____

School Name _____

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

Print your name and the name of your school on the lines above.

Use your knowledge of **Earth and Space Sciences** to answer all questions in this examination. Before you begin this examination, you must be provided with the **2024 Edition Reference Tables for Earth and Space Sciences**. You may need to use these reference tables to answer some of the questions.

You are to answer all questions in this examination. You may use scrap paper to work out the answers to the questions, but be sure to record your answers on your answer sheet and in your test booklet. A separate answer sheet for multiple-choice questions has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers for the constructed-response questions in your test booklet.

All answers in your test booklet should be written in pen, except for graphs and drawings, which should be done in pencil.

When you have completed the examination, you must sign the declaration printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and test booklet cannot be accepted if you fail to sign this declaration.

NOTICE ...

A four-function or scientific calculator and a copy of the **2024 Edition Reference Tables for Earth and Space Sciences** must be available for you to use while taking this examination.

Note that diagrams are not drawn to scale unless otherwise noted.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Base your answers to questions 1 through 4 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**. Be sure to record your answers for multiple-choice questions on the separate answer sheet provided. Record your answers for constructed-response questions in your test booklet.

Cyclic Patterns

Knowing how much tides will rise and fall each day is important to mariners, fishermen, and people who operate seaside industrial and commercial facilities. Predicting the tides is actually very complicated because many factors influence tides, such as the shape of the coastline, the flow of currents, and even the weather.

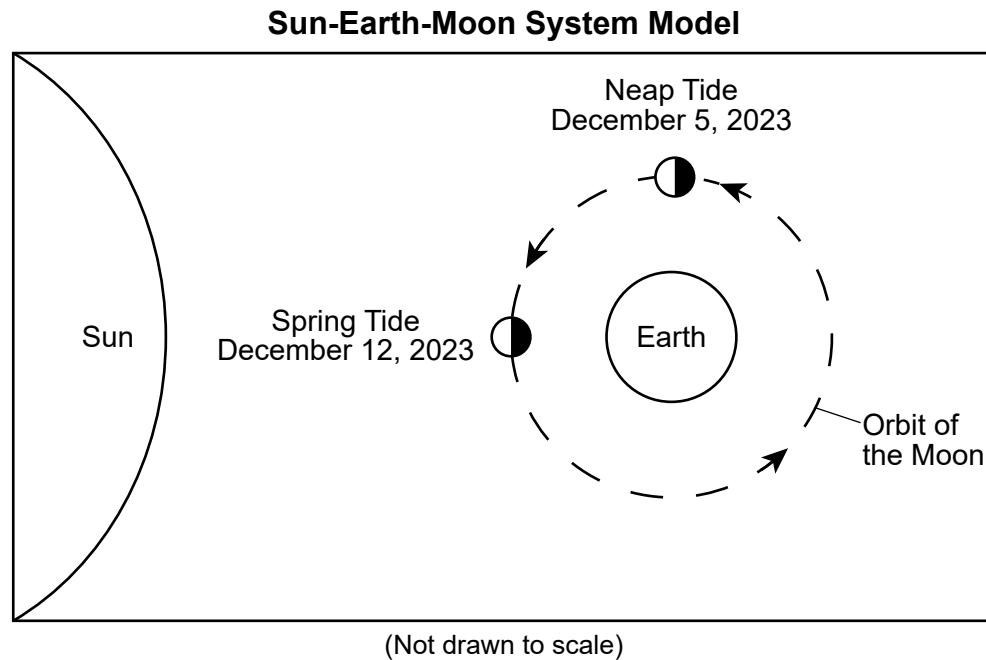
The table below shows the times and water levels for tides at a location in New York State. Water levels are relative to local standard elevations (average sea level).

Jones Inlet, NY, Tide Data December 6 – 16, 2023

Date		High				Low			
		a.m.	ft	p.m.	ft	a.m.	ft	p.m.	ft
6	Wed	1:56	3.1	1:56	3.0	8:04	0.9	8:32	0.5
7	Thu	2:45	3.2	2:48	3.0	9:02	0.8	9:18	0.4
8	Fri	3:34	3.4	3:44	3.0	9:53	0.6	10:01	0.3
9	Sat	4:22	3.6	4:37	3.1	10:41	0.3	10:43	0.2
10	Sun	5:06	3.9	5:25	3.2	11:28	0.1	11:25	0.1
11	Mon	5:47	4.1	6:09	3.2	no data	no data	12:15	0.0
12	Tue	6:28	4.2	6:53	3.3	12:09	0.0	1:03	−0.2
13	Wed	7:10	4.3	7:38	3.3	12:56	0.0	1:51	−0.3
14	Thu	7:55	4.4	8:27	3.3	1:44	−0.1	2:38	−0.4
15	Fri	8:45	4.3	9:21	3.3	2:33	−0.1	3:25	−0.4
16	Sat	9:40	4.2	10:20	3.3	3:22	−0.1	4:13	−0.3

- 1 Which evidence-based explanation supports the claim that ocean tides at Jones Inlet, New York, change cyclically?
 - (1) The time between a high tide and the next low tide is always between 12 and 13 hours.
 - (2) From December 12 through December 16, morning low tides have increased and decreased, while afternoon low tides have only decreased.
 - (3) High tides during the afternoon of December 6 and 7 are both three feet above the standard elevation.
 - (4) The time between consecutive high tides is always between 12 and 13 hours.

The combined gravitational forces that the Moon and the Sun exert on Earth result in the strength of tides. Spring tides and neap tides occur cyclically. The model below represents one possible set of positions of the Sun, Earth, and the Moon during a spring tide and a neap tide.



- 2 Which evidence-based statement supports the claim that the occurrence of a specific Moon phase is associated with an Earth tide?
- (1) A neap tide occurs during the full Moon phase.
 - (2) A spring tide occurs during the new Moon phase.
 - (3) Spring tides and neap tides occur during both first quarter and third quarter Moon phases.
 - (4) Spring tides and neap tides occur between full Moon and new Moon phases.

Perigean spring tides are the strongest spring tides and apogean spring tides are the weakest spring tides. The table below shows some information about the Moon's position in its orbit around Earth.

Approximate Earth–Moon Distance

Moon's Distance from Earth (km)	Date
369,818	November 21, 2023
404,346	December 4, 2023
367,899	December 16, 2023
404,910	January 1, 2024

- 3 Place a check mark (✓) in **one** box to indicate the date on which the orbital speed of the Moon around Earth was greater. Justify your response using your knowledge of Kepler's Laws. [1]

☐

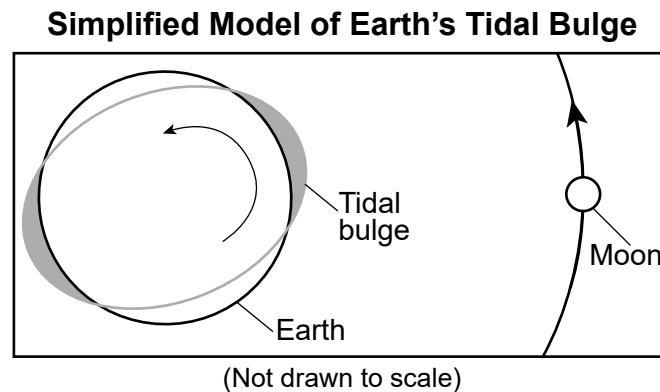
Orbital speed on December 16, 2023

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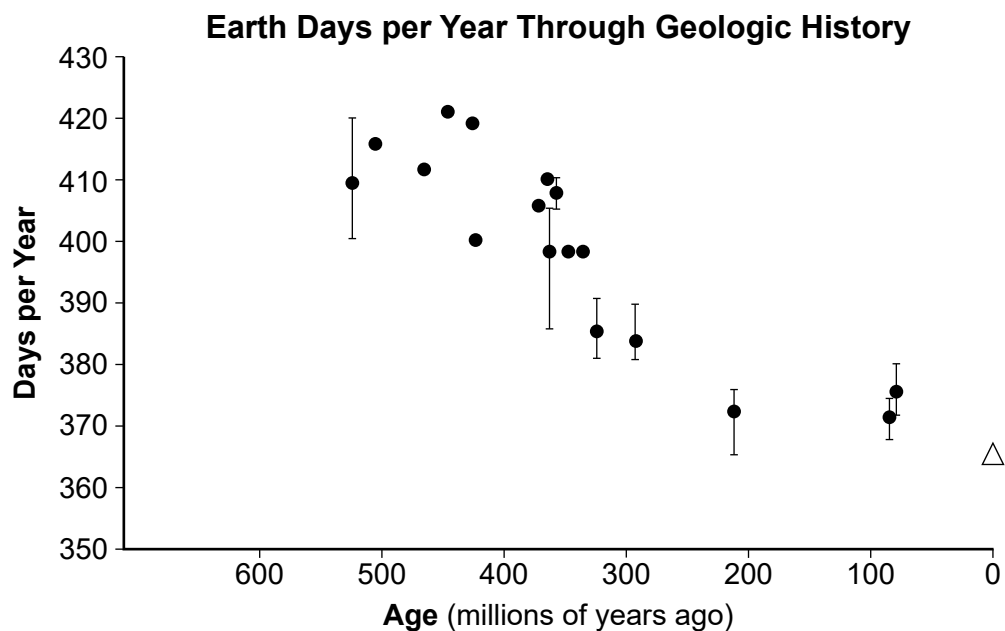
Orbital speed on January 1, 2024

Justification: _____

The rate of Earth's rotation is affected by lunar tidal friction. The gravitational force of the Moon causes a tidal bulge in the solid Earth and its oceans, as shown in the model below. The arrow on Earth indicates direction of rotation.



Evidence of the change in the rate of Earth's rotation has been found by studying ancient ocean organisms. These organisms developed growth lines on a daily basis. The number of days per year has been determined by counting these growth lines, as shown in the graph below. The Δ represents the number of days per year determined by the growth lines of modern-day ocean organisms.



- 4 Based on the information in the *Simplified Model of Earth's Tidal Bulge* model and the *Earth Days per Year Through Geologic History* graph, which row in the table correctly predicts the length of an Earth day 500 million years ago and explains why this length is different today?

Row	Length of Earth Day	Explanation
(1)	Approximately 21.5 hours	Earth's rate of rotation was faster 500 million years ago.
(2)	Approximately 26.5 hours	Earth's rate of rotation was faster 500 million years ago.
(3)	Approximately 21.5 hours	Earth's rate of rotation was slower 500 million years ago.
(4)	Approximately 26.5 hours	Earth's rate of rotation was slower 500 million years ago.

Base your answers to questions 5 through 9 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

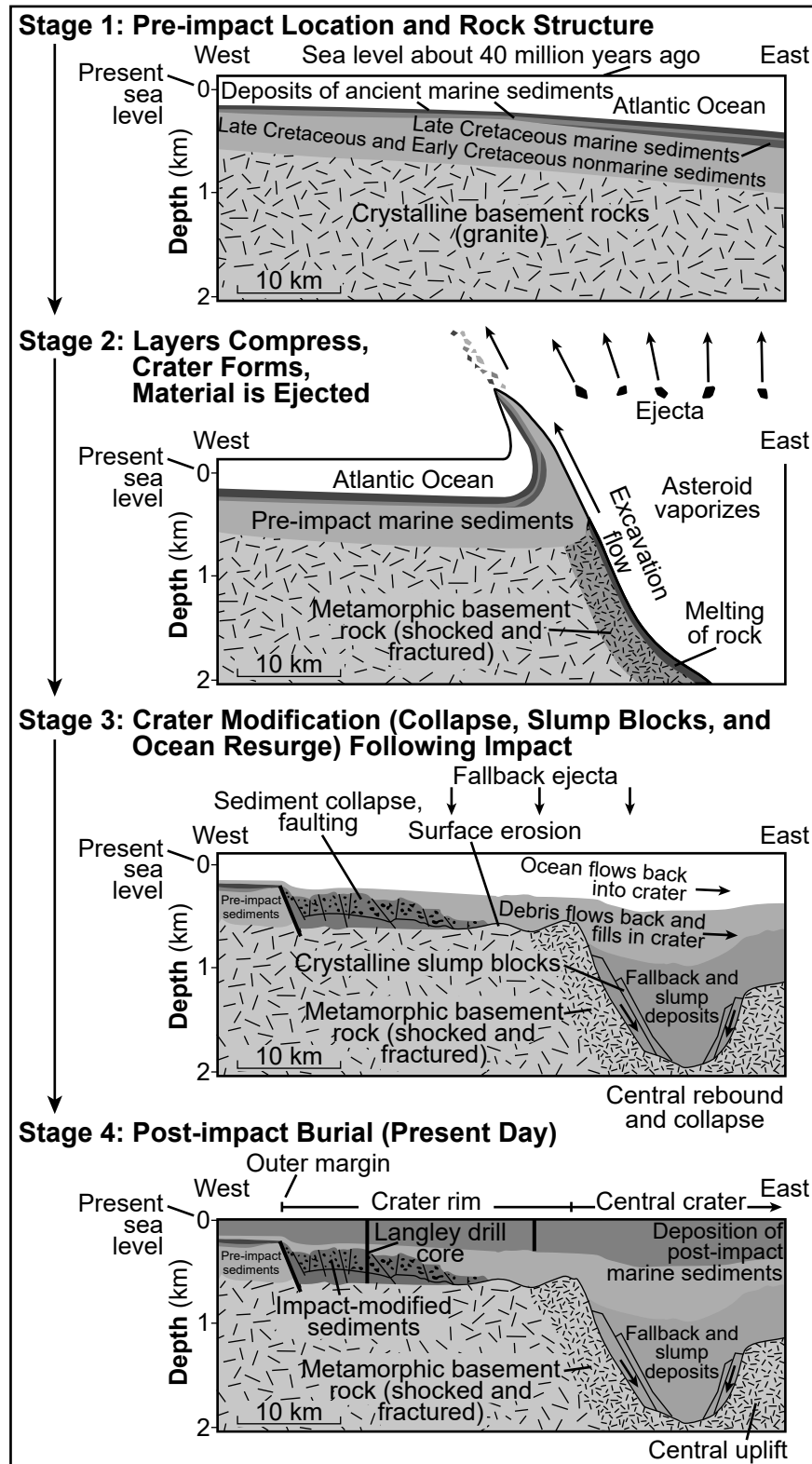
Chesapeake Bay Impact Event

Scientists have determined that an asteroid or meteorite between three to five kilometers in diameter hit the continental shelf of North America. This area is located near the present-day Chesapeake Bay. The impact occurred about 35 million years ago, when sea level was much higher.

A drill core sample was taken near the impact crater (Langley drill core). Scientists used a radioactive dating method on several zircon crystals found in the sample to determine the age of impact. These crystals formed when the existing rock material was subjected to the intense heat and pressure of the impact. This altered the structure of the rock. This Earth material was blasted away from the crater, forming ejecta material.

The models below show some information about the sequence of events and geologic changes that occurred to the continental shelf as a result of this impact event (Stage 2).

Progression of Chesapeake Bay Impact Event



- 5 The piece of evidence that directly supports the claim that an impact event occurred about 35 million years ago in the Chesapeake Bay Region is
- (1) the presence of shocked and fractured rocks under the present-day Chesapeake Bay
 - (2) the change in sea level from 35 million years ago to the present day
 - (3) the presence of crystalline basement granite in the Chesapeake Bay region
 - (4) the increase in marine sediment thickness from 35 million years ago to the present day
- 6 Based on the rock samples that have been found around the impact site, identify the parent isotope that could have been used to determine the age of the impact crater found in the Chesapeake Bay. Explain why that radioactive isotope can be used to date the zircons found in the sample. [1]

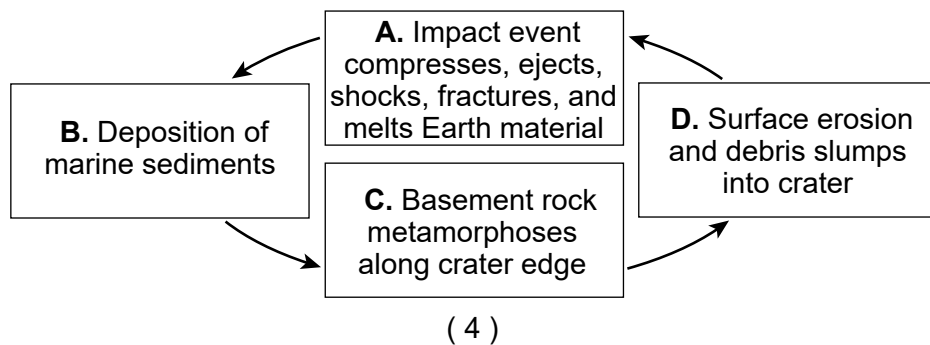
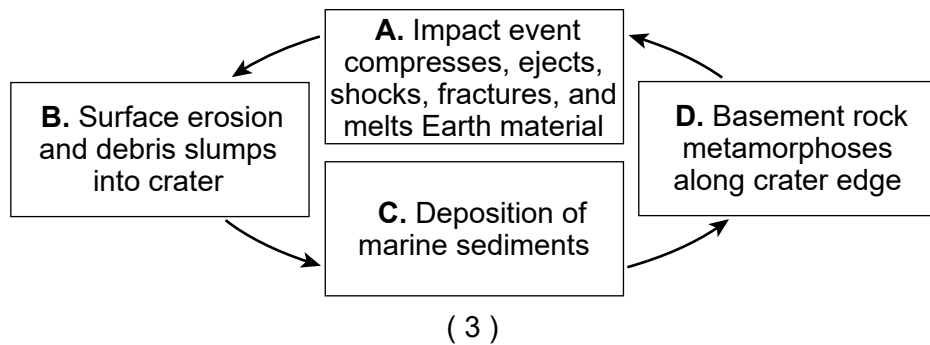
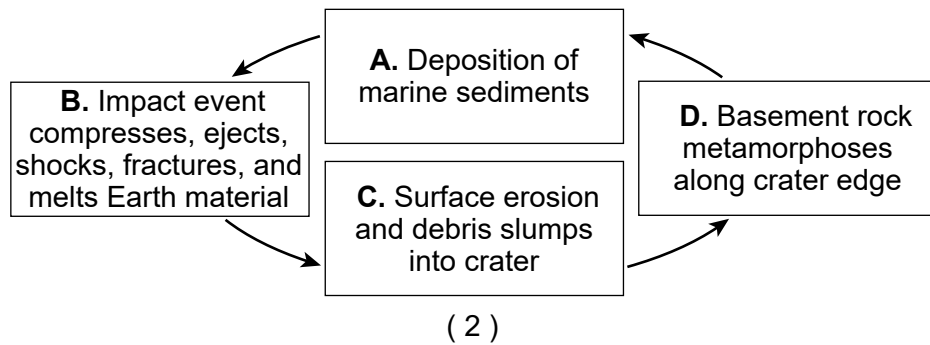
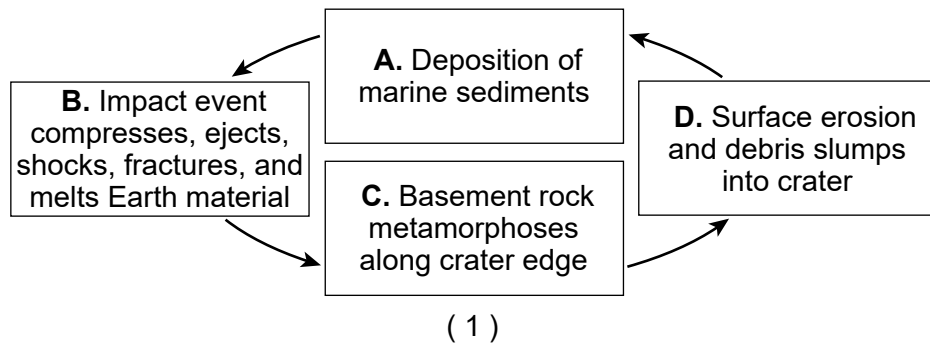
Parent radioactive isotope: _____

Explanation: _____

- 7 Which two stages in the models are evidence of constructive processes associated with the formation of the present-day Chesapeake Bay crater?
- (1) Stages 1 and 2
 - (2) Stages 2 and 3
 - (3) Stages 1 and 4
 - (4) Stages 3 and 4
- 8 Describe **one** piece of evidence that could be used to prove that the ancient marine sediments in Stage 1 were deposited after the late Cretaceous marine sediments. [1]

Evidence: _____

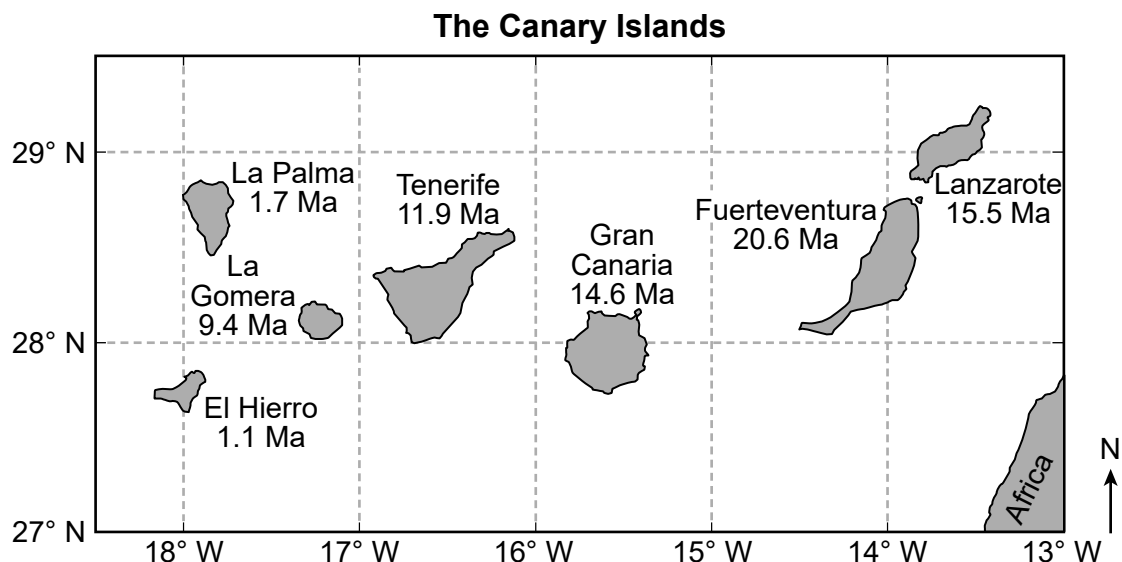
- 9 Which sequence (A-D) correctly identifies the stages of recycling of Earth materials that occurred in the Chesapeake Bay?



Base your answers to questions 10 through 14 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

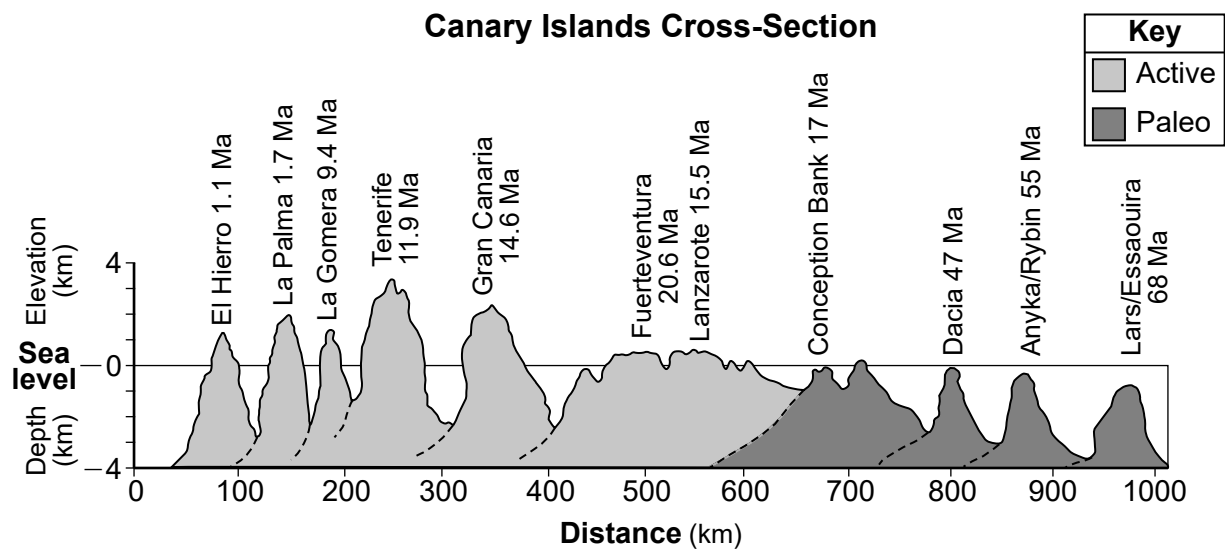
Canary Islands Hotspot

The Canary Islands are a series of islands and seamounts located near the west coast of Africa. These islands formed over a hotspot. The map below shows some information about the Canary Islands. Approximate island ages are shown in millions of years (Ma).



- 10 Which statement describes the approximate spatial and temporal scales associated with the movement of the African Plate as it travels over the Canary Islands Hotspot?
- (1) The African Plate moves southwest at a rate of 2.8 cm/yr as it separates from the Indian Australian Plate.
 - (2) The African Plate moves north at a rate of 1.6 cm/yr as it separates from the Antarctic Plate.
 - (3) The African Plate moves west at a rate of 4.0 cm/yr as it separates from the South American Plate.
 - (4) The African Plate moves east at a rate of 2.5 cm/yr as it separates from the North American Plate.

The cross-section below shows some information about the Canary Islands region. A distance of 0 km represents the relative start of the island chain.



- 11 For each of the three locations, place a check mark (✓) to indicate the correct surface feature and the correct geologic epoch. [1]

Three Locations	Surface Feature	Geologic Epoch
La Palma	☐ Island	☐ Pleistocene
	☐ Seamount	☐ Miocene
		☐ Eocene
Tenerife	☐ Island	☐ Pleistocene
	☐ Seamount	☐ Miocene
		☐ Eocene
Dacia	☐ Island	☐ Pleistocene
	☐ Seamount	☐ Miocene
		☐ Eocene

A student studying the mineral composition of a basalt sample from Gran Canaria made the following claim:

“The Gran Canaria basalt sample has a felsic composition and contains sodium-rich minerals.”

- 12 Cite evidence about the composition of basalt to *refute* the student’s claim. Justify your response by including at least **two** minerals as evidence. [1]

The Canary Islands region experiences relatively low average annual rainfall when compared to other tropical locations.

- 13 Which statement explains why the Canary Islands region experiences low average annual rainfall?
- (1) Rising air in the troposphere from the Polar Cell and Ferrel Cell creates a low pressure zone and a humid climate.
 - (2) Descending air in the troposphere from the Hadley Cell and Ferrel Cell creates a subtropical high pressure zone and an arid climate.
 - (3) Descending air in the troposphere from the subtropical jet stream creates an equatorial low pressure zone and an arid climate.
 - (4) Rising air in the troposphere from two Hadley Cells at the Intertropical Convergence Zone creates an equatorial low pressure zone and a humid climate.

In September through December of 2021, thousands of earthquakes, known as an earthquake swarm, were detected beneath the Cumbre Vieja volcano on the island of La Palma. Eruptions released volcanic ash and lava flows. The map below shows some information about the island of La Palma.



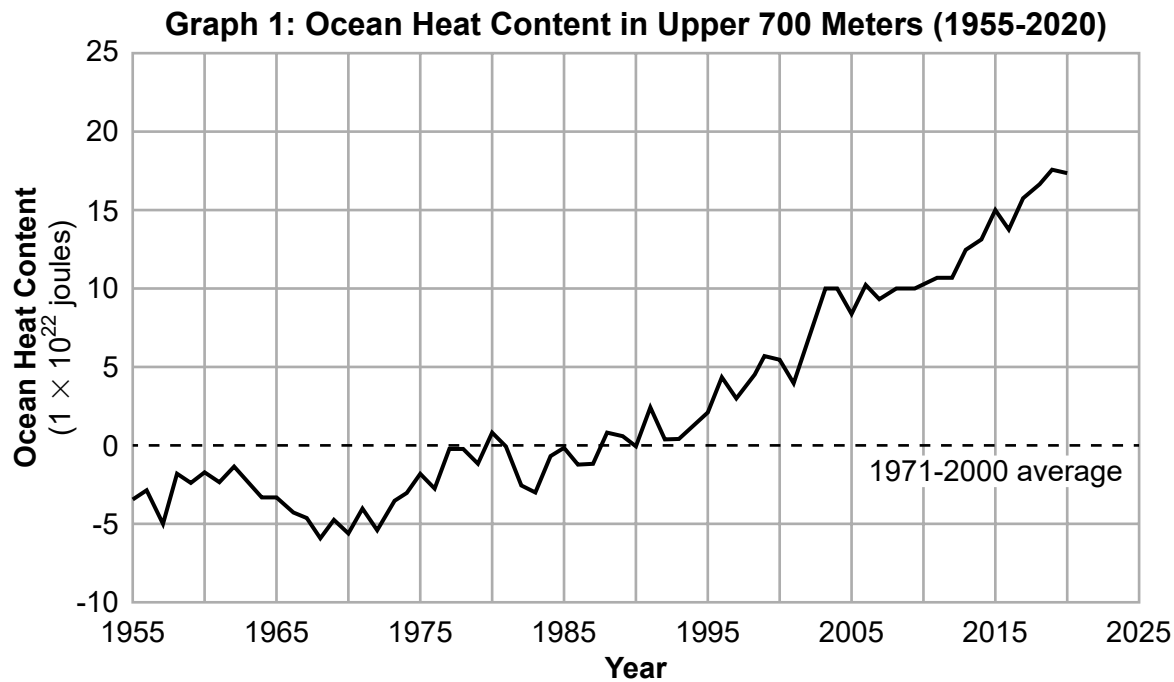
- 14 Which statement best describes how the earthquake swarm most likely helped predict another natural hazard and allowed communities to prepare for a larger natural disaster?
- (1) The earthquake swarm that occurred prior to the volcanic eruption allowed officials to plan evacuations and suspend air travel in the region.
 - (2) The volcanic eruption was a predictor of the earthquake swarm that allowed officials to open shelters at Las Norias.
 - (3) The earthquake swarm that occurred prior to the volcanic eruption allowed officials to plan evacuations at Jedey.
 - (4) The volcanic eruption was a predictor of the earthquake swarm that allowed officials to open shelters and suspend air travel over Cumbre Vieja.

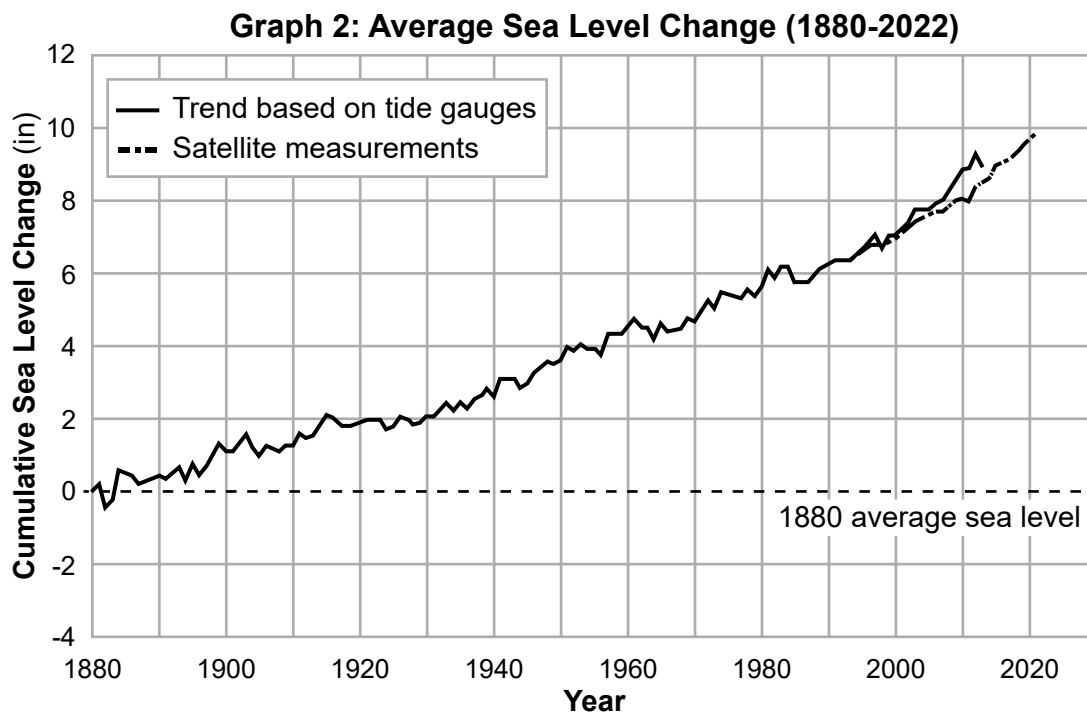
Base your answers to questions 15 through 18 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

Earth's Oceans—A Climate Change Indicator

Earth's ocean temperatures influence sea level change and climate. Oceans have the ability to absorb large amounts of heat energy with only a slight increase in temperature because of water's unique properties.

The graphs show some information about ocean heat content and sea level change. Joules are a unit of energy. One unit of ocean heat content is equal to 1×10^{22} joules. This amount of energy is equal to approximately 17 times the amount of energy used by all humans on Earth in one year.





- 15 Which table correctly matches the ocean trends that are most directly affected by the properties of water shown in the graphs?

Ocean Trend	Water Property
Ocean heat content	Density
Sea level change	Reflection of sunlight

(1)

Ocean Trend	Water Property
Ocean heat content	Specific heat
Sea level change	Thermal expansion of water

(3)

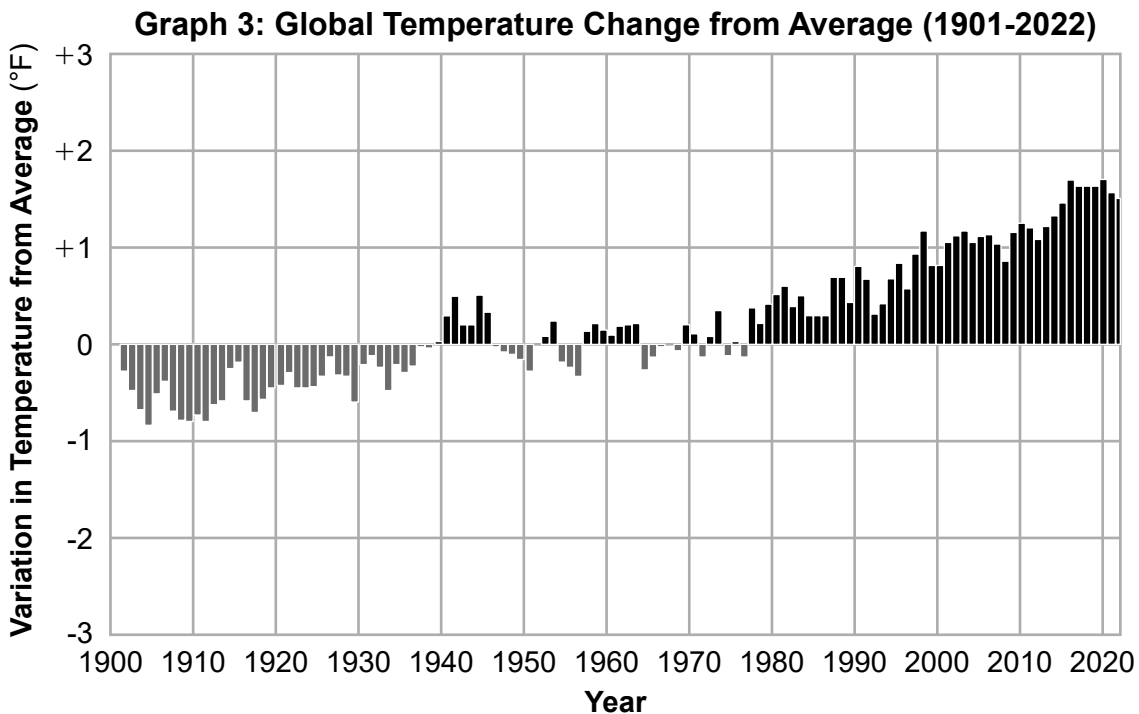
Ocean Trend	Water Property
Ocean heat content	Density
Sea level change	Thermal expansion of water

(2)

Ocean Trend	Water Property
Ocean heat content	Specific heat
Sea level change	Reflection of sunlight

(4)

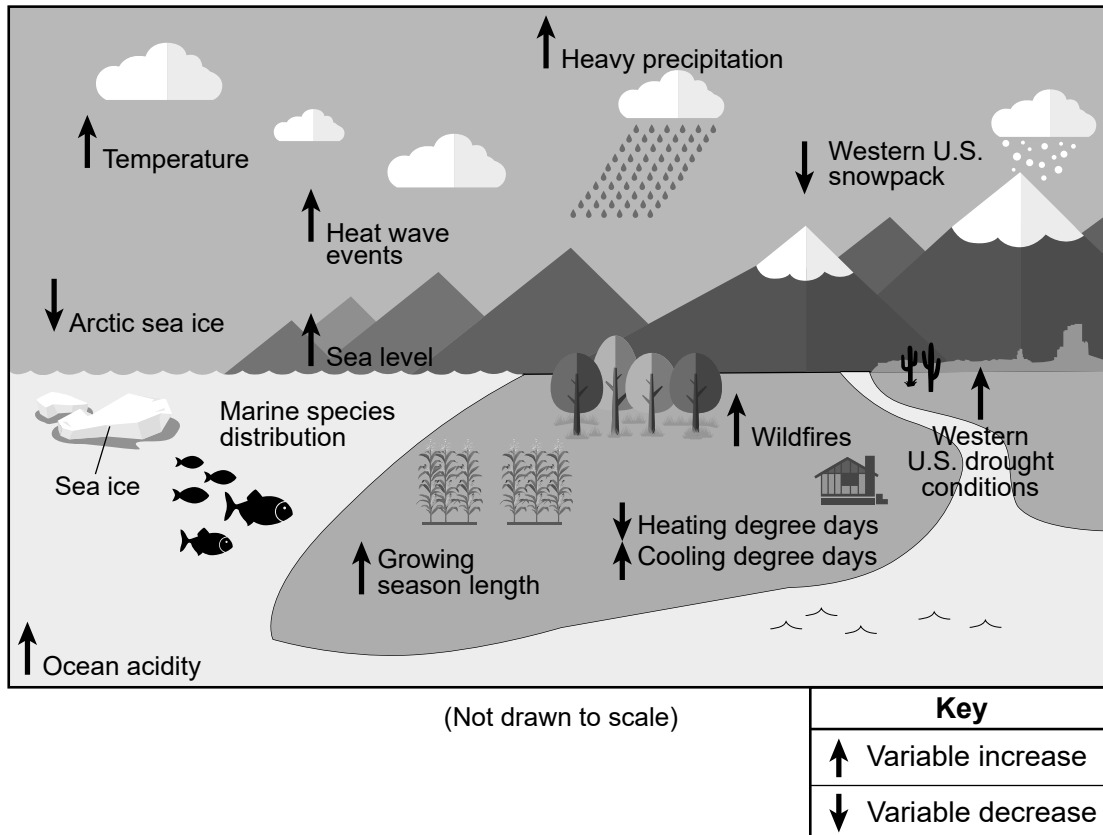
The graph below shows Earth's combined global land and ocean surface temperature variations from average. The 0 value is based on temperature data collected between 1901 and 2000 and represents the average atmospheric temperature.



- 16 Using data shown in Graphs 1, 2, and 3, describe how ocean heat content, average sea level, and global average temperature have changed from the average values since 1980 due to human activities. [1]

The infographic below shows some information about changes in natural processes and human activities. Heating and cooling degree days are the amount of days needed to either heat or cool a home.

Trends in Processes and Activities Related to Current Climate Change



17 Which set of explanations correctly describe how human activities will most likely be influenced by current changes in climate?

- A. People will need to cool their homes for more days per year.
- B. There will be less food production due to a change in growing season length.
- C. Farmers may need to decrease the amount of time used to successfully grow crops in the western U.S.
- D. Coastal communities will have to plan for an increase in coastal flooding due to a decrease in Arctic Sea ice.

(1) A and B

(3) C and D

(2) B and C

(4) A and D

- 18 Based on the information provided, which statement correctly explains how changes in energy flow due to human activities result in a change to a climate factor?
- (1) As more energy flows into Earth's oceans, all marine species migrate to cooler tropical regions.
 - (2) As more energy flows into Earth's oceans, ocean acidity increases.
 - (3) As more energy flows out of forests, the average air temperature will decrease, causing more wildfires.
 - (4) As more energy flows out of the atmosphere, heat waves in urban areas will increase.

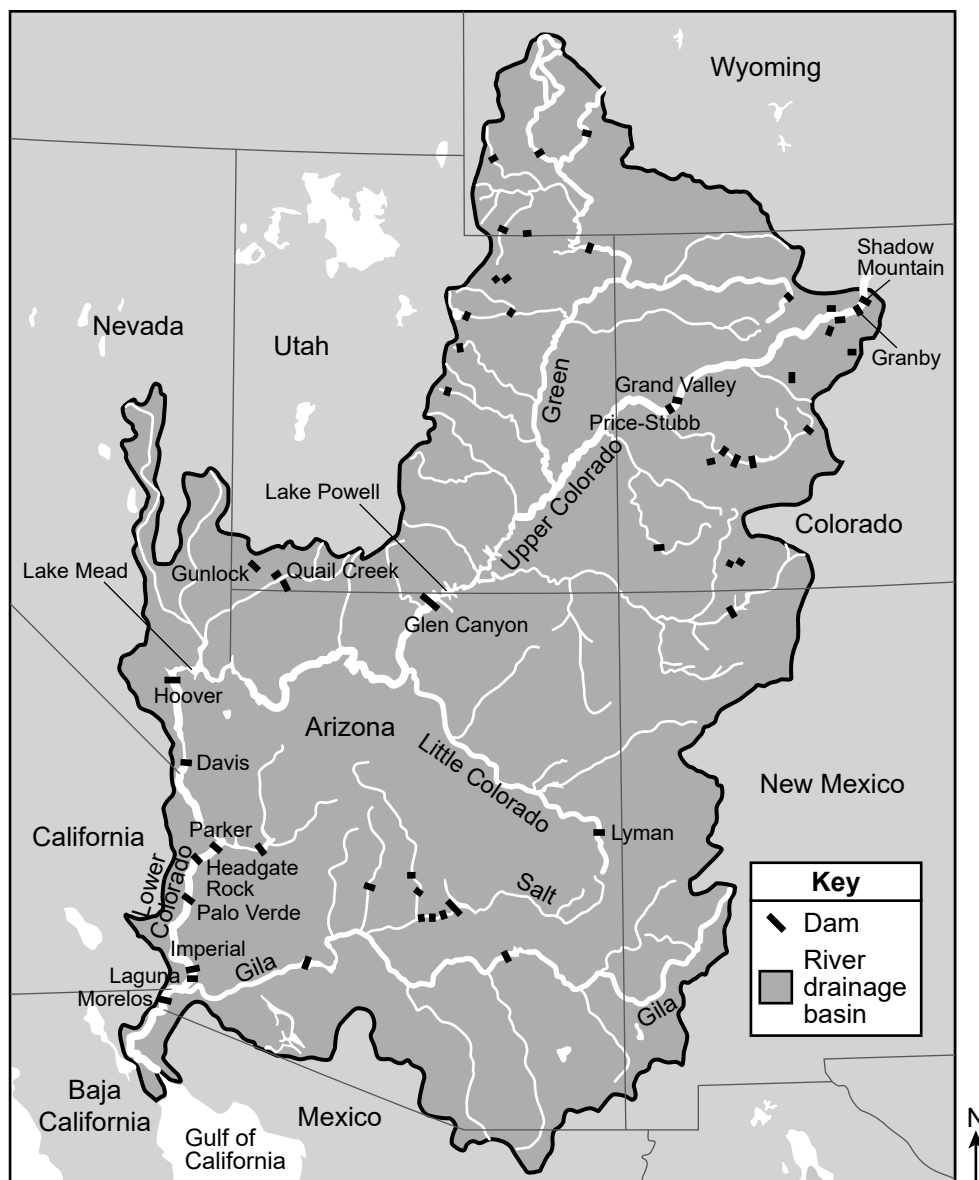
Base your answers to questions 19 through 22 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

Dams on the Colorado River

There are over 14 major dams located along the 1450-mile-long Colorado River. The dams were built to ensure equitable distribution of water along the entire length of the Colorado River. Two of the largest dams found along the Colorado River are the Hoover and Glen Canyon. The reservoirs (Lake Mead and Lake Powell) that were created upstream of the dams are two of the largest in the United States. During years of drought, these dams guarantee water to the Lower Colorado River states (Lower Basin). In years with excess precipitation, the dams store runoff for future use. Both dams are also a major source of hydroelectricity. The dams control seasonal flooding along the Colorado River and provide irrigation for farming.

The map below shows some information about the Colorado River. The Colorado River is the boundary between California, Nevada, and Arizona.

The Colorado River: Its Tributaries and Dams



The construction of the Hoover Dam in 1935 created Lake Mead, which extends 110 miles upstream. Sedimentation in Lake Mead is generally distributed along the bottom of the deepest parts of the lake.

The data table below shows some information about sedimentation in Lake Mead. An acre-foot is equal to the volume of material that covers one acre of land to a depth of one foot.

Lake Mead Sedimentation From 1935–2001

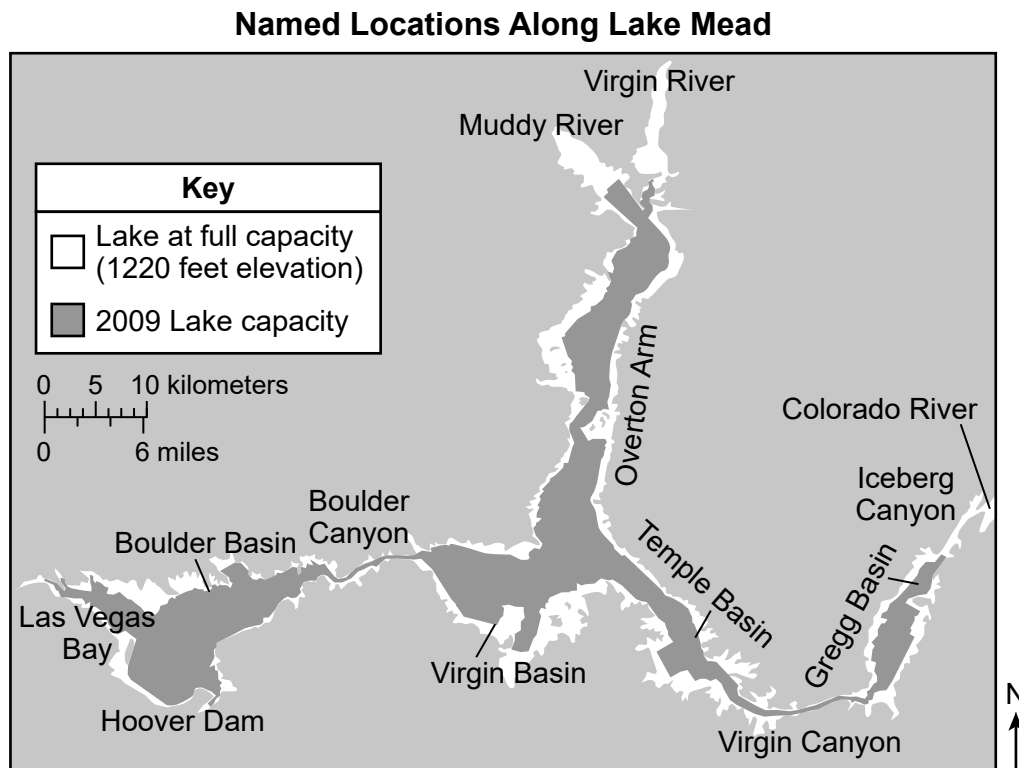
Year	Reservoir Capacity (acre-feet at 1220 feet elevation)	Rate of Sedimentation (acre-feet/year)	Sediment Volume (acre-feet)
1935	30,944,400	137,000	0
1948	29,878,000	97,429	1,066,400
1963	28,321,300	88,200	2,623,100
2001	28,543,420	< 10,000	2,400,980*

* due to significant compaction of sediments in some parts of the lake

19 Which statement most accurately describes the effect of moving water on the change in sediment volume in Lake Mead during the 66-year time span shown in the table?

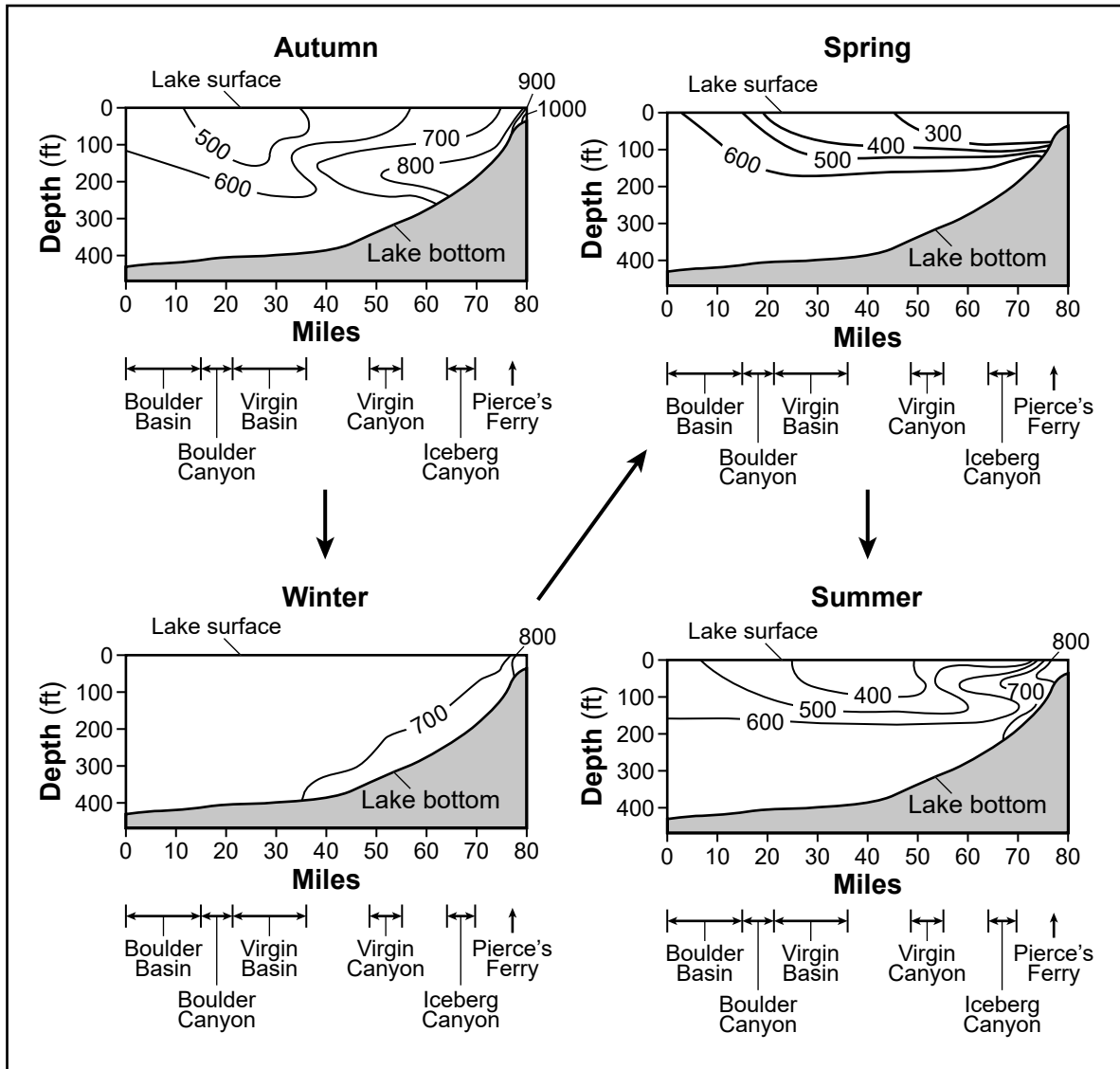
- (1) Moving water carried sediments that were deposited when the water velocity increased as it flowed from a high elevation above the dam to a lower elevation below the dam.
- (2) Moving water deposited sediments when velocity decreased as the water entered Lake Mead upstream of the Hoover Dam.
- (3) Moving water flowed through Lake Mead and carried most of the river sediment downstream of the dam.
- (4) Moving water increased in velocity as it entered Lake Mead, causing a decrease in the rate of sedimentation.

A 14-year investigation of seasonal salinity levels was conducted in Lake Mead. The map below shows some of the locations where salinity was measured.



The salinity cross-sections contain isolines that indicate salinity levels in parts per million (ppm).

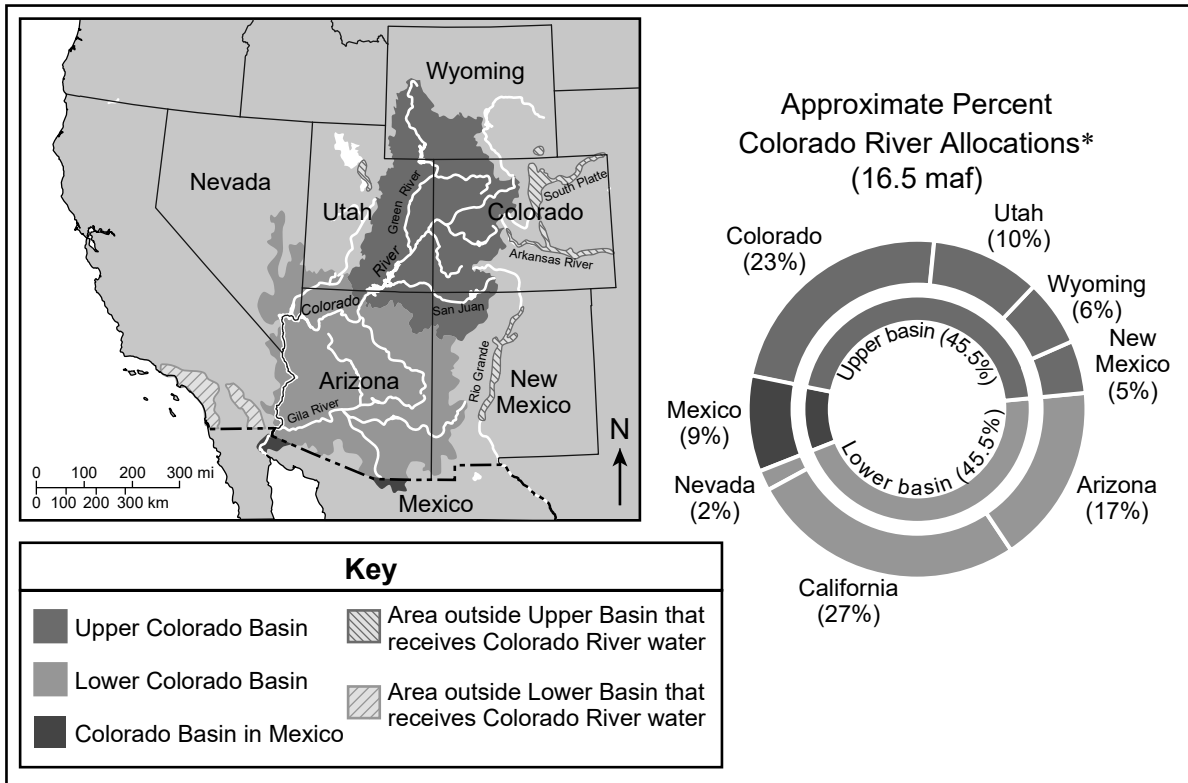
Salinity Cross-Sections for Four Seasons



- 20 Using your knowledge of seasonal water cycle processes, explain why the salinity of the body of water at Iceberg Canyon is different in autumn than in spring. [1]

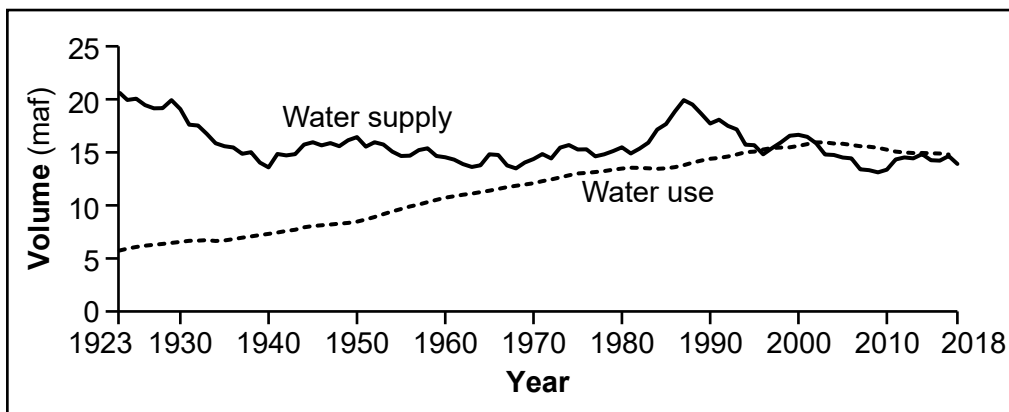
The map, model, and graph below show some information about the states that use water along the Colorado River. The unit maf represents millions of acre-feet.

Upper and Lower Basin States that Rely on the Colorado River for Water



*The percentages do not add up to 100 due to rounding.

Water Use in Lower Basin States



The Colorado River supplies water for a large farming industry in California and for many southern California cities. Due to drought conditions that have occurred in western states when supply did not meet demand, lower basin states have had to change their water usage practices. Some examples of these changes are summarized below.

- Farmers that use irrigation in California have exchanged money for 500,000 acre-feet of water a year to southern California communities.
- Farmers in California are investing in more efficient irrigation systems and intentionally not using large areas of land.
- Nevada is paying residents in many communities to not plant grass and remove existing grass.
- Arizona, Nevada, and California all agreed to reduce water usage until 2026 by at least 3 million acre-feet for each state.
- California lined several water canals to prevent water loss along the canals.

21 Which evidence-based statement correctly describes how the availability of water in the Colorado River has influenced human activity?

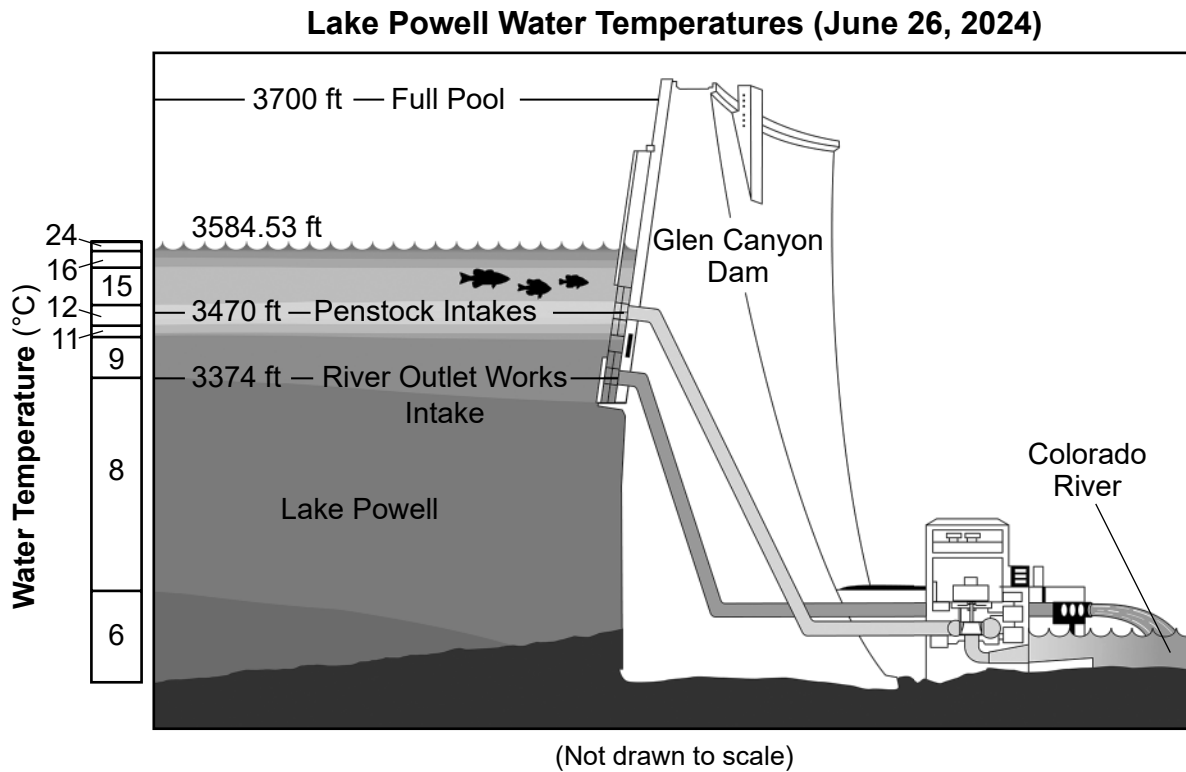
- (1) A drought beginning in 1990 caused water use to exceed water supply to the lower basin states, causing California to line many canals to prevent water loss.
- (2) Arizona receives 27% of the water allocated from the Colorado River and has responded to drought conditions by paying farmers for small amounts of water a year (100,000 acre-feet).
- (3) Evidence for the drought was when water use exceeded supply around 2003. This caused the lower basin states to eventually reach an agreement to reduce water use by about three million acre-feet.
- (4) Due to the onset of the drought in 1985, Nevada officials pay residents to remove grass from their properties to reduce water use.

Dams cause ecosystems to change when the normal flow of water is disrupted. The Glen Canyon Dam is downstream of Lake Powell. Drought conditions have caused the elevation of the lake to decrease and the temperature of the water to increase.

Warm water smallmouth bass now live in the lake. They pass through the dam and spawn downstream in the Colorado River. They prey on federally protected native fish species in the Grand Canyon downstream region.

Water management scientists have decided to release cold water from the lake to cool the Colorado River downstream of the dam.

The model below shows some information about water temperatures in Lake Powell near the Glen Canyon Dam.



- 22 Which row shows the choice from each column that correctly completes the statement that identifies how the solution of releasing pulses of water from the dam reduces the impact of smallmouth bass on the Colorado River ecosystem?

Releasing approximately (Column 1) water below the dam will (Column 2) because it (Column 3).

Choice	Column 1	Column 2	Column 3
A	8°C	disrupt spawning of native species	allows smallmouth bass to survive
B	9°C	increase spawning of smallmouth bass	provides warm water for spawning
C	15°C	increase spawning of native species	allows native species to eat smallmouth bass
D	16°C	disrupt spawning of smallmouth bass	makes water temperatures too cold for spawning smallmouth bass

Row	Column 1	Column 2	Column 3
(1)	A	C	C
(2)	B	D	D
(3)	B	A	C
(4)	D	A	B

Base your answers to questions 23 through 27 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

Carbon Emissions in Industry

Concrete is the most widely used building material worldwide. It is a mixture of cement, water, sand, and gravel. Cement is the glue that holds the sand and gravel together and gives the concrete its strength.

The production of cement and the use of concrete are major contributors to carbon dioxide (CO₂) emissions worldwide. Cement production is the most carbon-intensive part because it uses fossil fuels to heat a mixture of limestone (CaCO₃) and other ingredients to more than 2640°F in a kiln (furnace). Making one kilogram of cement sends one kilogram of CO₂ into the atmosphere.

Cement and concrete materials are mined from local or regional sources. There are close to 100 quarries in New York State that mine limestone for construction materials as well as other products. A quarry is a surface mine where the soil is removed and the exposed bedrock is extracted.

- 23 Which row in the table below correctly completes the model to show the effect of concrete production on the amount of CO₂ in the atmosphere, the flow of energy within or out of Earth’s atmosphere, and the resulting change in one factor of Earth’s climate?

Concrete
production

→

Atmospheric
CO₂

A

→

Atmospheric
Energy Flow

B

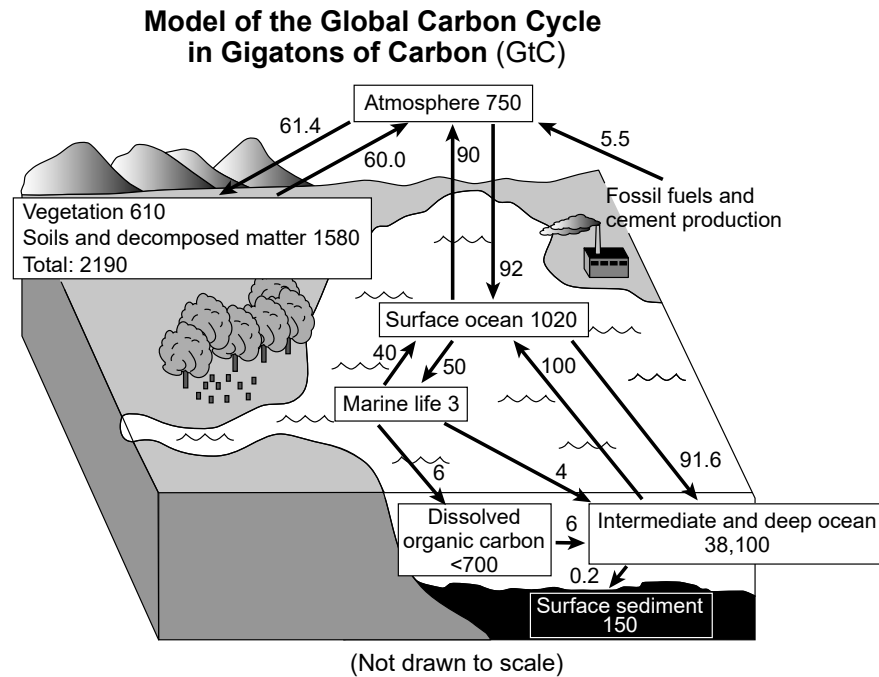
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Change
in Climate

C

Row	A	B	C
(1)	Increases	Greater amount of energy within than energy out of	Decrease in global temperatures
(2)	Increases	Smaller amount of energy within than energy out of	Increase in global temperatures
(3)	Increases	Greater amount of energy within than energy out of	Increase in global temperatures
(4)	Increases	Smaller amount of energy within than energy out of	Decrease in global temperatures

The model below represents the global exchange of carbon in different forms between Earth's spheres. The numerical amounts in boxes represent the gigatons of carbon stored in a component of an Earth sphere. The arrows with numbers represent the amount and direction of carbon exchange between these components in gigatons per year.



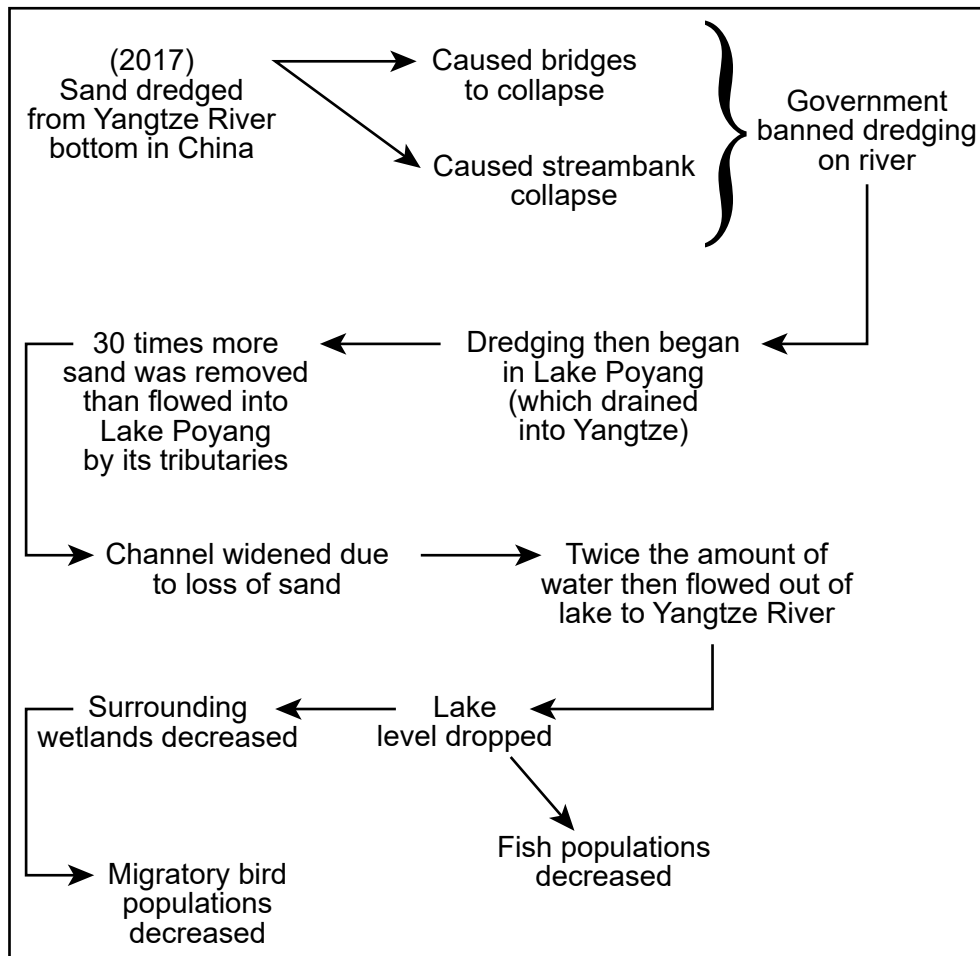
24 Which statement correctly describes how the cycling of carbon between two Earth spheres is represented in the model?

- (1) The atmosphere stores 270 fewer gigatons of carbon than the surface hydrosphere.
- (2) The geosphere stores 147 more gigatons of carbon than the biosphere.
- (3) The hydrosphere receives only 90 gigatons of carbon directly from the atmosphere.
- (4) The biosphere receives only 61.4 gigatons of carbon directly from the geosphere.

Sand mining is a necessary practice used to obtain the resources needed to make concrete. In 2017, China used 2.8 billion tons of sand in construction — enough to cover the entirety of New York State with a one-inch thick layer. Buildings, roads, and even the production of windows all require sand as a source material. The mining of sand, wherever it occurs, impacts Earth systems.

The model below shows the results of sand mining on Earth systems in China.

Model of Interacting Earth Systems Affected by Sand Mining for Concrete Production



25 Place a check mark (✓) next to the **three** claims that correctly describe a relationship among two Earth systems that have been modified as a result of sand mining practices in order to meet the demand for concrete production. [1]

☐

Sand dredged from the bottom of the Yangtze River directly caused Lake Poyang levels to rise.

☐

Lake Poyang sand dredging (mining) has caused surrounding wetlands to decrease in size.

☐

Removal of sand from the Yangtze River has caused increased erosion of streambanks.

☐

A drop in the water level of Lake Poyang has positively affected lake ecosystems.

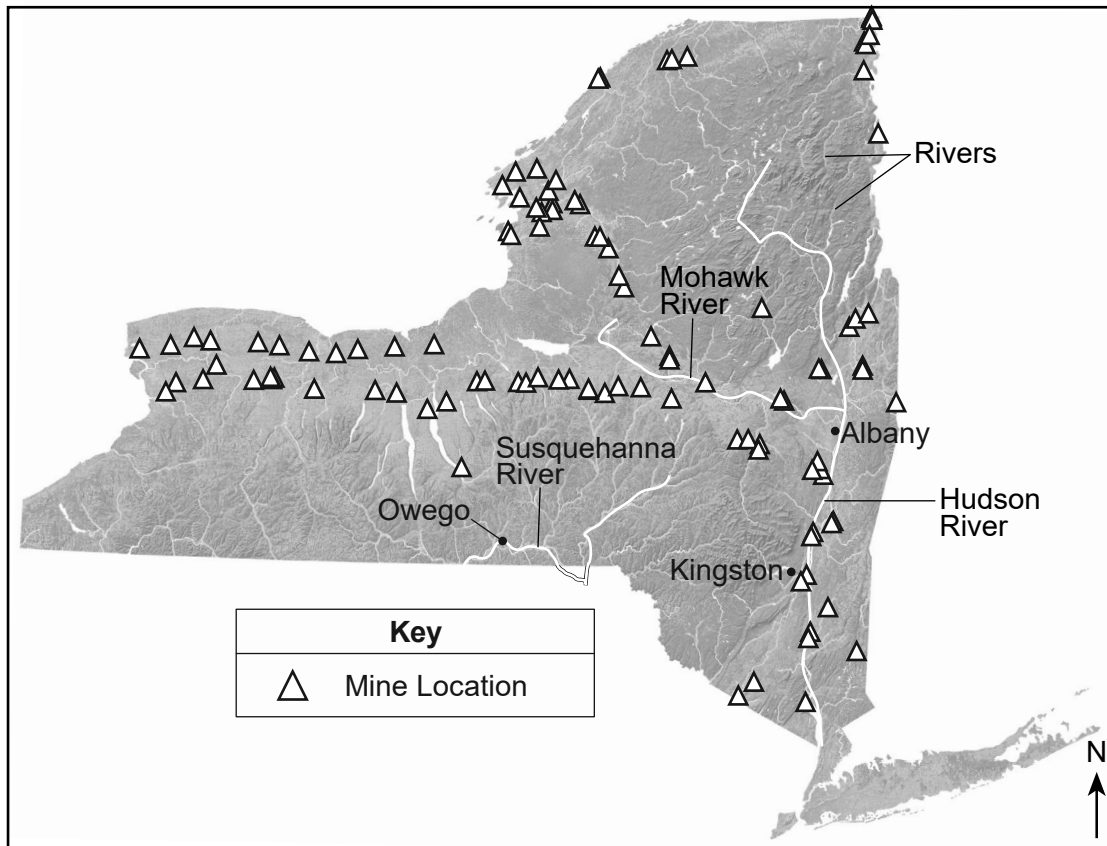
☐

Sand mining in Lake Poyang has caused more water to flow out of the lake and into the Yangtze River.

Kingston became New York State's first capital city in 1777, but was destroyed by the British on October 13, 1777. In the 19th century, Kingston grew in size due to its proximity to materials found in the region. Albany was later established as the permanent capital of New York State.

The map below shows some information about natural resource mines and bodies of water in New York State.

Selected Mines in New York State



- 26 Identify **one** natural or mineral resource that supports the claim that Albany and Kingston were considered to be better locations for a capital city than Owego. Explain how this natural or mineral resource most likely influenced the decision about where to construct the capital. [1]

Natural resource: _____

Explanation: _____

Cement and concrete manufacturing uses large amounts of energy that come from burning fossil fuels. Certain steps in the manufacturing process release CO₂ directly into the atmosphere.

The table below lists four design solutions for cement and concrete production that have a lesser impact on Earth systems.

Design Solutions: Concrete Production

Production Step	Solution
1. Mine and grind limestone: Grinding of limestone pieces, called “raw meal,” produces CO ₂ emissions.	– Use basalt instead of limestone to reduce emissions by 60 to 70% in this step.
2. Preheat raw material: Raw material is heated to 700°C in a combustion chamber above the kiln.	– Burn oxygen-rich air instead and add equipment to capture the CO ₂ . Burn biomass instead of fossil fuels to heat kiln. Reduces emissions by up to 60%.
3. Convert lime to clinker: Lime is burned to 1450°C, which fuses it into nodules of cement called “clinker.” Nodules will harden with cement when reacted with water.	– Add another mineral to lower the temperature required to fuse clinker, saving energy.
4. Blend clinker with gypsum: Clinker is mixed with gypsum in a ratio of 25 to 20.	– Switch to a grinder that will save energy.

27 Which design solution for producing cement has the *best* benefit to the environment?

- (1) Add equipment to capture oxygen-rich air from the 700°C kiln to reduce emissions.
- (2) Add another mineral to convert lime to clinker in order to lower temperature by 1450°C.
- (3) Burn biomass instead of fossil fuels to preheat raw material to reduce emissions by 90%.
- (4) Use basalt instead of limestone pieces to make “raw meal” to reduce emissions by 60%.

Base your answers to questions 28 through 32 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

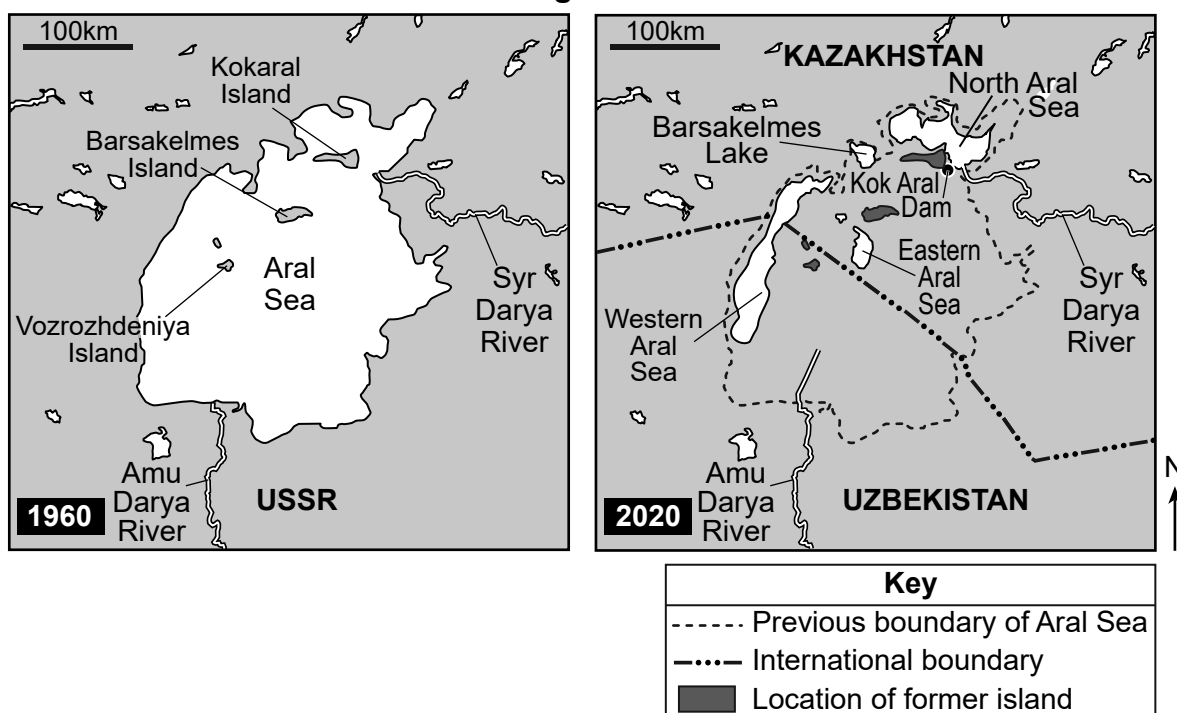
The Aral Sea Region

The Aral Sea, located in arid central Asia, is fed by the Amu Darya and the Syr Darya rivers. Agricultural productivity surrounding the Aral Sea has increased since the 1950s. During the 1960s, these two rivers were diverted to support irrigation, primarily for the cotton industry. This caused the Aral Sea to shrink, reducing the amount of fish available for food. It was the fourth largest lake in the world in the 1950s. It was only the sixth largest lake in the 1990s. Today, the Aral Sea isn't even in the top 40 largest lakes of the world.

The Kok-Aral Dam was completed in 2005 to control the water level of the shrinking Aral Sea. This dam separated the original Aral Sea into the North Aral Sea and the South Aral Sea. The Western Aral Sea is all that remains of the South Aral Sea since the construction of the dam. The dam was designed to keep water from flowing from the North Aral Sea to the South Aral Sea.

The maps below show some information about changes in the Aral Sea.

The Shrinking of the Aral Sea



The table below shows some information about the Aral Sea from 1960 to 2007.

Aral Sea Data 1960–2007

Year	Average Sea Level (m)	Annual Water Inflow (km³)	Average Volume (km³)	Average Salinity (%)	Number of Invertebrate and Fish Species
1960	53	56	951	10	182
1980	45	17	329	22	no data
1990	38	4	282	37	18
2007 North Aral	42	2	27	14	26
2007 South Aral	29.5	2	67.4	100	10

- 28 Construct an argument about how diverting the Amu Darya and Syr Darya rivers from 1960 to 1990 impacted *both* the Aral Sea and its biodiversity. Include numerical evidence for *both* the Aral Sea and its biodiversity in your argument. [1]

- 29 Which row in the table below contains a set of terms that correctly completes the statement below?

Construction of the Kok-Aral Dam in 2005 caused ____ **A** ____ in the water level of the North Aral Sea, causing ____ **B** ____ in sediment ____ **C** ____ of the dam by the river.

Row	A	B	C
(1)	a decrease	an increase	deposition upstream
(2)	a decrease	a decrease	erosion downstream
(3)	an increase	an increase	deposition upstream
(4)	an increase	an increase	erosion downstream

The table below shows some information about the Aral Sea region.

Aral Sea Region Changes from 1960-1990

Year	Human Population (millions of people)	Irrigated Area (millions of hectares)	Water Withdrawals for Irrigation (km ³)
1960	13.8	5.0	51.5
1970	19.9	5.5	83.5
1980	26.1	5.8	110.5
1990	33.0	6.8	110.0

- 30 Use the data tables *and* maps to describe how the management of fresh water in the Aral Sea region most likely *negatively* impacted the stability of the human population after 1990. [1]

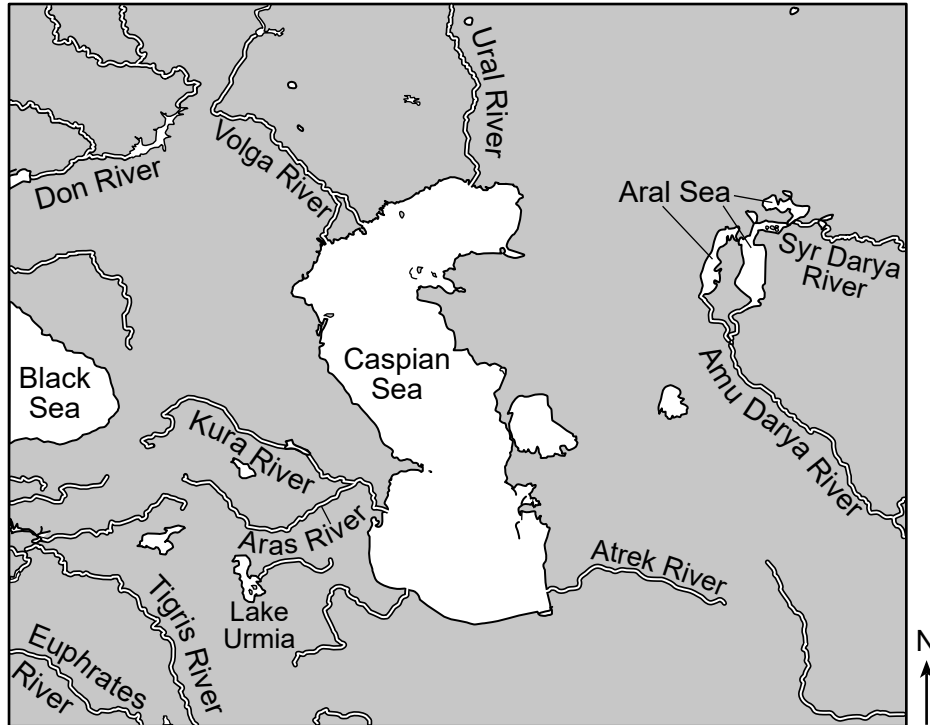
- 31 Which feedback pattern between Earth's spheres supports the claim that the shrinking Aral Sea contributes to the desertification (expansion of deserts) of the region?

- (1) decreased water volume → increased exposed land → increased air temperature → decreased local humidity → hotter and drier climate
- (2) decreased water volume → increased exposed land → increased air temperature → decreased local humidity → colder and drier climate
- (3) decreased water volume → increased exposed land → increased air temperature → increased local humidity → hotter and wetter climate
- (4) decreased water volume → increased exposed land → increased air temperature → increased local humidity → colder and wetter climate

Scientists are concerned that what happened to the Aral Sea could happen to the Caspian Sea. The Volga River provides 86% of the water for the Caspian Sea. Forty dams have been constructed along the Volga River in the 20th century to provide power for the region. Construction of these dams significantly reduced the amount of water flowing through the Volga River into the Caspian Sea. This decrease in streamflow, in addition to climate change, has caused the Caspian Sea level to begin to drop.

The map below shows some information about rivers associated with the Caspian Sea and Aral Sea region.

Area Surrounding Caspian Sea and Aral Sea (2004)



32 Which set of criteria and constraints would be most important to consider when proposing solutions to limit the further loss of water in the Caspian Sea?

(1)	Criteria		Constraints
	Decrease irrigation	→	Maximize impact on agriculture
	Improve water quality	→	Increase of sediment flowing downstream

(2)	Criteria		Constraints
	Decrease water use	→	Less water available for irrigation
	Remove 40 dams	→	Maintain existing biodiversity

(3)	Criteria		Constraints
	Increase irrigation	→	Increased demand for water
	Maintain supply chain of goods and services	→	Maximize fossil fuel production

(4)	Criteria		Constraints
	Decrease biodiversity	→	Long time period for implementation
	Increase power production	→	Lower cost of electricity

Base your answers to questions 33 through 37 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

The Gulf

The Gulf of Mexico, renamed to the Gulf of America in 2025, is an oceanic basin covering approximately 1,605,794 square kilometers with coastlines in the countries of Cuba, Mexico, and the United States of America. This body of water is commonly referred to as the Gulf. Thirty-three major rivers flow into the Gulf from the United States, with the largest being the Mississippi River. Approximately 70 million people live within the Mississippi River watershed.

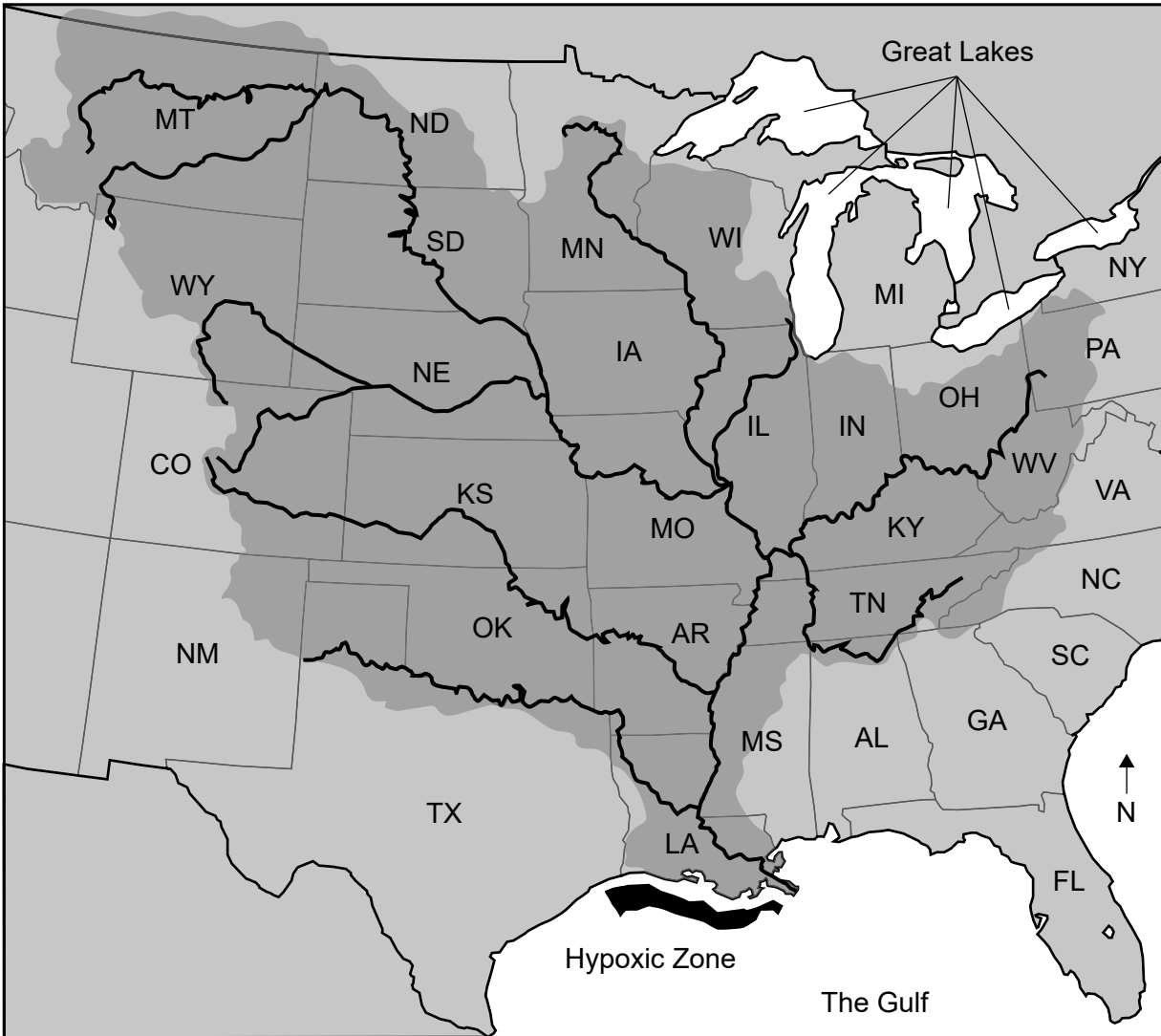
Map of the Gulf



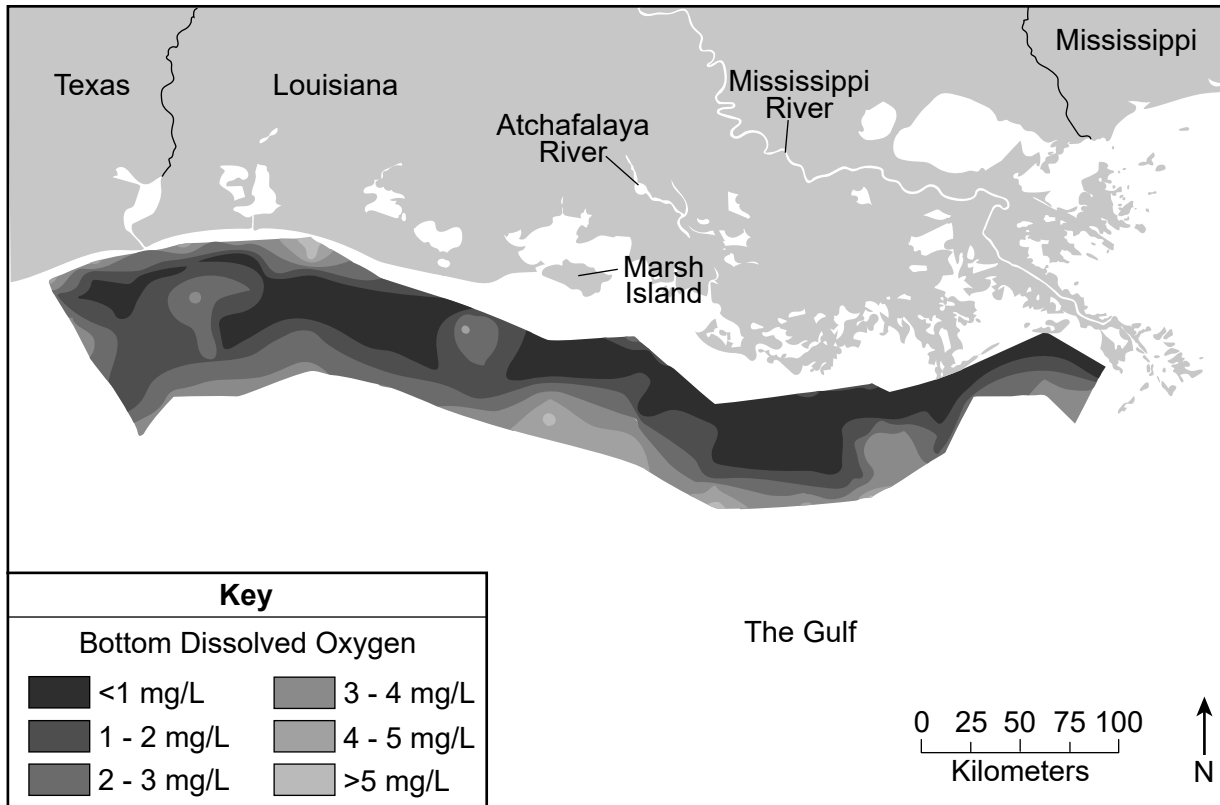
The Mississippi River watershed occupies about 3.1 million square kilometers of the United States. Most of this area is located in midwestern states. This is where agriculture plays a large economic role. Some farming practices negatively affect Earth systems.

The maps show some information about the Mississippi River watershed and a zone of hypoxia. The watershed area is shown on the map as a darker gray region. Hypoxia occurs when there is a critically low level of dissolved oxygen in the water. Dissolved oxygen levels of less than two to three mg/L can no longer support most aquatic life.

Map of Mississippi River Watershed and Hypoxic Zone



2024 Hypoxic Zone – Bottom Dissolved Oxygen

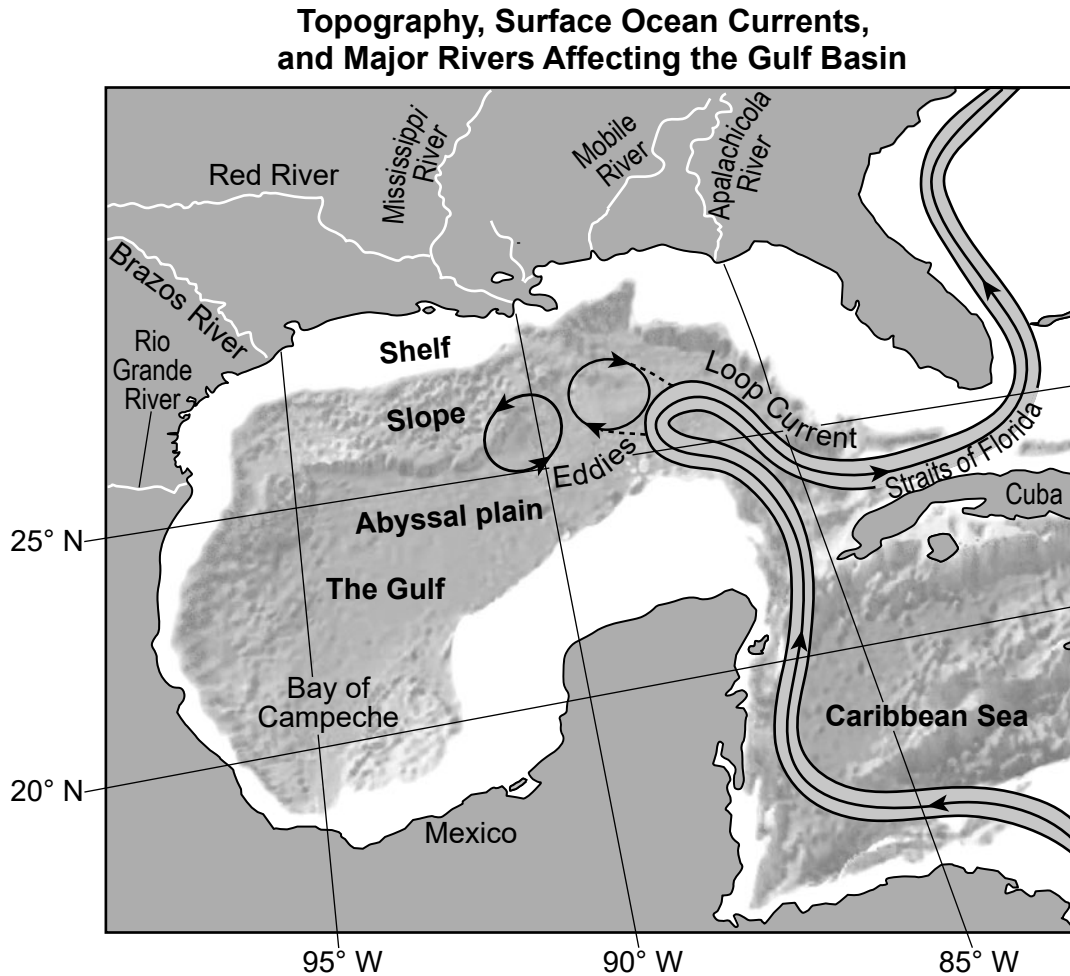


- 33 Use numerical data to describe how *both* the ocean *and* aquatic life are affected 30 km south of Marsh Island's southernmost coast as a result of agricultural runoff. [1]

Ocean: _____

Aquatic life: _____

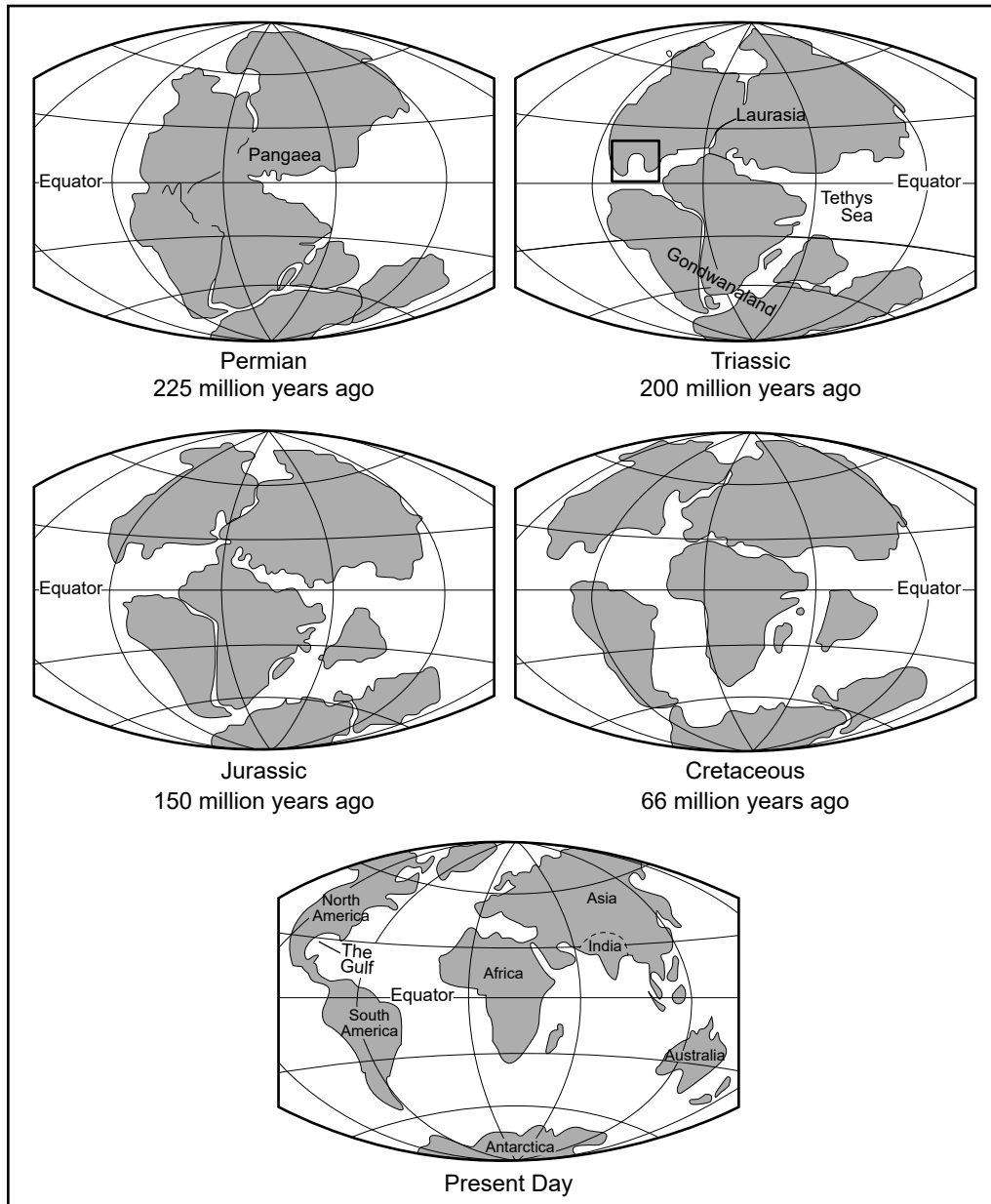
The Loop Current is the main surface ocean circulation feature in the open region of the Gulf. The eddies associated with the Loop Current change both spatially and temporally depending on the season. Climate computer models have projected that climate change will weaken the Loop Current and the eddies during this century. The map below shows some information about the Gulf region.



- 34 Changing atmospheric temperatures are predicted to cause the warm Loop Current to weaken. Which statement identifies a correct associated impact on the open Gulf water temperature and the transport of water westward along the shelf?
- (1) Water temperatures will become warmer, causing water transport to also weaken along the shelf.
 - (2) Water temperatures will become warmer, causing water transport to increase along the shelf.
 - (3) Water temperatures will become cooler, causing water transport to also weaken along the shelf.
 - (4) Water temperatures will become cooler, causing water transport to increase along the shelf.

The models below show some information about the formation of the present-day Gulf. The box in the Triassic model indicates the position of the early Gulf basin after the breakup of Pangaea.

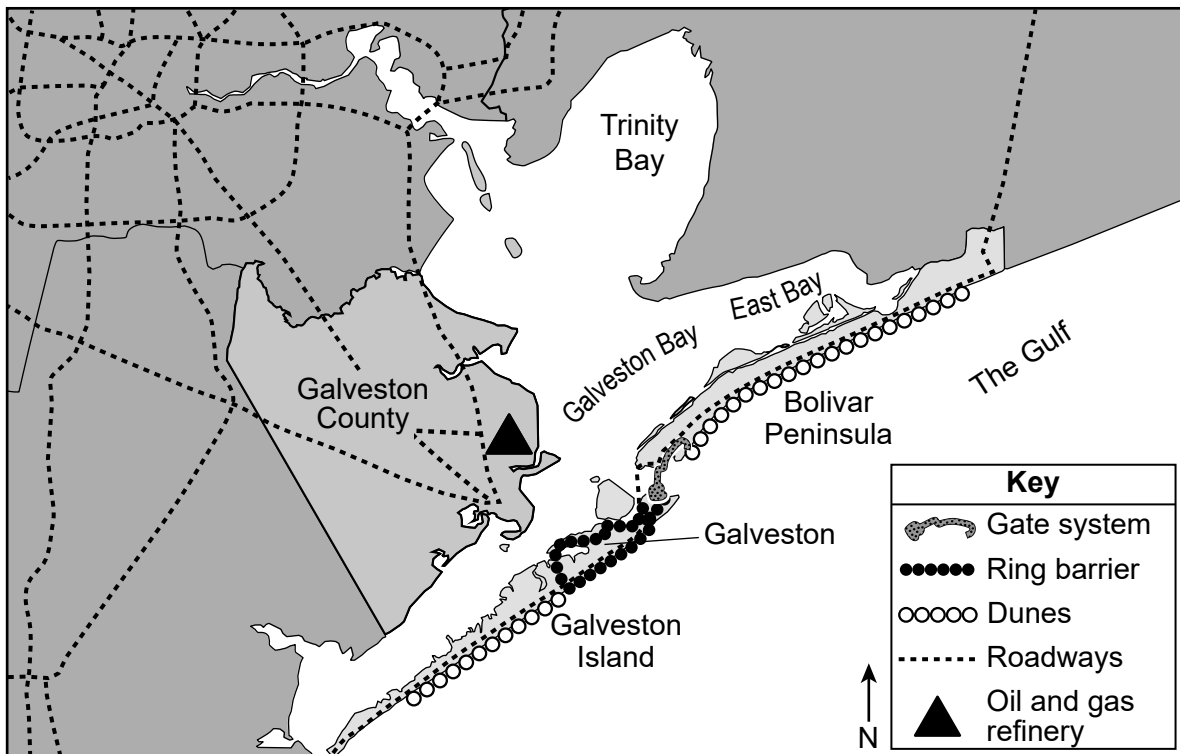
How the Gulf Formed



- 35 Use the models to explain how Earth's internal tectonic processes were responsible for the formation of the Gulf over a 200-million-year time span. [1]

The coastal resort city of Galveston, Texas, transports the most cargo of any port in the United States. In between Galveston Island and Bolivar Peninsula is the Houston Ship Channel. This channel generates over \$906 billion in commerce, mainly from oil and gas refineries in the area of Galveston County. For this reason, stakeholders have developed a plan to protect the region from hurricanes, storm surges, and flooding. The project is estimated to cost \$34 billion. It will include a series of 36 sea gates to seal off Galveston Bay from storm surge. It also includes building large dunes (12 to 14 feet tall) to shelter housing, and a ring barrier to protect the business district. It also includes building large dunes (12 to 14 feet tall) to shelter housing, and a ring barrier to protect the business district.

Galveston Coastline Protection Project Map



- 36 Which statement correctly describes how one of the solutions in the project that mitigates damage from extreme weather events is able to sustain human population and protect biodiversity?
- (1) The roadways along Galveston Island will allow residents to evacuate before a large hurricane.
 - (2) The gate system will stop storm surge and associated flooding to the oil refineries, preventing a loss of billions of dollars of commerce.
 - (3) The tall dunes will shelter houses and decrease erosion of the barrier island, stabilizing the beach.
 - (4) The ring barrier will create a high wall around Galveston City and protect the businesses closest to the coast.

- 37 Which two factors are mostly responsible for the changing global atmospheric and oceanic circulation patterns occurring in the Gulf?
- (1) decreased snowfall and extended drought conditions
 - (2) warming ocean temperatures and sea level rise
 - (3) increased building and industry along the coastline
 - (4) increased strength and number of hurricanes

Base your answers to questions 38 through 41 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

Full Supermoon Events in 2024

A full “supermoon” occurs when the Moon is at or very close to perigee in its orbit of Earth during full Moon phase. Perigee is when the Moon is closest to Earth. The apparent size of the Moon is measured from Earth as an angular diameter. Angular diameter measures the size of a circular disk in arc minutes.

The data tables and photographs below contain information about four full supermoons in 2024. The four Moon photographs are shown to scale relative to each other.

Date	Moon Distance from Earth (km)
August 19	361,969
September 18	357,485
October 17	357,363
November 15	361,866

				
Full Supermoon (letter)	A	D	C	B
Angular Diameter (arc minutes)	32.98	33.05	33.43	33.40

- 38 Write the letter for each full supermoon from the data table in the space provided next to the month each supermoon occurred. Then, explain how the relationship between the Moon's distance from Earth and the Moon's angular diameter provided evidence to support your identifications. [1]

August: _____

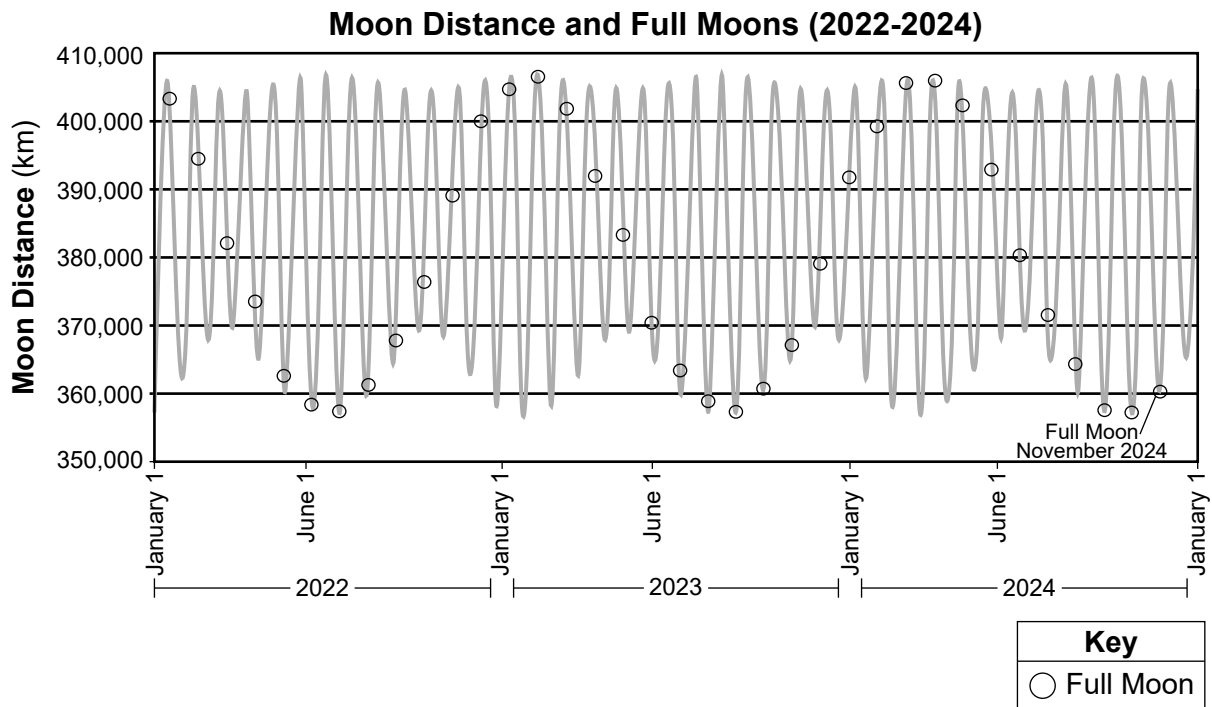
September: _____

October: _____

November: _____

Explanation: _____

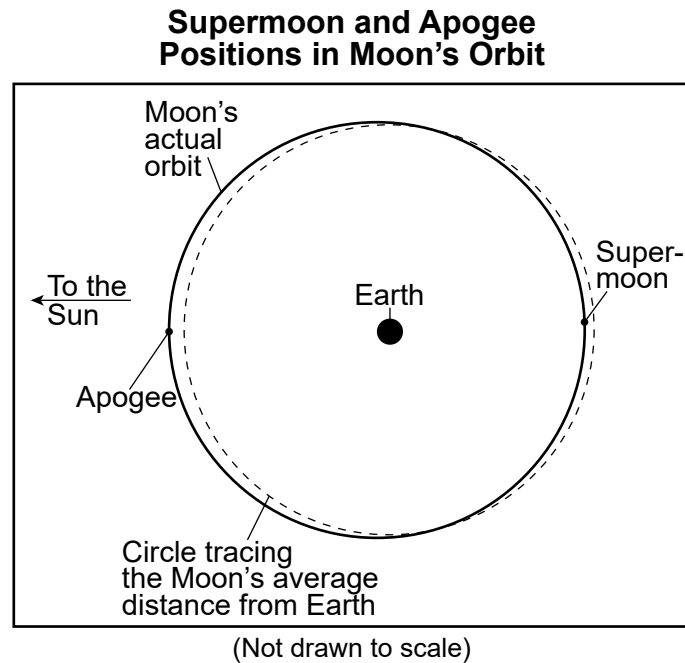
The graph below shows information about the cyclic changes that occurred in the Moon's distance from Earth. The full Moon for December 2024 has been intentionally omitted.



39 What is the most likely approximate Moon distance that occurred during the full Moon on December 15, 2024, based on information from the graph?

- | | |
|----------------|----------------|
| (1) 392,000 km | (3) 373,000 km |
| (2) 388,000 km | (4) 367,000 km |

The model below shows some information about the Moon's orbit around Earth.



- 40 Which statement correctly explains why the orbital velocity of the Moon at the supermoon position is different than at the apogee position?
- (1) The supermoon is closer to Earth and has a greater gravitational attraction to Earth than the Moon at apogee.
 - (2) The supermoon is closer to Earth and has a lesser gravitational attraction to Earth than the Moon at apogee.
 - (3) The supermoon is farther from Earth and has a greater gravitational attraction to Earth than the Moon at apogee.
 - (4) The supermoon is farther from Earth and has a lesser gravitational attraction to Earth than the Moon at apogee.

The Saros series is used to predict the occurrence of eclipses when the Sun, Earth, and Moon are aligned in the same geometry to produce identical eclipse conditions. The period of time between these eclipses is 18 years, 11 days, and 8 hours. A total solar eclipse was observed in Plattsburgh, New York, on April 8, 2024 at 3:25 p.m. This total solar eclipse occurred when the new Moon was near perigee.

- 41 Calculate the date and local time in Plattsburgh, New York, when the next total solar eclipse with the same geometry is predicted to occur. Then, circle yes *or* no to indicate whether this total solar eclipse will be observable in Plattsburgh, New York. Give a reason for your choice. [1]

Date of total solar eclipse: _____

Time of total solar eclipse: _____ **p.m.**

Observable in Plattsburgh, New York: Yes No (Circle one)

Reason: _____

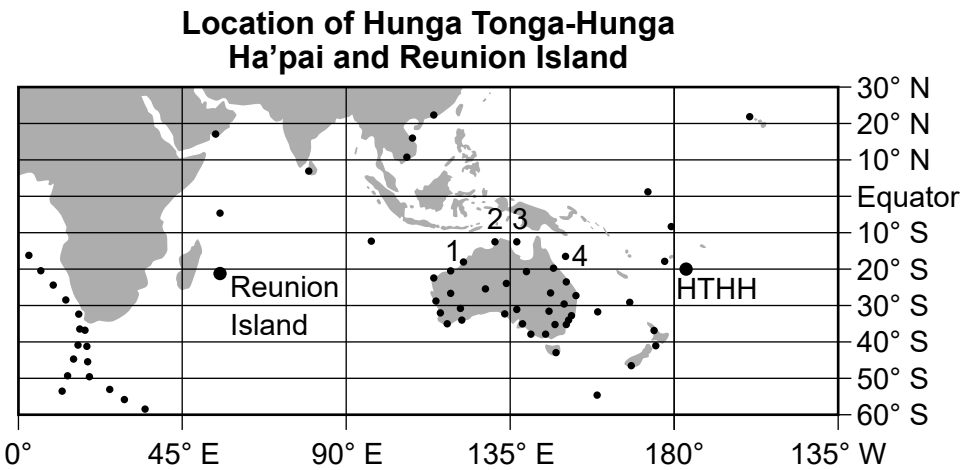
Base your answers to questions 42 through 46 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

Hunga Tonga-Hunga Ha’pai Volcano

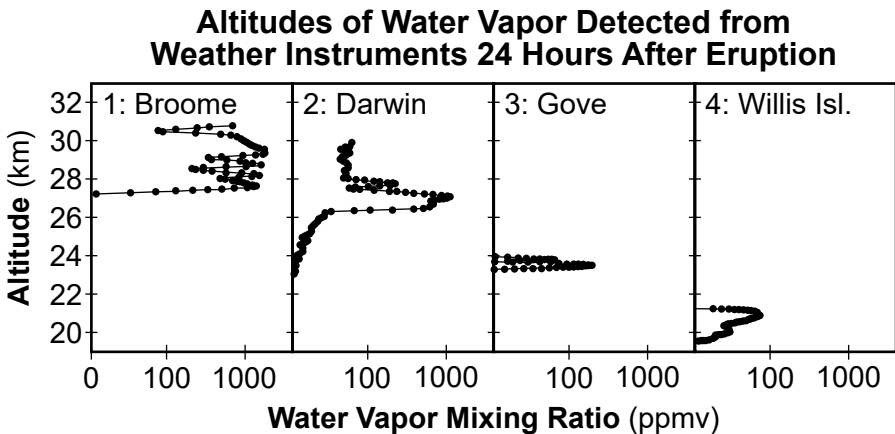
In January 2022, a submarine volcano named Hunga Tonga-Hunga Ha’pai (HTHH) caused the largest atmospheric explosion of the 21st century with the eruption column reaching a height of 58 km. Within the column, there were large amounts of liquid water and water vapor. The plume had layers of strongly enhanced water vapor that reached an altitude of between 19 and 28 km. The average ratio of water vapor at this level of Earth’s atmosphere is usually about 5 ppmv (ratio of the mass of water vapor to the mass of dry air). Twenty-four hours after the eruption, instruments attached to weather balloons measured water vapor ratios of 2900 ppmv. One recording station, Reunion Island, was still measuring ratios of 358 ppmv in the upper atmosphere one week after the eruption.

Water vapor plays a large role in climate feedbacks. Water vapor is the only greenhouse gas that will condense at temperatures present in the atmosphere. Water can be removed from the atmosphere by precipitation.

The map below shows the location of the undersea volcano, HTHH, and Reunion Island. Dots indicate locations where water vapor content data was collected.



The table below shows some information about water vapor measured from different locations around Australia.



42 Based on the geoscience information, which statement correctly describes how the volcanic eruption changed the amount of atmospheric water vapor at Location 2: Darwin?

- (1) The water vapor ratio consistently increased with altitude at Location 2: Darwin because of the eruption.
- (2) The water vapor ratio consistently decreased with altitude at Location 2: Darwin because of the eruption.
- (3) The water vapor ratio was greatest at 27 km at Location 2: Darwin because of the eruption.
- (4) The water vapor ratio was greatest at 22 km at Location 2: Darwin because of the eruption.

43 Which table identifies how the volcanic eruption of HTHH most likely affected the flow of energy to Earth's atmosphere and identifies the highest atmospheric layer of peak water vapor content?

Energy Flow	Highest Atmospheric Layer
Increased energy flow to atmosphere	Troposphere at Darwin

(1)

Energy Flow	Highest Atmospheric Layer
Decreased energy flow to atmosphere	Troposphere at Gove Island

(3)

Energy Flow	Highest Atmospheric Layer
Decreased energy flow to atmosphere	Stratosphere at Willis Island

(2)

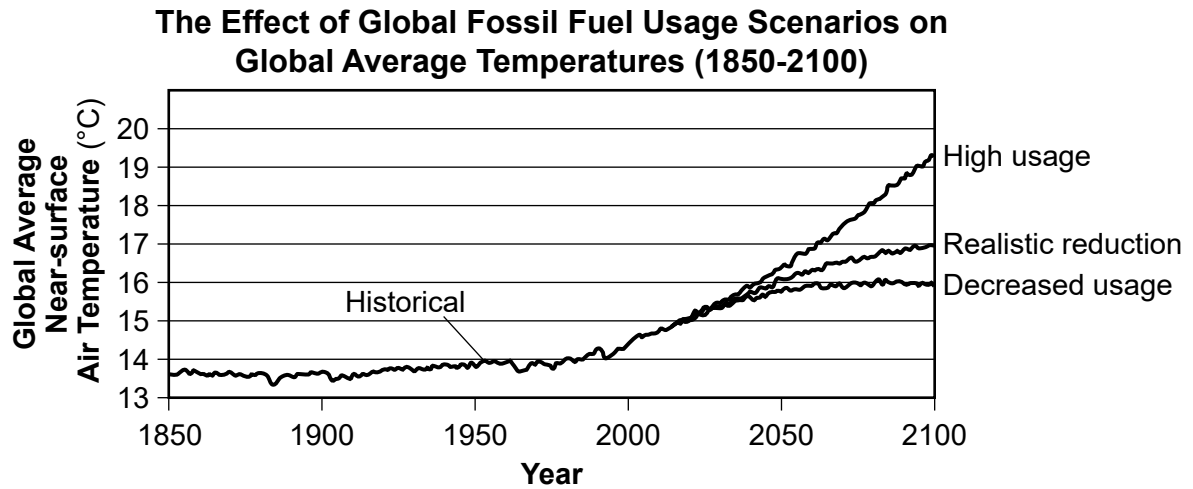
Energy Flow	Highest Atmospheric Layer
Increased energy flow to atmosphere	Stratosphere at Broome

(4)

44 The water vapor was moved by planetary wind circulation from the volcano to Reunion Island. Which row correctly matches the prevailing winds and the direction the water vapor moved?

Row	Planetary Wind	Direction of Movement
(1)	Northeast Trades	From west to east
(2)	Southeast Trades	From east to west
(3)	Westerlies	From west to east
(4)	Polar Easterlies	From east to west

Since the late 1800s, global average surface temperatures have increased by about 1.1°C. Data from satellites, weather balloons, and ground measurements confirm that as climate warms, the amount of atmospheric water vapor increases by 7% per degree Celsius. The graph below shows some information about global average temperatures based on the amount of fossil fuels used globally.



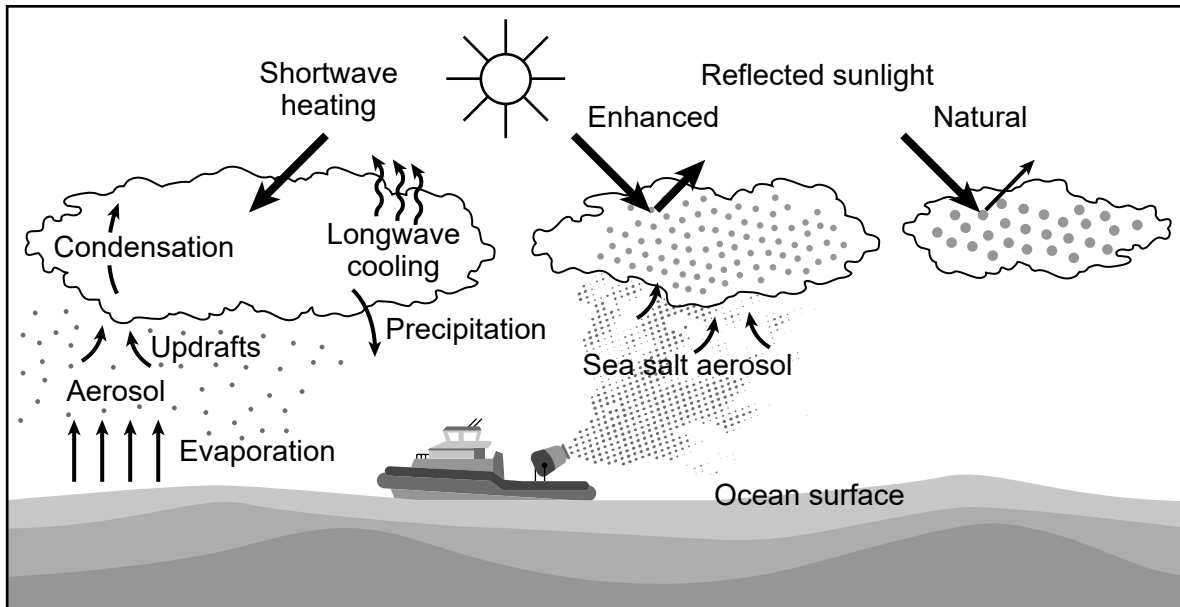
- 45 Determine the forecasted change in global average temperature according to the realistic reduction scenario of fossil fuel usage from 2020 to 2100. [1]

Global Average Temperature Change: _____ °C

Until a decrease in greenhouse gases occurs, creative ways to reduce climate change may be considered. One way is to make clouds thicker and brighter through a technique called “marine cloud brightening” (MCB). This process is shown in the model below. Arrows represent the direction of energy flow.

This method uses many ships that travel over large areas of the ocean. The ships spray seawater into the atmosphere, adding salt that acts as condensation nuclei. This creates thicker and brighter clouds that reflect additional solar radiation.

Model of Marine Cloud Brightening Process (MCB)



(Not drawn to scale)

- 46 The MCB solution to climate change involves many trade-offs. Place a check mark (✓) to indicate **one** positive and **one** negative trade-off and explain how each selection is positive or negative. [1]

Positive Trade-offs:

☐

Ships can travel over large areas of the ocean

☐

Introducing seawater into atmosphere

☐

Altering weather patterns

Explanation: _____

Negative Trade-offs:

☐

Ships can travel over large areas of the ocean

☐

Introducing seawater into atmosphere

☐

Altering weather patterns

Explanation: _____

Base your answers to questions 47 through 50 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the **2024 Edition Reference Tables for Earth and Space Sciences**.

Stars and Elements in the Universe

The table below describes the elements that form throughout a star's lifetime.
A solar mass of one is equivalent to the mass of our Sun.

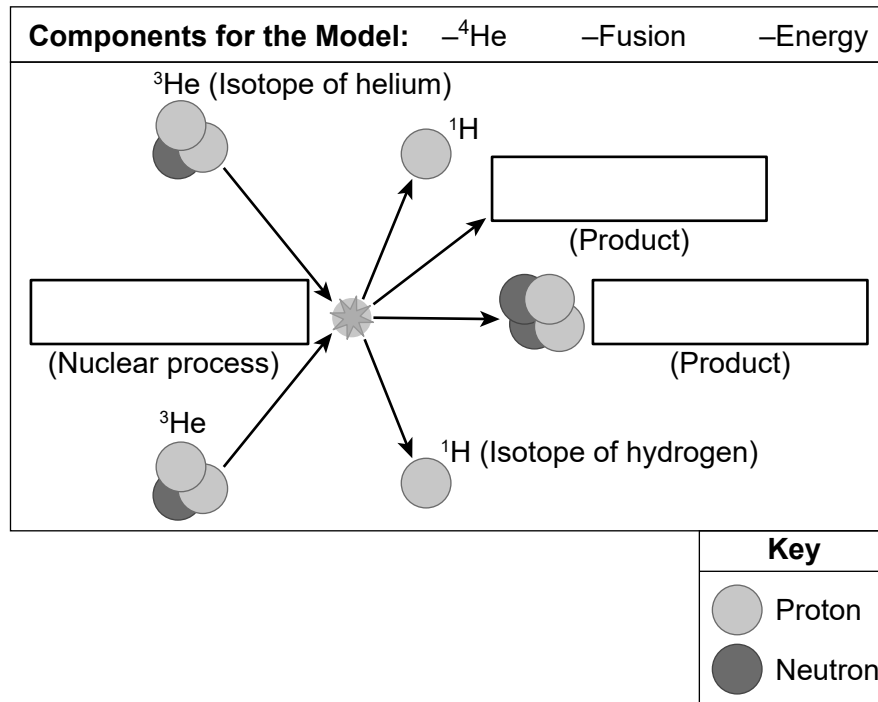
	Main sequence	Red giant	Supergiant	Supernova
Star Stages/ Events	Stars in the early/middle of their life cycles	(0.3-8 solar masses) when the hydrogen is depleted and the star begins to change	(8 to 100 solar masses) when the helium is depleted at the end of its lifetime	When a massive star explodes
Core Elements Formed	Fusion of hydrogen into helium	Helium primarily fuses into carbon, then oxygen	Fusion of heavier elements but not heavier than iron	Elements heavier than iron

47 Which two factors are responsible for nucleosynthesis in a star?

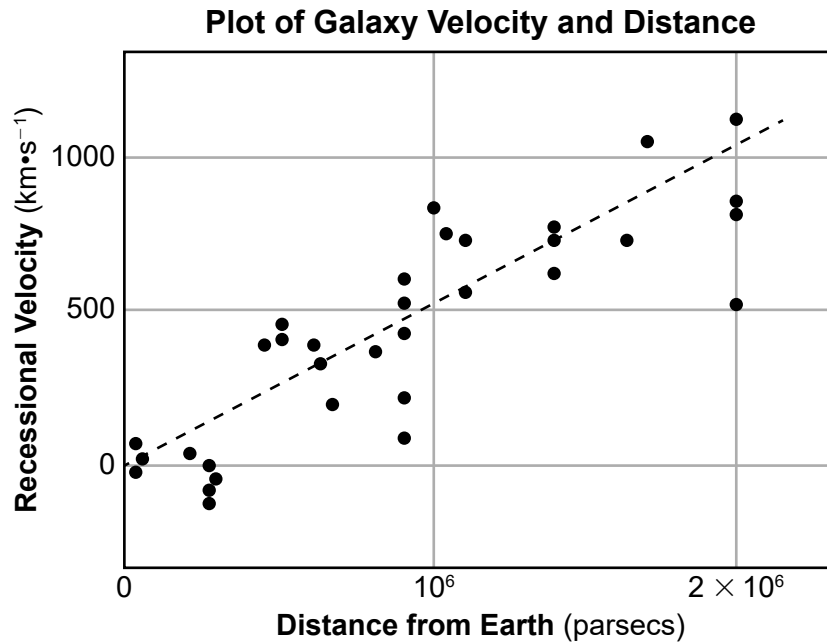
- (1) the surface temperature of a star and brightness of the star
- (2) the distance from Earth and a star's light spectra
- (3) the mass of the star and life cycle stage of the star
- (4) the velocity of the star and cosmic background radiation surrounding the star

- 48 The model below shows some information about part of a nuclear process that occurs in the Sun. Some components of the model are missing. Complete the model by filling in the correct terms in the boxes from the components provided to illustrate the nuclear process that occurs in the Sun's core and identifies the products. [1]

Generalized Partial Model of a Nuclear Process in the Sun



In the early 1900s, scientists believed the size of the universe was unchanging. In 1912, astronomer Henrietta Leavitt established the relationship between a star's distance and its apparent brightness. In 1924, Edwin Hubble used Leavitt's Law to measure distances to remote objects by looking at the speed these celestial objects (galaxies) were traveling. They were then graphed against the distance from Earth in parsecs, which is the distance light travels in 3.26 years (19 trillion miles). A simplified graph of Hubble's data shows the speed that galaxies are moving away from Earth (recessional velocity) and the galaxy's distance from Earth.



- 49 Hubble's work provided which piece of evidence that supports the Big Bang theory of an expanding universe?
- (1) The farther away a galaxy is from Earth, the greater its recessional velocity.
 - (2) Galaxies that are farther from Earth have a lower recessional velocity.
 - (3) Galaxies close to Earth have the same recessional velocity.
 - (4) Distance from Earth has no effect on the recessional velocity of galaxies.
- 50 Which type of evidence or data did Hubble most likely use to measure the speed these galaxies were traveling?
- (1) identification of the types of elements in the stars found in the galaxies using light spectra radiation
 - (2) light from many galaxies shifted to longer wavelengths at the red end of the visible spectrum
 - (3) detection of cosmic microwave background radiation from galaxies
 - (4) the changing temperature of stars in galaxies farther from Earth

