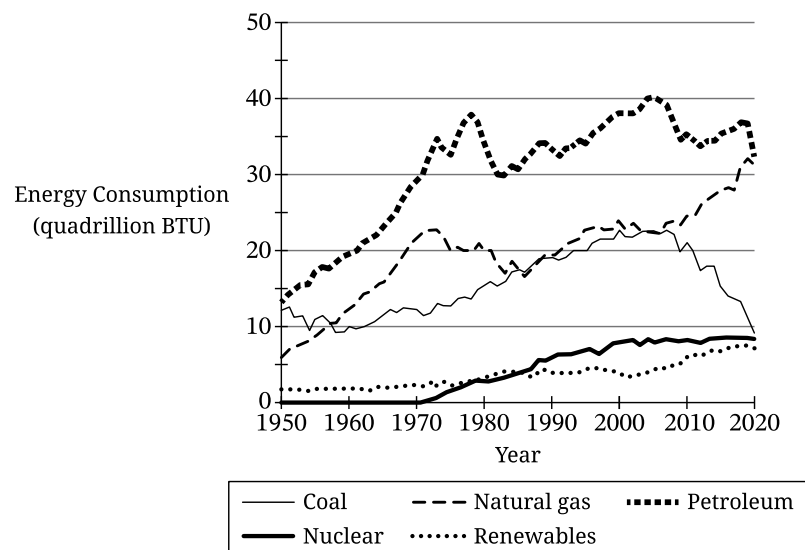


The following information applies to parts A, B, C, D, E, F, and G.

The following graph shows the number of quadrillion British thermal units (BTUs) that were consumed in the United States using five different energy sources from 1950 to 2020.

Energy Consumption by Source in the United States, 1950–2020



The following information applies to parts H and I.

Researchers studied an aquatic ecosystem near an area of land that had been converted to agricultural use. They reported an increase in nutrients, such as nitrates and phosphates, in the water.

2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

Part A

Identify one renewable energy source that is used to generate electricity.

Part B

Based on the data in the graph, **identify** the energy source that had the highest consumption in 2010.

Part C

Based on the data in the graph, **describe** the pattern in the energy consumption from coal in the United States from 1960 to 2020.

Part D

Based on the data in the graph and your knowledge of energy consumption, **explain** one likely reason why the use of coal for energy changed between 2010 and 2020.

Part E

Explain how fossil fuels are used to generate electricity.

Part F

In addition to fossil fuels, nuclear power can be used to generate electricity. **Identify** one negative impact associated with nuclear energy.

Part G

Fossil fuel combustion leads to ocean warming. **Describe** one environmental problem other than coral bleaching that is associated with warming oceans.

Part H

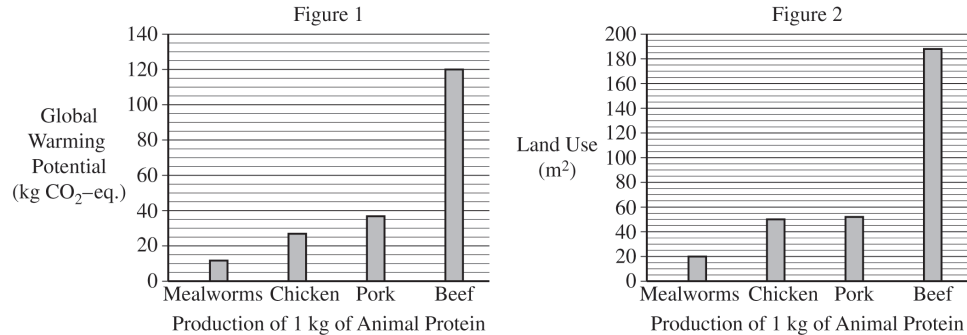
Explain how an increase in nutrients, such as nitrates and phosphates, can negatively affect an aquatic ecosystem.

Part I

- i. **Propose** a realistic solution that would reduce nutrient pollution of waterways, while still allowing cultivation of crops.
- ii. **Justify** the solution proposed in part I (i) by explaining one potential advantage other than reducing nutrient runoff.

2. As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO₂-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m²).

Global Warming Potential and Land Use from Animal Protein Production



- (a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

- (b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

- (c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

- (d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.

Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

- (e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.

Agricultural practices can have negative impacts on rivers and streams.

- (f) **Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.
- (g) **Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.
- (h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.
- (i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.
- (j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

ENVIRONMENTAL SCIENCE

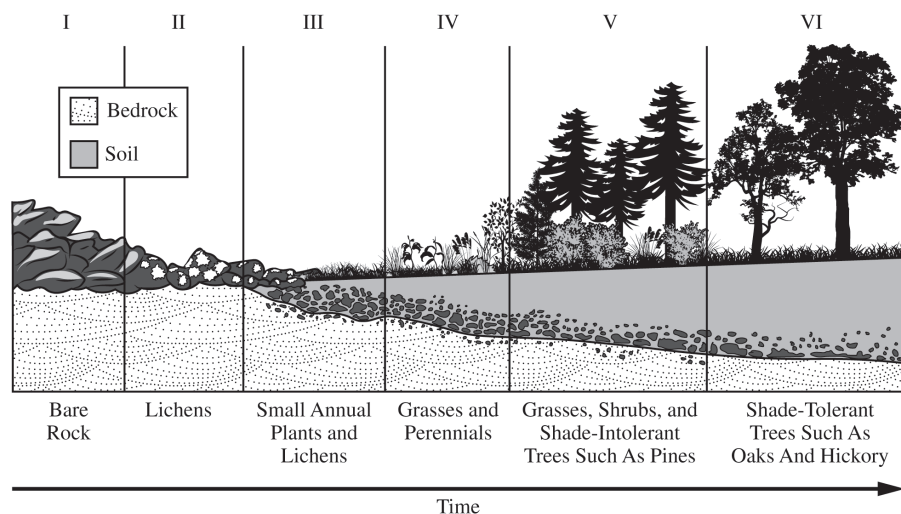
SECTION II

Time—1 hour and 10 minutes

3 Questions

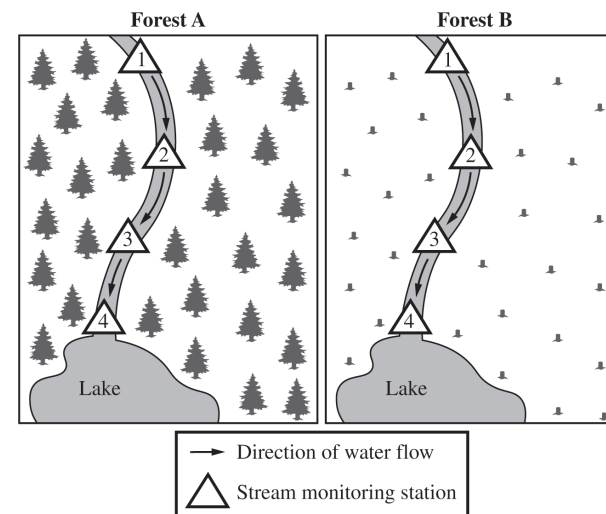
Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.



- Identify** the ecological change over time illustrated in the diagram.
- Identify** the stage in which pioneer species first appear.
- Describe** how soil forms from stage II to stage III.
- Identify** a cultural ecosystem service that may be provided by a mature forest.

Researchers are interested in investigating the effect of the removal of trees on the water quality of nearby waterways. To conduct their experiment, the researchers locate two identical forest watersheds, both with a river running through them. Forest A is an intact forest and forest B is a clear-cut forest. Four stream monitoring stations are set up in each forest study area. Each station monitors a variety of water quality indicators, including water temperature, at various locations along the river. The experimental setup is shown in the following diagrams. The arrows shown in the rivers represent the direction of water flow. The triangles in the river show the location of the stream monitoring stations.



- Identify** a testable hypothesis being investigated by the researchers.
- Identify** the independent variable in the experiment.
- Describe** the purpose of forest A in the experiment.
- Explain** why the water temperature might change because of clear-cutting trees in forest B.

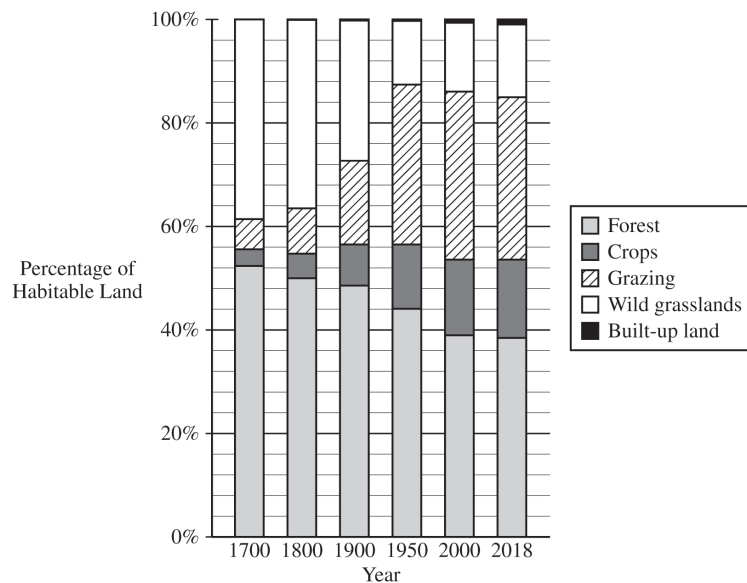
After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course may have on the water quality of the river. To monitor the river in forest B, the researchers repeated the experiment once the golf course had been constructed.

- Explain** why an indicator of water quality other than temperature could be altered by the golf course in forest B.
- Explain** how the aquatic organisms living in the lake illustrated in the diagram of forest B are likely to be affected by the new golf course.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. The following graph shows how global uses of habitable land have changed since 1700.

Land Use Changes on Earth, 1700–2018



- (a) Based on the data in the graph, **identify** the year with the highest percentage of forest.
- (b) Based on the data in the graph, **describe** the relationship between the land use changes in the wild grasslands and grazing from 1700 to 1950.
- (c) **Identify** an environmental problem associated with overgrazing by livestock.
- (d) A student hypothesized that the change in the percentage of forest from 1700 to 2018 has decreased atmospheric carbon dioxide concentrations. **Explain** whether the hypothesis is supported or refuted based on the data in the graph.

Urban environments have accounted for an increasing percentage of land use within the last few decades.

- (e) **Describe** a water-related environmental problem associated with urbanization.
- (f) **Describe** a potential response to mitigate the environmental problem identified in part (e).

Farmers who own large sections of cropland notice that bobcats, a medium-sized predatory forest cat, were present many years ago but are now virtually absent in the area. Instead, smaller mammal species now inhabit the area. Over time, the farmers have cleared nearly all of the forest on their property and converted it to farmland.

- (g) **Explain** why there are fewer bobcats present on the farmland now compared to several decades ago.

The small mammal species are considered pests by the farmers. The farmers partner with a conservation group to increase the number of bobcats in the area. As a solution, the conservation group will introduce bobcats onto the few isolated patches of the original forested habitat left in the area. They can introduce only a small number of bobcats in each patch.

- (h) **Describe** a disadvantage of introducing only a small population of bobcats.

- (i) **Propose** a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations.

- (j) **Justify** the solution proposed in part (i) by describing an additional advantage, other than reestablishing the bobcat population near the farms.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

ENVIRONMENTAL SCIENCE

SECTION II

Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Researchers interested in sustainability developed three new varieties of genetically modified green beans designed to produce higher yields in arid regions. Four plots (A–D) were set up on a floodplain of a river to grow beans. Plots A, B, and C were each planted with seeds of different types of genetically modified strains of green beans. Plot D was planted with seeds of unmodified green beans. Each plot was given equal amounts of fertilizer, which contains phosphorus and nitrogen, and water and was irrigated using spray irrigation for one hour per day. Throughout the growing season, researchers measured the amount of green beans harvested within each plot. The plots with genetically modified beans had higher crop yields than the plot with unmodified beans.

- (a) **Identify** the control group in this experiment.
- (b) **Identify** the scientific question for the investigation.
- (c) Researchers repeated the experiment by modifying the length of time for the spray irrigation to 20 minutes per day. **Explain** how the results of the experiment could be altered with this modification.

Researchers also monitored the amount of sediment and fertilizer washing into the river from each plot in the original study. The soil temperature was also measured in each plot at the same depth and at the same time each day approximately 0.05 meters below the surface of the soil.

Genetically Modified Green Bean Experimental Results

Plot	Sediment Runoff (mg/L)	Phosphorus Runoff (mg/L)	Nitrogen Runoff (mg/L)	Soil Temperature (°C)
A (Type 1 GMO beans)	2.4	0.11	1.07	18.6
B (Type 2 GMO beans)	2.1	0.02	0.56	18.3
C (Type 3 GMO beans)	0.9	0.04	0.68	18.3
D (Unmodified beans)	3.5	0.15	1.24	17.6

- (d) Based on the data in the table, **identify** the plot with the lowest soil temperature.
- (e) **Describe** how sediment runoff and fertilizer runoff compare between the unmodified green beans and the genetically modified green beans.

- (f) The Type 2 GMO beans in Plot B were developed to grow more quickly than the unmodified beans in Plot D. Researchers have hypothesized that the Type 2 beans would use fertilizer more completely than the other varieties. Based on the data in the table and the experimental design, **explain** whether the researchers' hypothesis was supported or refuted.

Once the experiment was concluded, the researchers burned the plots to remove the crops that had been planted. After a few years, the researchers returned to the plots and observed a variety of plants, insects, and bird species living there.

- (g) **Describe** the ecological process that occurred on the plots after the crops were burned.

A survey indicated that one of the plots had twice the plant diversity that the other plots had. Over the next five years, the river occasionally flooded the plots, killing off many of the species that inhabited the plots.

- (h) After each flooding event, the plot with twice the plant diversity returned to its prior level of biodiversity more quickly than the other plots did. **Explain** why a community with more plant diversity will recover more quickly from the flooding.
- (i) After the last flooding event, a beetle not previously known in the area appeared in one of the plots with less plant diversity. Over a period of a few months, the new beetle population increased, whereas the existing beetle species in the plot had declining populations. **Explain** why the new beetle species could be better able to successfully populate this plot than the existing beetle species could.
- (j) **Describe** one realistic method to prevent the new beetle from spreading beyond the experimental plot.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

3. Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

(a) **Describe** one environmental problem associated with the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

(b) **Describe** one factor that could affect the decomposition of the solid waste in a landfill.

(c) **Propose** a solution to decrease the amount of methane released from landfills into the atmosphere.

(d) **Justify** the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

(e) The average cow releases 150 liters of methane per day. **Calculate** the amount of methane that was released by all beef cattle raised in the United States in 2021. **Show** your work.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(f) A typical beef cow needs 11.8 kilograms of food per day, and each hectare of cattle pasture produces 26.2 kilograms of grasses. **Calculate** the number of hectares of pasture that would be needed to support all beef cattle raised in the United States for one day. **Show** your work.

(g) The average American consumes 2,250 kilocalories of food per day. Beef cattle can produce 2.7 million kilocalories per hectare of land. Corn can produce 30.4 million kilocalories per hectare of land. **Calculate** how many more American people could be fed if 150 hectares of land was used to grow corn instead of raising beef cattle. **Show** your work.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

STOP

END OF EXAM

ENVIRONMENTAL SCIENCE

SECTION II

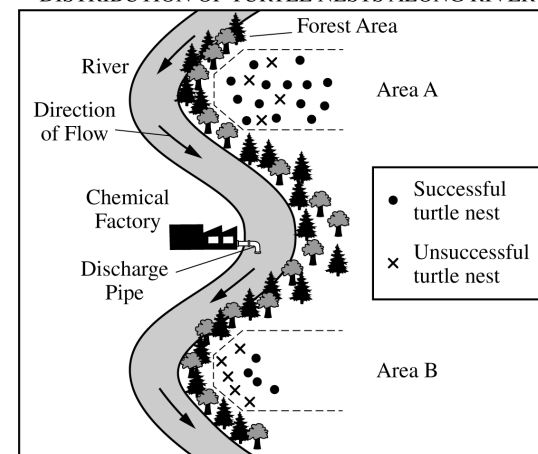
Time—1 hour and 10 minutes

3 Questions

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1. Common snapping turtles, *Chelydra serpentina*, are primarily aquatic, but they lay their eggs on land. Researchers are interested in understanding the impact of pollution on turtle nesting sites. The researchers examined nesting sites at two agricultural areas along the floodplain of a river upstream and downstream from a chemical factory that is a known source of aqueous mercury pollution. Turtle eggs, soil, and vegetation samples taken from areas around turtle nests downstream from the chemical factory showed high levels of mercury in a previous study. Mercury was not detected in samples taken upstream from the chemical factory.

DISTRIBUTION OF TURTLE NESTS ALONG RIVER



(a) The map shows locations of both successful and unsuccessful turtle nests.

- Identify** the area with the greatest nest success rate, based on the information in the diagram.
- Identify** the dependent variable in the study.
- Based on the information provided, **identify** a likely scientific question for the study.
- Describe** why researchers measured mercury levels in locations upstream from the factory.
- There are plans to remove trees and other vegetation along the river bank. **Explain** how this modification could affect the location and number of successful turtle nests in Area B.

(b) Mercury can affect organisms and ecosystems in many ways.

- Describe** how a persistent pollutant, such as mercury, can negatively affect an organism.
- Describe** how a persistent pollutant, such as mercury, can negatively affect an ecosystem.
- Researchers measured methylmercury in a location downstream from the factory. **Explain** how methylmercury could be present in the stream.
- Researchers claimed that the soil nearest to the river has higher levels of mercury than the field has, and those elevated levels have affected the nesting success for turtles. **Explain** how the pattern shown in the diagram supports or refutes this claim.

(c) The turtle study was conducted in an agricultural area. **Describe** how a specific agricultural practice changes the soil in an area.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

ENVIRONMENTAL SCIENCE

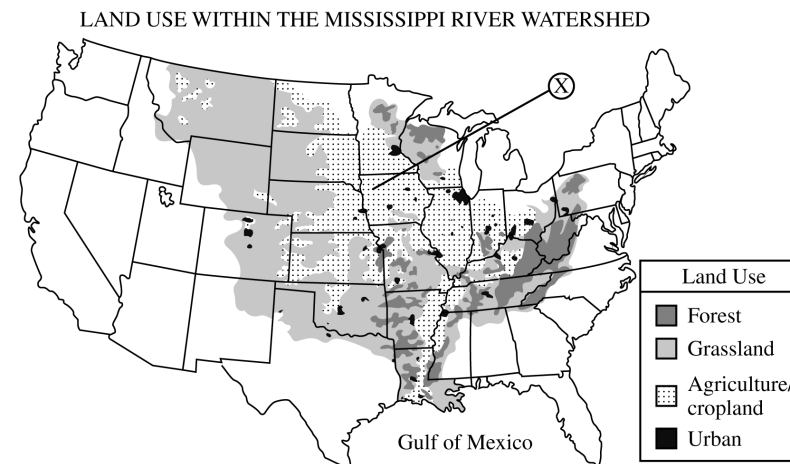
SECTION II

Time—1 hour and 10 minutes

3 Questions

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- The dead zone in the Gulf of Mexico occurs every summer when winter snow melts and spring rain flows into the Mississippi River. Recent studies have shown that both the total area covered by algae and the depth of the algal mass in the dead zone are increasing.



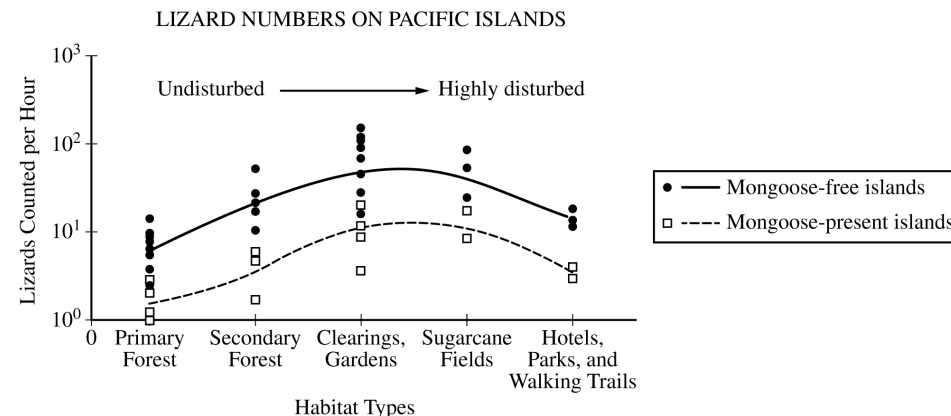
(a) Various land use practices can have different effects on the waters that surround a dead zone.

- Identify** the land use that covers the least amount of area in the Mississippi River watershed, based on the diagram.
- Describe** one way that the land use practice at location X in the diagram could contribute to the dead zone in the Gulf of Mexico.
- Describe** one way that urban areas in the Mississippi River watershed could contribute to the dead zone in the Gulf of Mexico.

- (b) The dead zone in the Gulf of Mexico has both economic and environmental effects for coastal communities.
- Describe** how a dead zone affects marine organisms living in the Gulf of Mexico.
 - Describe** one economic effect on communities along the Gulf of Mexico that can result from the presence of the dead zone.
 - Describe** one factor that causes the area of the dead zone in the Gulf of Mexico to increase in the summer months.
- (c) Researchers want to examine the effect of riparian vegetation buffers on water quality in streams in agricultural areas. Researchers will measure the water nutrient concentrations over the course of one year. The study sites are located 100 meters downstream from areas either with or without riparian vegetation buffers.
- Identify** a testable hypothesis for the study.
 - Describe** a control that the researchers could use in the study.
 - Identify** one water quality test, other than measuring nitrates or phosphates, that the researchers could use to evaluate how riparian vegetation buffers affect water quality.
 - During the investigation, researchers discovered that some of the land next to one of the streams with a riparian vegetation buffer is going to be converted from cornfields into a large-scale concentrated animal feeding operation. **Explain** one way that this change in land use could alter the results of the study.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

2. Biologists collected data on the abundance of lizards on several Pacific islands with and without mongoose populations. The surveys were conducted at different locations on the islands by counting the number of lizards observed per hour and included habitats with both undisturbed areas and anthropogenically disturbed areas.



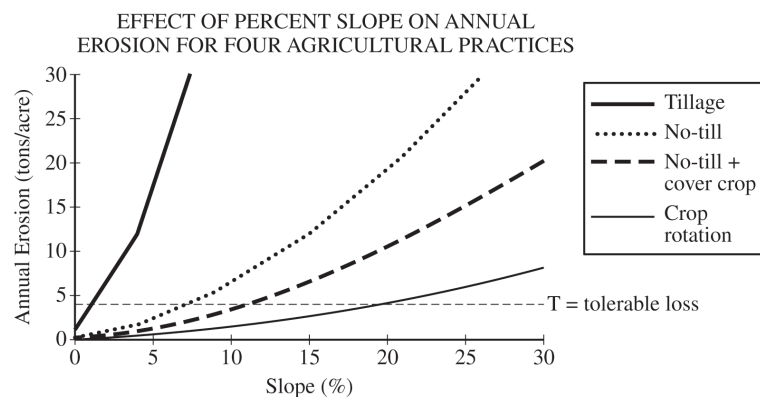
- (a) The graph shows data collected by biologists on lizard numbers on several Pacific islands.
- Based on the data in the graph, **identify** the habitat type with the greatest number of lizards.
 - Based on the data in the graph, **describe** the relationship between the lizard numbers observed on islands with and without mongoose populations.
- Globally, islands vary in size, location, and habitat.
- (b) Based on the theory of island biogeography, **describe** the characteristics of an island with the greatest species diversity.
- (c) Island ecosystems are often threatened by invasive species, such as the mongoose populations studied in the survey.
- Describe** one environmental problem caused by invasive animal species.
 - Invasive species are often pests. **Make a claim** that proposes one way to control pest species.
 - Justify** the solution proposed in (c)(ii) by providing an additional benefit of the solution.
- (d) Islands provide humans with many ecosystem services. However, humans may alter ecosystems when they obtain these services. Large-scale commercial sugarcane farming on the Pacific islands has led to significant ecological damage.
- Identify** a provisioning ecosystem service provided by primary forests.
 - Based on the data in the graph, **explain** how replacing primary forests with sugarcane fields may have affected the number of lizards counted on the mongoose-free Pacific islands.
 - The long-term use of monocultures in commercial sugarcane farming is one cause of the ecological damage. **Describe** one problem associated with monocultures.

One solution to the ecological damage of monocultures is to use a form of crop rotation using legumes.

- (e) **Describe** an advantage of crop rotation using legumes on soil fertility.

ENVIRONMENTAL SCIENCE
SECTION II
Time—1 hour and 10 minutes
3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**



1. Soil erosion is one of the most serious soil-degrading processes. Each year tons of soil erode from cropland, pastures, forests, and other places. The amount of erosion varies dramatically among various land-use types. The figure above shows the effects of different agricultural practices and slopes on annual erosion rates.

(a) Refer to the graph above for the following.

- (i) **Identify** the scientific question that resulted in the data presented in the graph.
- (ii) **Identify** the agricultural practice that could be used on a 15% slope without leading to a higher than tolerable loss of soil.
- (iii) **Describe** the effect of adding a cover crop compared to using the no-till method.
- (iv) **Identify** one natural mechanism of soil erosion.

- (b) Sediment from erosion can enter streams and affect water quality. One way sediment can enter a stream is from nearby road construction. Two methods to reduce sediment run-off in streams are to either put down straw bales or plant grass. The hypothesis to be tested is that straw bales reduce more sediment run-off than planted grass does. To test the hypothesis, two plots near a road under construction are measured. On one plot (A), straw bales are used to cover the soil, while a second plot (B) is planted with grass. The sediment discharge from each plot is measured after rainfall.

- (i) **Identify** the dependent variable stated in the hypothesis.
- (ii) **Describe** one way to add a control to improve the design of the study.
- (iii) **Identify** one variable that was not discussed that could affect the results of the study.

Sediments reaching streams affect water clarity, which is tested by determining turbidity. Turbidity can be determined by measuring the depth at which a submerged object can no longer be seen from the surface.

Sample Group	Turbidity
Straw bale plots (plot A)	12 cm
Planted grass plots (plot B)	28 cm

- (iv) Based on the data in the table above, **make a claim** about the stated hypothesis.
- (c) Several fish species lay their eggs in the gravel in the streams under investigation in the study.
- (i) **Describe** the type of survivorship curve expected for these fish species.
- (ii) **Explain** why the input of sediment to a stream can negatively affect reproduction of fish that lay their eggs in the gravel of the streambed.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

4. Soil is a complex mixture of living organisms and organic material, along with minerals and other abiotic components. Soils help sustain life and support ecosystem functions.

- (a) **Describe** how TWO climate factors affect the rate of soil formation.
- (b) As soils form, distinct layers known as horizons develop over time. One of these is the A horizon.
- (i) **Identify** one specific biotic component of the A horizon.
- (ii) **Identify** one abiotic component of the A horizon.

Resources such as soil and water can be degraded by human activities.

- (c) Nitrate levels exceeding the United States Environmental Protection Agency's primary drinking water standard have been found in the groundwater of areas with intensive agriculture.
- (i) **Identify** one agricultural practice that can lead to elevated nitrate levels in groundwater.
- (ii) **Describe** how the practice you identified in (c)(i) leads to elevated nitrate levels in groundwater.
- (d) Acid deposition has affected soil quality in many parts of the northeastern United States.
- (i) **Explain** one way acid deposition onto soil can affect plant health.
- (ii) **Describe** one method for remediating soil affected by acid deposition.
- (e) Climate change is causing far-reaching ecosystem changes, including soil degradation in many of the world's biomes. **Describe** TWO ways that climate change can degrade soil.

STOP

END OF EXAM

ENVIRONMENTAL SCIENCE

SECTION II

Time—90 minutes

4 Questions

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this book. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Read the article below and answer the questions that follow.

The Floridian Daily

May 21, 2013

The small community located on the edge of the magnificent wetlands of Florida's Everglades was the site of a press conference today where Governor Gayle Moss announced that the restoration of the Everglades is successfully underway. She noted that the Everglades ecosystem has suffered threats to its water quality, water quantity, and habitats in recent decades. Moss noted that intensive urban and agricultural development in adjacent areas has diverted substantial amounts of freshwater resources and impaired water quality. Governor Moss then emphasized that the preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state. She closed the press conference by saying, "The Everglades is a gem not only for Florida but for the entire world. Each of us has the responsibility to do our part to preserve this magnificent resource."

- (a) **Describe** how TWO human activities, other than those that result in anthropogenic climate change, have resulted in a decrease in the amount of freshwater flowing into the Everglades ecosystem.
- (b) In addition to water quantity problems, the Everglades is faced with a variety of water quality issues. For example, phosphorus concentrations in the Everglades have increased since the 1960s.
- (i) **Describe** how one specific human activity contributes to increased phosphorus levels in the Everglades.
- (ii) **Explain** one way in which an increase in phosphorus levels can adversely affect the Everglades ecosystem.
- (iii) **Describe** one step that could be taken to reduce phosphorus inputs from the activity you identified in part (i).
- (c) Climate change could have a variety of impacts on water quantity, water quality, and habitat. For EACH of these three factors, **identify and describe** one specific example of an impact on the Everglades likely to result from climate change.
- (d) The article states that Governor Moss believes that the "preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state."
- (i) **Describe** one way that restoring water quantity and water quality in the Everglades is expected to improve the structure and function of the ecosystem.
- (ii) **Describe** one way that restoring the Everglades is expected to provide economic benefits to Florida.