Chief Reader Report on Student Responses:

2019 AP® Environmental Science Free-Response Questions

• Number of Students Scored	172,456			
• Number of Readers	480			
• Score Distribution	Exam Score	N	%At	
	5	16,192	9.4	
	4	44,333	25.7	
	3	24,348	14.1	
	2	43,816	25.4	
	1	43,767	25.4	
• Global Mean	2.68			

The following comments on the 2019 free-response questions for AP® Environmental Science were written by the Chief Reader, Michele L. Goldsmith, Chair and Professor, Science Department, Southern New Hampshire University. They give an overview of each free-response question and of how students performed on the question, including typical student errors. General comments regarding the skills and content that students frequently have the most problems with are included. Some suggestions for improving student preparation in these areas are also provided. Teachers are encouraged to attend a College Board workshop to learn strategies for improving student performance in specific areas.

Question #1 **Task:** Document-Based Question **Topic:** Coastal Habitats

Max. Points: 10 **Mean Score:** 4.28

What were the responses to this question expected to demonstrate?

The intent of this question was for students to evaluate a diagram of the nesting sites of a species of migratory shorebirds, the piping plover, on Assateague Island, Virginia, and to describe issues impacting coastal species and coastal communities.

In the first part of the question, the stimulus provided a map of Assateague Island, Virginia, with various habitats and the distribution of piping plover nests in 1999 and in 2009. Students were asked to read the information about plovers provided and to use the maps to answer questions related to changes in nesting habitats over time. These concepts were drawn from the following sections of the topic outline: II. The Living World, A. Ecosystem Structure and D. Natural Ecosystem Change.

The next part of the question evaluated student understanding of human actions that could impact nesting coastal species. Students were asked to explain a way that features of barrier islands help preserve and protect the environment in coastal regions. They were asked to identify and describe a human action that directly threatens coastal habitats and an impact on species that use the habitat.

Students were then asked to identify an economic impact of rising sea levels and to describe two different methods that could be used locally to protect coastal communities from rising sea levels. These concepts were drawn from the following section of the topic outline: VII. Global Change, B. Global Warming and C. Loss of Biodiversity.

How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?
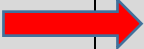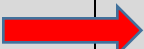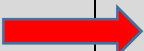
Students were expected to read and interpret a map and to be knowledgeable about coastal environments, with an emphasis on barrier islands. Students were also asked to identify and discuss direct threats to coastal habitats and to be knowledgeable about the effects of sea level rise and methods that may be used locally to protect coastal communities from sea level rise.

- Part (a) referred to the map included in the question. Nearly all students responded to (a)(i) correctly by identifying "unvegetated sand" or "sandy beaches" as the preferred nesting habitat for piping plovers based on the information in the map. In (a)(ii), correct responses included "decreased by almost half" or "decreased from 44 to 25." Responses that only noted a decrease in the number of nests were not accepted because students were asked to describe the change, not identify. Some responses only described the change in location of the nests, e.g., "closer to the water" or "moved closer together." These answers were not accepted because they did not address number of nests and indicated a misreading of the question. In (a)(iii) many responses correctly described habitat loss from an increase in vegetation or a decrease in unvegetated sand. Responses that were limited to "a decrease in unvegetated sand" did not earn a point because no link to habitat loss was made. Responses that described plovers being overhunted appeared to indicate a misunderstanding of the term "nineteenth century" or misapplication of the information in the stem.
- In part (b)(i) responses described restrictions that could be reasonably implemented to help prevent the destruction of plover nests. The most common correct responses described fencing or otherwise marking off the area around the nests or prohibiting vehicles. Responses that simply described closing or banning people from the beach were not accepted. Since plover nesting season begins in May and ends in September, this is not a reasonably implemented restriction. Additionally, "restrict access to the beach" is a repetition of the question stem and was not accepted. Correct responses in part (b)(ii) required two parts, a description of how the barrier island prevented damage and what damage was prevented. Common responses described how barrier islands block big waves and prevent coastal erosion. "Natural disasters" and "destruction" were not accepted because

they are vague, colloquial terms. Some responses indicated a misunderstanding that barrier islands protect the mainland from invasive species, and some indicated confusion between barrier islands and barrier reefs. In part (b)(iii), tourism, littering, and coastal development were most commonly identified as human actions that directly threaten coastal habitats. A key phrase in the question stem was "directly threatens." Fossil fuel combustion and nutrient pollution or eutrophication were not accepted because these are indirect threats. Ingestion of plastic by sea turtles/shore birds leading to blocked digestive tracts, and loss of habitat due to coastal development were most commonly described as an impact of human activity on a species.

- The most common correct responses in part (c) identified a decrease in property value, a decrease in tourist revenue, and damage to property that costs money to repair or replace. Some responses also correctly described an increase in insurance rates. In general, economic impacts had to include a reference to money or financial value.
- In part (d) students were asked to describe two methods that may be used locally to protect coastal communities from rising sea levels. Because the question stem asks for a description, both the method and how it protects the coast must be included in the response. Common responses described the construction of sea walls, levees, or flood barriers to prevent flooding. Putting houses on "stilts" and moving buildings back from the beach to prevent flood damage were also common responses. A key word in this stem is "locally." Responses that included the reduction of greenhouse gas emissions to prevent sea level rise were not accepted because these are not methods that can be used locally. Also, responses sometimes included a repetition of the question stem. For example, "building a sea wall can help protect the community from sea level rise" was not accepted because "protect from sea level rise" is part of the question stem and does not convey understanding of the method.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	Responses that Demonstrate Understanding
• Passive drainage can prevent coastal flooding from sea level rise.	• "The installation of water pumps like in areas of Florida that can pump water back out to sea can mitigate flooding."
• Hydroelectric dams (or just dams) will protect coastal areas from sea level rise.	• "Sea walls or levees can help prevent flooding in coastal communities."
• The increase in vegetated areas on Assateague Island is due to agriculture, therefore prohibiting agriculture or removing vegetation on barrier islands will protect plover nests.	• "Rope off places where nests are on the beach during nesting season."
• Barrier islands protect the mainland from invasive species.	• "Barrier islands block waves and provide calm and sheltered habitat for marine life like blue crabs to survive and flourish."

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve the student performance on the exam?

- Practice interpreting maps, diagrams, and other visual representations of environmental science concepts with your students. Students should be able to describe characteristics of visual representations as well as explain relationships among different characteristics presented visually.
- Emphasize the differences between environmental impacts and economic impacts. For an economic benefit or impact, students should focus on financial gain or loss.
- Remind students that when a question asks for two methods, only the first two methods will be scored. Students should choose their strongest answers and make that the focus of their discussion. Score items following these guidelines to help students best use their time when answering free-response questions.
- Remind students to provide answers that are not simply restating the question stem, as this does not earn points.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers will find sample student responses on the exam information page on AP Central, along with specific commentary explaining why each point was or was not earned. Teachers can use these samples to work with students to help them become more comfortable in practicing and producing responses within the suggested response time.
- Teachers will find scoring guidelines explaining how exam questions were scored on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the AP year so that students become familiar with how their responses will be scored.
- Teachers can review elements of Question 3 from the 2018 exam, Question 1 from the 2017 exam, Question 1 from the 2015 exam, and Question 1 from the 2013 exam.
- Teachers can use the Quantitative Skills Guide in AP Sciences (2018) to assist students in developing quantitative skills throughout the course.
- In AP Classroom, teachers will find a rich, new collection of resources for the 2019 school year that includes newly created formative and summative assessment items for every unit of the course and that represents each of the types of questions on the AP Exam. This includes practice FRQs for teachers to use as formative assessment pieces beginning with scaffolded questions that represent what students are ready for at the beginning of the school year and an increased challenge as teacher's progress through the course.
- The AP Environmental Science Online Teacher Community is active and there are many discussions concerning teaching tips, techniques, and activities that many have found helpful. It is easy to sign up for and you can search topics of discussions from all previous years.
- New teachers (and career changers) might want to consider signing up for an AP Summer Institute (APSI). An APSI is a great way to gain in-depth teaching knowledge on AP Environmental Science curriculum and exam and is also a great way to network with colleagues from around the country.
- Teachers of AP Environmental Science can find useful resources in the course audit webpage and the classroom resources page for AP Environmental Science. The following special focus modules will provide additional information on these concepts: Ecology

What were the responses to this question expected to demonstrate?

The intent of this question was for students to evaluate the benefits of forests, the consequences of extraction of bitumen and to complete several calculations relating to the extraction of bitumen and production of synthetic crude oil. Students were asked to identify an ecological benefit and an economic benefit provided by forests. These concepts were drawn from the following section of the topic outline: II. The Living World, A. Ecosystem Structure. Students were then asked to describe two environmental consequences that result from the extraction of bitumen or the transport of synthetic oil. These concepts were drawn from the following sections of the topic outline: IV. Land and Water Use, B. Forestry and VI. Pollution, A. Pollution Types.

In the second part of the question, students were asked to calculate the number of days needed to extract the recoverable volume of bitumen from oil sands based on a given extraction rate. Students were then asked to calculate how many years would be needed to fully extract the recoverable volume of bitumen from the oil sands. Finally, students were asked to calculate the number of barrels of freshwater needed to produce 30 million barrels of synthetic crude oil in a year. These concepts were drawn from the following sections of the topic outline: I. Earth Systems and Resources, C. Global Water Resources and Use and IV. Land and Water Use, E. Mining.
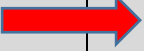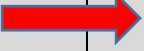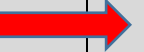
How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?

Students were expected to be knowledgeable about the ecological and economic benefits of forests. Students were also expected to convey an understanding about the process of extraction of bitumen and processing of synthetic oil in oil sand deposits. Students were expected to perform calculations related to the process of extraction of bitumen and processing of synthetic oil.

- The majority of responses in part (a) were able to correctly identify an ecological benefit of forests other than providing habitat. The most common responses included carbon sink, oxygen production, food for organisms, and reduction of soil erosion. Some responses described plants providing shade but did not clarify how that was unrelated to habitat. Identification that shade changes in temperature near the forest did earn a point. Some responses did not earn a point because they included a benefit to humans or an economic benefit rather than an ecological benefit.
- The majority of responses in part (b) were able to correctly identify an economic benefit of forests. Forest products such as timber or medicine and tourism were the most common correct responses. Some responses identified "wood" as a product but did not earn a point because an individual could obtain wood without a monetary exchange. "Timber" and "lumber" are terms for a commercial product and did earn a point, but responses that identified "wood" required an indicator of monetary exchange to earn a point.
- Responses identified several environmental consequences that result from the extraction of bitumen or transportation of synthetic oil in part (c). Correct responses included combustion of fossil fuels by mining equipment that leads to the release of greenhouse gases, pollution of surface water/groundwater by oil leaks during transport, noise pollution from mining equipment, and habitat fragmentation from pipelines outside the boreal forest habitat. Responses related to the loss of boreal forest habitat, such as loss of soil during excavation, did not earn a point. A key word in the question stem is "consequence." Responses that identified an event such as an oil spill but did not indicate the consequence of that oil spill (i.e., pollution of surface water) did not earn a point.
- In the second part of the question, students were required to apply mathematical routines to three different calculations related to bitumen extraction and the processing of synthetic oil. Calculations in parts (d), (e), and (f) required showing all units for the setup point. The setup for each part did not have to have the exact same format as the rubric, but the response had to be a correct mathematical relationship to earn the point. Students that included scientific notation in the setup were likely to earn a point for setup in each part. Responses that used

"million" or "billion" without the mathematical equivalent in the setup often did not include a conversion between units, which was an incomplete setup and therefore did not earn a point. Some responses included numerical values from the question stem but no evidence of a mathematical routine, so points for setup were not earned. The setup and answer points in part (e) relied on the answer from part (d). If the answer in part (d) was incorrect, but used in the setup for part (e) correctly, the setup and answer points in part (e) could be earned if the calculation was correct.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Dimensional analysis with all units included and demonstration of proper cancelling of units.	• $\dfrac{30 \text{ million barrels of oil}}{\text{month}} \times \dfrac{2 \text{ barrels of freshwater}}{1 \text{ barrel of oil}} \times \dfrac{12 \text{ months}}{1 \text{ year}}$ $= 720,000,000$ barrels of freshwater per year
• Incorrect calculation when dividing values written in scientific notation.	• $\dfrac{1 \text{ day}}{1 \times 10^6 \text{ barrels}} \times 7.3 \times 10^{10} \text{ barrels}$ $= 7.3 \times 10^4$ barrels
• Simple identification of an event like an oil spill is not describing the consequence of that event.	• "Oil leaks or an oil spill can happen during transportation of synthetic oil to customers. If oil leaks into waterways, it may harm the organisms living there (change their environment)"
• Atmospheric composition is a global pattern and does not change in the vicinity of a forest.	• "One ecological benefit of forests is their release of oxygen into the atmosphere, and intake of carbon dioxide in the process of photosynthesis, which lessens greenhouse gasses."

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve the student performance on the exam?

- Practice dimensional analysis with all units. Require students to routinely practice calculations, showing all work, which includes using unit conversions, dimensional analysis, and metric prefixes. Show all work in the test booklet.
- Encourage students to evaluate their answers for accuracy and correct units. Students should stop to ask if the answer of a calculation is reasonable. An answer that 73,000 days is equivalent to 4 million years should suggest that a calculation error has been made.
- Emphasize the complexity of an answer necessary for a "describe" compared to an "identify" prompt.
- Clarify the difference in the process of extraction and use of different fossil fuels. Compare different energy sources (renewable and nonrenewable) in their global distribution, use, and environmental impact.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers will find sample student responses on the exam information page on AP Central, along with specific commentary explaining why each point was or was not earned. Teachers can use these samples to work with students to help them become more comfortable in practicing and producing responses within the suggested response time.

- Teachers will find scoring guidelines explaining how exam questions were scored on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the AP year so that students become familiar with how their responses will be scored.
- Teachers can review elements of Question 3 from the 2017 exam.
- In AP Classroom, teachers will find a rich, new collection of resources for the 2019 school year that includes newly created formative and summative assessment items for every unit of the course and that represents each of the types of questions on the AP Exam. This includes practice FRQs for teachers to use as formative assessment pieces beginning with scaffolded questions that represent what students are ready for at the beginning of the school year and an increased challenge as teacher's progress through the course.
- Teachers can use the [Quantitative Skills Guide in AP Sciences (2018)](#) to assist students in developing quantitative skills throughout the course.
- The AP Environmental Science Online Teacher Community is active and there are many discussions concerning teaching tips, techniques, and activities that many teachers have found helpful. It is easy to sign up for and you can search topics of discussions from all previous years.
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- Teachers of AP Environmental Science can find useful resources in the [course audit webpage](#) and the [classroom resources page](#) for AP Environmental Science.

What were the responses to this question expected to demonstrate?

The intent of this question was for students to evaluate a graph showing the atmospheric carbon dioxide concentration at Mauna Loa and the oceanic pH at Station ALOHA, Hawaii. Students were asked to evaluate the effect of the changes in atmospheric carbon dioxide concentrations on Earth's oceans and to evaluate the affect that changes in the pH in the world's oceans pose to marine organisms. Additionally, students were asked to identify and describe an anthropogenic threat to coral reef ecosystems that was not posed by a change in pH.

In the first part of the question, the stimulus provided a line graph with two sets of data, the atmospheric concentration of carbon dioxide and the oceanic pH from 1960 to 2015. Students were asked to determine the concentration of CO_2 (in ppm) and the pH in 2005. Students were then asked to predict the effect of increased concentration of atmospheric CO_2 on the concentration of CO_2 in the ocean and to identify the relationship between the concentration of atmospheric CO_2 and the pH of ocean water. Students were asked to provide the complete chemical equation that represents the reaction between oceanic carbon dioxide and water and then to identify the specific environmental problem that directly results from the decrease in pH of Earth's oceans. These concepts were drawn from the following section of the topic outline: II. The Living World, E. Natural Biogeochemical Cycles and VII. Global Change, B. Global Warming.

Finally, students were asked to explain why certain organisms, in particular those with calcium carbonate shells or exoskeletons, are threatened by the decreasing pH levels measured in seawater. Students were asked to identify an additional anthropogenic threat to the world's coral reef ecosystem and to describe how that threat damages the coral reefs. These concepts were drawn from the following sections of the topic outline: II. The Living World, A. Ecosystem Structure; III. Population, B. Human Population, 3. Impacts of Population Growth; IV. Land and Water Use, F. Fishing; and VI. Pollution, A. Pollution Types, B. Impacts on the Environment and Human Health.

How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?

Students were expected to interpret a graph showing concentration of atmospheric CO_2 and ocean pH and use that information to address specific questions. Students had to be knowledgeable about ocean acidification and its impact on marine species. They also had to identify an additional anthropogenic threat to the world's coral reef ecosystems.

- In general, students were able to read and evaluate the data presented in the graph for part (a)(i) and part (a)(ii). The majority of responses were able to correctly identify the correct values (or within the acceptable range) for both the concentration of carbon dioxide and pH based on the data in the graph.
- For part (b)(i), the majority of students were also able to correctly determine the relationship between the variables in the graph. In part (b)(ii), students routinely demonstrated the ability to state the correct relationship, for example, "atmospheric CO_2 and the pH of ocean water have an inverse relationship." Once they established this relationship, many students went on to identify the problem by name, "ocean acidification," or by description, "more acidic water," as asked for in part (b)(iv). Many students struggled with part (b)(iii) where they were asked for the product of the reactants used to form carbonic acid. They could either use chemical symbols or write out the words. Some students made the error of presenting the correct chemical product (H_2CO_3) but would than label it incorrectly (e.g., "carbonate"), therefore, they did not earn the point.
- In part (c)(i), student responses indicated an understanding of the hazards of climate change on natural ecosystems. For example, one student wrote, "The increase in global warming will increase the temperatures of the ocean. This increase will move the temperature out of the coral's range of tolerance." Some responses were not able to explain the consequences that can result from ocean acidification. For example, one student wrote, "the increase in ocean acidity, which is dangerous to marine life." This response needs to be more specific about the hazards of increased acidity and the specific impacts on marine life, such as the student who wrote "because they can't access the carbonate group, they don't have the materials necessary for the growth of the shell." In part (c)(ii), students demonstrated an understanding that humans can impact ecosystems at a range of scales. Impact

at the local scale was well demonstrated by the student who wrote, "Trawling, in which a net is dragged across the ocean floor to catch fish; can severely damage coral reefs by braking off parts as it goes." More regional and global scale changes, particularly coral bleaching, were also well described by many students: "Rising water temperatures can cause photosynthetic algae in coral to leave the coral, causing coral bleaching and die off"; Global warming can cause the warming of the oceans and stress the coral leading to a discharge of the symbiotic algae from the polyps of the coral. This leads to discoloration and starvation of the coral reefs, eventually causing them to die."

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	Responses that Demonstrate Understanding
• Responses were incomplete or unclear in their expression of the formation of carbonic acid and carbonate buffering system.	• "$CO_2 + H_2O \ = \ H_2CO_3$"
• A change from a pH of 8.2 to 8.1 is "too acidic."	• "As a result of decreased pH, the ocean water is more acidic."
• Changes in pH will lead to melting or harm to organisms, (without offering specific or chemically correct explanations of the impact of pH on shells or exoskeletons).	• "Calcium carbonate shells are dissolved by decreasing pH."
• Responses demonstrated misunderstandings about the exchange of gases between the atmosphere and ocean.	• "Because of diffusion, if there is more CO_2 in the atmosphere the concentration of CO_2 in the ocean will rise." • "The increasing concentration or atmospheric CO_2 will continue to cause oceanic pH to fall as the CO_2 continues to dissolve into oceanic waters through precipitation of carbonic acid and the gas directly dissolving into the water."
• The existence of a material does not make it a pollutant. Students need to indicate the way the material enters the environment.	• "Algae blooms are most often caused by runoff that contains fertilizer with nitrogen and phosphorus components that promote algae growth." • "Wearing sunscreen in the ocean poses a human made threat to the worlds coral reefs. Sunscreen comes off in the water and gets on to the coral reefs in the ocean."

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve the student performance on the exam?

- Encourage your students to carefully read the question and evaluate the task verbs to determine how to best answer the question. Some students would contradict themselves in an attempt to write a more lengthy response, even when it is not needed (i.e. for an identify). It is important for students to practice writing out a clear, detailed response.
- Emphasize the names and molecular formulas of environmentally relevant molecules and compounds, such as water (H_2O) and carbonic acid (H_2CO_3).
- Practice analyzing ecological and/or environmental data sets, including data sets that have a two y-axes. Students should be aware of the differences (i.e., units and scale) between the different axes.
- Remind students that when they are responding to an "identify" prompt to provide the specific name or process that is the focus of the question.
- Emphasize that when prompted to connect a description to the identification, the two parts should be clearly linked in the response. This was a problem for some students in part (c)(ii).
- Provide opportunities to measure pH in the classroom to provide students appropriate framework for interpreting pH data.
- Reinforce that the involvement of humans should be clearly identified when a prompt asks about an "anthropogenic effect."
- Encourage students to be specific regarding the impact on the population, community, or ecosystem. Responses should focus on changes in specific ecological properties, for example changes in reproductive behavior and predator-prey interactions, instead of a more vague answer like death or harm in a population, community, or ecosystem.
- When considering the impact on a system, encourage students to indicate the direction of a change, for example increase/decrease or more/less, instead of only stating a change has occurred.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers will find sample student responses on the exam information page on AP Central, along with specific commentary explaining why each point was or was not earned. Teachers can use these samples to work with students to help them become more comfortable in practicing and producing responses within the suggested response time.
- Teachers will find scoring guidelines explaining how exam questions were scored on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the AP year so that students become familiar with how their responses will be scored.
- Teachers can review elements of Question 3 from the 2014 exam and Question 2 from the 2011 exam.
- In AP Classroom, teachers will find a rich, new collection of resources for the 2019 school year that includes newly created formative and summative assessment items for every unit of the course and that represents each of the types of questions on the AP Exam. This includes practice FRQs for teachers to use as formative assessment pieces beginning with scaffolded questions that represent what students are ready for at the beginning of the school year and an increased challenge as teacher's progress through the course.
- Teachers can use the Quantitative Skills Guide in AP Sciences (2018) to assist students in developing quantitative skills throughout the course.
- The AP Environmental Science Online Teacher Community is active and there are many discussions concerning teaching tips, techniques, and activities that many teachers have found helpful. It is easy to sign up for and you can search topics of discussions from all previous years.
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- Teachers of AP Environmental Science can find useful resources in the course audit webpage and the classroom resources page for AP Environmental Science.

What were the responses to this question expected to demonstrate?

The intent of this question was for students to evaluate a graph showing the visibility changes in four national parks, to identify and describe different types of air pollutants, and to discuss ways that national park ecosystems are being degraded by high levels of visitor use.

In the first part of the question, the stimulus provided a bar graph showing the historical visibility and the 2015 average visibility in four different national parks in the United States. Students were asked to use the data in the graph to identify the national park with the greatest loss of visibility as of 2015 when compared to the historical natural visibility.

Students were then asked to identify a primary pollutant and describe how a primary pollutant is formed, and to identify a secondary air pollutant and describe how a secondary pollutant is formed. Students were asked to use the visibility data in the graph and a provided value for 1990 to calculate the percentage increase in visibility from 1990 to 2015. Students were then asked to discuss two specific actions the state or federal government could take to further improve the visibility in Great Smoky Mountains National Park. These concepts were drawn from the following sections of the topic outline: VI. Pollution, A. Pollution Types, 1. Air Pollution and C. Economic Impacts.

Finally, students were asked to discuss two additional ways that national park ecosystems are being degraded by high levels of visitor use. These concepts were drawn from the following sections of the topic outline: III. Population, B. Human Population, 3. Impacts of Population Growth; VI. Pollution, A. Pollution Types, 2. Noise Pollution and 4. Solid Waste; and VII. Global Change, C. Loss of Biodiversity.

How well did the responses address the course content related to this question? How well did the responses integrate the skills required on this question?

Students were expected to demonstrate knowledge about air pollution, including an understanding of air pollutants, methods to reduce the effect of air pollutants, and the environmental problems associated with increased visitor use of national parks. In addition, students were expected to interpret a graph showing visibility in different national parks and perform a simple calculation related to change in visibility.

- The majority of responses in part (a) were able to evaluate a bar graph to determine the national park that had the greatest loss of visibility as of 2015. Correct responses were written as either "Sequoia" or "Sequoia National Park."
- Responses in part (b) were related to basic information about air pollutants. In part (b)(i), student responses were able to identify a primary air pollutant. Common, correct responses were carbon dioxide, carbon monoxide, particulate matter, NO_x, and methane. Responses were accepted as written words (carbon dioxide) or as correctly written chemical formula (CO_2). If more than one primary air pollutant was identified, only the first response was scored. Responses that identified a type of particulate matter such as dust, smoke, soot, ash, etc. did not earn a point as these are vague and colloquial terms. In part (b)(ii), responses described how primary pollutants become part of the atmosphere. A typical student response was "Carbon monoxide becomes a part of the atmosphere through incomplete combustion of fossil fuels." The burning of fossil fuel was the most common answer, but points were also earned for a description of an accurate biological source such as melting permafrost and belching cows. Some responses contained more descriptors than necessary, but also earned the point, such as "Primary pollutants are released, through natural or human activities, and eventually drift up into the atmosphere. The most common way how is through the burning of fossil fuels." In part (b)(iii), responses identified a secondary air pollutant. Typical responses were ozone (O_3), sulfuric acid (H_2SO_4), and sulfur trioxide (SO_3). Points were not earned for general responses such as smog, photochemical smog, or acid rain. Smog is a broad term used to describe a collection of many different, specific air pollutants combined in fog or water vapor. Acid rain is also a general term that describes many different, specific chemical compounds. In part (b)(iv),

responses had to appropriately describe how secondary air pollutants are formed when primary pollutants chemically react with other compounds in the atmosphere. Many different verbs, such as bond, join, interact, combine, etc., were accepted as synonyms of "chemically react." A common response was "A secondary air pollutant is formed when two primary air pollutants combine in the atmosphere." A response that used "mix" or "made a mixture" did not earn points because a chemical mixture is a physical, not a chemical, change and does not result in a new secondary air pollutant. Other student responses described the specific chemical reactions involved in the making of a secondary pollutant. These responses earned a point if the chemical reactions were accurate, though they did not need to be written as formula or chemically balanced. "A secondary air pollutant is formed within the atmosphere. For example, ozone is reacted by VOC + CO + sunlight with the VOC and CO as the primary pollutants, reacting with NO_x and oxygen to create another harmful pollutant, ozone."

- Responses in part (c) were related to the visibility of Great Smoky Mountains National Park, which according to the graph entitled "National Park Visibility Changes," has had an increase in visibility over the past 25 years. Part (c)(i) required a correct answer of 80%. This was determined using the data found in the given graph. The response was not required to show work in order to earn this point. Students were then asked, in part (c)(ii) to discuss two governmental actions that could improve the visibility in the park. Responses used many different verbs to describe a government action such as mandate, tax, subsidize, legislate, enact, regulate, etc. These were acceptable as long as a realistic strategy and target were also written, such as "[m]andate that utilities switch from burning coal to using clean energy wind or solar. This will reduce emissions of gases that decrease visibility." The verb "encourage" did not earn a point as it was used in the question stem. Student responses that did not include a state or federal government action or did not contain a realistic strategy to increase visibility did not earn points. Strategies such as "move factories to further than 100 miles from the park" or "close down all factories in the area" did not earn points because they were not realistic and also did not indicate knowledge of the regional aspect of air pollution that was described in the question stem. Other responses that focused on decreasing the amount of individual vehicles driven to the park and discussed strategies such as "providing busses to the park could help reduce motor vehicle pollution by decreasing the number of individual cars being driven to the park" earned points.

- Part (d) shifted the focus from air pollution to the degradation of national park ecosystems by high levels of visitor use. Since the question stem asked for a discussion of additional ways that national parks are being degraded by high levels of visitor use, responses that only included verbs such as destruction, degradation, loss, disruption, etc., were vague and did not earn a discussion point. A common response discussed the specific impact of litter on the health of wildlife, such as "Another way National Parks are being degraded is by all of the waste produced by the humans that visit them. Things such as plastic water bottles, food wrappers, soda cans, etc., all get left in the park. These items can be ingested by animals which could cause their death." Other responses discussed the impact of walking off designated trails and "trampling and killing vegetation." Responses indicated an understanding of how high levels of visitors impact the parks (littering, off-trail hiking, noise pollution, picking flowers) but may not have extended the discussion to include the effect of this impact/action on national park system ecosystems. The responses "Tourists also litter and, even if it's accidental, can disrupt habitat areas within the park" or "By venturing off trails visitors disturb the habitat potentially harming it" did not earn points because they did not discuss the specific impact on national park ecosystems.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Moving or stopping industry which would leave at least a 100-mile buffer around national parks is a realistic method to improve visibility.	• "The government could require regional air pollutant sources within a certain radius of the park to have scrubbers installed to reduce the emission of air-polluting gases."
• All primary pollutants destroy the stratospheric ozone layer.	• "Primary pollutants enter the atmosphere during the complete burning of fossil fuels, one of its most common sources is from exhaust in cars."
• Visibility in Great Smoky Mounts National Park referred to the state of being seen, from a marketing perspective.	• "The federal government could mandate an increase in using renewable energy sources like solar or wind rather than getting our electricity from fossil fuels like coal, which creates smog and lowers visibility."

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve the student performance on the exam?

- Remind students of the meaning and depth of answer required in a response. Identify, describe, and explain all require different levels of detail and support. In general, a question stem that asks a student to identify the response requires less information and time than a question stem that asks a student to explain.
- Practice applying common science data-related skills such as graph reading, percent deviation, and dimensional analysis in a variety of contexts
- Emphasize to students that responses that describe solutions must be realistic and effective. Requiring all factories to move more than 100 miles from a national park is not realistic with 61 national parks in the United States.. Banning all vehicular traffic in Great Smoky Mountains National Park is also unrealistic when it is over 800 mi^2 in size.
- Clarify the difference between colloquial terms (such as smog) and environmental science vocabulary (such as VOC_s, aldehydes, or ozone) when responding to a question. The second demonstrates an understanding of AP Environmental Science, but the first does not.
- Review sources of different, specific pollutants. Compare different types of air pollutants and clarify the difference between pollutants that impact air, land, and water.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers will find sample student responses on the exam information page on AP Central, along with specific commentary explaining why each point was or was not earned. Teachers can use these samples to work with students to help them become more comfortable in practicing and producing responses within the suggested response time.
- Teachers will find scoring guidelines explaining how exam questions were scored on the exam information page on AP Central. Teachers can use and adapt these scoring guidelines throughout the AP year so that students become familiar with how their responses will be scored.
- In AP Classroom, teachers will find a rich, new collection of resources for the 2019 school year that includes newly created formative and summative assessment items for every unit of the course and that represents each of the types of questions on the AP Exam. This includes practice FRQs for teachers to use as formative assessment pieces beginning with scaffolded questions that represent what students are ready for at the beginning of the school year and an increased challenge as teacher's progress through the course.
- Teachers can review elements of Question 4 from the 2007 exam.
- Teachers can use the Quantitative Skills Guide in AP Sciences (2018) to assist students in developing quantitative skills throughout the course.
- The AP Environmental Science Online Teacher Community is active and there are many discussions concerning teaching tips, techniques, and activities that many teachers have found helpful. It is easy to sign up for and you can search topics of discussions from all previous years.
- New teachers (and career changers) might want to consider signing up for an AP Summer Institute (APSI). An APSI is a great way to gain in-depth teaching knowledge on the AP Environmental Science curriculum and exam and is also a great way to network with colleagues from around the country.
- Teachers of AP Environmental Science can find useful resources in the course audit webpage and the classroom resources page for AP Environmental Science.