

**Question 3: Analyze an Environmental Problem
and Propose a Solution Doing Calculations**
10 points

- (a) **Identify** a typical type of plant that would be used in a desert-tolerant landscaping. **1 point**

Accept one of the following:

- Cactus/cacti
- Succulent plants
- Drought-tolerant plants

- (b) **Justify** the removal of landscaping and lawns that use grasses not native to the local area by describing an additional advantage, other than reducing the amount of water needed for irrigation. **1 point**

Accept one of the following:

- Native desert plants support habitat/provide food for local/native wildlife.
- Less mowing leads to decreased yard maintenance time/costs.
- Desert tolerant plants need less fertilizer/pesticide.
- Creates jobs for landscapers to remove/replace turf.
- Decreased use of gas-powered yard tools reduces air pollution/noise pollution/gasoline consumption.

- (c) **Describe** how a prescribed burn would reduce the severity and spread of forest fires. **1 point**

Accept one of the following:

- Prescribed burns/they remove undergrowth, decreasing fuel/flammable material.
- Prescribed burns/they thin forests/create a fire break, reducing the spread of fires.

- (d) **Describe** a disadvantage of a prescribed burn in a forested ecosystem. **1 point**

Accept one of the following:

- Reduces habitat for wildlife/can harm or displace animals.
- Releases carbon dioxide, which contributes to climate change.
- Releases particulates/air pollutants, which worsens air quality.
- Runoff following a prescribed burn can degrade water quality.
- Reduces competition, which helps invasive species spread/expand.

- (e) **Calculate** the number of million acre-feet (maf) of water currently in Lake Powell. **Show** your work. **1 point**

One point for the correct setup to calculate number of million acre-feet (maf) of water currently in the lake:

Accept one of the following:

- $25.16 \text{ maf} \times 36\%$
- 25.16×0.36

One point for the correct calculation of the number of million acre-feet (maf) of water currently in the lake: **1 point**

Accept one of the following:

- 9.0576
- 9.058
- 9.06
- 9.1

Total for part (e) 2 points

- (f) The watershed of the Upper Colorado River contributes an average of 9.60 maf of water to Lake Powell annually. The melted mountain snow found in the watershed contributes 50% of the average river flow into Lake Powell. In 2021, the river flow was 36% of the annual average. Assuming that all resources to that flow contributed with the same proportions as in prior years, **calculate** the amount of water (in million acre-feet) that was contributed by the melted mountain snow in 2021. **Show** your work. **1 point**

One point for the correct setup to calculate amount of water in million acre-feet that was contributed by the melted mountain snow:

Accept one of the following:

- $9.60 \text{ maf} \times 36\% \times 50\%$
- $9.60 \text{ maf} \times 0.36 \times 0.5$
- $9.60 \times 0.36 \times 0.5$

One point for the correct calculation of the amount of water in million acre-feet: **1 point**

Accept one of the following:

- 1.728
- 1.73
- 1.7

Total for part (f) 2 points

- (g) The average household in the United States consumes 5.0×10^4 gallons of water in a year. **Calculate** the number of households that could be supported for one year by the average flow of 9.60 maf of water into Lake Powell. **Show** your work. **1 point**

One point for the correct setup to calculate the number of households that could be supported for one year by the average watershed flow:

Accept one of the following:

- $9.60 \text{ maf} \times \frac{3.26 \times 10^{11} \text{ gallons}}{1 \text{ maf}} \times \frac{1 \text{ household}}{5.0 \times 10^4 \text{ gallons}}$
- $9.60 \text{ maf} \times \frac{3.26 \times 10^{11} \text{ gallons}}{5.0 \times 10^4 \text{ gallons}}$
- $9.60 \times \frac{3.26 \times 10^{11}}{5.0 \times 10^4}$

One point for the correct calculation of the number of households: **1 point**

Accept one of the following:

- 62,592,000
- 6.2592×10^7

Total for part (g) 2 points

Total for question 3 10 points

Question 1: Design an Investigation 10 points

- (a) Based on the data in the graph, **identify** the average number of species found in technically restored piles 16–25 years after restoration started. **1 point**

Accept one of the following:

- 8
- 9

- (b) Based on the data in the graph, **describe** the relationship between the average number of species and age of the spontaneous restoration piles. **1 point**

Accept one of the following:

- The number of species increases with age of piles.
- The average number of species increases as the years since restoration increase.
- There is a direct/positive relationship/correlation between the two variables.

- (c) Using the data in the graph, **make a claim** that supports or refutes the hypothesis that the number of animal species in the spontaneously restored piles would be higher than the number of animal species in the technically restored piles. **1 point**

- The spontaneously restored areas support more plant species, which provides habitat, food, and/or shelter for animal species.

- (d) **Describe** a characteristic of a plant species that would have been present in the spontaneous restoration piles from years 1 to 5. **1 point**

Accept one of the following:

- A description of a characteristic of pioneer or generalist species such as:
 - Able to grow with little/poor soil
 - Able to grow in soil with low organic matter/low nutrients
 - Able to grow in full sunlight
 - Able to colonize an area quickly
 - Able to grow in a wide range of habitats

- (e) **Explain** how the return of plant life would have been altered in the spontaneous piles if the mining had taken place in the tundra rather than in temperate forests. **1 point**

Accept one of the following:

- It would be slower because it is colder/growing season is shorter/there is less rain.
- It would include plants that are native to the tundra not the temperate forests.
- It would reflect the lower species diversity found in the tundra.

(f) **Identify** the scientific question for the investigation. **1 point**

Accept one of the following:

- Does the presence of vegetation affect the amount/appearance of runoff?
- Does the presence of soil covering affect the amount/appearance of runoff?
- Does the presence of different materials affect the amount/appearance of runoff?

(g) **Identify** a dependent variable in the experiment. **1 point**

Accept one of the following:

- Water collected
- Runoff volume
- Water appearance

(h) **Explain** how the results of the experiment would likely have been altered if the soil had contained a higher percentage of sand, which has the largest particle size of the components of loam. **1 point**

Accept one of the following:

- The amount/volume of water collected/runoff would decrease because more water would infiltrate into the soil.
- The water collected could be clearer as the sand particles settle faster.

(i) **Describe** one ecological impact that could result from the drainage from mine waste into nearby waterways. **1 point**

Accept one of the following:

- Acidic/low pH runoff could be outside the range of tolerance of some species.
- Acidic/low pH runoff could lead to disease/death of some species.
- Heavy metals in runoff can accumulate/biomagnify in wildlife leading to disease/death.
- Soils may run off into nearby waterways and could increase turbidity/sedimentation outside the range of tolerance of some species.
- Soils may run off into nearby waterways and could increase turbidity/sedimentation leading to disease/death.

(j) **Describe** one strategy to reduce the drainage from mine waste into waterways downstream from mines. **1 point**

Accept one of the following:

- Vegetation can be planted, reducing sediments/heavy metals flowing into streams.
- Mine waste can be covered with soil/plastic/concrete.
- Mine waste can be covered with lime or other alkaline substances.
- Mine waste can be removed to another location that cannot run off into waterways.
- Water can be diverted to avoid contact with mining waste.
- Contaminated water can be treated to reduce acidity.
- Contaminated water can be treated to remove heavy metals.
- Mine waste can be disposed underwater.
- Mine waste drainage can be diverted into holding basins.

Total for question 1 10 points

2018

AP[®]

CollegeBoard

AP Environmental Science

Scoring Guidelines

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Question 1

Read the following article from the *Fremont Daily Times* and answer the questions that follow.

(a) The students want to reduce the school's carbon footprint.

(i) **Define** carbon footprint.

(1 point for correct definition of carbon footprint)

- The amount of carbon dioxide and/or other carbon compounds released to the environment by a product, process, or activity
- A measurement of the amount of carbon released by human activities

(ii) **Identify** one way the school's heating system is likely adding to the school's carbon footprint.

(1 point for correct identification of a way the school's heating system is adding to its carbon footprint)

- The burning/combustion of fossil fuels releases carbon dioxide
- The incomplete combustion of fossil fuels releases carbon monoxide

(iii) **Describe** one realistic way to reduce the contributions of the heating system to the school's carbon footprint

(1 point for correct description of a realistic way to reduce the contributions of the heating system)

- Switch to renewables (solar, wind, etc.)/switch to a more efficient fossil fuel (natural gas, propane)/switch to a provider that uses nuclear energy.
- Decrease the temperature/thermostat in the school during the winter/program thermostat to lower energy consumption during certain times.
- Purchase credits through environmental agencies for carbon-offsetting projects.
- Increase insulation or implement other efficiency/design methods to reduce energy demand (green roof, double paned glass, south-facing windows for passive solar heating, change air filters, etc.).

(b) **Identify** TWO environmental benefits of a living green roof, such as that suggested by Councilperson Fassler.

(2 points; 1 point for each correct identification of an environmental benefit of a green roof)

- Insulation/reduced use of fossil fuels for heating and/or cooling
- Habitat for wildlife and/or plants/increases biodiversity
- Area to grow crops/production of food locally
- Reduction in the number of heat islands in the environment/urban heat island mitigation
- Photosynthesis/carbon capture/CO₂ storage/oxygen release
- Stormwater treatment/runoff reduction
- Filters particulates, VOCs, O₃ from air

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Question 1 (continued)

(c) **Describe** TWO practices the cafeteria's food service could use to decrease the environmental impacts of Fremont High School.

(2 points; 1 point for each correct description of a practice that decreases the environmental impact of the school)

- Offer more vegetarian options/serve fewer animal products, etc. to reduce impact from meat production.
- Use some locally sourced food to reduce transportation.
- Grow food at the school to reduce transportation.
- Compost food waste to reduce the amount disposed in landfills.
- Donate leftover food to reduce food waste.
- Use energy-friendly practices (LED lighting, serve more cold-cut sandwiches, etc.) to decrease energy use.
- Purchase bulk packaged items to reduce material waste.
- Use recyclable food containers/don't use disposable straws/food containers/trays to reduce material waste.
- Install a water fountain/stop selling single-serving water bottles to reduce material waste.
- Use reusable take-out containers/offer savings or credit for reusing containers to reduce material waste.
- Allow students to choose appropriate portions to reduce food waste.
- Purchase organic foods to reduce pesticide use.
- Use gray water to irrigate landscaping to reduce potable water use.

(d) **Discuss** TWO benefits of using native plants for landscaping at Fremont High School.

(2 points; 1 point for each correct discussion of benefits of using native plants)

- Native plants require less pesticides because they are better adapted to their environment.
- Native plants require less fertilizer because they are better adapted to their environment.
- Native plants require less irrigation water because they are better adapted to their environment.
- Native plants increase biodiversity by providing native habitat areas.
- Native plants support native food webs/native food production by providing native habitat areas.
- Native plants reduce the amount of land available for the establishment/spread of invasive species.
- Native plants save the school money by requiring less water/fertilizer/pesticides/upkeep.

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Question 1 (continued)

- (e) During the renovation, the carpeting must be replaced. **Discuss** one environmental benefit of using flooring made of plant material, such as cork or bamboo, instead of carpet made of synthetic fibers.

(1 point for correct discussion of benefits of using flooring made of plant material)

- Plant-based material is more easily compostable/is biodegradable/can be reused/repurposed, unlike carpet.
- Plant-based material is from a renewable resource making it more sustainable than carpet. Plant-based material is a carbon sink/reservoir, so growing plant materials removes CO₂ from the atmosphere, unlike carpet.
- Plant-based materials require less fossil fuels/toxic chemicals for production than synthetic fibers found in carpets.
- Plant-based materials produce less indoor pollutants (off-gas pollutants/VOCs/release toxins) than carpet.
- Plant-based materials harbor fewer pathogenic vectors/diseases/allergens (fleas, ticks, dust mites, mold spores, etc.) than carpets.
- Plant-based material when cultivated provides habitat for native species.

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Question 2

An offshore wind farm project using turbines to generate electricity is to be built along the Atlantic coast of the United States. It will be located about 13 km from the coast in water with an average depth of 10 m.

- (a) **Describe** one environmental benefit associated with an offshore wind project.

(1 point for correct description of an environmental benefit associated with an offshore wind project)

- Reduced environmental damage from decreased reliance on fossil fuels, such as:
 - Less habitat/ecosystem destruction due to less exploration and extraction (less mining or drilling, etc.)
 - Less air/soil/water pollution (less exhaust emissions, pipeline leaks, tanker leaks) due to less transportation of fossil fuels
 - Less air pollution (no/fewer particulates, VOCs, NO_x, SO_x, CO₂, or greenhouse gases) due to less fossil fuel combustion
- Reduced environmental damage from decreased reliance on nuclear power, such as:
 - No risk of radioactive releases with accidents
 - No hazardous/radioactive wastes to store
 - Less exploration/ extraction/processing for uranium ore
- Increased aquatic habitat/artificial reefs for barnacles, sponges, other invertebrates, fish

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Question 2 (continued)

- (b) **Identify and describe** one potential economic effect of an offshore wind project.

(2 points; 1 point for correct identification of a potential economic effect and 1 point for correct description of an identified economic effect. The description point cannot be earned without correct identification of a potential economic effect.)

Identify one potential economic effect	Describe one potential economic effect
Job creation (+)	• Jobs will be created in construction, operation, maintenance, etc.
Additional income (+)	• Local municipalities receive more taxes (income, sales, property) paid by utility and workers • Wind power company will make money/profits in the long run
Decreased electricity costs (+)	• Electrical production costs will be lower, which will reduce electricity rates for consumers
Less reliance on foreign energy resources (+)	• Transportation costs to deliver fuels will be reduced
High initial construction/ high maintenance costs (-)	• Local taxes/fees/rates will increase to support construction costs associated with building of facility • Parts and personnel must be transported off-shore for construction, repairs and maintenance
Decreased property value (-)	• Property values will decrease in coastal areas due to unfavorable aesthetics
Loss of income (-)	• Turbines negatively affect the aesthetics, which negatively impacts tourism, fishing, whale watching, etc. • Local fishing opportunities will be disrupted • Less revenue for fossil fuel companies as demand decreases
Job loss (-)	• Jobs will be lost in the traditional energy production sectors (coal, nuclear)
Subsidies cost (-)	• State subsidies to offset cost of building offshore and transmission lines to coast will increase; costs may be recovered with increased taxes

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Question 2 (continued)

- (c) **Describe** one additional way, other than wind power, that oceans can provide renewable energy for the generation of electricity.

(1 point for correct description of energy source from ocean)

- Use of tidal movement/currents to turn turbines
- Utilize a device designed to capture energy from wave motion
- Harness the solar energy absorbed by the oceans/use natural thermal gradient in tropical and temperate oceans to create electricity (OTEC — Ocean Thermal Energy Conversion)
- Harvest algae and convert to biofuel

The project will consist of 200 wind turbines, each with a capacity of 4 megawatts (MW). Each turbine costs \$1.2 million to build. Electrical demand in the area to be served by the project is expected to be 2.0×10^6 MWh per year.

- (d) **Calculate** how much electricity (in MWh) the wind project needs to generate per year in order to provide 80% of the annual electrical demand in the service area. Show all work.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$(0.80) \times (2.0 \times 10^6 \text{ MWh}) = 1.6 \times 10^6 \text{ MWh}$$

- (e) Customers in the service area pay \$0.20/kWh for electricity. **Calculate** how much revenue will be produced if the wind turbines provide 80% of the annual electrical demand in the service area. Show all work.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$1.6 \times 10^6 \text{ MWh} \times \frac{\$(2 \times 10^{-1})}{\text{kWh}} \times \frac{1 \times 10^3 \text{ kWh}}{1 \text{ MWh}} = \$3.2 \times 10^8 = \$320,000,000 = \$320 \text{ million}$$

- (f) Assuming all turbines are operating, **calculate** how many hours the wind turbines must operate to provide 80% of the annual electrical demand in the service area. Show all work.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$1.6 \times 10^6 \text{ MWh} \times \frac{1 \text{ turbine}}{4 \text{ MW}} \times \frac{1}{2 \times 10^2 \text{ turbines}} = 2 \times 10^3 \text{ hr} = 2,000 \text{ hours}$$

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Question 3

An Arctic food web includes the following organisms.

- (a) Refer to the diagram above to complete the following table.

(3 points; 1 point for correct identification of each organism in the table)

	Organism from Arctic food web
(i) Identify a primary producer	Diatom (phytoplankton)
(ii) Identify a primary consumer	Krill (zooplankton)
(iii) Identify a secondary consumer	Cod or seal

- (b) Other than showing which organisms are consumed by others, **describe** what is indicated by the direction of the arrows in the diagram.

(1 point for correct description of what is indicated by the direction of the arrows)

- Shows the flow of energy among trophic levels
- Shows the flow of matter through trophic levels

As the amount of sea ice has decreased, larger expanses of the Arctic Ocean are now completely free of sea ice for several weeks each summer. Ringed seals, the preferred prey of polar bears, come to holes in the sea ice to breathe.

- (c) **Describe** how the change in sea ice habitat is affecting polar bears' ability to hunt and feed.

(1 point for correct description of how the change in sea ice habitat affects ability to hunt and feed)

- Decreasing area of hunting ground (area of ice used for hauling out/fewer seal breathing holes/seals are a less available food source because of more open water) makes it more difficult for polar bears to get food
- Increasing area/distance between hunting ground means the polar bears have to exert more energy to swim to find food/physical exhaustion from swimming results in less energy available for hunting
- Increasing physiological stress (dehydration, exhaustion, cub mortality, etc.) because polar bears are not physiologically adapted to warmer temperatures
- Increasing the time between successful kills results in bears spending more time waiting/hunting for prey

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Question 3 (continued)

- (d) **Explain** how melting sea ice leads to a feedback loop that increases Arctic warming.

(2 points; 1 point for correct explanation of the connection between melting ice and the increased absorption of sun's energy and 1 point for correct explanation that increased absorption of sun's energy leads to increased melting of ice. For the second point the student must complete the positive feedback loop.)

- Melting of sea ice leads to a decrease in albedo, or reflectivity, leads to water surfaces absorbing more of the sun's energy.

AND

- Increasing absorption of sun's energy warms the water surface further, which leads to further ice melt (completes positive feedback loop).

- (e) Many species, including some whales and birds, will travel thousands of kilometers during annual migrations.

- (i) **Provide** one reason a species may migrate a long distance.

(1 point for a correct reason why a species may migrate a long distance)

- Limited food/water supply leads to migration to locations with more food/water supply
- Food supply migrates and species follow prey
- More hospitable climate during certain seasons
- Availability of mates/breeding/birthing occurs in different location
- Protection of offspring from predators

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Question 3 (continued)

- (ii) The North Atlantic right whale migrates between subtropical and polar waters annually. Nearly 50 percent of right whale deaths are due to human activities. **Describe** one commercial activity, other than whaling, that may result in the death of right whales.

(1 point for correct description of one commercial activity, other than whaling)

- (iii) **Describe** one strategy that could reasonably be implemented to decrease right whale deaths caused by the commercial activity you described in part (ii).

(1 point for correct strategy linked to activity in (ii))

Description of commercial activity	Description of one strategy
• Fishing nets entangle whales as by-catch. • Fishing gear can accidentally trap.	• Require change of fishing method (location, timing, or materials) that traps whales to reduce the number of whales trapped in nets/gear • Fines for discarded fishing gear (long-line gear, ropes for hauling pots up, etc.) so less gear is discarded reducing the number of whales trapped in gear
• Ships and whales use the same channels, which can increase number of ship strikes.	• Improved navigational technology to spot whales that are close to ships in order to avoid collisions • Increased education of ship captains and crews about whale habitat/migration routes/feeding behaviors in order to reduce ship collisions with whales • Expansion of low-speed navigational zones around ports to reduce ship collisions with whales
• Noise pollution from seismic surveys/sonar/engine noise can disrupt a whale's internal navigational system.	• Reduction of seismic survey activity/sonar use in coastal areas to reduce exposure to noise pollution • Installation of quieter motors to reduce or eliminate noise pollution

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Question 4

In many parts of the world, biomass like peat, wood, and animal waste is burned indoors for cooking and home heating. Combustion of these fuels releases harmful household air pollutants that pose a health threat to billions of people, mostly in less developed countries.

(a) Air pollutants are released during the burning of biomass indoors for cooking and heating.

- (i) **Identify** TWO air pollutants released during the burning of biomass indoors for cooking and heating.

(2 points; 1 point for each correct identification of an air pollutant released during the burning of biomass)

- (ii) **Identify** a specific human respiratory illness that one of the pollutants you identified may cause.

(1 point for correct identification of a specific respiratory illness linked to identified pollutant)

Identification of TWO air pollutants	Identification of a specific human respiratory illness linked to identified pollutant
- Carbon monoxide (CO) - Particulate matter (PM)	- CO poisoning - Asthma - Chronic obstructive pulmonary disease (COPD) - Emphysema - Bronchitis - Lung cancer
Nitrogen oxides (NO_x)	- Pneumonia - Asthma
Sulfur oxides (SO_x)	- Bronchitis - Emphysema - Asthma
Trace metals, such as lead, mercury, arsenic, and cadmium	Bronchitis
Methane (CH₄)	Bronchitis
Volatile organic compounds (VOCs)	Asthma

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Question 4 (continued)

- (b) **Identify** one realistic approach, other than banning the practice of burning biomass indoors, which could be used to reduce the impact of biomass combustion indoors on human respiratory health. **Describe** how this approach could reduce the incidence of respiratory illness.

(2 points; 1 point for correct identification of a realistic approach to reducing the impact and 1 point for correct description of reduction of illness linked to identified approach)

Identify one realistic approach	Describe how this approach would reduce the incidence of respiratory illness
Ventilate through structural change (chimney construction, opening windows and doors)	Removes some or all of the air pollution from indoors/transfers pollutants out of the home, leading to less respiratory illness
Switch to cleaner-burning/more efficient cooking stove	Requires less fuel to be burned releasing fewer air pollutants into the home, leading to less respiratory illness
Switch to a different energy source (solar, natural gas, biogas, electric)	Produces less or no indoor air pollutants, leading to less respiratory illness
Cook outdoors	Move the source of the air pollutant outside/leads to less or no concentrated air pollution inside, leading to less respiratory illness

In 2016 approximately four million people died from illnesses attributed to household air pollutants from burning biomass indoors. More than 10 percent of these deaths occurred in children under the age of five in less developed countries.

- (c) **Discuss** one reason children under the age of five are at a greater risk than adults for illnesses linked to household air pollutants.

(1 point for correct discussion of why children under the age of five are at a greater risk)

- Children have an underdeveloped or less-developed immune systems leading to a greater risk of illness following exposure.
- Children have a lower body mass leading to a higher relative dose of air pollution.
- Children spend more time indoors leading to higher exposure to air pollution.
- Children have smaller respiratory systems (narrow airways) so mild inflammation may cause more severe respiratory distress.

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Question 4 (continued)

In more developed countries, indoor air pollution is also a problem. Common indoor air pollutants in developed countries include:

- asbestos
- radon
- mold

(d) Choose TWO of the three common indoor air pollutants (asbestos, radon, or mold) listed above and complete the following table.

(i) **Identify** a source for each indoor air pollutant

(2 points; 1 point for correct identification of a source of each indoor air pollutant chosen)

(ii) **Describe** a method for reducing exposure to each of the two pollutants you chose.

(2 points; 1 point for correct description of method of reduction for each indoor air pollutant chosen)

	Identification of a source	Description of a method for reducing exposure
Asbestos	• Building materials (cement, floor tiles, ceiling panels, drywall, popcorn ceiling) • Insulation • Naturally occurring in soil and rocks in a dirt-floor basement or crawlspace	• Safely remove asbestos-containing materials/abatement • Encapsulate/cover and seal materials/construct temporary enclosure • Leave undisturbed
Radon	• Soil, rocks, Earth's crust • Gas from uranium containing rocks • Gas penetrates foundation	• Seal floors, walls, and joints • Install structural exhaust venting • Install subfloor depressurizing system
Mold	• Water from flooding, natural disasters, or leaks • Poorly vented or maintained damp environments	• Replace or repair damaged surfaces/structures • Clean and/or disinfect affected areas • Dehumidify or ventilate inside air • Improve drainage (from roof or yard, sump pump the basement)