

Question 1: Design an Investigation**10 points**

(a) **Identify** the ecological change over time illustrated in the diagram. **1 point**

- Primary Succession

(b) **Identify** the stage in which pioneer species first appear. **1 point**

- II/2

(c) **Describe** how soil forms from stage II to stage III. **1 point**

Accept one of the following:

- Wind/rain/weather can erode the rock/parent material.
- Wind/rain can break down rocks.
- Pioneer species (lichen/algae/fungi) die off adding small amounts of organic material.
- Pioneer species (lichens/algae/fungi) help break down rocks.

(d) **Identify** a cultural ecosystem service that may be provided by a mature forest. **1 point**

Accept one of the following:

- Recreation
- Aesthetic enjoyment
- Spiritual use
- Ecotourism
- Education

(e) **Identify** a testable hypothesis being investigated by the researchers. **1 point**

Accept one of the following:

- The removal of trees/clear-cutting will lead to an increase/decrease in water quality (temperature/turbidity/dissolved oxygen).
- The removal of trees/clear-cutting will have no effect on water quality (temperature/turbidity/dissolved oxygen).
- Water quality (temperature/turbidity/dissolved oxygen) will increase/decrease between stations.
- Water quality (temperature/turbidity/dissolved oxygen) will not change between stations.

(f) **Identify** the independent variable in the experiment. **1 point**

Accept one of the following:

- Presence or absence of clear-cutting
- Intact or clearcut forest
- Location of stream monitoring stations

(g)	Describe the purpose of forest A in the experiment.	1 point
	Accept one of the following: • Forest A/It is included so the researchers can compare the temperature/turbidity/water quality in clear-cut areas (forest B) to intact areas. • Forest A/It acts as a control so researchers can compare intact areas/Forest A to clear-cut areas/Forest B.	
(h)	Explain why the water temperature might change because of clear-cutting trees in forest B.	1 point
	Accept one of the following: • Water temperature will increase because there will be no/fewer trees to block the sunlight. • Water temperature will increase because there will be additional sediment from erosion. • Water temperature will increase because more sunlight will reach the water surface.	
(i)	Explain why an indicator of water quality other than temperature could be altered by the golf course in forest B.	1 point
	Accept one of the following: • There could be a decrease in dissolved oxygen because fertilizer runoff leads to algal blooms/eutrophication. • There could be a decrease in sedimentation/turbidity because the grass will decrease erosion compared to the clear-cut land. • There could be an increase in nitrates/phosphates due to fertilizer runoff resulting in algal growth/bloom.	
(j)	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.	1 point
	Accept one of the following: • Aquatic organisms would die off from a lack of oxygen created by the decomposition of algae/eutrophication. • Aquatic organisms would survive at a higher rate because there is less sediment to suffocate them/clog their gills. • Aquatic organisms would die off due to increased toxicity from pesticide runoff.	
Total for question 1		10 points

Question 2: Analyze an Environmental Problem and Propose a Solution 10 points

(a) Based on the data in the graph, **identify** the year with the highest percentage of forest. **1 point**

- 1700

(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. **1 point**

Accept one of the following:

- The percentage/amount of wild grasslands has decreased, and the percentage/amount of grazing (land) has increased.
- The two variables have an inverse relationship.

(c) **Identify** an environmental problem associated with overgrazing by livestock. **1 point**

Accept one of the following:

- Loss of vegetation
- Soil erosion
- Desertification
- Sedimentation/turbidity in waterways
- Soil compaction

(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. **1 point**

- The hypothesis is refuted/disproved/not supported. The percentage of forest has decreased, so the amount of photosynthesis/carbon sequestration has decreased.

(e) **Describe** a water-related environmental problem associated with urbanization. **1 point**

Accept one of the following:

- Increased runoff/flooding because urban areas have more impermeable surfaces.
- Decreased groundwater/saltwater intrusion because urban areas have many people/groundwater is overused.
- Increased water pollution because precipitation/runoff can carry contaminants/pollutants/waste.
- Destruction of aquatic habitats from increased development/land use changes.

- (f) **Describe** a potential response to mitigate the environmental problem identified in part (e). **1 point**

Accept one of the following:

Environmental problem identified in part (e)	Potential response to mitigate environmental problem
Increased runoff/flooding	• Use permeable road/parking lot materials. • Set aside green spaces/parks/conservation areas. • Construct green roofs/rain gardens/storm water retention ponds/basins.
Decreased groundwater/saltwater intrusion	• Use permeable road/parking lot materials. • Establish groundwater conservation/management plans. • Set aside green spaces/parks/conservation areas in recharge zones. • Construct green roofs/rain gardens/storm water retention ponds/basins.
Increased water pollution	• Encourage walking/biking or other methods of transportation. • Reduce use of home pesticides/fertilizers. • Reduce use of road salts/de-icing chemicals • Pick up trash and litter along waterways. • Dispose of toxic chemicals (for example, used oil and household cleaners).
Destruction of aquatic habitats from increased development/land use changes	• Create conservation areas/preserves/wetlands to protect aquatic habitats. • Restore degraded aquatic habitats.

- (g) **Explain** why there are fewer bobcats present on the farmland now compared to several decades ago. **1 point**

Accept one of the following:

- Loss of forest habitat has led to a decrease in resources/food/shelter/ mates/migration.
- Trapping/hunting has reduced the bobcat population.

(h) **Describe** a disadvantage of introducing only a small population of bobcats. **1 point**

Accept one of the following:

- Small populations have lower genetic diversity.
- Genetic bottlenecks can lead to inbreeding/passing on negative traits.
- Small populations are more vulnerable to diseases/disturbances like wildfire.
- Small populations do not control small mammals/pests as well as large populations.
- Small populations are less likely to survive.

(i) **Propose** a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations. **1 point**

Accept one of the following:

- Increase connectivity/build habitat corridors (so bobcats can safely mate/find food/build dens).
- Restore/reforest/preserve areas of bobcat habitat.

(j) **Justify** the solution proposed in part (i) by describing an additional advantage, other than reestablishing the bobcat population near the farms. **1 point**

Accept one of the following:

Solution proposed in part (i)	Justification of the proposed solution by stating an advantage
Increase connectivity/build habitat corridors (so that bobcats can safely mate/find food/build dens)	• Habitat corridors can be used by other species. • Habitat corridors would increase biodiversity/population of other species. • Habitat corridors can attract other species that might be beneficial for farmers (such as predators of pests and/or pollinator species). • Habitat corridors could help decrease road kills/the frequency of car accidents with wildlife.
Restore/reforest/preserve areas of bobcat habitat	• Restored habitat can be used by other species. • Restoration/reforestation/preservation could increase diversity/improve air quality/improve water quality. • An increase in the number of trees will improve aesthetic value/enhance tourism/reduce erosion/serve as a carbon sink.

Total for question 2 10 points

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

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- (a) Describe** a characteristic of a specialist species that would make the specialist species more likely to be negatively affected by habitat fragmentation than a generalist species. **1 point**

Accept one of the following:

- Specialists have narrow ecological niches compared to broad niches of generalist species, which are reduced even further by habitat fragmentation.
- Specialists with specialized adaptations are unable to adapt quickly, making them more vulnerable to habitat fragmentation than generalists that adapt quickly.
- Specialists tend to have small populations with less genetic variation than generalist species with larger populations and more genetic variation, making specialists more vulnerable to habitat fragmentation.

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- (b) Identify** the symbiotic relationship between the wood thrush and the cowbird. **1 point**

Accept one of the following:

- Parasitism
- Brood Parasitism
- The cowbird uses the wood thrush (as the surrogate parent) to raise their hatchling, which negatively affects the wood thrush and benefits the cowbird.

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- (c) Describe** one ecological advantage of leaving areas of undeveloped forest in the development plan as compared to clear-cutting the property. **1 point**

Accept one of the following:

- Since the habitat isn't being clear-cut, it does preserve some biodiversity by allowing some of the species to survive in the fragmented areas of the forest.
 - Habitat fragmentation can benefit some generalist species or species which thrive in edge habitat, leading to population increases for those species.
 - If planned with buffer zones around targeted conservation areas, edge disturbances for specialist species can be reduced.
 - The remaining forest/trees will reduce soil erosion.
 - The remaining forest will help with climate/cooling resulting from transpiration/shade from trees.
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- (d) **Propose** a solution that will minimize the effect of development on the resident population of wood thrush while still meeting the municipality's need for a housing development. **1 point**

Accept one of the following:

- Leave areas for wildlife corridors/crossings to prevent isolating populations.
- Include conservation easements in the plan that will preserve species and also provide tax breaks for the residents.
- Create buffer zones near the development to separate it from wildlife habitat.
- Create a mitigation plan that preserves land elsewhere of similar quality.
- Cluster housing or vertical development to limit the development footprint.
- Incorporate common green spaces that promote wood thrush populations.

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- (e) A male wood thrush needs a minimum of 800 m² of territory for reproduction. The municipal development committee has set a biodiversity preservation target of 275 male wood thrush territories. **Calculate** the area that must be set aside to support the goal of 275 male thrush territories. **Show** your work. **1 point**

One point for the correct setup to calculate the area:

- $275 \text{ territories} \times \frac{800 \text{ m}^2}{1 \text{ territory}}$

One point for the correct calculation of the area:

- 220,000 m²

Total for part (e) 2 points

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- (f) A real estate developer wants to build houses on the property. The plan will support 1,000 lots with a lot size of 1,100 m². The developer has proposed setting aside land equal to 10% of the size of each lot it sells. **Calculate** the maximum number of male wood thrush territories that could be created under this proposal. **Show** your work. **1 point**

One point for the correct setup to calculate the number of male wood thrush territories:

- $1,000 \text{ lots} \times \frac{1,100 \text{ m}^2}{1 \text{ lot}} \times 0.10 \div 800 \text{ m}^2 \text{ per territory}$

One point for the correct calculation of the number of male wood thrush territories, accept one of the following:

- 137.5 male wood thrush territories
- 137 male wood thrush territories
- 138 male wood thrush territories

Total for part (f) 2 points

- (g) **Calculate** the percentage of each of the 1,000 lots that would need to be set aside in order to support the goal of 275 male wood thrush territories. **Show** your work. **1 point**

One point for the correct setup to calculate the percentage of each lot to be set aside:

- $\frac{220,000 \text{ m}^2}{1,100,000 \text{ m}^2} \times 100$
- $275 \text{ territories} \times \frac{110,000 \text{ m}^2}{137.5 \text{ territories}} \div 1,100,000 \text{ m}^2 \times 100$
- $\frac{275 \text{ territories} \times 10\%}{137.5 \text{ territories}} \times 100$

One point for the correct calculation of the percentage of each lot to be set aside: **1 point**

- 20% of each lot

Total for part (g) 2 points

Total for question 3 10 points

Question 2: Analyze an Environmental Problem and Propose a Solution**10 points****(a) (i) Identify** the latitudinal range with the greatest amphibian species richness.**1 point**

Accept one of the following:

- Between the Tropic of Cancer and the Tropic of Capricorn
- The range between 30 degrees N and 30 degrees S latitude
- The range between 10 degrees N and 15 degrees S latitude

(ii) Identify what biome this range most likely represents.**1 point**

- Tropical Rainforest

(iii) Describe one reason amphibian species richness would tend to be highest in this region.**1 point**

Accept one of the following:

- More rainfall/warm temperatures year-round are the preferred conditions for amphibians.
- Greater biodiversity/higher NPP provides more habitat/food sources/niches.

Total for part (a) 3 points**(b)** There are many environmental threats facing amphibians today, such as deforestation.**1 point****Describe** one possible anthropogenic reason for deforestation.

- Human demand for agriculture/housing/firewood/forest products (medicine/food/lumber).

(c) (i) Explain how the species richness of an ecosystem influences its response to environmental stressors.**1 point**

- An ecosystem with greater species richness/diversity is more resilient/resistant to environment stressors because some species will survive helping to restore/stabilize the ecosystem.

(ii) Explain why amphibian biodiversity is declining globally, other than from deforestation. **1 point**

Accept one of the following:

- Increasing water pollution including:
 - Pollution from pharmaceuticals that cause reproductive harm/decrease reproductive success.
 - Pesticide pollution that is absorbed via the skin and is toxic to amphibians leading to death.
 - Endocrine disruptors (such as atrazine) can alter reproductive development leading to decreased number of successful offspring.
- Pesticide use reduces food sources for amphibians (insects), leading to decreasing population size.
- Microclimatic changes from overall global climate change (e.g., warmer, drier conditions in previously cool, moist areas, loss of wetlands) decreases available habitat leading to a decline in population size.
- Illegal amphibian trafficking removes species from an area leading to a decline in population sizes.
- Introduction of invasive species that compete for niche space leading to a decline in population sizes.
- Habitat fragmentation from human activity would limit range/reduce the ability to access resources, decreasing survival.
- Fungal infections (such as Chytrid) cause their skin to dry out, and they cannot breathe.

Total for part (c) 2 points

(d) (i) Identify one specific piece of legislation that has been designed to protect species threatened by extinction. **1 point**

Accept one of the following:

- Endangered Species Act (ESA)
 - Convention on the International Trade of Endangered Species (CITES)
 - Lacey Act
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- (ii) **Explain** how the requirements of the legislation identified in part (d)(i) specifically protect species threatened by extinction. **1 point**

Accept one of the following:

Legislation identified in (d)(i)	Explanation of requirements that specifically protect species threatened by extinction
Endangered Species Act (ESA)	- Lists endangered/threatened plant and animal species and prevents them from being killed or harmed. - Designates/protects critical habitat to promote survival and recovery of listed species. - Creates plans to restore populations to healthy sizes. - Identifies species that are threatened before they become endangered to provide protections.
Convention on the International Trade of Endangered Species (CITES)	A global agreement that protects endangered/threatened plants and animals (including goods such as ivory, shark fins, or rhinoceros' horns) by banning/regulating the trade of these species.
Lacey Act	Prohibits the trade of wildlife, fish, and plants that have been illegally taken, possessed, transported, or sold.

Total for part (d) 2 points

- (e) (i) **Propose** a viable solution that will result in the protection of the endemic frog species while still allowing for maximum profit of the property development. **1 point**

Accept one of the following:

- Move/transplant the frog populations to an adjacent undeveloped area prior to development.
- A portion of the wetland can be designated as a park/preserve.
- Wildlife corridors (land/bridges) can be built/created on a portion of the wetlands.
- Restrict development within a minimum setback away from the wetland.
- Project developers can group buildings together/can build up, not out.

- (ii) **Justify** the solution proposed in (e)(i) by describing a potential advantage of the plan, other than frog protection. **1 point**

Accept one of the following:

Solution proposed in (e)(i)	Justification of how solutions offer potential advantages, other than frog protection
Move/transplant frogs	- Developers will only have a one-time disruption during the removal but will not have to deal with continued disruptions (such as increasing human population, increasing use of fertilizer/pesticides). - Developer will have the maximum amount of land available.
Designate as a park/preserve	- By protecting areas, animal species will have more food and space availability increasing survival rates. - Potential educational/environmental draw of living near a park/preserve may allow the developer to charge higher rents for the apartments. - There is aesthetic value of the wetland and its species for the people that live there. - The preserved wetland area will help prevent flooding.
Use of wildlife corridors	- By establishing corridors, the other species will also not be as greatly affected by multiple habitat fragments. - The animal species can continue to move back and forth for food, shelter, and reproduction by way of the habitat corridors.
Setback	- By establishing setbacks, a buffer zone will be created between the development and the wetland area, filtering runoff into the wetland. - A buffer zone will add privacy for residents between the two developments.
Project development	By developing the apartments in groups/clusters and leaving preserved wetlands, the species will not be as affected by multiple habitat fragments.

Total for part (e) 2 points

Total for question 2 10 points

Question 3: Analyze an Environmental Problem and Propose a Solution**Doing Calculations****10 points****(a) Describe** why coal is considered a nonrenewable energy source.**1 point**

Accept one of the following:

- Nonrenewable energy sources like coal exist in a fixed/finite/limited amount.
- The formation rate of coal is less than the consumption/combustion rate of coal.

(b) Describe one potential environmental advantage of replacing a coal-fired power plant with a natural-gas power plant.**1 point**

Accept one of the following:

- Natural gas combustion emits fewer greenhouse gases/less CO₂.
- Natural gas combustion does not emit mercury/lead/cadmium/uranium.
- Natural gas combustion emits less NO_x/SO_x/reduces acid precipitation.
- Natural gas combustion produces less/no particulate matter/soot/smog.
- Transport of natural gas destroys/fragments less habitat or requires less fossil fuel use than transport of coal.
- Habitat destruction due to the impoundment of coal ash or coal slurry is negated.
- Coal extraction destroys habitat by strip mining or mountaintop removal.

(c) Describe one economic advantage of using natural gas, rather than coal, in producing electricity.**1 point**

Accept one of the following:

- Transport of natural gas (in pipelines) costs less than transport of coal (by rail).
- Natural gas (methane) harvested from a decomposition reaction (landfills, wastewater treatment plants, biodigesters) costs less than coal.
- There are fewer health-related issues linked to the burning of natural gas than are linked to burning coal, leading to lower health care costs for individuals or society as a whole.
- There are fewer pollution controls needed for a natural gas powerplant, decreasing the cost of operation/construction/permitting.
- There are lower combustion-residue disposal costs from the operation of natural gas burning powerplants than from coal-burning power plants.
- Natural-gas-burning power plants are much more efficient (more electricity output from the same energy input) than coal-burning power plants leading to lower fuel costs.

- (d) When natural gas is used to heat homes, it can produce carbon monoxide gas, which can lead to carbon monoxide poisoning in humans. **Propose** a solution to reduce the incidence of carbon monoxide poisoning in humans. **1 point**

Accept one of the following:

- Install/use/replace/update carbon monoxide detectors/alarms/sensors or replace the batteries within these devices.
- Perform regular maintenance on natural gas furnaces to ensure that minimal carbon monoxide is created or that the combustion products are properly vented/exhausted to the building exterior.
- Create laws or regulations that mandate that carbon monoxide detectors must be installed in all homes of any type.
- Use PSA's, billboards, or other methods to inform/educate the public about carbon monoxide poisoning.
- Change the home heating system to a method that does not include the combustion of a fuel that may produce carbon monoxide.

- (e) **Calculate** the percent change in the average annual $\text{PM}_{2.5}$ concentration in the air from 1990 to 2016. **Show** your work. **1 point**

One point for the correct setup (must include units and multiplication by 100 to yield a true percentage) to calculate the percent change:

- $$\frac{(188 \mu\text{g}/\text{m}^3 - 85 \mu\text{g}/\text{m}^3)}{85 \mu\text{g}/\text{m}^3} \times 100$$

One point for the correct calculation of the percent change:

1 point

- 121%
- 120%
- 121.2%

Total for part (e) 2 points

- (f) Trees can remove $\text{PM}_{2.5}$ from the atmosphere when particulates settle on the leaves and are subsequently washed onto soil by rain. The average annual removal of $\text{PM}_{2.5}$ is 2.3 kilograms per hectare. **Calculate** the decrease in $\text{PM}_{2.5}$ removal in kilograms if logging reduced a forested area from 50,000 hectares to 43,000 hectares. **Show** your work. **1 point**

One point for the correct setup (must include units) to calculate the number of kilograms of $\text{PM}_{2.5}$:

- $$(50,000 \text{ ha} - 43,000 \text{ ha}) \times \frac{2.3 \text{ kg}}{\text{hectare}}$$
- $$50,000 \text{ ha} \times 2.3 \text{ kg/ha} = 115,000 \text{ kg}; 43,000 \text{ ha} \times 2.3 \text{ kg/ha} = 98,900 \text{ kg}$$

$$115,000 \text{ kg} - 98,900 \text{ kg}$$

One point for the correct calculation of the number of kilograms of PM_{2.5}: **1 point**

- 16,100 kilograms of PM_{2.5}
- 16,000 kilograms of PM_{2.5}

Total for part (f) 2 points

- (g)** Research has shown that hospital admissions for cardiovascular problems increase 1% with every 10% increase in PM_{2.5} concentration. A city experienced a 23% increase in PM_{2.5} concentration and had 7,390 hospital admissions for cardiovascular issues over a one-year period. **Calculate** the anticipated increase in the number of hospital admissions for cardiovascular issues during the next year if the PM_{2.5} concentration continues to rise at an identical rate. **Show** your work. **1 point**

One point for the correct setup to calculate the increase in hospital admissions:

- $\frac{0.23}{0.10} \times 0.01 \times 7,390$ admissions
- $\frac{0.23}{0.10} \times \frac{1}{100} \times 7,390$ admissions
- $\frac{23\%}{10\%} \times 1\% \times 7,390$ admissions

One point for the correct calculation of the increase in hospital admissions. **1 point**

Accept one of the following:

- 169 more admissions
- 170 more admissions

Total for part (g) 2 points

Total for question 3 10 points