An in-depth look at scientific solutions to a real-world problem

Provided by:

Arizona Game & Fish
MANAGING TODAY FOR WILDLIFE TOMORROW
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Wildlife and Highway Management

Lesson 1: Is There a Problem with Wildlife on Our Roads?

LESSON OVERVIEW

Students must determine whether or not wildlife-vehicle collisions are a legitimate problem on which to spend money. They will be divided into small groups and given some data regarding this situation. Each group must analyze and present their data to the class. Then, each student will independently reach a conclusion and write a brief essay supporting it.

SUGGESTED GRADE LEVELS

- 7 – 12

ENDURING UNDERSTANDINGS

- Scientists often work in teams to solve problems.
- Accurate and reliable data need to be analyzed impartially to develop conclusions.

OBJECTIVES

Students will:

- Make a graph to represent numerical information.
- Analyze graphs to come to a conclusion.
- Write an essay in which their conclusions are supported by facts.

ARIZONA DEPARTMENT OF EDUCATION STANDARDS

Grade	Science	Mathematics	Writing
7	S1-C3-01; S1-C3-05; S1-C4-05; S3-C1-03; S3-C1-04; S3-C2-01; S4-C3-04	S2-C1-04; S2-C1-05; S2-C1-07; S2-C1-08; S2-C1-09	S2-C1-01; S2-C1-03; S2-C1-04; S2-C2-03; S2-C2-05; S2-C3-02; S2-C3-04; S2-C4-01; S2-C4-03; S2-C5-02; S3-C4-01
8	S1-C3-01; S1-C3-05; S1-C4-01; S1-C4-03; S1-C4-05; S3-C1-01; S3-C2-01	S2-C1-07; S2-C1-08	
High School	S1-C1-01; S1-C4-01; S1-C4-02; S1-C4-03; S1-C4-04; S3-C1-01; S3-C1-03; S3-C1-04; S3-C2-03	S2-C1-08; S2-C1-09	S2-C1-03; S2-C1-05; S2-C2-03; S2-C2-05; S2-C3-02; S2-C3-03; S2-C4-01; S2-C4-02; S2-C4-03; S2-C5-03; S3-C4-01

Note: The full text of these standards can be found in Appendix A.

TIME FRAME

- Two days (45 minutes each day)

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MATERIALS

- *Wildlife-Vehicle Collision Data Analysis* worksheets (one per group)
- Butcher paper (one per group)
- Markers
- Rulers
- *Is There a Problem? Rubric* (one per student)

TEACHER PREPARATION

- Make copies of the *Wildlife-Vehicle Collision Data Analysis* worksheets. Please note that there are six versions of this worksheet. Each group should get a different version. You might also want to make enough copies for each group member to have one.
- Make copies of the *Is There a Problem? Rubric* for each student.
- Gather enough materials for six groups.

SUGGESTED PROCEDURES

1. Divide the class into six groups of equal size. Number the groups, 1 through 6.
2. Hand out the *Wildlife-Vehicle Collision Data Analysis* worksheets.
3. As a class, read the information presented in the first three paragraphs. This will give the students a basic idea of what to expect.
4. Inform them that each group will be looking at the data concerning one small aspect of this whole situation. Each group must become experts on their part of the problem. After analyzing their data, they will be presenting the information to the class. Emphasize that they must pay attention to all of the presentations because they will use all of the information presented to determine what should be done, if anything, to prevent wildlife-vehicle collisions.
5. Let the groups work. Allow enough time for them to look at the data, graph it, and prepare their presentations. This will probably take the remainder of Day 1.
6. Ask each group in numerical order to make their presentation. Advise the students that they should take notes about important parts because they will be writing an essay on what they think should be done.
7. When all groups have presented, inform the students that they will now be working independently. Each student will write a brief essay summarizing the information that was presented by each group and coming to their own conclusion. They must first decide if there is a problem with wildlife-vehicle collisions, and, if so, what types of management measures can be used to control or prevent them. At this point, each student should be working independently. Hand out the rubric so that each student knows how the paper will be graded. Students who do not finish in the allotted class time may work on the essay as a homework assignment.

ASSESSMENT

- Group presentations
- Individual essay

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EXTENSIONS

- Have the students construct a graph using Excel and prepare their presentations using PowerPoint.

Appendix A: Arizona Department of Education Standards – Full Text

Science Standards

Grade	Strand	Concept	Performance Objective
7	1	3 – Analysis and Conclusions	1 – Analyze data obtained in a scientific investigation to identify trends 5 – Formulate a conclusion based on data analysis
		4 – Communication	5 – Communicate the results and conclusion of the investigation
	3	1 – Changes in Environment	3 – Propose possible solutions to address the environmental risks in biological or geological systems 4 – Analyze the environmental risks caused by human interaction with biological or geological systems
		2 – Science and Technology in Society	1 – Propose viable methods of responding to an identified need or problem
	4	3 – Populations of Organisms in an Ecosystem	4 – Evaluate data related to problems associated with population growth and the possible solutions
8	1	3 – Analysis and Conclusions	1 – Analyze data obtained in a scientific investigation to identify trends 5 – Explain how evidence supports the validity and reliability of a conclusion
		4 – Communication	1 – Communicate the results of an investigation 3 – Present analyses and conclusions in clear, concise formats 5 – Communicate the results and conclusions of the investigation
	3	1 – Changes in Environment	1 – Analyze the risk factors associated with natural, human induced, and/or biological hazards
		2 – Science and Technology in Society	1 – Propose viable methods of responding to an identified need or problem

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Science Standards Continued

Grade	Strand	Concept	Performance Objective
High School	1	1 – Observations, Questions, and Hypotheses	1 – Evaluate scientific information for relevance to a given problem
		4 – Communication	1 – For a specific investigation, choose an appropriate method for communicating the results 2 – Produce graphs that communicate data 3 – Communicate the results clearly and logically 4 – Support conclusions with logical scientific arguments
	3	1 – Changes in Environment	1 – Evaluate how the processes of natural ecosystems affect, and are affected by, humans 3 – Assess how human activities can affect the potential for hazards 4 – Evaluate how urban development affects the quality of the environment
		2 – Science and Technology in Society	3 – Support a position on a science or technology issue

Mathematics Standards

Grade	Strand	Concept	Performance Objective
7	2	1 – Data Analysis (Statistics)	4 – Interpret data displays including histograms, stem-and-leaf plots, circle graphs, and double line graphs 5 – Answer questions based on data displays including histograms, stem-and-leaf plots, circle graphs, and double line graphs 7 – Interpret trends from displayed data 8 – Compare trends in data related to the same investigation 9 – Solve contextual problems using histograms, line graphs or continuous data, double bar graphs, and stem-and-leaf plots
8	2	1 – Data Analysis (Statistics)	7 – Formulate reasonable predictions based on a given set of data 8 – Compare trends in data related to the same investigation
High School	2	1 – Data Analysis (Statistics)	8 – Make reasonable predictions for a set of data, based on patterns 9 – Draw inferences from charts, tables, graphs, plots, or data sets

Writing Standards

Grade	Strand	Concept	Performance Objective
7 – 8	2	1 – Ideas and Content	1 – Use clear, focused ideas and details to support the topic 3 – Develop a sufficient explanation or exploration of the topic 4 – Include ideas and details that show original perspective
		2 – Organization	3 – Place details appropriately to support the main idea 5 – Construct paragraphs by arranging sentences with an organizing principle (e.g., to develop a topic, to indicate a chronology)
		3 – Voice	2 – Convey a sense of identity through originality, sincerity, liveliness, or humor appropriate to the topic and type of writing 4 – Choose appropriate voice (e.g., formal, informal, academic discourse) for the audience and purpose
		4 – Word Choice	1 – Use accurate, specific, powerful words that effectively convey the intended message 3 – Use vocabulary that is original, varied, and natural
		5 – Sentence Fluency	2 – Create sentences that flow together and sound natural when read aloud
	3	4 – Persuasive	1 – Write persuasive text that: a) establishes and develops a controlling idea, b) supports arguments with detailed evidence, c) includes persuasive techniques, and d) excludes relevant information
High School	2	1 – Ideas and Content	3 – Provide sufficient, relevant and carefully selected details for support 5 – Include ideas and details that show original perspective and insights
		2 – Organization	3 – Place details appropriately to support the main idea 5 – Employ a variety of paragraphing strategies (e.g., topical, chronological, spatial) appropriate to application and purpose
		3 – Voice	2 – Convey a sense of identity through originality, sincerity, liveliness, or humor appropriate to the topic and type of writing 3 – Choose appropriate voice (e.g., formal, informal, academic discourse) for the application

Writing Standards Continued

Grade	Strand	Concept	Performance Objective
High School	2	4 – Word Choice	1 – Use accurate, specific, powerful words and phrases that effectively convey the intended message 2 – Use vocabulary that is original, varied, and natural 3 – Use words that evoke clear images
		5 – Sentence Fluency	3 – Demonstrate a flow that is natural and powerful when read aloud
	3	4 – Persuasive	1 – Write a persuasive composition that: a) states a position or claim, b) presents detailed evidence, examples, and reasoning to support effective arguments and emotional appeals, c) attributes sources of information when appropriate, d) structures ideas, and e) addresses the reader's concerns (grades 9 – 10) or acknowledges and refutes opposing arguments (grades 11 – 12)

Appendix B: Worksheets and Overheads

The pages that follow contain the worksheets listed below:

A. *Wildlife-Vehicle Collision Data Analysis* – Six different worksheets that present relevant information (6 pages)

B. *Is There a Problem? Rubric* – One method to evaluate student writing (1 page)

Wildlife-Vehicle Collision Data Analysis

Scientists have estimated that highway accidents kill between 500,000 and 700,000 deer in the United States every year.[1] These accidents can also result in injuries or death to humans as well as extensive property damage.

Many people believe that wildlife-vehicle collisions are a significant problem and millions of dollars should be invested to make roads safer for the humans that drive them and the animals that cross them. Other people disagree. Although they admit that accidents involving wildlife do occur, they believe that the problem is minor and our money is better spent elsewhere. You must take a careful look at the facts and come to your own conclusion.

Often in science, there is too much information for one person to analyze independently. As a result, scientists often work in teams. For this activity, your teacher will divide the class into six teams and provide each team with a piece of the data relevant to this problem. Each team must then analyze their data, prepare a graph and then present it to the class so that everyone becomes familiar with all the issues. To help your team be successful, each member will have to become an expert.

Group 1: Arizona Population

Use the table below to complete the tasks and answer the questions.

Table 1: Total Population of Arizona (in millions)

Year	1997	1998	1999	2000	2001	2002	2003
Population	4.6	4.8	4.9	5.1	5.3	5.5	5.6

Source: Arizona Department of Transportation

Tasks:

1. Use the data in the table above to make a line graph. Feel free to use large paper and markers to ensure that everyone will be able to see it.
2. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class.
3. Answer the following questions:
    a. What is the total change in population over this time period?
    b. What is the average change in population per year?
    c. If this trend were to continue, what do you expect the population of Arizona to be in 2010? 2050?
4. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class. Present your graph and your analysis to the class.
5. When all groups have presented, write a short essay (1-2 pages) in which you summarize the major facts and statistics, state whether or not the citizens of Arizona should be concerned about wildlife-vehicle collisions, and explain what action, if any, the Arizona government should take.

[1] Romin, L. A. and J. A. Bissonette. 1996. *Deer-vehicle collisions: status of state monitoring activities and mitigation efforts*. Wildlife Society Bulletin 24:276-283.

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Group 2: Statewide Wildlife-Vehicle Collisions

Use the table below to complete the tasks and answer the questions.

Table 2: Total Number of Vehicle Collisions Involving Wildlife in Arizona

Year	1997	1998	1999	2000	2001	2002	2003
# of Crashes	1285	1136	1480	1671	1638	1791	1414

Source: Arizona Department of Transportation

Tasks:

1. Use the data in the table above to make a bar graph. Feel free to use large paper and markers to ensure that everyone will be able to see it.
2. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class.
3. Answer the following questions:
    a. Which year had the most collisions involving wildlife? The least?
    b. What is the average number of collisions per year?
    c. Does the number of collisions appear to be increasing, decreasing, or staying the same?
    d. If this trend were to continue, what would you expect the number of similar collisions to be in 2010?
4. Present your graph and your analysis to the class.
5. When all groups have presented, write a short essay (1-2 pages) in which you summarize the major facts and statistics, state whether or not the citizens of Arizona should be concerned about wildlife-vehicle collisions, and explain what action, if any, the Arizona government should take.

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Group 3: Injuries Resulting from Collisions

Use the table below to complete the tasks and answer the questions.

Table 3: Total Reported Injuries and Deaths from Vehicle Collisions Involving Wildlife in Arizona

Year	1997	1998	1999	2000	2001	2002	2003
Injuries	248	206	260	280	344	314	244
Deaths	2	7	2	2	1	3	5

Source: Arizona Department of Transportation

Tasks:

1. Use the data in the table above to make a bar graph. Feel free to use large paper and markers to insure that everyone will be able to see it.
2. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class.
3. Answer the following questions:
    a. What is the total number of people injured over this time period? Killed?
    b. What is the average number of people injured/killed per year?
    c. Does the number of injuries/deaths appear to be increasing, decreasing, or staying the same? If this trend were to continue, what would you expect the number of injuries/deaths to be in 2010?
4. Present your graph and your analysis to the class.
5. When all groups have presented, write a short essay (1-2 pages) in which you summarize the major facts and statistics, state whether or not the citizens of Arizona should be concerned about wildlife-vehicle collisions, and explain what action, if any, the Arizona government should take.

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Group 4: Elk Population Near State Route 260

Use the table below to complete the tasks and answer the questions.

Table 4: Estimated Number of Elk in the Vicinity of State Route 260

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
# of Elk	1683	1678	1665	1672	1660	1710	1542	1716	1587	1488

Source: Arizona Game and Fish Department

Tasks:

1. Use the data in the table above to make a line graph. Feel free to use large paper and markers to ensure that everyone will be able to see it.
2. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class.
3. Answer the following questions:
    a. Which year had the most elk? The least?
    b. What is the average number of elk per year?
    c. Does the population of elk appear to be increasing, decreasing, or staying the same?
    d. If this trend were to continue, what would you expect the number of elk to be in 2010?
4. Present your graph and your analysis to the class.
5. When all groups have presented, write a short essay (1-2 pages) in which you summarize the major facts and statistics, state whether or not the citizens of Arizona should be concerned about wildlife-vehicle collisions, and explain what action, if any, the Arizona government should take.

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Group 5: Elk Killed on State Route 260

Use the table below to complete the tasks and answer the questions.

Table 5: Elk Killed by Vehicle Collisions on State Route 260

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
# of Elk Killed	20	25	23	27	33	39	14	29	36	34	42

Source: Arizona Game and Fish Department and Arizona Department of Transportation

Tasks:

1. Use the data in the table above to make a bar graph. Feel free to use large paper and markers to ensure that everyone will be able to see it.
2. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class.
3. Answer the following questions:
    a. In which year were the most elk killed? The least?
    b. What is the average number of elk killed per year?
    c. Does the number of elk killed by vehicles appear to be increasing, decreasing, or staying the same? If this trend were to continue, what would you expect the number of (or: collisions resulting in elk deaths) to be in 2010?
4. Present your graph and your analysis to the class.
5. When all groups have presented, write a short essay (1-2 pages) in which you summarize the major facts and statistics, state whether or not the citizens of Arizona should be concerned about wildlife-vehicle collisions, and explain what action, if any, the Arizona government should take.

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Often in science, there is too much information for one person to analyze independently. As a result, scientists often work in teams. For this activity, your teacher will divide the class into six teams and provide each team with a piece of the data relevant to this problem. Each team must then analyze their data, prepare a graph and then present it to the class so that everyone becomes familiar with all the issues. To help your team be successful, each member will have to become an expert.

Group 6: Average Daily Traffic on State Route 260

Use the table below to complete the tasks and answer the questions.

Table 6: Average Annual Daily Traffic Volume (AADT) on State Route 260

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
AADT	3124	3123	3652	3750	3950	4930	5112	4500	6267	8700

Source: Arizona Game and Fish Department and Arizona Department of Transportation

Tasks:

1. Use the data in the table above to make a line graph. Feel free to use large paper and markers to ensure that everyone will be able to see it.
2. Write a brief paragraph explaining what the graph shows. This will be the main information that your team will present to the class.
3. Answer the following questions:
    a. How much has the average daily traffic increased during this time period?
    b. What is the average increase in traffic per year?
    c. If this trend were to continue, what would you expect the average daily traffic to be in 2010? 2050?
4. Present your graph and your analysis to the class.
5. When all groups have presented, write a short essay (1-2 pages) in which you summarize the major facts and statistics, state whether or not the citizens of Arizona should be concerned about wildlife-vehicle collisions, and explain what action, if any, the Arizona government should take.

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Wildlife and Highway Management

Is There a Problem? Rubric

The following rubric will show you how your essay will be evaluated. Use it as you write.

CATEGORY	4	3	2	1
Accuracy of Facts (Content)	All supportive facts are reported accurately.	Almost all supportive facts are reported accurately.	Most supportive facts are reported accurately.	NO facts are reported OR most are inaccurately reported.
Adding Personality (Voice)	The writer has developed a unique and persuasive voice. There is a strong sense of personality.	The writer has developed a convincing voice. There is some sense of personality, but it may be inconsistent or weak at times.	The writer occasionally develops a convincing voice, but generally it is weak and inconsistent.	There is no sense of voice in the essay.
Sequencing (Organization)	Details are placed in a logical order, and the way they are presented effectively keeps the interest of the reader.	Details are placed in a logical order, but the way in which they are presented/ introduced sometimes makes the writing less interesting.	Some details are not in a logical or expected order and may distract or confuse the reader.	Many details are not in a logical or expected order. There is little sense that the writing is organized.
Word Choice	Writer uses vivid words and phrases that linger or draw pictures in the reader's mind, and the choice and placement of the words seems accurate, natural and not forced.	Writer uses vivid words and phrases that linger or draw pictures in the reader's mind, but occasionally the words are used inaccurately or seem overdone.	Writer uses words that communicate clearly, but the writing lacks variety, punch or flair.	Writer uses a limited vocabulary that does not communicate strongly or capture the reader's interest. Jargon or clichés may be present and detract from the meaning.
Flow and Rhythm (Sentence Fluency)	All sentences sound natural and are easy-on-the-ear when read aloud. Each sentence is clear and has an obvious emphasis.	Almost all sentences sound natural and are easy-on-the-ear when read aloud, but one or two are stiff, awkward or difficult to understand.	Most sentences sound natural and are easy-on-the-ear when read aloud, but several are stiff, awkward or difficult to understand.	The sentences are difficult to read aloud because they sound awkward, are repetitive, or difficult to understand.

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Wildlife and Highway Management

Lesson 2: How Do We Solve the Problem of Wildlife on Our Roads?

LESSON OVERVIEW

Students use actual scientific data to evaluate the movement of elk. Using this information, they must determine where to build three wildlife bridges or underpasses along the highway as well as develop several cost-saving alternatives. They will write a formal report to present their findings.

SUGGESTED GRADE LEVELS

- 7 – 12

ENDURING UNDERSTANDINGS

- Accurate and reliable data need to be analyzed impartially to develop conclusions.
- Technology has improved data collection for scientists.

OBJECTIVE

Students will:

- Analyze tables and graphs to come to a conclusion.
- Write a report in which their conclusions are supported by facts.

ARIZONA DEPARTMENT OF EDUCATION STANDARDS

Grade	Science	Mathematics	Writing
7	S1-C3-01; S1-C3-05; S1-C4-02; S1-C4-03; S1-C4-05; S3-C1-03; S3-C2-01; S3-C2-02	S2-C1-03; S2-C1-04; S2-C1-05; S2-C1-07; S2-C1-08; S2-C1-09	S2-C1-01; S2-C1-03; S2-C1-04; S2-C2-03; S2-C2-05; S2-C3-02; S2-C3-04; S2-C4-01; S2-C4-03; S2-C5-02; S3-C2-01; S3-C2-03
8	S1-C3-01; S1-C3-05; S1-C4-01; S1-C4-02; S1-C4-03; S1-C4-05; S3-C2-01; S3-C2-02	S2-C1-03; S2-C1-07; S2-C1-08	
High School	S1-C1-01; S1-C4-01; S1-C4-02; S1-C4-03; S1-C4-04; S3-C1-01; S3-C1-03; S3-C1-04; S3-C2-02; S3-C2-03; S3-C2-05	S2-C1-02; S2-C1-08; S2-C1-09; S2-C1-11	S2-C1-03; S2-C1-05; S2-C2-03; S2-C2-05; S2-C3-02; S2-C3-03; S2-C4-01; S2-C4-02; S2-C4-03; S2-C5-03; S3-C2-01

Note: The full text of these standards can be found in Appendix A.

TIME FRAME

- Two to three days (45 minutes each day)

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MATERIALS

- *How Do We Stop Wildlife-Vehicle Collisions* worksheet (one per team)
- *Ecology* of *Elk* worksheet (one per team)
- *Elk Movement Research* worksheet (one per team)
- *Research Rubric* (one per team)
- Computers with Internet access (one per team) or copies of various Web sites for research

TEACHER PREPARATION

- Make copies of the *How Do We Stop Wildlife-Vehicle Collisions*, *Ecology of Elk*, and *Elk Movement Research* worksheets and the *Research Rubric* for each team. You might also want to make copies for each student.
- If computer access is not available, preview the Web sites and print out relevant information. You should find specific ways to prevent wildlife-vehicle collisions. Make copies of these for students to use in class.

SUGGESTED PROCEDURES

1. Divide the class into teams and hand out the worksheets.
2. Read the first worksheet, *How Do We Stop Wildlife-Vehicle Collisions*, as a class and review the map of proposed sites.
3. Inform the teams that the remaining worksheets present data on elk ecology and elk movements across the highway. They must analyze the data to determine where to build the bridges or underpasses. They will then use the computers or the printed material to research alternatives to bridges and underpasses and determine if any will work best in this situation. Each team (or each student if you prefer) will then write a research report that explains their conclusions.
4. Be sure to allow sufficient time. This portion of the assignment may take more than one day.
5. When the teams have completed their analyses, assign the research report.

ASSESSMENT

- Research report

EXTENSIONS

- Have students research the work done in Banff National Park along the Trans-Canada Highway and compare it to the plan for State Route 260 in Arizona.

Appendix A: Arizona Department of Education Standards – Full Text

Science Standards

Grade	Strand	Concept	Performance Objective
7	1	3 – Analysis and Conclusions	1 – Analyze data obtained in a scientific investigation to identify trends 5 – Formulate a conclusion based on data analysis
		4 – Communication	1 – Choose an appropriate graphic representation for collected data 2 – Display data collected from a controlled investigation 3 – Communicate the results of an investigation with appropriate use of qualitative and quantitative information 5 – Communicate the results and conclusion of the investigation
	3	1 – Changes in Environments	3 – Propose possible solutions to address the environmental risks in biological or geological systems
		2 – Science and Technology in Society	1 – Propose viable methods of responding to an identified need or problem 2 – Compare solutions to best address an identified need or problem
8	1	3 – Analysis and Conclusions	1 – Analyze data obtained in a scientific investigation to identify trends 5 – Explain how evidence supports the validity and reliability of a conclusion
		4 – Communication	1 – Communicate the results of an investigation 2 – Choose an appropriate graphic representation for collected data 3 – Present analyses and conclusions in clear, concise formats 5 – Communicate the results and conclusions of the investigation
	3	2 – Science and Technology in Society	1 – Propose viable methods of responding to an identified need or problem 2 – Compare solutions to best address an identified need or problem

Science Standards Continued

Grade	Strand	Concept	Performance Objective
High School	1	1 – Observations, Questions, and Hypotheses	1 – Evaluate scientific information for relevance to a given problem
		4 – Communication	1 – For a specific investigation, choose an appropriate method for communicating the results 2 – Produce graphs that communicate data 3 – Communicate results clearly and logically 4 – Support conclusions with logical scientific arguments
	3	1 – Changes in Environment	1 – Evaluate how the processes of natural ecosystems affect, and are affected by, humans 3 – Assess how human activities can affect the potential for hazards 4 – Evaluate how urban development affects the quality of the environment
		2 – Science and Technology in Society	2 – Recognize the importance of basing arguments on a thorough understanding of the core concepts and principles of science and technology 3 – Support a position on a science or technology issue 5 – Evaluate methods used to manage natural resources

Mathematics Standards

Grade	Strand	Concept	Performance Objective
7	2	1 – Data Analysis (Statistics)	3 – Determine when it is appropriate to use histograms, line graphs, double bar graphs, and stem-and-leaf plots 4 – Interpret data displays including histograms, stem-and-leaf plots, circle graphs, and double line graphs 5 – Answer questions based on data displays including histograms, stem-and-leaf plots, circle graphs, and double line graphs 7 – Interpret trends from displayed data 8 – Compare trends in data related to the same investigation 9 – Solve contextual problems using histograms, line graphs or continuous data, double bar graphs, and stem-and-leaf plots

Mathematics Standards Continued

Grade	Strand	Concept	Performance Objective
8	2	1 – Data Analysis (Statistics)	3 – Determine the appropriate type of graphical display for a given data set 7 – Formulate reasonable predictions based on a given set of data 8 – Compare trends in data related to the same investigation
High School	2	1 – Data Analysis (Statistics)	2 – Organize collected data into an appropriate graphical representation 8 – Make reasonable predictions for a set of data, based on patterns 9 – Draw inferences from charts, tables, graphs, plots, or data sets 11 – Evaluate the reasonableness of conclusions drawn from data analysis

Writing Standards

Grade	Strand	Concept	Performance Objective
7 – 8	2	1 – Ideas and Content	1 – Use clear, focused ideas and details to support the topic 3 – Develop a sufficient explanation or exploration of the topic 4 – Include ideas and details that show original perspective
		2 – Organization	3 – Place details appropriately to support the main idea 5 – Construct paragraphs by arranging sentences with an organizing principle (e.g., to develop a topic, to indicate a chronology)
		3 – Voice	2 – Convey a sense of identity through originality, sincerity, liveliness, or humor appropriate to the topic and type of writing 4 – Choose appropriate voice (e.g., formal, informal, academic discourse) for the audience and purpose
		4 – Word Choice	1 – Use accurate, specific, powerful words that effectively convey the intended message 3 – Use vocabulary that is original, varied, and natural
		5 – Sentence Fluency	2 – Create sentences that flow together and sound natural when read aloud

Writing Standards Continued

Grade	Strand	Concept	Performance Objective
7 – 8	3	2 – Expository	1 – Record information (e.g., observations, notes, lists, charts, map labels and legends) related to the topic 3 – Write a process essay that includes: a. a thesis statement b. supporting details c. introductory, body, and concluding paragraphs
High School	2	1 – Ideas and Content	3 – Provide sufficient, relevant and carefully selected details for support 5 – Include ideas and details that show original perspective and insights
		2 – Organization	3 – Place details appropriately to support the main idea 5 – Employ a variety of paragraphing strategies (e.g., topical, chronological, spatial) appropriate to application and purpose
		3 – Voice	2 – Convey a sense of identity through originality, sincerity, liveliness, or humor appropriate to the topic and type of writing 3 – Choose appropriate voice (e.g., formal, informal, academic discourse) for the application
		4 – Word Choice	1 – Use accurate, specific, powerful words and phrases that effectively convey the intended message 2 – Use vocabulary that is original, varied, and natural 3 – Use words that evoke clear images
		5 – Sentence Fluency	3 – Demonstrate a flow that is natural and powerful when read aloud

Writing Standards Continued

Grade	Strand	Concept	Performance Objective
High School	3	2 – Expository	1 – Write a multi-paragraph essay that: a. includes background information to set up the thesis (hypothesis, essential question), as appropriate b. states a thesis with a narrow focus c. includes evidence in support of a thesis in the form of details, facts, examples, or reasons d. communicates information and ideas from primary and/or secondary sources accurately and coherently, as appropriate e. attributes sources of information as appropriate f. includes a topic sentence for each body paragraph g. includes relevant factors and variables that need to be considered h. Includes visual aids to organize and record information on charts, tables, maps, and graphs, as appropriate i. includes an effective conclusion

Appendix B: Worksheets and Overheads

The pages that follow contain the worksheets listed below:

A. *How Do We Stop Wildlife-Vehicle Collisions?* – A handout describing the activity (1 page)

B. *Ecology of Elk* – A brief summary of the history and ecology of elk in Arizona (1 page)

C. *Elk Movement Research* – A summary of the actual data collected on elk movement near State Route 260 (3 pages)

D. *Research Rubric* – One method to evaluate the student report (1 page)

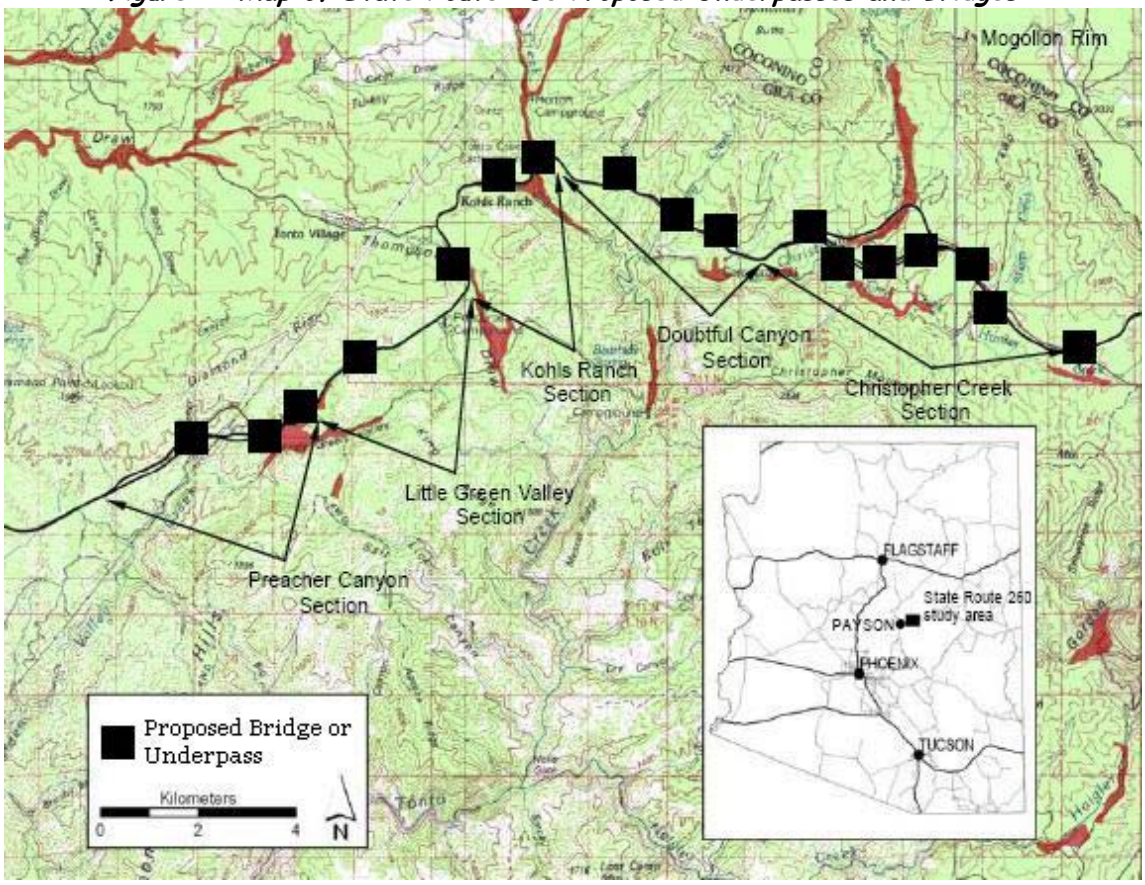
Wildlife and Highway Management

How Do We Stop Wildlife-Vehicle Collisions?

The Arizona Department of Transportation has decided that wildlife-vehicle collisions are a serious issue in Arizona. One main area of concern is Highway 260 east of Payson. This 18.5-mile stretch of highway cuts right through the middle of prime elk habitat but is also experiencing a significant increase in highway traffic.

The proposed plan calls for increasing the size of this road from a two-lane to a four-lane highway while improving wildlife permeability (passage). It would incorporate 11 bridges and 6 underpasses (Figure 1).

Figure 1: Map of State Route 260 Proposed Underpasses and Bridges



The research has been performed and construction is ready to begin. However, concerns have been raised over the cost. Your team has been chosen to analyze the data with two goals in mind:

1. Evaluate and characterize wildlife movements, particularly elk, across State Route 260.
2. Research alternatives to bridges and underpasses that may reduce the costs.

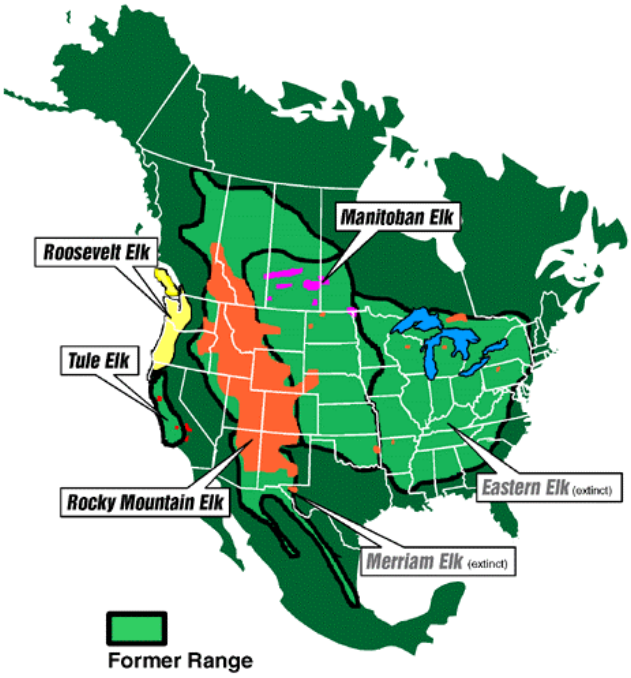
The Arizona Department of Transportation has asked for a formal report in which you describe three ideal locations for bridges or underpasses as well as two cost-saving alternatives.

On the following pages, you will find information and data collected during this research project that is available for you to use as you make your decisions. Good luck!

Wildlife and Highway Management

Ecology of Elk

At one time, elk were the most widely distributed member of the deer family in North America. Their population size was estimated at 10 million. But that was before Europeans arrived. Just as with the buffalo, agriculture and market hunting took their toll on the elk. By 1922, the population had shrunk to 90,000, most of them living in Yellowstone Park, which became a reservoir to preserve them. As the Yellowstone elk reproduced, some were transplanted to bolster or begin herds in other parts of the country. Between 1912 and 1967, more than 13,000 elk were relocated. Eighty-three of them were sent to Arizona, and this small population is responsible for the 35,000 elk now in the state.



Elk have two distinct coats. They grow a heavy winter coat that is primarily dark brown across the head, belly, neck, and legs, and grayish brown on the sides and back. The rump is yellow with a dark brown stripe. They shed this coat in the spring, revealing the summer coat, which is usually a deep red-brown with no undercoat. They shed this coat as fall arrives.

One of the elk's most distinctive features is its antlers, which are shed every year. Adult males (bulls) shed their antlers between January and March, and the new antlers begin to grow soon after. By August, antler growth is complete. During this time of growth, the males have increased nutritional needs.

Most elk cows weigh between 450 and 600 pounds; bulls average 600 to 800 pounds. Some large bulls have been reported to weigh as much as 1,200 pounds. Elk are extremely fast and can run up to 40 miles per hour for short distances and 30 miles per hour for longer ones. They have been known to swim a distance of more than a mile. They can jump 8 to 10 feet into the air. An elk's life span is usually between 14 and 17 years, although some have reached the age of 25.

The elk breeding period is during the months of September and October. One bull elk may breed with as many as 30 females (cows), but the average is around 15 to 20. Calves are born about 8 months later, in late May. The calves weigh approximately 30 pounds. Twins are extremely rare. The mother's nutritional demands increase during gestation (pregnancy) and in the weeks following the birth, when she must produce milk to feed her calf. A few weeks after birth, the calf is able to run and join in the regular activities of the herd. At this time, herds may number in the hundreds.

Information for this article was provided by the Arizona Game and Fish Department and the Rocky Mountain Elk Foundation.

Elk Movement Research

Researchers with the Arizona Game and Fish Department used global positioning satellite (GPS) telemetry to assess the movement of elk within the research area near State Route 260. Elk were captured and fitted with GPS receiver collars. These collars, which had a life of approximately 15 months, were programmed to report a fix (elk location) every four hours. From May 2002 to April 2004, a total of 33 elk (25 cows and 8 bulls) were studied. The scientists collected more than 101,000 GPS fixes. The following tables summarize the data they collected.

Definitions

Crossing – any time an elk moved from one side of the road to another (the crossings are all inferred based on the elk's location between two consecutive GPS fixes)

Weighted Crossing – a number of crossings corrected to reflect the number of different elk that crossed at a given point and the evenness in the distribution of crossings among the different elk

Approach – any time an elk traveled within 0.15 miles of the highway but did not cross (based upon GPS fixes)

Passage Rate – a relationship between the number of times the elk approached the highway and the number of times they crossed (highway crossings/highway approaches)

A Note About the Tables

All of the data included in the following tables were collected from May 2002 to April 2004 along the research area on State Route 260 (see Figure 1).

Elk Movement Data – The following data tables (1 – 5) deal specifically with the movement of elk around the research area.

Table 1: Elk Crossings by Highway Section

Highway Section	# of Miles	# of Elk	# of Elk Crossings	Crossings/Mile	Weighted Crossings	Weighted Crossings/Mile
Preacher Canyon	3.0	13	1298	432.7	1312	437.3
Little Green Valley	2.5	13	132	52.8	193	77.2
Kohl's Ranch	3.4	13	212	62.3	237	69.7
Doubtful Canyon	2.8	8	292	104.3	332	118.6
Christopher Creek	5.0	15	1070	214.0	1451	290.2

Table 2: Average Number of Elk Highway Approaches and Crossings

	Elk Gender		
	All	Cow	Bull
# of Highway Crossings	92.6	112.0	32.1
Highway Crossings/Day	0.22	0.28	0.06
Highway Approaches/Day	0.73	0.83	0.43
Highway Passage Rate	0.35	0.36	0.34

Table 3: Frequency of Elk Fixes Found in Various Habitats

		Proportion of Habitat Area where Elk are Found				
		Chaparral	Pinyon-Juniper	Ponderosa	Mixed Conifer	Riparian
Proportion of Total Habitat Area		0.16	0.12	0.46	0.22	0.04
Elk Gender	All	0.15	0.10	0.39	0.18	0.18
	Bull	0.12	0.07	0.42	0.19	0.20
	Cow	0.14	0.10	0.39	0.19	0.17

Table 4: Highway Crossings and Passage Rates by Month

Month	Bull		Cow	
	Crossing	Passage Rate	Crossing	Passage Rate
Jan	0	0.00	151	0.32
Feb	0	0.00	120	0.26
Mar	2	0.34	257	0.30
Apr	13	0.68	128	0.36
May	16	0.59	142	0.54
Jun	54	0.47	199	0.42
Jul	33	0.27	184	0.31
Aug	61	0.48	230	0.30
Sep	25	0.53	199	0.38
Oct	31	0.49	259	0.52
Nov	3	0.08	201	0.27
Dec	0	0.00	116	0.22

Table 5: Proportion of Highway Crossings by Time of Day

Crossing Time	12am	2am	4am	6am	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm
Proportion	0.14	0.15	0.10	0.18	0.06	0.02	0.01	0.00	0.01	0.07	0.13	0.12

Note: Times represent the midpoint of a 2-hour time interval (i.e., 2am = 1am-3am)

Elk-Vehicle Collision Data – The following tables (6 – 9) deal with comparisons between elk movement and the number of collisions that occur

Table 6: Elk Highway Crossings and Elk-Vehicle Collisions by Highway Section

Highway Section	# of Elk Crossings	# of Elk-Vehicle Collisions
Preacher Canyon	1312	78
Little Green Valley	193	3
Kohl's Ranch	237	39
Doubtful Canyon	332	9
Christopher Creek	1451	98

Table 7: Proportion of Elk-Vehicle Collisions and Highway Crossings by Month

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Proportion of Crossings	0.06	0.05	0.11	0.11	0.06	0.10	0.09	0.12	0.09	0.12	0.08	0.05
Proportion of Collisions	0.06	0.06	0.04	0.07	0.06	0.05	0.08	0.08	0.16	0.20	0.13	0.07

Table 8: Proportion of Elk-Vehicle Collisions and Highway Crossings by Time of Day

Time	12am	2am	4am	6am	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm
Crossing Proportion	0.14	0.15	0.10	0.18	0.06	0.02	0.01	0.00	0.01	0.07	0.13	0.12
Collision Proportion	0.12	0.07	0.08	0.08	0.04	0.01	0.01	0.00	0.00	0.11	0.31	0.16

Note: Times represent the midpoint of a 2-hour time interval (i.e., 2am = 1am-3am)

Table 9: Proportion of Elk-Vehicle Collisions Occurring by Hours Away from Sunrise or Sunset

Hours From Sunrise/Sunset	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Collisions	0.11	0.23	0.11	0.09	0.07	0.06	0.04	0.04	0.05	0.06	0.06	0.07

Note: Times represent how close the elk crossing occurred to sunrise or sunset (0.5 = half hour before or after sunrise or sunset)

Data Analysis Questions

Use the following questions to help focus your ideas as you develop your report.

1. How much more likely is a female elk to cross the highway than a male elk? Does this make a significant difference in the passage rates of the two genders?
2. In which type of habitat are there more elk than would be expected based upon the area of that habitat?
3. At what time of year are the most elk crossing the highway? Does it vary depending on the gender of the elk? Why are they crossing during this time? Does this match the time when the most elk-vehicle collisions occur? Why or why not?
4. At what time of day do the most elk cross the highway? Does this match the time when the most elk-vehicle collisions occur? Why or why not?
5. Which highway section has the largest proportion of elk-vehicle collisions compared to elk crossings? Is this the same area that has the highest number of elk-vehicle collisions?

Formal Report

You must now use this information to prepare a report for the Arizona Department of Transportation. The report must identify three locations where bridges or underpasses should be built and present any cost effective alternatives to deal with this situation rather than building 18 bridges or underpasses. In this report, you must address the following issues:

1. Describe the movement of elk across State Route 260. Be sure to focus on when and where the elk are moving. Use graphs if necessary.
2. Identify on the map, three locations where bridges or underpasses should be built. Be sure to explain why you selected these locations. Use graphs if necessary.
3. Analyze possible alternatives to bridges and underpasses. If possible, describe where alternatives are currently being used and how effective they are. Use graphs if necessary.
4. Identify two cost-saving alternatives that could be used in place of the bridges or underpasses. Describe how these would be used at these locations. Use graphs if necessary.

Use the links below (or your own Internet search) to find information about alternative solutions:

- Wildlife-Vehicle Accident Prevention Program: *http://www.wildlifeaccidents.ca/*
- Wildlife Crossings Toolkit: *http://www.wildlifecrossings.info/beta2.htm*
- Wildlife Protection – Keeping It Simple: *http://www.fhwa.dot.gov/environment/wildlifeprotection/index.cfm?fuseaction=home.viewTopic&topicID=1*
- Critter Crossings: *http://www.fhwa.dot.gov/environment/wildlifecrossings/index.htm*

Wildlife and Highway Management

Research Report Rubric

The following rubric will show you how your essay will be evaluated. Use it as you write.

CATEGORY	4	3	2	1
Accuracy of Facts (Content)	All supportive facts are reported accurately.	Almost all supportive facts are reported accurately.	Most supportive facts are reported accurately.	NO facts are reported OR most are inaccurately reported.
Adding Personality (Voice)	The writer has developed an academic voice appropriate for the audience.	There is some sense of academic discourse, but it may be inconsistent or weak at times.	The writer occasionally develops an academic voice, but generally it is weak and inconsistent.	There is no sense of voice in the essay.
Sequencing (Organization)	Details are placed in a logical order and the way they are presented effectively keeps the interest of the reader.	Details are placed in a logical order, but the way in which they are presented or introduced sometimes makes the writing less interesting.	Some details are not in a logical or expected order, and may distract or confuse the reader.	Many details are not in a logical or expected order. There is little sense that the writing is organized.
Word Choice	Writer uses appropriate words and phrases, and the placement of the words seems accurate, natural and not forced.	Writer uses appropriate words and phrases, but occasionally the words are used inaccurately or seem overdone.	Writer uses words that communicate clearly, but the writing lacks interest.	Writer uses a limited vocabulary that does not communicate strongly or capture the reader's interest. Jargon or clichés may be present and detract from the meaning.
Flow and Rhythm (Sentence Fluency)	All sentences sound natural and are easy-on-the-ear when read aloud. Each sentence is clear and has an obvious emphasis.	Almost all sentences sound natural and are easy-on-the-ear when read aloud, but 1 or 2 are stiff, awkward or difficult to understand.	Most sentences sound natural and are easy-on-the-ear when read aloud, but several are stiff, awkward or difficult to understand.	The sentences are difficult to read aloud because they sound awkward, are repetitive, or difficult to understand.
Citations	At least three citations are used and all are cited correctly.	At least three citations are used but one is not cited correctly.	Less than three citations are used or more than one is not cited correctly.	There are no citations.

An in-depth look at scientific solutions to a real-world problem

Wildlife and Highway Management

Lesson 3: How Can We Determine if We Have Been Successful?

LESSON OVERVIEW

Students read about an experiment designed to collect data on which animals use wildlife underpasses and how they use them. The students use this information to design a research question that they could answer with the collected data and propose a hypothesis. Then, they have the opportunity to analyze the data to develop a conclusion about their research question.

SUGGESTED GRADE LEVELS

- 7 – 12

ENDURING UNDERSTANDINGS

- Accurate and reliable data must be analyzed impartially to develop conclusions.
- Technology has improved data collection for scientists.

OBJECTIVE

Students will:

- Read and understand an experimental design.
- Formulate a research question and propose a hypothesis.
- Use data to develop a conclusion.

ARIZONA DEPARTMENT OF EDUCATION STANDARDS

Grade	Science	Mathematics	Writing
7	S1-C1-01; S1-C2-02; S1-C3-01; S1-C3-02; S1-C3-03; S1-C3-04; S1-C3-05; S1-C3-06; S1-C3-07; S1-C4-01; S1-C4-02; S1-C4-03; S1-C4-05; S2-C1-04; S3-C1-01	S2-C1-03; S2-C1-04; S2-C1-07; S2-C1-08; S2-C1-09	S2-C1-01; S2-C1-03; S2-C1-04; S2-C2-03; S2-C2-05; S2-C3-02; S2-C3-04; S2-C4-01; S2-C4-03; S2-C5-02; S3-C2-01; S3-C2-03
8	S1-C1-01; S1-C1-03; S1-C2-02; S1-C3-01; S1-C3-02; S1-C3-04; S1-C3-05; S1-C3-08; S1-C4-01; S1-C4-02; S1-C4-03; S1-C4-05	S2-C1-03; S2-C1-07; S2-C1-08	

An in-depth look at scientific solutions to a real-world problem

Grade	Science	Mathematics	Writing
High School	S1-C1-01; S1-C1-02; S1-C1-03; S1-C3-01; S1-C3-02; S1-C3-07; S1-C4-01; S1-C4-02; S1-C4-03; S1-C4-04; S3-C1-01; S3-C1-03; S3-C1-05; S3-C2-05	S2-C1-02; S2-C1-08; S2-C1-09; S2-C1-11	S2-C1-03; S2-C1-05; S2-C2-03; S2-C2-05; S2-C3-02; S2-C3-03; S2-C4-01; S2-C4-02; S2-C4-03; S2-C5-03; S3-C2-01

Note: The full text of these standards can be found in Appendix A.

TIME FRAME

- Two days (45 minutes each day)

MATERIALS

- *Do Underpasses Really Work?* worksheet (one class set)
- *Experiment Planning and Comprehension* worksheet (one per student)
- *Analyzing the Data* worksheet (one per student)
- *Research Rubric* (one per student)
- Optional: Computers with Internet access

TEACHER PREPARATION

- Make a class set of copies of the *Do Underpasses Really Work?* worksheet.
- Make copies of the *Experiment Planning and Comprehension, Analyzing the Data* worksheets and the *Research Rubric* for each student.

SUGGESTED PROCEDURES

1. Hand out the *Do Underpasses Really Work?* worksheet.
2. Inform the students that the Arizona Game and Fish Department and the Arizona Department of Transportation have begun building underpasses to prevent wildlife-elk collisions. It is now the responsibility of the students to determine if these underpasses are successful.
3. Give the students time to read the worksheet.
4. Initiate a brief discussion of the worksheet. Point out that a lot of information was presented about what researchers are doing to study the underpasses. Now it is up to the students to come up with a research question that can be answered using the data collected by the researchers and propose a hypothesis.
5. Hand out the *Experiment Planning and Comprehension* worksheet.
6. Provide time for the students to answer the questions. If they do not finish, allow them to complete the worksheet for homework.
7. When the students have completed the worksheet, inform them that they will now have the opportunity to look at the data collected so far. Make it clear that they don't need to use all of the data on the worksheet. They should use only the information that is related to their question and hypothesis. When they are ready, they will prepare a formal scientific report in which they share the results of their experiment.
8. Hand out the *Analyzing the Data* worksheet and the *Research Rubric*.
9. Allow time for the students to prepare their reports using the rubric for guidance as they write.

An in-depth look at scientific solutions to a real-world problem

ASSESSMENT

- Scientific report

EXTENSIONS

- Have the students compare their results with the official results posted at the Arizona Game and Fish Web site and explain why there may or may not be differences.
- Students can develop visual displays of their experiment and the class can hold a poster session or similar scientific conference to present their results.

Appendix A: Arizona Department of Education Standards – Full Text

Science Standards

Grade	Strand	Concept	Performance Objective
7	1	1 – Observations, Questions, and Hypotheses	1 – Formulate questions based on observations that lead to the development of a hypothesis
		2 – Scientific Testing	2 – Design an investigation to test individual variables using scientific processes
		3 – Analysis and Conclusions	1 – Analyze data obtained in a scientific investigation to identify trends 2 – Form a logical argument about a correlation between variables or sequence of events 3 – Analyze results of data collection in order to accept or reject the hypothesis 4 – Determine the validity and reliability of results of an investigation 5 – Formulate a conclusion based on data analysis 6 – Refine hypotheses based on results from investigations 7 – Formulate new questions based on the results of a previous investigation
		4 – Communication	1 – Choose and appropriate graphic representation for collected data 2 – Display data collected from a controlled investigation 3 – Communicate the results of an investigation with appropriate use of qualitative and quantitative information 5 – Communicate the results and conclusion of the investigation
	2	1 – History of Science as a Human Endeavor	4 – Analyze the use of technology in science-related careers
	3	1 – Changes in Environments	1 – Analyze environmental risks caused by human interaction with biological or geological systems
8	1	1 – Observations, Questions, and Hypotheses	1 – Formulate questions based on observations that lead to the development of a hypothesis 3 – Generate a hypothesis that can be tested
		2 – Scientific Testing	2 – Design a controlled investigation to support or reject a hypothesis

Science Standards Continued

Grade	Strand	Concept	Performance Objective
8	1	3 – Analysis and Conclusions	1 – Analyze data obtained in a scientific investigation to identify trends 2 – Form a logical argument about a correlation between variables or sequence of events 4 – Formulate a future investigation based on the data collected 5 – Explain how evidence supports the validity and reliability of a conclusion 8 – Formulate new questions based on the results of a previous investigation
		4 – Communication	1 – Communicate the results of an investigation 2 – Choose an appropriate graphic representation for collected data 3 – Present analyses and conclusions in clear, concise formats 5 – Communicate the results and conclusion of the investigation
High School	1	1 – Observations, Questions, and Hypotheses	1 – Evaluate scientific information for relevance to a given problem 2 – Develop questions from observations that transition into testable hypotheses 3 – Formulate a testable hypothesis
		3 – Analysis, Conclusion, and Refinement	1 – Interpret data that show a variety of possible relationships between variables 2 – Evaluate whether investigational data support or do not support the proposed hypothesis 7 – Propose further investigations based on the findings of a conducted investigation
		4 – Communication	1 – For a specific investigation, choose an appropriate method for communicating the results 2 – Produce graphs that communicate data 3 – Communicate results clearly and logically 4 – Support conclusions with logical scientific arguments

An in-depth look at scientific solutions to a real-world problem

Science Standards Continued

Grade	Strand	Concept	Performance Objective
High School	3	1 – Changes in Environments	1 – Evaluate how the processes of natural ecosystems affect, and are affected by, humans 3 – Assess how human activities can affect the potential for hazards 5 – Evaluate the effectiveness of conservation practices and preservation techniques on environmental quality and biodiversity
		2 – Science and Technology in Society	5 – Evaluate methods used to manage natural resources

Mathematics Standards

Grade	Strand	Concept	Performance Objective
7	2	1 – Data Analysis (Statistics)	3 – Determine when it is appropriate to use histograms, line graphs, double bar graphs, and stem-and-leaf plots 4 – Interpret data displays including histograms, stem-and-leaf plots, circle graphs, and double line graphs 7 – Interpret trends from displayed data 8 – Compare trends in data related to the same investigation 9 – Solve contextual problems using histograms, line graphs or continuous data, double bar graphs, and stem-and-leaf plots
8	2	1 – Data Analysis (Statistics)	3 – Determine the appropriate type of graphical display for a given data set 7 – Formulate reasonable predictions based on a given set of data 8 – Compare trends in data related to the same investigation
High School	2	1 – Data Analysis (Statistics)	2 – Organize collected data into an appropriate graphical representation 8 – Make reasonable predictions for a set of data, based on patterns 9 – Draw inferences from charts, tables, graphs, plots, or data sets 11 – Evaluate the reasonableness of conclusions drawn from data analysis

Writing Standards

Grade	Strand	Concept	Performance Objective
7 – 8	2	1 – Ideas and Content	1 – Use clear, focused ideas and details to support the topic 3 – Develop a sufficient explanation or exploration of the topic 4 – Include ideas and details that show original perspective
		2 – Organization	3 – Place details appropriately to support the main idea 5 – Construct paragraphs by arranging sentences with an organizing principle (e.g., to develop a topic, to indicate a chronology)
		3 – Voice	2 – Convey a sense of identity through originality, sincerity, liveliness, or humor appropriate to the topic and type of writing 4 – Choose appropriate voice (e.g., formal, informal, academic discourse) for the audience and purpose
		4 – Word Choice	1 – Use accurate, specific, powerful words that effectively convey the intended message 3 – Use vocabulary that is original, varied, and natural
		5 – Sentence Fluency	2 – Create sentences that flow together and sound natural when read aloud
	3	2 – Expository	1 – Record information (e.g., observations, notes, lists, charts, map labels and legends) related to the topic 3 – Write a process essay that includes: a. a thesis statement b. supporting details c. introductory, body, and concluding paragraphs
High School	2	1 – Ideas and Content	3 – Provide sufficient, relevant and carefully selected details for support 5 – Include ideas and details that show original perspective and insights
		2 – Organization	3 – Place details appropriately to support the main idea 5 – Employ a variety of paragraphing strategies (e.g., topical, chronological, spatial) appropriate to application and purpose

Writing Standards Continued

Grade	Strand	Concept	Performance Objective
High School	2	3 – Voice	2 – Convey a sense of identity through originality, sincerity, liveliness, or humor appropriate to the topic and type of writing 3 – Choose appropriate voice (e.g., formal, informal, academic discourse) for the application
		4 – Word Choice	1 – Use accurate, specific, powerful words and phrases that effectively convey the intended message 2 – Use vocabulary that is original, varied, and natural 3 – Use words that evoke clear images
		5 – Sentence Fluency	3 – Demonstrate a flow that is natural and powerful when read aloud
	3	2 – Expository	1 – Write a multi-paragraph essay that: a. includes background information to set up the thesis (hypothesis, essential question), as appropriate b. states a thesis with a narrow focus c. includes evidence in support of a thesis in the form of details, facts, examples, or reasons d. communicates information and ideas from primary and/or secondary sources accurately and coherently, as appropriate e. attributes sources of information as appropriate f. includes a topic sentence for each body paragraph g. includes relevant factors and variables that need to be considered h. Includes visual aids to organize and record information on charts, tables, maps, and graphs, as appropriate i. includes an effective conclusion

Appendix B: Worksheets and Overheads

The pages that follow contain the worksheets listed below:

A. *Do Underpasses Really Work?* – A summary of the experimental design for the highway underpasses along State Route 260 (3 pages)

B. *Experiment Planning and Comprehension* – A handout which helps the students determine questions that they can study (1 page)

C. *Analyzing the Data* – A summary of the actual data collected on wildlife usage of highway underpasses along State Route 260 (2 pages)

D. *Research Rubric* – One method to evaluate the student report (1 page)

Do Underpasses Really Work?

In this activity, you will have the opportunity to design your own experiment to see if underpasses and bridges are actually successful in reducing the potential for wildlife-vehicle collisions on the highway. The following article will give you some basic background information you can use to help you design your experiment. With this information as your starting point, you will be asked to develop your own scientific question that can be answered with the data collected. Just as in all science, however, much more information is provided here than you will actually need. It is your responsibility to sift through the data to find relevant information. Good luck.

INTRODUCTION

Wildlife underpasses and bridges are being constructed across the country (Figure 1). The structures, built specifically for animals to use when crossing from one side of a major road to the other, connect a habitat fractured by highways. Transportation agencies, such as the Arizona Department of Transportation, invest money in these projects in order to build safer, more environmentally friendly roads.

Figure 1: Underpass under construction

In the past, these structures were typically focused on a single species of concern in a region. Today, however, governments want more "bang for their buck." They want multiple species to use these structures on a regular basis. But how do we know that animals, whether one species or many, will actually use the underpasses and bridges?

Since it is impossible for anyone to watch these structures all the time, and wildlife movements can be unpredictable, monitoring the use of bridges and underpasses has always been difficult. Usually it has consisted of indirect physical evidence, such as footprints or scat, that animals leave near the structures. The advent of motion-sensitive cameras and infrared lighting, however, has revolutionized this field. Now large amounts of direct evidence can be collected and analyzed with minimal effort by the researcher. But, is the promise of this technology more than the actual payoff? Can it be used to determine whether or not elk and other animals are using the underpasses along the highway?

Scientists with the Arizona Game and Fish Department are working hard to answer these questions. In fact, the 18.5-mile length of State Route 260 east of Payson, Arizona, is one of the first areas in the world to fully implement this technology.

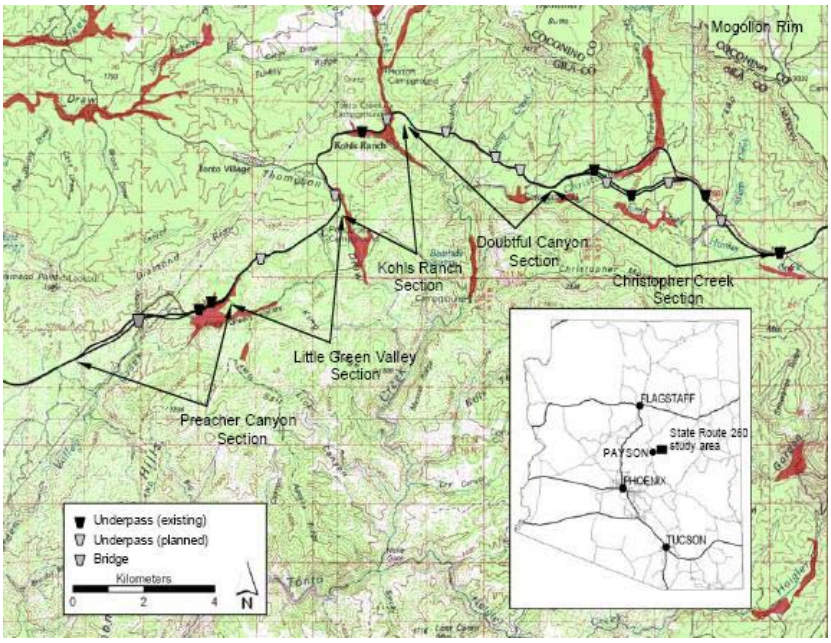


Figure 2: Map of State Route 260 research area

Table 1: Phased Construction Initiation and Completion Dates

Highway Section	Construction Upgrade Dates	
	Begun	Completed
Preacher Canyon	1999	2001
Christopher Creek	2002	2004
Kohl's Ranch	2003	2005
Little Green Valley	Control	
Doubtful Canyon	Control	

PHASED CONSTRUCTION

The original plan of construction along State Route 260 calls for an upgrade from a two-lane to a four-lane highway to accommodate increased traffic volume in the region. The plan has been designed in five phases. This phased construction has three main advantages. First, it is easier to secure funding for five smaller projects than for one large project—individual sections can be upgraded as funds become available. Second, because some sections are upgraded and others are not, researchers can make comparisons between them. By monitoring animal behavior at completed sections, at sections under construction, and at sections where construction has not yet started, researchers can analyze the impact of major roadway construction projects on Arizona's wildlife. This leads to the third advantage: adaptive management. Monitoring completed sections of the highway gives engineers the opportunity to change the plans for future sections, if necessary. So, if they discover that animals avoid certain types of bridges or underpasses, they can remove these from the remaining projects.

When the monitoring project began, the section known as Preacher Canyon had already been completed, the Christopher Creek and Kohl's Ranch sections were being upgraded, and the Little Green Valley and Doubtful Canyon construction had not yet begun (Figure 2 and Table 1).

Figure 3: Preacher Canyon underpasses

UNDERPASS USE AND PREFERENCE BY WILDLIFE

Since the Preacher Canyon section of State Route 260 had already been completed, researchers began there. This section has two underpasses within 750 feet of each other (Figure 3). Because they are so close, the same type of vegetation surrounds them. The dense forest to the north and the small grassy valley to the south are ideal habitats for numerous animals, especially elk. But despite their similarities, the bridges do have some distinct differences in their physical characteristics (Table 2).

To try and maximize wildlife use of the underpasses, 8-foot high fencing was installed along the highway between the two bridges and extended beyond the ends of the bridges 330 feet to the west and 1,000 feet to the east. Since the animals cannot go over the fence, access to the other side of the road is limited. They can either go through one of the underpasses or go to the end of the fence and cross on the highway. The use of video surveillance (described below) should allow the researchers to determine which method the animals prefer.

The video cameras have another advantage: scientists can

monitor an animal's behavior as it approaches and uses an underpass. Previously, only indirect signs, such as tracks, could be used to estimate the number of animals that approached an underpass compared to the number that went through it. This method is not reliable and does not give us the reason an animal turned around. Videos may provide that evidence.

Table 2: Physical Characteristics of Preacher Canyon Underpasses

Characteristic	East Underpass	West Underpass
Construction Type	Open I-beam span	Open I-beam span
Distance[1]	124 feet	124 feet
Height	22 feet	38 feet
Atrium[2]	36 feet	36 feet
Width	30 feet	50 feet
Length[3]	173 feet	360 feet
Side Construction	Sloped earth	Concrete walls

[1] The distance that cars travel on the bridge
[2] The width of the opening between the eastbound and westbound lanes of the highway
[3] The distance that animals must cross to make it from one side to the other

MULTIPLE SPECIES CORRIDORS

Highway upgrades like the ones described here can be quite expensive. Currently, one underpass can cost between $1.5 million and $2 million. Although most of the past research has centered on elk because they provide the greatest potential for damage to vehicles (an elk can weigh nearly 1,000 pounds), the immense monetary investment has the government calling for crossing structures to be designed to accommodate numerous animals. Since elk are among the larger animals found in this region, any underpass that is large enough for elk should be large enough for other species. Here is a way that video surveillance can once again help scientists.

Most animals are instinctively wary of humans. By remotely videotaping any animal that uses the underpasses, researchers can identify a species without being near it. Although an animal can often be identified by its tracks, the video allows for more accurate data collection. After all, tracks may not be left behind in all circumstances. Video cameras can record every animal that passes by, as well as when it passes. Scientists can also monitor underpasses to see if predators are using them to "trap" their prey.

VIDEO SURVEILLANCE

To gather the most useful data, a complex video surveillance system was set up at both underpasses in the Preacher Canyon section. Each underpass was monitored with four black-and-white video cameras on the north side. Two cameras were mounted on trees approximately 100 feet from each underpass to record approaching animals. One camera was positioned in each underpass to record the animals entering and crossing. The last camera faced the highway to record traffic. Special infrared lights, which the cameras could detect but most animals could not, were installed to provide adequate lighting for the cameras at night. To prevent the cameras from recording hours of useless footage and to preserve battery life, numerous infrared beams, positioned at less than two feet above the ground, served as triggers. When an animal crossed through a beam, all of the cameras began filming and continued to film for two minutes.

In addition to the system monitoring the underpasses, another system was installed at the eastern end of the fence. A single camera was triggered to record for one minute any time an animal attempted to cross the highway.

The video cameras have allowed researchers to collect a large amount of data that previously could not be captured. Researchers recorded the date, time of day, total time animals spent in the area, species, gender, number of animals, number of animals approaching and crossing through underpasses, direction of travel, behavior, and number of vehicles on the highway. In many cases, they were also able to determine the age and gender of the animals.

Experiment Planning and Comprehension

The background information on monitoring wildlife use of underpasses has been described to you. Now you must determine what types of questions can be answered from the data that will be made available to you. There are a lot of possibilities, so be creative. Use the questions below to focus the information from the reading and to guide your thinking.

1. What are some examples of indirect physical evidence scientists have used to determine if animals are using underpasses?

2. Why are these considered indirect?

3. What are the advantages of upgrading the highway in phases?

4. What is adaptive management?

5. What was the first section to be completed? When was it completed?

6. What is a control? Why are Little Green Valley and Doubtful Canyon considered controls?

7. Compare and contrast the East and West underpasses in the Preacher Canyon section.

8. Why have elk been the primary focus of this research?

9. Draw a diagram of the camera setup at one of the underpasses.

10. Why have scientists put a camera at the end of the fence?

11. Write a question that you can probably answer based on the data that will be collected in this experiment.

12. Write a hypothesis for your question.

Analyzing the Data

Below you will see a lot of the data that have been collected from video surveillance of the two underpasses in the Preacher Canyon section as well as some additional data that may be significant. Look through all the tables and locate data that are relevant to your research question.

Table 1: Total Animals Approaching and Crossing Preacher Canyon Underpasses

Wildlife Species	East Underpass			West Underpass		
	Approached	Crossed	Passage Rate	Approached	Crossed	Passage Rate
Elk	1,883	1,400	0.74	752	392	0.52
Whitetail Deer	123	5	0.04	59	5	0.08
Coyote	49	8	0.16	9	2	0.22
Gray Fox	15	7	0.47	6	5	0.83
Mountain Lion	4	0	0.00	0	0	N/A
Mule Deer	2	0	0.00	9	0	0.00
Raccoon	1	1	1.00	0	0	N/A
Black Bear	1	1	1.00	0	0	N/A
Ringtail	0	0	N/A	1	0	0.00
All Species	2,081	1,426	0.68	853	415	0.49

Table 2: Total Animals Caught by End-of-Fence Camera

Wildlife Species	# of Animals Crossing at Fence	Ratio of Animals Crossing at Fence : Crossing at Underpasses
Whitetail Deer	283	28.3:1
Elk	110	0.06:1
Mountain Lion	1	N/A
All	394	0.22:1

Table 3: Proportion of Elk Displaying Various Behaviors Near Underpasses

Elk Behavior	East Underpass	West Underpass
No Delay in Crossing[1]	0.57	0.55
Minor Delay in Crossing[2]	0.21	0.19
Obvious Delay in Crossing[3]	0.19	0.25
Would Not Cross[4]	0.26	0.46
Enter Underpass and Retreat[5]	0.11	0.17
Alarmed Flight[6]	0.13	0.25
Feeding in Area[7]	0.22	0.42
Standing/Milling About[8]	0.44	0.46

[1] Crossed within 10 seconds
[2] Crossed within 11 – 30 seconds
[3] Took more than 30 seconds to cross
[4] Left without crossing
[5] Entered the underpass and then left
[6] Approached or entered underpass and left rapidly
[7] Fed within about 150 feet of underpass
[8] Stood within about 150 feet of underpass

Table 4: Crossing and Approach by Construction Phase

Phase	Approaches/Day	Crossings/Day	Passage Rate
Control	0.87	0.22	0.40
Under Construction	0.60	0.26	0.45
Completed	0.81	0.27	0.21

Table 5: Average Number of Elk-Vehicle Collisions per Year by Construction Phase

Highway Section	Before Construction	During Construction	After Construction
Preacher Canyon	7.7	8.0	7.0
Little Green Valley	0.3	N/A	N/A
Kohl's Ranch	5.8	6.0	N/A
Doubtful Canyon	0.6	N/A	N/A
Christopher Creek	7.6	19.7	N/A

Table 6: Number of Elk-Vehicle Collisions by Highway Section and Year

Highway Section	2001	2002	2003	2004	Average
Preacher Canyon	10	13	10	14	11.8
Little Green Valley	3	0	2	1	1.5
Kohl's Ranch	9	7	7	6	7.3
Doubtful Canyon	1	2	5	4	3.0
Christopher Creek	7	18	19	56	25.0
Total	30	40	43	81	48.5

FORMAL SCIENTIFIC REPORT

Now that the experiment is complete, it is time for the next step. Your research must be shared with your fellow scientists. You will do this by writing a formal report that may appear in a scientific journal. Follow the format below (or any other that your teacher recommends).

Title The name of your project indicating exactly what you studied.

Abstract A paragraph summary of your research that should include a statement of your research problem, a brief description of the experimental procedures used, the results, and a concluding statement explaining the results.

Introduction Give background information about your research and identify your problem and hypothesis.

Methods Describe how the research was performed. Be sure to include the materials that were used. Although you did not perform the research, you can summarize how it was done.

Results Present the data in tables and charts. You do not interpret the data at this point, only describe the observations and data.

Discussion Explain what the data mean, describe any trends, make comparisons to other research, and determine if your hypothesis has been supported. In addition, discuss future research ideas that can now be studied based on these results.

References If you used any resources, such as Internet sites, books, or articles, you need to list them here.

Wildlife and Highway Management

Research Report Rubric

The following rubric will show you how your essay will be evaluated. Use it as you write.

CATEGORY	4	3	2	1
Accuracy of Facts (Content)	All supportive facts are reported accurately.	Almost all supportive facts are reported accurately.	Most supportive facts are reported accurately.	NO facts are reported OR most are inaccurately reported.
Adding Personality (Voice)	The writer has developed an academic voice appropriate for the audience.	There is some sense of academic discourse, but it may be inconsistent or weak at times.	The writer occasionally develops an academic voice, but generally it is weak and inconsistent.	There is no sense of voice in the essay.
Sequencing (Organization)	Details are placed in a logical order and the way they are presented effectively keeps the interest of the reader.	Details are placed in a logical order, but the way in which they are presented or introduced sometimes makes the writing less interesting.	Some details are not in a logical or expected order, and may distract or confuse the reader.	Many details are not in a logical or expected order. There is little sense that the writing is organized.
Word Choice	Writer uses appropriate words and phrases, and the placement of the words seems accurate, natural and not forced.	Writer uses appropriate words and phrases, but occasionally the words are used inaccurately or seem overdone.	Writer uses words that communicate clearly, but the writing lacks interest.	Writer uses a limited vocabulary that does not communicate strongly or capture the reader's interest. Jargon or clichés may be present and detract from the meaning.
Flow and Rhythm (Sentence Fluency)	All sentences sound natural and are easy-on-the-ear when read aloud. Each sentence is clear and has an obvious emphasis.	Almost all sentences sound natural and are easy-on-the-ear when read aloud, but 1 or 2 are stiff, awkward or difficult to understand.	Most sentences sound natural and are easy-on-the-ear when read aloud, but several are stiff, awkward or difficult to understand.	The sentences are difficult to read aloud because they sound awkward, are distractingly repetitive, or difficult to understand.
Citations	At least three citations are used and all are cited correctly.	At least three citations are used but one is not cited correctly.	Less than three citations are used or more than one is not cited correctly.	There are no citations.