Date: _____

Your Name: _____

HUBBARD BROOK RESEARCH FOUNDATION
ENVIRONMENTAL LITERACY PROGRAM

Suggested Answer Guide

Grade 11

Science Inquiry Task

Road Salt Contamination

Prepared by S. Turtle (HBRF) with input from G. Wilson (HBRF), A. Bailey (USFS), P. Benoit (LHS), B, Church (LHS), and K. Murray (LHS). Mirror Lake data supplied by G. E. Likens through Hubbard Brook Ecosystem Study. Template created by K. Murray (LHS). Data supplied by USFS and HBEF.

Directions:

This Inquiry Task will measure your ability to think scientifically. This task will ask you to form hypotheses, plan and critique investigations, analyze data, and develop explanations.

First you will read a short story, and then you will make predictions based on the information in the story. You will have 75 minutes to answer the questions about the story.

Write your answers in the spaces provided. Explain the reasons for all of your answers. You may include drawings or labeled diagrams to help explain your answers.

Part 1: Planning an Investigation.	Part 2: Evaluating Explanations and Making Predictions.	Part 3: Developing Explanations and Applying What You Learned

Word Bank

Lake watershed	Area of land that drains into a lake.
Ion	An atom that has a positive or negative charge because it has fewer or more electrons than protons.
Cation	A positively charged ion.
Anion	A negatively charged ion.
Hectare	An area of 10,000 square meters.
Sodium	Symbol Na, atomic number 11, atomic mass 22.99
Chlorine	Symbol Cl, atomic number 17, atomic mass 35.45

GO ON

Read the story below.

Road Salt Contamination

The New Hampshire highway department is going to lengthen Interstate 93 (I 93) through a northern New Hampshire town to help reduce the number of large trucks driving on the town's narrow main street. The plan is for the road to be open in three years. The road will be constructed within the watershed of two lakes that are used for recreation purposes and as wildlife refuges. Students from the local high school are concerned that highway runoff will be contaminated with road salt and that this runoff will be transported through nearby streams to the lakes hurting the water quality.

The students collect information of the physical characteristics of the two lakes and their watersheds and organize this information into the table below. They used maps to determine the percentage of incoming stream water that may be contaminated by highway runoff. They also determined the surface area and average temperature of each lake.

Students learn that road salt used by the highway department contains primarily sodium chloride (NaCl). They also learn that on average the highway department uses approximately 18 tons of road salt for every lane mile per year to keep the interstate clear of snow and ice. They remembered from chemistry class that sodium chloride breaks apart into the ions sodium (Na^+), a cation, and chloride (Cl^-), an anion, when dissolved in water. They also remembered that chloride was a heavier element compared to chloride.

Students decide to monitor the sodium and chloride concentrations of the two lakes starting this year, three years before the road opens, to determine if they become contaminated by road salt after the highway is completed.

Table 1. Physical characteristics of Lake A and Lake B

Lake	% of incoming streamwater potentially contaminated by road salt	Lake surface area (hectare)	Average lake depth (m)
LAKE A	10.0 %	11.5	12.1 m
LAKE B	5.0 %	14.7	12.7 m

GO ON

Planning Investigations

1. After examining the data in Table 1, provide an explanation for why the students think they should study both lakes instead of just one.

***Broad Area of Inquiry**: Developing and Evaluating Explanations*
***Inquiry Construct 11 (DOK 2):** Analyze data, including if data are relevant, artifact, irrelevant, or anomalous.*

Do students recognize that the lakes have different physical characteristics and that these characteristics might affect the results? Does the response include scientific knowledge of how testing multiple sites increases our understanding of how the dependent variable is affected?

***Example Answer:** Lake A and Lake B are not exactly the same and the differences may cause the sodium and chloride concentrations to be different. Lake A has a smaller surface area and a higher percentage of incoming water potentially contaminated with runoff then Lake B.*

2. No salt will be used on the road until it is complete. Explain why it is important to start collecting data three years before the highway is even completed.

***Broad Area of Inquiry**: Planning and Critiquing of Investigations*
***Inquiry Construct 4 (DOK 2):** Identify information/evidence that needs to be collected in order to answer the question, hypothesis, prediction.*

Response indicates understanding the importance of collecting sufficient data to answer the question and how the variables may affect the outcome of the investigation. Students show that they understand the need to collect background data on water chemistry before the watershed is affected by the opening of the road for comparison purposes.

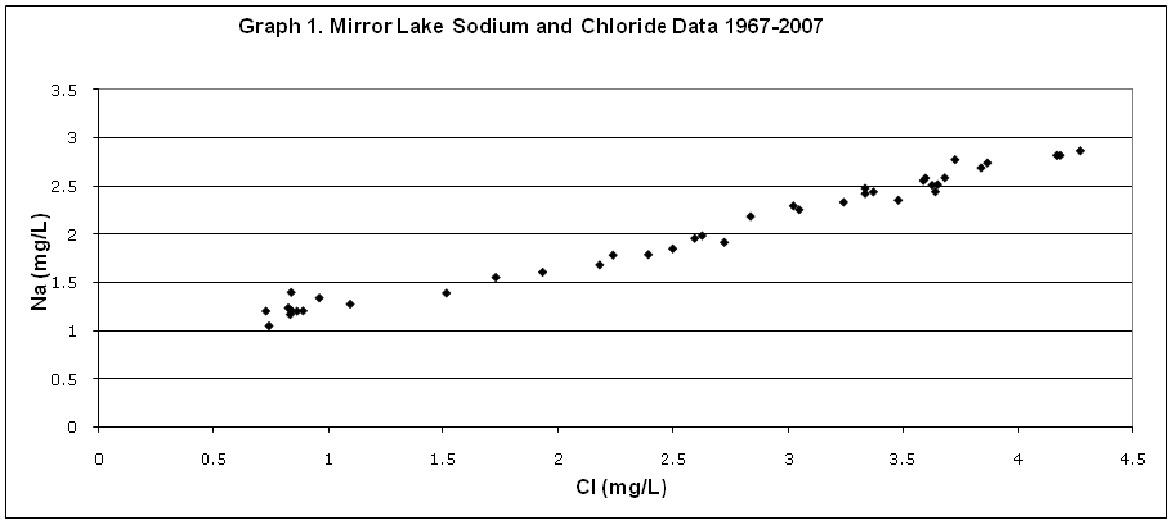
***Example answer**: Students need to collect data before the road opens so they have background data on sodium and chloride levels to compare to concentrations after the road has opened. This will help them learn if the changes are caused by the road.*

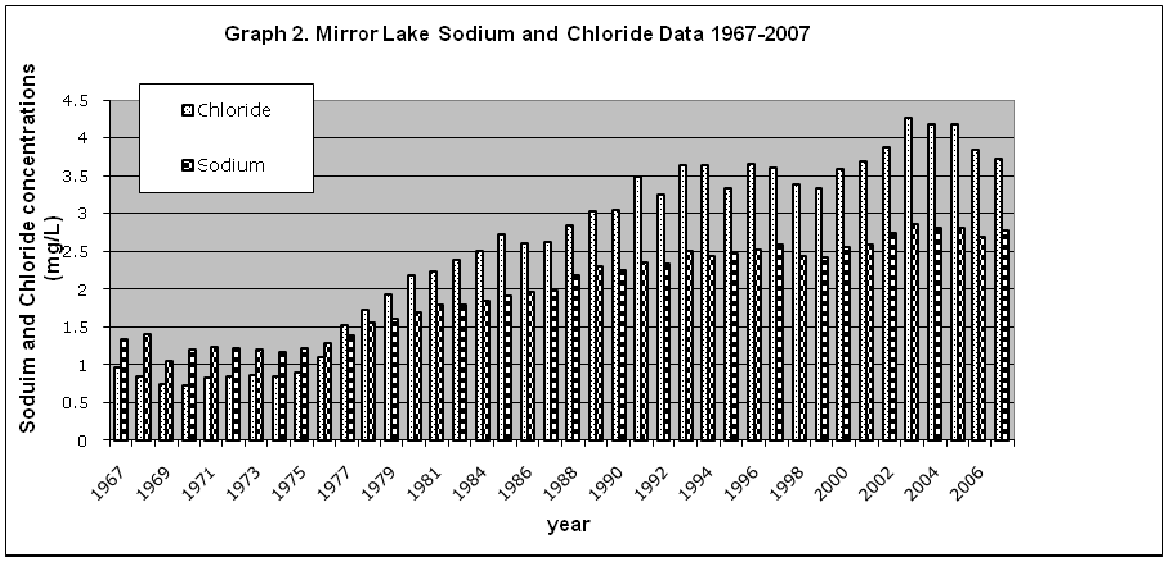
Evaluating Explanations and Making Predictions

The students use the internet to learn if other NH lakes have been contaminated by sodium and chloride in road salt from highway runoff. They found data describing sodium and chloride concentrations and physical characteristics from the Hubbard Brook Ecosystem Study at Mirror Lake. Interstate 93 runs through the watershed of this lake. They found data for Mirror Lake from 1967 to 2007. They also learned that Interstate 93 opened in 1970. This data will help them predict what might happen to Lakes A and B.

The students organized the sodium and chloride data into the graphs below.

Graphs 1 and 2: Long term sodium and chloride data for Mirror Lake. Hubbard Brook Experimental Forest, Woodstock, NH. (Likens, G. E.)





GO ON

3. Which graph best represents the change in sodium and chloride concentration on water quality over time? Explain why the graph you chose best represents the data.

***Broad Area of Inquiry**: Conducting Investigations*
***Inquiry Construct 8 (DOK 2):** Use accepted methods for organizing, representing, and manipulating data.*

Response indicates that graph B is correct and indicates that the graph features and labels are correct or because the graph shows the correct relationship between the variables that were monitored.

***Example answer**: Graph B shows changes in sodium and chloride over time. Time is the independent variable and sodium and chloride concentrations are the dependent variable. Graph A, the scatter plot does not show a change in concentration over time. Here the independent variable is chloride and the dependent variable is sodium. It plots the association between sodium and chloride and this is not the goal of the study.*

The students organized the physical data from all three lakes into Table 2 so they could make comparisons.

Table 2. Physical characteristics of Mirror Lake

Lake	% of incoming streamwater potentially contaminated by road salt	Lake surface area (hectare)	Average lake depth (m)
MIRROR LAKE	3.0 %	15	11.0 m
LAKE A	10.0 %	11.5	12.1 m
LAKE B	5.0 %	14.7	12.7 m

4. For this question, use the concentration of sodium and chloride data collected at Mirror Lake and the data describing the physical characteristics of Lake A and Lake B. Form a hypothesis predicting the effect of highway runoff on the sodium and chloride concentrations of the Lakes A and B. Be sure to include if your predictions are the same for both lakes.)

***Broad Area of Inquiry:** Formulating Questions and Hypothesizing*
***Inquiry Construct 1 (DOK 3):** Analyze information from observations, research, or experimental data for the purpose of formulating a question, hypothesis, or prediction.*

Students have been given physical characteristics of Lakes A and B and an example of a similar scenario with Rt 93 and Mirror Lake. Can students use this information and data to help them form a hypothesis?

Their response should include a logical prediction that summarizes the cause and effect relationship between the potential incoming contaminated streamwater and sodium and chloride concentrations It may also show an understanding that the different physical parameters of lakes may affect the impact of roadsalt.

***Example answer**: Sodium and chloride concentrations will increase in Lake A and B after the road is opened in 2013. Lake A is smaller and may receive more contaminated streamwater than Lake B therefore concentrations will increase more in Lake A than Lake B.*

GO ON

Developing Explanations and Applying What You Learned

Directions: Use the data from Table 2 (on page 6) and Table 3 (below) to answer questions 5, 6, 7 and 8.

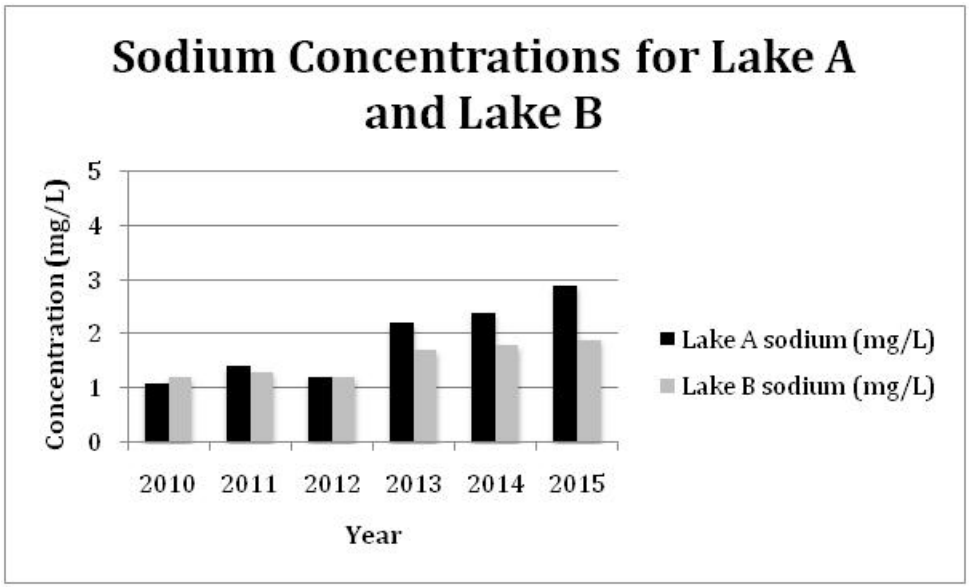
Students from the high school begin the project. Water chemistry data is collected for 6 years. The sodium and chloride data are displayed in the table below. The road opens in 2013.

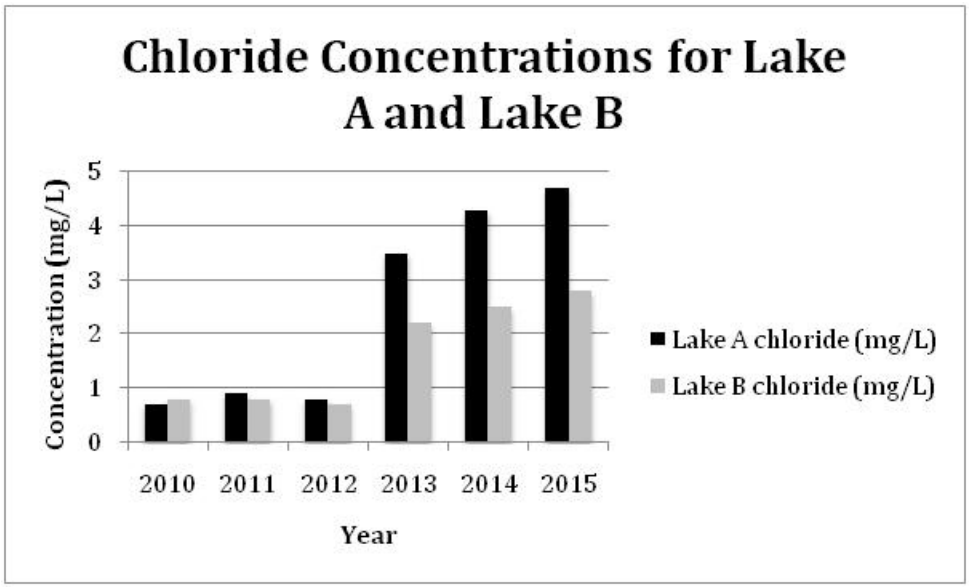
Table 3. Sodium and Chloride concentrations for Lake A and Lake B.

Year	Sodium (mg/L)		Chloride (mg/L)	
	Lake A	Lake B	Lake A	Lake B
2010	1.1	1.2	0.7	0.8
2011	1.4	1.3	0.9	0.8
2012	1.2	1.2	0.8	0.7
2013	2.2	1.7	3.5	2.2
2014	2.4	1.8	4.3	2.5
2015	2.9	1.9	4.7	2.8

5. Organize the data from Table 3 into a sodium graph and a chloride graph to show how the concentrations change over time in Lakes A and B.

Broad Area of Inquiry 3*: Conducting Investigations*
Inquiry Construct 8 (DOK 2): *Use accepted methods for organizing, representing, and manipulating data Students should represent data accurately in an appropriate graph. Bar graph or line graph work well to show counts. They should include a graph title and axes labels. Labels should be clear and use scientific terminology. Axes should have appropriate scales.*





GO ON

6. Explain how the results support or did not support the hypothesis predicting the effect of road salt on the sodium and chloride concentrations of Lake A and Lake B? Use the data from Table 3 to support your answer.

Broad Area of Inquiry: *Developing and Evaluating Explanations*
Inquiry Construct 12 (DOK 3): *Use evidence to support and justify interpretations and conclusions or explain how the evidence refutes the hypothesis.*

Can students use the data to describe the changes in sodium and chloride concentrations? Using relevant data in the answer is the key. It might help to use this as an example of practicing ways to use numbers in sentences.

Two example answers*:*
a. Sodium and chloride concentrations are higher after the road opened compared to the concentrations before the road opened, supporting the hypothesis. Before the road opened in Lake A, sodium concentrations were 1.1 mg/L in 2010, 1.4 mg/L in 2011 and 1.2 mg/L in 2012, chloride were 0.7 mg/L in 2010, 0.8 mg/L in 2011, and 0.8 mg/L in 2012. In Lake B sodium concentrations were 1.2 mg/L in 2010, 1.3 mg/L in 2011, and 1.2 mg/L in 2012, chloride concentrations 0.8 mg/L in 2010 and 2011, and 0.7 mg/L in 2012. After the road opened the sodium concentrations increased to 2.2 mg/L in 2013, 2.4 mg/L in 2014, and 2.9 mg/L in 2015 and chloride concentrations increased to 3.5 in 2013, 4.3 in 2014 and 4.7 in 2015 in Lake A. In Lake B the increases in sodium and chloride concentration were not as large as in Lake A, also supporting the hypothesis. Sodium concentration increased to 1.7 mg/l in 2013, 1.8 in 2014, and 1.9 in 2015, chloride concentration increased to 2.2 mg/L in 2013 2.5, mg/L in 2014, and 2.8 m in 2015.

b. Sodium and chloride concentrations are higher after the road opened compared to the concentrations before the road opened supporting the hypothesis. For example in Lake A sodium = 2.2 mg/L, 2.4 mg/L, and 2.9 mg/L after the road opened compared to 1.1 mg/Lm 1.4 mg/L and 2.4 mg/L before the road opened. In Lake B the increases in sodium and chloride concentration were not as large as that of Lake A, also supporting the hypothesis. For example sodium in Lake A increased to 2.2 mg/L, 2.4 mg/L, and 2.9 mg/L and in Lake B the sodium increased to 1.7 mg/L, 1.8 mg/L and 1.9 mg /L after the road opened.

7. Describe the difference in chloride concentrations for Lakes A and B using the data from Table 3. Use the physical characteristic data from Table 2 (page 3) to explain why these concentrations are different between the two lakes.

Broad Area of Inquiry: *Developing and Evaluating Explanations*
Inquiry Construct 12 (DOK 3): *Use evidence to support and justify interpretations and conclusions or explain how the evidence refutes the hypothesis.*

Do the students correctly identify the relevant physical parameters and their differences? (Lake surface area and % incoming streamwater potentially contaminated with high roadsalt). Do they correctly explain the relationship between the identified physical parameters of the lakes and the impact of roadsalt? (Lake A receives more contaminated streamwater and is smaller in size so it has less water to dilute the contaminated water.)

Example answer: *The chloride concentration in Lake A is higher than that of Lake B. This probably has to do with two things: the volume of Lake A is most likely less than that of Lake B (Lake A has a smaller surface area and is shallower, on average), and Lake A has a higher percentage of incoming water that is potentially contaminated by road salt. The greater input of contaminated water into a smaller volume lake would create higher chloride concentrations in Lake A.*

8. The data from Mirror Lake and from the students' study of Lake A and Lake B indicate that chloride contamination is generally higher than sodium contamination. Give a possible reason why these chemical concentrations might be different. Use information provided in the beginning narrative to help.

Broad Area of Inquiry: *Developing and Evaluating Explanations*
Inquiry Construct 13 (DOK 3): *Communicate how scientific knowledge applies to explain results, propose further investigations, or construct and analyze alternative explanations.*

Can students provide a thoughtful explanation for the observed trend using scientific terminology appropriately? The wording of the question implies that the answer does not have to be correct necessarily, but it does have to show that students can think.

Example answers: *One possible answer might include recognition that sodium, a cation, and chloride, an anion, might behave differently as they are transported through the soil. (Did students use the terms 'anion' and 'cation' correctly?) Another answer might focus on how different atomic mass quantities might affect concentrations measured in mg/L. (Did students use appropriate terms to compare atomic mass?)*

X X X X X X X X

Note: The water budget of lakes has been simplified for this exercise. Water enters lakes via precipitation directly into the lake, surface runoff directly into the lake (not via a stream), stream water, and groundwater. For the purposes of this exercise, we just used stream water inputs in order to keep the focus on the data inquiry.