LESSON TITLE	Who Owns the Water				
SUBJECT (S):	Earth Science, Environmental Science, Geography, Social Science, Politics				
GRADE LEVEL:	6-12	**AUTHOR:**	Jerome Patoux		
TYPE OF LESSON (activity, lab, project…)	Literacy Activity			**DAY(S):**	3 days + homework

OBJECTIVE

Students will learn about the right to pump groundwater and extract water from rivers. They will investigate and identify major American aquifers, then draw conclusions about their use and depletion rate. In a second exercise, students will investigate the major dams of the Colorado River and their use. In both exercises, students will create a map that serves as a visual aid to illustrate the issue at hand. They will then write a persuasive essay in which they will describe existing rules and solutions, and voice their own opinion with substantiated argumentation.

NGSS/CC STANDARDS	ASSESSMENT(S) & GRADING/RUBRIC
NGSS Science and Engineering: 1, 6, 7, 8 Crosscutting Concepts: 2, 4, 5, 7 Core Ideas: ESS2, ESS3, LS2, PS1 **PERFORMANCE EXPECTATIONS** Earth and Space Sciences: HS-ESS3-1, HS-ESS3-4, HS-ESS3-5, HS-ESS3-6, MS-ESS3-1, MS-ESS3-4 **CC ELA/Literacy** HS – RST 9-10.10, RST 11-12.7; MS – RST.6-8.1, WHST.6-8.1, WHST.6-8.9	Persuasive essay rubric Opinion essay rubric

SUBJECT AREA(S):

This activity can be used in earth or environmental science, as well as in social sciences (in the framework of how societies deal with limited resources) and world or U.S. politics (in the framework of how water rights are being handled across states and across countries).

TEXTS/MATERIALS/TECHNOLOGY/AUDIO-VIDEO/OTHER RESOURCES:

Computer/internet
Worksheets (see attached)
A map of the United States (with the name of the 50 states).

General aquifer information:
https://en.wikipedia.org/wiki/Aquifer
See additional links below.

Chinatown (1974), by Roman Polanski, illustrates the political tension around the need for water in the American Southwest. 40 years later, the theme still resonates, as global warming threatens to put ever more pressure on California.

INSTRUCTIONAL STRATEGIES/PROCEDURES/GROUPING:

Day 1: **Aquifers**

In day 1, students will make a list of water sources on earth and establish that we depend mostly on groundwater and rivers/lakes for our freshwater needs. They will read and annotate a text, and define some basic concepts about aquifers. They will answer questions about natural and human-induced variations in deep aquifers, as well as groundwater depletion.

(5-10 min) Introduction: If you have taught the lesson, "**Sources of Water on Our Planet**," prior to this one, then refer to the list of water resources available to us, which students built throughout the lesson. Otherwise, introduce this activity by asking students to think about the different sources of water available to us. Make a list on the board (through discussion as a class):

- the ocean
- the atmosphere (i.e., rain and snow)
- mountain glaciers and snow
- lakes
- rivers
- groundwater and deep aquifers

Establish that our freshwater comes mostly from: (1) groundwater and aquifers, and (2) rivers and lakes (i.e., precipitation, through drainage in the various water basins). The first activity will address aquifers, while the second one will address river runoff.

(5-10 min) Hand out the reference text, **Handout #1 – The ins and outs of aquifers**, and ask the students to read it. Have them annotate the text or highlight the key points, so that they can return to them quickly when they fill in the worksheet (**Handout #2 – Aquifers**).

You might want to hand out the corresponding worksheet, **Handout #2 – Aquifers**, at the same time and encourage students to have a quick look *before* reading the text, so that they know what to look for, as they read. However, encourage them *not* to write their answers right away, because the answer to a question might be in several separate places in the text.

(10-15 min) Definitions: Have students work in groups of 2 to 4 to write the definitions of "confined aquifer, unconfined aquifer, and water table." One representative of each group will report their definition on a small white board or sheet of paper, for all to see during a gallery walk. Discuss the definitions as a class and have students apply **constructive criticism** to come up with a final class definition, approved by all (consensus). Note: The definitions

should be concise, yet explicit, with enough detail to make them unambiguous.

(10-15 min) Pass out **Handout #2 – Aquifers.** Students will work through the worksheet (schematics and questions) by themselves or as groups (same groups of 2 to 4). Repeat the constructive criticism exercise for the last question.

Day 2: **The right to pump aquifers**

In day 2, students will make a map of the main aquifers of the United States and identify the states that intersect the Ogallala aquifer. They will write a persuasive essay about the right to pump and use the Ogallala aquifer water (homework).

(5-10 min) As a class, briefly review the basic concepts about aquifers learned in day 1. Leading questions could include:

- What is an aquifer?
- What are different types of aquifers?

(15-20 min) Using the internet, have students research the different **aquifers** in the U.S. and draw and label the most important ones on the map provided in attachment – **Handout #3 – Aquifers of the United States**. Have them use a simplified map such as:
http://hi.water.usgs.gov/studies/GWRP/
or a reference page such as:
https://en.wikipedia.org/wiki/Aquifers_in_the_United_States
Ask them to represent, as a minimum:

- the Ogallala aquifer
- the Floridan aquifer
- the Edwards aquifer
- the Basin and Range aquifer
- and possibly the aquifer corresponding to the area where they live, if relevant.

They can label the aquifers with arrows and labels, or build a legend with colors.

It is important that students draw the boundaries of the aquifers quite exactly, for them to realize that aquifers do not know about political boundaries.

(5-10 min) Pick the **Ogallala aquifer** as an example (i.e., the largest one, under the Great Plains) and assume that any state that intersects the aquifer can claim a share of its water. Ask students to identify and label on their map all the states that can claim a share of the Ogallala aquifer.

(5-10 min) Engage students in a **preliminary class discussion** with the following questions:

- Should the water of the Ogallala aquifer be the exclusive property of the overlying states, or the property of all Americans?
- If the water is to be shared among overlying states, what should be the rationale for calculating ratios and assigning shares? Should it be based on population? Surface area of the states? Agricultural needs?

- Should the water be sold? And if so, by whom? Who should set and control the price?
- If shares are assigned, how do we control the amount of water pumped by all shareholders?

The following assignment could be given for homework or class time could be used for research and writing. Have students write a **persuasive essay** about the right to pump and use the Ogallala aquifer water. "Who owns the Ogallala aquifer?" Use the following guidelines:

- Introduce your essay with a description of the Ogallala aquifer and the issue around sharing its water.
- Describe at least 3 ways in which the issue could be handled, indicating the pros and cons in each case. (For example, search for "who owns Ogallala aquifer" on the internet.)
- Indicate which sounds like the better solution to you, and use sound argumentation to justify your position.
- Conclude by opening up to a larger issue that is maybe similar to the Ogallala aquifer issue, but larger in either scope or significance.
- Research whether the Ogallala aquifer is pumped out faster than it can recharge ("groundwater overdrafting") and make it part of your argumentation. A starting point is: http://water.usgs.gov/edu/gwdepletion.html
- Research the T. Boone Pickens issue in Texas and make it part of your argumentation.

In addition to the above questions (addressed in class), use these additional questions to guide the argumentation:

- If an aquifer is being depleted, should we limit pumping?
- How should we set limits to how much can be pumped by each party?
- Should we look at how much has been pumped in the past and assign responsibility for depletion, or should we start from a blank slate?
- Should we plan for future generations and be conservative, or attend to the needs of the current population?

Extension: As these aquifers are being pumped out and the water table is dropping, the land subsides. Some parts of the U.S. have been measured to subside at a rate of up to one meter a year. The most famous example is in Mexico, where the water table has dropped by more than 20 meters in 50 years and Mexico City has been subsiding at an alarming rate, causing structural damage in streets and buildings. Consider a side project in which students will make a poster or an oral/slide presentation along the following line:

- Describe the phenomenon of subsidence caused by groundwater pumping. (Use a schematic.)
- Provide at least 3 examples of cities or regions where it has caused structural damage or casualties. (Use visuals showing buildings, roads, etc.)
- Document the cost of the structural damage (value of property, lost infrastructure, cost of rebuilding, etc.).
- Describe some of the solutions that have been put in place to address subsidence.

Start here on the internet:
http://water.usgs.gov/edu/earthgwlandsubside.html
http://geochange.er.usgs.gov/sw/changes/anthropogenic/subside/
http://water.usgs.gov/ogw/pubs/fs00165/

Day 3: **Dams and river water rights**

After exploring groundwater and aquifers, in day 3 students will explore the right to tap into rivers. They will use the Colorado River as an example and make a map of the dams built along the river. They will read an article and answer questions about the dams and artificial lakes of the Colorado River. They will write an essay about the right to dam rivers and extract their water, in particular with regard to downstream users (Mexico, for example, in the case of the Colorado River).

(5-10 min) Introduction: First, discuss dams and their impacts. You might want to use the activity "The Impact of Dams on the Environment". You can illustrate the resulting artificial lakes by projecting satellite imagery on the board, showing before and after, such as:
http://earthobservatory.nasa.gov/IOTD/view.php?id=7769

Discussion points can include:
- Purposes of dams
- How do dams help people and their communities?
- How do dams harm/help the environment?

(15-20 min) Hand out the last worksheet, **Handout #4 – Dams of the Colorado River**. Have students research, identify, and locate some of the dams built on the Colorado River, along with their artificial lake. For example, here:
https://en.wikipedia.org/wiki/List_of_dams_in_the_Colorado_River_system

There are many dams, so maybe suggest to the students that they only select the lakes bigger than 500,000 acre ft, for example.

Ask them to draw the dams and the lakes (with a thick blue pen) on the map provided in attachment, and to label them. In particular, they should identify:
- Granby Dam and Lake Granby
- Glen Canyon Dam and Lake Powell
- Hoover Dam and Lake Mead
- Davis Dam and Lake Mohave
- Parker Dam and Lake Havasu

As you regroup as a class to discuss the results, illustrate the various dams by projecting satellite imagery on the board:
http://earthobservatory.nasa.gov/IOTD/view.php?id=1501
http://earthobservatory.nasa.gov/IOTD//view.php?id=5076
http://earthobservatory.nasa.gov/IOTD/view.php?id=86426

To facilitate discussion, ask students to identify and label on their map all the states intersecting the Colorado River Basin, as well as Las Vegas, Mexico, Baja California, and Yuma, where the Colorado River crosses the border.

(5-10 min) Initiate the discussion to probe the students' thinking about the following:

- What do you think the dams are used for along the Colorado River?
- What do you think the water behind the dams is used for?
- Why does the water need to be stored into artificial lakes?
- Do you think that dams impact the environment? How?
- How many dams can we, or should we, build along a river like the Colorado River?

(15-20 min, or homework) Have students read the following article in order to answer the questions below:
http://www.waterencyclopedia.com/Ce-Cr/Colorado-River-Basin.html

- What is the water from the Colorado River primarily used for? Answer: The Colorado River waters are used primarily to irrigate farmland and provide water to major cities such as Las Vegas and Phoenix.
- What is the major purpose of the dams on the river? Answer: The dams generate hydroelectric power for millions of people.
- By the time the river reaches the border with Mexico, what has happened to 90% of the water? Answer: 90% of the water has been used or diverted.
- What happened to the remaining 10%? Answer: The remaining 10% are heavily polluted by upstream sewage, pesticides, and waste from the industries lining up the river.
- What has happened to the landscape beyond Yuma? Answer: Beyond the border, the landscape, once a vast network of wetlands, is dry and desolated. The river has dried up due to upstream demand and the Colorado River now rarely reaches the Gulf of California, where it once emptied.

The following assignment could be given for homework or class time could be used for research and writing. Students will write an **opinion essay** about the right to dam the Colorado River and extract its water before it reaches Mexico. "Who owns the Colorado River?" Rubric is provided. To help students differentiate between persuasive and opinion essays, have them review this source.

They should research current rules and regulation on the internet. For example, they can search for "who owns Colorado water," "riparian rights," and "appropriation doctrine."

The paper should *reflect their own opinion*. They should address the following questions within the essay:

- Who owns the waters of the Colorado River?
- Should it be "first come, first served" without leaving water to downstream users, or should the river runoff be distributed among all users? (And why?)
- What should be the rationale for calculating the amount of water that can be extracted

at each bend of the river? Should it be based on population? Surface area of the drainage basin? Agricultural and industrial needs? Proximity to the river? Historical rights?
- Can a private entity extract the water to sell it? Or should the water be the property of the state?
- Should individual states be allowed to extract water from the river to sell it to neighboring states?
- Can individual states pollute the waters that will be extracted by downstream users?

In conclusion, mention that, with global warming (and man-induced desertification), the American Southwest is predicted to get drier, while the population is predicted to increase on both sides of the border. Tension is predicted to build between the United States and Mexico, but also between states in the American Southwest itself.

SAFETY/SECURITY ISSUES:

Because students will have the opportunity to write essays, reinforce what plagiarism is and how they can avoid plagiarism in their writing.

NOTES/REFLECTIONS:

The issue can be generalized as follows:
In principle, no one owns the water - it is a natural resource that should be freely available to everyone. Yet, water is limited, and if not monitored, it will be used and abused. Therefore, some entity is necessary to oversee the usage and distribution of water. How is that entity to be organized, nominated, overseen? Should it be public or private? What rules and limits should they enforce? What principles should be guiding these rules and limits?

Recently, conflicts have been avoided or diminished by setting up a commission to discuss water rights, as in India/Bangladesh, and in Namibia/Botswana/Angola.

Wars and tension over water is a classic case of the “tragedy of the commons,” a concept that can be interesting to discuss in class. It raises broader issues of natural justice, as well as man’s stewardship of the planet.

Handout #1: The ins and outs of aquifers

When groundwater saturates a layer of soil or permeable rock, it forms an **aquifer**. When the underground layer contains water under pressure and is capped by impermeable material, it is called a **confined** aquifer. The pressure has built up because water has seeped or flown into the layer of soil and has accumulated into the aquifer. When we dig a well that reaches down to an unconfined aquifer, the pressure forces the water to rise into the well and we do not need to pump.

When the layer of soil is saturated with water, but the water is not under pressure, it is called an **unconfined** aquifer. When we dig a well that reaches down into an unconfined aquifer, the pressure is not sufficient to force the water upward, and we need to pump to extract water. The upper boundary of an unconfined aquifer, where it transitions from saturated to non-saturated, is called the **water table**.

Since a confined aquifer is contained within impermeable layers of rock, the water tends to remain in place, sometimes for thousands of years. And since it is deep underground, it is little affected by seasons or the day-to-day variability of weather. It is greatly affected, however, by pumping, when man decides to dig a well and to extract thousands of gallons of water over a short amount of time. Granted, the aquifer gets slowly "recharged," as rain water seeps through the ground and reaches layers of soil from where it can flow into the aquifer, but the rate of recharge is typically very slow compared to the rate of pumping. Moreover, with our growing population and increasing agricultural and industrial needs, the rate of water extraction keeps rising.

An aquifer is a **system** with **inputs** (seepage and underground flow) and **outputs** (mostly pumping). When the output is greater than the input, the aquifer becomes depleted. This is the case for most aquifers on earth, and will be a concern for future generations: "What will we do when we reach the bottom?"

Handout #2 – Aquifers

Read handout #1 – **The ins and outs of aquifers**. Based on the text, write a definition of the following terms:

Confined aquifer: _____

_____

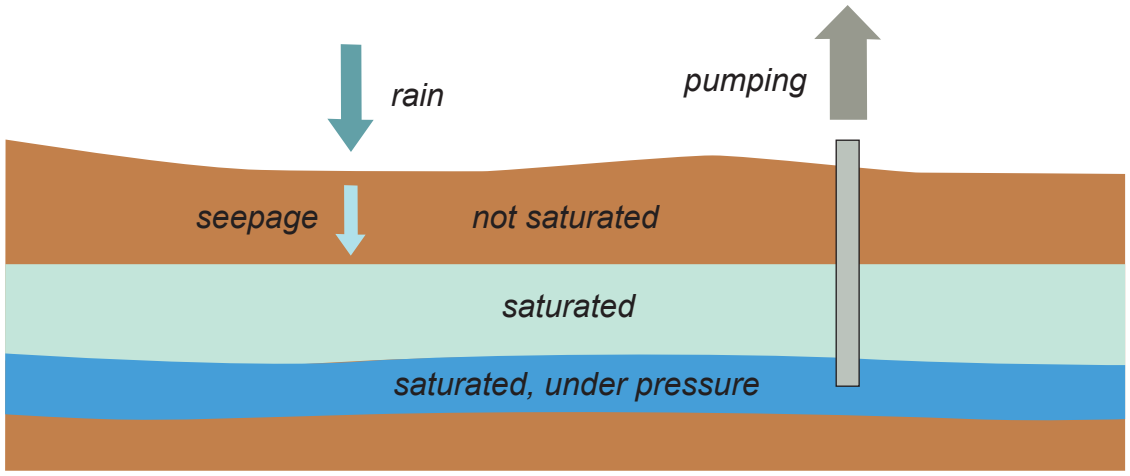
Unconfined aquifer: _____

_____

Water table: _____

_____

Label the following schematic with “confined aquifer,” “unconfined aquifer,” and “water table.”



What is the main input to the aquifer? _____

_____

What is the main output to the aquifer? _____

_____

On what time scales does the amount of water vary naturally, in a deep aquifer? _____

_____

Explain why and how a deep aquifer can become depleted when we start extracting water by mechanical means? _____

_____

_____

_____

_____

Handout #2 – Aquifers (key)

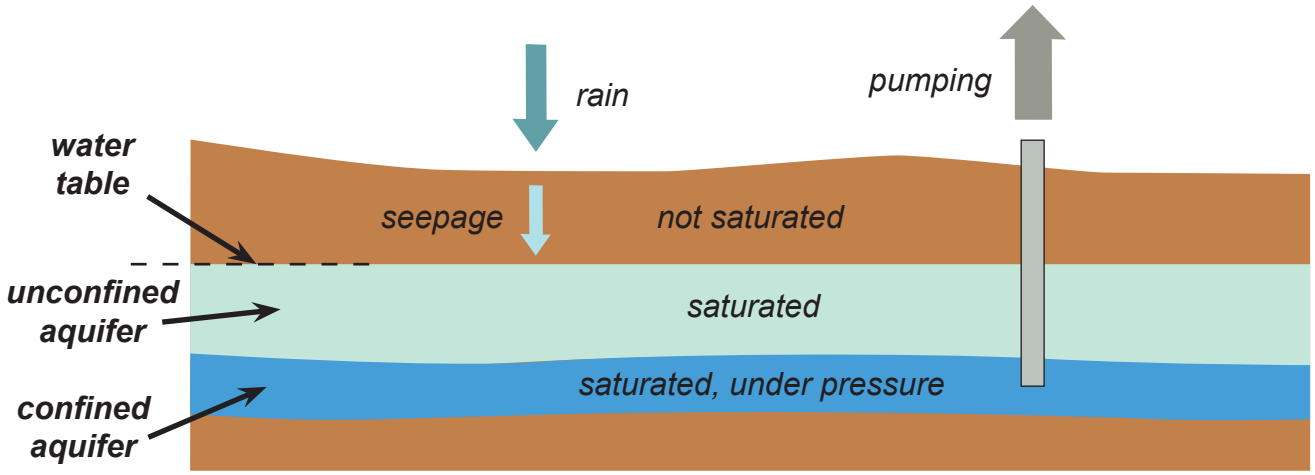
Read handout #1 – **The ins and outs of aquifers**. Based on the text, write a definition of the following terms:

Confined aquifer: An underground layer of permeable rock/soil containing water under pressure and capped by impermeable material. Importantly: when we dig a well, the pressure forces the water to rise into the well and we do not need to pump.

Unconfined aquifer: A water-saturated layer transitioning into a non-saturated layer, with zero pressure. Importantly: when you dig a well, you have to pump the water to force it to rise into the well.

Water table: The upper boundary of an unconfined aquifer, where it transitions from saturated to non-saturated.

Label the following schematic with “confined aquifer,” “unconfined aquifer,” and “water table.”



What is the main input to the aquifer? Water seeping downward through the ground. Typically, rain that did not collect as surface runoff and rivers, but seeped underground and reached the saturated layer. [Underground water can also flow horizontally and collect into the aquifer.]

What is the main output to the aquifer? Pumping, either forced by the pressure in the aquifer, or forced mechanically.

On what time scales does the amount of water vary naturally, in a deep aquifer? On *long* time scales, from decades to centuries, and sometimes millenia (thousands of years).

Explain why and how a deep aquifer can become depleted when we start extracting water by mechanical means? If we pump water out of the aquifer faster than the aquifer is recharging through seepage or underground flow, then the output is greater than the input, and the reservoir, i.e., the aquifer, gets depleted.

Handout #3: Aquifers of the United States

Handout #4: Dams of the Colorado River

Persuasive Essay Rubric

Teacher Name: _____ Per: _____ Date:_____

Student Name: _____

CATEGORY	4	3	2	1
Organization & Structure	A solid introduction with thesis, and overview followed by supporting ideas that are logically presented and engaging with a strong conclusion.	Includes and introduction with thesis, support, and conclusion, but flow is not always logical and engaging to audience.	Introduction, support, and conclusion are present, but logic difficult to follow and personal opinion or writer is unclear.	Organization and structure of essay mostly ignored, and opinion of writer not known.
Engaging Opening & Clear Thesis	Opening of essay immediately attracts the reader and thesis of essay is clear and strong from the beginning.	Thesis is clear and the opinion of the writer is easily discerned.	Writer attempts to introduce issue but fails to clearly state personal opinion and thesis.	No clear introduction to issue or thesis of writer's personal opinion.
Support & Evidence	Multiple pieces of evidence are referenced as support and tied to writer's personal opinion with evident thought to the issue.	Multiple pieces of evidence are referenced, but their relation to the issue and opinion stated are questionable.	Only 1-2 evidences are used and they are somewhat weak arguments to support writer's opinion.	No evidence is given or evidence sited has little or no relation to the issue.
Audience & Level of Writing	Voice, word choice, and essay layout indicate awareness of target audience and appropriate level of complexity in writing level.	Voice, word choice, and essay layout indicate an attempt to connect to audience and is somewhat complex.	Writer appears to be unaware of their target audience or writes at a level not appropriate for expected complexity.	No thought is taken for target audience and complexity of writing is below expected level.
Grammar, Mechanics, & Spelling	Very few or no spelling, grammar, or mechanics errors are found in the essay.	Only a moderate amount of errors in spelling, grammar or mechanics are found, and they do not infringe on understanding of essay.	A fair amount of spelling, grammar, and mechanics errors are found and they cause difficulty in readability and understanding of essay.	A large amount of errors in spelling, grammar, and mechanics are found making the document incomprehensible in many areas.

OPINION ESSAY RUBRIC							
TOPICS	**5**	**4**	**3**	**2**	**1**	**Pt Multiplier**	**Points Earned**
CONTENT/OPINION • Fact based • Use of details • Awareness of purpose • Sense of completeness • Opinion	The paper is focused. Purpose of paper is evident. Opinion is well supported by facts and evidence from cited sources.	The paper is focused. Purpose and opinion is evident. Opinion is well supported by facts and evidence but lacking sources.	The paper is somewhat focused.. Purpose and opinion is somewhat evident. Opinion is somewhat supported by facts and evidence but lacking sources.	The paper is minimally focused. Purpose of paper is incomplete. Opinion is hard to identify and somewhat supported by facts and evidence but lacking sources.	The essay has little to no focus, lacking in supporting ideas and examples. The purpose and/or opinion is lacking.	X3	
QUESTIONS ADDRESSED • Who owns Colorado River? • What should be the rationale for calculating the amount of water that can be extracted at each bend of the river? • Can a private entity extract the water to sell it? • Should states be allowed to extract water from the river to sell it to neighboring states? • Can individual states pollute the waters that will be extracted by downstream users? Who should monitor?	All questions are thoroughly addressed.	All or most questions are thoroughly addressed	Most questions are thoroughly addressed	Analysis of questions is lacking.	Analysis of questions is lacking.	X2	
ORGANIZATION • Introduction/body/conclusion • Grouping of ideas • transitions	The organization supports the purpose. Ideas are grouped in a logical manner. Transitions are effective and varied.	The organization is appropriate and the sequencing of ideas is logical. Varied transitions are used.	The organization somewhat supports the purpose. Ideas are grouped in a logical manner. Transitions are somewhat effective.	The organization is hard to follow. Lacks a clear introduction and conclusion. Transitions are seldom used.	The paper shows very little organization. Ideas are sporadic. Transitions are lacking.	X1	
CONVENTIONS • Punctuation, spelling, and capitalization	The writer demonstrates full command of the conventions of written English language. No errors are evident.	The writer demonstrates knowledge of the conventions of written English. Errors are minor and do not interfere with meaning.	The writer demonstrates sufficient control of the conventions of written English. Errors may interfere with meaning, but are not distracting.	The writer demonstrates minimal control of the conventions of written English. Errors are frequent and interfere with meaning.	The writer lacks understanding of the conventions of written English. Errors are pervasive. The response is incomplete or too brief.	X1	
					TOTAL POINTS POSSIBLE (out of 35)		