HANFORD & THE RIVER

High School Environmental Science
Produced by Columbia Riverkeeper

The Hanford Nuclear Site ("Hanford" or "Hanford Site") is the most contaminated place in the Western Hemisphere, where the United States discharged billions of gallons of radioactive waste near the banks of the Columbia River and directly into the River. Waste has contaminated the groundwater, and dozens of underground storage tanks have leaked high-level nuclear waste. Vast areas of groundwater are contaminated with nuclear and chemical waste, and, in some places, this groundwater is flowing into the Columbia River.

The 586-square-mile Hanford Site is a legacy of nuclear weapons production during World War II and the Cold War. But, nuclear activities were confined to a minor part of the site, leaving much of the site relatively undisturbed. The resulting "accidental nature" includes shrub-steppe habitat, cliff habitat, wetlands and river systems, and the most productive spawning ground for wild Chinook salmon on the main stem of the Columbia River.

The materials in this curriculum allow teachers and students to explore Hanford and the Hanford Reach of the Columbia River. This curriculum includes lesson plans, Teacher's Guides and Student Worksheets along with primary documents and supplemental materials to help facilitate student learning. The lessons permit students to analyze Hanford's history, ecology, and the risks and rewards of cleanup.

The lessons also allow students to learn about Hanford's ecology through the eyes of Hanford's threatened and endangered species. Specifically, the curriculum allows students to investigate the connection between the cleanup of Hanford and Hanford's impact on human health and the environment.

The lessons are based on an inquiry approach, which engages the students in known and unknown science concepts, has them explore and investigate, then reflect and explain their thinking and reasoning, applying and extending their new knowledge.

Teachers can use this curriculum in a variety of ways. They could use a handful of documents to supplement existing readings and lesson plans. They could also use the materials to create a new teaching unit lasting anywhere from a day to a week.

This curriculum allows students to go beyond hearing about Hanford, the shrub steppe habitat, or endangered species. Researching the species of the Hanford Reach and researching the risks and rewards of cleanup and the stakeholders, enables each student to become an investigator.

HANFORD & THE RIVER
High School Environmental Science
Lesson 2: Hanford's Pollution & Risk

	Subject Area: Environmental Science **Description:** 1 hour 30 minutes
State Standards:	**Environmental and Sustainability Learning Standards –** Standard 1: Ecological, Social and Economic Systems Standard 2: The Natural and Built Environment
Lesson Overview:	In this lesson, students will: • Learn about the Superfund law. • Learn about Hanford's pollution. • Discover how nuclear waste adversely affects human health and the environment. • Examine the sources of Hanford's pollution, and the breadth and depth of it. • Study how Hanford's operations and pollution have affected Hanford's natural resources.
Learning Objectives:	At the end of this lesson students will be able to: • Understand how Hanford's waste could adversely affect human health and the environment. • Identify the historic sources of pollution at Hanford. • Identify the current sources of pollution at Hanford. • Identify how Hanford's wastes enter the environment and the Columbia River. • Understand how humans and wildlife interact with radionuclides and pollution in the environment.
Engage & Encounter	Ask students to read the background information on waste products produced during plutonium production, the main sources of pollution at Hanford and the pollution pathways to the environment. Sources include: • Hanford & the River, published by Columbia Riverkeeper, pages 11-16 and 6-8. http://columbiariverkeeper.org/our-work/hanford-report/ • History of the Hanford Site, published by PNNL, page 33. http://ecology.pnnl.gov/library/History/Hanford-History-All.pdf • Hanford Site video, http://www.youtube.com/user/HanfordSite
Explore & Investigate	Students will work as a class to explore the effect of the long-term contamination of Hanford on human health and the environment.

Reflect and Explain	Students will understand the extent of Hanford's contamination by creating a graph describing the amount of radionuclides released into the air and the Columbia River.
Apply & Extend	Students will extend their understanding about long-term contamination by estimating the remaining curies of pollution into the future.
Assessment	Students will compare Hanford's pollution to other superfund sites, focusing on nuclear sites. Students will compare the amount of pollution, type of pollution, and threat to the environment.

Identifying Risks at Hanford

This activity helps students understand the types of risks found at Hanford and how these risks are identified and assessed. Students will discuss the activities undertaken by the government or other parties to identify sources of contamination, determine the type and extent of contamination, and evaluate the risks posed to human health and the environment.

If your students are not familiar with the concept of risk, then a simple exercise in probability can help them evaluate the impact of risk on the basis of probabilities, benefits, and their perceptions. You can use the ***Assessing Risk*** worksheet to help review.

When it comes to the environment, the chance of something dangerous happening is called risk. Each type of hazardous substance, hazardous waste, or dangerous situation involves a different amount of risk. Human risk is made up of two parts: (1) the chance that people will be exposed to the substance, and (2) the chance that exposure will injure or harm people. Environmental risk measures the probability that the environment will be damaged by a particular hazardous situation. Decisions on cleaning up a Superfund site, discussed in detail below, are based on the risks the site poses to people and the environment.

There are generally many factors involved in determining the risks surrounding a particular hazardous situation. These factors include the potential for damage each harmful substance can cause, the chance that the substance is going to spread from the original site through water, wind, or some other means, and the chance that people will come in contact with the substance.

Teacher Background: The Superfund Program in the United States was created as a response to widely publicized contamination problems caused by hazardous waste. The Superfund law specifies a process for reporting potentially contaminated hazardous waste sites to the Federal government. The U.S. Environmental Protection Agency (EPA) and states investigate hazardous waste sites to determine the seriousness of the contamination. The most serious sites are cleaned up using Superfund authority and funding.

EPA assesses the hazards of exposure posed by each site. Tied to the concept of exposure is the concept of risk. Risk is a measure of the probability of suffering harm or loss. For example, risk is used to measure the probability that a person will be exposed to a hazardous substance and the chances that the exposure will harm the person's health. Environmental risk is a measure of the probability that hazardous substances will harm the environment.

Engage: Ask students to read the background information on waste products produced during plutonium production, the main sources of pollution at Hanford and the pollution pathways to the environment. Sources include:

- Hanford & the River, published by Columbia Riverkeeper, pages 11-16 and 6-8.
- Hazardous Substances and Hazardous Waste, published by Environmental Protection Agency, http://www.epa.gov/superfund/students/clas_act/haz-ed/ff01.pdf

- The Superfund Cleanup Program, published by Environmental Protection Agency, http://www.epa.gov/superfund/students/clas_act/haz-ed/ff01.pdf

Explore: Students will explore their understanding of the long-term contamination at Hanford. Briefly review the reading materials. Lead a class discussion about contamination.

Classroom Discussion

1. Ask students how contaminants might spread from the hypothetical site. Possible answers include:

- The wind can blow contaminant vapors.
- The wind can blow small soil particles to which contaminants are attached.
- Contaminants can be washed into the Columbia River by rainfall running off the site.
- Liquid contaminants can flow down through the soil to the groundwater.
- Contaminants can be washed down through the soil to the groundwater by rainfall.
- Groundwater moving underground can spread contaminants in the aquifer.
- Contaminated groundwater can move into the flowing Columbia River.
- Surface water sediments can be washed downstream, particularly during floods.

2. Ask students how animals or plants might be exposed to contaminants from the site. Possible answers include:

- The wind can blow contaminants to tree leaves, grasses, or crops.
- Animals can eat contaminated plants.
- Fish and aquatic plants can be exposed to contaminants washed into the Columbia River.
- Farmland crops could be exposed to contaminants through irrigation from the Columbia River.

3. Ask students how communities surrounding Hanford and downstream communities might be exposed to contaminants from the site. Possible answers include:

- Eating contaminated crops.
- Eating contaminated fish from the Columbia River.
- Residents drinking contaminated water from the Columbia River.
- Children playing in the Columbia River.
- Fishermen fishing on the Columbia River.
- Downwind residents breathing contaminated air blown off the site.
- Recreating on the river.
- Hunting and eating contaminated animals.
- Gathering contaminated fruits and roots.

4. Ask students to name some factors that are important to consider in determining the risk of exposure to site contamination. Possible answers include:

- Amount (volume) of contamination originally released at the site.
- Concentration of the released contaminants.
- Degree of dispersion (dilution) of the contaminants.
- Frequency of contact with contaminated water, soil, plants, and animals.
- Amount of physical, chemical, and biological transformation of the contaminants into a harmless state (degradation, containment).
- Long-lived nature of the nuclear waste.

Reflect: Distribute the ***Hanford Preliminary Assessment and Site Inspection*** handout. Divide the class into groups of 5 or 6 and instruct each team to choose a spokesperson.

- Have each group discuss and answer the questions listed on the handout. After about 10 minutes, have the class reassemble and have the spokesperson for each team present the team's responses.
- Record the responses and discuss any differences between the groups. Why does EPA focus on these questions when investigating potential hazardous waste contamination? Does the class believe direct contact is more serious than food chain contamination? Is human health protection more critical than protection of sensitive environments?

Apply: In order for students to better understand the amount of contamination already released into the environment and the long-lived nature of nuclear waste students will work independently to research the amount of waste produced, and then together to assess the threat of this waste to future generations using the ***Radionuclide Worksheet.***

1. Have each student create a graph describing the amount of radionuclides released into the air and the Columbia River by Hanford (http://bit.ly/HXUHgf)

Extend: Reassemble student groups, assign each group a radionuclide. Ask each group to research the half-life of a radionuclide and then, using the ***Half Life Worksheet***, graph the remaining curies of the radionuclide in 10 years, 100, 1,000, 10,000, 100,000, 1,000,000 years.

The groups will reflect back to the species they researched in Lesson 1 and hypothesize how their radionuclide can adversely affect their species today and in the future.

Assessment: Ask students to compare Hanford's pollution to other Superfund sites, focusing on the Manhattan Project nuclear sites. Students will compare the amount of pollution, type of pollution, and threat to the environment.

Radionuclide Worksheet – Student Worksheet

Part A

For each situation listed below, describe a potential risk (something that could happen that would cause concern for public health.) List at least two ways people or the environment could be injured and, if possible, at least one benefit that people or the environment could gain from it.

- *Transportation of hazardous substances on highways, along major rivers*
- *An old municipal and industrial dump that does not meet current design and safety standards*
- *A large housing area build on an unknown hazardous waste site contaminated with radioactive substances, uranium, chromium and iodine 151*
- *Storage of nuclear waste in underground storage tanks in the dessert*
- *Travel by automobile*
- *Cigarette smoke*
- *Pesticides*
- *An earthquake*

Example:

- ***Risk:*** *Transportation of hazardous substances on highways, along major rivers*

Injury to people or the environment #1:

Injury to people or the environment #2:

Benefit to people or the environment:

Part B

Now, answer the following questions:

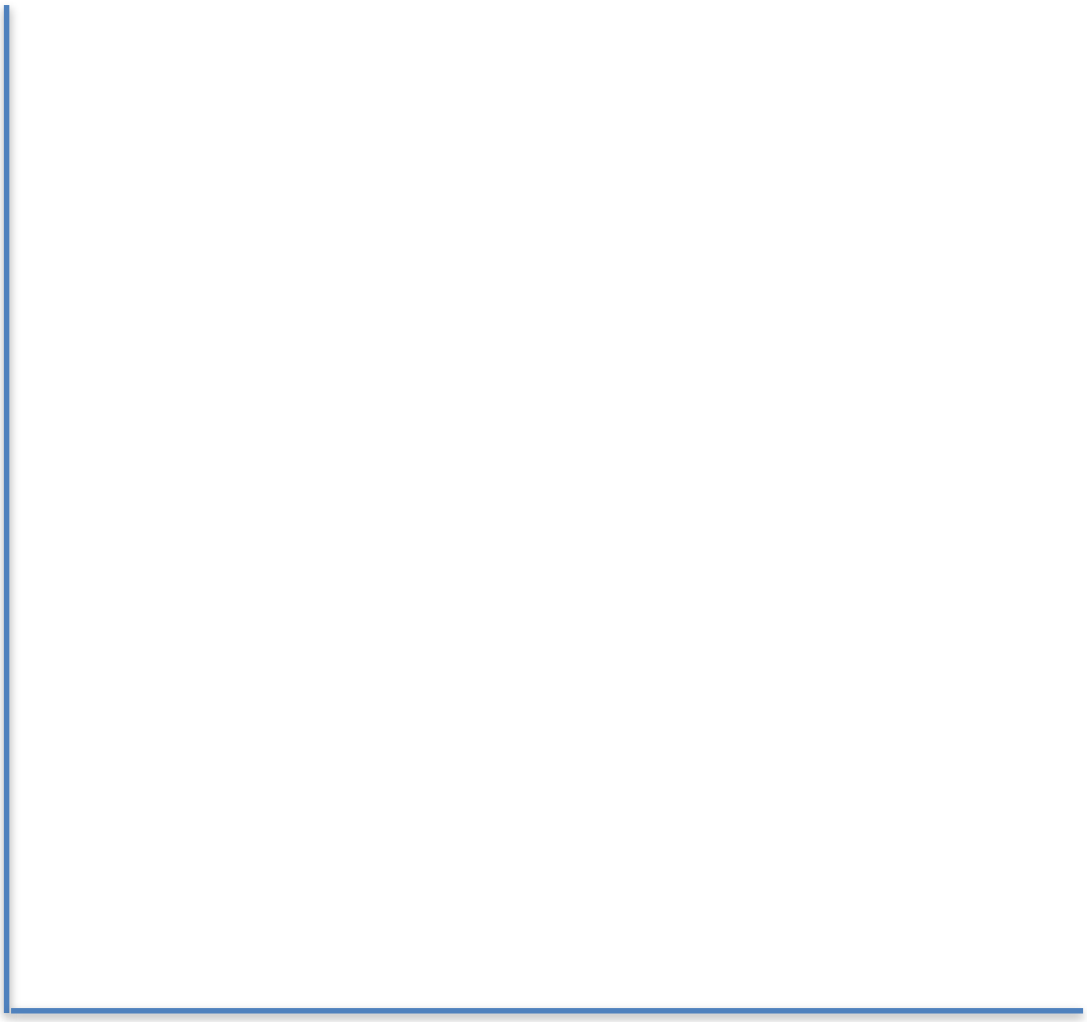
1. *How would you rank the situations in Part A in terms of how risky they are and how likely injuries are to happen?*

2. *How would you rank the risks in terms of the number of people affected and the severity of the possible harm? (That is, which situations present the deadliest and most widespread risk?)*

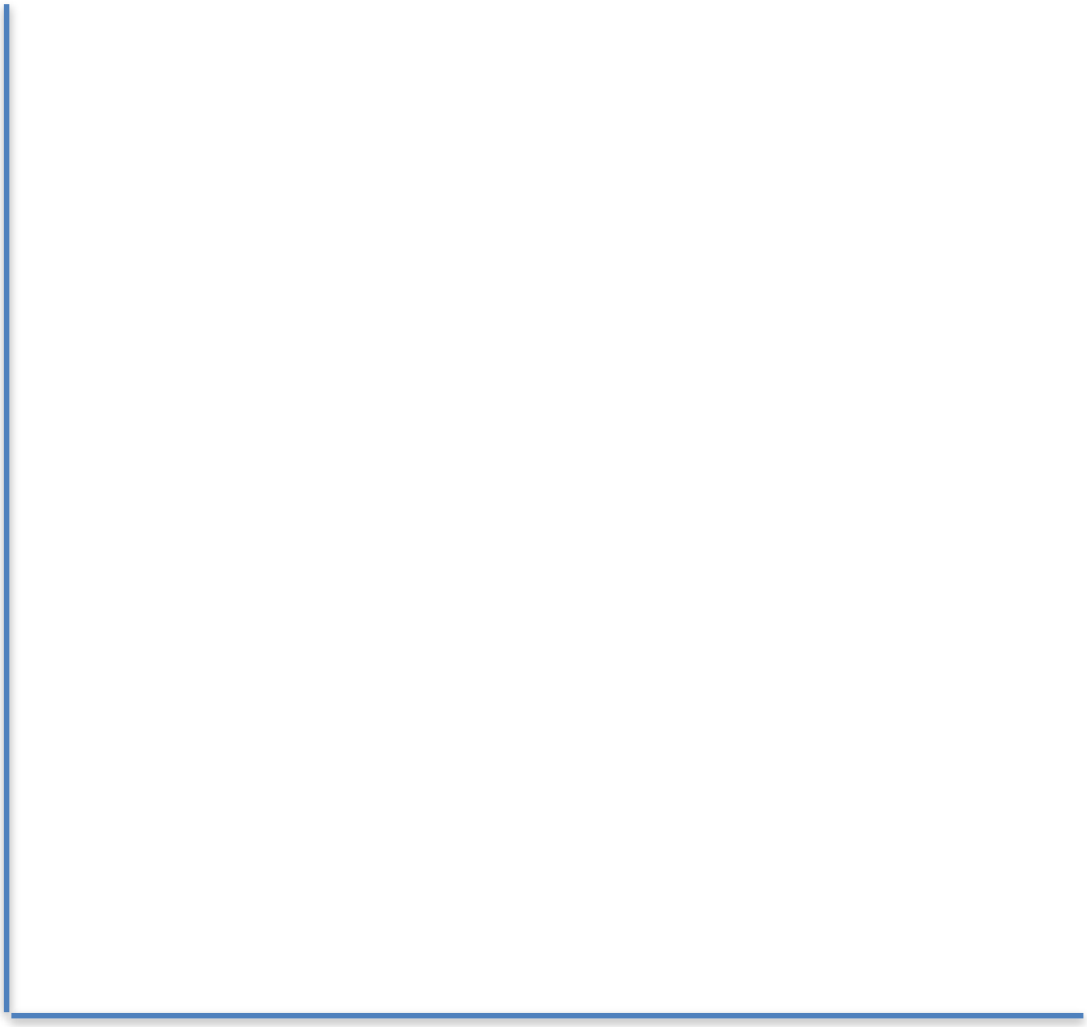
3. *Which of the risks are you willing to accept (voluntarily), and which do you have to accept (involuntarily)? (For example, you can choose not to smoke cigarettes but you may not be*

able to prevent the use of pesticides by farms near where you live.) In this exercise, you will create two bar graphs, one illustrating the amount of radionuclides Hanford operations released into the air, between 1944 and 1972, and the other illustrating the amount of radionuclides Hanford released into the Columbia River, from 1944-1971. A complete list is available at http://bit.ly/HXUHgf.

The x-axis, should include the radionuclides. The y-axis, should include the curies released for each radionuclide. Label your graph.



Radionuclide Worksheet – Student Worksheet



Radionuclide Worksheet – Student Worksheet

The Release of Radioactive Materials from Hanford: 1944-1972.

TABLE I **Estimates of Radiation Released into the Air by Hanford, 1944-1972**		
Radionuclide	*Amount Released (curies)*	*Half-Life*
Iodine-131	740,000	8 days
Tritium (H-3)	200,000	12 years
Strontium-90	64	29 years
Iodine-129	46	16 million years
Cesium-137	42	30 years
Plutonium-239	1.8	24,000 years

TABLE II **Estimates of Radiation Released into the Columbia River by Hanford, 1944-1971**		
Radionuclide	*Amount Released (curies)*	*half-life*
Chromium-51	7,200,000	28 days
Zinc-65	490,000	245 days
Arsenic-76	2,500,00	26 hours
Iodine-131	48,000	8 days

Hanford Preliminary Inspection & Site Assessment – Student Worksheet

Some radionuclides last for a long time in the environment, while others decay more quickly. In order to assess the current and future risk, we need to look at the quantity released as well as the half-life - the length of time it takes for half the nuclei to undergo radioactive decay.

Assume that all of the curies were released in 1960. For each radionuclide, calculate the number of years until less than one curie remains.

Air Releases

	Curies released in 1960	*Number of years until less than 1 curie remains.*	*Year when less than 1 curie remains*
	740,000		
	200,000		
	64		
	46		
	42		
	1.8		

Water Releases

Radionuclide	*Curies released in 1960*	*Number of years until less than 1 curie remains.*	*Year when less than 1 curie remains*
Chromium-51	7,200,000		
Zinc-65	490,000		
Arsenic-76	2,500,00		
Iodine-131	48,000		

Hanford Preliminary Inspection & Site Assessment – Student Worksheet

Discuss within your group the following questions about Hanford Site. Use information from ***Hanford & the River*** *to answer the questions. Then select a spokesperson to present your answers.*

1. *What are your biggest concerns regarding the site and why?*

    - *Health concerns?*

    - *Environmental resource concerns?*

2. *What are the ways in which the contamination can spread? (These are commonly referred to as "routes of migration.")*

Hanford Preliminary Inspection & Site Assessment – Student Worksheet

3. *On a scale of 1 to 5, 1 being the lowest and 5 being the greatest, how would you rank the threats to human health and the environment from Hanford? Choose from the list of threats below, or come up with your own. What is the rationale for your ranking of the threats?*

- *Groundwater, that flows to the Columbia River.*
- *Underground storage tanks that hold nuclear waste.*
- *The central disposal facility that holds 13 million tons of waste.*
- *The Columbia River as a source of drinking water for City of Richland.*
- *The air.*
- *Medicinal plants and roots used by Native Americans.*