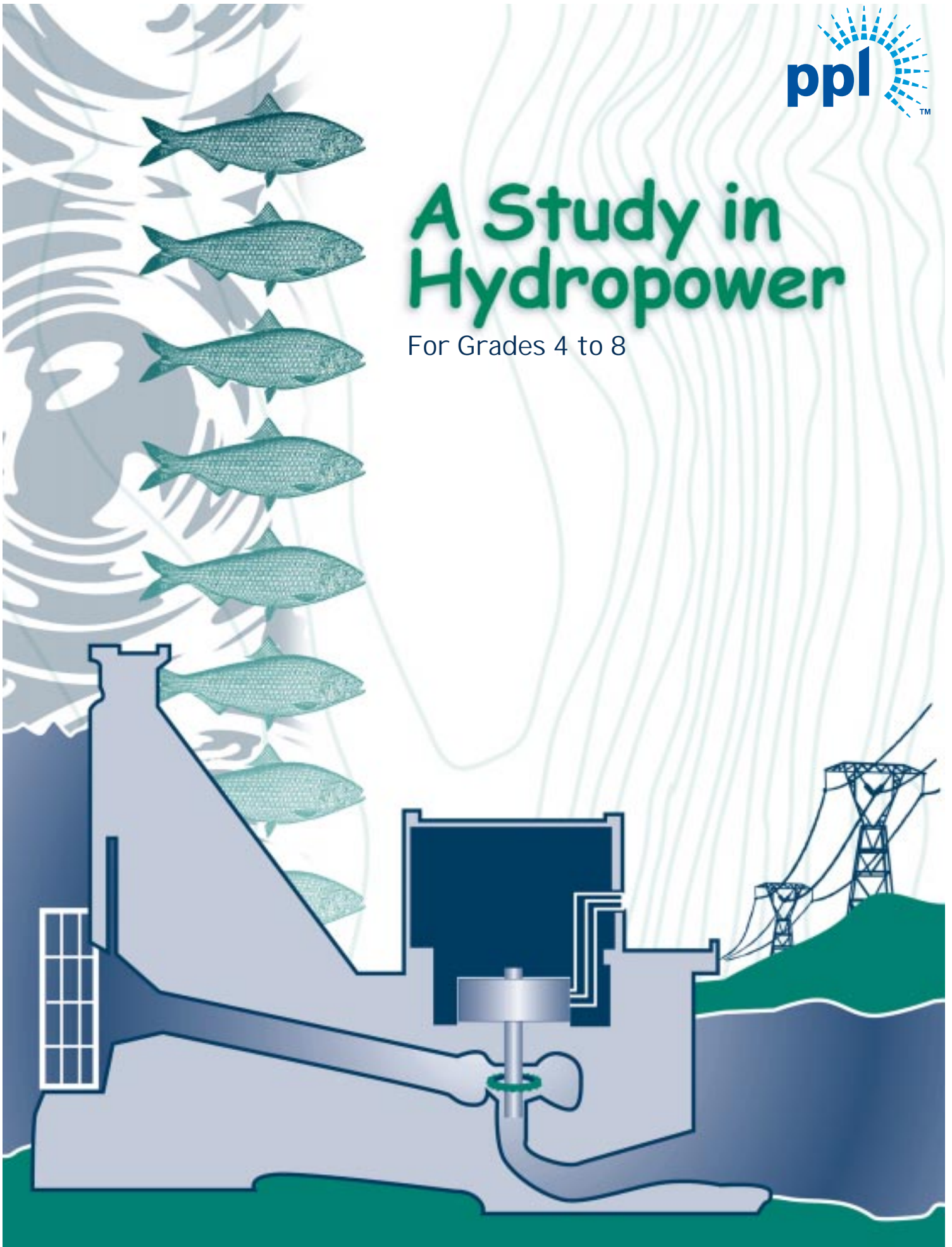




A Study in Hydropower

For Grades 4 to 8





A Study in Hydropower Table of Contents

Unit I Source of Hydropower	1
Unit II History of Hydropower and Water at Work	7
Unit III Water + Gravity = Energy	21
Unit IV How Does Hydropower Work?	31
Unit V Dams and Ecology	47
Unit VI The Future of Hydropower	57
Unit VII Glossary	67
Pennsylvania Environment & Ecology Education Standards	
	back of binder



Acknowledgements

This publication represents the combined efforts of the educational community and PPL.

A Curriculum Writing Task Force authored the study during a week-long session at PPL Lake Wallenpaupack Hydroelectric Station in the Pocono area. The educators on the task force deserve special mention for their dedicated work during that session and in follow-up meetings. There were six middle school classroom teachers, one high school classroom teacher, and one elementary instructional support educator. They are:

Mark Alderfer, Wallenpaupack Area School District

Mary Ellen Burkart, Donegal School District

Brian Young, Allentown Central Catholic High School

Gail Bundra, Instruction Support, Northampton Area School District

Keith Venanzi, Northampton Area School District

Lowell Fehnel, Northampton Area School District

Ed Wytovich, Williams Valley School District

Dan Zulli, Easton Area School District

PPL's Corporate Communications Department handled the editing, typesetting, graphic presentations, printing, and binding.

PPL's Advisory Council for Excellence in Education (ACEE), an independent group of educators in Central Eastern Pennsylvania, reviewed the discussion guide and provided input throughout the development process.

Connections to Pennsylvania Academic Standards

Connections between this manual and Pennsylvania academic standards are evident throughout, e.g., science, social studies, history, math, etc. Because of the strong relationship of energy and hydroelectric power to our environment, the Pennsylvania Standards for Environment & Ecology are especially complemented by the activities in the manual.

As stated in the Pennsylvania Standards for Environment and Ecology, "Environment and Ecology is grounded in the complexity of the world we live in and our impact on its sustainability. The human interactions with the ecosystem and the results of human decisions are the main components of this academic area. Environment and Ecology examines the world with respect to the economic, cultural, political, and social structure as well as natural processes and systems. This integration across systems is what sets this academic area apart from all others."

So you, as an educator, can apply the activities to the standards. We have included a copy of the Pennsylvania Environment & Ecology Standards in the manual.

Unit I

Source of Hydropower

UNIT GOAL

To show the relationship between the solar powered water cycle and its effect on recharging of the watershed for hydropower.

INTRODUCTION

1. Read poem Recycle! by Verne Rockcastle.
2. Question: How do clouds form? Is there water in the air?
3. Teacher explanation of the water cycle introducing vocabulary words, leading to condensation experiment-final explanation after student discovery.

The hydrologic (water) cycle: Water constantly moves through a vast global cycle in which it evaporates from lakes and oceans, forms clouds, precipitates as rain or snow, and then flows back to the ocean. The energy of this water cycle, which is driven by the sun, is tapped most efficiently with hydropower.

CROSS-CURRICULAR

Math/Graphics

DEMONSTRATIONS AND EXPERIMENTS

1. Condensation Demonstration
2. Evaporation Energy Experiment
3. Solar Sill Activity
4. Water Cycle in a Bottle Demonstration
5. Wet Finger Demonstration
6. Hot Spray Demonstration
7. Evaporation Demonstration

REVIEW

Have students write an essay titled "My life as a water molecule."

ASSESSMENT

Water Cycle Assessment Sheet.

RESOURCES

Cloud apparatus;
Carolina Biological.

1. CONDENSATION DEMONSTRATION

Goal

Students will be able to see that there is water vapor in the air and that removing energy by cooling the air will condense the water to a liquid.



Procedure

Fill a glass with ice and water and place it in the room. Water will condense on the outside of the glass.

*Note: If your room is very dry you may have to add salt to the water or have a student blow onto the glass.

2. EVAPORATION ENERGY EXPERIMENT

Goal

Students will be able to measure energy changes as water evaporates.

Materials

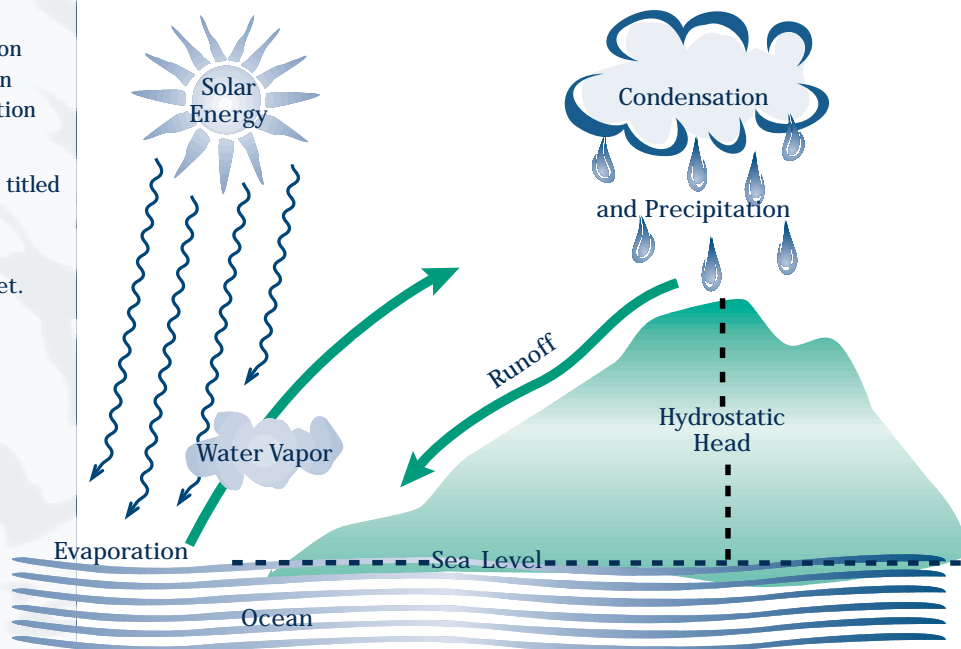
- 2 Erlenmeyer flasks (500 mls)
- 2 one-holed rubber stoppers to fit flasks
- paper towels
- watch or clock

Procedure

Carefully insert thermometers into each of the rubber stoppers, making sure that the room temperature degree line is below the stopper and readable. Fit the thermometers into the flasks. At time Zero, measure the temperature in each flask. Cover one of the flasks with a wet paper towel. This will be the experimental flask for evaporation (Flask E).

continued on next page

THE HYDROLOGIC CYCLE





The second flask should reflect changes in room temperatures as a control (Flask C). Measure the temperatures every 2 minutes for 10 to 14 minutes. Avoid any unnecessary handling of the flasks to minimize extraneous temperature changes.

Record data on the chart. Graph the results in a time versus temperature line graph. Discuss results in terms of the energy changes during evaporation.

Data Chart

Time in minutes	0	2	4	6	8	10	12	14
Flask C Temperature								
Flask E Temperature								

Which flask shows the greatest change in temperature?
 What is happening to cause this energy change?
 Does evaporation require addition of heat energy in order to take place? Explain.

3. SOLAR STILL ACTIVITY

Goal

Students will be able to purify water using solar energy.

Materials

- heat source (lamp)
- 2-inch deep cake pan
- clear plastic wrap
- small cup
- tape or large rubber band
- small weight (penny)
- dirty water

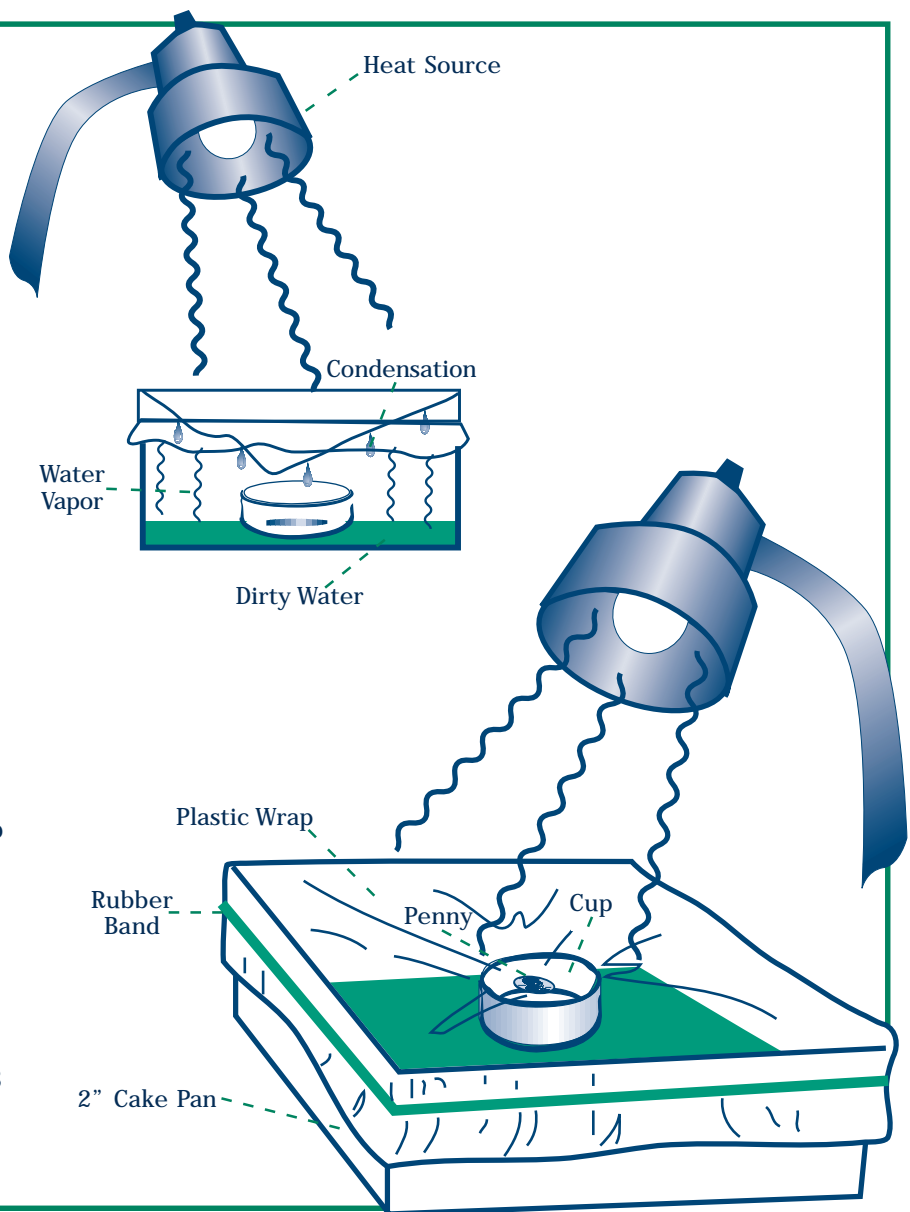
Procedure

Students will choose the substances to add to make the water dirty. They then must construct an apparatus that will promote evaporation of the dirty water, condensation of the water vapor, and precipitation of the purified water into the collection cup.

Assessment

Students should draw a diagram of their model and label it with appropriate terms.

*Note: For this experiment to work well, it requires at least 8 hours exposure to sun or light.



UNIT VOCABULARY

1. Condensation: phase change from a gas to a liquid; example: a glass of ice water cooling
2. Cycle: an endless loop
3. Evaporation: phase change from liquid to gas occurring at the surface of liquids; requires energy and causes cooling
4. Fog: clouds which form close to the ground; a form of condensed water in which the droplets are not large enough to fall
5. Gas: phase of matter with no definite shape or volume at normal temperature and pressure
6. Gravity: the natural force that causes things to be attracted to the center of the earth
7. Hail: large frozen water "stones" usually occurring during severe thunderstorms
8. Liquid: phase of matter that has a definite volume but no definite shape
9. Precipitation: atmospheric water falling in any form to the surface of the earth
10. Rain: liquid form of precipitation
11. Recycle: to make new again
12. Sleet: frozen rain (solid)
13. Snow: a crystalline solid form of precipitation
14. Solid: a phase of matter that has a definite volume and a definite shape
15. Vapor: the gaseous state of fluids which exist as liquids under normal conditions; thus, we speak of water vapor and oxygen gas
16. Water: a naturally occurring molecule composed of two parts hydrogen to one part oxygen (H_2O); aka the Mickey Mouse molecule
17. Water cycle: the solar powered system whereby water is endlessly recycled and purified

4. WATER CYCLE IN A BOTTLE DEMONSTRATION

Goal

Students will be able to see the water cycle in action and compare it to the earth's closed system.

Materials

- cup with a dome-shaped lid
- water
- marker
- tape window or light source

Procedure

Fill a transparent cup with a dome-shaped lid 1/3 full of water and mark the level on the outside of the cup. Place the lid on the cup and seal any openings on the cup with tape. Let the cup stand on a windowsill or someplace where it will receive light. Watch the water cycle as you proceed through the unit. After a day or so, examine the cup.

Questions

What do you observe happening in the bottle?

What is causing this to happen?

Where is the energy for this change coming from?





5. WET FINGER DEMONSTRATION

Goal

Students will be able to feel that evaporation is a cooling process and uses heat energy from their bodies to take place.

Materials

- isopropyl alcohol or ethanol

Procedure

Apply a small amount of alcohol to the finger (or back of the hand) of each student and allow them to feel the effect of evaporation.

6. HOT SPRAY DEMONSTRATION

Goal

Students will be able to feel that evaporation is a cooling process and uses heat energy from their bodies to take place.

Materials

- spray bottle that has a mist setting
- very hot water

Procedure

Add some very hot water to the spray bottle. Allow student to feel the outside of the bottle to assure them that the water is hot. Making sure that the bottle spray is set on mist, spray the student's hand with a small amount of water. The spray should feel cool as the water evaporates.

7. EVAPORATION DEMONSTRATION

Goal

Students will be able to see that evaporation removes water but leaves dissolved substances behind.

Materials

- water
- salts (Epsom salts works well)
- petri dish or other shallow, clear glass dish

Procedure

Create a solution of salt (Epsom salt) and water. Show it to the class and ask what will happen if the dish is allowed to stand for several days.

Allow the dish to stand until all the water has evaporated. Again, show the dish to the class to view the salt crystals left behind.

Questions

What do you see in the dish?
Where did the substance come from?

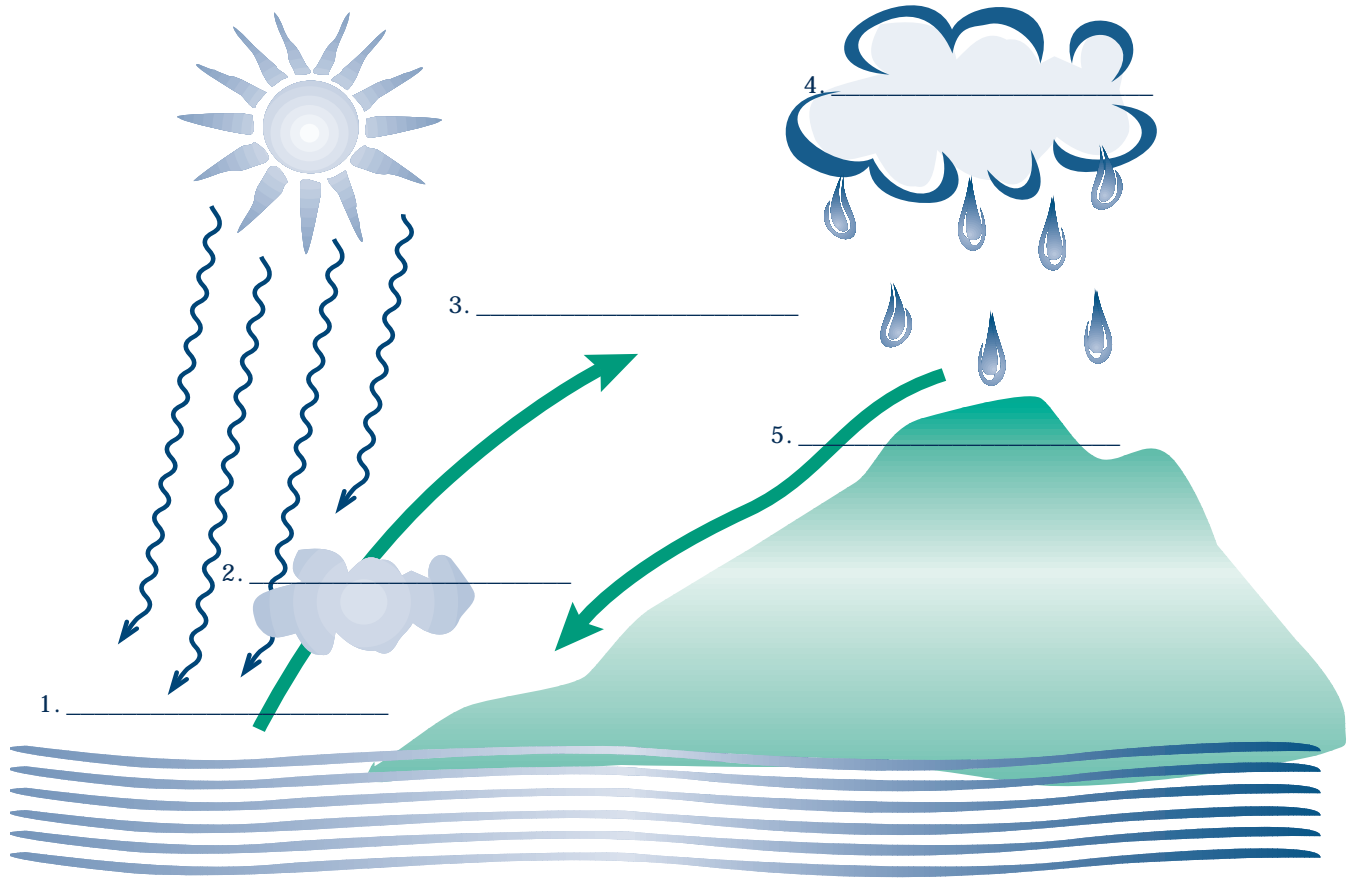
Does evaporation leave behind dissolved materials?

How will this affect water purification?





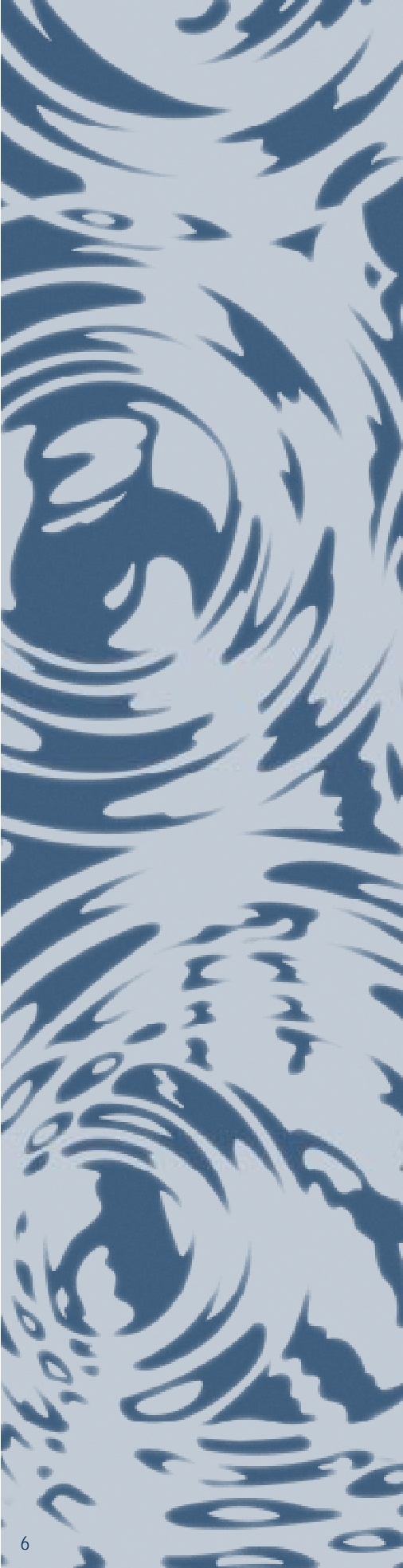
WATER CYCLE ASSESSMENT NAME _____



Questions 1-5 refer to numbers on diagram.

1. What phase change is happening here?
2. What phase is water in for this part of the cycle?
3. What phase is happening at this point?
4. What phase is water in a cloud?
5. What is happening here?
6. A cloud close to the ground is called _____
- 7-11. Name the 5 forms of precipitation. _____

12. Does evaporation require an addition or loss of heat energy? _____
13. Does condensation require an addition or loss of heat energy? _____
14. What energy source drives the water cycle? _____



The Italian physicist and chemist, Avogadro, determined in an elegant experiment that in any molecular mass of a substance there are 6.02×10^{23} molecules. A molecular mass of water (H_2O), for example, is 18 grams of water, or about one cubic inch of water. Avogadro found that in this much water there are 6.02×10^{23} water molecules. Or in a glassful, about 7×10^{24} molecules!

Compare this with the number of glassfuls of water on all of Earth—oceans, lakes, rivers, ground water, glaciers, and atmospheric water—which totals about 7×10^{21} glassfuls. That means in one glass-ful of water, there are about 1,000 times as many molecules as there are glassfuls of water on all the Earth. This leads to an interesting idea. Suppose you pour a glassful of water back into “the system,” and it gets thoroughly mixed (which may take many, many years). When you dip another glassful of water out of the system, the chances are that you’ll get back about 1,000 of the molecules from the original glassful of water that you poured into the system. And that suggests the following poem:

Recycled!

by Verne N. Rockcastle

The glass of water you’re about to drink
Deserves a second thought, I think,
For Avogadro, oceans, and those you follow
Are all involved in every swallow.
The molecules of water in a single glass,
In number, at least a thousand times outclass
The glassfuls of water in stream and sea,
Or wherever else that water can be.
The water in you is between and betwixt,
And having traversed you is thoroughly mixed,
So someone slaking a future thirst
Could easily drink what you drank first!
The water you are about to taste
No doubt represents a bit of the waste
From prehistoric beast and bird—
A notion not at all absurd!
The fountain spraying in the park
Distributes bits from Joan of Arc . . .
And Adam and Eve, and all their kin:
You’d be surprised where your drink has been!
Just think! The water you cannot retain
Will some day hence return as rain,
Or be beheld as the purest dew,
Though long ago it passed through you!

Teacher's Notes

Teacher's Notes

Teacher's Notes

Teacher's Notes

Unit 11

History of Hydropower & Water at Work

UNIT GOALS

1. To show the importance and influence of hydropower throughout history.
2. To show students why hydropower flourished in certain areas and not others.

INTRODUCTION

1. Definition of hydropower: the use of water to do work.
2. To look at and discuss civilizations who used hydropower.
3. To look at and discuss how hydropower has influenced the growth of communities, including a relationship to agriculture.
4. To show how the position or lack of water influences the ability of water to do work.

ACTIVITIES

1. Students will construct a time line of hydropower using various research materials and a list of significant dates provided by the teacher. See History of Hydropower Resource Materials.
2. If possible, use computer software [PowerPoint, Hyperstudio, etc.] to create a presentation on a specific date or event in hydropower history. See History of Hydropower Resource Materials.
3. Students will use a topographic map to find areas where hydropower would be practical and economical. See Cliff River Quadrangle Activity.
4. Students will use a topographic map to locate a new dam, showing the impact it would have on the area. For example, the land that would be submerged by the creation of a lake, individual families or communities that would need to be relocated, possible changes in local economy, etc. See Cliff River Quadrangle Activity.
5. Students will complete a map to locate various designated hydroelectric sites. Possible resource - National Geographic Map of U.S. Waterways.

continued on page 8

SITING A HYDROELECTRIC POWER PLANT

See Activity 3

Use the map on the next page for this activity.

Brief History

The area shown was once covered by forest. Salmon and trout swam in the river. After settlement, all but the most remote areas, such as Gorgeous Gorge, were clear-cut for timber. The Gorge and a few isolated areas remain primordial forest.

Presently, almost the entire acreage north of Bison Ridge is forested by second-growth timber. A small amount of this northern portion is private land. There is limited logging occurring. There are a few private vacation cabins on the banks of the Cliff River between the junction of Clear Flow Creek and Pineton. The vast majority of this northern section is public, made up of state gamelands and state forest. Hunters, hikers, and mountain bikers all enjoy this area, along with kayakers and canoeists. Salmon once spawned in this watershed. Trout still thrive in the upper reaches of

the river and its two tributaries, but downstream of the gorge the water is warmer due to deforestation. Siltation has also degraded the river. Only limited warm water fishing opportunities exist downstream.

The area south of the ridge is mostly agricultural. During especially dry summers, crops suffer. As a result, some farms have been abandoned.

Riverbergh has a growing population of 4,000. Most residents are employed by small factories and businesses, and the town's water and power demands are growing along with its population. Its water comes from several deep wells, some of which have become unusable due to pollutants. Most of the region's electricity is produced by a nuclear facility located 150 miles away. An 80-foot high hydroelectric dam is to be constructed at Point A. The water immediately behind the dam will be 60-foot deep with a pool elevation of 1,580 feet. Water will be released from the bottom of the lake.

continued from page 7

6. Possible field trip to an area of local interest, such as a grist-mill or hydroelectric plant.

REVIEW

Teacher designed worksheets and/or games.

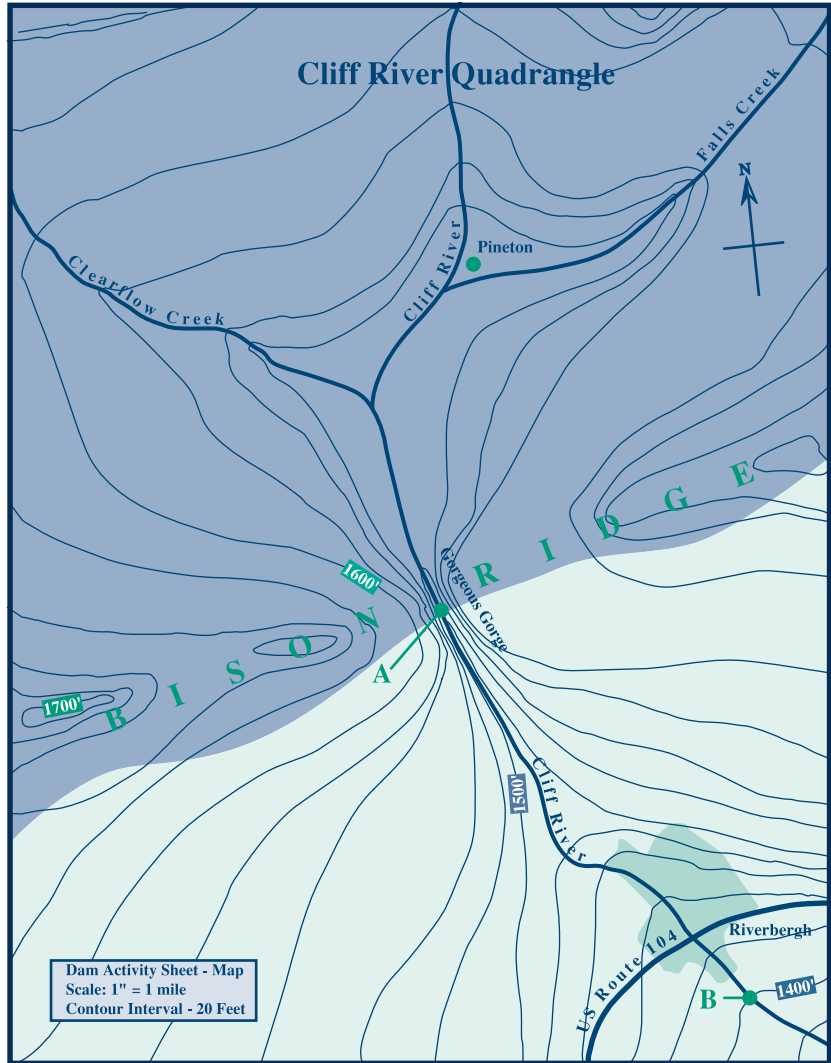
ASSESSMENT

Graded classwork and homework, teacher-designed tests and quizzes and graded presentations.

RESOURCES

Science teacher, library, pamphlets/community, Internet (ex: National Geographic. /dams.com, computer resources-encyclopedias).

UNIT II, ACTIVITY 3





UNIT II, ACTIVITY 3 NAME _____

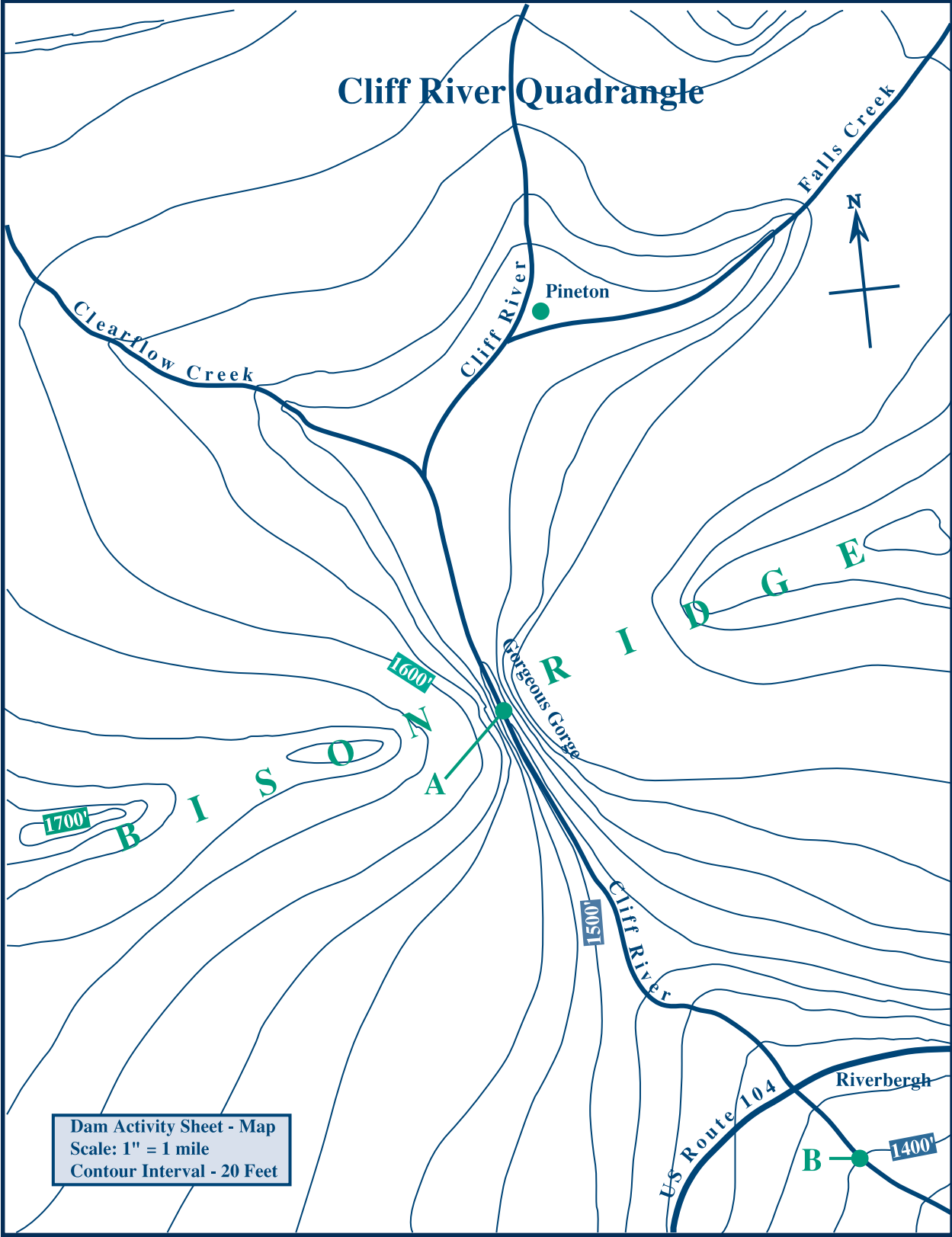
On the map on the reverse side, draw the dam and color the lake blue.

Questions

1. Why was it better to build the dam at Point A rather than Point B? List the reasons.

2. In what four ways would the area benefit from the dam?

3. What would be some negative consequences? List four.



Dam Activity Sheet - Map
Scale: 1" = 1 mile
Contour Interval - 20 Feet

GOAL

Students will recognize on a map the characteristics of a good hydro-power location and be able to design a simple hydropower system.

INTRODUCTION

1. Discuss what makes a good location for a hydropower site.
 - 1.1 What type of work the water will have to do
 - 1.2 Population in surrounding area
 - 1.3 Cost vs. gain => easy access or not, amount of use vs. location, size of evacuation project
 - 1.4 Slope of stream and depth of stream
 - 1.5 Flow rate of stream
 - 1.6 If needed, location of dam and generation plant
 - 1.6.1 Type of plant
 - 1.6.2 Head: the distance water falls to generate power
 - 1.6.3 Height of dams
 - 1.6.4 Location of discharge area

CROSS CURRICULAR

Social Studies and Geography

REVIEW

Teacher-designed worksheets based on the student examples.

ASSESSMENT

Teacher-generated quizzes, graded projects, and graded oral presentation.

TIME FRAME

Four to eight hours or one to two days.

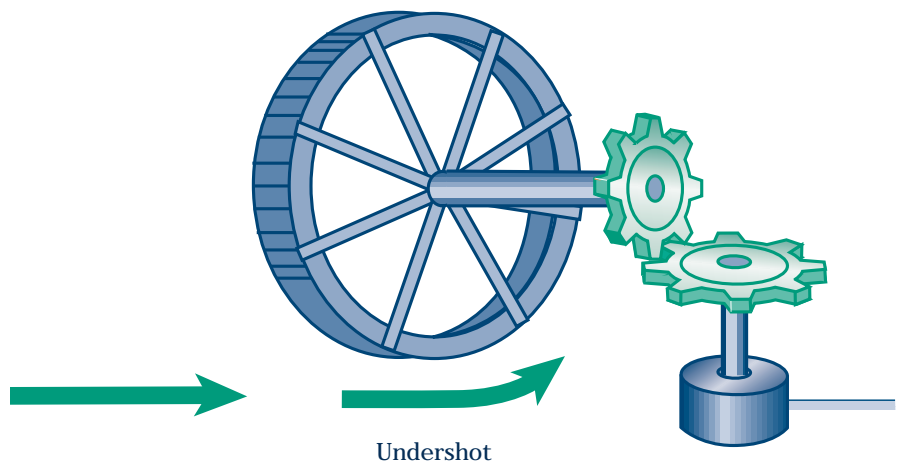
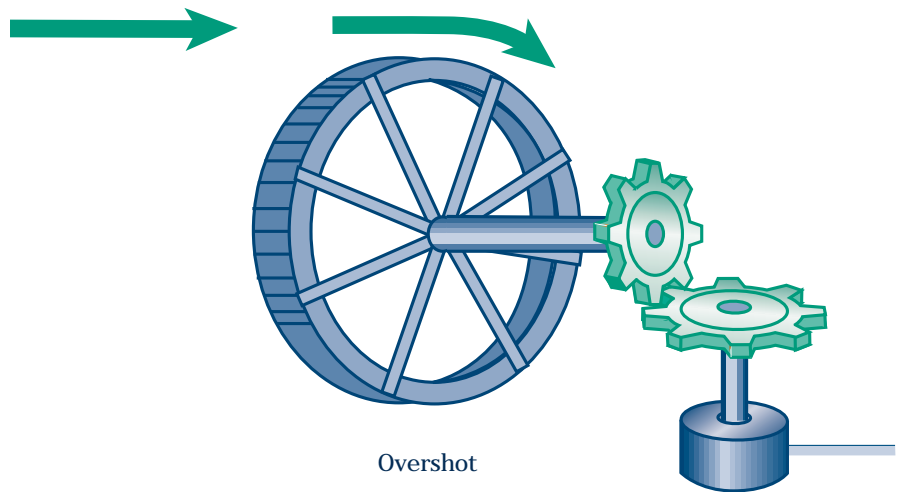
RESOURCES

Science teacher, the other units in this packet, references in this unit.

UNIT II, ACTIVITY 4

Using a topographic map and the following list of real life situations and time frames, the students will create a hydropower operation.

1. You own a logging operation and you need to buy land where you can cut down trees. You will need to build a saw mill on a stream on the property, pick the amount of land needed to form a successful operation, pick a location for the mill, and look at the cost for the operation vs. the profits gained. Time frame: late 1700's.
2. You want to open a gristmill. You need to find a location, consider the cost of the mill vs. what you will gain in profit; design a water wheel system: overshot water wheel (the water comes in from above the wheel) or undershot water wheel (the water comes in from below the wheel). Time frame: 1840's to 1870's.





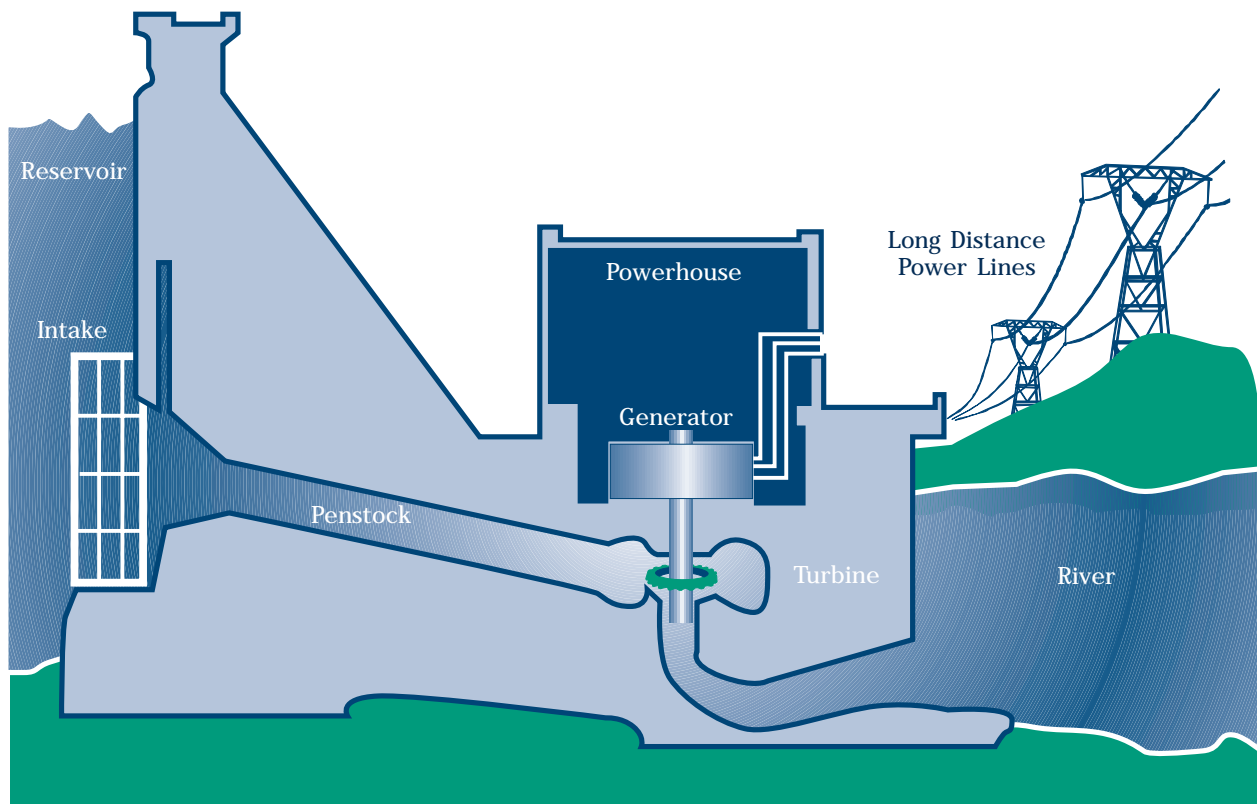
3. You want to build a hydroelectric plant. Pick the location for the dam and generating station, the location and length of the penstock (the pipe that carries the water from the dam to the generator), the height of the dam, and evacuation needs (if necessary).

Students can conduct research on the necessary information needed to complete the task they have chosen.

The teacher should also have a few different topographic maps. All maps should have some water on them.

Students can choose their assignments from a hat or they can be teacher-assigned.

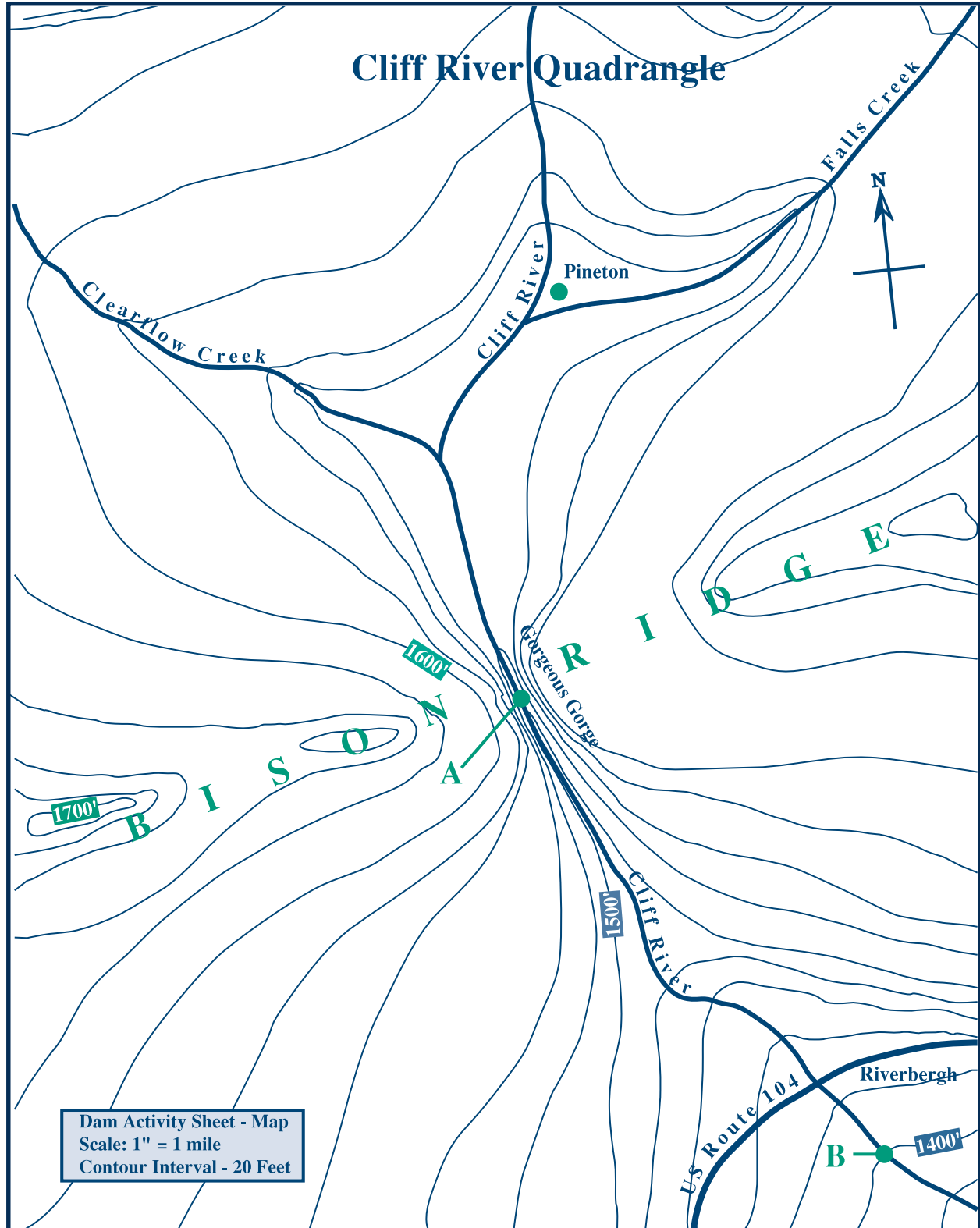
Hydroelectric Dam





UNIT II, STUDENT ACTIVITY 4 NAME _____

Use this or other topographic maps for Unit II, Activity 4.





The History of Hydropower Development

By using water for power generation, people have worked with nature to achieve a better lifestyle. The mechanical power of falling water is an age-old tool. It was used by the Greeks to turn water wheels for grinding wheat into flour more than 2,000 years ago. In the 1700's, Americans recognized the advantages of mechanical hydropower and used it extensively for milling and pumping. By the early 1900's, hydroelectric power accounted for more than 40 percent of the nation's supply of electricity. In the 1940's, hydropower provided about 75 percent of all the electricity consumed in the West and Pacific Northwest and about one-third of the total United States' electrical energy. With the increase in development of other forms of electric power generation, hydropower's percentage has slowly declined and today provides about one-tenth of the nation's electricity.

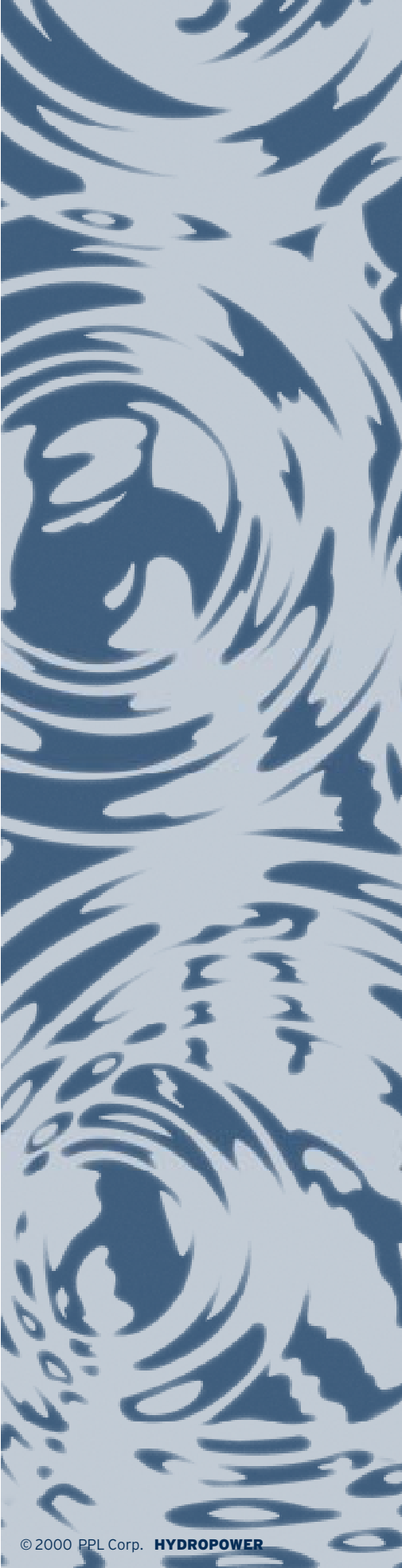
Niagara Falls was the first of the American hydroelectric power sites developed for major generation and is still a source of electric power today. The early hydroelectric plants were direct current stations built to power arc and incandescent lighting during the period from about 1880 to 1895. When the electric motor came into being, the demand for new electrical energy started its upward spiral. The years 1895 through 1915 saw rapid changes occur in hydroelectric design and a wide variety of plant styles built. Hydroelectric plant design became fairly well standardized after World War I with most development in the 1920's and 1930's being related to thermal plants and transmission and distribution.

The Bureau of Reclamation became involved in hydropower production because of its commitment to water resource management in the arid West. The waterfalls of the Reclamation dams make them significant producers of electricity. Hydroelectric power generation has long been an integral part of Reclamation's operations while it is actually a by-product of water development. In the early days, newly created projects lacked many of the modern conveniences, one of these being electrical power. This made it desirable to take advantage of the potential power source in water.

Power plants were installed at the dam sites to carry on construction camp activities. Hydropower was put to work lifting, moving, and processing materials to build the dams and dig canals. Power plants ran sawmills, concrete plants, cableways, giant shovels, and draglines. Night operations were possible because of the lights fed by hydroelectric power. When construction was complete, hydropower drove pumps that provided drainage of conveyed water to lands at higher elevations than could be served by gravity-flow canals.

Surplus power was sold to existing power distribution systems in the area. Local industries, towns and farm consumers benefited from the low-cost electricity. Much of the construction and operating costs of dams and related facilities was paid for by this sale of surplus power, rather than by the water users alone. This proved to be a great savings to irrigators struggling to survive in the West.

Reclamation's first hydroelectric power plant was built to aid construction of the Theodore Roosevelt Dam on the Salt River about 75 miles northeast of Phoenix, Arizona. Small hydroelectric generators, installed



prior to construction, provided energy for construction and for equipment to lift stone blocks into place.

Surplus power was sold to the community, and citizens were quick to support expansion of the dam's hydroelectric capacity. A 4,500 kilowatt power plant was constructed and, in 1909, five generators were in operation, supplying power for pumping irrigation water and furnishing electricity to the Phoenix area.

Power development, a byproduct of water development, had a tremendous impact on the area's economy and living conditions. Power was sold to farms, cities, and industries. Wells pumped by electricity meant more irrigated land for agriculture, and pumping also lowered water tables in those areas with water logging and alkaline soil problems. By 1916, nine pumping plants were in operation irrigating more than 10,000 acres. In addition Reclamation supplied all of the residential and commercial power needs of Phoenix. Cheap hydropower in abundant supply attracted industrial development as well. A private company was able to build a large smelter and mill nearby to process low-grade copper ore using hydroelectric power.

The Theodore Roosevelt Power Plant was one of the first large power facilities constructed by the federal government. Its capacity has since been increased from 4,500 kW to over 36,000 kW.

Power, first developed for building Theodore Roosevelt Dam and for pumping irrigation water, also helped pay for construction, enhanced the lives of farmers and city dwellers, and attracted new industry to the Phoenix area.

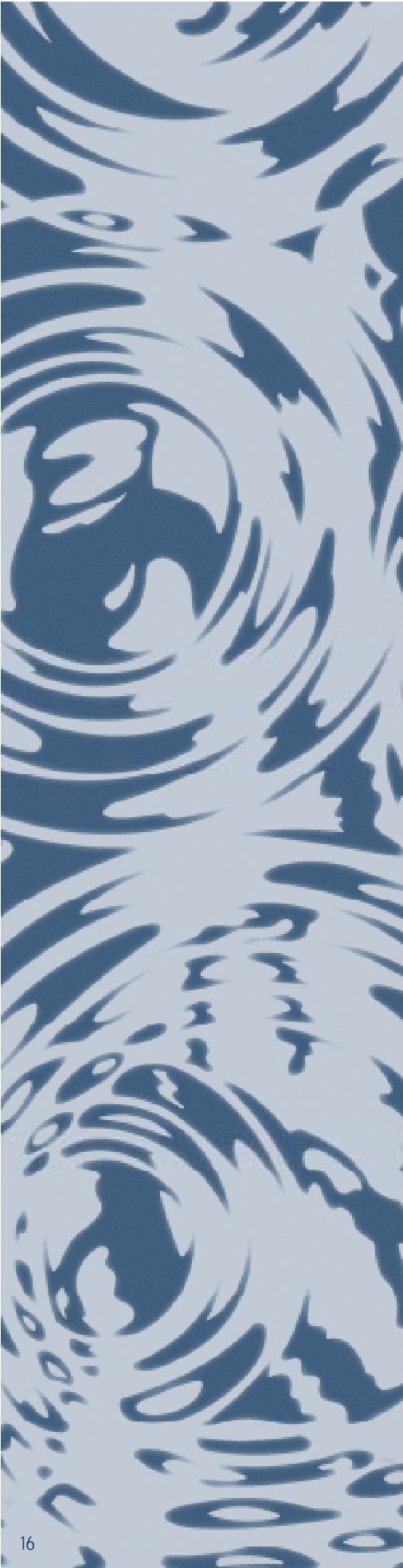
During World War I, Reclamation projects continued to provide water and hydroelectric power to western farms and ranches. This helped to feed and clothe the nation, and the power revenues were a welcome source of income to the federal government.

The Depression of the 1930's, coupled with widespread floods and drought in the West, spurred the building of great multipurpose Reclamation projects such as Grand Coulee Dam on the Columbia River, Hoover Dam on the lower Colorado River, and the Central Valley Project in California. This was the "big dam" period, and the low-cost hydropower produced by those dams had a profound effect on urban and industrial growth.

With the advent of World War II, the nation's need for hydroelectric power soared. At the outbreak of the war, the Axis nations had three times more available power than the United States. The demand for power was identified in this 1942 statement on "The War Program of the Department of the Interior:"

"The war budget of \$56 billion will require 154 billion kWh of electric energy annually for the manufacture of airplanes, tanks, guns, warships, and fighting material, and to equip and serve the men of the Army, Navy and Marine Corps."

Each dollar spent for wartime industry required about 2-3/4 kWh of electric power. The demand exceeded the total production capacity of all existing electric utilities in the United States. To produce enough aluminum to meet the President's goal of 60,000 new planes in 1942 alone required 8.5 billion kWh of electric power.



Hydropower provided one of the best ways for rapidly expanding the country's energy output. Addition of more power plant units at dams throughout the West made it possible to expand energy production, and construction pushed ahead to speed up the availability of power. In 1941, Reclamation produced more than 5 billion kWh, resulting in a 25 percent increase in aluminum production. By 1944 Reclamation quadrupled its hydroelectric power output.

From 1940 through 1945, Reclamation power plants produced 47 billion kWh of electricity, enough to make:

- 69,000 airplanes
- 79,000 machine guns
- 5,000 ships
- 7,000,000 aircraft bombs
- 5,000 tanks
- 31,000,000 shells

During the war, Reclamation was the major producer of power in the West where needed resources were located. The supply of low-cost electricity attracted large defense industries to the area. Shipyards, steel mills, chemical companies, oil refineries, and automotive and aircraft factories all needed vast amounts of electrical power. Atomic energy installations were located at Hanford, Washington, to make use of hydropower from Grand Coulee.

While power output of Reclamation projects energized the war industry, it was also used to process food, light military posts, and meet needs of the civilian population in many areas.

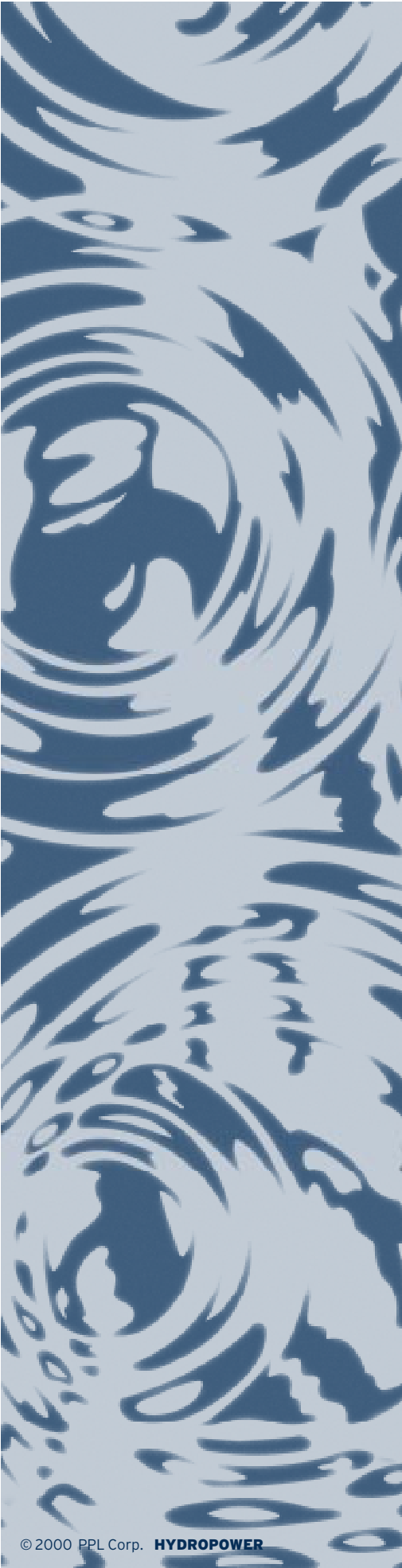
With the end of the war, power plants were put to use in rapidly developing peacetime industries. Hydropower has been vital for the West's industries which use mineral resources or farm products as raw materials. Many industries have depended wholly on federal hydropower. In fact, periodic low flows on the Columbia River have disrupted manufacturing in that region.

Farming was tremendously important to America during the war and continues to be today. Reclamation delivers 10 trillion gallons of water to more than 31 million people each year and provides 1 out of 5 western farmers (140,000) with irrigation water for 10 million farmland acres that produce 60 percent of the nation's vegetables and 25 percent of its fruits and nuts.

Hydropower directly benefits rural areas in three ways:

- It produces revenue which contributes toward repayment of irrigation facilities, easing the water user's financial burden.
- It makes irrigation of lands at higher elevations possible through pumping facilities.
- It makes power available for use on the farm for domestic purposes.

Reclamation is second only to the Corps of Engineers in the operation of hydroelectric power plants in the United States. Reclamation uses some of the power it produces to run its facilities, such as pumping plants. Excess hydropower is sold first to preferred customers, such as rural electric power co-ops, public utility districts, municipalities, and state and federal agencies. Any remaining power may be sold to private electric utilities. Reclamation generates enough hydropower to meet the needs of millions of people, and power revenues exceed \$900 million a year. Power revenues are returned to the Federal Treasury to repay the cost of constructing, operating, and maintaining projects.



An excellent book detailing the history of hydroelectricity is the two-volume set of “Hydroelectric Development in the United States 1880 - 1940” prepared for the Task Force on Cultural Resource Management, Edison Electric Institute, Duncan Hay, New York State Museum, 1991. This book details American hydroelectric development from the first use of hydroelectric power around 1880 up to 1940.

The following time line includes data from the above referenced book highlighting a chronology of American hydroelectric development.

- 1879 First commercial arc lighting system installed, Cleveland, Ohio.
- 1879 Thomas Edison demonstrates incandescent lamp, Menlo Park, New Jersey.
- 1880 Grand Rapids Michigan: brush arc light dynamo driven by water turbine used to provide theater and storefront illumination.
- 1881 Niagara Falls, New York; Brush dynamo, connected to turbine in Quigley’s flour mill lights city street lamps.
- 1882 Appleton, Wisconsin; Vulcan Street Plant, first hydroelectric station to use Edison system.
- 1883 Edison introduces “three-wire” transmission system.
- 1886 Westinghouse Electric Company organized.
- 1886 Frank Sprague builds first American transformer and demonstrates use of step up and step down transformers for long distance AC power transmission in Great Barrington, Massachusetts.
- 1886 40 to 50 water powered electric plants reported on line or under construction in the U.S. and Canada.
- 1887 San Bernardino, California; High Grove Station, first hydroelectric plant in the West.
- 1888 Rotating field AC alternator invented.
- 1889 American Electrical Directory lists 200 electric companies that use water power for some or all of their generation.
- 1889 Oregon City, Oregon, Willamette Falls Station, first AC hydroelectric plant. Single-phase power transmitted 13 miles to Portland at 4,000 volts, stepped down to 50 volts for distribution.
- 1891 Ames, Colorado; Westinghouse alternator driven by Pelton water wheel, 320 foot head. Single phase, 3,000 volt, 133 cycle power transmitted 2.6 miles to drive ore stamps at Gold King Mine.
- 1891 Frankfort on Main, Germany; first three-phase hydroelectric system used for 175 km, 25,000 volt demonstration line from plant at Lauffen.
- 1891 60 cycle AC system introduced in U.S.
- 1892 Bodie, California; 12.5 mile, 2,500 AC line carried power from hydroelectric plant to ore mill of Standard Consolidated Mining Co.



- 1892** San Antonio Creek, California; single-phase 120 kW plant, power carried to Pomona over 13 mile 5,000 volt line. Voltage increased to 10,000 and line extended 42 miles to San Bernardino within a year. First use of step-up and step-down transformers in hydroelectric project.
- 1892** General Electric Company formed by the merger of Thomson-Houston and Edison General Electric.
- 1893** Mill Creek, California; first American three-phase hydroelectric plant. Power carried 8 miles to Redlands on 2,400 volt line.
- 1893** Westinghouse demonstrates “universal system” of generation and distribution at Chicago exposition.
- 1893** Folsom, California; three-phase, 60 cycle, 11,000 volt alternators installed at plant on American River. Power transmitted 20 miles to Sacramento.
- 1889-93**
Austin, Texas; first dam designed specifically for hydroelectric power built across Colorado River.
- 1895** Niagara Falls, New York; 5,000 horsepower, 60 cycle, three-phase generators go into operation.
- 1897** Mechanicville, New York; Hudson River Power Transmission Company completes 5,250 kW, 38 cycle plant and 17 mile line to Schenectady.
- 1897** Minneapolis, Minnesota; Lower Dam hydroelectric plant completed at St. Anthony’s Falls on the Mississippi.
- 1898** Los Angeles, California; 83 mile line built from Santa Anna River No. 1 hydroelectric plant.
- 1899** Nevada City, California; power from Nevada City, Yuba, and Colgate hydroelectric plants sold to Sacramento Power & Light Co. over 62 mile line to Folsom.
- 1899** Kalamazoo, Michigan; 24-mile, 22,000 volt line built from Trowbridge Dam hydroelectric plant.
- 1900** Oakland, California; 140 mile line built from Colgate hydroelectric plant by Bay Counties Power Company.
- 1901** First Federal Water Power Act.
- 1901** Trenton Falls, New York; first installation of high head reaction turbines designed and built in the U.S.
- 1889-1902**
Massena, New York; dam and powerhouse built at confluence of St. Lawrence & Grasse Rivers. Power primarily used for smelting by Aluminum Corporation of America (ALCOA).
- 1902** Reclamation Act of 1902 establishes the Reclamation Service which later becomes the U.S. Bureau of Reclamation. Included in the act is the authority to develop the hydropower potential of Reclamation projects.
- 1897-1903**
Sault Ste. Marie, Michigan; Michigan, Lake Superior Power Company Plant, 80 horizontal shaft units delivered 40,000 horsepower.
- 1905** Sault Ste. Marie, Michigan; first low head plant with direct connected vertical shaft turbines and generators.
- 1906** Ilchester, Maryland; fully submerged hydroelectric plant built inside Ambursen Dam.
- 1906** Town Sites and Power Development Act - Authorized Secretary of the Interior to lease surplus power or power privileges.
- 1907** Hauser Lake, Montana; short lived steel dam built across Missouri River by Wisconsin Bridge & Iron Co. for Helena Power & Transmission Co.
- 1910** Federal Water Power Act revised.
- 1910** Big Creek, California; construction begins on a hydroelectric system that would eventually include eight powerhouses, over a 6,200 foot fall, rated at 685,000 kW.
- 1905-1911**
Roosevelt Dam, Salt River, Arizona; largest and last masonry dam ever built by U.S. Bureau of Reclamation. Mixed use irrigation/hydroelectric project.
- 1911** R. D. Johnson invents differential surge tank and Johnson hydrostatic penstock valve.
- 1912** Holtwood, Pennsylvania; first commercial installation of Kingsbury vertical thrust bearing in hydroelectric plant.
- 1910-1913**
Keokuk, Iowa; Mississippi River Power Transmission Plant.



- 1913 Tallulah Falls, Georgia; highest head hydroelectric plant in the East.
- 1913 Nolenchucky, Tennessee; first use of W. M. White's plate steel spiral turbine case.
- 1914 S. J. Zowski develops high specific speed reaction (Francis) turbine runner for low head applications.
- 1914 Argo, Michigan; streamlined draft tube introduced.
- 1916 First commercial installation of fixed-blade propeller turbine designed by Forrest Nagler.
- 1917 Hydracone draft tube patented by W. M. White.
- 1917 National Defense Act authorizes construction of government dam and power plant at Muscle Shoals, Alabama.
- 1919 Viktor Kaplan demonstrates adjustable blade propeller turbine runner at Podedbrady, Czechoslovakia.
- 1920 Federal Power Act establishes Federal Power Commission with authority to issue licenses for hydroelectric development on public lands.
- 1922 First hydroelectric plant built specifically for peaking power.
- 1924 First World Power Conference, London.
- 1929 Del Rio, Texas; first Kaplan turbines installed in the U.S. — Lake Walk plant.
- 1929 Rocky River Plant, New Milford, Connecticut; first major pumped storage hydroelectric plant.
- 1930 Federal Power Act revised, independent full-time Federal Power Commission established.
- 1931 Construction begins, Boulder (later Hoover) Dam, Colorado River, Arizona-Nevada.
- 1933 Tennessee Valley Authority Act.
- 1933 Construction begins, Grand Coulee Dam, Columbia River, Washington.
- 1935 Federal Power Commission authority extended to all hydroelectric projects built by utilities engaged in interstate commerce.
- 1933-1937 Bonneville Dam, Columbia River, Washington/Oregon.
- 1937 First power generated at Hoover Dam, Arizona/Nevada.
- 1937 Bonneville Project Act - Created BPA (Bonneville Power Administration).
- 1940 Over 1,500 hydroelectric facilities produce about one third of the United States' electrical energy.
- 1941 First power generated at Grand Coulee power plant, Washington - Presently the third largest hydroelectric plant in the world at 6,800 megawatts installed capacity.
- 1944 First power generated at Shasta Dam in California.
- 1964 First power generated at Glen Canyon Dam in Arizona.
- 1968 Wild and Scenic Rivers Act - Protects rivers in their natural state by excluding them from consideration as hydroelectric power sites.
- 1969 National Environmental Policy Act - Ensures that environmental considerations are systematically taken into account by federal agencies.
- 1974 Fish and Wildlife Coordination Act - Ensures equal consideration of fish and wildlife protection in the activities of federal agencies.
- 1978 Public Utility Regulatory Policies Act - Encourages small-scale power production facilities; exempted certain hydroelectric projects from federal licensing requirements, and required utilities to purchase - at "avoided cost" rates - power from small production facilities that use renewable resources.
- 1979 First power generated at New Melones Dam in California. Built by the Corps of Engineers and turned over to the Bureau of Reclamation, this is the last of the larger power plants (over 30 megawatts) in the Bureau of Reclamation's power program.
- 1980 Energy Security Act - Exempted small-scale hydroelectric power from some licensing requirements.
- 1980 Crude Oil Windfall Profit Tax - Provided tax incentives to small-scale hydro-power producers.
- 1983 First power generated at Itaipu power plant, Brazil/Paraguay - Presently the largest hydroelectric power plant in the world at 12,600 megawatts installed capacity.



- 1986** Electric Consumers Protection Act - Amended the Federal Power Act to remove public preference for relicensing actions; gives equal consideration to nonpower values (e.g., energy conservation, fish, wildlife, recreation, etc.) as well as to power values when making license decisions.
- 1986** First power generated at Guri (Raul Leoni) power plant, Venezuela - Presently the second largest hydroelectric power plant in the world at 10,300 megawatts installed capacity.
- 1992** The top five electric generating countries in order are Canada, the United States, Brazil, Russia, and China.
- 1992** Energy Policy Act of 1992 - An act to provide for improved energy efficiency. Includes provisions to allow for greater competition in energy sales and amendments to Section 211 of the Federal Power Act.
- 1994** The Federal Energy Regulatory Commission has authorized, through its licensing authority under the Federal Power Act, almost 1,700 hydroelectric projects. These projects include about 2,300 dams and multipurpose water resource developments that provide about 55,000 MW of hydroelectric generating capacity (about one-half of the nation's hydro capacity).
- 1994** Hydropower Research Foundation established by the National Hydropower Association to facilitate research and to promote educational opportunities on the value of hydropower.
- 1997** Hydroelectric generation provides about 10 percent of the United States' electricity.

Hydropower's Historical Progression

- BC Used by the Greeks to turn water wheels for grinding wheat into flour, over 2,000 years ago.
- 1775 U.S. Army Corps of Engineers founded, with establishment of Chief Engineer for the Continental Army.
- 1880 Michigan's Grand Rapids Electric Light and Power Company, generating electricity by dynamo, belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps.
- 1881 Niagara Falls, city street lamps powered by hydropower.
- 1886 About 45 water-powered electric plants in the U.S. and Canada.
- 1887 San Bernardino, California, first hydroelectric plant in the West.
- 1889 200 electric plants in the U.S. use water power for some or all generation.
- 1901 First Federal Water Power Act.
- 1902 Bureau of Reclamation established.
- 1907 15 percent of electric generating capacity in U.S. was provided in hydropower.
- By 1920 25 percent of U.S. electrical generation was hydropower.
- 1920 Federal Power Act establishes Federal Power Commission authority to issue licenses for hydro development on public lands.
- 1933 Tennessee Valley Authority established.
- 1935 Federal Power Commission authority extended to all hydroelectric projects built by utilities engaged in interstate commerce.
- 1937 Bonneville Dam, first federal dam, begins operation on the Columbia River.
- 1937 Bonneville Power Administration established.
- By 1940 40 percent of electrical generation was hydropower.
- Between 1921 and 1940
Conventional capacity in the U.S. tripled; almost tripled again between 1940 and 1980.
- Currently About 10 percent of U.S. electricity comes from hydropower. Today, there is about 74,000 MW of conventional capacity and 18,000 MW of pumped storage.

Teacher's Notes

Teacher's Notes

Teacher's Notes

Teacher's Notes

Unit III

Water + Gravity = Energy

UNIT GOAL

This unit will demonstrate four conditions that affect how water can provide energy to do work. The concepts of falling water, water pressure, slope angle of falling water, and changing the diameter of the water flow outlet will be discussed in four laboratory exercises. It is important to stress the concepts of potential and kinetic energy and how they relate to a body of water for a lead into the next unit.

ACTIVITIES

1. Falling Water Activity: Students will observe and understand the potential energy of falling water.
2. Waterfall Angles and Flow Rate: Students will observe and understand how the slope of falling water affects the rate of flow.
3. Water Pressure and Flow Rate: Students will observe, document and understand the relationship between water pressure and water flow.
4. Diameter and Water Flow: Students will understand how the rate of water flow can be influenced by the diameter of the outlet through which it flows.

DEMONSTRATIONS

See attached activities.

REVIEW

Teacher-generated questions or make a review sheet.

ASSESSMENT

Teacher-generated quiz or test on the topic covered.

UNIT VOCABULARY

1. Energy: ability to do work
2. Kinetic energy: energy of motion (moving water)
3. Potential energy: stored energy (reservoir)
4. Water flow: speed at which water is moving
5. Water pressure: downward force of water upon itself and other materials caused by gravity

1. FALLING WATER ACTIVITY

Introduction

Prior to performing this experiment, discuss the concepts of potential energy and kinetic energy. The water in the tube has potential energy prior to being released. The higher the tube is held, the more potential energy it has. When the water is released from the tube, it is in motion and the falling water possesses kinetic energy.

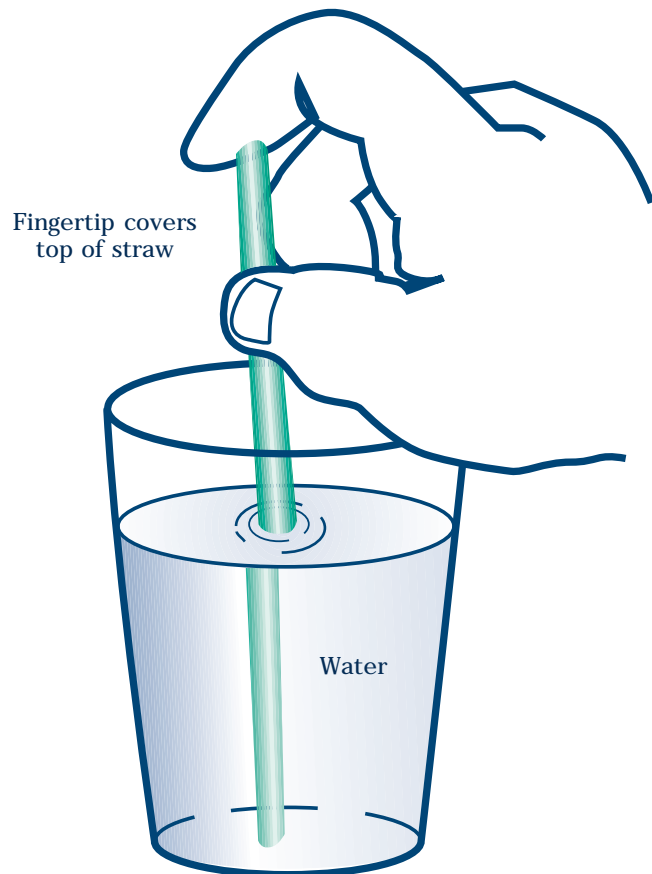
Objectives

Students will perform an experiment to determine whether the height from which water falls influences the size of the splash. Students will develop an understanding between the potential energy water possesses and its kinetic energy.

Materials

- cup of water
- straw
- meter stick
- metric ruler
- newspaper

continued on page 16





continued from page 15

Procedure:

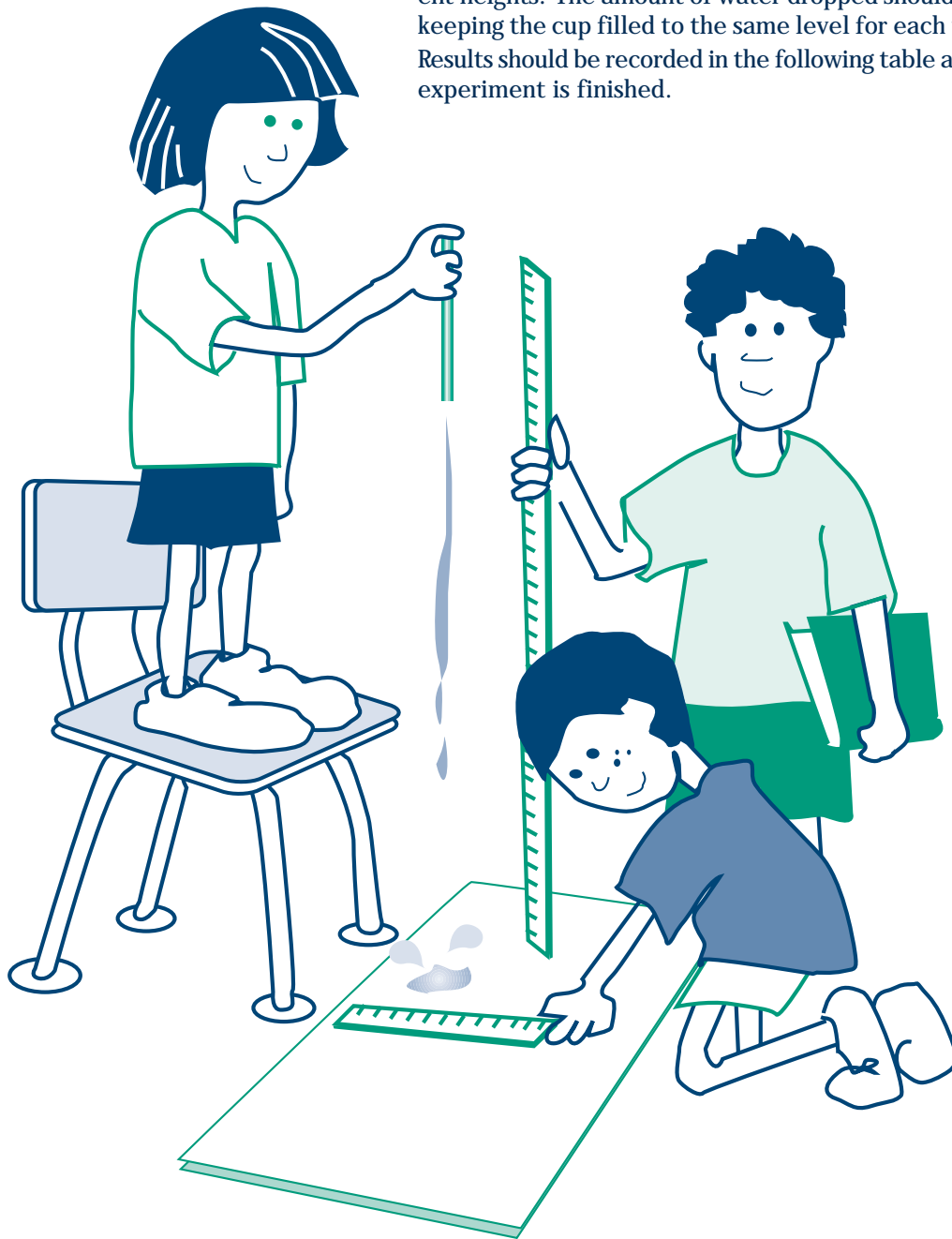
One student holds a meter stick perpendicular to the floor.

One student fills a cup or beaker of water to a measured line. Insert a drinking straw to the bottom of the cup. Place one finger over the top of the straw to hold the water in the straw. Hold the straw a measured distance from the floor and remove the finger to release the water.

One student spreads newspaper on the floor under the meter stick and, after the water is dropped, measures the size of the splash.

This procedure should be repeated at least two more times at different heights. The amount of water dropped should be kept the same by keeping the cup filled to the same level for each trial.

Results should be recorded in the following table and graphed when the experiment is finished.





UNIT III, ACTIVITY 1 NAME _____

height	trial 1	trial 2	trial 3	splash average

1. Which height produced the greatest splash distance?

2. At which height does the water have the greatest potential energy? _____

3. Why was it important to do an average of three trials?

4. What is the relationship between drop height and splash size?



2. WATERFALL ANGLES AND FLOW RATE

Will different angles of moving water affect the speed of its flow rate?

Introduction

This experiment will show how water energy can be changed into mechanical energy by the use of the flow meter. Changing the slope of how the water flows will allow students to conclude that more work can be created with a steeper slope.

Objectives

Students will determine whether the vertical distance/slope of a water source affects the speed of its flow.

Students will understand how the rate of falling water corresponds with its potential as a power source.

Materials

- two 2-liter soda bottles
- two pour spouts
- two pieces of salastic tubing (30 cm each)
- flow meter
- stop clock
- meter stick

Procedure

1. The instructor assigns two proportional vertical distances, using slope 0 (90 degrees) as the third control standard.
2. The instructor assigns a volume of water to be present within the source container.
3. Students proceed to connect the tubing to both ends of the flow meter.

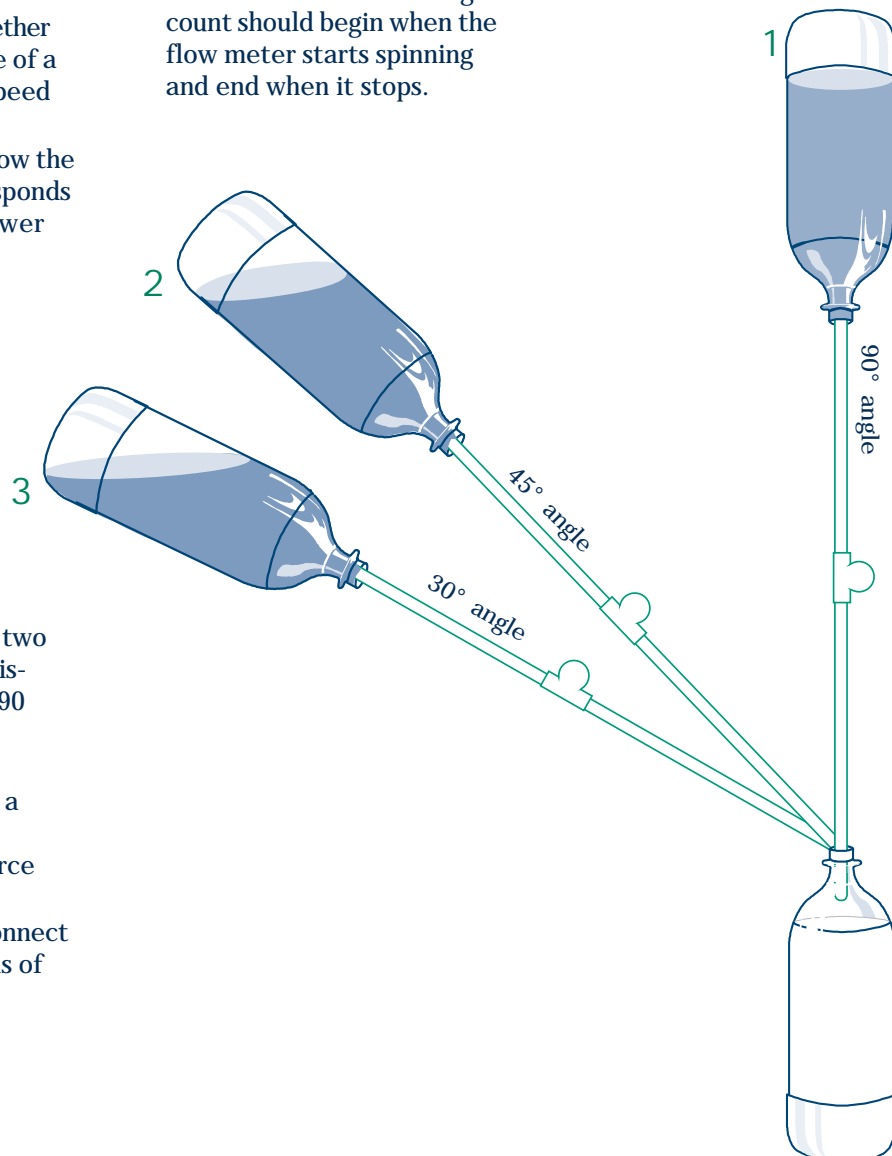
4. Students label containers “Source” and “Reservoir” respectively, and attach a pouring spout to the top of each.
5. The tubing is connected to each spout and water is placed at the appropriate volume in the source container.

* Note: Be sure salastic tubing is fully extended to allow for accurate flow results.

6. Initiate water flow for trial #1 at slope 0 (90 degrees) and record results. Timing count should begin when the flow meter starts spinning and end when it stops.

* Note: Be sure “Source” container is held upright during each trial.

7. Repeat procedure for trials #2 and 3 at the assigned vertical height and record results.
8. Results should be recorded in the following data chart and graphed to illustrate the relationship between the force of falling water and its flow rate.





UNIT III, ACTIVITY 2 NAME _____

Which vertical distance produces the fastest flow rate? _____

Prediction: _____

Data Chart

slope change height (cm)	flow rate (seconds)

1. Which vertical height produced the fastest flow rate? _____

2. Explain why this occurred. _____

Match the following:

3. ____ mechanical energy

a. water stored in bottle

4. ____ potential energy

b. flowing water

5. ____ kinetic energy

c. flow meter



3. WATER PRESSURE AND FLOW RATE

How can the rate of water flow be affected by water pressure?

Introduction

Water pressure influences the rate of water flow. In a collection chamber or reservoir, water pressure is greatest at the bottom and least at the top. This activity will demonstrate the concept of water pressure.

*Note: Review the concepts of potential energy and kinetic energy. The water in the container acts as a reservoir of stored (potential) energy. When the water is released, it is transformed into kinetic energy.

Objectives

- Students will understand the relationship between water pressure and water flow
- Students will record data collected
- Students will interpret data and form conclusions

Materials

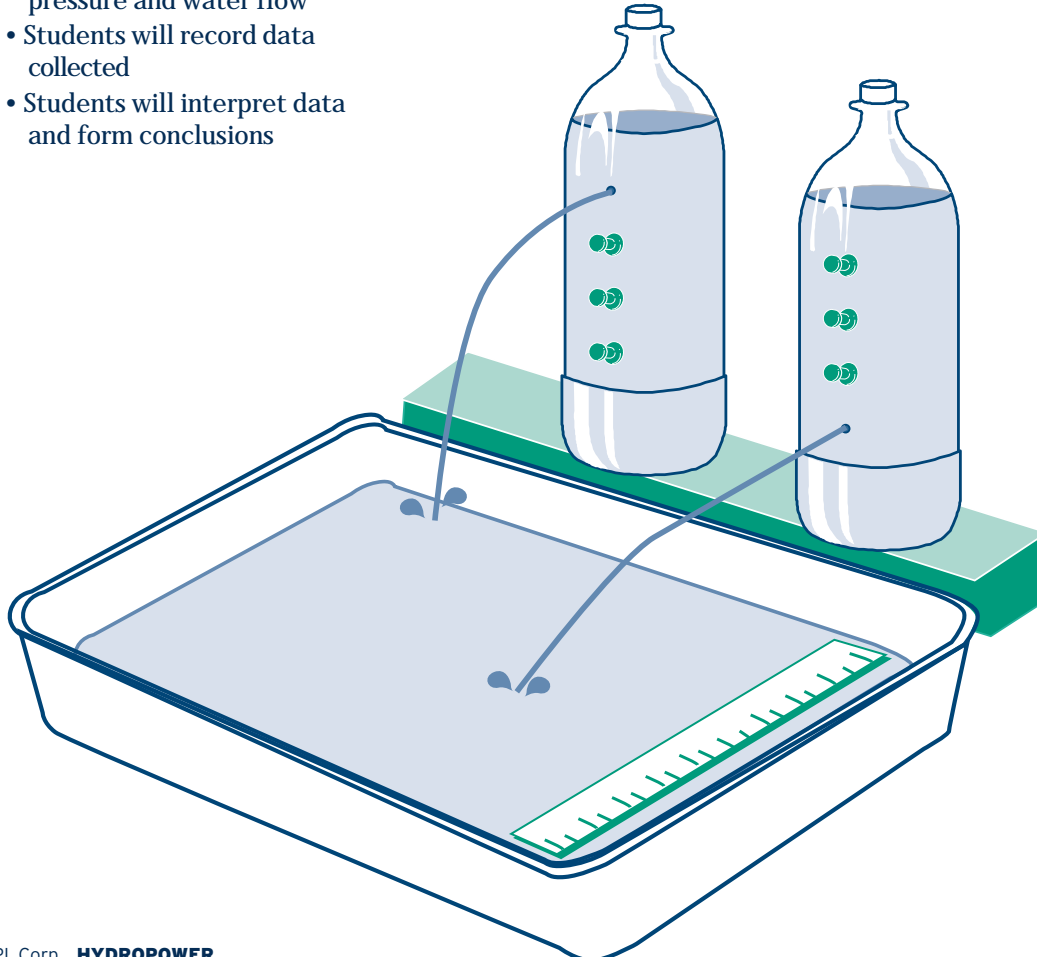
- two 2-liter soda bottles
- 4 tacks or push pins
- 1 meter stick
- 1 collection tray (aluminum pan)

Procedure

1. Hand out lab worksheet, materials, and organize students into groups.
2. Have students punch pin holes at 5 cm intervals from the bottom of the container to the top. Leave the pin in each hole.
3. Fill the container to the top with water and place on a book or similar flat object for higher elevation.
4. Place the collection tray below the container to capture the falling water.

5. Before removing the pins, ask the question: "From which pin hole will the water travel out the farthest?" Have the students answer the question in the prediction section of the worksheet.
6. Start by removing the top pin. Measure the distance where the water touches the tray and record in the data chart. Make sure to refill the container before every test!
7. Refill and repeat 3 times
8. Continue this procedure for the next height and record in the data chart. Compute the averages when completed and answer the follow up questions.

* Note: If needed, use scotch tape to fill the holes to prevent leakage.



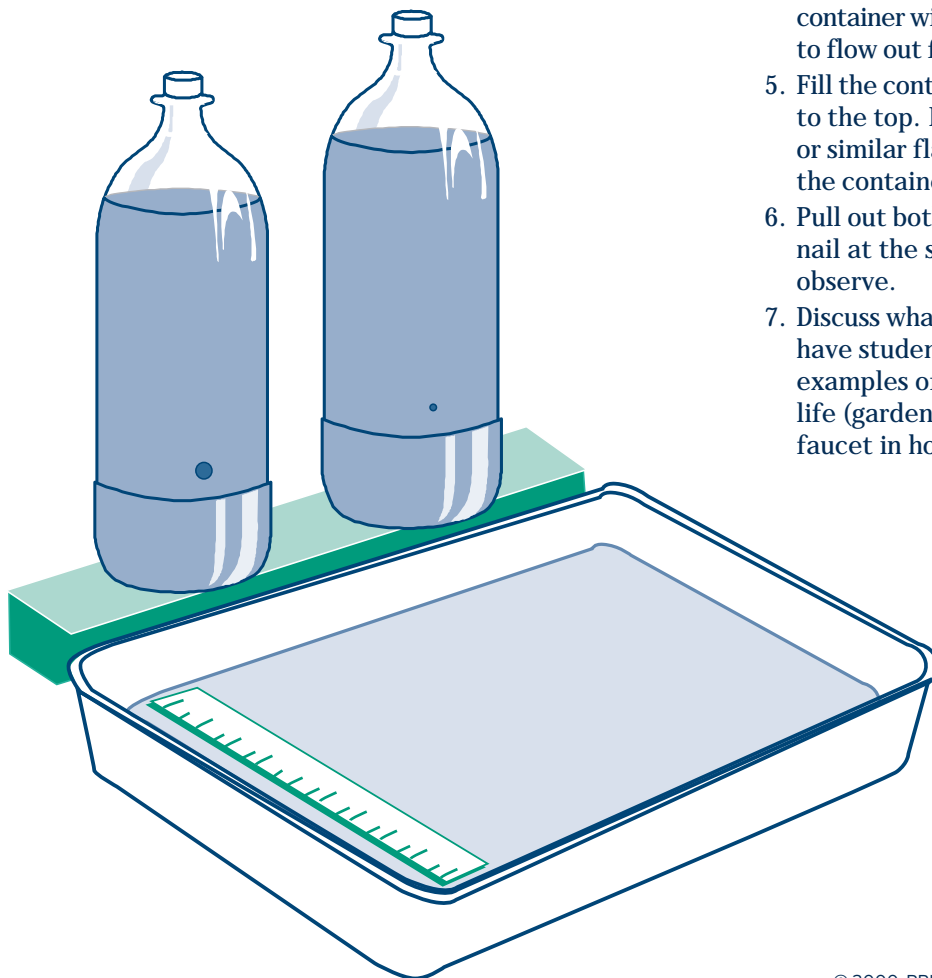


4. OUTLET DIAMETER AND WATER FLOW

How can the rate of water flow be influenced by the diameter of the object through which it flows?

Introduction

It is recommended to do this demonstration after completing Activity 3. The diameter of the outlet in which water flows can influence the rate, or speed, of the water. For instance, the water in a garden hose comes out at a given speed. When a nozzle is placed over the hose, this decreases the diameter of the outlet for the water to flow out. When the nozzle is then opened, the water rushes out with a greater speed or force. This demonstration will be used to show this concept.



Objectives

Students will understand how the diameter of the outlet through which water flows influences the rate, or speed, of the water.

Materials

- two 2-liter soda bottles
- 1 push pin
- 1 ten penny nail

Procedure

1. Punch 1 hole with a push pin 2 inches from the bottom of container 1.
Leave the pin in the container.
2. Punch 1 hole with a ten penny nail 2 inches from the bottom of container 2. Leave the nail in the container.
3. Explain the difference between the hole size diameters.
4. Have students predict which container will allow the water to flow out faster and further.
5. Fill the containers equally to the top. Place a book or similar flat object under the containers for elevation.
6. Pull out both push pin and nail at the same time and observe.
7. Discuss what occurred and have students come up with examples of this in everyday life (garden hose, water faucet in house).



UNIT III, ACTIVITY 3 NAME _____

From which pin hole will water travel out the farthest? _____

Prediction: _____

Data Chart

DISTANCE OF FLOW IN CM				
pin height	test 1	test 2	test 3	average
top				
bottom				

Questions

1. At which pin height did the water travel the least? _____

2. At which pin height did the water travel the most? _____

3. Approximately how many times farther did the water released at the bottom of the container travel than at the top of the container? _____

4. Explain why the water travels the most when released from the bottom of the container.

Teacher's Notes

Teacher's Notes

Teacher's Notes

Teacher's Notes

Unit IV

How Does Hydropower Work?

UNIT GOALS

1. This unit will show and compare how various hydropower systems have been used through the ages. A diagram of the two basic water wheel types (overshot and undershot) and the water wheel activity will be used to show how people first started to harness the power of water. A labeled diagram of a hydropower plant will help students understand the hydropower process. The electrical generator activity will show how a generator is capable of making electricity.
2. Students will understand how water is used to do work.
3. Students will identify the components used to create a hydropower system.
4. Students will apply their knowledge of hydropower systems to understand how water is used to create electricity.
5. Students will be able to analyze efficiency of different water-wheel systems.

ACTIVITIES

1. How can falling water do work?
Diagram: Overshot and undershot waterwheel.
2. How does a generator make electricity? Demonstration.
Diagram: Electrical generator.
Diagram: Hydropower plant.
3. Economics of hydropower.

REVIEW

Teacher generated questions.
See attached hydroelectric dam illustration.

ASSESSMENT

Teacher-generated quiz or test, vocabulary quiz on terms.

CROSS-CURRICULAR

Technology/Math

1. FALLING WATER DOING WORK

Goal

Students will design a waterwheel model to show how water can do work.

Materials

- water
- plastic one-gallon milk jug (cut in half below handle)
- scrap plastic from milk jug to make fins
- coat hanger or dowel
- utility knife
- 1 large cork
- hole punch
- pour spout for milk jug
- string (cut into equal lengths for each team)
- film canister
- pennies
- tape
- scissors

Time Period

Two class periods.

Day 1 Activity

1. Break into lab groups and hand out materials to students.
2. Show students how to make a water wheel fin using the cork, utility knife and waste plastic (cut slit in cork and insert plastic fin).
3. Give students the following problem: How can you design a water wheel to raise a canister of weights? Explain how the weights (pennies) will go into the film canister.
4. Have students make a drawing of what their water wheel design will look like.
5. Students will then construct their models.
6. Students will then document on their lab worksheet how many pennies they were able to raise with their water wheel.

* Note: You may set this up as some type of competition and award prizes for best design.

Day 2 Activity

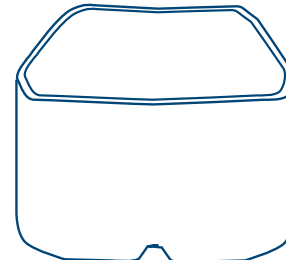
Testing Variables

1. Teams will test the following variables that may affect their results:
 - a. Fin size (small to larger)
 - b. Water height
2. After this is completed, the teacher should discuss results with the class.
3. Hand out vertical water wheel diagrams and discuss their uses.

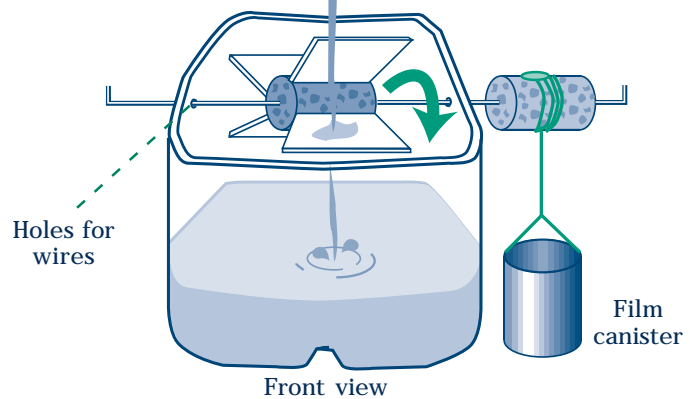
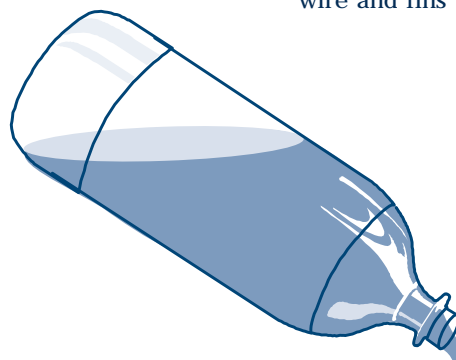
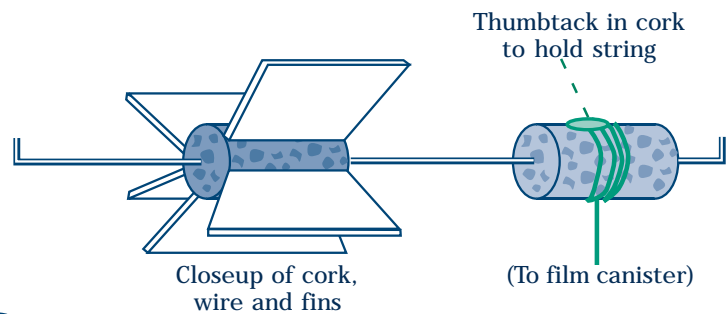
UNIT VOCABULARY

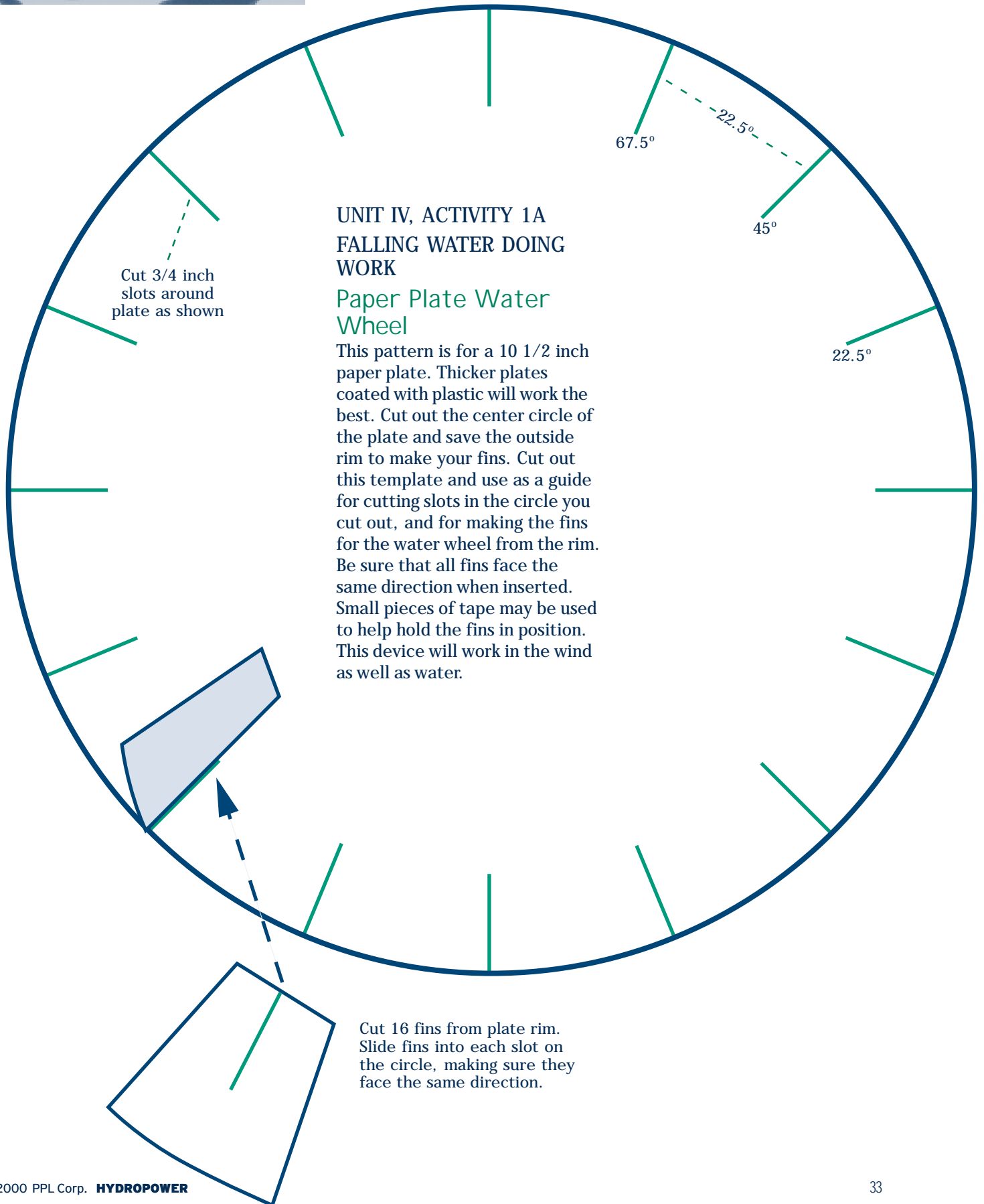
1. Dam: structure which stores water and increases headflow
2. Generator: device that converts mechanical energy into electrical energy through the use of magnetic fields and a rotating turbine shaft
3. Head: distance water falls to generate power
4. Hydropower: using the energy of moving water to do work
5. Penstock: pipe that carries the water from the dam to the turbines
6. Reservoir: body of water stored for human use behind a dam
7. Shaft: connects turbine to generator
8. Spillway: area of dam used for overflow of water to regulate reservoir levels
9. Transformer: device which converts electricity from the hydro-plant to a distribution system
10. Turbine: a horizontal wheel with special blades that is attached to a shaft which rotates when moving water strikes it
11. Vertical waterwheel: early form of hydropower system consisting of a rotating wheel set in motion by moving water; useful in creating mechanical energy
12. Wicket gates: regulate the amount of water that enters the turbines from the penstock

UNIT IV, ACTIVITY 1 FALLING WATER DOING WORK



Side view





UNIT IV, ACTIVITY 1A
FALLING WATER DOING
WORK

Paper Plate Water Wheel

This pattern is for a 10 1/2 inch paper plate. Thicker plates coated with plastic will work the best. Cut out the center circle of the plate and save the outside rim to make your fins. Cut out this template and use as a guide for cutting slots in the circle you cut out, and for making the fins for the water wheel from the rim. Be sure that all fins face the same direction when inserted. Small pieces of tape may be used to help hold the fins in position. This device will work in the wind as well as water.

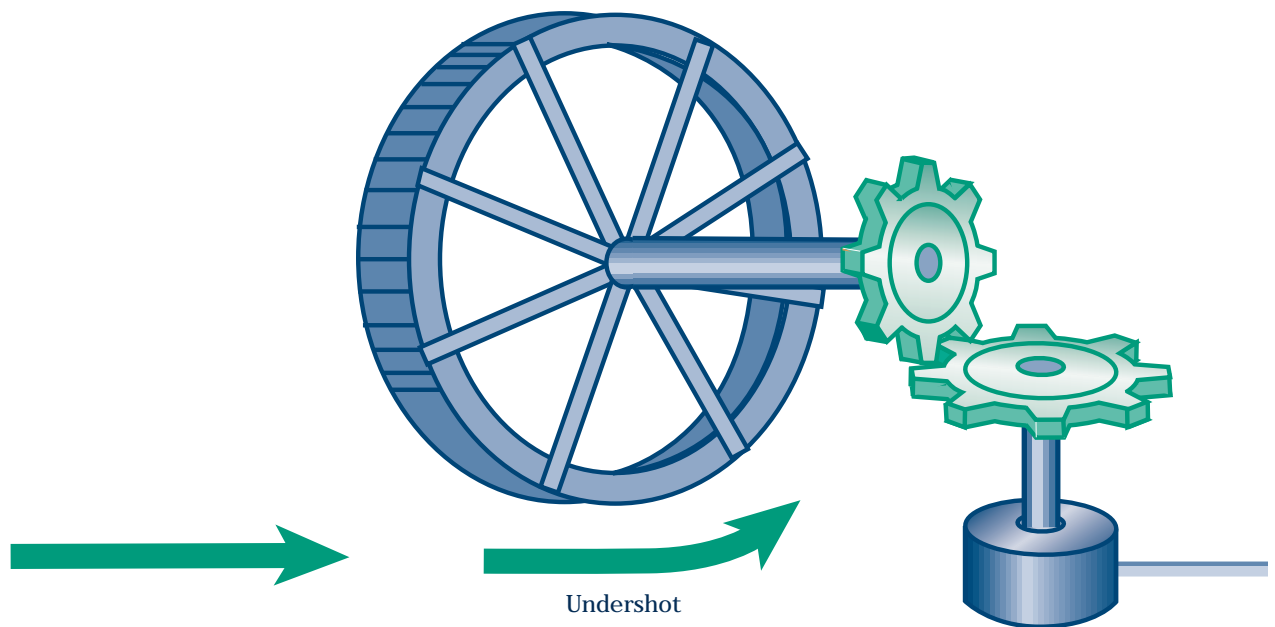
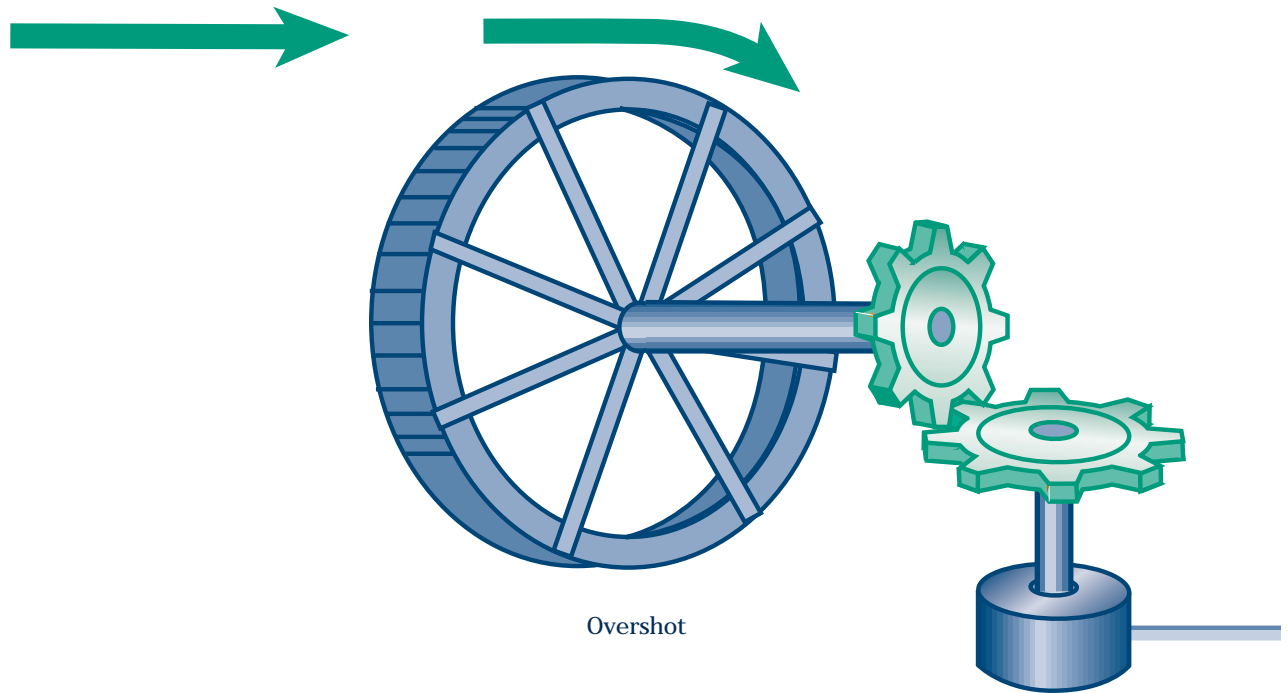
Cut 3/4 inch slots around plate as shown

Cut 16 fins from plate rim. Slide fins into each slot on the circle, making sure they face the same direction.



UNIT IV, ACTIVITY 1

Vertical water wheel model.
See student activity sheet.





UNIT IV, ACTIVITY 2

PART I

Demonstration

How does a generator make electricity?

Objectives

Students will understand how a generator makes electricity by watching a demonstration and completing a generator diagram. Students will learn that when a shaft is attached to a turbine (water wheel), a generator can be used to produce electricity.

Materials

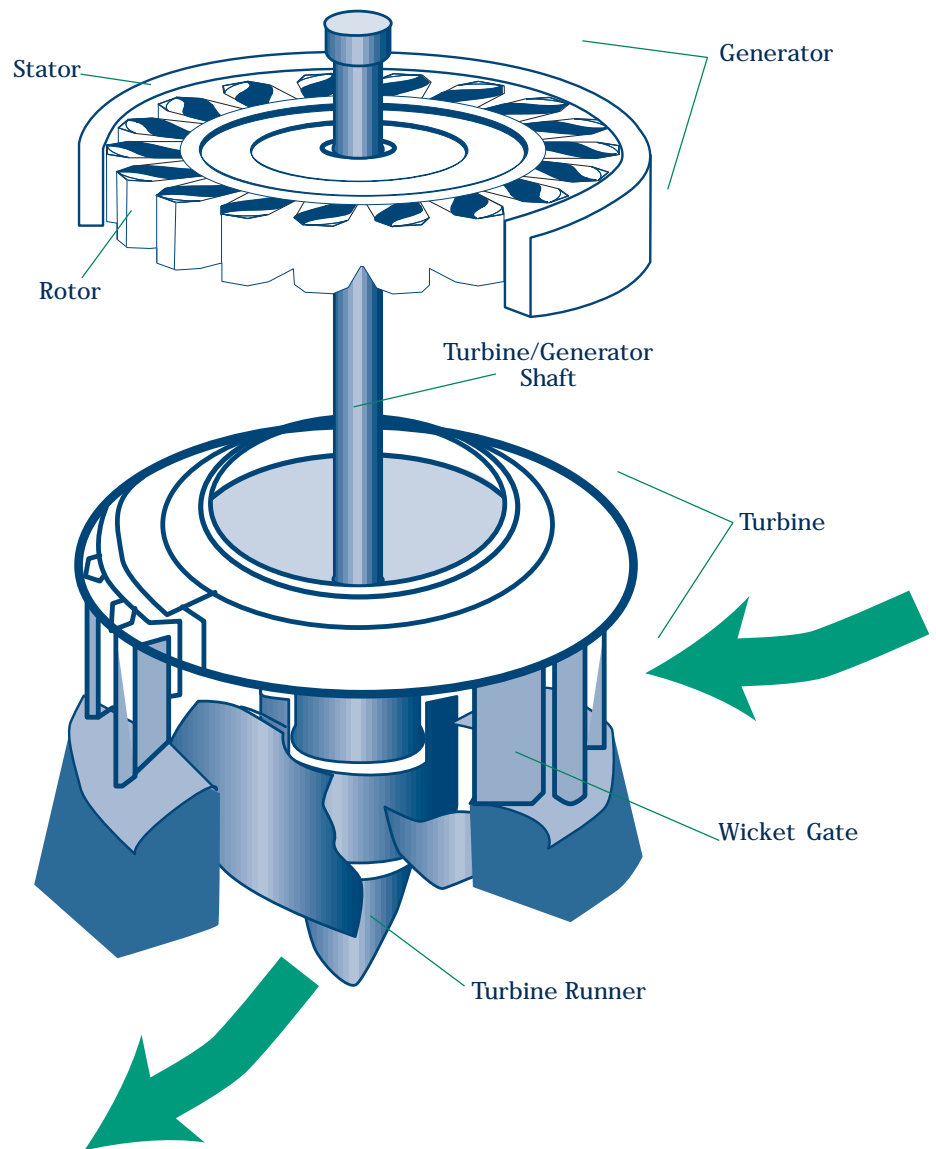
Any type of electrical demonstration generator that can be purchased through a science catalogue.

Examples: AC/DC generator, Magneto Generator, dyanlite flashlight.

Procedure

1. Hand out electrical generator diagram.
2. Use the electrical generator to show how an electrical current can be developed.
3. Have students fill in the diagram with the following terms: shaft (turbine), stator (stationary coil), rotating magnets.
4. Discuss how water power is used to move the turbine and make electricity.

See student activity sheet.





PART 2

DESIGNING A HYDROPOWER PLANT

See student activity sheet.

Materials

Paper, pencils, vocabulary list with hydropower parts

Procedure

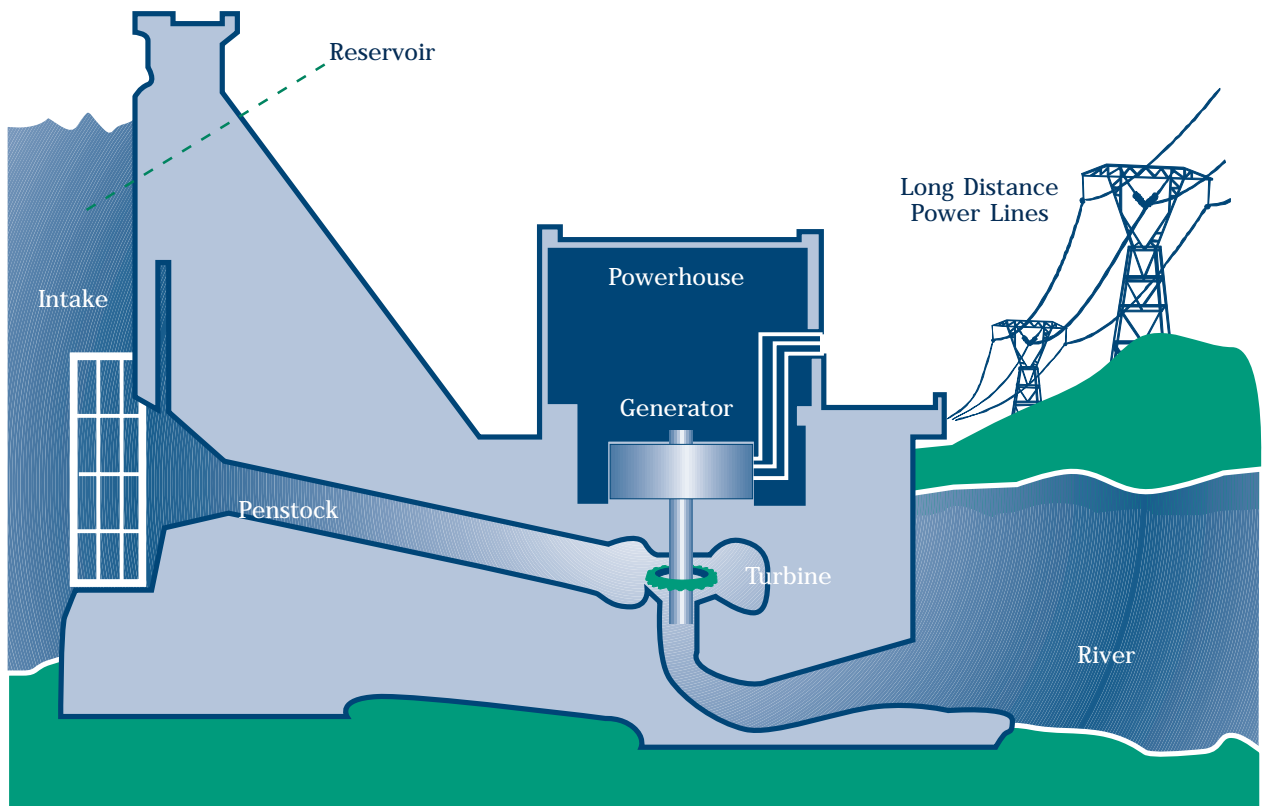
1. Using what they have learned about water wheels and generators, have students design a hydropower dam using the vocabulary list.

* Note: Review the terms prior to doing the drawings.

2. When completed, hand out the hydropower dam diagram and have students fill in the parts with the vocabulary terms.
3. Explain the process step by step to the class.

Alternative idea: Design a hydropower plant puzzle and have students put it together instead of filling out the diagram.

Hydroelectric Dam





UNIT IV, ACTIVITY 3
ECONOMICS OF
HYDROPOWER

Introduction

This lesson can be used as a cross-curricular activity for math or economics. The formulas and story problems provided will help students develop the understanding that hydropower is of economic and monetary value to our society.

Procedure

1. See attached sheets.
2. Teacher will explain problems and students will complete story problems on hydro-electricity.

\$ Value of Hydropower \$

The potential value of a proposed hydropower facility can be found quite easily if:

- (a) the height (head) that water fall is known
- (b) the flow in cubic feet per second (CFS) is known and
- (c) the cost per kilowatt hours (kWh) of electricity is known

The formula for calculating kWh produced is:

$$kWh = \left(\frac{Qh}{11.8} \right) Et$$

- where: Q = flow in CFS
 h = head or height that water falls
 E = efficiency expressed as a decimal equivalent (e.g. 80% = 0.8)
 t = time in hours

- 1 CFS at 8.8 feet of head = 1 Hp
- 1 CFS at 11.8 feet of head = 1 (kilowatt)
- 1 cubic foot of water = 7.48 gal

To convert gallons per minute (gpm) to CFS use the following formula:

$$CFS = \frac{\left(\frac{gpm}{7.48 \text{ gal/ft}^3} \right)}{60 \text{ sec/min}}$$

If the average residential rate for electrical power use is \$0.085/kWh, what is the value of one (1) hour (hr) production, 1 day production, and 1 year (yr) production of power?

1 hr production = 228.8 kWh

$$kWh \times \frac{\text{rate}}{kWh} = \text{Value}$$

$$228.8 \text{ kWh} \times \frac{\$0.085}{kWh} = \$19.45/\text{hr}$$

24 hr production = rate/hr x 24 hr/day = \$466.80/day

1 yr production = \$466.80/day x 365/yr = \$170,382/yr



Example: What is the flow in CFS if it is 4,000 gpm?

Formula:

$$\begin{aligned} \text{CFS} &= \left(\frac{\text{gpm}}{7.48 \text{ gal/ft}^3} \right) \\ &= \left(\frac{4,000 \text{ gpm}}{7.48 \text{ gal/ft}^3} \right) \\ &= \frac{534.759}{60} \\ &= 8.91 \text{ CFS} \end{aligned}$$

EXAMPLE POWER PROBLEM:

If 30 CFS goes through a hydropower generator from a height of 90 feet, how many kilowatts does it produce at 100% efficiency?

Formula:

$$\begin{aligned} \text{kWh} &= \left(\frac{Qh}{11.8} \right) Et \\ 228.8 \text{ kWh} &= \left(\frac{30 \times 90}{11.8} \right) \times 1 \times 1 \end{aligned}$$

How many kWh will this generate in 1 day?

$$\begin{aligned} \text{kWh} \times 24 \text{ hr/day} &= \\ 228.8 \text{ kWh} \times 24 &= \\ 5,491.2 \text{ kWh/day} & \end{aligned}$$

A proposed dam to produce hydropower and provide recreation will have a flow of 500CFS falling from a height (head) of 118 ft. If the turbine has an efficiency of 80% (0.8), how many KW will it produce in 24 hours?

$$\begin{aligned} \text{kWh} &= \left(\frac{Qh}{11.8} \right) Et \\ &= 500 \text{ CFS} \times 118 \text{ ft} \times 0.8 \times 24 \text{ hrs} \\ &= 5,000 \times 0.8 \times 24 \text{ hrs.} \\ &= 96,000 \text{ kWh} \end{aligned}$$

If this plant ran continuously for one (1) year, what would the value of the electricity be that it produced if it sells for \$0.085/kWh?

$$\begin{aligned} &365 \text{ days} \times 96,000 \text{ kWh} \times \$0.085 \\ &\quad \text{yr} \quad \quad \quad \text{day} \quad \quad \text{kWh} \\ &= \$2,978,400/\text{yr} \end{aligned}$$

See student activity sheet.



STUDENT ACTIVITY SHEET NAME _____

Draw your own water wheel model.

1. How many pennies were you able to lift with your wheel? _____

2. What provided the energy to lift the pennies? _____

Testing variables which can affect your water wheel efficiency .

1. Explain what happens when you increase the fin size on your wheel. _____

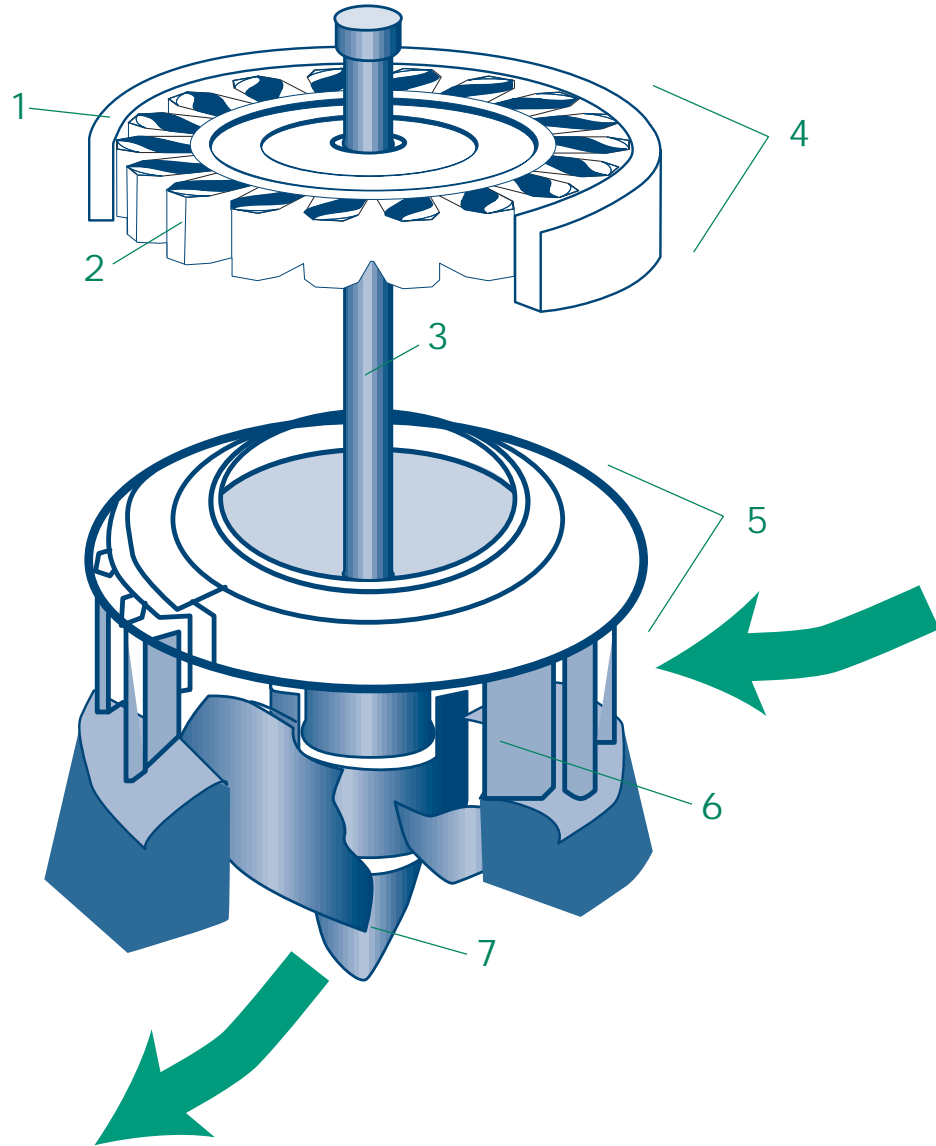
2. Explain what happens when you increase the height of the water you are pouring.

3. Describe what set up of your water wheel worked the best.



STUDENT ACTIVITY SHEET NAME _____

Label the parts of the generator.



1. _____

4. _____

2. _____

5. _____

3. _____

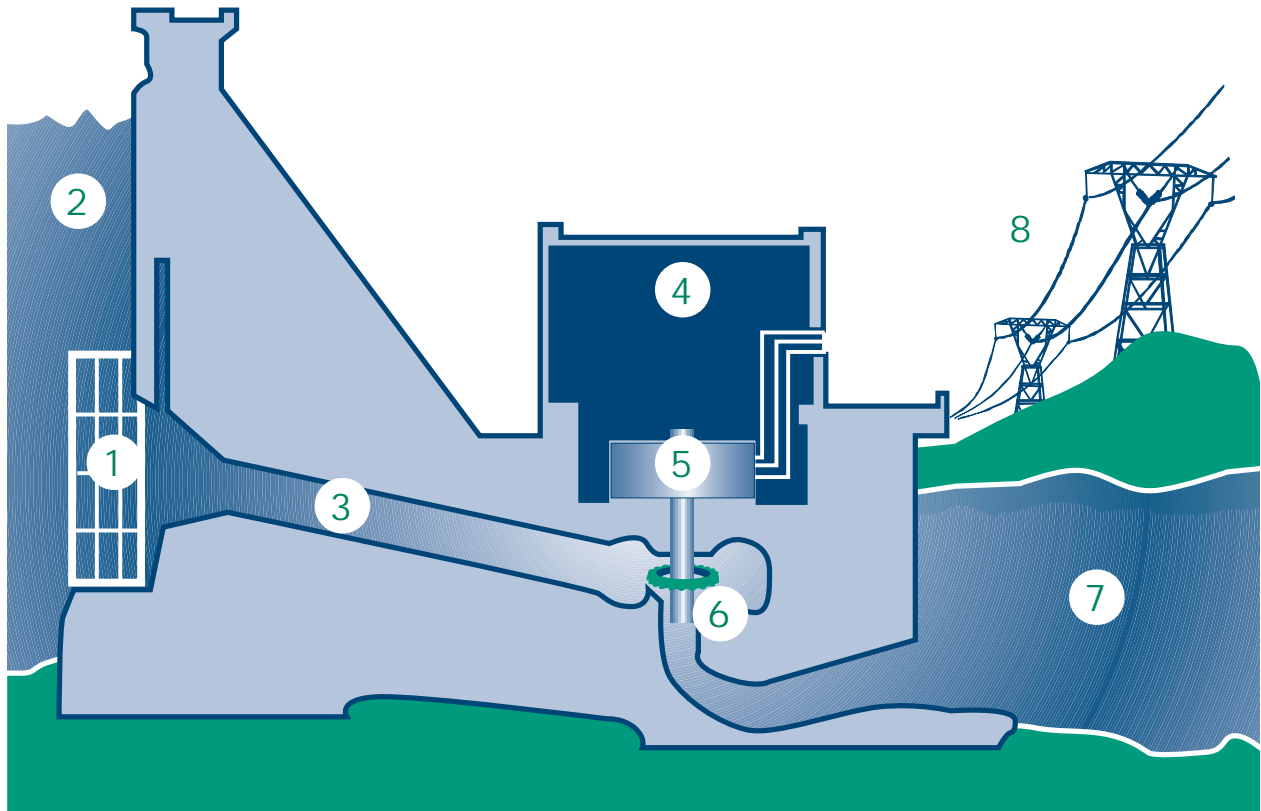
6. _____

7. _____



STUDENT ACTIVITY SHEET NAME _____

Label the parts of the hydropower plant.



- 1. _____
- 2. _____
- 3. _____
- 4. _____
- 5. _____
- 6. _____
- 7. _____
- 8. _____



STUDENT ACTIVITY SHEET NAME _____

A proposed dam to produce hydropower and provide recreation will have a flow of 500CFS falling from a height (head) of 118 ft. If the turbine has an efficiency of 80% (0.8), how many KW will it produce in 24 hours?

$$\begin{aligned}
 \text{kWh} &= \frac{Qh}{11.8} \times \text{Et} \\
 &= \text{CFS} \times \text{ft} \times \text{hrs} \\
 &= \text{CFS} \times \text{ft} \times \text{hrs} \\
 &= \text{kWh}
 \end{aligned}$$

If this plant ran continuously for one (1) year, what would the value of the electricity be that it produced if it sells for \$0.085/kWh?

$$\begin{aligned}
 365 \text{ days} \times \text{yr} \times \text{kWh} \times \$ \frac{\text{day}}{\text{kWh}} &= \$ \text{ /yr}
 \end{aligned}$$

Teacher's Notes

Teacher's Notes

Teacher's Notes

Teacher's Notes

Unit V

Dams and Ecology

UNIT GOAL

To increase student awareness of the beneficial and undesirable effects of hydropower.

INTRODUCTION

1. Present background on the life cycle of the American shad, an anadromous fish. Share the article Shad in the Mountains by John Page Williams.
2. Show the video Circle of Life. Available from PPL.

CROSS-CURRICULAR

Language Arts: Write a persuasive essay expressing your recommendation to the city council about building a dam during the role-playing activity.
Social Studies:

1. Research the destruction of rainforest when building a dam in the Amazon. See In the Rainforest by Catherine Caulfield.
2. Research the global implications of the damming of the Yangtze River in China.
3. Research the Aswan Dam near Cairo, Egypt and the problem of sediment buildup.
4. Find out from newspaper or other current source if there are any proposals to create new dams, or any other proposals that will affect wildlife habitat in your area. If so, investigate the pros and cons from your perspective.

DEMONSTRATIONS AND ACTIVITIES

1. Bringing back the Shad
2. Watershed Topography and Pollution
3. Safety Around Dams Lesson
4. Let's Get Real Activity
5. Hooks and Lifts?
6. Where Have All The Shad Gone?

REVIEW

See review sheet.

continued on page 49

Since ancient times, people have taken advantage of the energy in flowing water. Today, the US is the world's leading hydropower producer with a capacity of more than 92,000 megawatts. Hydropower produces approximately 10% of the electric generation in the US. It is the leading renewable energy source, accounting for 97% of our nation's renewable energy. Hydropower continues to produce 24% of the world's electricity and supplies more than one billion people with power.

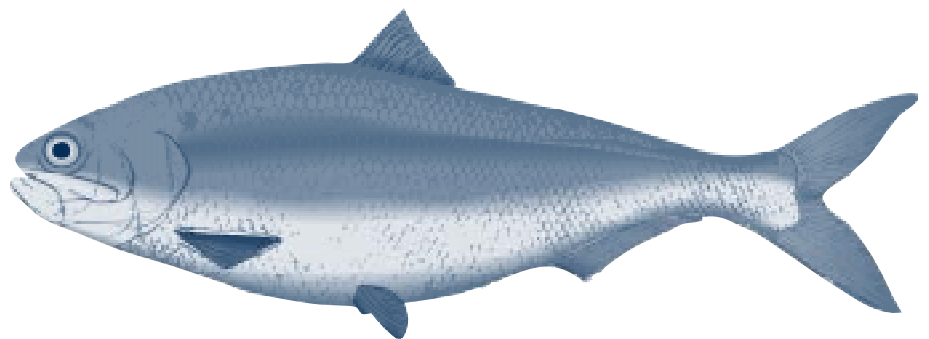
1. BRINGING BACK THE SHAD

PART 1

Introduce the activity of "Hooks and Lifts" by giving students the background information given in the activity.

PART 2

Have the students complete the activity by doing the shad run. Discuss the results.



continued on page 42

continued from page 41

ASSESSMENT

See assessment sheet.

RESOURCES

Circle of Life video (PPL).

Pa Fish and Boat Commission.

Shad in the Mountains by John Page Williams.

Sustainable Energy by Christopher Flavin and Rick Piltz with Chris E. Nichols, Renew America, 1989, Washington DC.

A Field Guide to Water Safety (PPL).

EPA: An Ecological Assessment of the United States Mid-Atlantic Region.

In the Rainforest by Catherine Caulfield, 1986, ISBN 0-226-09786-2.

UNIT V, ACTIVITY 2

TEACHER ASSESSMENT MAP

Watershed Topography and Pollution



PART 1

A watershed is the land area that drains into a waterway. Since water flows downhill, the highest elevation marks the boundaries of a watershed. Outline the watershed on this map by finding and connecting the highest elevations around the stream.



UNIT V, ACTIVITY 3 SAFETY AROUND THE DAM LESSON

1. Ask students for some of the water safety guidelines they follow.
2. Discuss any they may have missed.
3. Ask students if they know of any special regulation that may apply to dams in their area.
4. Show video A Field Guide to Water Safety and discuss.

UNIT V, ACTIVITY 4 LET'S GET REAL ACTIVITY Goal

To encourage critical thinking skills and creative problem solving.

Include an explanation of the "Let's Get Real" program similar to the following:

Conduct a competition among teams of students (2-6 members each) in which the members work cooperatively to solve a real-life problem related to hydropower. Various resources should be used (including interviews and contact with appropriate agencies, as well as written information) to make a written and/or oral presentation to a panel of judges. The presentations may include a wide variety of visual aids, such as a slide show, PowerPoint demonstration, video, etc. Teams should be prepared for a question and answer session and can be judged on categories such as:

- Creativity
- Cost effectiveness
- Feasibility of solution
- Knowledge of subject

Use any of the following problems or generate your own.

Example Problems:
Teams choose a problem to work on.

1. As sediment builds up behind a dam, a potential problem arises with the threat of the sediment breaking loose, including the toxic chemicals which are imbedded there.

Problem: What should be done about this buildup behind the dam?

- It might cost millions of dollars to undertake removal. Would this be economically justified?
- Is it better to let a sleeping dog lie? (After all, it isn't going anywhere.)
- If you attempted removal, where would you dispose of the sediment which could contain toxins?
- Is the sediment buildup decreasing the dam's efficiency?

2. Given a set amount of money to work with in your energy budget (designed to fund new sources of energy), build and present a case as to why you would use this money to construct a hydro-power facility as opposed to investing in an alternate form of energy. Include efficiency, financial, and environmental issues. Also include a comparison of the advantages and disadvantages of various sources of energy.



UNIT V, SUPPLEMENTAL INFORMATION

Hydropower is the leading renewable energy source in the United States. It produces approximately 10% of the electric generation nationwide. It accounts for 97.9 % of our nation's renewable energy.

ADVANTAGES OF HYDROPOWER

- Renewable
- Efficient
- Plants have historically had long operating lives
- No fuel cost for production
- Inexpensive (one of the least expensive form of electricity generation)
- Low operating and maintenance cost
- No atmospheric pollution (such as CO₂, NOX, SOX)
- No water pollution
- No global warming
- No waste storage
- Provides a water supply
- Provides a source of irrigation
- Provides recreational facilities
- Provides employment opportunities
- Provides habitat for warm water fish
- Flood control
- Storm water control
- Possible thermal advantage for trout in release stream

DISADVANTAGES OF HYDROPOWER

- Habitat destruction
- Flooding thousands of acres including areas of historical significance
- Relocation of residents and area structures (cemeteries, historical structures, etc.)
- Changing ecological complexion of the original area
- Decrease in dissolved oxygen levels
- Blockage of upstream and downstream movement of fish that live in the river
- Altering the natural flow of the source body of water
- Loss of water downstream
- Improperly maintained dams could contribute to flooding
- Number of sites is limited
- Sediment build up behind the dam possible containing organic pesticides, heavy metal particulates



UNIT V, STUDENT REVIEW SHEET

Review of Dams and Ecology

An Electric Company employee would like to use Ourtown River as a site to build a dam to generate hydroelectricity. What are some of the reasons she could give Ourtown citizens for building a dam there? __

A park ranger employed at Ourtown Park, which would be flooded when the Electric Company builds its dam, is opposed to the project. What are some of the reasons he could give Ourtown citizens for not building a dam there? _____

You are a citizen of Ourtown. What would be your feelings about building the Ourtown Dam? Support your answer. _____



UNIT V, STUDENT ACTIVITY SHEET

NAME _____



A watershed is the land area that drains into a waterway. Since water flows downhill, the highest elevation marks the boundaries of a watershed. Outline the watershed on this map by finding and connecting the highest elevations around the stream.



UNIT V, STUDENT ACTIVITY SHEET

NAME _____

1. Draw and label the lifecycle of a shad and note where the stage would take place.

2. List some special safety precautions which must be observed when using areas near a dam.

3. What is a watershed? _____

4. Classify each of the following as a point source or non-point source pollutant.

a. Pesticides spread on a farmer's field _____

b. Pesticides leaking from a factory's tank _____

c. Overflow at a sewage treatment plant _____

d. Excess manure from a cattle ranch _____

e. Oil spill from a tanker truck accident _____



5. List five positive features of using hydroelectricity. _____

6. List five negative features of using hydroelectricity. _____

7. Give three reasons that the shad populations have decreased since the early 1800's. _____

8. List two special safety precautions which must be observed when using areas near a dam. _____

9. Classify each of the following as a point source or non-point source pollutant.

a. Chemical spill from a tanker truck accident _____

b. Overflow at a sewage treatment plant _____

c. Fuel spill at a gas station _____

d. Excess fertilizer from home lawn care _____

e. Pesticide spread on fields _____

AGE

Grades 4-9

SUBJECTS

Science, Math, History or Social Studies

SKILLS

analysis, description, discussion, generalization, inference, interpretation, kinesthetic concept development, observation, psychomotor development, recognition, synthesis, using time and space

DURATION

one 30 to 60-minute period

GROUP SIZE

20 to 30 students

SETTINGS

indoors or outdoors

KEY VOCABULARY

anadromous, migration, limiting factors, life cycle and fish lift

REFERENCES

“Back to the Sea”, “Diadromy” and “Fish Ways” fact sheets; “Fish Restoration and Passage on the Susquehanna River” booklet; “Return From the Sea: Restoration of American Shad to the Atlantic Coast,” “Coming Home: The American Shad Restoration” and “Return of the American Shad” videos; “American Shad in the Susquehanna River Basin” book by Richard Gerstell and “Susquehanna River of Dreams” book by Susan Stranahan.

UNIT V, ACTIVITY 5

HOOKS AND LIFTS?

Adapted with permission from Project WILD, Project WILD Aquatic Education Activity Guide. The complete Activity Guide can be obtained by attending a KARE Teacher Workshop. For more information, contact the Pennsylvania Fish and Boat Commission at 717-657-4540

OBJECTIVES

Students will: 1) recognize that shad migrate as part of their life cycle; 2) identify the stages in the life cycle of the American Shad; 3) describe limiting factors affecting American Shad as they complete their life cycle and distinguish those factors between natural and human made; 4) describe what steps have been taken to correct the human made limiting factors; 5) explain where shad have migrated and still migrate in Pennsylvania.

METHOD

Students participate in a role playing game that simulates the life cycle of an American Shad and the many obstacles that it encounters.

AMERICAN SHAD BACKGROUND

The American Shad is an anadromous fish and the largest of the herring family. The word anadromous means that it migrates from salt water to fresh water to spawn. The shad’s scientific name, *Alosa sapidissima* means “shad good to eat.”

The American Shad once comprised a major commercial and recreational fishery in Pennsylvania. Shad would migrate from the Atlantic Ocean into our waters through two major routes: the Susquehanna River via the Chesapeake Bay or the

Delaware River via the Delaware Bay. Shad continue to migrate up the Delaware today and remain a popular sport fish on this waterway. On the Susquehanna, shad would migrate over 500 miles upriver to Binghamton, New York. Unfortunately, they no longer make this long journey. Efforts have been underway to restore this once common fish to the Susquehanna Basin.

MATERIALS

Large playing area (playground, football field or gym), rope or cones to outline playing area, large rope loop, two cardboard boxes, poker chips or checkers for tokens and a long jump rope.

PROCEDURE

1. Review some basics about shad migration and the problems associated with migration. The video “Retain of the American Shad” is available from the Fish & Boat Commission and will provide information on shad natural history and efforts to restore it to the Susquehanna River.
2. Set up the playing field as shown (see diagram on page 59).
3. Assign student’s roles:
 - Choose two students to be the turbine-turners. These students will use a jump rope to simulate a hydroelectric power turbine. If the turbine catches a shad, the shad is hurt and cannot swim as fast. It must then walk to avoid the predators on the other side of the turbine. Those that are not hurt may run. After all the shad have gone through the turbine, the turbine-turners go to the other side of the field and become anglers.



- Choose two students to become commercial anglers. These students must keep their foot in a cardboard box to reduce their maneuverability and speed. This is to simulate a commercial fishing boat. The boats only need to tag a shad with one hand to send them to the holding area. Shad go the holding area on their own.
 - Choose two students to be predators. Bass, walleye and minnows are some of the predatory fish that a young shad may encounter on its journey through the upper reaches of the Susquehanna. A predator must tag a shad with both hands and then escort the shad to the holding area. Once all the students get into the open ocean the two predators then become anglers on the other side of the field.
 - The remaining students are shad. The more students you have the better (minimum of 20 students).
4. Walk students through once to give them an idea of how the course is run. Explain each obstacle and why it affects the shad.
 5. Explain to students that they are young shad, which must migrate from their freshwater birthplace to the ocean. Include the turbine and predators on this first run.
 6. Once the shad reach the ocean, they must collect four tokens to represent the four years of food it takes to become mature. They must travel between two separate boxes that are filled with the tokens. The commercial anglers are located between the two boxes, and must be avoided. Shad can not continue to their river spawning areas until they have collected all four tokens.
 7. On their way up river, the shad first encounter the fish lift at Conowingo Dam. As many students as possible must squeeze into a rope circle to simulate the crowded conditions of the fish lift. Students that arrive early should wait until the lift (rope circle) is completely filled, as determined by the instructor. Once the lift is filled, the students will pick up the rope that surrounds them and move as a group five feet forward. This movement will simulate the lift carrying fish over the dam. They then drop the rope and continue their journey. Alternatively, the instructor may wish to use a fish ladder instead of a lift. The “ladder” is made up of students on their hands and knees, which the shad must jump over. The shad will then encounter anglers (previously the fish predators) after they pass the ladder or lift.

EVALUATION

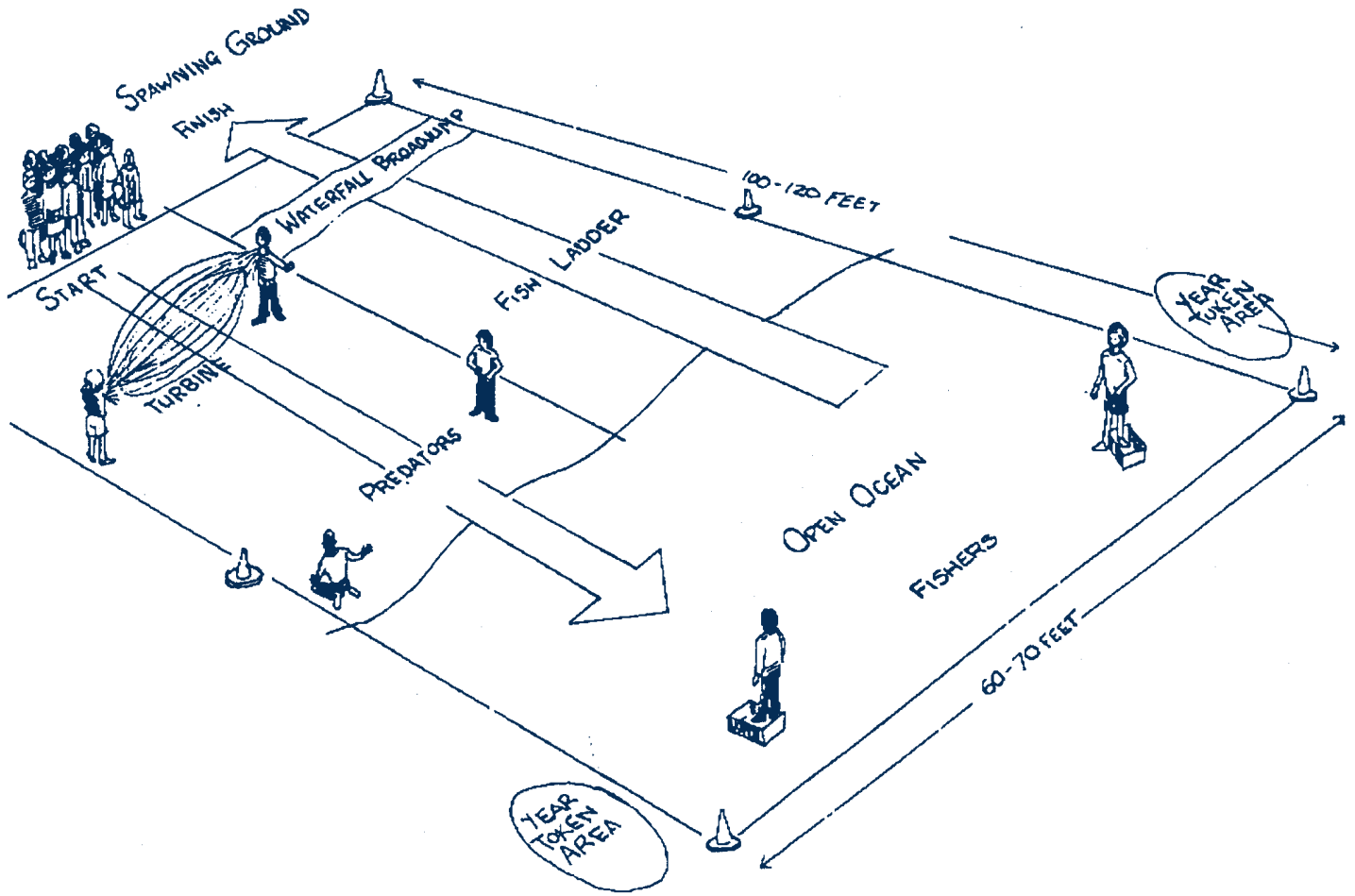
- List, describe and illustrate the major stages in the American Shad’s life cycle.
- Discuss some of the reasons why the American Shad’s population has dropped.
- Discuss what is being done to restore shad to the waterways of Pennsylvania.

EXTENSIONS

1. Explore ways that dams can be modified to let fish safely pass downstream and upstream. Have students design the “perfect” fish lift or ladder.
2. Have students think of ways to eliminate various limiting factors.
3. Research the history and importance of shad to Pennsylvania.
4. Modify the playing field to be used in a pool.
5. Visit Conowingo Dam during the shad-lifting season or visit the Fish and Boat Commission’s Van Dyke facility.



Playing field for game that simulates the life cycle of an American Shad and the many obstacles that it encounters.



AGE

Grades 6-12

SUBJECTS

Science, Math, History or Social Studies

SKILLS

analysis, classification, comparing similarities and differences, computation, identification, inference, interpretation, listing, media construction, reading

DURATION

one 40 to 60-minute period

GROUP SIZE

any

SETTINGS

indoors

KEY VOCABULARY

population, inventory and trend

REFERENCES

“Back to the Sea”, “Diadromy” and “Fish Ways” fact sheets; “Fish Restoration and Passage on the Susquehanna River” booklet; “Return From the Sea: Restoration of American Shad to the Atlantic Coast,” “Coming Home: The American Shad Restoration” and “Return of the American Shad” videos; “American Shad in the Susquehanna River Basin” book by Richard Gerstell and “Susquehanna River of Dreams” book by Susan Stranahan.

UNIT V, ACTIVITY 6

WHERE HAVE ALL THE SHAD GONE?

Adapted with permission from Project WILD, Project WILD Aquatic Education Activity Guide. The complete Activity Guide can be obtained by attending a KARE Teacher Workshop. For more information, contact the Pennsylvania Fish and Boat Commission at 717-657-4540

OBJECTIVES

Students will: 1) interpret and make inferences about fluctuations in a fish population from actual data; and 2) analyze the effects of human use and habitat changes on a fish population.

METHOD

Students graph and interpret actual fish population data in relation to historical events.

BACKGROUND

Data gathered about a wildlife population in a similar manner over a period of time may be useful in detecting trends in that population. Those who analyze the data may interpret it in a variety of ways. Because a fish population is influenced by many factors, it may be difficult to measure the effect of a single factor. Thus, assumptions must often be made that factors other than the ones being measured are not significantly affecting the population.

In measuring populations of living creatures, biologists are seldom able to get a total count. Usually only a sample of the population can be obtained and inferences about the total population must be made from this sample. Errors or inconsistencies in gathering the data over time may greatly influence the accuracy of the

data. Despite the influence of unknown factors and possible inconsistencies in data gathering, regularly conducted counts or inventories of a population may still be the best information available and decisions must be made from this information. At times, biologists are simply unable to make any type of reasonable reliable count. How many fish are there in the sea, for example? How many of each species? There is simply no way to know. In these cases, some type of index to abundance may be used.

The purpose of this activity is for students to make inferences about factors that affect a fish population. Students can make these inferences by comparing a historical timetable to commercial shad catch data. Correlations found between historical events and changes in commercial catch data can then be used to make inferences about the entire shad population.

AMERICAN SHAD

The American Shad once comprised a major commercial and recreational fishery in Pennsylvania. Shad would migrate from the Atlantic Ocean into our waters through two major routes: the Susquehanna River via the Chesapeake Bay or the Delaware River via the Delaware Bay. Shad continue to migrate up the Delaware today and remain a popular sport fish on this waterway. On the Susquehanna, shad would migrate over 500 miles upriver to Binghamton, New York.

Unfortunately, they no longer make this long journey. Efforts have been underway to restore this once common fish to the Susquehanna Basin.



MATERIALS

- graph paper
- colored pencils
- reference information on the American Shad
- copies of Historical Information and Commercial Shad
- catch Data sheets.

PROCEDURE

1. Provide students with fish catch data and historical information on the American Shad. Have them graph the number of pounds of shad caught for each location on two separate graphs (or one graph with two different colors). Students should prepare their own graphs and include a title and legend. You may want to make an overhead of a graph for students to use as an example or for use in discussions. The fish catch data is taken from actual commercial fish catches in the Chesapeake Bay and Susquehanna River. Figures are in millions of pounds. The historical information provides an overview of human activity in the river plus developing regulatory and management efforts over time.
2. Have the students compare the two graphs and list or explain whatever inferences they can draw from the data provided. Do the graphs show any long-term trends? Are there any similarities between the two graphs? Are there periods where the rates of fish caught change rapidly in a short time? What inferences about population

abundance of shad can be made from the graphs? What factors may be affecting the number of fish caught or the population levels?

3. Provide the students with the historical background. Have them review this new information in relation to what their graphs show. It may be helpful for students to make notes on the graphs at the points where significant historical events occur. What new inferences can be made? Must some of the previous inferences or explanations be changed to fit the historical data? Do any lag times in shad population changes exist after the occurrence of a specific historical event? Remember that a new event or factor may take some time to have an effect on a population or to be detected. Do the graphs seem to show any of these situations in relation to historical events? Are there different interpretations that individual students can make from the same information? Do each of the interpretations seem to explain or fit the information and data? If faced with making a management decision based on one of the interpretations, how would you decide which interpretation to use?

NOTE: This activity does not address ethical questions related to the appropriateness or inappropriateness of catching fish for human uses. This dimension may be added at the professional discretion of the educator conducting the activity.



EVALUATION

Study the graph to answer these questions:

- Can commercial catch data be used to obtain an estimate of the entire shad population?
- Does either of the shad populations appear to be stable?
- Does there appear to be any similarity or connection between population changes in the Chesapeake Bay and the Susquehanna River?
- What major events accounted for subsequent decreases in shad populations between 1900 and 1935?
- What might explain a lag in population changes after a major event, for example construction of a dam?
- What actions might have been taken to prevent these shad population decreases?
- What actions could state agencies take to increase shad populations closer to their original numbers?

EXTENSIONS

Students will look at efforts that are underway to restore the American Shad to the Susquehanna River Basin and determine if these efforts are successful by measuring more recent population numbers.

1. Using the references as a source, have the students review and make notes of the efforts that are underway to restore shad to the Susquehanna. Discuss these efforts, including stocking and construction of fish passage structures.
2. Provide students with recent fish count data and historical information on the American shad. Have them graph the number of shad captured at the Conowingo fish lift on the Susquehanna. A sample graph is included. The fish count data is taken from actual shad captures during studies at the Conowingo Dam on the Susquehanna River. Figures are in number of fish. The historical information provides an overview of natural events and efforts to restore shad to the river.
3. Ask the students to study the graph and discuss changes in shad numbers over time. Are there any changes in population? Do any historical events coincide with changes in the population? Do stocking efforts appear to work over time? Does it appear that fish passage structures work? Finally, ask the students to compare this graph to the others. Have them speculate or estimate what might happen to shad populations in the near and distant future.

Teacher's Notes

Teacher's Notes

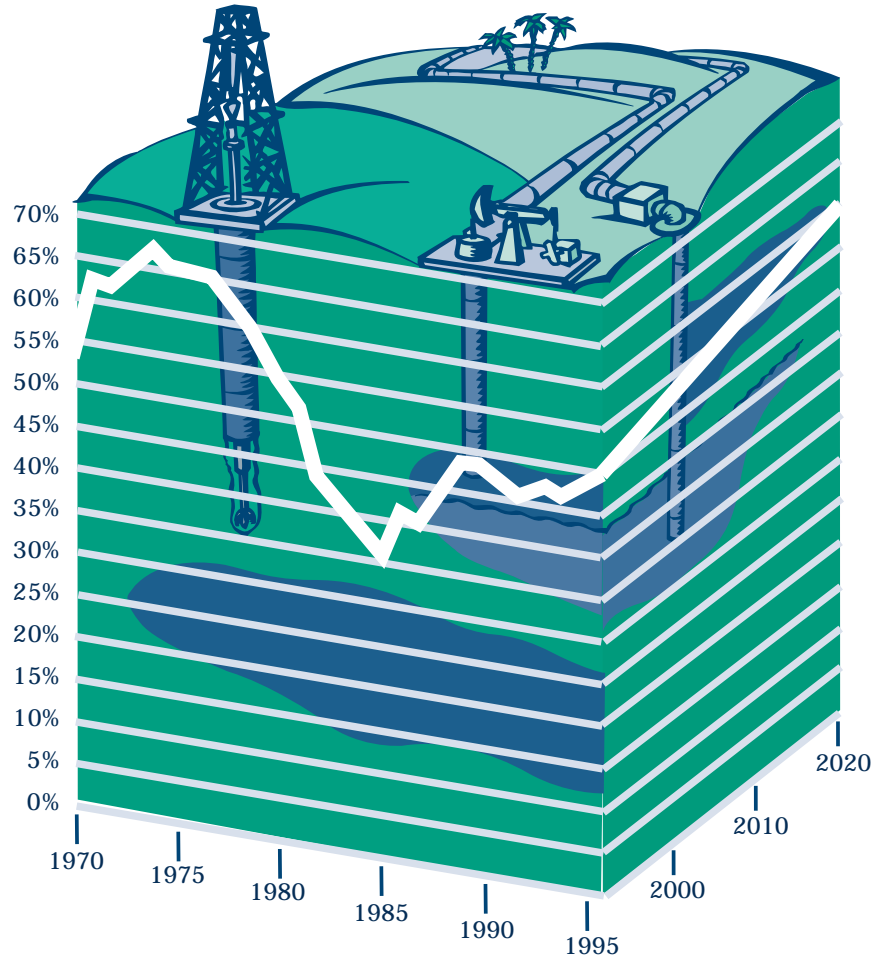
Teacher's Notes

Teacher's Notes

Unit VI

The Future of Hydroelectricity

Percentage of Oil Imported by the United States



UNIT GOALS

1. To look at how future demands for electricity will impact the hydroelectric industry.
2. To look at the problems hydroelectricity will have to overcome to be a major contributor to our energy solutions.

INTRODUCTION

1. Have the students graph or discuss the relationship between population and electricity use on the local, state, or national level.
2. Through discussion or research, create a list of problems associated with other forms of electricity production: expense, non-renewable, environmental impacts, radiation, removal or waste, etc.
3. If possible, show a video on ways to produce electricity.

ACTIVITIES

1. Have students create a presentation or chart on the various ways of producing electricity, possibly including cost analysis, associated problems, how and where each is used, fuels used, etc. Students should work in small cooperative groups on this activity.

REVIEW

Students will debate further development of hydroelectric facilities.

ASSESSMENT

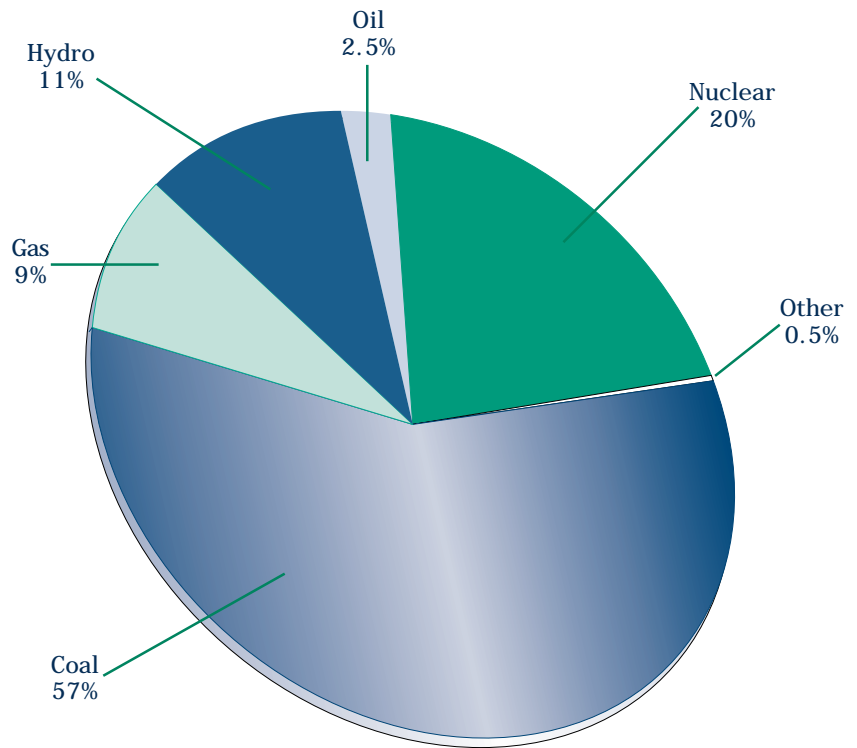
1. Individual grade on debate and/or self-evaluation of debate
2. Graded activities

TEACHER RESOURCES

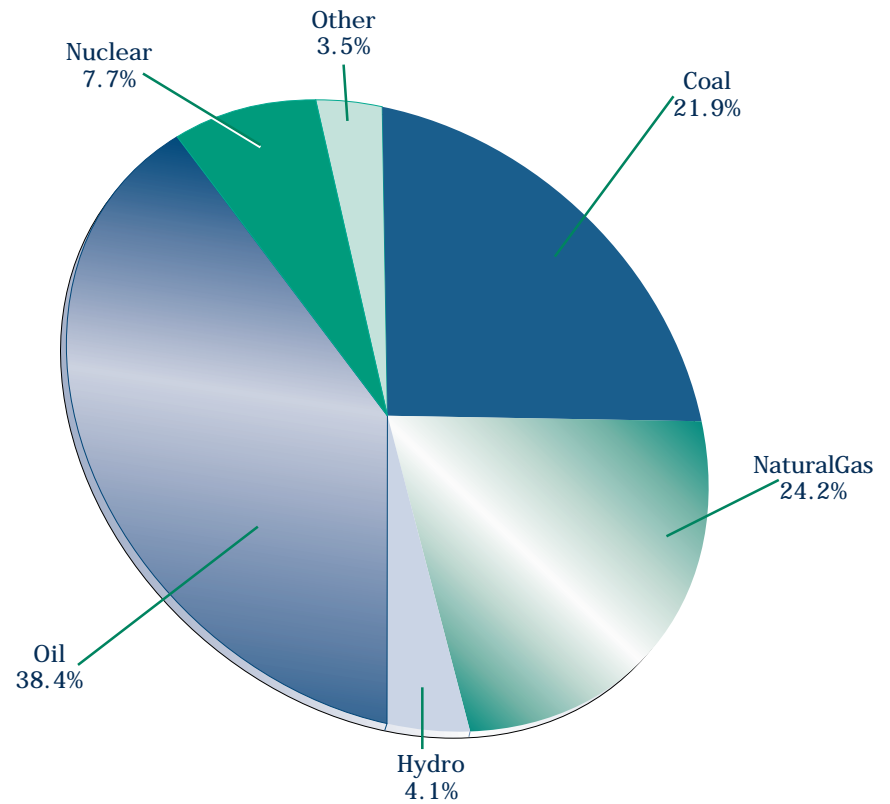
See attached materials.



Sources of Electrical Energy Use in the United States-1997



Sources of Total Energy Use in the United States-1996





UNIT VI, ENERGY PROS AND CONS

SOURCE	GOOD THINGS	PROBLEMS
Coal	<ul style="list-style-type: none"> + sufficient supply in the U.S. + easy to remove from the ground 	<ul style="list-style-type: none"> - burning contributes to air pollution - accidents and diseases from mining - contributes to acid rain - limited supply - strip mines hurt land
Oil	<ul style="list-style-type: none"> + easy to acquire and store + used for many things, like fuel, plastic, paint, medicine, fertilizer, etc. 	<ul style="list-style-type: none"> - limited foreign supply - insufficient supply in the U.S. - oil spills cause pollution - expensive, and prices rising
Natural Gas	<ul style="list-style-type: none"> + easy to transport and store + burns cleanly + can be used for heating, cooking, and light 	<ul style="list-style-type: none"> - limited supply - expensive, and prices rising - can accidentally explode and burn
Nuclear Energy	<ul style="list-style-type: none"> + uranium found in the U.S. + produces a lot of energy + no air pollution 	<ul style="list-style-type: none"> - power plants are expensive to build and run - waste disposal problems
Hydropower	<ul style="list-style-type: none"> + renewable + water is free + no pollution 	<ul style="list-style-type: none"> - dams flood farmland and change animal homes - dams are expensive, making hydropower expensive to use
Solar Energy	<ul style="list-style-type: none"> + renewable + no pollution + the sun is free + available anywhere 	<ul style="list-style-type: none"> - sun doesn't shine all the time - equipment is expensive - more research needed - difficult to store energy
Wind Energy	<ul style="list-style-type: none"> + renewable + wind is free + no pollution 	<ul style="list-style-type: none"> - wind doesn't blow all the time - windmills require a lot of room but make only a little electricity - more research needed
Wood Energy	<ul style="list-style-type: none"> + wood is inexpensive + the U.S. has a sufficient supply + more trees can be planted 	<ul style="list-style-type: none"> - contributes to air pollution - wood storage requires a lot of space - increased fire potential



UNIT VI, ENERGY RESOURCES NAME _____

Questions and More Questions

Complete the chart by checking the energy sources that correctly complete each statement. There may be more than one correct choice.

THIS ENERGY SOURCE	OIL	COAL	NATURAL GAS	NUCLEAR	HYDROPOWER	SOLAR	WIND	WOOD
is widely used now								
is used in a small way in this country								
is renewable								
is a fossil fuel								
is an atomic power								
is not available every minute of the day and night								
can be used to make electricity								
is used to make gasoline, plastic, polyester, fertilizer, etc.								
contributes to air pollution								
is plentiful in the U.S.								
involves expensive transportation								
can be used to heat homes								
involves mining								
creates a waste disposal problem								
needs more technology to make it cheaper								
needs more technology to make it cleaner								
is only good in certain places in the country								



Hydroelectric Power

Hydroelectric power plants convert the kinetic energy contained in falling water into electricity. The energy in flowing water is ultimately derived from the sun and is, therefore, constantly being renewed. Energy contained in sunlight evaporates water from the oceans and deposits it on land in the form of rain. Differences in land elevation result in rainfall runoff and allow some of the original solar energy to be captured as hydroelectric power.

Hydropower is currently the world's largest renewable source of electricity, accounting for 6 percent of worldwide energy supply or about 15 percent of the world's electricity. In Canada, hydroelectric power is abundant and supplies 60 percent of our electrical needs. Traditionally thought of as a cheap and clean source of electricity, most large hydroelectric schemes being planned today are coming up against a great deal of opposition from environmental groups and native people.

HISTORY OF HYDROPOWER

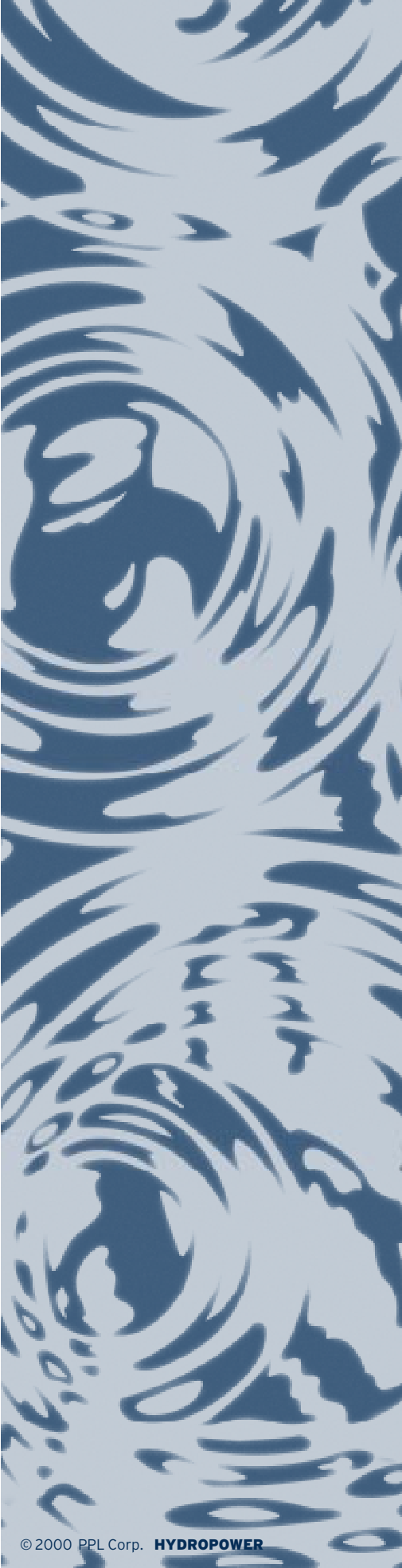
The first recorded use of water power was a clock, built around 250 BC. Since that time, humans have used falling water to provide power for grain and saw mills, as well as a host of other applications. The first use of moving water to produce electricity was a water wheel on the Fox River in Wisconsin in 1882, two years after Thomas Edison unveiled the incandescent light bulb. The first of many hydroelectric power plants at Niagara Falls was completed shortly thereafter. Hydropower continued to play a major role in the expansion of electrical service early in this century, both in North America and around the world. Contemporary hydroelectric power plants generate anywhere from a few kW, enough for a single residence, to thousands of MW, power enough to supply a large city.

Early hydroelectric power plants were much more reliable and efficient than the fossil fuel fired plants of the day. This resulted in a proliferation of small to medium sized hydroelectric generating stations distributed wherever there was an adequate supply of moving water and a need for electricity. As electricity demand soared in the middle years of this century, and the efficiency of coal and oil fueled power plants increased, small hydro plants fell out of favor. Most new hydroelectric development was focused on huge "mega-projects."

The majority of these power plants involved large dams which flooded vast areas of land to provide water storage and therefore a constant supply of electricity. In recent years, the environmental impacts of such large hydro projects are being identified as a cause for concern. It is becoming increasingly difficult for developers to build new dams because of opposition from environmentalists and people living on the land to be flooded. This is shown by the opposition to projects such as Great Whale (James Bay II) in Quebec and the Gabickovo-Nagymaros project on the Danube River in Czechoslovakia.

HYDROELECTRIC POWER PLANTS

Hydroelectric power plants capture the energy released by water falling through a vertical distance and transform this energy into useful electricity. In general, falling water is channeled through a turbine



which converts the water's energy into mechanical power. The rotation of the water turbines is transferred to a generator which produces electricity. The amount of electricity which can be generated at a hydroelectric plant is dependent upon two factors. These factors are (1) the vertical distance through which the water falls, called the "head," and (2) the flow rate, measured as volume per unit time. The electricity produced is proportional to the product of the head and the rate of flow. The following is an equation which may be used to roughly determine the amount of electricity which can be generated by a potential hydroelectric power site:

$$\text{POWER (kW)} = 5.9 \times \text{FLOW} \times \text{HEAD}$$

In this equation, FLOW is measured in cubic meters per second and HEAD is measured in meters.

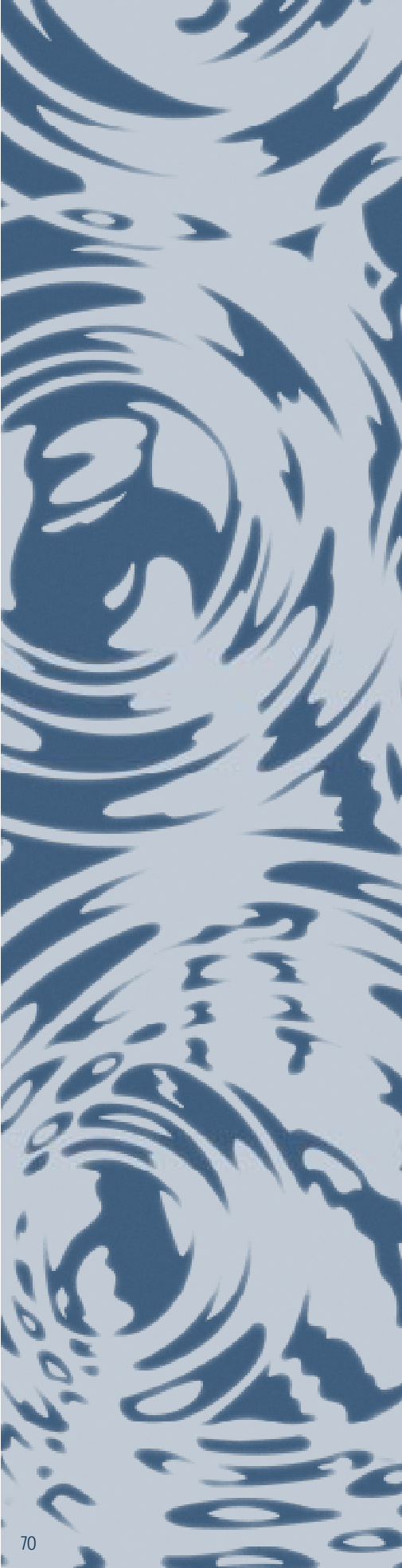
Based on the facts presented above, hydroelectric power plants can generally be divided into two categories. "High head" power plants are the most common and generally utilize a dam to store water at an increased elevation. The use of a dam to impound water also provides the capability of storing water during rainy periods and releasing it during dry periods. This results in the consistent and reliable production of electricity, able to meet demand. Heads for this type of power plant may be greater than 1,000 m. Most large hydroelectric facilities are of the high head variety. High head plants with storage are very valuable to electric utilities because they can be quickly adjusted to meet the electrical demand on a distribution system.

"Low head" hydroelectric plants are power plants which generally utilize heads of only a few meters or less. Power plants of this type may utilize a low dam or weir to channel water or no dam and simply use the "run of the river." Run of the river generating stations cannot store water, thus their electric output varies with seasonal flows of water in a river. A large volume of water must pass through a low head hydro plant's turbines in order to produce a useful amount of power. Hydroelectric facilities with a capacity of less than about 25 MW (1 MW = 1,000,000 watts) are generally referred to as "small hydro," although hydroelectric technology is basically the same regardless of generating capacity.

"Pumped storage" is another form of hydroelectric power. Pumped storage facilities use excess electrical system capacity, generally available at night, to pump water from one reservoir to another reservoir at a higher elevation. During periods of peak electrical demand, water from the higher reservoir is released through turbines to the lower reservoir, and electricity is produced. Although pumped storage sites are not net producers of electricity - it actually takes more electricity to pump the water up than is recovered when it is released - they are a valuable addition to electricity supply systems. Their value is in their ability to store electricity for use at a later time when peak demands are occurring. Storage is even more valuable if intermittent sources of electricity such as solar or wind are hooked into a system.

ENVIRONMENTAL IMPACTS

Hydroelectric power plants have many environmental impacts, some of which are just beginning to be understood. These impacts, however,



must be weighed against the environmental impacts of alternative sources of electricity. Until recently there was an almost universal belief that hydropower was a clean and environmentally safe method of producing electricity. Hydroelectric power plants do not emit any of the standard atmospheric pollutants such as carbon dioxide or sulfur dioxide given off by fossil fuel fired power plants. In this respect, hydropower is better than burning coal, oil, or natural gas to produce electricity, as it does not contribute to global warming or acid rain. Similarly, hydroelectric power plants do not result in the risks of radioactive contamination associated with nuclear power plants.

A few recent studies of large reservoirs created behind hydro dams have suggested that decaying vegetation, submerged by flooding, may give off quantities of greenhouse gases equivalent to those from other sources of electricity. If this turns out to be true, hydroelectric facilities such as the James Bay project in Quebec that flood large areas of land might be significant contributors to global warming. Run of the river hydro plants without dams and reservoirs would not be a source of these greenhouse gases.

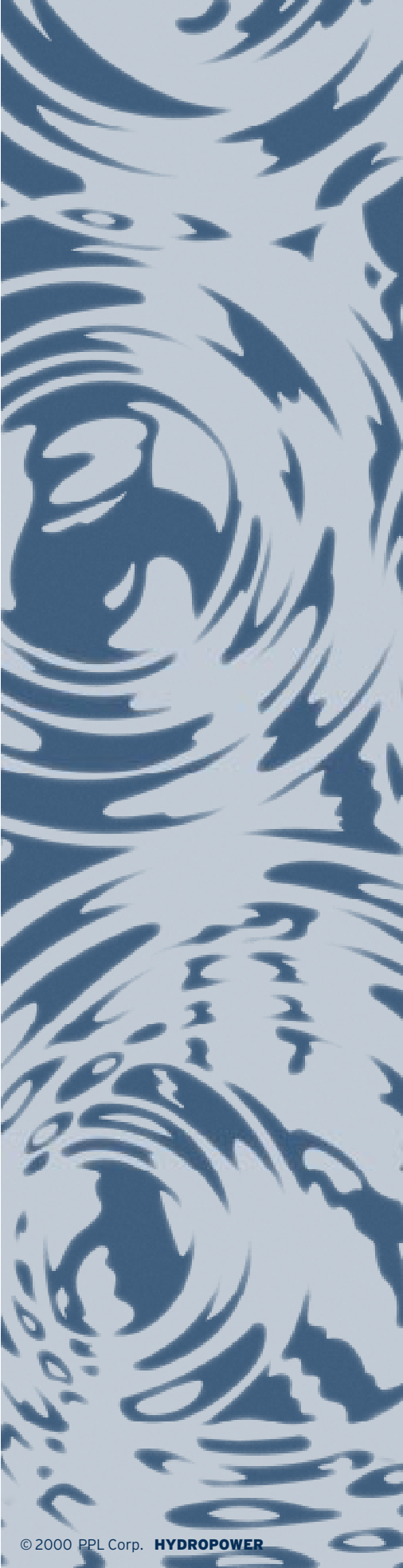
The most obvious impact of hydroelectric dams is the flooding of vast areas of land, much of it previously forested or used for agriculture. The size of reservoirs created can be extremely large. The La Grande project in the James Bay region of Quebec has already submerged over 10,000 square kilometers of land; and if future plans are carried out, the eventual area of flooding in northern Quebec will be larger than the country of Switzerland. Reservoirs can be used for ensuring adequate water supplies, providing irrigation and recreation, but in several cases they have flooded the homelands of native peoples whose way of life has then been destroyed. Many rare ecosystems are also threatened by hydroelectric development.

Large dams and reservoirs can have other impacts on a watershed. Damming a river can alter the amount and quality of water in the river downstream of the dam, as well as prevent fish from migrating upstream to spawn. These impacts can be reduced by requiring minimum flows downstream of a dam and by creating fish ladders which allow fish to move upstream past the dam. Silt, normally carried downstream to the lower reaches of a river, is trapped by a dam and deposited on the bed of the reservoir. This silt can slowly fill up a reservoir, decreasing the amount of water which can be stored and used for electrical generation. The river downstream of the dam is also deprived of silt which fertilizes the river's floodplain during high water periods.

Bacteria present in decaying vegetation can also change mercury, present in rocks underlying a reservoir, into a form which is soluble in water. The mercury accumulates in the bodies of fish and poses a health hazard to those who depend on these fish for food. The water quality of many reservoirs also poses a health hazard due to new forms of bacteria which grow in many of the hydro rivers. Therefore, run of the river type hydro plants generally have a smaller impact on the environment.

THE FUTURE OF HYDROELECTRIC POWER

The theoretical size of worldwide hydropower is about four times greater than that which has been exploited at this time. The actual



amount of electricity which will ever be generated by hydropower will be much less than the theoretical potential. This is due to the environmental concerns outlined above, and economic constraints. Much of the remaining hydro potential in the world exists in the developing countries of Africa and Asia. Harnessing this resource would require billions of dollars, because hydroelectric facilities generally have very high construction costs. In the past, the World Bank has spent billions of foreign aid dollars on huge hydroelectric projects in the third world. Opposition to hydropower from environmentalists and native people, as well as new environmental assessments at the World Bank will restrict the amount of money spent on hydroelectric power construction in the developing countries of the world.

In North America and Europe, a large percentage of hydropower potential has already been developed. Public opposition to large hydro schemes will probably result in very little new development of big dams and reservoirs. Small scale and low head hydro capacity will probably increase in the future as research on low head turbines and standardized turbine production lowers the costs of hydroelectric power at sites with low heads. New computerized control systems and improved turbines may allow more electricity to be generated from existing facilities in the future. As well, many small hydroelectric sites were abandoned in the 1950's and 60's when the price of oil and coal was very low and their environmental impacts unrealized. Increased fuel prices in the future could result in these facilities being refurbished.

CONCLUSIONS

Hydroelectric power has always been an important part of the world's electricity supply, providing reliable, cost effective electricity, and will continue to do so in the future. Hydropower has environmental impacts which are very different from those of fossil fuel power plants. The actual effects of dams and reservoirs on various ecosystems are only now becoming understood. The future of hydroelectric power will depend upon future demand for electricity, as well as how societies value the environmental impacts of hydroelectric power compared to the impacts of other sources of electricity.

Written by Stuart Baird, M.Eng., MBA

SOURCES:

Philip Raphals, "The Hidden Cost of Canada's Cheap Power," *New Scientist*, February 15, 1992.

Geoffrey P. Sims, "Hydroelectric Energy," *Energy Policy*, October 1991.

Eric M. Wilson, "Small-scale Hydroelectricity," *Energy Policy*, October 1991.

Michael Brower, *Cool Energy: The Renewable Solution to Global Warming*, Union of Concerned Scientists, 1990.

Solar Energy Research Institute, *The Potential of Renewable Energy*, An Interlaboratory White Paper, SERI/TP-260-3674, Golden, Colorado, 1990.

Peter Kakela, Gary Chilson & William Patric, "Low-Head Hydropower for Local Use," *Environment*, January/February 1984.

g:misc\lsb1P-mlt.doc



Unit VII Glossary

A Listing of Terms Which Appear in this Manual

Anadromous: Fish species that are hatched in fresh water and then migrate downstream to the ocean to mature. They must migrate back to fresh water to reproduce.

Condensation: Phase change from a gas to a liquid, ex.: a glass of ice water cooling.

Cycle: An endless loop.

Dam: Structure which stores water and increases headflow; a physical structure that holds back an impoundment.

Energy: Ability to do work.

Evaporation: Phase change from liquid to gas occurring at the surface of liquids. Requires energy and causes cooling.

Federal Power Act: An act expanding FERC to license non-federal hydropower.

FERC: (Federal Energy Regulatory Commission); has jurisdiction over licensing non-federal hydropower.

Fog: Clouds which form close to the ground; a form of condensed water in which the droplets are not large enough to fall.

Gas: Phase of matter with no definite shape or volume at normal temperature and pressure.

Generator: Device that converts mechanical energy into electrical energy through the use of magnetic fields and a rotating turbine shaft.

Gravity: The natural force that causes things to be attracted to the center of the earth.

Hail: Large frozen water “stones” usually occurring during severe thunderstorms.

Head: Distance water falls to generate power.

Hydropower: Using the energy of moving water to do work.

Impoundment: The lake behind the dam; a storage area for water.

Kinetic Energy: Energy of motion (moving water).

Liquid: Phase of matter that has a definite volume but no definite shape.

Mitigation: A beneficial project which addresses an environmental impact.

Nonpoint Source: Pollution from an unspecified origin, such as widespread pesticide runoff from many agricultural fields within a watershed.

Nonrenewable Source: An energy source which is not naturally replenished and therefore can be used up such as fossil fuels.

Penstock: Pipe that carries the water from the dam to the turbines.

Point Source: Pollution from a fixed origin, such as a factory smokestack or an end-of-pipe discharge.

Potential Energy: Stored energy (reservoir).

Precipitation: Atmospheric water falling in any form to the surface of the earth.

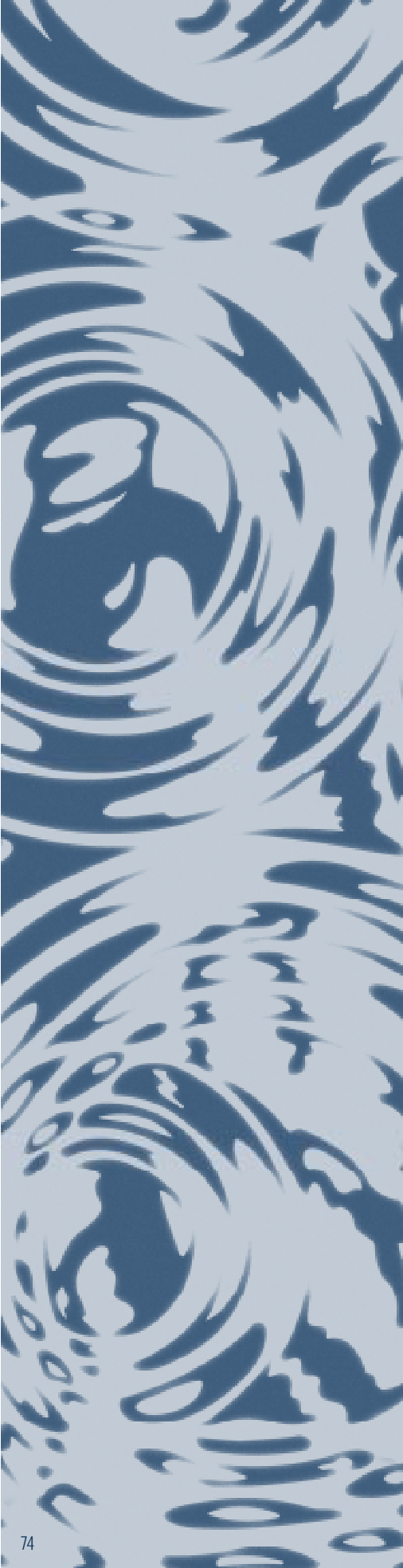
Rain: Liquid form of precipitation.

Recycle: To make new again.

Renewable Source: Energy source that is naturally replenished, ex.: wind, solar, tidal and hydropower.

Reservoir: Body of water stored for human use behind a dam.

Shaft: Connects turbine to generator.



Siltation: A form of nonpoint source pollution whereby fine soil particles are washed off the ground and into the waterway. It is caused by runoff from farm fields, construction, forestry, and other forms of soil disturbance. Siltation effects include clogged porespace within rocks and stream gravel, thereby limiting spawning opportunities for fish and destroying habitat for bottom dwelling creatures.

Sleet: Frozen rain (solid).

Snow: A crystalline solid form of precipitation.

Solid: A phase of matter that has a definite volume and a definite shape.

Spillway: Area of dam used for overflow of water to regulate reservoir levels.

Tradeoff: A compromise, a willingness to accept some mitigation effect in order to achieve a positive result.

Transformer: Device which converts electricity from the hydro-plant to a distribution system.

Turbine: A horizontal wheel with special blades that is attached to a shaft which rotates when moving water strikes it.

Vapor: The gaseous state of fluids which exists as liquids under normal conditions; thus, we speak of water vapor and oxygen gas.

Vertical Water Wheel: Early form of hydropower system consisting of a rotating wheel set in motion by moving water. Useful in creating mechanical energy.

Water: A naturally occurring molecule composed of two parts hydrogen to one part oxygen (H₂O) AKA the Mickey Mouse molecule.

Water Cycle: The solar powered system whereby water is endlessly recycled and purified.

Water Flow: Speed at which water is moving.

Water Pressure: Downward force of water upon itself and other materials caused by gravity.

Watershed: All the land that drains to a common waterway, whether it be a lake or a river.

Wicket Gates: Regulate the amount of water that enters the turbines from the penstock.

Teacher's Notes

Teacher's Notes

Teacher's Notes

Teacher's Notes