Design of a canal for a new water park in Lafayette

Grade Level:	**Total Time Required:**
4	~ 4 – 6 class sessions (30 minute each)

Prepared By: Venkatesh Merwade, Brad Harriger, David Eichinger, and Ryan Habben

Lesson Objectives:

In this lesson, Students will be able to:

1. Learn what erosion is.
2. Explore the erodibility of different earthen materials.
3. Explore the effect of slope on erosion.
4. Design a structure for controlling erosion in a canal.
5. Evaluate their team's results and present their findings to the class.
6. Learn about and apply the principles of the engineering design process.

Indiana Standards:

4.ESS.3 Describe how geological forces change the shape of the land suddenly and over time.

Next Generation Science Standards: 3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost. Science/Engineering Practices 1. Asking questions (for science) and defining problems (for engineering) 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence Crosscutting Concepts 2. Cause and effect: Mechanism and explanation. 3. Scale, proportion, and quantity.
Common Core Mathematics:
Common Core English and Language Arts: 4. RI.4 Determine the meaning of general academic and domain-specific words or phrases in a text relevant to a grade 4 topic or subject area. 4.RI.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

Concepts and Vocabulary

Term	*Defined by a scientist or engineer*	*Defined by a student*
Erosion	The process by which the surface of the earth is worn away by the action of water, glaciers, winds, etc.	Ground/earth being washed away by water or wind.
Resistance (to erosion)	Ability of a soil to resist being eroded or worn away.	Ability of soil to not be washed or blown away.
Drainage	The act or process of draining. Controlling or channeling water by use of a ditch, canal or pipe.	Allowing water to be channeled or directed away from an area.
Runoff	Water not absorbed by soil but flows into surface waters; agricultural or industrial waste products carried by rainfall and melting snow into surface waters.	Rain water that does not sink into the ground and flow over the ground.
Slope or Gradient	The degree of inclination, or the rate of ascent or descent in a highway or area of earth.	The angle or steepness of a hill.
Sheet erosion	The uniform removal of soil in thin layers by the forces of raindrops and overland flow.	
Rain Splash	Soil particles are knocked into the air by raindrop impact.	
Sedimentation	The deposition or accumulation of sediment	
Degradation	The wearing down of the land by erosive action.	
Clay	A natural earthy material that is plastic when wet; earth; mud	
Sand	The more or less fine debris of rocks, consisting of small, loose grains, often quartz.	
Cohesive Soil	Soil that naturally binds together and is resistant to being dragged apart.	
Rip Rap	Erosion control measure, consisting of stones being placed over eroded areas.	
Erosion Control Blankets	Straw or synthetic materials used to help contain extremely erosive soil where vegetation is planted.	
Sources:	http://bing.com/search (Bing Dictionary) http://dictionary.com http://milford.nserl.purdue.edu/weppdocs/overview/sheet.html http://www.paversearch.com/erosion-control-glossary.htm	

Equipment, Materials, and Tools

Materials		
2 liter plastic bottles with lids, preferably clear (two per group)	Fine top soil (50 ml per group)	Popsicle sticks
Small Gravel (pea gravel) ¼ - 1 inch diameter (250 ml)	Duct tape	Rubber bands
Tangrams/ pattern blocks (Variety of shapes and sizes)	Cheese cloth	Binder clips 2 X 2”, 2 X ½ “
Play sand (50 ml per group)	Yarn/Twine	Double sided tape
Screen	Scotch tape	Sand paper (80 or 100 grit) Two 8X10 sheets per group
Playdoh or modeling clay	Construction paper	

Tools		
10 ml Graduated Cylinders / Clear Cup (two per group)	Drill or something to punch holes at the bottom of the plastic cups (one for the class)	1inch three-ring binder
Angle template sheet for measuring slope of the canal (one per group)	Spray bottle for water	12 inch Ruler

Safety Guidelines:

Science Content – Basics

Canal

An open canal, channel, or ditch, is an open waterway whose purpose is to carry water from one place to another. Channels and canals refer to main waterways supplying water to one or more farms. Field ditches have smaller dimensions and convey water from the farm entrance to the irrigated fields.

According to the shape of their cross-section, canals are called rectangular (a), triangular (b), trapezoidal (c), circular (d), parabolic (e), and irregular or natural (f) as shown in the figure below.

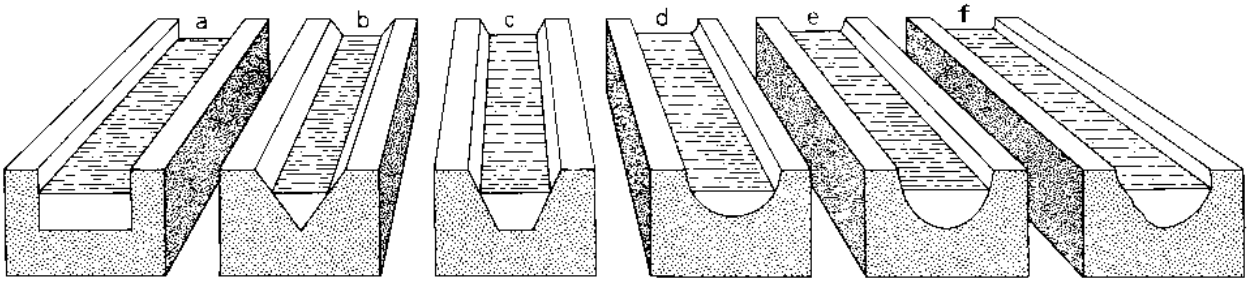


Image retrieved December 2014 from http://www.fao.org/docrep/r4082e/r4082e06.htm

Canal Design Considerations

There are a number of criteria to consider when designing channels. The main criteria include the amount of water that will enter and leave the canal, construction cost, maintenance requirements, environmental conservation and aesthetics. Related to this design activity are maintenance and environmental criteria because of erosion. In this activity the students will deal with a natural triangular canal that has to be lined with a material that is least erodible. The key variables in controlling the erosion are velocity of the water flowing through the canal and the slope; both slope and velocity are related. A steeper slope will cause higher velocity and more erosion; whereas a milder slope will cause lower velocity and less erosion.

Erosion Control

Erosion control is the practice of preventing or controlling wind or water erosion in agriculture, land development, coastal areas, riverbanks and construction. Effective erosion controls are important techniques in preventing water pollution, soil loss, wildlife habitat loss and human property loss.

Erosion controls are used in natural areas, agricultural settings or urban environments. In urban areas erosion controls are often part of stormwater runoff management programs required by local governments. The controls often involve the creation of a physical barrier, such as vegetation or rock, to absorb some of the energy of the wind or water that is causing the erosion. On construction sites they are often implemented in conjunction with sediment controls such as sediment basins and silt fences.

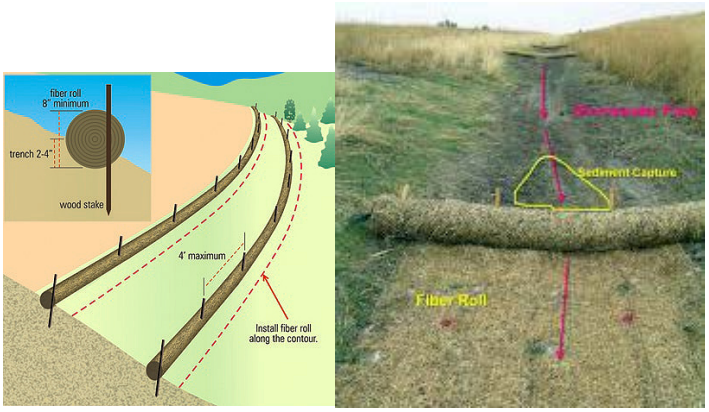
Bank erosion is a natural process: without it, rivers would not meander and change course. However, land management patterns that change the hydrograph and/or vegetation cover can act to increase or decrease channel migration rates. In many places, whether or not the banks are unstable due to human activities, people try to keep a river in a single place. This can be done for environmental reclamation or to prevent a river from changing course into land that is being used by people. One way that this is done is by placing riprap or gabions along the bank.

Some examples of erosion control measures are:

Rip Rap

Riprap, also known as rip rap, rip-rap, shot rock, rock armour or rubble, is rock or other material used to armor shorelines, streambeds, bridge abutments, pilings and other shoreline structures against scour, water or ice erosion.

Fiber Roll



A fiber roll is a temporary erosion control and sediment control device used on construction sites to protect water quality in nearby streams, rivers, lakes and seas from sediment erosion. It is made of straw, coconut fiber or similar material formed into a tubular roll.

Mulching

Mulch is a layer of material applied to the surface of an area of soil. Its purpose is any or all of the following:

- to conserve moisture
- to improve the fertility and health of the soil
- to reduce weed growth
- to enhance the visual appeal of the area

A mulch is usually but not exclusively organic in nature. It may be permanent (e.g. plastic sheeting) or temporary (e.g. bark chips). It may be applied to bare soil, or around existing plants. Mulches of manure or compost will be incorporated naturally into the soil by the activity of worms and other organisms. The process is used both in commercial crop production and in gardening, and when applied correctly can dramatically improve soil productivity.

Silt Fence

A silt fence, sometimes (misleadingly) called a "filter fence," is a temporary sediment control device used on construction sites to protect water quality in nearby streams, rivers, lakes and seas from sediment (loose soil) in stormwater runoff. Silt fences are widely used on construction sites in North America and elsewhere, due to their low cost and simple design. However, their effectiveness in controlling sediment can be limited, due to problems with poor installation, proper placement, and/or inadequate maintenance.

Engineering Design

Synopsis of the Design Activity:

Problem:	Water needs to be transported to a new water park from an existing clean water supply.
Goal:	To carry water from clean water source to water park through a ditch or canal
Who is the client:	Mayor of Lafayette
End-User:	City of Lafayette; waterpark employees
What is the design:	To design a trapezoidal ditch or canal that minimizes the erosion.
Criteria:	• The canal should be able to carry water from one place to another. • Carry the water with least erosion. • The canal should be leak proof. • Must have erosion control mechanism. • The bed should be flat and at least 3 inches wide. • Should have at least 0.5 inch bank on each side. • The earth material should only cover the bed of the canal.
Constraints:	• Only available material should be used in the design. • The canal/ditch should be open without any obstructions at both ends.

Lesson Plan #1
Enquiry Activity – testing the erodibility of earth materials on a sloping surface

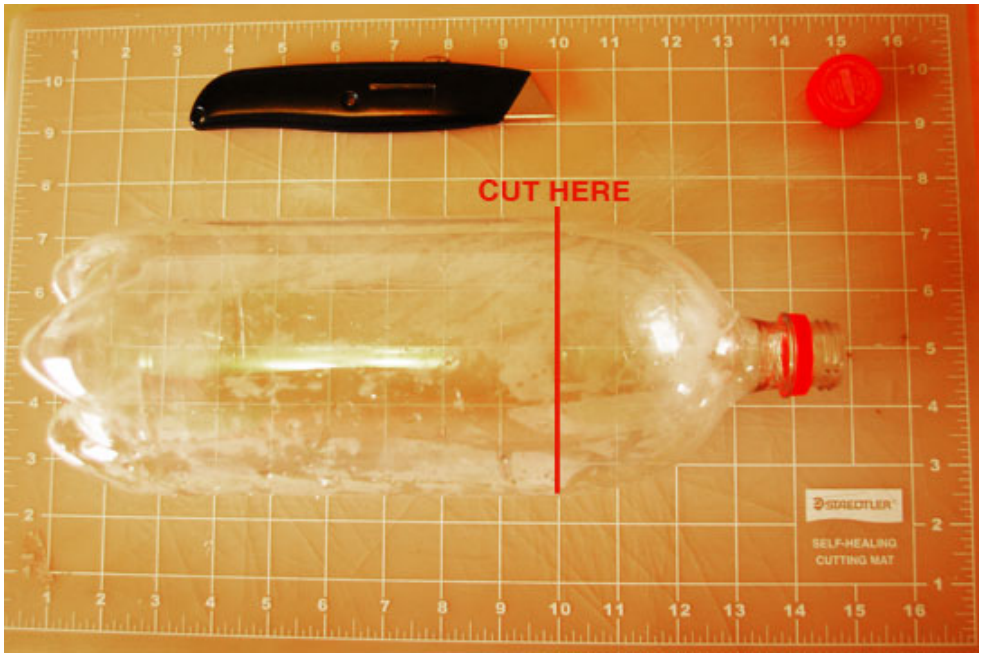
Time: 30 minutes

Note: In this lesson students will learn:
1) How the shape of sand and soil/clay particles affects their erodibility.
2) How the slope of a canal affects the amount of erosion that can occur.

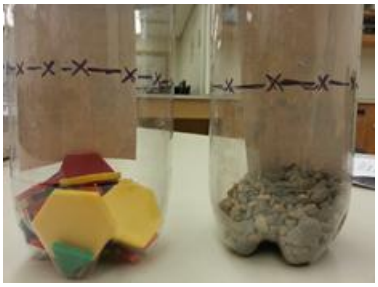
Procedure:

1. Before the class, the teacher needs to prepare the material required for this activity. Assuming four students in each group, prepare the following for each group:

   i. Models of sand and clay particles: Using the diagram below as a guide, cut a 2-liter bottle near the top but do not cut all the way around. This will allow you to open the top of the bottle enough so that you can add the necessary materials and then tape the cut portion to seal the materials inside. For each group, cut one bottle as shown below, add a 4" X 7" piece of sandpaper and use double sided tape to secure it to the inside of the bottle with the rough side of the sandpaper facing the inside of the bottle. Add the pea gravel (representing sand particles), then reseal the cut portion using duct tape. Follow the same procedure with the second bottle, only this time add the tangrams (representing soil/clay particles) instead of the pea gravel. You now have a set of models for each group.

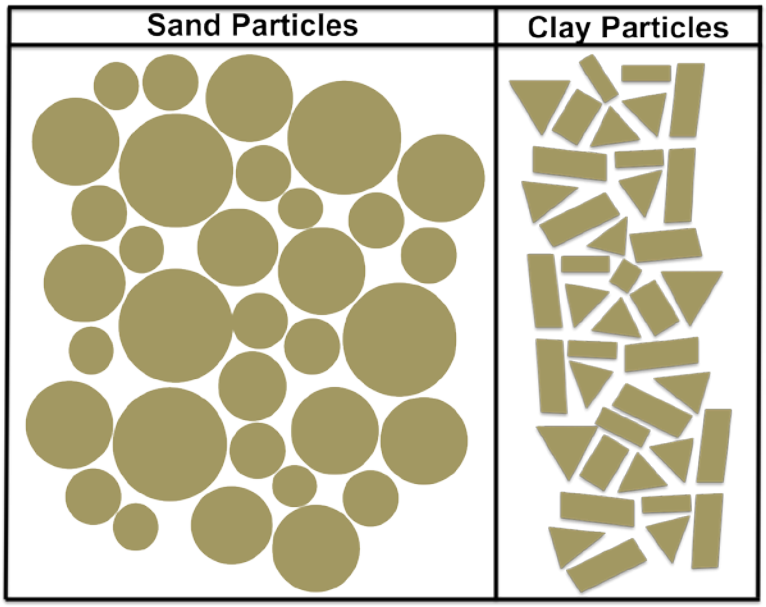


Mark a line on the outer diameter of the bottle approximately at 60 - 65% of the height of the bottle. The figure below shows how the bottles may look like when it is done.



2. Start a whole class discussion focusing around the following key questions:
   - *What is erosion?*
   - *What causes erosion to happen?*
   - *What are different kinds of erosion?*
   - *Where do you see examples of erosion around you?*
   - *Does the size and shape of the material being eroded have an effect on how much erosion will happen? If so, how and why?*
   - *Does the slope (how much it is tilted) of the material being eroded have an effect on how much erosion will happen? If so, how and why?*

3. Explain to the class the purpose and set up of the sand and soil/clay particle models. Ask them what they think the tiny particles of sand and soil/clay look like. What shapes are they similar to? Then you can show them the following figure that represents the comparison:



Ask them to explain which bottle (with the pea gravel) represents a model of what sand particles look like and which bottle (with the tangrams) represents a model of what soil/clay particles look like.

4. Divide the class into groups with 3-4 students per group. Provide a set of bottles to each group. Have each group perform the following inquiry activities:

   a) Predicting the stability of sand vs. soil/clay: Have one student in the group place both the bottles on a one-inch ring binder as shown below.

Top view

Side view

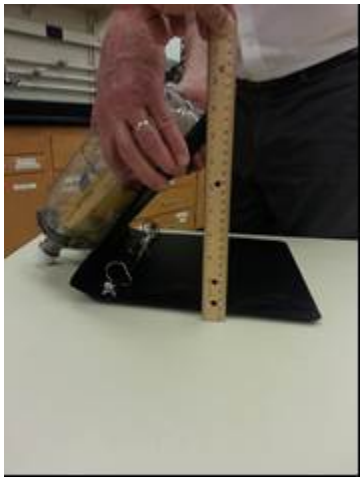
   b) With the bottles resting on the binder, have each group **predict** which material, sand or soil/clay, will be less stable, that is, more of it will move to the small end of the bottle more easily if the students continue to open the binder. Have them record their predictions and explanations in Table 1.

   c) While one student holds the bottles on the binder, have another student SLOWLY open the binder such that the bottles will tilt and the material will begin to slide towards the bottle opening. Open the binder until all the material passes the line on one of the bottles as shown in the figure below.

Side view

Front view

d) Measure the height at which the binder is open as shown below using a ruler as shown below. Record the height for the material in Table 2.



e) Continue opening the binder until the material in the second bottle crosses the line. Record the height at which the binder is open.

f) After all groups complete Table 2, have students describe which material is more stable, and why.

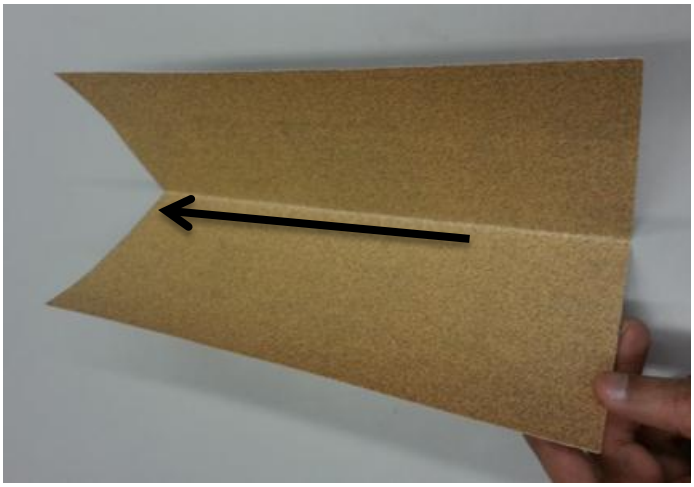
Lesson Plan #2
Guiding Question – How does the slope of a waterway affects the erosion

Time: one 30 minute class session

In this session, students will see how the slope of a waterway along the flow direction causes and affects erosion. This activity can be done in two ways: (i) as a demonstration activity where the teacher does all the work and have students only observe and record the final readings; or (ii) forming small groups for students and have each group perform the activity, but teacher will do the spreading of sand and spraying of water to keep the procedure consistent among all the groups.

Procedure:

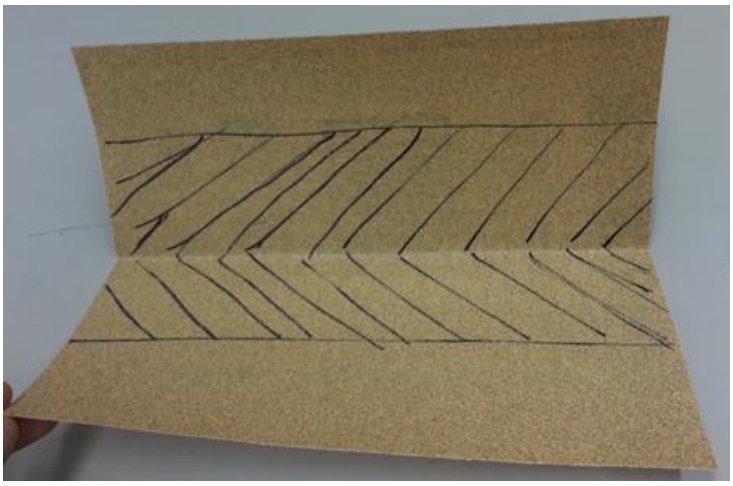
1. Take a sand paper and fold it in half along its length as shown below.



2. Explain students that this represents a water way (i.e., a river or a canal) where the water is flowing in the direction of the length of the sand paper (shown by arrow), and we are going to study how its slope along the flow of water affects erosion.

3. Spray water on the sand paper using the spray bottle to dampen it just enough so sand particles can stick on it.

4. Take 50 ml of sand and spread it evenly in the middle portion of the stream or canal, leaving the sides uncovered as shown below (the black hatched area represents the sand layer).



5. Dampen the sand again using the spray bottle so it sticks to the canal.

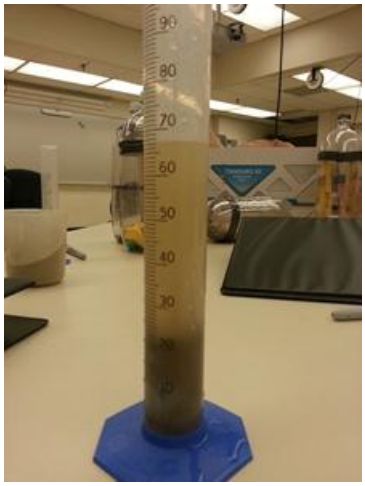
6. Place the stream on a one inch binder towards the end of the table to give some slope to the water way. Next, have a student hold a graduated cylinder at the lower or downstream end next to the table as shown below.

Side view

Top view

7. Add 50 ml of water to the spray cup that has holes in the bottom. Move the cup along the two sides of the canal (i.e., where there is no sand) so the water gets collected at the center and flows downstream. The water and the eroded earth material should then be collected in the graduated cylinder as shown below.

8. Let the sand settle in the graduated cylinder (i.e., wait a few minutes as shown below). Meanwhile, show the channel (sand paper) to the students to demonstrate how the running water eroded the sand from the river. Have the students record the depth of sand and relatively clear water in the graduate cylinder. Use table 3 to record the readings.



9. Repeat this experiment with a new sand paper, but use a three inch binder as a support for the channel to represent a steeper slope. Compare the eroded river from both experiments and the amount of sand and water measured from both experiments.

10. Have students discuss how the slope of a river affects the amount of erosion.

Lesson Plan #3
Designing a canal

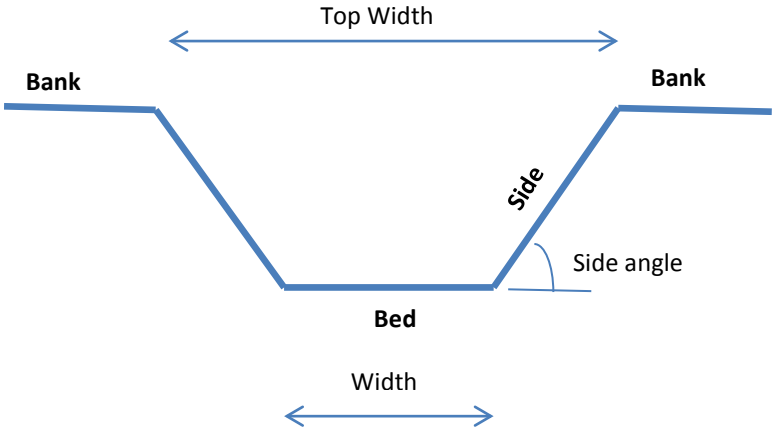
Time: one 30 minute class session

Procedure:

1. Begin the class by briefly reviewing the outcomes from Lesson 1 and 2 such as the erodibility of sand and clay, and the effect of slope on erosion.

2. Guide students through the design brief. Ask students the following questions:
   - *What is the problem?*
   - *What is the goal?*
   - *Who is the client?*
   - *Who is the end user?*
   - *What are the criteria?*
   - *What kinds of materials can you use?*

3. After introducing the challenge, give a brief overview of a canal and some of the nomenclature associated with it such as the flow area, bed slope and side slope (utilize vocabulary words that are described earlier). Use the materials in the resources and the figure below to help with this explanation.



   Similarly, explain the purpose of erosion control and show some real-world examples of erosion control structures. The material provided in the science content/resources should be helpful with this explanation.

4. Instruct students to develop his/her individual plan in his/her design notebooks. Encourage students to label their sketches, include dimensions, and list the materials they will use.

5. Instruct students to work in small teams to share their plans. Next, instruct students to decide on one plan or design and to select a representative from the team to share his/her plan to the teacher for his/her approval.

6. Have each group create a sketch of their canal cross-section indicating the sides, bed and the banks. Have them give dimensions on their sketch and the side angle if the total width of the sand paper is 9 inch. Indicate and draw the erosion control measures in the sketch. After the sketch is complete, have the students get approval from the teacher before giving access to the materials.

7. Ask the students to construct the canal from the sand paper as per their sketch. Emphasize the following in making their canal:

   - that the bed should be flat
   - The canal should have some mechanism to control erosion
   - Choose a slope for their canal (one inch or three inch)

Lesson Plan #4
Guiding Question – Testing you design

Time: One 30 minute class session

Procedure:

1. After the canal is constructed, have the student groups bring their canal to the teacher for testing. For testing, the teacher will rest the canal on a sloping surface (i.e., the three inch binder or one inch binder as decided by the group) as in lesson plan 2.

2. Dampen the canal with water using the spray bottle. Next, evenly spread 50 ml of sand on the canal except the banks, and again dampen the sand. Next, the teacher will then take 50 ml of water in the spray cup that has holes in the bottom. Move the cup along the banks of the canal so the water gets collected at the center and flows downstream.

3. The water and the eroded earth material should then be collected in a graduated cylinder to measure the amount of water and sand collected and recorded in Table 4.

4. If the team chose the one inch slope, check if the canal is able to work with the three inch slope.

Lesson Extension Ideas
Designing a canal

The activity can be extended to include more than one material such as soil for both inquiry and design.

An enquiry activity can also be added to check the effectiveness of different types of erosion control measures such as cheesecloth, screen, etc.

Designing a canal or ditch for the new water park in Lafayette

A new water park is coming to the City of Lafayette. However, the water needs to be transported to this park from a clean water supply. The mayor of Lafayette needs your help in designing a canal or ditch to carry this water to the water park. The canal or ditch design should also incorporate a mechanism to control bed erosion.

Criteria:

- The canal should be able to carry water from one place to another.
- Carry the water with least amount of erosion.
- The canal should be leak proof.
- Should have a mechanism for controlling bed erosion.
- Should have at least 0.5 inch bank on each side.
- The bed should be flat and at least 3 inches wide.
- The earth material should only cover the bed of the canal.

Constraints:

- Only available materials can be used in the design
- The canal must be open without any obstructions at both ends.

Table 1: Predict the stability of the sand and soil/clay materials.

Material	Less Likely to erode	More Likely to Erode	Why?
Sand			
Soil/clay			

Table 2: Record the stability of the sand and soil/clay materials.

Material	Height at which the binder is open (inch)	Less likely or more likely to erode	Explanation based on particle shapes
Sand			
Soil/clay			

Table 3: Amounts of water and sand collected when comparing the effect of varying slope on the amount of erosion.

	Volume (ml) for one-inch binder	Volume (ml) for three-inch binder
Amount of water collected		
Amount of sand or clay collected		

Table 4: Amounts of water and sand collected while testing team's prototype.

	Volume (ml) for one-inch binder	Volume (ml) for three-inch binder
Amount of water collected		
Amount of sand collected		