**Printouts:** Roles and Optimization Worksheet (pdf)

Budget Worksheet (pdf)

**Engineering Connection**

Engineers design landfills to contain waste from many types of anthropogenic (human-generated) sources. The garbage comes from many places, including household trash cans, worn-out tires, sludge from wastewater treatment plants, old couches, and scrap metal. The main challenge for engineers is to keep the waste materials from being a health hazard. Also, because of economic constraints, landfills must be as small as possible while holding the most amount of waste material possible. Engineers work with regulators to design landfills that are suitable for hazardous and non-hazardous waste.

**Introduction/Motivation**

The people living in the US make about 250 million tons of trash every single year! (EPA, 2009) And, about 300 million people live in the US. So, that works out to about 4½ pounds of trash generated per person — every single day!

How much of this garbage do you think gets recycled and composted? Only about one-third of this trash gets recycled or composted, which means that on average, you make three pounds of trash every day that we have to put somewhere (and the US makes 470 tons of trash every day).

Where do you think we should put this trash? Can we just dump it out in a field? Why not? What if the dump or landfill is near a lake or a river? Groundwater that is stored in aquifers is always flowing. People use wells to bring groundwater up from the aquifers to drink. We must keep dirty water that comes from the landfill (leachate) from getting into the groundwater, otherwise we can make people sick.

**Vocabulary/Definitions**

1. Anthropogenic: Created by people or caused by human activity.
2. Aquifer: An underground layer of permeable rock, sand, gravel or soil that contains or conducts groundwater. The pore spaces in aquifers are filled with water and are interconnected, so that water flows through them. Source of water for springs and wells.
3. Geosynthetic: Human-made materials for earth systems (such as landfills, dams, roads and retaining walls).
4. Impermeable: A material characteristic that does not allow a fluid (such as water) to flow through it.
5. Landfill: An engineered site used to dispose of garbage by burying it.
6. Leachate: Contaminated water that seeps out of landfills. Often contains high amounts of organic matter and toxic chemicals.
7. Liner system: The technical term for the layers of materials (such as clay and geosynthetics) that protect landfills from erosion, and keep trash and leachate from escaping from landfills.
8. Optimize: To make a system as good or functional as possible.
9. Requirement: What a particular product, system or service should do. A necessary attribute, capability, characteristic, quality or limitation. In engineering, sets of requirements are inputs into the design stages of product development.

**Procedure**

**With the Students: Create Model Landfills**

1. Divide the class into groups of four students each. Hand out the Roles and Optimization Worksheets.
2. Assign each group member one of four team roles (or let the students decide amongst themselves). Have them indicate on their worksheets who is responsible for each role.
	1. **Project engineer:** The project engineer is the project leader. This person is in charge of final decisions. S/he listens to all of the engineers and helps to decide the best idea. S/he makes sure the landfill gets built on schedule.
	2. **Design engineer**: The design engineer plans how the landfill will work and look. This person is in charge of picking materials and deciding how the landfill should be built. S/he works with the budget office (when picking materials) and construction engineer (when deciding how to build the landfill)
		1. Have the "design engineer" students draw out his/her team's landfill design and complete the budget worksheet. If time permits, have the "design engineer" calculate the volume of the plastic bin and compare this to the volumes of materials (e.g., sand, clay, etc.) they are using. Note: 1 cup ≈ 15 in3.
	3. **Construction engineer:** The construction engineer builds the landfill. This person gets the plans about how to build the landfill from the design engineer. If the landfill design must be fixed, s/he talks to the budget office about getting more or different materials.
	4. **Budget office:** The budget office makes sure that the project spends the least amount of money possible. This person helps the design engineer pick materials. S/he is in charge of filling out the budget worksheet, doing the calculations, and keeping track of how much money has been spent. You cannot go over budget!!
		1. Hand out the budget worksheets to the "budget office" students in each group and talk with them about the different materials.
3. Introduce the project objectives to the students:
	1. Each group must design a landfill that:
		1. can hold the most garbage
		2. minimizes the cost, while making sure that
		3. the landfill is able to contain the waste during a rainstorm without allowing leachate to get to the town.
4. Sign-off on the engineering landfill designs and budget worksheets for each group.
5. Have students bring both their approved (signed) designs and completed budgets to the "supply shop" to get their supplies.
6. Have students construct the base liner systems for their model landfills.
	1. The goal is to keep water from getting out of the landfill. Therefore, materials such as clay and geosynthetics are good choices, because water cannot flow through them easily.
	2. Basically, the liner should look like a clay bowl or box. Of course, not all teams will choose this path — so you may see Popsicle sticks, toothpicks, etc., at this stage.
	3. Save some funds to purchase materials to build your top cap (to put on after the garbage is inserted). A landfill without a top is no good for anybody!
	4. The top also needs to be secured in such a way that it can be removed and reattached.
7. Fill the landfill with "garbage" making sure not to let the food coloring seep out into the area around the landfill before construction is completed.
	1. Count how many cotton balls you put in. Have the Project Engineer tell you how many to put in.
8. Have students record the quantity of garbage cotton balls that their landfills can hold on the worksheet.
9. Give students time to finish constructing the top cap liner systems for their landfills.
	1. The purpose of the top cap is to keep the rain out of the landfill. Therefore, like the bottom liner system, it should be made of materials water cannot flow through.

**With the Students: Test Landfill Performance**

1. Create "rainstorms" by pouring water on the model landfills.
2. Use a pencil or Popsicle stick to dig into the sand outside of the landfill and near the town to look for any seeping food coloring (leachate). Make multiple soils tests.
3. Repeat the rainstorm, if desired.
4. Leave the landfill overnight.
5. Retest the landfill for leachate the next day.

**Post-Activity Assessment**

Optimization Discussion: Lead a class discussion asking students the following questions:

1. Which group had the most optimal design (most garbage, least cost and best performance)?
2. What were some characteristics of good vs. bad designs

Materials:

Each group needs:

* clear plastic tub (~12-in long × 6-in wide × 5-in deep) (~30-cm x 15-cm x 13-cm) with about 1 inch (2.54 cm) of sand in the bottom
* clay (~750 cm3), this clay does not need to be the high-quality type used for modeling; clayey or silty soil from your backyard works fine
* sand (~1500 cm3) (available at home and garden stores)
* gravel (~100 cm3) (available at home and garden stores)
* ~15 cotton balls
* (optional) tiny houses and buildings (such as Monopoly game houses and hotels), or any other simple representation to simulate the presence of a town sitting on the sand base
* [Roles and Optimization Worksheet](https://www.teachengineering.org/content/cub_/activities/cub_enveng/cub_enveng_lesson05_activity2_rolesopsworksheet_v2_dwc.pdf)
* [Budget Worksheet](https://www.teachengineering.org/content/cub_/activities/cub_enveng/cub_enveng_lesson05_activity2_budgetworksheet_v2_dwc.pdf)

Note: The amounts of clay, gravel and sand are approximate (based on experience with teaching the activity), but because students can choose how much of each type of material they want to use, it is helpful to have a bit extra on hand.

**For the entire class to share:**

* food coloring
* clear plastic tub in which to mix together food coloring, water and cotton balls ("garbage")
* (optional) gloves or spoon to "mix" the garbage
* strips of plastic garbage bags, to simulate geosynthetics used in landfills
* toothpicks
* straws
* popsicle sticks
* small, paper "Dixie" cups (~85 ml size), to measure and distribute clay, gravel and sand
* access to water
* watering can, water bottle or other "rain storm" device
* (optional) electric fan, to simulate the erosion force of wind
* (optional) graph paper