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## Incorporating environmental engineering and science topics into elementary education

Jessica G. Billings  
*Michigan Technological University*

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<https://doi.org/10.37099/mtu.dc.etds/508>

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INCORPORATING ENVIRONMENTAL ENGINEERING AND SCIENCE TOPICS INTO  
ELEMENTARY EDUCATION

By

Jessica G. Billings

A REPORT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

ENVIRONMENTAL ENGINEERING SCIENCE

MICHIGAN TECHNOLOGICAL UNIVERSITY

2011

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This report, "INCORPORATING ENVIRONMENTAL ENGINEERING AND SCIENCE TOPICS INTO ELEMENTARY EDUCATION," is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING SCIENCE.

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# **PART I**

# **OVERVIEW**

## Introduction and Scope of the Project

This research report explores the benefits and importance of introducing environmental engineering and science topics to children at the elementary level. The first part of the report examines the current literature on elementary science and engineering research, as well as current programs available to teachers. The second part details the design, creation, implementation, and evaluation of a 5-day unit aimed toward upper elementary (grades 3-6) teachers. The unit incorporates hands-on learning with an introduction to engineering, focusing primarily on environmental water topics. The lessons deal with the water cycle and catchment basins, drinking water filtration, landfill leachate, and cleaning up oil spills.

The third and fourth parts of the report take two topics from the 5-day unit and go into greater detail. Part 3 includes the design, creation, implementation, and evaluation of an activity that introduces upper elementary students to the regulations regarding new landfill placement. Students use real-life maps to evaluate possible locations and understand why a past landfill had to be abandoned. The fourth part of the report takes an existing lesson on drinking water treatment and reworks it into a new activity, based on the field testing comments and criticism. Both of these activities were presented multiple times at Family Science Nights at local schools and the responses were recorded and assessed. Lastly, the fifth part of the report assesses the projects as a whole and offers possible ideas on how to proceed.

This research report offers a multitude of ways to introduce elementary –aged children to environmental engineering and science, both in school and in other settings. The goal is to emphasize how valuable an introduction to engineering is at that young age and provide a portfolio of curriculum that can be used individually or as a unit. It also examines students' and families' preconceived notions of engineering and how the lessons helped develop those ideas, noting misconceptions and areas to focus on when introducing engineering to a new group.



## Literature Review

In the United States, interest in engineering has been steadily declining in recent years. Even as we become a more technological society, depending heavily on the feats of engineers, colleges are seeing a drop in the number of engineering students. A study conducted in 2007 found a startling 18% drop in the interest of high school students in engineering careers since 1991 (Jamieson 2007). Of these students in engineering, gender and ethnic diversity is often lacking (Brophy, Klein, Portsmore & Rogers 2008). The strong majority of entering undergraduate students in engineering programs are Asian males, followed by Chicano and white males, while there is a very small percentage of white and Chicano females (Jamieson 2007).

To change this trend, it is important to give elementary school students of all backgrounds an introduction to engineering and expose them to engineering careers. Elementary school sets the foundation of learning for many more years in school and can impose some negative stereotypes that resonate throughout the rest of their lives. Some have hypothesized that the reason there is such a major male-female gap in their interest in engineering is because males are encouraged to engage in “tinkering” activities during out-of-school time, while females are not encouraged to the same extent. For this reason, it is important for both sexes to be introduced to engineering in school (Crawford, Wood, Fowler & Norrell 1994). Additionally, the fact that engineering is currently male-dominated may be discouraging some women from entering the field. Researchers suggest that if engineering were addressed more, beginning in elementary school, both males and females might be more interested in entering the field (Cunningham, Lachapelle & Lindgren-Streicher 2005).

In addition to the declining interest in engineering, there is also a strong misconception among elementary students about the role of engineering. One group of researchers gave over 6000 elementary students a quiz about what kinds of work engineers do and found that the majority of students believe engineers are auto mechanics and construction workers (Cunningham et al. 2005). If these misconceptions persist past elementary school, it could be deterring some students from the engineering field because they do not understand what it entails. The top six choices that elementary students picked in the quiz were all associated with construction, building, machinery, and vehicles. On the open-ended question of what they thought an engineer does, the most common answer was that an engineer fixes things (Cunningham et al. 2005).

In another study, students had no idea what to draw when asked to draw a picture of an engineer (Caldino, Palou, Macias, López-Malo, & Garibay 2009). This demonstrates a clear lack of understanding of one of the main ideas of engineering: design. Clearly, most elementary students are not currently being taught enough about engineering so that they understand what it is. Engineering is often not a core topic in the elementary school curriculum, but research suggests that perhaps it should be.

The U.S. national education standards are focused around seven core topics, which are most often found in schools: fine arts, language arts, mathematics, physical education and health, science, social science, and technology (Education World 2011). Although standards can vary by state, these subjects represent topics that are typically focused on and tested for. Because educational standards are often required to be identified in a teacher's lesson plan, subjects that fall outside the realm of the standards are sometimes neglected, such as engineering. As some educational experts explain:

The last decade of the 20<sup>th</sup> century witnessed considerable interest in curriculum integration, especially at the middle level. Paradoxically, at the same time, schools were being subjected to increasing pressure for 'accountability' and for 'standards-based reform.' These demands have been accompanied by high-stakes testing, a standardized, subject-centered curriculum, and sometimes even scripted teaching lessons. This trend continues today. (Vars & Beane 2000)

Instead, these subjects must be included in the other core topics wherever possible, until the time when engineering and other neglected topics are included in the core curriculum. Unfortunately, this does not encourage teachers to focus on them, as they have limited time to address all the standards already imposed on them. The researchers go on to say that one study estimated that it would take a very competent student an additional nine years of school to reach an acceptable performance in every recommended national standard. It is simply not possible for a teacher to address every subject competency (Vars & Beane 2000).

Of the engineering lessons currently being used in elementary schools, researchers have found that a design-centered curriculum where students are encouraged to design, construct, and test experiments is the most successful (Jamieson 2007). The objective of this type of lesson is that students learn that science and engineering are fun and creative career fields and it breaks down barriers between students of different ages, gender, ethnicities, economic backgrounds, and academic skill levels (Caldino et al. 2009). However, many of these lessons also neglect to include quantitative reasoning, and

instead focus on the qualitative (Parsons, et al. 2007). One of the integral objectives of engineering is to teach students how to gather data to support their observations and findings so that they are able to make predictions and conclusions based on data. If students do not learn how to collect data, the process of making predictions and conclusions can be mystifying.

Perhaps one of the reasons teachers shy away from incorporating data and math into their lessons is because they have a lack of knowledge in engineering and math and instead prefer to rely on lectures and demonstrations (Parsons et al. 2007). In fact, education reform often centers on test results, but does not typically work to improve the teachers' knowledge of the subject so that they can better teach it (Bainer & Williams 1995). Many teachers have not taken an engineering or environmental science class in their training, so lesson plans that include important background knowledge are vital. Some research suggests that colleges should require an inquiry-based environmental science course in the teaching program, because these classes have a positive effect on teachers' attitudes toward science and the scientific method (Brown 2000). Even a brief introduction to a subject such as this can bolster a teacher's confidence in teaching the subject and cause them to be interested in learning more about the topic of interest.

There is a great need for lesson plans that help teachers become more confident in engineering so that they are more willing to approach the topic with their students (Brophy et al. 2008). There is also a push towards encouraging teachers to partner up with research professionals to assist in teaching environmental science in the classroom. The partnership between an expert in the field and a teacher has met with very positive results, for both the teachers and the students. In fact, many of the teachers studied in these partnership programs responded that they felt more confident teaching the subject and even found environmental science to be more "active" and "exciting" than previously thought (Bainer & Williams 1995). With an expert for back-up, there is no longer a fear that they will be unable to answer a students' questions or fail in the objective of the lesson. It takes much of the pressure off the teacher and instead, the teacher can be just as involved in the learning process as the students.

Other researchers have come to the same conclusion – that teachers are teaching engineering in a way that does not engage or effectively teach possible future engineering students. Many studies agree that there is a strong correlation between how students are taught engineering and which ones decide they want to become an engineer (Jamieson 2007). Engineering students are typically "visual, sensing, inductive, and active" learners, meaning they need hands-on stimulation, pictures, and a better grasp on overall concepts (Felder & Silverman 1988). However, teachers often fail to teach lessons in a

way that addresses these types of learners, instead resorting to a lecturing environment where the students are not an active part of the learning process.

The most creative of engineers are often “global” learners, meaning they do not follow a sequential learning pattern. These students are often the ones that fall behind the fastest in a conventional learning situation and are easily discouraged because they cannot immediately see the big picture like some of their classmates. Oftentimes, these students will understand an earlier lesson only after several other lessons (and perhaps after they have been tested on the subject). However, they can also make very inventive engineers if they persevere (Felder & Silverman 1988).

One particularly important concept of engineering is teamwork, which is often overlooked (Crawford et al. 1994). In the real world, engineers often work in teams and it is an important part of the engineering process. Therefore, it should be a part of any introductory engineering activity, even at the earliest ages. For the youngest students, the most effective way to teach engineering is through craft-based projects and a design-based inquiry approach (Brophy et al. 2008). In these lessons, the teacher acts merely as a guide and the students are allowed to use their exploratory skills to learn the concepts (Crawford et al. 1994). As teachers become more confident with the concepts of engineering, they may be more willing to expand up on and build their own lesson plans related to engineering (Caldino et al. 2009).

Another hope is that teachers will begin to look at their schools in a new way. Many engineering and environmental science lessons can be done in the classroom or in the schoolyard, with everyday materials. Research has shown that short, frequent lessons and experiences based in the outdoors at school have a positive effect on students’ attitudes toward the environment. One study looked at a 10-day unit that took students into the schoolyard to learn about plant and animal ecology. The students who participated in this unit learned significantly more than students in a traditional, indoor experience (Cronin-Jones 2000).

The involvement of a student’s family can also have a very positive impact on his or her interest in a particular subject. Studies have shown that students whose families are involved in their academic life are more successful at school. To top it all off, many families want to be more involved in their child’s schoolwork, but they often feel overwhelmed by unfamiliar material (Eccles & Harold 1996). There can also be time and resource constraints, language and cultural differences, as well as a school structure that does not support parent involvement (Funkhouser & Gonzales, 1997). It is no wonder that

the school-family link is often severed or at the very least, severely limited. Not only do lessons need to reach out to teachers unfamiliar in the subject, they also need to reach out to parents.

Based on this research, I have put together a selection of elementary engineering activities focused on environmental engineering and science. I have conducted the lessons in several school-like setting with a diversity of ages, ethnicities, and gender. I was interested to see whether the students' interest in engineering is different based on sex or race and whether that changed after the unit. I have chosen a selection of design and creation-based lessons to emphasize the engineering process. Each lesson includes the appropriate educational standards that support it as a core piece of an elementary education. The standards fall under such subjects as mathematics, science and technology, geography, science as inquiry, and social perspectives.

In every lesson, I have included an appropriate amount of background knowledge so that teachers or parents without an engineering background would feel comfortable using them. I included data measurement with every possible lesson – including such things as measuring cups, stopwatches, and rulers. Using a pre- and post-assessment, I looked at what preconceptions and ideas these students had about engineering and how those changed after the unit. I emphasized teamwork and had the students work in small groups whenever possible. Lastly, I attempted to involve the students' parents and gauged their reaction to the activities.

## Current Elementary Engineering and Science Programs

There are many programs widely available to classroom teachers in both engineering and environmental science. The following is a list of some of the most popular ones:

**Engineering is Elementary:** <http://www.mos.org/eie/>

This program covers a variety of engineering topics and is presented to the student through a short story, problem-solving, and teamwork. Each short story features a child from a different country or ethnic background. The story presents an engineering problem and follows the engineering design process in order to address the problem. These lessons focus on science, technology, engineering, and math (STEM), but also use literacy and social studies to convey the lessons. It is currently being used in at least one classroom in every state, and over 20,000 teachers have used the program. There are currently 18 lessons available (with 2 more planned) and each lesson is designed to cover a 5-day period of time.

**Teach Engineering:** <http://www.teachengineering.org/>

This website hosts a free library of engineering-based lessons, submitted by teachers. They stress that the lessons are teacher-friendly and easily understood by non-engineers. The library includes lessons for students of all grades, but there are many for elementary students. It is possible to search by grade level, branch of engineering, keyword, or educational standards.

**Future Scientists and Engineers of America:** <http://www.discoverycube.org/fsea.aspx?q=47>

This is an after-school program where students learn about engineering in hands-on projects. It is geared towards upper elementary (and above) grades and invites local scientists, engineers, and technicians into the classroom. Students engage in designing, building, and testing projects that they create. To fund the program, the website offers a variety of grant proposal ideas and letters ready to submit.

**A World in Motion:** <http://www.sae.org/exdomains/awim/aboutus/>

This website sells a variety of kits for engineering lessons. The lessons focus on aerodynamics, gravity, and electricity. They are designed for upper elementary programs (and above). A World in Motion also offers workshops for teachers, to help them to become more comfortable with the projects.

**International Technology and Engineering Educators Association:** <http://www.iteea.org/>

This association offers lesson plans, activities, and guides on teaching engineering to students of all elementary grades. It provides lots of background material for the teachers, links to state

standards, and focus on the design process. It also publishes a magazine four times during the school year with articles about teaching engineering to elementary students.

**Project Learning Tree:** <http://www.plt.org/>

This program targets students in grades pre-K through 12. It is an environmental education program that uses the slogan: “PLT helps students learn how to think, not what to think, about the environment.” It provides training, materials, and support for teachers interested in the program and have trained over 500,000 educators. They offer a variety of activities to members and include two sample activities on their website.

**Project WET and Project WILD:** <http://dnr.wi.gov/education/pltwildwet/>

These two programs offer curriculum and activities for grades K-12. Project WET focuses on water education and Project WILD focuses on wildlife education. Educators are trained at workshops in order to use the materials. Although it is organized nationwide, it is only delivered in Wisconsin. Each project offers an activity guide containing over 150 activities.

**Michigan Environmental Education Curriculum Support (MEECS):**

[http://www.michigan.gov/deg/0,1607,7-135-3307\\_3580\\_29678---,00.html](http://www.michigan.gov/deg/0,1607,7-135-3307_3580_29678---,00.html)

This is a Michigan-specific set of activities for upper elementary and middle school students. After completing a workshop, educators are provided with a variety of classroom kits for environmental subjects such as land use, biodiversity, water quality, energy resources, and air quality. The kits come prepared with activities, posters, tests, videos, and background information for the teacher.

**NASA Education Programs:** <http://www.nasa.gov/offices/education/programs/index.html>

NASA offers activities, challenges, and competitions for students of all grade levels, to encourage interest in STEM subjects. The activities vary at different times of the year, but it keeps a list of current projects on its website. Additionally, it keeps a list of free lesson plans in a searchable database.

**Tech Alive:** [http://techalive.mtu.edu/meec\\_index.htm](http://techalive.mtu.edu/meec_index.htm)

This website hosts a variety of online lessons and activities related to the environment. The lessons cover water quality, ecosystems and biodiversity, and energy resources. Each activity uses diagrams, animations, and games to explain the concept. The website is free for anyone to use.

**PART II**

**FIVE-DAY**

**UNIT**



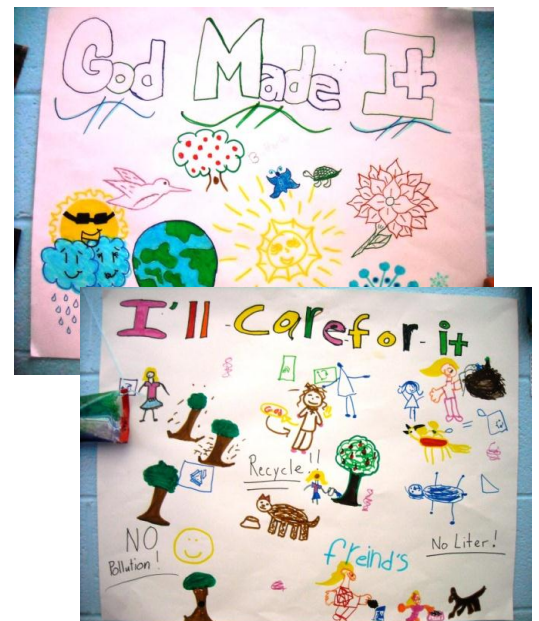
## Classroom Context and Description of Learners

This unit was presented at Woodstock Early Learning Center, located in Woodstock, IL: a small town of approximately 25,000, located 50 miles northwest of Chicago. The daycare cares for around 150 children from ages 6 weeks to 12 years. Classes are divided up by age with one class per age group, so many of the children have known each other for several years. They provide an after-school and summer program for children aged 6-12, many whom go to the same elementary school during the school year. The daycare strives to supplement the children's experience at school, offering homework assistance and educational field trips.

The teachers use the Creative Curriculum, which focuses equally on physical, emotional, cognitive, and social growth. They adhere to the guidelines of the National Association for the Education of Young Children. The daycare is Christian-based and provides religious education at all ages, although they accept students and families from all religious backgrounds. Most of the families are from a low to middle socioeconomic class, and many single-parent families are represented.

I worked with the elementary-aged class of 18 students. There were 5 female students in the class and 13 males. Both teachers were men, although there were often female assistant teachers in the classroom. 9 students (50%) were Hispanic, 2 students (11%) were African American, and the remaining 7 students (39%) were Caucasian. Many of the Hispanic students were ELL, whose first language was Spanish, but all were fluent in English. There were relatively few issues with discipline and no known learning disabilities. Most of the students were from public school.

The classroom atmosphere was very relaxed, and the students spent much of the day playing video games, watching movies, and playing outside. During my time in the classroom, I also saw students building with blocks, making forts out of pillows, watching the fish in the aquarium, and using flash cards to learn about different types of birds. The daycare implements a new "theme" every month, which many of the lessons in the class are based on. The theme for the month of July, during my unit, was: "Recycling – God Made It; I'll Care For It," and the students made posters about how they help the environment and did several craft projects with recycled materials.



## Adaptations for Students of Diverse Needs

The primary obstacle in this class was the diversity of ages. The students ranged greatly in their ability to read and write, so all instructions had to be read aloud. Students worked in groups of both older and younger children during activities. Students who felt confident in the material were able to help the other students in their group. I was available during the activities to help individual students and struggling groups. I wrote key instructions and diagrams where all students could see, using drawings and visual aspects whenever possible.

## Prerequisite Skills of Learners

- Students should be able to follow oral instructions and work as a group.
- Students should be motivated to contribute to our discussions and be able to listen to their peers respectfully.
- Students should be able to design and create objects in response to the challenges presented.
- Students should be able to understand the five parts of the engineering process.

This unit fits in with the Illinois state goals of math and science of:

- Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.
- Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.
- Use algebraic and analytical methods to identify and describe patterns and relationships in data, solve problems and predict results.

## Common Curriculum State Goals and Benchmarks

**CCG 1: State Goal 11 (Science)** - Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

**BMK 1: 11.B.2b** Develop a plan, design and procedure to address the problem identifying constraints (e.g., time, materials, technology).

**CCG 2: State Goal 12 (Science)** - Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

**BMK 2: 12.E.2a** Identify and explain natural cycles of the Earth's land, water and atmospheric systems (e.g., rock cycle, water cycle, weather patterns).

**CCG 3: State Goal 8 (Mathematics)** - Use algebraic and analytical methods to identify and describe patterns and relationships in data, solve problems and predict results.

**BMK 3: 8.B.1** Solve problems involving pattern identification and completion of patterns.

## National Standards

### **NS.K-4.1 SCIENCE AS INQUIRY**

As a result of activities in grades K-4, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

### **NS.K-4.5 SCIENCE AND TECHNOLOGY**

As a result of activities in grades K-4, all students should develop

- Abilities of technological design
- Understanding about science and technology
- Abilities to distinguish between natural objects and objects made by humans

### **NSS-G.K-12.5 ENVIRONMENT AND SOCIETY**

As a result of activities in grades K-12, all students should

- Understand how human actions modify the physical environment.
- Understand how physical systems affect human systems.
- Understand the changes that occur in the meaning, use, distribution, and importance of resources.

## Generalizations, Unit Goals and Objectives

### **Generalization #1: Engineering can be described as a 5-step process.**

Goal 1: Students will learn the five steps of the engineering process.

Objective: Students will gain information from lessons to be able to name the five steps of the engineering process: ask, imagine, plan, create, and improve.

Goal 2: Students will identify one every-day activity that uses the engineering process.

Objective: Students will associate the engineering process with their lives and identify one activity in their lives that is similar to what an engineer does.

### **Generalization #2: Environmental engineering is using science and technology to improve the environment and protect human health.**

Goal 1: Students will identify improving water quality as one aspect of environmental engineering.

Objective: Students will gain information from activities to list 2-3 ways environmental engineers help improve water quality.

## Contributions

Lessons are adapted from activities found on <http://teachengineering.org/>

- *Can You Catch the Water?*

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado at Boulder

- *Water Filtration*

Contributed by: Center for Engineering Educational Outreach, Tufts University

- *Eek, It Leaks*

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado at Boulder

- *Oil Spill Clean Up*

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado at Boulder

## Introduction to Unit

This unit is designed to introduce elementary students to the basics of engineering and get them interested in the engineering process. It focuses on environmental engineering, which is the use of science, math, and design to improve our environment. Environmental engineering encompasses the quality of our air, water, and land, but this unit will focus primarily on water.

### **Who is an Engineer?**

Engineers are people who use science, math, and technology in creative ways in order to solve problems. There are many different types of engineers who focus on different fields. For example, civil engineers design, construct, and maintain built products, such as buildings and bridges. Aerospace engineers deal with airplanes and spacecrafts. Many elementary students incorrectly believe that engineers are auto mechanics and construction workers. This assumption fails to incorporate the 5 key steps of the engineering process.

### **What is the Engineering Process?**

The engineering process includes 5 cyclical steps:

- **Ask:** The process generally begins with a question or a challenge. For example, how can we improve the quality of our drinking water? How can we clean up this oil spill?
- **Brainstorm:** The next step is to begin brainstorming and imagining possible solutions to the problem at hand. Are they possible? Reasonable?
- **Create a Plan:** Once a possible solution presents itself, it is time to begin the design process. This often includes sketching a picture and writing a list of materials.
- **Develop:** After the plan has been created, the product can be built.
- **Experiment:** Now it's time to test the solution and see how it works. How well does it work? Can it be improved? After this step, we begin asking questions again and start the process over to find the best possible solution to the problem in the time and with the resources allowed.

To help students remember the process, the 5 steps are alphabetical. It is important to point out that after a solution has been built, engineers often repeat the 5 steps again to improve their product. These steps have been applied to every lesson in this unit so that students can see how the steps are used in real-life situations. Once students learn the engineering process, they will realize that it is a process they use informally in their every-day lives.

## **Why Teach Engineering?**

Engineering is a subject that incorporates many other disciplines: namely science, math, and technology. It is teamwork based and easily engages children, since they are natural builders and problem-solvers. It is very much hands-on and may introduce students to possible careers they did not know existed.

Engineering is a quickly growing field, which many students do not consider because they do not correctly understand what it entails. This unit is designed to get children interested in engineering and focuses on one possible branch.

## **How to Use This Unit:**

This unit is separated into 5 different lessons. It is designed to be used with elementary school students and possible adaptations have been included for students of different ages. All project-based lessons (Lessons 2-5) are to be done in groups: 3-6 students per group. Encourage the students to take home their products to show their parents or further improve upon. Each lesson takes around 45 minutes to complete.

At the beginning of each lesson is a description of the material and the background knowledge that may be useful to teach the lesson. Much of this knowledge will help answer the students' questions and is designed to make teaching the lesson easier, especially for someone without a strong science or engineering background.

The lessons cover:

- What is an engineer?
- How can we collect water from the environment for human use?
- How can we filter out unwanted particles from our drinking water?
- What problems can occur with water passing through a landfill?
- What are some possible ways to clean up an oil spill?

## Vocabulary Terms

### **Lesson 1: Introduction to Engineering**

- Engineering - the use of science, math, and technology in creative ways in order to solve problems.
- Environmental engineer - the use of science, math, and design to improve our environment and protect human health.
- 5-step engineering process:
  - Ask: What is the question or problem that needs solving?
  - Brainstorm: Imagine all the possible solutions to the problem/question.
  - Create a Plan: Once a possible solution presents itself, design it in more detail, describing what you will need and how you will do it.
  - Develop: Build the solution.
  - Experiment: How well does this solution work? Can it be improved? Begin the process again to improve the solution.

### **Lesson 2: Catchment Basins**

- The water cycle - the movement of water on Earth, from the atmosphere to the land to various bodies of water in a continuous cycle
  - Precipitation - another name for rain or snow, or any kind of moisture that falls from the sky
  - Evaporation - another name for the water drying up and returning to the air
  - Runoff - water that flows over the ground and eventually reaches a larger body of water.
- Catchment basin - the area where the water collects due to runoff and can be used by humans

### **Lesson 3: Drinking Water Filtration**

- Drinking water treatment – the process water must go through to remove impurities (such as dirt and clay), parasites, bacteria, and chemicals before it is safe to drink
- Surface water - water from lakes, rivers, reservoirs, or other bodies of water
- Filtration – the process which removes many of the particles of dirt and clay from the water

### **Lesson 4: Landfill Leachate**

- Landfill - a place where waste is collected and disposed of by burial
- Leachate – water that has seeped through a landfill, which is contaminated with toxic chemicals and bacteria from the garbage
- Liner - a layer that keeps leachate from leaving the landfill
- Groundwater - water located beneath the Earth's surface

### **Lesson 5: Oil Spill Cleanup**

- Oil spill – when oil is spilled into a body of water (usually accidentally), causing great damage to the environment
- Density – the mass per unit volume of a material (how tightly it is packed together); liquids with a lesser density (like oil) will float on top of liquids with a higher density (like water)
- Hydrophobic – “scared of water”; the property of oil that makes it impossible to mix with water
- Dilution – to lessen the concentration of something by letting it spread out into a larger area

## Materials List

### **Lesson 1: Introduction to Engineering**

- 5-step engineering process handout/transparency (*provided*)
- List of every-day engineering tasks (*provided*)

### **Lesson 2: Catchment Basins**

- Water cycle transparency/handout (*provided*)
- A variety of small objects to create landforms (small cups, rocks, bunched up paper, etc.)
- Light-weight white plastic (garbage bags work well)
- A spray bottle
- Cookie sheets or large tubs to contain the water
- Sponges
- Food coloring

### **Lesson 3: Drinking Water Filtration**

- One cup of muddy water per group (mix the water with a variety of contaminants, such as dirt, woodchips/mulch, and cat litter)
- A variety of filtration materials (cotton balls, tissues, coffee filters, paper towels, aquarium gravel, sand)
- One 2L-plastic bottle per group, cut in half
- Food coloring (*optional*)

### **Lesson 4: Landfill Leachate**

- 12" of tape per group
- Garbage Bags, cut into approx. 2"-wide strips
- Large bowls to collect the water
- Measuring cup

### **Lesson 5: Oil Spill Cleanup**

- Aluminum pie pan (one per group)
- Large stone (one per group)
- Bird feathers
- Plastic spoons
- Measuring cups
- Cotton balls
- Bottle of dishwashing detergent (must be labeled "Dispersant")
- Vegetable oil, dyed with food coloring



## Pre/Post-Test

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### **What is an Engineer?**

1. An engineer is someone who \_\_\_\_\_.
2. What are the five steps of the engineering process (in order)?
  1. \_\_\_\_\_
  2. \_\_\_\_\_
  3. \_\_\_\_\_
  4. \_\_\_\_\_
  5. \_\_\_\_\_
3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.
4. What is the water cycle? (circle one)
  - a. The way water circles when it goes down a drain
  - b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
  - c. The movement of water through the human body
  - d. A boat that has pedals, like a bicycle
5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)

TRUEFALSE
6. Why do engineers worry about water seeping through garbage in our landfills?  
\_\_\_\_\_
7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)

YESNO

Why did you choose that answer? \_\_\_\_\_

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## KEY

### What is an Engineer?

1. An engineer is someone who *uses science and technology to solve problems / designs, builds, and improves solutions to our problems*
2. What are the five steps of the engineering process (in order)?
  1. *Ask / Question / Find a problem*
  2. *Brainstorm / Think of possible solutions / Imagine solutions*
  3. *Create a plan / Make a plan*
  4. *Develop the solution / Build something*
  5. *Experiment / Test / Improve the solution*
3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.  
*Accept any reasonable answer*
4. What is the *water cycle*? (circle one)
  - a. The way water circles when it goes down a drain
  - ☒ b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
  - c. The movement of water through the human body
  - d. A boat that has pedals, like a bicycle
5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)

TRUE

FALSE
6. Why do engineers worry about water seeping through garbage in our landfills?  
*When water seeps through landfills, it can bring chemicals/leachate/toxins/pollution out of the landfill and into the groundwater, which can make plants and animals (including people) sick.*
7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)

YES

NO

Why did you choose that answer? \_\_\_\_\_

# Lesson 1

## Introduction to Engineering

Lesson Time: 20-30 minutes

This first lesson is designed to provide a platform for the other four, more hands-on lessons. In it, the students will learn that every-day activities they have done before are related to engineering.

### Objectives:

- Students will learn what an engineer is and some of the things they do.
- Students will be introduced to the 5-step engineering process.

**Anticipatory Set:** Ask the students if anyone knows what an engineer is, or some of the things they do.

### Procedure:

- Define engineering - the use of science, math, and technology in creative ways in order to solve problems.
- Ask the students if any of them are engineers.
- If they say yes, ask what they do and what sorts of problems they solve.
- If they say no, begin listing off some of the “every-day engineering tasks” from the handout following this lesson and ask the students to raise their hands (or stand up) if they have ever done the activity.



### Materials

- *5-step engineering process handout/transparency (provided)*
- *List of every-day engineering tasks (provided)*

### Vocabulary

- *Engineering*
- *Environmental engineer*
- *5-step engineering process - Ask, Brainstorm, Create a plan, Develop, Experiment*



**Procedure (cont.):**

- As you read through the list, explain how each activity is related to engineering and how there are different areas of focus in engineering.
- At the end, describe that no matter what kind of engineer they are, all engineers follow the same process.
- Display the 5-step engineering process for the students, explaining each step and reinforcing the idea that it is a cyclical process. Mention that an easy way to remember the process is to look at the first letter of each step (ABCDE).
  - Ask: The process generally begins with a question. How can we improve the quality of our drinking water? How can we clean up this oil spill?
  - Brainstorm: The next step is to begin brainstorming and imagining possible solutions to the problem at hand. Are they possible? Reasonable?
  - Create a Plan: Once a possible solution presents itself, it is time to begin the design process. This often includes sketching a picture and writing a list of materials.
  - Develop: After the plan has been created, the product can be built.
  - Experiment: Now it's time to test the solution and see how it works. How well does it work? Can it be improved? After this step, we begin asking questions again and start the process over to find the best possible solution to the problem.
- Explain that in this unit, the students will be learning about environmental engineering - the use of science, math, and design to improve our environment and protect human health.

Consider asking students if they have any other ideas of every-day activities they have done that relate to engineering.



When first discussing engineering, be on the lookout for common misconceptions:

- Engineers are construction workers.
- Engineers just build things.
- Only men are engineers.



**Closure:** Explain that in the next few lessons, the class will be using the 5-step engineering process to solve problems related to water.

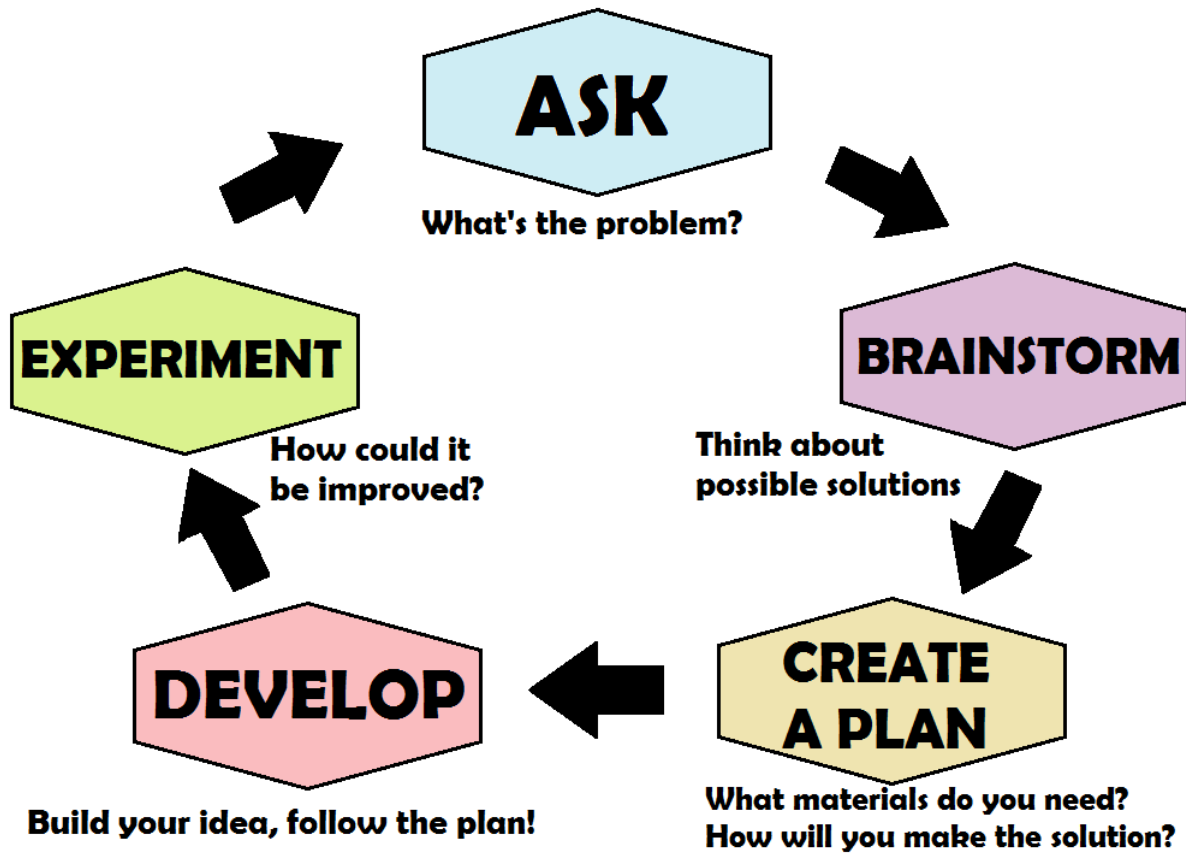
## List of Every-Day Engineering Tasks

<i>Have you ever?</i>	<i>Engineering Connection</i>
Built a building out of LEGOS or blocks?	<b>Civil engineers</b> design, build, and maintain buildings. They have to make sure the buildings are sturdy and can stand up to winds and earthquakes.
Cleaned a fish tank?	<b>Environmental engineers</b> make sure we have clean water to drink and for fish to live in. Water we use has to be treated before it can go back into the environment.
Designed and built paper airplanes?	<b>Aerospace engineers</b> design and build airplanes and spacecrafts. Different airplanes can withstand different temperatures, pressures, and loads.
Experimented with a recipe?	<b>Food engineers</b> experiment with food and create new foods to eat. They have to make sure the food is safe to eat, tastes good, and can last a long time.
Built a dollhouse?	<b>Civil engineers</b> also help build houses. They have to think about the best materials to use and how to lay out the rooms.
Designed a train track set?	<b>Transportation engineers</b> make sure people and goods can safely be transported from one place to another. People love to travel and these engineers help make sure their trips are safe and swift.
Tuned up a bicycle?	<b>Mechanical engineers</b> think about how things move. They help solve problems with machines and vehicles of all sizes.
Created a webpage?	<b>Software engineers</b> help build the programs for your computer. They think about how to make them easy to use and nice to look at. They combine art and technology to create very useful programs.

Taken apart a toy?	<b>Materials engineers</b> think about what materials should be used to build things. They help many other engineers decide what would work best when they're building something new.
Helped put together a computer?	<b>Computer engineers</b> help design and build computers. This is a fairly new branch of engineering and they are coming up with new ideas every day to make computers work better.
Used a water filter on your sink and wondered how it worked?	<b>Environmental engineers</b> also figure out the best way to filter water before you drink it. They make sure it's clear, tastes good, and is safe to drink.
Taken care of a garden?	<b>Agricultural engineers</b> help come up with the best way to grow food. They design new machinery and equipment, plus think about how to get plants to grow.

There are many other kinds of engineers, too! Engineers are always thinking of new ways to improve our lives and solve problems by using science, math, and technology in creative ways.

# 5-Step Engineering Process





# Lesson 2

## Catchment Basins

Lesson Time: 30-40 minutes

The water cycle describes the movement of water on Earth – from the atmosphere to the land to various bodies of water in a continuous cycle. This lesson will introduce students to the concept of the water cycle and tie-in an engineering concept: the catchment basin.

### Objectives:

- Students will understand the various steps of the water cycle.
- Students will design a landscape to see how water flows and collects.
- Students will experiment to see how human activity affects catchment basins.

**Anticipatory Set:** Ask students to describe what happens to water when it rains. Some answers may include: “It runs downhill.” “It goes into lakes/rivers/oceans.” “It gets soaked up by the ground/plants.” “It makes puddles on the ground.” “It evaporates.” Explain that all these answers are part of the water cycle – the movement of water through the environment.

### Procedure:

- Display the water cycle diagram provided and walk students through the different steps. Explain that precipitation is just another name for rain or snow, or any kind of moisture that falls from the sky.



### Materials

- *Water cycle transparency/handout (provided)*
- *A variety of small objects to create landforms (small cups, rocks, bunched up paper, etc.)*
- *Light-weight white plastic (garbage bags work well)*
- *A spray bottle*
- *Cookie sheets or large tubs to contain the water*
- *Sponges*
- *Food coloring*

### Vocabulary

- *The water cycle*
- *Precipitation, Evaporation, Runoff*
- *Catchment basin*



**Procedure (cont.):**

- Show on the diagram the answers they gave previously and describe any of the steps they might have missed. Mention that evaporation is just another name for the water drying up and returning to the air.
- Explain that they will be building a catchment basin – the area where the water collects and can be used by humans. Due to gravity, the precipitation runs down-hill and much of the water becomes runoff - water that flows over the ground and eventually reaches a larger body of water.
- Sometimes engineers build models of things they want to understand better. Environmental engineers often try to find good sources of water for humans to drink, so that is what we will be doing today.
- Refer back to the engineering process to look at the first step: Ask. The question today is, “How do we find a good place to collect water for human use?”
- Remind the students that the next step is to Brainstorm. Have them think about what kinds of materials they could use to build a model. Show them some of the possible materials and explain that they will set up a landscape with those materials, then cover it loosely with a sheet of plastic to create landforms.
- Have the students Create a Plan of how they want their model to look by sketching it out and estimating where the water will collect.
- When each group is ready to begin the Develop step, hand out the materials and have them build it on the cookie sheet or tub to contain the water. If necessary, have the students tape down the materials. When they have everything positioned to their satisfaction, loosely lay the plastic sheet over the top.

**Steps of the engineering process:**

- Ask: How do we find a good place to collect water for human use?
- Brainstorm: What materials could we use to build our model?
- Create a plan: Sketch out a design of the proposed landscape and where the water might collect.
- Develop: Build the model and sprinkle water on the plastic to see how the water runs and collects.
- Experiment: How could we better shape the landscape to collect more water?

**Questions to discuss during the lesson:**

- How might humans affect the shape of the landscape and how water runs?
- What steps of the water cycle does our model not take into account?





**Procedure (cont.):**

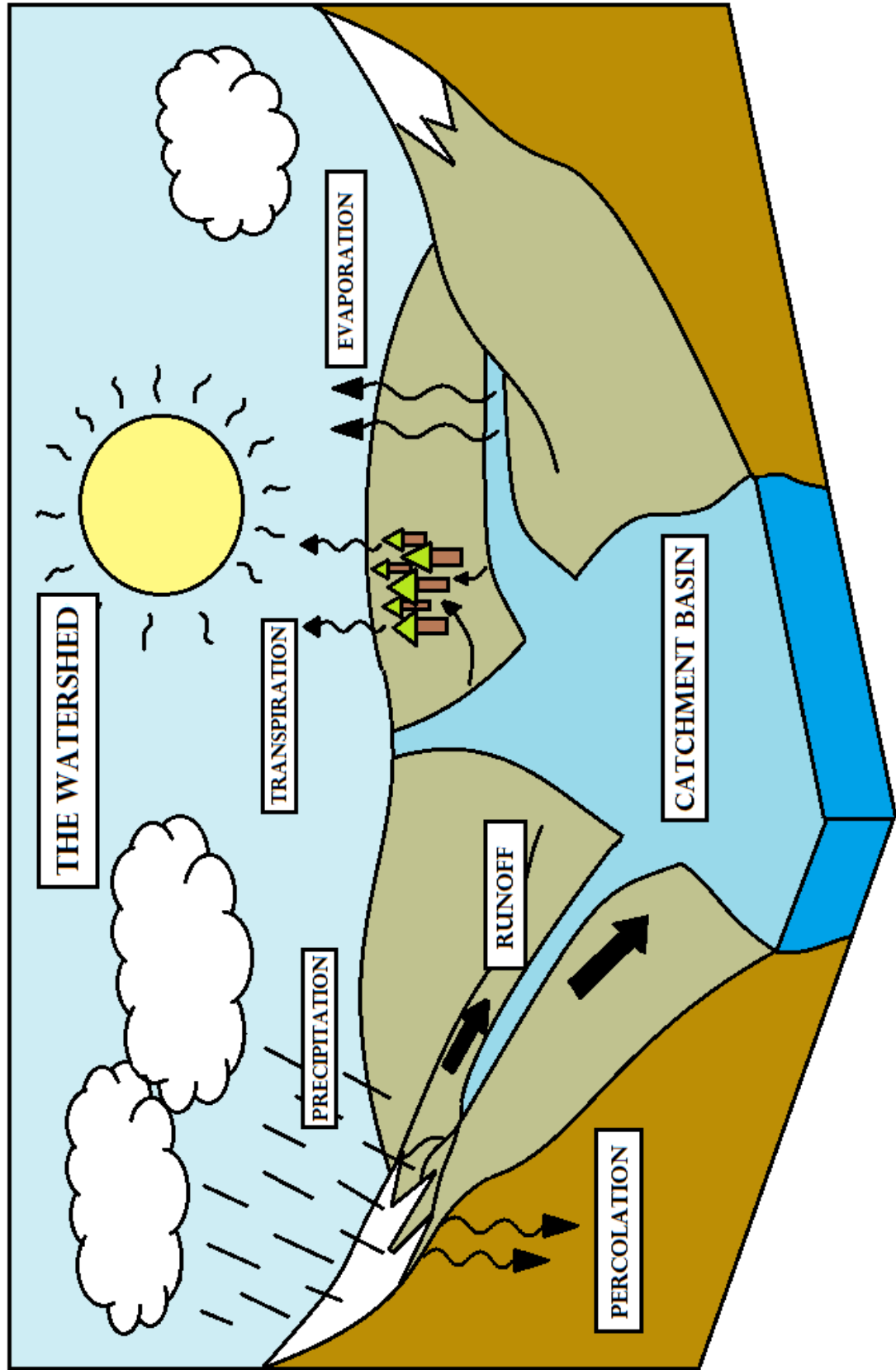
- Have the students make a prediction about where the water will collect and allow them to use the spray bottle to make it “rain” on the highest point of their landscape. This is the precipitation.
- Have the students watch as the water runs downhill (runoff) and collects in a larger body of water (the catchment basin).
- For the Experiment step, ask the students what other human influences might change the flow of the water. Suggest that the students might try several experiments to see their effect:
  - What if a dam was built into one of the streams that flows into the catchment basin? Have the students place a sponge in the stream and sprinkle water on the landscape again.
  - What if a town was built on one of the mountains and their pollution was dumped into the water? Drop the food dye into a stream near the top of a mountain and sprinkle water to see where the dye spreads.
  - What if a town in the valley needed to use some of the water to water their crops? Have the students create canals leading away from one of the major streams to see how the flow of water changes.
  - How could we better collect water for humans? Encourage them to try changing the landscape slightly to see if they can gather more water in their catchment basin.



**Closure:** Ask the students to share their experiences and results with each other. Explain that in the next lesson, they will learn about one the important steps in making drinking water fit to consume after it has been collected.

For an assessment tool, you can consider having students write down the answers to these questions, to be collected afterward.

# The Water Cycle





# Lesson 3

## Drinking Water Filtration

Lesson Time: 30-40 minutes

Before it is safe to drink, water must go through a treatment process to remove impurities (such as dirt and clay), parasites, bacteria, and other chemicals. Untreated water typically goes through several steps to separate out particles before it is disinfected to kill off any disease-causing organisms. After letting the larger particles settle out, the smaller particles are removed through filtration. This filtration step is what this lesson focuses on.

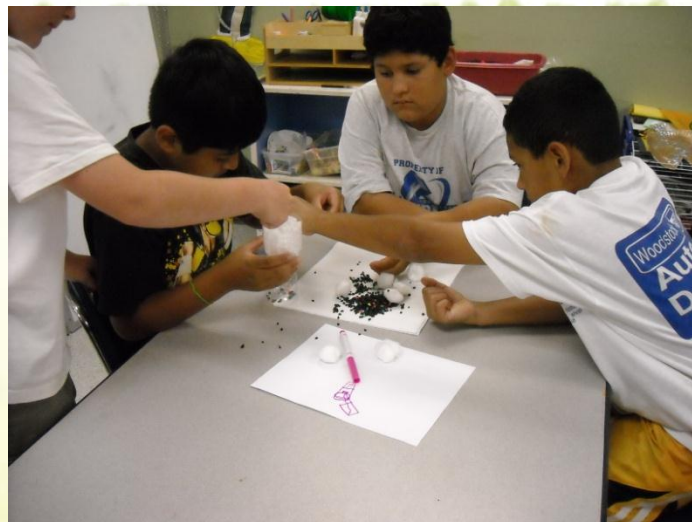
### Objectives:

- Students will learn about one of the steps of drinking water treatment.
- Students will experiment to find how well different materials filter dirty water.

**Anticipatory Set:** Remind the students how in the last lesson, they created and studied a catchment basin. One of the possible uses of a catchment basin is for drinking water.

### Procedure:

- Ask the students if they know where their drinking water comes from (it could be from a reservoir, a lake, wells, etc.). If possible, find out for them.
- Ask if they would drink water straight from a lake or river and explain why it wouldn't be safe (because it would contain a lot of dirt and germs).



### Materials

- One cup of muddy water per group (mix the water with a variety of contaminants, such as dirt, woodchips/mulch, and cat litter)
- A variety of filtration materials (cotton balls, tissues, coffee filters, paper towels, aquarium gravel, sand)
- One 2L-plastic bottle per group, cut in half
- Food coloring (optional)

### Vocabulary

- Drinking water treatment
- Surface water
- Filtration



**Procedure (cont.):**

- Explain that water has to be treated to get rid of the dirt and germs. Mention that in the case of wells, the ground does most of the work for us, but any surface water (water from lakes, rivers, reservoirs, or other bodies of water) has to be purified at a water treatment plant.
- One of the steps in water treatment plant is filtration – taking out most of the little particles of dirt and clay from the water. Point out that filtration doesn't remove all the bacteria and viruses, so it also has to be disinfected before it's safe to drink. Environmental engineers are often responsible for figuring out the best way to clean water.
- Explain that in today's lesson, the students will be experimenting with different materials to try to filter some dirty water. Show the students the dirty water and tell them that the Ask part of the engineering process is: How can we best filter this water?
- Have the students Brainstorm what kind of materials might work well for filtration. Show the students what materials you have picked out for them, but allow them to also use any other reasonable ideas.
- Have each group Create A Plan of their proposed filtration design, then pass out the supplies to let them begin the Develop step.
- While the students work on building and filtering the water (make sure they don't try drinking their filtered water), you might want to offer the following tips to struggling groups:
  - If the filter is getting clogged, try using coarser filtering materials (such as the gravel) or let the water sit longer.
  - If materials are falling through the filter, try laying the coffee filter on the very bottom to hold everything in.

**Steps of the engineering process:**

- Ask: How can we best filter this water?
- Brainstorm: What kind of materials can we use?
- Create a plan: Have each group make a sketch of their proposed filtration design.
- Develop: Let the groups build their filtration devices and try filtering their cup of dirty water.
- Experiment: Have the groups discuss their results and which methods worked better than others. Talk about what changes they would make to their designs.



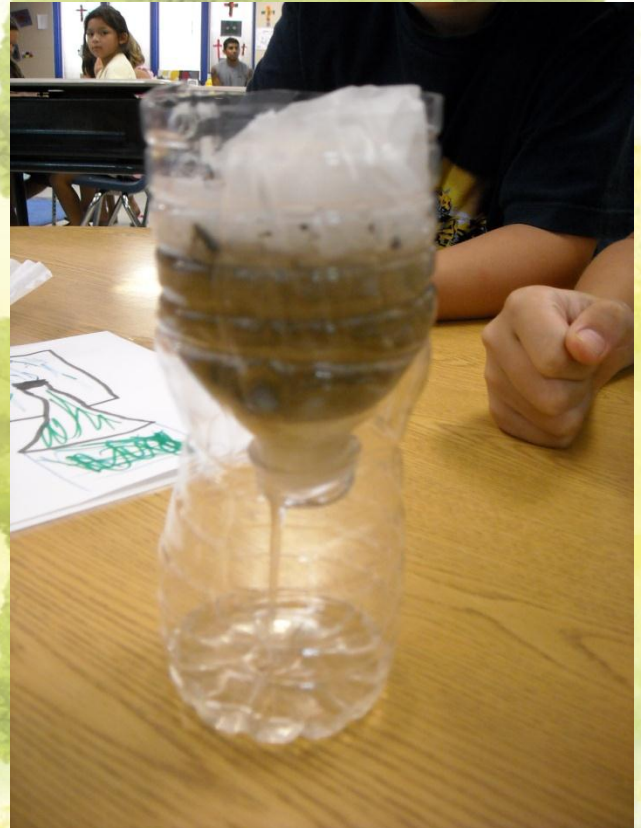


**Procedure (cont.):**

- After ~10 minutes once all the students are satisfied with their filtration results, have the groups compare and discuss their designs and results. Have them talk about any problems they encountered and what they would do to improve their design (Experiment).
  - Did they put the materials in the filter in any sort of order? Why?
  - Did they leave out any of the materials from the filter? Why?
- Discuss how some filtration materials filtered out certain impurities better (coarser materials are best at getting out bigger chunks of impurities without getting clogged, but finer materials will filter out the smaller particles more effectively)
- If time allows, add food dye to the dirty water in order to simulate chemicals or bacteria. Have the students see if their filtration systems will filter out the dye.

**Closure:** You may want to show the students a picture of the filtration system used in an actual treatment plant. Environmental engineers often use activated carbon (carbon that has been steam-treated to make it especially adsorbent), sand and gravel. They have found it is most effective to put the gravel and coarsest sand at the bottom, with the finer sand at the top. Did the students find the same results? Explain that in the next lesson, the students will be turning their attention back to rainwater and how it interacts with landfills

Many water treatment plants are closed to field trips, but you may be able to find virtual video tours online. Be sure that it is a drinking water treatment plant, and not a wastewater treatment plant!



You may want to ask the students how they would clean their filtration system when it got clogged – real water filters often have to be backwashed (where water runs through it backwards, then is disposed of), or scraped off periodically.

For a possible extension, consider having the students research drinking water filtration processes in less developed countries.



# Lesson 4

## Landfill Leachate

Lesson Time: 30-40 minutes

One of the major environmental problems with landfills is that when it rains, the water seeps through the waste, carrying harmful pollutants with it. If it does not have anything on the bottom to keep the water from leaking out, it could seep into the groundwater (water located beneath the Earth's surface). Once pollution reaches the groundwater, it can spread and contaminate other water sources, which is harmful for plants and animals. To keep this from occurring, engineers line landfills with a liner – a layer underneath the landfill that contains any water seeping through. However, if the liner tears, the polluted water that seeps through is called leachate.

### Objectives:

- Students will be able to describe how landfills pollute groundwater.
- Students will experiment to design an effective landfill liner.
- Students will collect data to determine how effective their liner is.

**Anticipatory Set:** Explain to the students that all the things they throw out in the garbage eventually winds up in a landfill – a place where waste is collected and buried. Ask the students if they see any potential problem with landfills when it rains.



### Materials

- *Scotch tape*
- *Garbage Bags, cut into approx. 2"-wide strips*
- *Large bowls to collect the water*
- *Measuring cup*
- *Ruler (optional)*
- *Stopwatch (optional)*

### Vocabulary

- *Landfill*
- *Leachate*
- *Liner*
- *Groundwater*



**Procedure:**

- Explain to the students that when it rains, water seeps through the garbage and can carry harmful chemicals and bacteria into the groundwater, where it can spread. This toxic water is called leachate. If students are confused about where these chemicals and bacteria come from, remind them that rotting food will contain bacteria (which is why we don't eat it!) and as some materials break down, they release harmful chemicals.
- Remind the students that during the last lesson, they worked on filtering drinking water. If any of this leachate traveled from the groundwater into their drinking water source, it could be very difficult to get out.
- Explain that engineers put down a liner under the landfill, which is a layer that keeps the leachate from leaving the landfill. Instead, it is collected in pipes and sent off to be treated. However, the liner has to be laid down in strips because landfills are very big (imagine the size of a football field – or bigger!) and it is impossible to make one sheet of plastic that large. Oftentimes, these seams, where the strips are put together leaks a little.
- Tell the students that today's Ask step is: How can we create a less leaky liner?
- Explain that they will be making a model again, so they will use strips of a garbage bag to try and hold one cup of water without it leaking through.
- Have the students Brainstorm what strategy will work best. For the Create A Plan step, have them describe the strategy they picked, then hand out the materials.
- Let the students Develop and build their liners. Have them build their liners inside the large bowls to simulate the bottom of the landfill.

**Steps of the engineering process:**

- Ask: How can we create a less leaky liner?
- Brainstorm: What strategies could we come up with?
- Create a plan: Have each group describe how they will put their liner together.
- Develop: Let the groups build their liners and try to hold a cup of water.
- Experiment: Have the groups discuss their results and which methods worked better than others. Talk about what changes they would make to their designs.





**Procedure (cont.):**

- Give the groups 10-15 minutes to work and once they are all finished and ready, have the students hold up their liners and pour in one cup of water, making sure not to let it spill over the edges of the liner. The water that leaks out will be collected in the large bowls, which can then be poured into the measuring cups. You can also use a timer to see whose leaks the fastest or slowest. You could also use a ruler to see whose liner covered the biggest area.
- Have the students compare results – whose liner leaked the least? Did they use a different design than the other groups? Did they use multiple layers of liner or let it overlap? Which group made the largest liner with their limited materials? Where did their liner leak the most? Which group used the most amount of tape?
- For the Experiment step, discuss what they would change in their design or if time allows, let them redesign their liner entirely.

**Closure:** Discuss some of the other challenges of creating a less leaky liner – rocks or other sharp materials in the landfill might pierce a hole in the liner and there are some common household chemicals that actually dissolve some plastic liners entirely! Most landfills also have a layer of clay beneath the liner to keep water from getting through, but even clay isn't completely impenetrable and leachate will eventually leak through it.

You can also consider letting the students research other garbage disposal methods, finding the pros and cons of each method.



For an extra challenge, consider letting the students sag their liners across a cup or bowl. Put in different "leachates" such as detergent, bleach, vinegar, or soda. Let the liners sit for an extended period of time (several days) and see if the liners begin to break down



# Lesson 5

## Oil Spill Cleanup

Lesson Time: 30-40 minutes

Oil spills can cause widespread damage to the environment. They occur when machinery fails or oil tankers spring a leak. Our current way of life requires a lot of oil to be collected, but when something goes wrong, all that oil can wreak havoc on the environment because it is so difficult to clean up. There are many different methods to clean up oil spills and engineers are often involved with finding the best way for the particular situation.

### Objectives:

- Students will be able to explain why oil is so harmful to the environment.
- Students will compare different methods of oil spill cleanup.

**Anticipatory Set:** Pour a cup of water into the measuring cup and pour a small portion of oil on top (enough to make a noticeable layer). Pass the measuring cup around the class and ask the students what they notice. Discuss why the oil might sit on top of the water like that. Listen for answers about density – how tightly the liquids are “packed together.” Oil has a lesser density than water, so it floats on top. Also listen for answers about the way oil refuses to mix with water, because it is hydrophobic – which literally means “scared of water.” It is the property of oil that makes it impossible to mix with water. This is easy to demonstrate by mixing the two liquids together, then watching how the oil separates.



### Materials

- Aluminum pie pan (one per group)
- Large stone (one per group)
- Bird feathers
- Plastic spoons
- Measuring cups
- Cotton balls
- Bottle of dishwashing detergent (must be labeled “Dispersant”)
- Vegetable oil, dyed with food coloring

### Vocabulary

- Oil spill
- Density
- Hydrophobic
- Dilution



**Procedure:**

- Ask if any of the students have heard of an oil spill or seen pictures. It may be useful to bring in pictures of past oil spills, so that students can see how large of an area they affect. Explain that oil spills usually occur either when an oil tanker (the boat that carries the oil) begins leaking or when the mechanical parts that collect the oil are damaged. Sometimes warring countries even damage each other's oil tankers on purpose!
- Oil spills are especially harmful because oil cannot be diluted by the water, like some other toxins can, meaning it cannot spread out and lose some of its damaging effects. Because it has a lighter density and is hydrophobic, it floats on top of the water and sticks to things like animals, plants, the beach, and rocks. To keep the oil from doing this, it's important to clean it up as effectively, quickly, and cheaply as possible.
- Dip a feather into the previous oil-water mixture and let the students look at and touch the feather. Discuss how the oil affected it and what that would mean for birds.
- Explain that there are many different ways to clean up an oil spill, but each spill is a little different and engineers have to try different methods to see which works best. In today's lesson, the students will create models of an oil spill and try different methods to clean it up. Today's Ask question is: What is the most effective way to clean up this oil spill?
- Have the students Brainstorm what methods they think would work best. Ask how they would represent these methods in a model.

**Steps of the engineering process:**

- Ask: What is the most effective way to clean up this oil spill?
- Brainstorm: What strategies could we use to clean the oil?
- Create a plan: Have each group decide on their method of cleaning the oil spill.
- Develop: Let the groups work on cleaning the oil, using their particular method.
- Experiment: Have the groups discuss what method they chose and how well it worked. Discuss the benefits and downfalls of each method and if they would make any changes to their method or choose a different one entirely.





**Procedure (cont.):**

- Show the students what materials you brought and explain that each group will get to choose from 3 different methods:
  - Skimming: one of the methods of containing and cleaning up an oil spill is to gently skim off the oil layer from the water. The group modeling this method will use the plastic spoons to skim off the water, depositing their skimmed oil-water into a measuring cup.
  - Absorbing: another method of cleaning up the oil is to absorb it. The groups modeling this method will use the cotton balls to absorb the oil, depositing their cotton balls soaked in oil into a measuring cup.
  - Dispersing: the last method of cleaning the oil is to use a dispersant – a liquid that breaks up the oil and makes it lose some of its ability to stick together.
- To Create a Plan, have the students choose one of the methods (or make up their own). Try to have at least one group using each method, however.
- To Develop their ideas, provide each group with an aluminum pie pan filled with water, with a large rock in the middle (this represents the land that they should try to protect!). Put a spoonful of oil into each pan and allow the students to try out their methods. Make sure they collect their used materials.
- After each group has successfully (or unsuccessfully) contained and removed their oil spill, have the class discuss each method for the Experiment step. What worked well? What did they have problems with? Compare the amount of materials they used in each method, along with which method they think would be cheapest, most effective, and fastest. Which method would they recommend to clean this oil spill?

**Closure:** Consider discussing some specific past oil spills and how they were cleaned. See the side note for notable oil spills.



Encourage the Dispersant group to try dipping a feather into their treated oil spill. It should look much better than the one dipped into the oil earlier.

**Some notable past oil spills were:**

- 1978 – Amoco Cadiz spill in Brittany
- 1979 – Ixtoc I spill in Mexico
- 1989 – Exxon Valdez spill in Alaska
- 1991 – Arabian Gulf spills
- 2010 – BP spill in the Gulf of Mexico

Consider sharing the story (or having students research) one or more of these spills.

## Assessment Strategies

I used several different types of assessment strategies throughout my unit. These strategies included:

**Pre and Post Assessment:** If this were a graded unit, the pre-assessment would not be included as part of the students' grade, but helped shape the lessons and can be compared with the post-assessment to see if the lessons were effective.

**Create a Plan:** The design plans each group created were collected or discussed to determine if the students understood the reason for the project and the purpose of creating a plan. If this were a graded unit, this step could be used to check-off if a group is working productively.


**Observation:** The students worked as a group in almost every lesson, where everyone was supposed to participate and work as a team. By monitoring individual students or scanning the classroom, it was evident which students grasped the material and which students might be having more trouble.

**Experiment:** Answers to the experiment step could easily be collected as written answers after we had discussed them as a class. If it were a graded unit, I probably would have collected these answers to grade and examine to make sure all the students understood what the experiment step was about.

## Reporting to Parents

One week prior to the unit, a short letter was sent home to the parents of the students. It introduced me and explained what we would be learning about in the upcoming week. Parents were encouraged to discuss the lessons with the students or contact me with any further questions. Students were also encouraged to bring home each day's project to show the parents what they had done.

A letter was also provided to the daycare's staff, so that they could answer parents' questions more effectively and understand what I would be doing with the students.



July 5, 2010

Dear WELC family,

I hope you are staying cool and comfortable this warm summer season! My name is Jessica Billings and I am a graduate student at Michigan Technological University, studying environmental engineering. Next week (the 12<sup>th</sup> – 16<sup>th</sup>), I will be in your child's class for 30-40 minutes every day, teaching a unit on environmental engineering. It is part of my research report in order to graduate from the master's program.

Your child will be learning about how water cycles through the environment, how engineers filter water to help make it safe to drink, some of the problems with water passing through landfills, and some of the methods engineers use to clean up oil spills. We will be building models, playing with water, and learning more about what engineering is all about. I am greatly looking forward to the unit and anticipate the class will enjoy the lessons I have planned. I hope your child will share with you some of the activities we do together. If you have any questions, concerns, or comments, feel free to contact me. I would love to hear from you!

**Please see the attached Informed Consent form and return it to WELC so that your child can participate in our engineering activities!**

Sincerely,

Jessica Billings  
815-814-6429

[Jessy.Billings@gmail.com](mailto:Jessy.Billings@gmail.com)

## ENVIRONMENTAL ENGINEERING: INFORMED CONSENT

During the week of July 12 – 16, your child will be invited to participate in a set of engineering activities at Woodstock Early Learning Center. These activities are a part of a research report being done by Jessica Billings, a student at Michigan Technological University. Please see the accompanying letter with more specific information about the project. Your child's name will NOT be used in any part of the report. If you have any questions, comments, or concerns, please contact Jessica Billings at 815-814-6429 or by e-mail at [Jessy.Billings@gmail.com](mailto:Jessy.Billings@gmail.com).

**Please sign and print your name below if you are willing to have your child participate in the activities.**

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Printed Name

\_\_\_\_\_  
Date

\_\_\_\_\_  
Child's Name

☐ Please check here if you do NOT want your child's photograph taken, to be used in the report.

**Return by Monday, July 12!!**

### Pre and Post-Assessment Class Data

Student Number	Age	Sex	Pre-Test Answer to #7	Post-Test Answer to #7	Pre-Test Score (out of 15)	Pre-Test Percentage	Post-Test Score (out of 15)	Post-Test Percentage	Change in Test Score	Change in Percentage
1	6	F	no	yes	4	27%	5	33%	+1	+7%
2	7	M	yes	yes	7	47%	8	53%	+1	+7%
3	7	M	yes	yes	1	7%	6	35%	+5	+29%
4	7	F	no	yes	2	13%	8.5	57%	+6.5	+43%
5	8	M	no	no	2	13%	3	20%	+1	+7%
6	8	M	no	no	3	20%	8	53%	+5	+33%
7	8	M	no	no	7	47%	11	73%	+4	+26%
8	8	M	no	yes	1	7%	12	80%	+11	+73%
9	8	F	no	no	4	27%	6	35%	+2	+13%
10	8	F	no	no	4	27%	7	47%	+3	+20%
11	8	F	no	no	5	33%	5	33%	0	0%
12	9	M	yes	no	5	33%	8	53%	+3	+20%
13	9	M	yes	yes	8	53%	11	73%	+3	+20%
14	10	M	no	no	0	0%	10	67%	+10	+67%
15	10	M	yes	yes	11	73%	12	80%	+1	+7%
16	10	M	yes	yes	7	47%	9	60%	+2	+13%
17	10	M	yes	yes	5	33%	8	53%	+3	+20%
18	11	M	no	no	3	20%	13	87%	+10	+67%
<b>Mean</b>	<b>8.4</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>4.4</b>	<b>29%</b>	<b>8.4</b>	<b>56%</b>	<b>+4.0</b>	<b>+26%</b>

### Interpretation of Learning Gains

On average, the students improved their post-test score by 26%. All students (except #11, who neglected to answer most of the questions on either the pre-test or the post-test and received the same score on both tests) improved their score at least slightly, which I considered a success. The older students apparently had an easier time learning the material, as they (the 9-11 year olds) improved their score by 31% on average, while the younger students (the 6-8 year olds) improved by 23% on average, as I expected would happen. I chose not to compare the male to female scores because there were so few females and they were all in the younger range. I also did not see any major differences on a racial basis. There were actually around ten more students who participated in some of the lessons, but not all. Because it was a daycare situation, not every child showed up every day. I eliminated the part-time children from the results because they missed many of the lessons or tests.

The area most students had trouble with were the five steps of the engineering process. I believe four engineering activities in only a one week period of time were not enough to allow most of the students to learn the five steps. Many of them remembered the first two or three, but forgot the



others. If this unit were part of a larger component, I imagine more of the students would remember and understand the steps. Many students (mostly younger ones) also misunderstood the concept of an engineer. Because the week focused solely on environmental engineering, many students wrote that engineers “help the environment” or “clean up the water.” While that is true, I hoped the students would gain a wider understanding of what an engineer does. Again, if this were part of a larger unit encompassing several different types of engineering, that could have been prevented. Another problem may have been that the students were learning about recycling this month, which focused on being environmentally-conscious. As a result, their answers centered on the environment, instead of engineering as a whole.

The last question of both the pre-test and the post-test asked the students if they thought becoming an engineer would be a fun job, and why they felt that way. In the pre-test, 7 students (39%) said that yes, engineering would be a fun job. However, no student gave an answer as to why, except that it would be cool/fun. Looking at what they thought an engineer was, it is clear they do not have a clear understanding of what being an engineer would entail. The same can be said of the students who answered no. One student wrote that he did not want to become an engineer because “i don’t know how to fix engines plus no money.”

In the post-test, 9 students (50%) wrote that they would like to be an engineer and their reasoning was much more solid. One student wrote they would like to be an engineer “because I like building stuff to the world.” Another wrote, “because you can help a lot of people.” Surprisingly, one student changed his answer from yes (no reasoning) to no, “because you have to go threw garbage.” That student’s reasoning was surprisingly similar to one other student, who wrote on the post-test that they did not want to become an engineer “because it’s dirty...”. I hadn’t realized that many of the students did not like getting dirty and doing such hands-on activities, so I did not emphasize that many engineering jobs are not so hands-on.

I also did not broach the topic of pay. I did not expect elementary students to be thinking about how much an engineering job would pay when they considered the question. However, several students (aged 8, 8, and 11) wrote on the post-test that they did not want to become an engineer because “I have a better job,” or “I can get a better job.” On the pre-test, one of these students wrote that engineers “work on engines” and they would not want to become an engineer “because you can find better job if not dirty and pay low.” Although they corrected their assumption of what an engineer does by the time of the post-test, it seems their idea of how much the job pays did not change.

### Pre/Post-Test Examples:

## Student #4

Female  
**Pre-Test**

Aged 7

## What is an Engineer?

1. An engineer is someone who NO.
2. What are the five steps of the engineering process (in order)?
1. \_\_\_\_\_
  2. \_\_\_\_\_
  3. \_\_\_\_\_
  4. \_\_\_\_\_
  5. \_\_\_\_\_
3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.
4. What is the water cycle? (circle one)
- a. The way water circles when it goes down a drain
  - b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
  - c. The movement of water through the human body
  - d. A boat that has pedals, like a bicycle
5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)
- TRUE FALSE
6. Why do engineers worry about water seeping through garbage in our landfills?
7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)
- YES NO
- Why did you choose that answer? \_\_\_\_\_

Student #4

Female

Aged 7

## Post-Test

### What is an Engineer?

1. An engineer is someone who they make stuff.
2. What are the five steps of the engineering process (in order)?
  1. \_\_\_\_\_
  2. \_\_\_\_\_
  3. \_\_\_\_\_
  4. \_\_\_\_\_
  5. Do The Project
3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.



4. What is the water cycle? (circle one)
  - a. The way water circles when it goes down a drain
  - ☒ b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
  - c. The movement of water through the human body
  - d. A boat that has pedals, like a bicycle
5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)  
☒ TRUE                      FALSE
6. Why do engineers worry about water seeping through garbage in our landfills?  
We don't want to drink dirty water
7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)  
☒ YES                      NO  
Why did you choose that answer? Because you can help a lot of people

10



Student #8 Male Aged 8

# Pre-Test

## What is an Engineer?

1. An engineer is someone who helps out.

2. What are the five steps of the engineering process (in order)?

1. school
2. school
3. school
4. \_\_\_\_\_
5. \_\_\_\_\_

3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.



4. What is the water cycle? (circle one)



- a. The way water circles when it goes down a drain
- b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
- c. The movement of water through the human body
- d. A boat that has pedals, like a bicycle

5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)

TRUE

FALSE

6. Why do engineers worry about water seeping through garbage in our landfills?

\_\_\_\_\_

7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)

YES

NO

Why did you choose that answer?

I don't know a lot about engineers.

Student #8

Male

Aged 8

## Post-Test

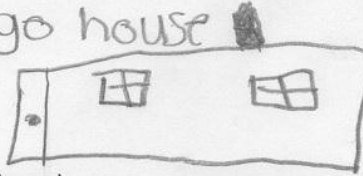
### What is an Engineer?

1. An engineer is someone who helps the environment

2. What are the five steps of the engineering process (in order)?

1. ask a question
2. brain storm
3. create a plan
4. do it
5. experiment

3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does. Lego house



4. What is the water cycle? (circle one)

- a. The way water circles when it goes down a drain
- b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
- c. The movement of water through the human body
- ☒ d. A boat that has pedals, like a bicycle

5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)

☒ TRUE

FALSE

6. Why do engineers worry about water seeping through garbage in our landfills?

We can drink dirty water

7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)

☒ YES

NO

Why did you choose that answer?

you get to do a lot of experiments.



Student #18 Male Aged 11

## Pre-Test

### What is an Engineer?

1. An engineer is someone who works on engines.

2. What are the five steps of the engineering process (in order)?

1. check engine
2. fix engine
3. look at engine
4. build engine
5. finish engine

3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.



4. What is the water cycle? (circle one)

- ☒ a. The way water circles when it goes down a drain
- ☐ b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
- ☒ c. The movement of water through the human body
- ☐ d. A boat that has pedals, like a bicycle

5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)

☒ TRUE

☐ FALSE

6. Why do engineers worry about water seeping through garbage in our landfills?

---

7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)

YES

☒ NO

Why did you choose that answer?

✓ because you get  
job if not dirty and pay  
yes low. Can find better

Student #18

Male

Aged 11

## Post-Test

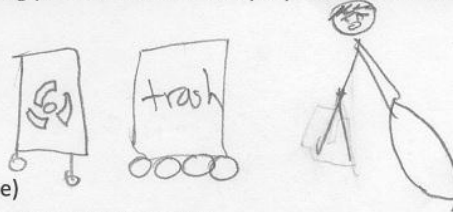
### What is an Engineer?

1. An engineer is someone who solves problems.

2. What are the five steps of the engineering process (in order)?

1. ask a question
2. brain storm
3. create a plan
4. \_\_\_\_\_
5. experiment

3. Draw and label a picture of one thing you have done in everyday life that is similar to what an engineer does.



4. What is the water cycle? (circle one)

- a. The way water circles when it goes down a drain
- ☒ b. The movement of water through the environment (including rain, collection in a body of water, and evaporation)
- c. The movement of water through the human body
- d. A boat that has pedals, like a bicycle

5. Water from lakes and rivers needs to be *filtered* before it is safe to drink. (circle one)

TRUE ☒

~~FALSE~~ ☐

6. Why do engineers worry about water seeping through garbage in our landfills?

It might go into our clean water.

7. Do you think being an engineer would be a fun job? Don't worry, there's no right or wrong answer! (circle one)

YES

☒ NO

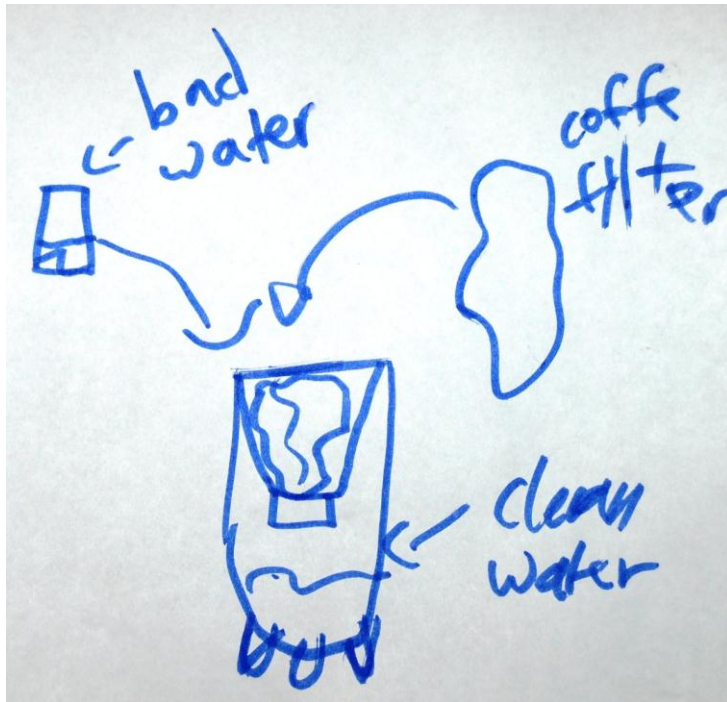
Why did you choose that answer?

because can get better job,

## Overall Unit Reflection

Of particular interest to me was the “Create a Plan” portion of each activity. Because this is such an overlooked part of an engineer’s job, I was curious to see if the students would be so quick to dismiss it. Surprisingly, it was quite the opposite. Each group spent a large amount of time in the Brainstorm and Create a Plan portion of the activities, drawing detailed sketches and including parts lists and arrows to indicate movement. In fact, some groups were slightly *too* detailed and created plans that were overly complicated and impossible for us to make in only 30-40 minutes. An example is during the Catchment Basin activity, when several groups wanted to create waterfalls, beaches, and vegetation in their landscapes.

### **Example from Water Filtration:**



It was actually the Experiment step that was often overlooked by the students, since they did not always want to compare their results with other groups or re-make part of their contraption. If we were in a true classroom setting, I think it would be easier to emphasize the Experiment step because the students would be able to regroup. In the daycare setting, it was very difficult to re-group afterwards, because the students took such different amounts of time (partially due to the large age span) and the ones who finished early often wandered off to play games with their friends, unrelated to the lesson.



I was also interested in the parents' involvement in the unit. Although none of the parents contacted me, I encouraged every student to take home at least one of the projects they created in class. I heard several reactions from the students. Some of the parents were excited by the students' creations, while other students told me that their mom or dad threw away their project when they got home. However, the daycare staff's reactions were highly positive and many of the staff members ventured into the classroom during the activities to see what the students were doing. The unit was also included in the daycare's monthly newsletter to the parents.

At the end of the unit, I asked the students what their favorite activities were. By far, the favorite two activities were the Oil Spill Cleanup and Drinking Water Filtration. The students' reaction to the unit was very positive and several of the students came to me and asked if I could come back next year or think of some more activities for them to do. The one activity that I might change for a younger group would be the Landfill Liner activity. Many of the younger students (aged 6-7) had a very difficult time manipulating the tape and became very frustrated. For these students, I would probably forego the activity altogether, or at least give them more tape or larger strips of garbage bags.

The largest problem I encountered with the unit was the students' interactions with each other. There was a lot of "group drama" because I let them pick their own groups and a lot of bickering over who was allowed to take the activity home each day when they finished. I am also slightly concerned about the amount of materials required for this unit, but tried to include a lot of things that teachers might already own.

Overall, I was very pleased with the unit. Because there was such a wide range of ages, I often worried that the younger ones were not actually learning anything, but from their test scores, it seems almost everyone learned at least a little. More important for me was creating an interest in engineering and educating the students as to what an engineer actually does. There were certainly a lot of misconceptions about engineers in the beginning of the week and I was pleased that after only one week, there was such increased interest in engineering and I was able to clear up so many mistaken notions. I think this unit would work far better as part of a larger component where other engineering disciplines could be explored in depth. It would also help get more of the students interested, since it was clear they did not all enjoy working with water. A true classroom setting would probably help as well, since the daycare was so relaxed and the students would simply wander off if they got bored.

**PART III**  
**LANDFILL PLACEMENT**  
**ACTIVITY**

## Introduction

This activity is designed as an introduction to engineering and geography for upper elementary-aged students through the use of map overlays to determine the best possible location for a landfill. Students will learn about six considerations when deciding on a landfill site: airports, highways, fault lines, flood zones, towns, and sinkhole areas. Additionally, they will study the location of an abandoned landfill and hypothesize why it might have been abandoned. Transparencies are provided of each map “layer,” which are designed to be displayed on an overhead projector. The students will use their own paper map to follow along and block out the areas of each layer that are unsuitable for landfill placement. The purpose of this activity is to present the use of maps in a new way and procure the students’ interest in engineering, which is a growing field often not touched upon in elementary school.

## Background Information

The regulations around the placement of landfills can be very strict. For full regulations, please examine the Code of Federal Regulations Title 40: Protection of the Environment, Part 258 – Criteria for Municipal Solid Waste Landfills, Subpart B – Location Restrictions. The restrictions we will be studying are:

1. Airports – New landfills must be located at least 10,000ft away from existing airports. The reason for this is because birds tend to gather near landfills and these birds can become a hazard to planes flying nearby.
2. Fault Lines – New landfills must be at least 200ft away from any fault lines. Landfills located along fault lines are at a greater danger for leakage if the ground shifts beneath them and the liner underneath the landfill tears. All landfills have a liner installed at the bottom which is designed to prevent groundwater contamination and it is important to keep this liner intact.
3. Flood Zones – These areas are potential flood zones where, on average, the water floods every 100 years. Landfills must be built so that they do not restrict the flow of this water, reduce the storage capacity of the floodplain, or result in solid waste being washed away by a flood. All these scenarios could be a hazard to human health and the environment. Therefore, flood zones are to be avoided as a potential landfill location.

4. Sinkhole Areas – These areas are usually avoided as a site for potential landfills because they are signs of instability. Landslides, avalanches, rock slides, and rock falls are much more common in these areas which could damage the integrity of the landfill.

In addition, we will be looking at several other criteria which would come into play when determining the landfill location:

1. Highway – There is a highway through this county which is important to look at. Landfills are typically built in close proximity to highways so that trucks have easy access to the site and traffic problems due to increased traffic and heavier trucks are mitigated. In this case, we want the landfill to be built within 10,000ft of a major road.
2. Towns – The towns in this county are included because the landfill should be built nearby the towns for easier access, but not so close that the residents complain of the odor. Students can discuss exactly what distance from towns they think is appropriate. In this case, we want the landfill to be built within 20,000ft of a town, but not inside the town itself.
3. Abandoned Landfill – A landfill used to exist in this county, but was abandoned due to erosion and water concerns. It was built adjacent to a pond that flows through several creeks and ultimately into the Mississippi River. If you examine the sinkhole layer, you will also notice that it is located in the middle of one of the sinkhole areas.

The area we will be looking at is Union County in Illinois. This county is located in the southern portion of Illinois and has a population of around 18,000 and an area of approximately 422 mi<sup>2</sup> (1,093 km<sup>2</sup>).

**Title:** Using Maps to Determine the Placement of a Landfill

**Estimated Time:** 40 minutes

**Targeted Grade Level:** 3-6

**National Standards:**

NSS-G.K-12.6 THE USES OF GEOGRAPHY

*As a result of activities in grades K-12, all students should*

- Understand how to apply geography to interpret the past.
- Understand how to apply geography to interpret the present and plan for the future.

NS.5-8.6 PERSONAL AND SOCIAL PERSPECTIVES

*As a result of activities in grades 5-8, all students should develop understanding*

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

**Supplies Needed:**

- Projector
- Map layer transparencies (included)
- Paper map and legend (included), make a copy for each student
- Markers

**Objectives:**

- Students will practice reading legends and measuring scale.
- Students will gain interest in engineering as a possible career choice.
- Students will learn more about how professionals decide where to place a new landfill.

**Anticipatory Set:**

Discuss landfills with the students. Define what a landfill is: a place where waste is disposed of and buried in the ground. You may want to show the included cross-section of a landfill so that students can

see how it is laid out. Landfills have liners on the bottom of them to keep water from seeping all the way through the waste into the ground. Once a landfill is full, they also cover it with a cap to keep water from entering it from the top. If water was allowed to leach out from the landfill, it could contaminate nearby water sources with pollution. Therefore, landfills must be built in an appropriate location so that these liners don't tear or break. It's also important to make sure the landfill doesn't flood because solid waste could be washed away. Explain that today, they will be acting as engineers to find a suitable place to build a new landfill.

**Procedure:**

- Pass out the paper maps to the students. Ask them if they are able to tell anything from the map. When they guess or say no, explain that they will also need a legend to understand what the different symbols mean.
- Pass out the legend as well and discuss the importance of each piece of the map, referencing the explanation in the background information. Have the students hypothesize how each part affects the placement of a landfill before giving them the additional information.
- Explain that they will be looking at each consideration individually in order to find the best place to put a new landfill, following a set of rules that real engineers must follow as well.
- Make sure each student has a marker and instruct them to color out the places that would NOT work to put a landfill. In other words, anywhere that is still white at the end of the lesson is a good place to put a landfill.
- Pick one layer and reference the rule stated in the background information (for example, the landfill must be at least 10,000 ft away from any airports). You may want to write this rule on the chalkboard. Point out the scale at the bottom of their map, which will help them estimate distances. Explain that it is a way to determine the real-world distance as represented on the map. Have the students work in pairs or groups if they are struggling.
- Power up the overhead projector and put on the first transparency that you just referenced. The students' maps should look like the transparency.
- Repeat this process with the other layers, piling them up on the overhead so that they line up and students can see how most of the map is being blocked out. Their own paper maps should show the same thing.
- The last layer used should be the abandoned landfill. Have students look at the location of this abandoned landfill and think about why it might have been abandoned (it is in the marked-out

area of the sinkhole area). Make sure to give them the background information on this landfill after they discuss it for a few minutes, explaining the reason why it was abandoned. Students can trace on the map how the pollutants might have made their way to the Mississippi River (bordering the left-side of the map).

- Have the students determine where they think the best place for a landfill would be, based on the six considerations. It is highly recommended that they share this location with others as a group or as a class. Have them discuss with each other why they chose that spot. There is no right or wrong answer, but it should be in a white area (not rejected due to one of the considerations).

**Closure:**

Discuss as a class how maps are a real-world tool that many professionals use to make decisions. Stress how they truly acted out being engineers today and practiced making an important recommendation. Ask if there are any other layers they can think of that might also be useful in deciding where to place a landfill.

## Response to Project

I presented this activity for the first time at a K-12 school in Dollar Bay, MI. The activity was advertised as being for 5<sup>th</sup> and 6<sup>th</sup> graders, but because of a basketball game going on during the science night, only 5<sup>th</sup> graders were in attendance. Even so, I was able to teach two sessions. During the first session, three students came to the activity: 2 girls and 1 boy. None of the parents were present because they either had younger children or had just dropped off the students. Because of the very small group, it was difficult to get any of the students to talk or respond to my questions. However, they all completed the activity and seemed to understand the concepts. The second session was much more successful.

The second session was attended by six students: 2 girls and 4 boys. Several of their parents popped in and out of the room during the activity, but were not present for the entire thing. I later talked to a couple of them. One of the mothers told me that her daughter was working on a science fair project in school and she was testing to see what materials biodegrade faster, so she was especially excited about the landfill activity. Another mother was present for part of the lesson and wrote on her comment sheet that she thought the lesson was age-appropriate and fun. Her only complaint was the basketball game that took place at the same time, and she wished the science night was held on a different night.

The two girls who attended this session were especially talkative during the activity and I discovered that they enjoyed hypothesizing. When I first introduced them to the idea of using a map to determine where to place a landfill, they asked if they could make a guess as to where to put it. Several of the boys also had some ideas. They believed that we should place garbage in the sinkhole areas or in a fault line so that it would “fall into the Earth and we wouldn’t have to worry about it.” I had to later explain how that could possibly contaminate the water system and pointed out that I knew I didn’t want to swim or drink from a water source that was polluted with a bunch of garbage.

The two girls stuck around after the activity was over to talk to me more about landfills. One of them shared that she wanted to be a marine biologist when she got older and she really loved science. She also agreed with me that it would be bad to let garbage go into rivers or lakes because she heard that turtles and other sea life sometimes got their heads stuck in plastic or tried to eat it and got sick. She was very interested in landfills and told me that her father had told her something about collecting the gases from landfills. We talked a little about some landfills collect methane and can use it for energy. I made a note to discuss that more with the next group because the two girls seemed so interested in it.



The other girl was very excited to describe to me exactly how she would design a landfill. She was concerned about animals getting into the landfill and either getting sick or distributing the waste to other places. She spent a lot of time describing to me where she would place the landfill on the map and how she would design it so that animals and birds couldn't get into it. She also asked to fill out an evaluation form for me, although it's typically only the parents who do so. I allowed her to do so and she wrote that the family science night was "very interesting & fun" and that she couldn't think of any way to improve it. She requested a future activity to focus more on water.

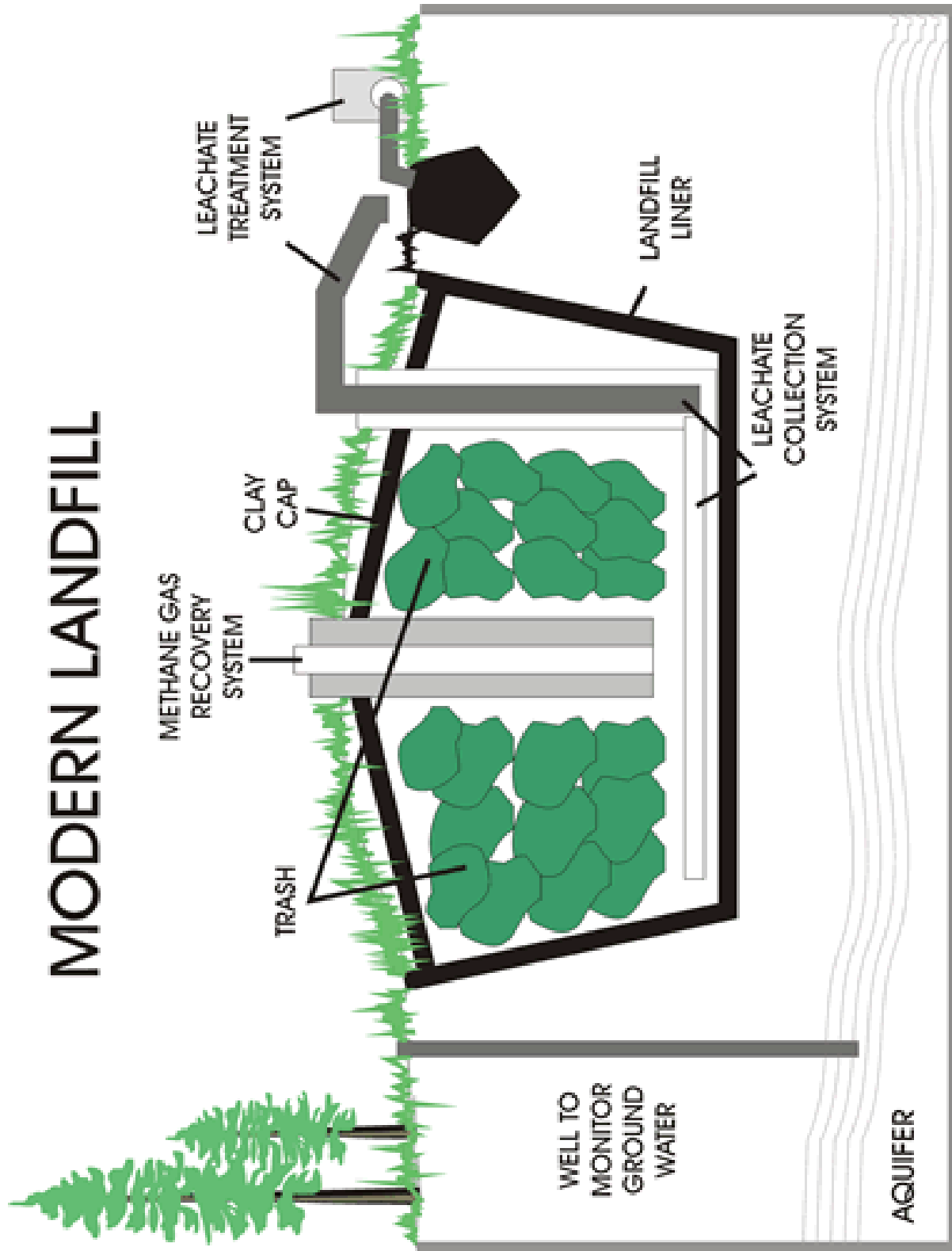
For the next family science night, I included more hypothesizing at the beginning of the lesson and also made sure to bring an extra overhead transparency. At the first night, I found myself constantly turning the projector on and off and rolling the screen up and down so that I could write the landfill "rules" on the board, then show the maps on the overhead. It was much simpler to just use the overhead and have an extra blank transparency to write the rules on.

The first session was attended by five girls (one in 1<sup>st</sup> grade, three in 4<sup>th</sup> grade, and one in 5<sup>th</sup> grade) and five parents (three moms and two dads). The girls all seemed very shy and were reluctant to volunteer answers, but their parents encouraged them to speak up and by the end of the activity, three of the girls wanted to come up to the front and show me where they would place a landfill. Afterwards, one of the mothers asked me where I found the maps and was very interested in looking at more maps. I gave her a few ideas on where to find GIS maps and what program to look for in order to view them.

The second session was attended by four boys (one in 4<sup>th</sup> grade and three in 5<sup>th</sup> grade) and four parents (three moms and one dad). This group was much more talkative and eager to volunteer their opinions on landfills. I heard from both groups that they had been learning about maps in school and were familiar with the different parts of a map. They seemed confident with using the scale to measure distances. The parents in both groups sat with their children and helped them follow the regulations.

I found that during this night, the activity ran a little short, only around 30 minutes. I believe this was primarily because the parents were so involved with helping the students and they were able to complete each step of the regulations much more quickly. In a classroom setting where such personalized help would not be available, I imagine it would run closer to the estimated 40 minutes. One change I did find useful was to discuss each part of the legend as it came up in the regulations, instead of all at once in the beginning. This way, there was more discussion throughout the lesson and we had an ongoing dialogue. Overall, I believe it was a successful lesson and both the students and the parents seemed to enjoy it. The evaluations were very positive and many of the parents wrote that it was fun and very educational.

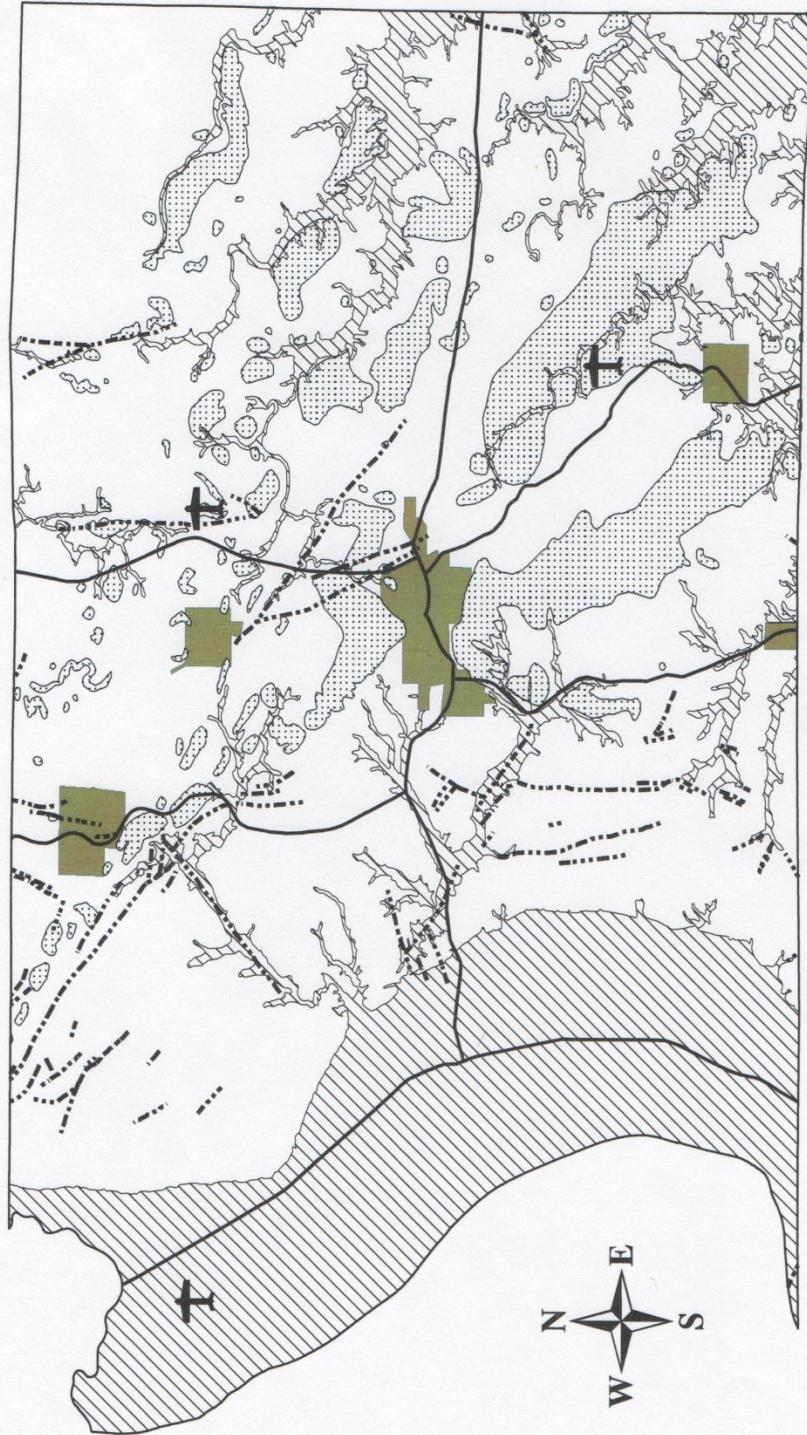
# MODERN LANDFILL



From <http://oceanworld.tamu.edu/>

Name: \_\_\_\_\_

Date: \_\_\_\_\_



0 20,000 40,000 80,000 120,000 160,000 Feet



# Legend

✈ Airport

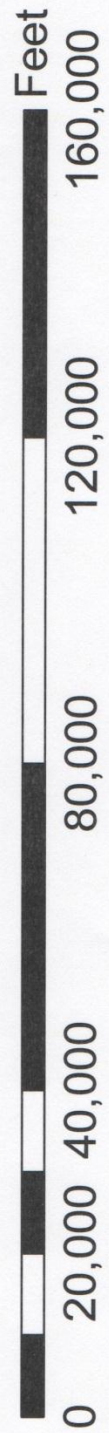
— Highway

- - - Fault Line

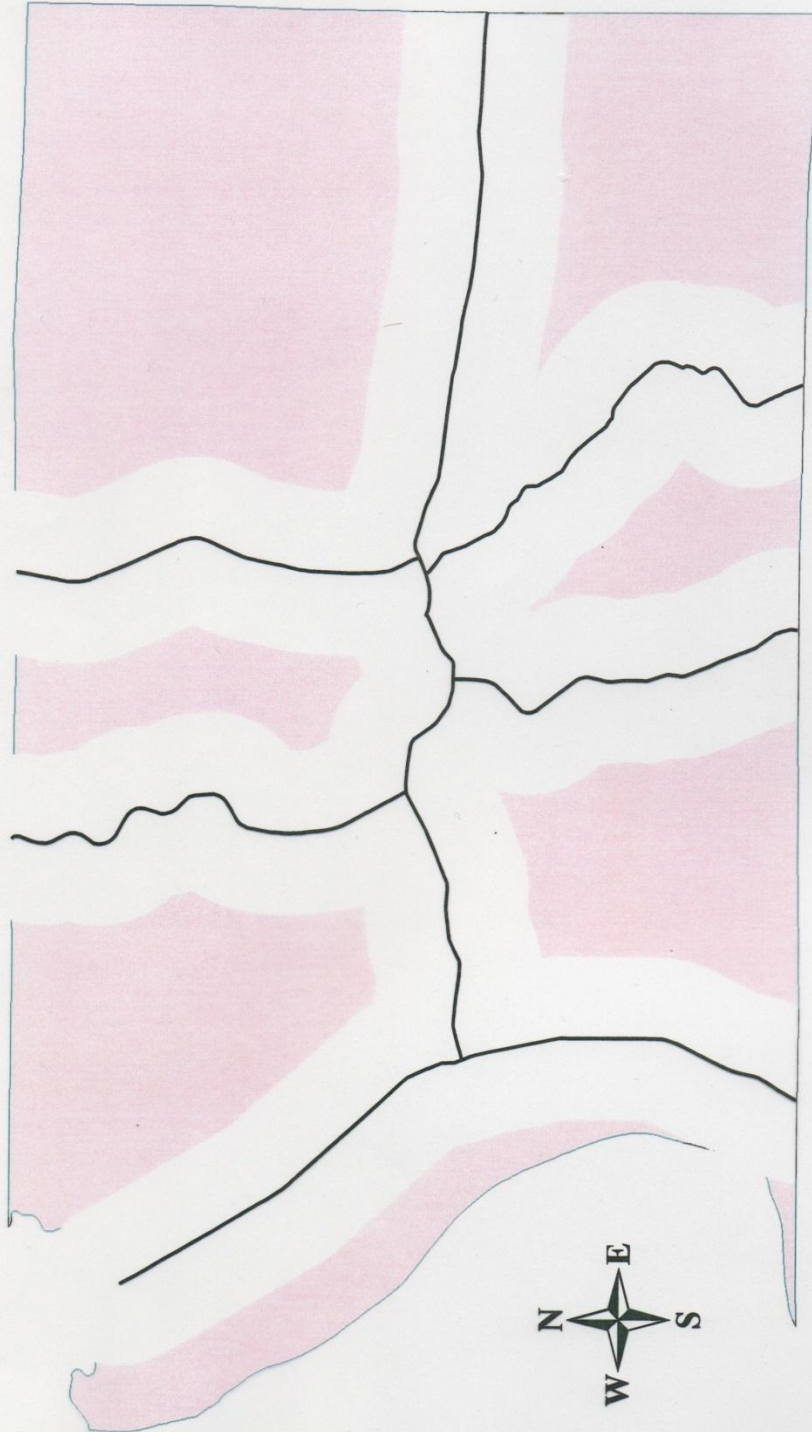
 Flood Zone

 Sinkhole Area

 Towns & Villages

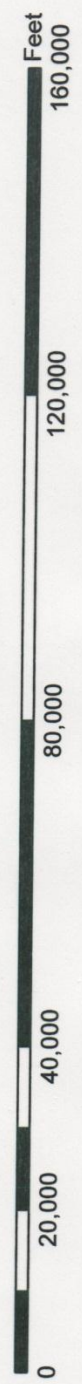
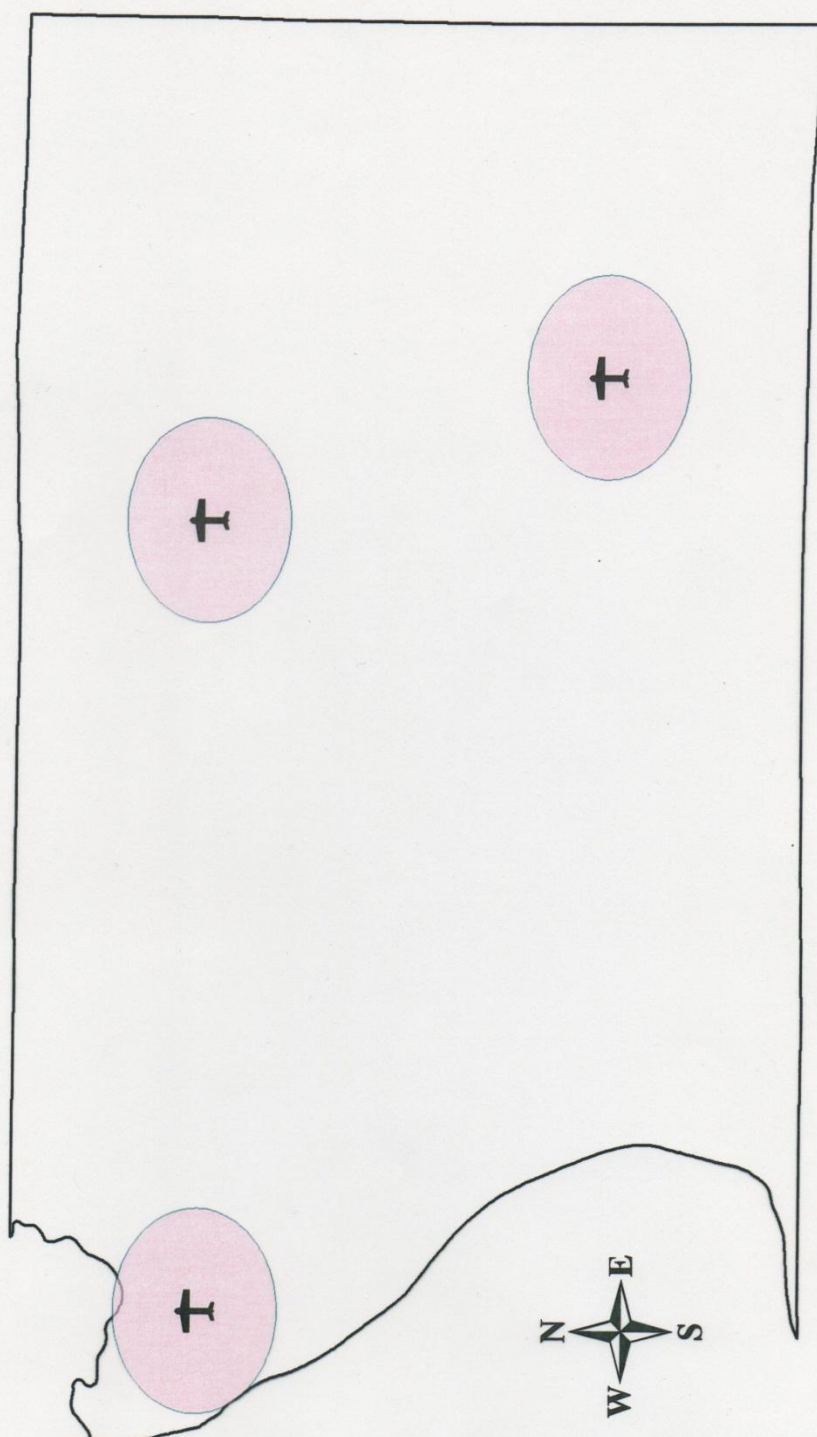


# Major Roads



0 20,000 40,000 80,000 120,000 160,000 Feet

# Airports



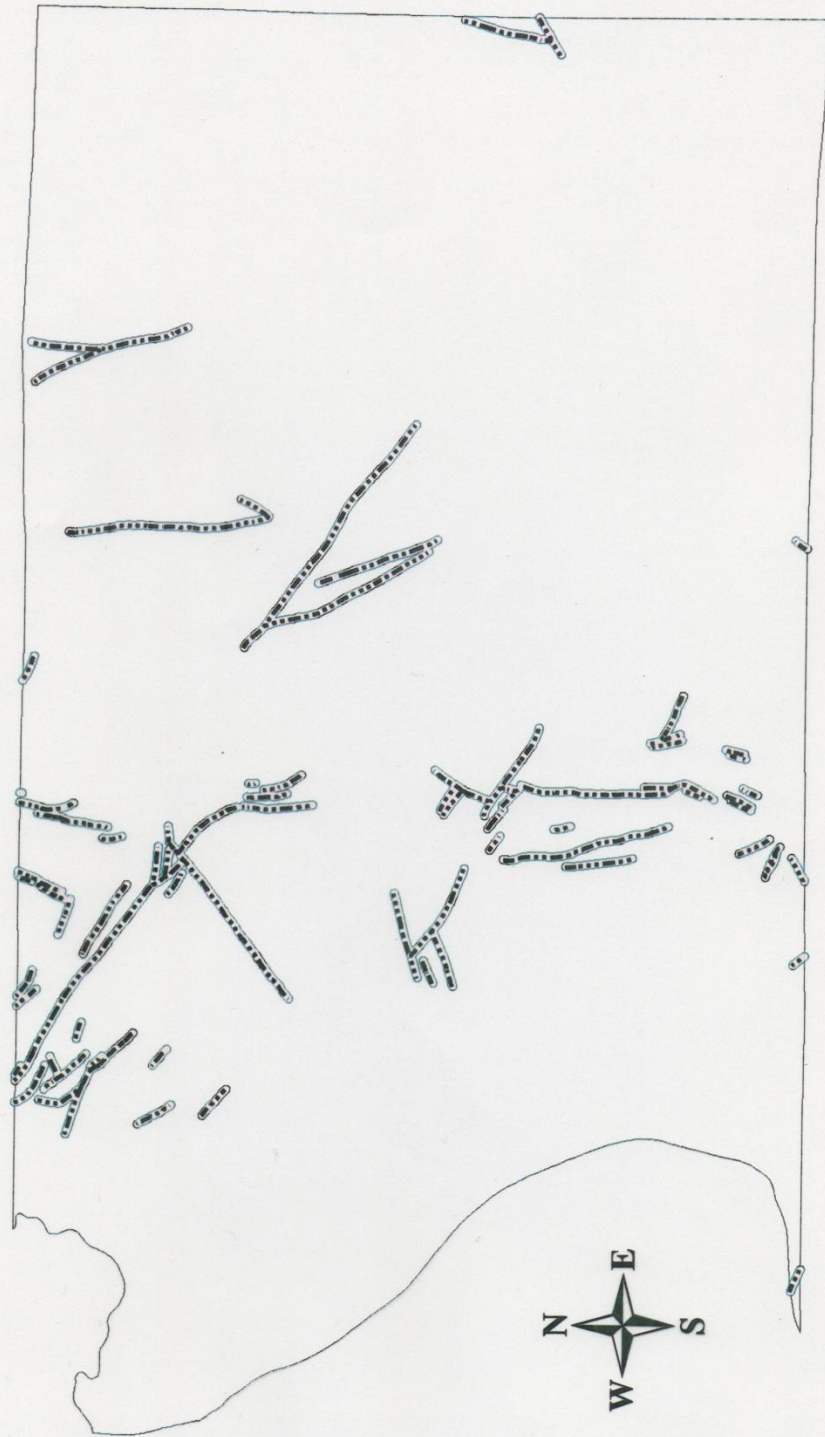


# Sinkhole Areas



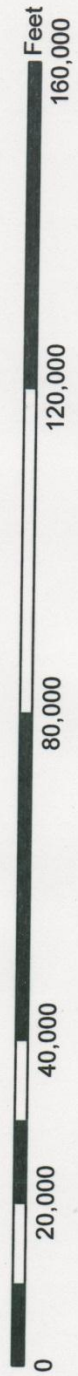
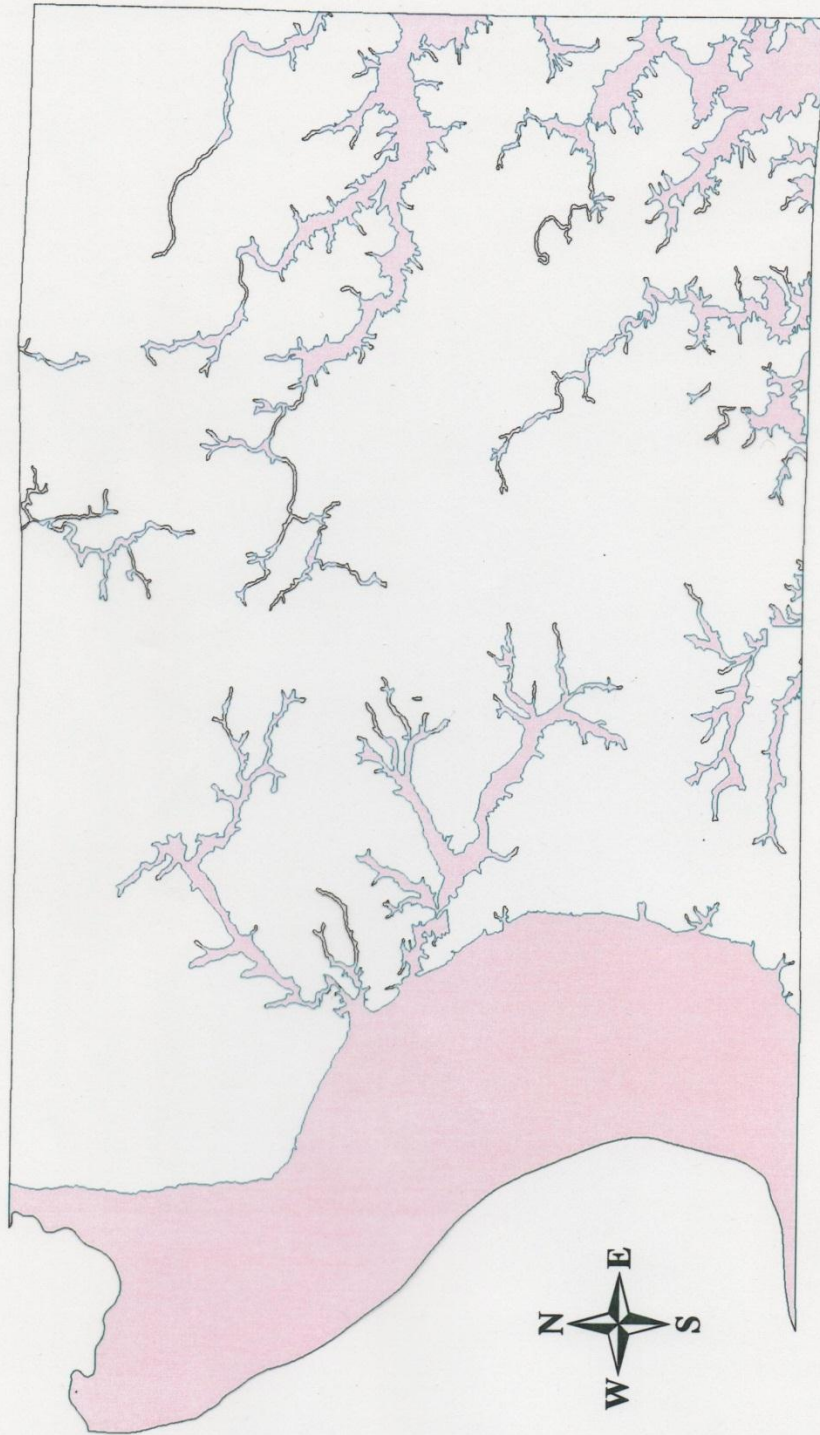
Feet  
0 20,000 40,000 80,000 120,000 160,000

# Fault Lines

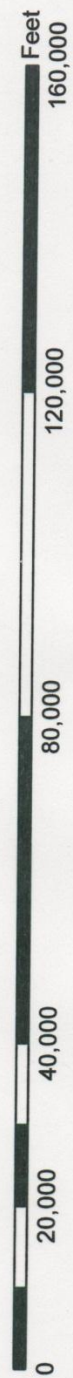
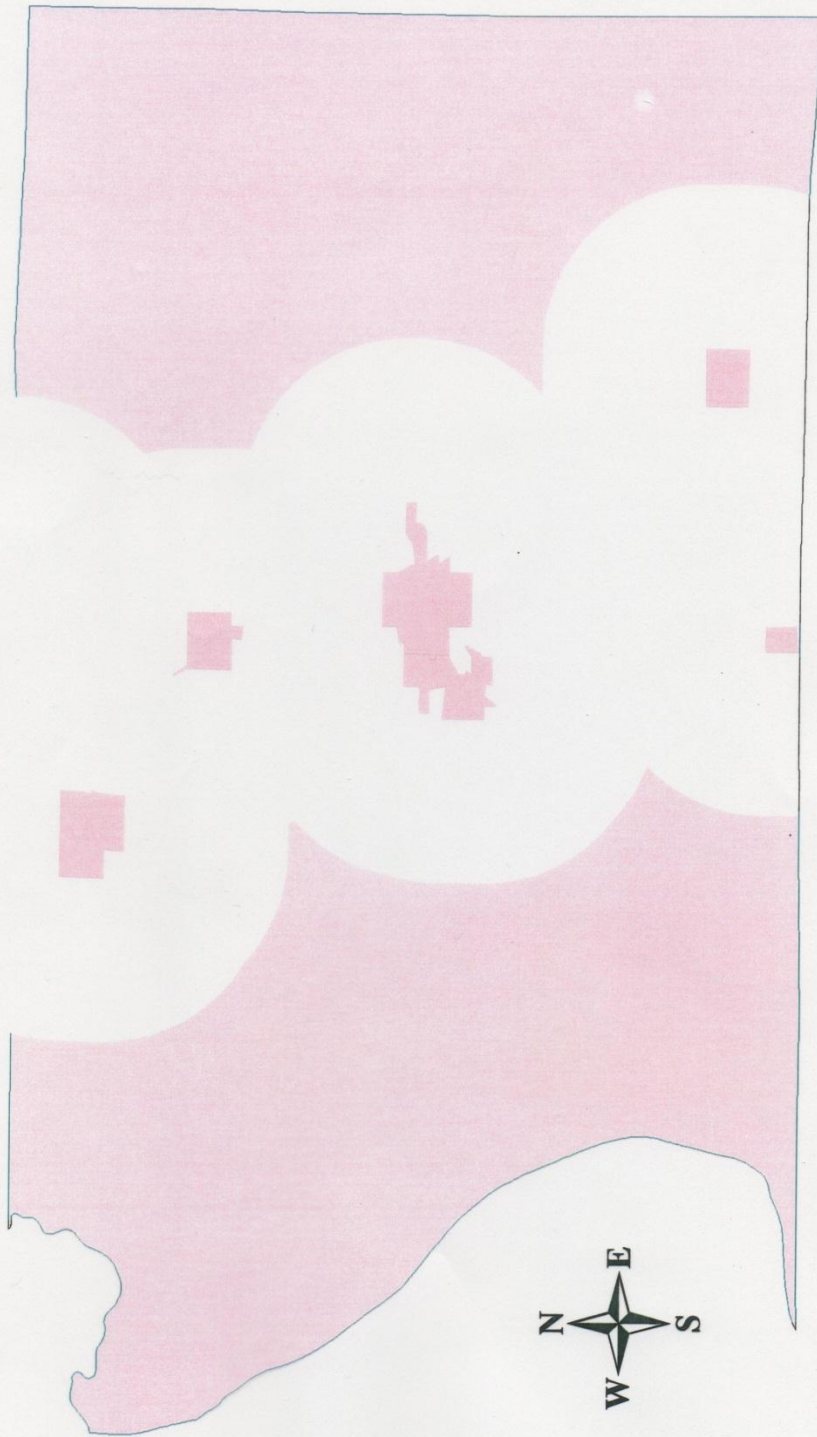




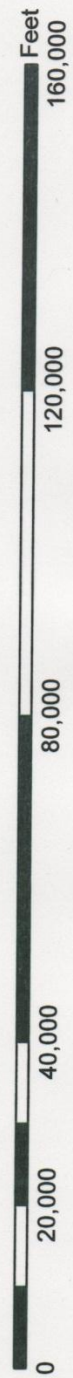
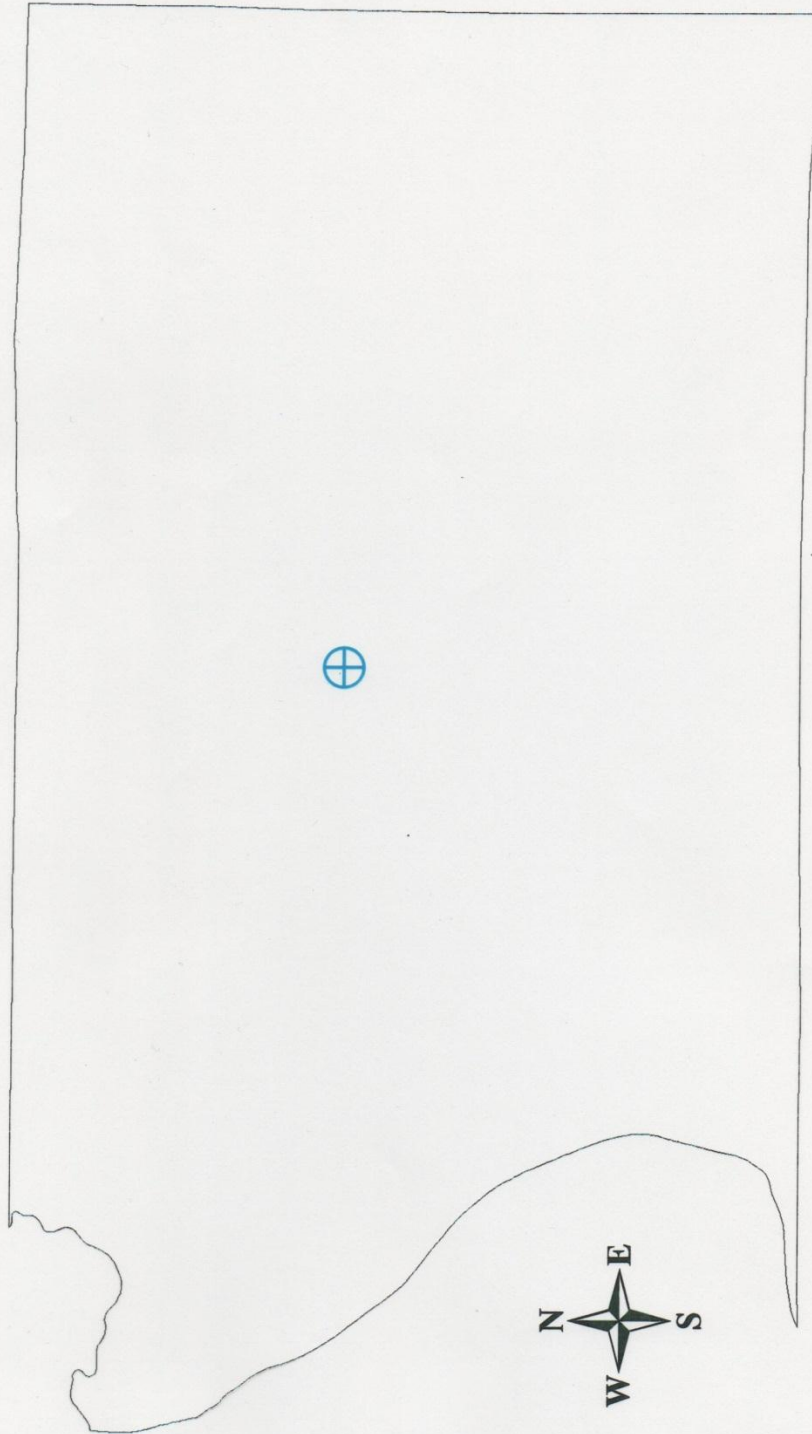
# Flood Zones



# Towns and Villages



# Abandoned Landfill



**PART IV**  
**CLEAN WATER**  
**CHALLENGE**

## Original Activity

**Title:** Clean Water Challenge!

**Engineering Discipline:** Environmental Engineering

**Engineering Concepts/Skills:** systems, properties of materials, engineering design process, societal and environmental impact

**Estimated Time:** 40 minutes

### **Supplies Needed:**

- permanent marker
- 1 roll of masking tape
- 1 strong push pin (plastic end bulletin board pins work best)
- 1 pencil
- 1 plastic-lined trash container
- 4 index cards

### *Per 10 families:*

- 1 clear, wide-mouthed, plastic gallon container
- ¼ cup of powdered clay (cat litter)
- ¼ cup of potting mix (such as Miracle Grow)
- 1 tablespoon of baking soda

### *Supplies per family:*

- copy of Clean Water Challenge Data Sheet
- 2 clear plastic cups with holes punched in bottom (9 oz. wide-mouthed Solo cups work best)
- 6 clear plastic cups without holes in the bottom (a narrow-mouthed 8 oz. cup works well to hold the filter cup and let it drain). *Note: 2 cups are labeled 'Clean Water #1' and 'Clean Water #2,' 2 cups are used to dispense 'river water,' and 2 cups of collect water from filter cups.*
- 1 small paper cup (3 oz.)
- 1 teaspoon of alum per family (available in baking/spice section of grocery store)
- ¼ cup gravel (available at pet stores or landscaping stores)
- ¼ cup washed sand
- 4" x 4" square of standard window screen material
- 1 coffee filter



- 1 pencil
- 1 plastic spoon
- 2 paper towels
- 1 tray or plastic shoebox tub (to collect supplies from supply table and upon which to design their water treatment system)

**Note:** *Suggest that participants ‘wash’ their sand and gravel between uses if there is access to a faucet.*

**Why:** To design a water treatment system.

**What:** One-sixth of the world’s population is without clean drinking water. If people drink dirty water, they may get sick, but if they don’t drink any water, they cannot live. This is one of the problems that environmental engineers are trying to solve. In this activity, families will be challenged to create a water treatment system that can turn dirty “river water” into clean drinking water.

**Advance Preparation:**

- Make one gallon of “River Water” for every 10 families:
  - Fill gallon container with tap water, leaving 4-5 inches from the top.
  - Add ¼ cup of potting soil
  - Add ¼ cup of clay-based cat litter
  - Add 1 tablespoon of baking soda
  - Mix well
- Prepare 2 plastic 9 oz. filter cups per family by poking 15 holes in the bottom of each cup with a pushpin. Place ¼ cup (1 inch) of sand in one cup and ¼ cup (1 inch) of gravel in the other cup.
- Use a permanent marker to label two 8 oz. plastic cups “Cleaned Water #1” and “Cleaned Water #2” for each family.
- Make a Family Supply Bag by placing the following materials into a resealable plastic bag:
  - 4” x 4” square of window screen
  - pencil
  - 2 plastic cups labeled “Cleaned Water #1” and “Cleaned Water #2”
  - 2 empty plastic cups
  - 1 plastic spoon



- Place the following items (per family) on the supply table:
  - plastic tray or plastic shoebox tub to carry supplies and to catch water during activity
  - Family Supply Bag
  - 1 gravel filter cup
  - 1 sand filter cup
  - One teaspoon of alum in a 3 oz. cup (1/2 teaspoon per cleaning)
  - 2 cups of river water (have a volunteer pour at the beginning of the activity so there is little time for particles to settle)
- Make 4 labels on index cards – Sand, Gravel, Alum, and River Water. Tape these labels in front of the corresponding materials on the supply table.

#### **Activity Facilitation Steps/Procedure:**

1. Ask families if they know where their drinking water comes from. What does it look like when it comes from the faucet? (clear) How long could they live without drinking water? (3-4 days)
2. Show families the container of cloudy “river water.” Explain that in some parts of the world, people do not have easy access to drinking water. They must walk long distances to get water from lakes or rivers and then carry it back to their village. Often the water they get from a river or lake is not clean. Ask families what kinds of contaminants might be in the water. (silt, animal wastes, human wastes, chemicals, bacteria, etc.) Explain that engineers are helping to solve this problem around the world and right here in our country by designing systems to clean the water that we use every day – especially for drinking!
3. Ask the families what drinking water should look like. (clear, no color, no smell) What are some things that we could do to this “river water” to clean it up. (allow water to settle, filter it, add chemicals)
4. Hand out one Clean Water Challenge Data Sheet to each family and introduce families to their challenge – **Design a series of treatment steps for the “river water” that will result in the cleanest water.**
  - Tell the names of each of the filtering materials provided and demonstrate how to pour water through a filter cup (with holes) and catch it in another cup. Tell families that, in addition to filtering things out of water, sometimes different chemicals are mixed in to the water to help clean it. They can add a small amount of the alum to their water to see how it might help in their water treatment process.

- Tell families to pour final water from their treatment system into the cup labeled “Clean Water #1.”
  - Families will send one family member to collect all supplies into a plastic tub or tray, except the “river water.”
  - Once families have created a treatment plan – determined which filter materials to use and in what order, and written the steps onto their Data Sheet, they can send one family member to the supply table to collect a cup of “river water”
5. Allow 15-20 minutes for families to plan and test their water treatment systems. Ask them to record their treatment steps and the results of each treatment step. Engineers want to design the most effective water treatment system – with the fewest steps and the lowest cost. They should pour the results of their first treatment design into the cup labeled “Cleaned Water #1.”
  6. After testing their initial water treatment systems design, families should discuss what worked and what didn’t work so well. If time allows, families can get a second cup of “river water” from the supply table and design a second, improved system and test it. Pour the water into the cup labeled “Clean Water #2.”  
  
Remind families that even after using their water treatment system, they should NOT drink the water...there could still be contaminants, like bacteria, that cannot be seen.
  7. When families have completed testing their treatment systems, have families hold up their cups of cleaned water so everyone can look around and see the results. Ask a few families to share their treatment steps with the group and how well they worked. Ask the group how they used information they discovered in their first design to improve their second design.

### Typical Water Treatment Steps

- **Screening:** used to remove large materials from wastewater
  - **Coagulation:** alum is added to water to form tiny sticky particles called “floc” which attract the dirt particles
  - **Sedimentation:** heavy particles (floc) settle to the bottom and clear water is removed off the top
  - **Filtration:** water passes through filters that help to remove smaller particles
  - **Disinfection:** small amount of chlorine is added to kill any bacteria or microorganisms that may be in the water
8. Tell families that engineers are always looking for ways to improve their designs, to make them more effective or faster. Next time you enjoy a drink of clean water, thank an environmental engineer!

**Clean Up** – Ask families to help with clean up by discarding used sand, paper filters, etc. into the trash containers and returning their remaining supplies (cups, gravel, etc.) to the supply table. Plastic cups may be rinsed and reused.

*Note: A system with the following steps will yield the best treatment results:*

1. *Use the screen to remove large particles*
2. *Filter with sand.*
3. *Add alum to clump small particles together.*
4. *Allow some time for settling.*
5. *Filter with sand to remove remaining particles.*

*A disinfectant such as chlorine bleach is often added to kill germs at the end of a treatment process before water is piped into buildings for drinking.*

**Extension:** Challenge families to find out where the drinking water comes from in their community and what kinds of treatment it undergoes before they drink it.

**Engineering Connection:** Most people in the United States enjoy some of the cleanest, safest water in the world, but this does not happen by magic. Environmental engineers must first find a suitable source of water and remove impurities so that it meets standards set by the U.S. Environmental Protection Agency (EPA) and the local state within the water is being used. The most common sources of drinking water are surface water, such as rivers and lakes, and water found underground (groundwater). Lessons learned in the U.S. and other developed countries are helping developing countries improve their own drinking water supplies.

**Fascinating Fact:** Lack of access to safe drinking water is a critical problem in many parts of the world. Many who live in less-developed countries need to walk more than an hour to get water from a river or lake. Unfortunately, the river water is often not very clean due to erosion and human and animal wastes put into the water by communities upstream. If people drink dirty water, they may get sick, but if they don't drink any water, they cannot live. Contaminated water greatly increases the risk of water-borne diseases that result in diarrhea. It is estimated that 4,500 children die every day due to dehydration caused by diarrhea. Worldwide, engineers are working on simple sustainable solutions for providing safe drinking water.

## Issues with Original Activity

In the field tests, many reviewers commented that the activity was very resource-intensive and while it was socially relevant and meaningful, the preparation took too long. One reviewer stated, “I am concerned that folks might choose to not do this activity because of the large amount of materials and advance preparation that is required.” Another reviewer also mentioned that “photographs of the water treatment process might be a nice connection to the outcomes of the engineering work to improve the system.” Lastly, yet another reviewer was concerned that “the attention span of children varies greatly during elementary school years. Younger children would not respond as well to this activity since you have to wait for the water to move through the filter between each step. A suggested grade band (i.e. Most effective with children in grades 3-5) might be beneficial.”

When testing the original activity myself, I noted several other concerns. Beyond the overwhelming list of supplies, I had trouble cleaning the water because when I poured the water from one cup to another, some of the debris was left in the initial cup, which was reintroduced at a later stage. I also had trouble seeing what the alum did when it was an intermediate step in the process. The recommended treatment system was also confusing, as it listed the sand process twice.

To rewrite this activity, I made several changes. I cut out many of the unnecessary materials and combined the supplies and preparation lists into one comprehensive list. I included an explanation at the beginning of the activity to introduce the reader to the idea of water treatment which explained the typical treatment steps and designed a poster-sized chart of these steps. I also included pictures of the procedure and suggested that alum be used as the last step of the design for the first trial so that the students can clearly see how alum affects the water.

## Updated Activity

**Title:** Clean Water Challenge

**Targeted Grade Level:** 3 – 6

**Engineering Discipline:** Environmental Engineering

**Engineering Concepts/Skills:** systems, properties of materials, engineering design process, societal and environmental impact

**Time Required:** 40 minutes

### **National Standards:**

NS.K-4.7 HISTORY OF NATURE AND SCIENCE

*As a result of activities in grades K-4, all students should develop understanding of*

- Science as a human endeavor

NS.5-8.6 PERSON AND SOCIAL PERSPECTIVES

*As a result of activities in grades K-4, all students should develop*

- Abilities of technological design
- Understanding about science and technology
- Abilities to distinguish between natural objects and objects made by humans

### **Supplies per 10 families:**

- Large jar or jug, with lid, to hold “river water.” Inside jug, mix:
- ¼ cup cat litter (powdered clay)
- ¼ cup potting mix
- 1 tablespoon baking soda
- Add water to mostly fill jug (leave some room to mix – solids will settle)

### **Supplies per family:**

- 1 copy of the Clean Water Challenge Data Sheet
- 1 pencil
- 2 clear plastic cups with around 15 holes punched in the bottom (the holes must be pushed from the inside of the cup out, so a straight dissection probe is the easiest way to do so)
- Add one inch of gravel to one cup (available at pet stores or landscaping stores)
- Add one inch of washed sand to the other cup (if sand is too fine, you may need to add a coffee filter to the bottom of the cup so that the sand does not fall through the holes) - Quickrete

Commercial Grade Fine Sand is recommended because it does not contain organic material. You can find it in a brown paper bag with blue printing in the concrete/cement supplies at Home Depot

- 2 clear plastic cups without holes punched in the bottom
- Using a permanent marker, label one cup *Clean Water #1* and the other *Clean Water #2*
- 1 clear plastic cup without holes punched in the bottom, to hold a sample of the “river water”
- 4” x 4” square of standard window screen material
- Plenty of paper towels to clean up any spills
- 1 teaspoon of alum in a small cup (available in baking/spice section of grocery store)

### **Explanation:**

Before it is safe to drink, water must go through a treatment system to remove impurities (such as dirt and clay), parasites, bacteria, and chemicals. Untreated water typically goes through five steps to separate out particles before it is disinfected to kill off any disease-causing organisms. The five steps are:

1. Screening – a screen is used to remove large materials from the water
2. Coagulation – alum is added to the water to cause the small particles to begin sticking together and forming larger particles called “floc”
3. Sedimentation – the heavier particles (floc) settle to the bottom and clear water is removed from the top to proceed to the next step
4. Filtration – the water passes through filters that remove remaining particles
5. Disinfection – a small amount of chlorine is added to kill any bacteria or microorganisms that remain in the water

This activity will focus on the first four steps (disinfection will be mentioned, but not included in the activity). Families will use their materials to try to find the best series of treatment steps to clean the dirty water. They will record the order of the materials used on their data sheet and then work to improve their design with a second try. The four steps available to use are:

1. Screening (the window screen square)
2. Gravel filter (gravel in a cup with holes)
3. Sand filter (sand in a cup with holes)
4. Alum addition and settling



### Procedure:

1. Ask families if they know where their drinking water comes from (it could be from a reservoir, a lake, a river, a well, etc.) If possible, find out beforehand.
2. Ask if they would drink water straight from a lake or river and explain that it might not be safe because it could contain dirt, silt, animal wastes, human wastes, chemicals, bacteria, etc.
3. Show the families your jug of “river water” and explain that not everyone is as lucky as them because they can simply turn the faucet to get clean water. In some parts of the world, people must walk long distances to get water from lakes or rivers, then carry it back to their village. Often this water is not clean, so engineers are helping to solve this problem all around the world (and in this country) by designing systems to clean the water that we drink every day.
4. Have the families brainstorm some ways to clean up the “river water” (filter it, let it settle, add disinfectants). Explain that today, they will be acting as engineers to find the best way to use some limited materials and time to get the water as clean as they can. Remind the families that no matter how clean they get their water sample, it will not be safe to drink. So don’t!
5. Hand out the Clean Water Challenge Data Sheet and explain what they will do with it.
  - For each step, they will list what treatment they use first, second, third, and fourth. Show them each possibility: window screen, gravel filter, sand filter, and alum. Explain that alum is already filled in as the last step for Design #1 so that they can add it to their water at the end and see what happens to the water.
  - Demonstrate how they can stack the cups and screen so that they pour the water in the top and catch it in the final “Clean Water” cup. They should observe the water through the cups and write down their observations during each step of the process.
  - Mention that they should only use half their alum in the first try, since they will use the other half during their second attempt (bring extra alum in case they forget).
  - If they are having trouble seeing the effect of the alum, have them swirl the water around in the cup a little, then wait. They should see a layer of particles settling in the cup, leaving cleaner water at the top.



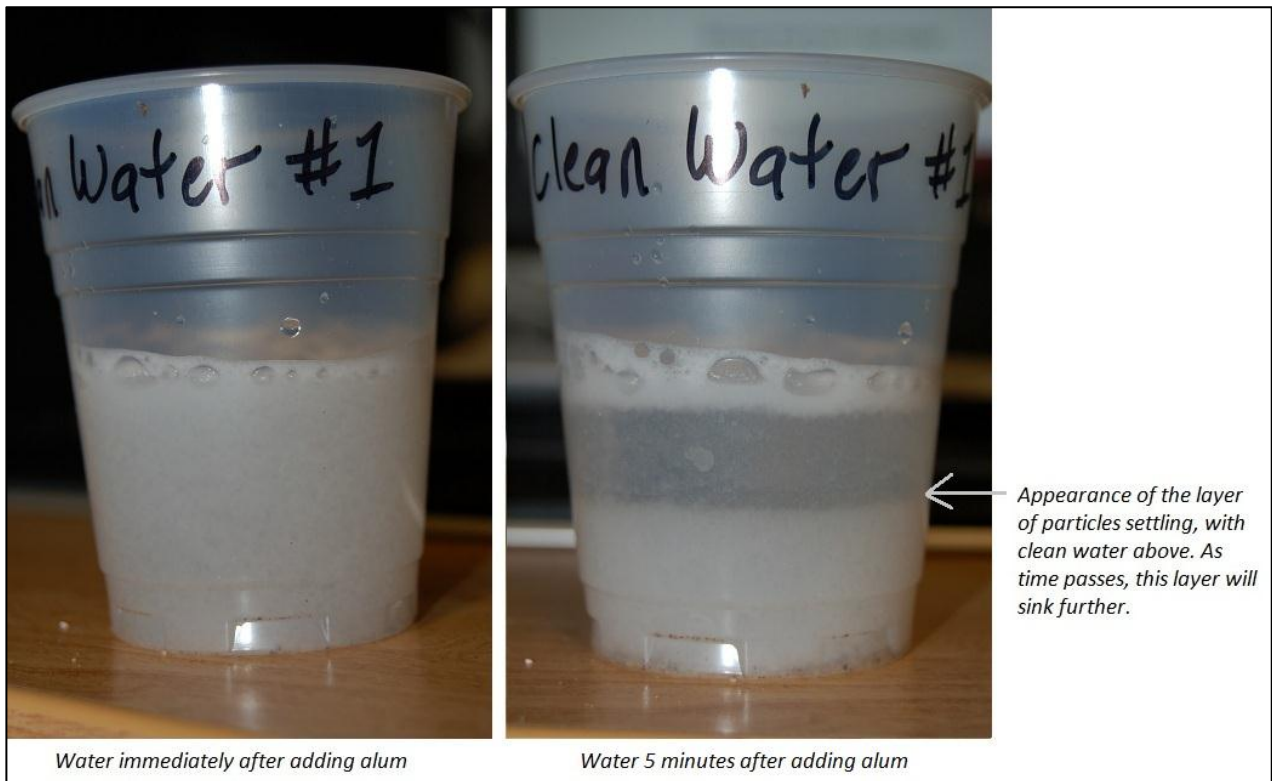
*Example of the stacked design*

6. Allow the families to make their treatment plan, then come to get their supplies. After 15-20 minutes of planning and testing the first design, bring the families back together to compare results and discuss their design.
7. Ask if anyone noticed a difference once they added the alum. Explain that in a water treatment system, it is added to the water to make the particles stick together and sink to the bottom faster so the clean water can spill over the top and go through further filtration.
8. Describe the typical water treatment steps described above: screening, coagulation, sedimentation, filtration, and disinfection. Have the families try to identify what steps they used in their design and how it compares to a traditional water treatment system.
9. Allow the families to improve their design and try the process again, refilling their cup of “River Water” when they are ready. This time, mention that they can add the alum at any point now that they know what it does.
  - If they wish to add the alum during one of the middle steps, show them how they can pour the water into the alum cup, then pour it through the other filters so that it ends up in the Clean Water Cup #2. Suggest that they wait a few minutes for settling to take place before going to the next step.
  - Encourage the families to wash the gravel and sand filter between the two attempts so that most of the muck from Design #1 is removed. You may wish to provide extra filters if you have a small group or no sink is available.
  - Note: a system with the following steps should yield the best treatment results:
    - i. Use the screen to remove large particles.
    - ii. Add alum to clump small particles together and allow some time for settling.
    - iii. Filter with sand to remove remaining particles.
10. If time remains, have the families compare their newly cleaned water and report if their second attempt worked better than the first. Ask how they decided which order to use their materials and how they used information they discovered in their first design to improve their second.



*Each layer can be lifted to observe the water at each step.*

11. Remind the families that the water is still not clean enough to drink and ask why they think that might be. Describe how in a water treatment plant, they must disinfect the water as a last step to kill off all the bacteria and microorganisms that made it through the filtration.
12. Tell families that engineers are always looking for ways to improve their designs and make them more effective or faster. Next time you enjoy a drink of clean water, think about all the steps it had to go through to get so clean!



#### **Clean-Up:**

1. Ask families to help clean up by discarding used sand, gravel, and water.
2. Have the families return all the other supplies (cups and screens) to you. These can be rinsed and reused.

#### **Engineering Connection:**

Most people in the United States enjoy some of the cleanest, safest water in the world, but this does not happen by magic. Environmental engineers must first find a suitable source of water and remove impurities so that it meets standards set by the U.S. Environmental Protection Agency (EPA) and the local state within the water is being used. The most common sources of drinking water are surface

water, such as rivers and lakes, and water found underground (groundwater). Lessons learned in the U.S. and other developed countries are helping developing countries improve their own drinking water supplies.

**Fascinating Fact:**

Lack of access to safe drinking water is a critical problem in many parts of the world. Many who live in less-developed countries need to walk more than an hour to get water from a river or lake.

Unfortunately, the river water is often not very clean due to erosion and human and animal wastes put into the water by communities upstream. If people drink dirty water, they may get sick, but if they don't drink any water, they cannot live. Contaminated water greatly increases the risk of water-borne diseases that result in diarrhea. It is estimated that 4,500 children die every day due to dehydration caused by diarrhea. Worldwide, engineers are working on simple sustainable solutions for providing safe drinking water.

## Family Engineering Clean Water Challenge Data Sheet

**Challenge:** Design a series of treatment steps that will result in the cleanest water. Be sure to record your steps and list what each treatment step does to help clean the water (how does the water look after each step?).

### Water Treatment System – Initial Design #1

Water Treatment Step	Observations
1.	
2.	
3.	
4. <i>Add alum, then wait</i>	

How well did your water system work? \_\_\_not at all \_\_\_a little \_\_\_pretty well \_\_\_great!

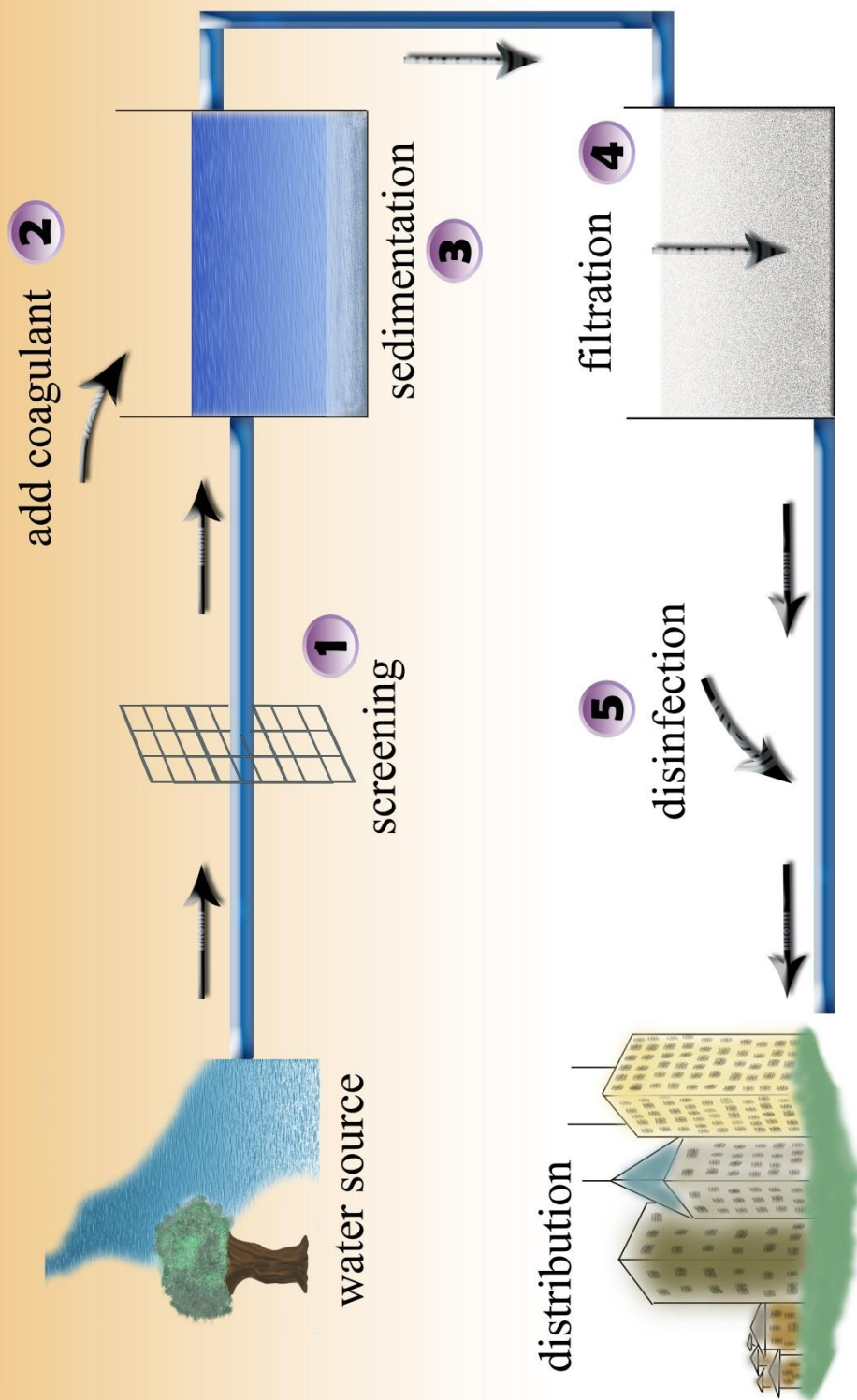
### Water Treatment System – Improved Design #2

Water Treatment Step	Observations
1.	
2.	
3.	
4.	

How well did your water system work? \_\_\_not at all \_\_\_a little \_\_\_pretty well \_\_\_great!



# Drinking Water Treatment



## Response to Updated Activity

I presented the updated activity for the first time during a family science night at Wakefield-Marinesco Elementary School. Eight sixth-graders and two parents attended the activity, as well as a sixth-grade teacher who popped in and out of the room. In this trial, the adults sat back and did not get involved in the activity and the students worked in groups of two, which worked well (except for one boy who did not want to work with the only girl, but after the initial complaints, they cooperated). The students had recently visited a wastewater treatment plant, which created a few misconceptions. They did not differentiate between drinking water and wastewater treatment until we discussed some of the differences. They also believed some of their drinking water came from stormwater run-off.

The activity itself went well. The group was small enough that I was able to use separate materials for each trial, which worked best in testing. They were able to match the steps they used in the activity to the steps in a real drinking water treatment plant and two of the groups figured out the recommended method. All four groups improved their design the second time. They especially enjoyed the settling step where they could see floc settle in the bottom. They were very interested in learning the technical names for each step (such as coagulation and floc). That inspired me to create a crossword puzzle for the students to take home (see below).

The student most interested in the activity was the only girl present. She came to me as everyone was leaving and explained that she and her mom (one of the parents present) had been talking about the best way to clean water if they were stranded in the wilderness. She was also curious how people cleaned drinking water before treatment plants were in use. Both parents told me briefly as they were leaving that they enjoyed the activity and thought their kids had learned a lot from it.

The only small issue we had with the activity was that none of the students left enough time for the alum to take effect and settling to take effect. Most of the students simply mixed it in with one of the filters. I made a note to myself to put more of an emphasis on the waiting and settling step during the next presentation.

The second presentation took place a week later at Hancock Elementary School. This family science night was much more widely attended and I taught two sessions. There were approximately 10 students during each session, with around 6 parents total. Many of the science teachers offered extra credit to the students who attended family science night, which might explain the large turn-out.

Additionally, the ages were much more varied. The majority of the students were in 4<sup>th</sup> and 5<sup>th</sup> grade, but some younger siblings were present as well.

This time, the parents joined the groups with the students and actively worked on the activities with them. One father was a civil engineer and was able to give helpful hints to his daughters. All of the parents were encouraging, pointing out that the “clean” water was much cleaner than how it began. Some of the parents also disassembled the system to show their children how the design was working at each step, pointing out things like that the sand filter was getting clogged, or that the screen was not screening out any material in its current placement. There were enough groups that I was able to get the groups to compare results and designs with each other in order to figure out the best way to clean their “river” water.

Again, there were enough supplies that I was able to use fresh supplies with most of the groups. The groups that did not have fresh filters to use on the second design had many more problems with clogging and dirt getting through the filter and overall, their final water quality was much poorer. This time, we set aside the water after we added the alum during the first design and continually checked back on it over the course of the evening. The students were excited to see how the layer of floc continually got thicker as it settled and the water on top got much clearer.

The students also seemed to enjoy the crossword puzzle, although the pencils I supplied did not have erasers, which was a bit of a problem. Most of them were excited to have something to be able to take home with them. I also had a volunteer assistant for this presentation, who helped pass out supplies. This was very helpful for the larger groups, although I think if the groups were any larger, I would have to set up a supply table for the groups to help themselves.

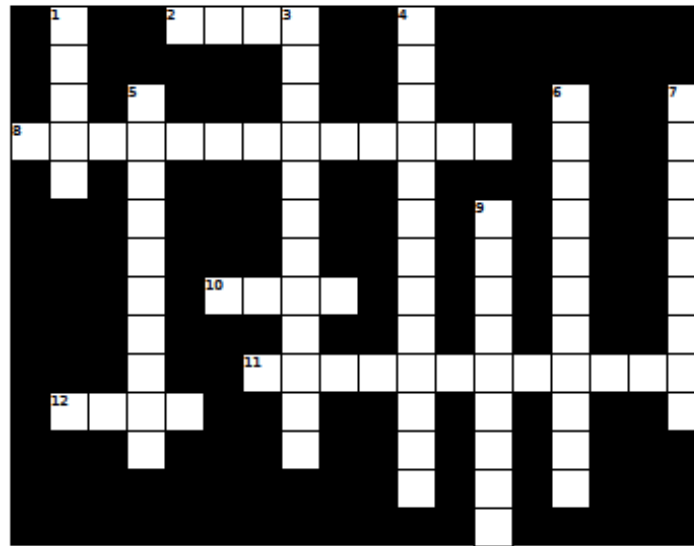
As with the first science night, the families all seemed to enjoy the activity and the students were eager to compare their results with the other groups to see who had the cleanest water. Not surprisingly, the girls with the civil engineer father had by far the best results. The parents commented that the activity was a lot more fun than they expected and they were glad they came. One mom asked me about how well-water is treated differently than surface water and expressed concern that her sister’s well-water smelled strongly of sulfur.

During both family science nights, the initial turn-out for the first session was very small. This suggests to me that the description of the activity (It’s easy to dirty water, but can you clean it? Become an environmental engineer and find out!) does not appeal to the families as much as some of the other

activities offered at the science night. The other remaining issue is the clean-up, which can be daunting after all the activities are finished. This may turn off some potential teachers of this activity. Additionally, it would be difficult to proceed with this activity with a very large group, or with a group with a wide age range.

I would recommend this activity be used with smaller groups of no more than 10-15 students, where there are 2-3 students per group. Of these students, the age range should be centered around grades 3-6. A few younger siblings are fine if the older sibling does the brunt of the work, but most younger children do not have the coordination to manipulate the water and would probably have trouble understanding the concepts as they are currently presented. The groups where parents were actively involved in the process ran much more smoothly and I believe the cooperation of parents enhanced the activity greatly.

# Drinking Water Treatment



## WORD BANK

WATER  
SEDIMENTATION  
FILTRATION  
FLOC  
SAND  
DISTRIBUTION  
ALUM  
DISINFECTION  
ENVIRONMENTAL  
SCREENING  
COAGULATION  
TREATMENT

### Across

- 2 A common type of filter.  
8 The step of treatment where particles are allowed to sink to the bottom.  
10 A common chemical added to the water to make particles start sticking together.  
11 The step of treatment where chlorine is added to the water to kill off bacteria and microorganisms.  
12 Fluffy clumps of particles that sink in the water after a coagulant is added.

### Down

- 1 Something everyone needs to drink in order to live!  
3 The act where clean drinking water is sent to people to drink.  
4 The type of engineer that often works on coming up with a process to clean water in order to drink it.  
5 The step of treatment where the water travels through sand to remove the remaining particles.  
6 The step of treatment where a chemical is added to help particles stick together.  
7 The process of cleaning water in order to make it safe to drink.  
9 The first step of the treatment process where large materials are separated from the water.



# **PART V**

## **CONCLUSION & RECOMMENDATIONS**

## Conclusion

I am pleased with the environmental engineering lessons and units I laid out, but believe they all need to be a part of a larger, more encompassing engineering unit. Simply focusing on environmental engineering was far too limiting and gave the students the wrong idea that engineering was only associated with the environment, particularly water. The unit was most effective with upper-elementary aged children and I believe that is where a true introduction to engineering is the most fitting. At younger ages, they could start learning some of the individual ideas associated with engineering, such as “design” or “experimentation” and then put it all together starting around third or fourth grade.

If I were to do the 5-day unit again, I would focus more on the experimentation step because that seemed to be the one most overlooked. The brainstorming and planning stages seemed to come naturally to the students, as did the building. However, once they had a completed project, they considered it to be done and didn’t want to further tweak it. I believe one way to encourage this step would be to give the students extra time at the end, where they use the information gained from comparison with the other groups to further improve their product. This was difficult to implement in a daycare setting where the students would simply wander off if they believed they were finished, but might be easier in a true school setting.

I noticed that the students worked very effectively in groups with everyone inputting ideas and helping build. However, I think a group size of 3-4 worked the easiest together, as opposed to some of the groups that numbered 5-6. This was further enforced during the family science nights where the groups often consisted of 3-4 children and 1-2 parents. The parents often acted as supervisors and offered advice, while allowing the children to do the actual building and decision-making. Although these activities were not tested in a classroom setting, I believe they would still work with a teacher or assistant roving through the room and acting as the “supervisor” to help lead students down the path when they get stuck.

I believe the individual lessons that went into further detail on their respective topics (the landfill location activity and the drinking water treatment activity) were more educationally valuable to the students because they gave a more accurate view of engineering. The unit was a good introduction to the engineering process, but the activities included were a little simplistic as to how engineers actually use the process. The family science nights at which they were presented were an interesting setting to examine how they worked because the families had such differing engineering backgrounds.

One thing that was not included in any of the lessons that I think would greatly increase their potential is a way for students to “bring home” their knowledge. From talking to the students during the 5-day unit, I found that families seemed to be mostly disinterested in their projects, often throwing them away. If the students could instead bring home some sort of fun game or activity to share with their parents, such as an assignment to examine their own family’s environmental impact, I believe it might be more accepted by the parents. I believe the family’s involvement in their child’s interest in engineering is very important and would make the educational messages longer-lasting.

At the family science nights, the parents were often very interested in the activity and wanted to learn more about the topics. Many of the parents discussed the subjects with their children and encouraged them to ask further questions. If parents are more involved in the learning process, either directly (as in the family science night) or indirectly (through a take-home activity), the ideas become more meaningful to the family as a whole and the student may further pursue their interest in engineering or science.

## How to Proceed

I think it is vital that teachers start introducing students to engineering at an elementary age because of the misconceptions regarding the field and the waning interest at later ages. I believe many children are natural engineers with their creativity, interest in building, and willingness to problem-solve. Elementary-aged children are often very interested in figuring out what they want to do “when they grow up” and engineering should be a part of that conversation.

Because teachers may not have a strong background in engineering or science, a curriculum must support the teacher as well. Important information that sets up the activity must be made easily accessible and easy to understand. Many existing lesson plans do not contain this important element, which discourages teachers from using it, or if they try to teach it, makes it difficult for the students to understand the material. This curriculum must be made available to a wide set of teachers in different areas, possibly through the Internet.

I would also encourage any teachers to look into getting a series of engineering kits or setting up an afterschool program to expose their students to engineering. I included a list of resources on page 6 that might prove helpful in that aspect. I have seen some teachers bring in science or engineering professionals who know how to work with children, which also seems to work well. However, a single unit introducing engineering seemed to leave a lot of misconceptions intact in the students. It needs to be a part of a larger discussion where the engineering concepts are often revisited.

In the future, I also hope to see engineering as a more prominent part of state curriculum, so that teachers feel free to address it. I have seen that in many core curriculum schools, teachers will shy away from any subject (such as engineering) that their students will not be tested on. However, by incorporating engineering with many other subjects, such as science, math, literacy, social studies, and art (as many engineering programs do) I hope that teachers will be more willing to experiment with those units.

I have found national standards that fit all the lessons and activities I created, which demonstrates that it is clearly possible to incorporate engineering into the standard subjects already widely taught in elementary schools. Engineering can enforce many of these subjects while also broadening the students’ views, introducing an entirely new realm of thinking and creativity that may grow into a passion and future career.

The activities included in this report all fall under an environmental science theme, but there is a wide variety of other engineering topics that need to be addressed as well. In my 5-day unit, the first activity introduced students to many of the other types of engineering, but without any follow-up activities, these other branches of engineering could be lost to those particular students. As I saw in the post-tests, many of the students equated engineering with solely environmental concepts. With the single activities in water treatment and landfill placement, I saw a similar result, where students did not truly understand the wider view of what engineering encompasses.

To proceed, I believe engineering can and should be included in today's elementary curriculum. The activities included in this report can be used as a basis for creating future lessons in all engineering topics. With a solid introduction to the activity that supports both the teacher and the student, a way to incorporate core subjects and standards, and a view that encompasses the many branches of engineering, many of the misconceptions about engineering will be eradicated and student interest will grow. I believe this interest will persist throughout their development and could help the declining enrollment in engineering majors at the university level, as discussed in the literature review.



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