AMP IT UP

Advanced Manufacturing & Prototyping Integrated to Unlock Potential

LIFE SCIENCE

Experimental Design

OIL SPILL DRILL

Oil Spill Challenge

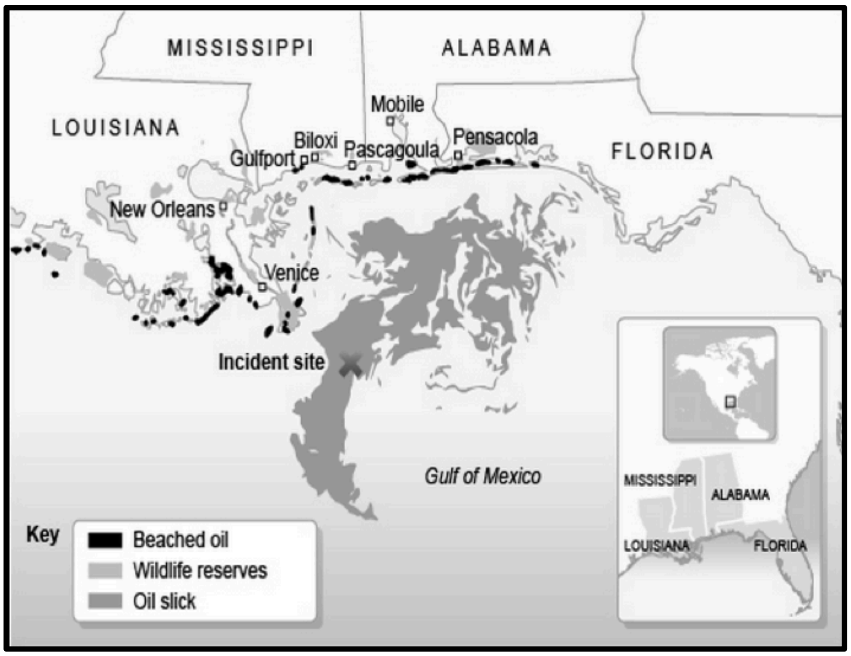
Fall 2018

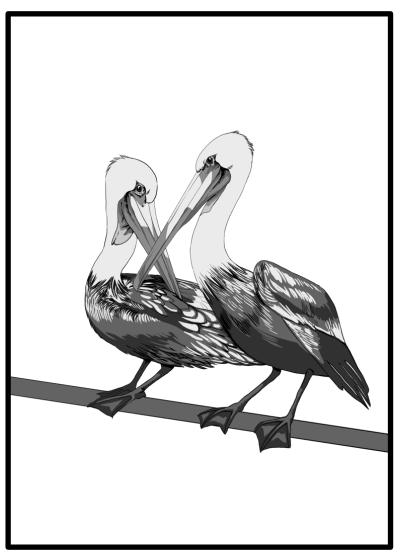
7EDS

SECTION 1 – THE OIL SPILL CHALLENGE

1.1 INTRODUCTION

Oil spills are a very serious pollution problem in our oceans. Every year 52 million gallons of oil are released into our oceans through oil spills or off shore drilling. In April of 2010, the Gulf of Mexico suffered one of the worst oil spills in United States history. This oil spill affected the ocean and shoreline from Florida to Louisiana (see map below). More than 8,000 birds, sea turtles and mammals were found injured or dead in this area in the months following the spill.





This oil spill was named the Deepwater Horizon oil spill and occurred after the explosion of an oil rig called the Macondo Well. The oil leaked into the ocean for around 87 days. Around 210 million gallons of oil flowed into the ocean. You might be familiar with the size of a gallon of milk. Imagine 210 million milk jugs of oil being released into the ocean; this is a lot of oil. Watch the video below to learn more about the Deepwater Horizon oil spill and the damage it caused to the surrounding environment.

Watch ***Video #1: Deepwater Horizon Oil Spill***.

Discuss these questions as a class:

1. What did you notice about the oil on the surface of the ocean?
2. Describe the condition of birds and other sea life after the oil spill.

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1.2 CLEANING UP OIL SPILLS

As you saw in the video, the Deepwater Horizon oil spill caused a lot of damage to the ocean and beach ecosystem. An **ecosystem** is all the living organisms (plants, animals, bacteria) that live in an area and the nonliving features (air, water, temperature) of their environment. The longer it takes it to clean up the oil spill, the more oil that will reach the shoreline where it may have more severe consequences on the economy and ecosystem.

At Georgia Tech, there are many research groups that study the effect of the oil on both the ocean and shoreline ecosystems. Ecosystem Impacts of Oil and Gas Inputs to the Gulf, also known as ECOGIG, is research team composed of oceanographers, marine biologists, and chemists from different research institutions including Georgia Tech. The ECOGIG team is looking at the long-term effects of the Macondo Well explosion and Deepwater Horizon oil spill on the deep sea ecosystems in the Gulf of Mexico. The deep water ecosystems play an important role in nutrient cycling and supports a high diversity of living organisms, which is important in the ocean food chain. Therefore, it is very important to protect the organisms in these deep sea ecosystems by preventing the spread of oil to protect the health of the ocean. Watch the video below to see some of the biodiverse organisms on the deep sea floor.

ECOGIG remotely operated underwater vehicle, ALVIN, on the bottom of the Gulf of Mexico to visit some deep sea coral reefs and evaluate the damage from the Deepwater Horizon oil spill.

KEY TERMS

Ecosystem: all the living organisms that live in an area and the nonliving features of their environment

Biodiversity: the variety of life in the world or in a particular habitat or ecosystem.

Watch ***Video #2: Diversity of Organisms***.

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Dr. Joel Kostka (pictured), a Biology and Earth and Atmospheric Sciences professor at Georgia Tech, studies what happens to the oil once it is washed ashore and carried deeper into the sand. The oil that is buried in the sand can seep into the groundwater and contaminate it. Therefore, it is very important to clean up as much oil as possible before it washes ashore. You will learn more about Dr. Kostka's work later in this module.

Oil molecules are more attracted to one another than water molecules. Therefore, oil does not dissolve in water. So how then do scientists clean up an oil spill in the ocean? Watch the following video to find out more about the different tools and technologies used to clean up oil spills on our oceans. Use the discussion questions below as a guide to watching the video.

Watch ***Video #3: Cleaning Up Oil Spills***.

Discuss these questions as a class:

1. What are some cleanup methods that are being used to clean up the oil in the Gulf of Mexico?
2. What are some disadvantages to using dispersants and absorbers in cleaning up an oil spill?
3. What are some new technologies that could be used to clean up the oil in the Gulf of Mexico?

1.3 YOUR CHALLENGE

United States Congress has proposed allowing oil exploration along Atlantic seaboard, which is the coastline from Virginia to Georgia, in the next few years. This would directly impact the coast of Georgia and their ecosystems. Many migrating birds and threatened species live on Georgia's barrier islands. If there were an oil spill anywhere along the seaboard, it would cause damage to Georgia's coast.

An oil spill would also negatively impact the state's shipping and tourism industries. The Port of Savannah is the United States' fourth busiest port. A port is a place where ships come in to unload and load goods. Historic Savannah and the barrier islands generate $3 billion or more in tourism every year.

It is important to develop a cleanup procedure before any drilling occurs on the Georgia coast. The Georgia Tech research team wants to make sure that they have a cleanup procedure that would protect the biodiversity of the ocean and minimize the damage of the spill.   They want to prevent the Georgia coast and deep sea ecosystems from similar destruction that occurred on the Gulf Coast from the Deepwater Horizon oil spill.

You have been asked to act as an environmental engineer and develop a procedure that would remove the greatest amount of oil in the ocean in the shortest time possible. Environmental Engineers combine their knowledge of science and engineering to improve the natural environment by trying to ensure clean water, air, and land by cleaning up pollution sites.   As you have learned, the longer the oil stays in the water, the more time it has to spread to beaches, affecting more wildlife and possibly contaminating groundwater. In addition to removing the greatest amount of oil, you will also try to remove the least amount of ocean water in order to not disturb the natural ocean ecosystem. Oil cleanups should not remove large amounts of ocean water.

1.4 MODELING AN OIL SPILL

Your will have to send the Georgia Tech research team your oil spill cleanup procedure, along with evidence that your procedure is accurate from data you will collect in your investigation. Your group will demonstrate that you can develop and oil cleanup procedure by **simulating** a **model** of an oil spill.

KEY TERMS

Model: A model of the real-life situation can test important aspects of a phenomenon under investigation and can be used to generate predictions, explanations, and solutions. However, models are limited in what they can represent about the real-life situation

Simulation: A simulation is the imitation of the operation of a real-world process over time. A simulation will show how a model operates.

We simulate a model because:

1. We cannot test a real-life oil spill, as we would cause damage to the ecosystem that we are attempting to protect.
2. If we wait for another oil spill, it will be too late, and many animals will be injured or may even die while we test our cleanup methods .

Scientists frequently use models to stand in for actual events, processes, and situations. This allows them to safely investigate dangerous or difficult events and understand better how things work. For example, scientists often use lab mice to study the effects of cancer treatments to model how those treatments might work with human cancer victims.

Discuss this question as a class:

1. What are some other models that scientists use to investigate real-life situations?

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SECTION 2 – INVESTIGATE AN OIL SPILL

2.1 PLAN AN INVESTIGATION

Because you cannot recreate an actual oil spill in the ocean, you are going to make a model of an oil spill. In this case, your model will use the same elements of an actual oil spill, but will be completed on a smaller scale in a laboratory environment. This called a scale model**.** A **scale model** is a representation of an object or process that is larger or smaller than the actual object being represented. A globe is an example of a scale model. In your investigation, you will use a smaller model of the ocean and the oil spill. You will then apply your procedure to the larger object or the ocean and the oil spill.

In your model, you will use:

- 400 milliliters (ml) of water in an aluminum tray to represent the ocean,
- 60 milliliters (ml) of oil to represent the oil spill, and
- Tools (cups and spoons) to model **skimmers** and tools (popsicle sticks) to model **booms**.

KEY TERMS

Scale model: representation of an object or process that is larger or smaller than the actual object being represented
Skimmer: sweeps oil across the water surface, concentrating the oil.
Boom: oil-containment device that floats on the surface of the water and is used as a barrier to keep oil in or out of a specific location.
Absorber: material used to soak up oil while it is being contained.
Dispersant: chemicals sprayed on oil to cause it to break up and sink.

Unfortunately, you will not have access to an absorber or a dispersant as Georgia Tech researchers have decided that these materials will cause too much damage to the ocean ecosystem.

Your challenge is to:

- Remove at least 20 milliliters (ml) of oil (1/3 of the total oil) from the water in a one minute time period**.** We are using 20ml to symbolize when the oil concentrations are no longer toxic to humans, animals, and plants.
- Remove the smallest volume of water in the same one minute time period. Remember even in your model, you need to protect the ocean ecosystem.

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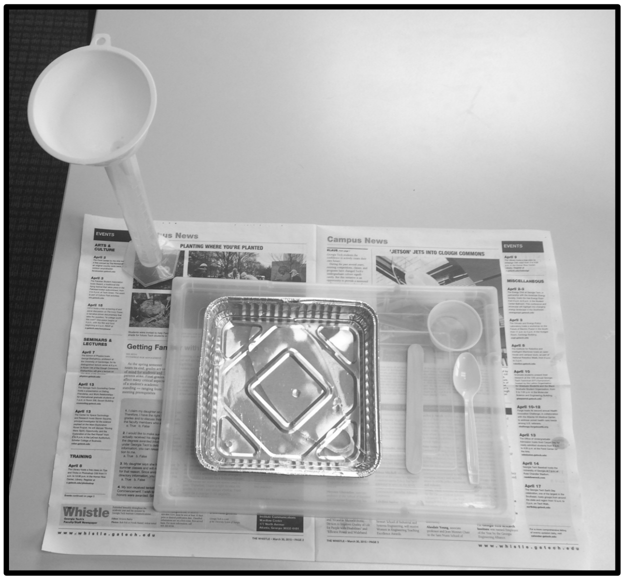
Use the pictures below to set up your model spill that you will use to test your procedure.



Procedure:

1. Spend 5-6 minutes discussing and creating a cleanup procedure for removing the greatest amount of oil in a one minute time period.
   a. You can use the materials listed here to design and conduct a procedure to remove at least 20 milliliters (ml) of oil in a one minute time period from the tray of water while removing the least amount of water in the process. The tray of water represents the ocean so you <u>cannot move or tip the tray of water</u>.
   b. You must complete at least 4 trials during your investigation.
2. Write your procedure on *Investigation Sheet 1*.
3. Raise your hand for your teacher to come by to make sure that you have recorded your procedure and are ready to begin your investigation.

MATERIALS

- Aluminum tray
- Plastic beaker
- Graduated cylinder
- Funnel
- Water (400 ml)
- Oil (60 ml)
- Plastic spoon
- Wide popsicle stick
- Wide mouthed plastic cup
- Stopwatch/timer
- Paper towels/newspaper
- Gloves/apron
- *Investigation Sheet 1*

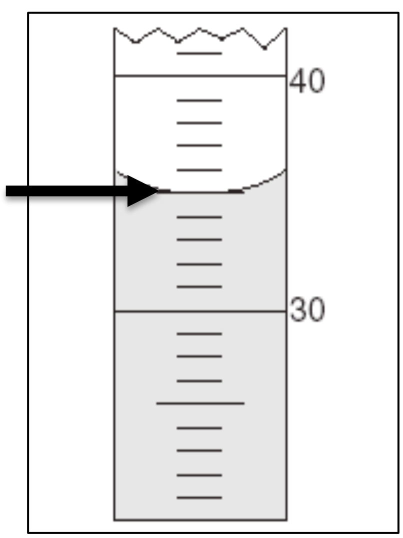
2.2 CARRY OUT YOUR INVESTIGATION

You will have 15 minutes to run your procedure and conduct all your trials. You have everything you need to model the oil spill. Your teacher will provide you with instructions of how to set-up the oil spill. You should also view the picture of the model of the oil spill on page 8 of your *Student Edition*.

Procedure:

1. Read the tutorial on reading a graduated cylinder before you begin.
2. Follow the procedure that your group created for at least five trials. After each trial, pour the water and oil back into the aluminum tray and then repeat your procedure.
   a. If you remove 100ml of liquid (any combination of water and oil) from the tray before the minute time limit has expired, stop your procedure.
3. Record the results of each trial on your *Investigation Sheet 1*.
   a. You will record *if* you removed 20 milliliters of oil, how much oil (milliliters) you removed, and how much water (milliliters) was removed.

Tutorial: Reading a Graduated Cylinder



In the diagram above,
the correct measurement would be 35 ml.

Graduated Cylinders are pieces of laboratory equipment that measure the volume of a liquid. In this investigation, you are using a 100 milliliter (ml) graduated cylinder. Each small line is equal to one ml, each medium line is equal to 5ml, and each large line is equal to 10 ml.

When reading the graduated cylinder, you will need to find the **meniscus**, or little dip (or curve) at the top of the liquid sample. Get at eye-level with the meniscus and imagine a line running parallel with the bottom of the meniscus and the measurement closest to that line is the volume of the liquid

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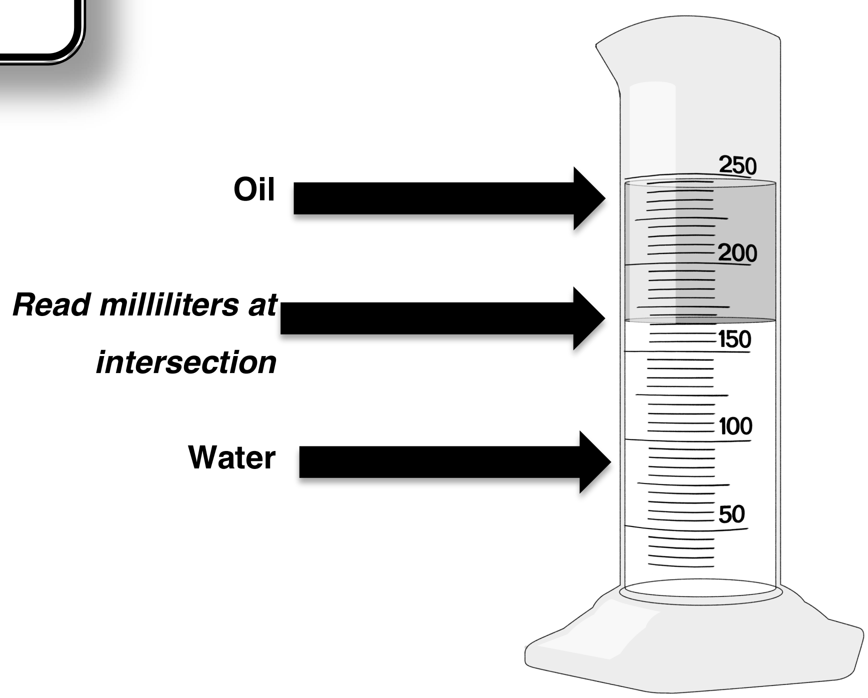
Oil and water have different densities**.** **Density** is the amount of mass per unit volume. In simpler terms, density is how close the molecules of a substance are or how much mass a substance has in a given space. Oil is less dense than water. Therefore, oil will float on water. In the graduated cylinder, the oil will separate above or float on the water in the cylinder. <u>You may need to wait a minute or two after removing the oil to record your results as the water and oil will need time to separate in the graduated cylinder.</u> See the diagram below to assist with determing how to record ml of oil and ml of water. Recording results allows scientists to accurately report their findings. The data you record will help others understand your group's work. Be prepared to share your results with your class.

KEY TERMS

Density: the amount of mass per unit volume



2.3 COMMUNICATE YOUR RESULTS

Each group will report to the class the results of their investigation. Your teacher will record the outcomes on a graph known as a histogram. For each result measured during the investigations, we will place an “X” on the graph. Each X will represent the number of milliliters of water that your class removed during each trial. When a group reads their results, you will also ask if they removed 20 milliliters of oil. If they did not remove the minimum amount of oil, you will mark that X with a ***red*** pencil. This will allow you to compare the milliliters of water removed with groups that successfully removed the oil and groups that did not remove enough oil.

Procedure:

1. As each group reports their results, chart those trials by placing an “X” on the graph for every data point on your *Results Graph 1*.
2. Your class will analyze the graph to see if your team has demonstrated that they have developed a quality oil removal procedure.

2.4 ANALYZE THE DATA

Procedure:

1. Look at the histogram that was created from the class data.
2. Answer the discussion questions as a class. Have your written procedure available as your answer the questions.

?

Discuss these questions as a class:

1. Did your group have any difficulties (mistakes, spills, etc.) while following your procedure? Describe each one.
2. Did you remove 20 milliliters (ml) of oil for each trial?
3. How similar are the results of different groups?
4. Did you notice patterns on the histogram between groups that were able to remove the 20ml of oil and groups that were not? (Compare results of Red vs. Black X's on the histogram)
5. What did the distribution, or spread, of data on the histogram look like? What do you think this says about how reliable the class's data are?
6. What could the class do to get results that are more similar (consistent)?
7. Do you think the Georgia Tech research team would trust your class data for using this procedure to clean up an oil spill?

3. Discuss how your answers may help you to complete the Oil Spill Challenge better.

SECTION 3 – REDESIGN YOUR INVESTIGATION

3.1 THINK ABOUT PROCEDURES

Your class probably did not agree on the best way to remove 20 milliliters of oil without removing large amounts of water. Your histogram may have shown that your class cannot produce results that can be trusted. Now, you will see if you can find a way to make the results more consistent across groups.

Think about what you might want to do differently. Everyone is trying to answer the challenge – how to remove 20 milliters of oil in the shortest period of time while removing the least amount of water. Every group used same unit of measurement, milliliters. Every group had the same materials. However, every group used a different procedure and removal techniques. No wonder the results were so different.

3.2 ADD TO YOUR UNDERSTANDING: TRUSTWORTHY INVESTIGATIONS

Scientific and engineering investigations happen for many reasons. Some help to explain new events or processes. Some test a theory or model, while others compare different solutions to see which best solves a problem or question. When they carry out investigations, scientists and engineers try hard to use consistent procedures in order to get trustworthy data. **Consistency** refers to using the same procedure repeatedly to collect data. In order to make sure trustworthy data is collected, they develop and use a consistent procedure for all trials of their investigation.

KEY TERMS

Consistency: using the same procedure repeatedly to collect data

Scientists and engineers do not decide on their procedure once and then stop. Instead they refine their procedure to make it more consistent and more precise. After collecting data they might consider ways to improve their procedure for their next experiment. They then collect data again, this time using the revised procedure.

Scientists also share their procedure and data with other scientists. This collaboration helps reveal any patterns and relationships within the data. The data can be better communicated through graphing and statistical analysis, which is how you interpreted patterns on the *Results Graph 1*.

You probably saw a wide spread of data in the histogram. This is called **variation**. It is important to use the same procedure every time you test or measure something. Your results will then be consistent, they will probably be repeatable and it will likely reduce the variation in the data collected.

The class will decide on a standardized procedure that everyone will use to remove the oil from the tray without removing the water. A standardized procedure means that everyone will do each step the same way. That way, you will be sure that the results obtained by different people or groups can be compared. You will also concentrate on being consistent from one trial to the next.

KEY TERMS

Variation: a change or difference in condition

Error: a measure of the estimated difference between the observed or calculated value of a quantity and its true value

Creating a good procedure requires identifying the steps in the procedure very specifically, so it can be run the same way each time. It also requires identifying possible sources of **error**. This tells someone following a procedure how to do it to get repeatable results and what to be careful about as they are running it. When procedural differences are unintentional then we say that they add error to the data. Scientists try to remove as much error from their data as possible.

Discuss what techniques were most successful in removing oil and not water. You may want to review the histogram and compare the removal techniques of groups with red and black **X's**. Each group should share what techniques worked best in oil removal. Think about how each tool could be used and which use of the tool was most effective in removing the oil and not the water. You may decide to only use one or two tools in the next procedure.

Procedure:

1. Your teacher will make a list of the procedural differences you noticed during your first investigation.
2. As a class, discuss changes that could make your procedure more consistent and identify sources of error.
3. As a class, revise the procedure to decide which procedural details that all groups should follow. Your teacher will record and display the new procedure as the class designs it.
4. After the class has decided on the procedure, each group should review and discuss the new procedure.
5. Each group member should record the new procedure on *Investigation Sheet 2*.
6. Raise your hand for your teacher to come by to make sure that you have recorded your procedure and are ready to run the investigation again.

Discuss these questions as a class:

1. What are three or four key differences between your previous procedure and the new class procedure?
2. What are you now controlling better in the new procedure?
3. What effect do you think this new procedure will have on the range of results across groups?
4. How did you develop your new class procedure to improve your design to remove oil from the water tray?
5. What are your predictions for the removal of oil when you repeat the procedure? What are your predictions of the removal of water when you repeat the procedure?
6. What could the class do to produce a procedure to achieve consistent (same every time) results?

SECTION 4 – OIL SPILL CHALLENGE WITH A NEW PROCEDURE

4.1 CARRY OUT YOUR NEW INVESTIGATION

Now that you have a new procedure, your class should be able to produce more reliable results and reduce the amount of water removed with the oil. Your class will soon collect another set of data and produce a new histogram.

Procedure:

1. Follow your new procedure using the materials listed to complete 5 trials.
2. Record your results on *Investigation Sheet 2,* which you used to write your revised procedure.

Be prepared to share your results with your class and teacher. You will have 15 minutes to perform your investigation and collect your data.

MATERIALS

- Aluminum tray
- Plastic beaker
- Graduated cylinder
- Funnel
- Water
- Oil
- Plastic spoon
- Wide popsicle stick
- Wide mouthed plastic cup
- Stopwatch/timer
- Paper towels/newspaper
- Gloves/apron
- *Investigation Sheet 2*

4.2 COMMUNICATE YOUR RESULTS

Procedure:

1. Once all groups finish collecting data, each group will share their results.
2. Each student will plot the results on his or her *Results Graph 2* as the teacher creates another histogram, too. Each group should report any problems they had completing the procedure (e.g., mistakes, spills, or other uncontrolled variables). <u>Continue to mark results in red if a group did not remove 20 milliliters of oil in their trial.</u>

4.3 ANALYZE THE DATA

After your class creates the histogram, think about and discuss as a class how the new, more specific procedure demonstrates the class's ability to consistently remove 20ml oil from the water tray without removing the water.

Discuss these questions as a class:

1. How do the results from this investigation compare to the ones from your first set of trials?
2. Did all groups get results similar to yours?
3. Do you trust these results more? Why or why not?
4. Did your procedure produce consistent results and meet the goals of the challenge?

One more time?

You might find that the range of results is still too large for you to trust or you might have found that you have consistent results, but you are still removing too much water or not enough oil from your tray. If so, return to your procedure. See if there are ways to standardize and control the procedure even further. Discuss how to better standardize the steps and process, and record a new procedure. Then, run this new procedure with 5 trials. Afterward, as a class, plot these new results on another histogram to see if you are getting more trustworthy data and a more efficient design because of a better procedure.

4.4 ANSWER THE CHALLENGE

Science and engineering require using well-designed, consistent procedures for measuring and collecting data. To do this, scientists and engineers carefully record their procedure so that they and others can repeat the procedure and verify measurements.

In the first investigation some groups might have used the spoon to scoop out the oil, while other groups used the spoon to skim the oil. Other groups may have not even used the spoon at all and used the wide mouthed plastic cup to remove the oil. You may have even changed the method of use of the tool from trial to trial. The type of tool used to remove the oil and how it was used is an example of a ***variable***. A variable is any part of the procedure that could change. By changing variables between groups and trials, you are more likely to have inconsistent results.

In the second investigation, every group should have used the same tool(s) and method of use of that tool. Because each group consistently used the same tool in the same way, the tool and method that it was used became a **controlled variable.** A controlled variable is a variable that is "controlled" so that it stays the same each time the procedure is run. Controlling a variable usually reduces error. The data should have been more accurate, more clustered together on the histogram.

KEY TERMS

Variable: any part of the procedure that could change

Controlled variable: one element that is not change throughout an experiment

By developing a precise procedure for everyone in the class to use, your results became more consistent. The more consistent your class results are, the more your procedure will be trusted. Whether it was two or three rounds, you should better understand how important good procedures are. You planned an investigation with your classmates where you identified:

- variables and controls
- tools needed to gather data
- measurements to be recorded
- data to help people make decisions about a problem or challenge

Now your team can demonstrate that it can accurately and repeatedly remove oil without removing too much water. You are confidently ready to the assist the Georgia Tech research team to develop a cleanup procedure for oil spills if they start drilling off the Georgia coast. You can apply your knowledge learned in your model and apply it on a larger scale. You will be able make recommendations on how to remove oil without disturbing the ocean ecosystem and prevent another environmental disaster like what happened with the Deepwater Horizon oil spill.

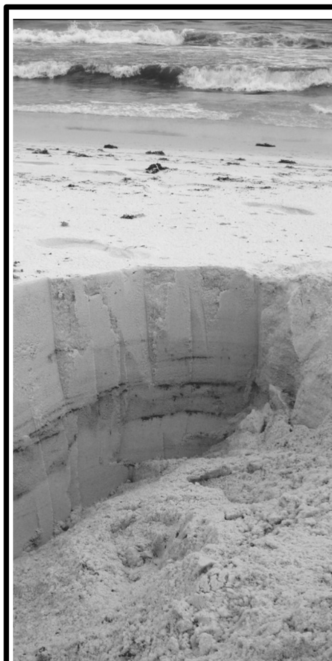
Procedure:

1. Complete the *Recommendation Letter* student sheet and explain what you have learned about the importance of writing and following clear procedures.

SECTION 5 – GEORGIA TECH CONNECTION: WHAT HAPPENED TO ALL THE OIL?

5.1 OIL ON THE SHORELINE

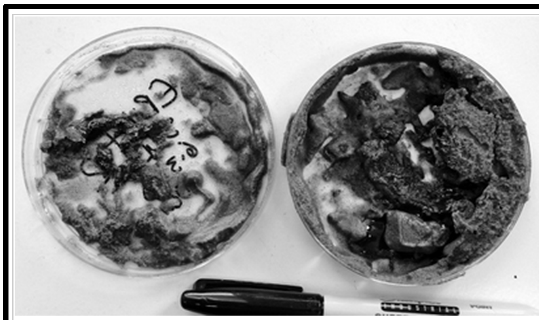
As mentioned earlier in the module, Dr. Kostka, an oceanographer and professor at Georgia Tech, studied how the oil from the Deepwater Horizon oil spill affects the shoreline along the Gulf Coast. He specifically looks at how oil in the sand of the beaches is being broken down by microorganisms in the sand. **Microorganisms (or microbes)** are living organisms that you need a microscope to see. Examples of microorganisms are bacteria and fungi. Oil deposited on the beach surface can be easily removed by scraping off the top layer of sand. However, the oil that seeps deep into the sand can only be removed by being broken down by microbes Oil deep in the sand not only threatens the ground water in these areas but can only kill fish larvae. In the picture, you see how oil seeps deep into the sand.



Trench dug to reveal oil transect on Pensacola Beach in the Gulf of Mexico

Bacteria can break down oil to carbon dioxide and water. However, no single microorganism can break down all the components of crude oil or refined fuels. **Crude oil or refined fuels** is the type of oil was was released into the water during the Deepwater Horizon oil spill. Therefore, the tens of thousands of different compounds that make up oil can only be broken down by communities of microorganisms working together.

In order to analyze how these microorganisms breakdown the oil, Dr. Kostka has to write a procedure and design an investigation with controlled variables. Dr. Kostka analyzes **sediment** (sand and soil) cores, as in the picture below, collected from Gulf beaches to find out how much and how deep oil washed onto the shore is carried into the sand. He studies how rapidly microorganisms in the sand are breaking it down, and how the oil pollution may be affecting the natural microorganism communities that help to protect water quality on the coast. He also collects sand and soil sendiments from beaches not affected by the oil spill to compare his results.



Samples provided to professors Kostka and Huettel that consist of heavily oiled sediments from a barrier island off the coast of Louisiana. (Photo courtesy of Joel E. Kostka)

Sediment cores and water samples collected at St. George Island on June 8. These samples are not affected by oil and provide the reference data to compare with data generated in case oil affects this beach. (Photo courtesy of Markus Huettel)

Discuss these questions as a class:

1. Why is important to study how microorganisms break down oil on the beaches in the gulf?
2. What are some variables that Dr. Kostka has to control as he completes his investigation?
3. Why is it important that Dr. Kostka has a consistent procedure to study how microorganisms break down oil?

5.2 WHAT HAPPENED TO ALL THE OIL THAT STAYED IN OUR OCEANS?

The ECOGIG team has been exploring the deep sea ecosystem five years after the initial Deepwater Horizon oil spill. Watch the video below to learn where the oil traveled in the ocean and how clean-up methods may have affected how the oil spread to deep water ecosystems.

Watch ***Video #4: Where did the oil go?***

Georgia Tech

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This curriculum is produced by Advanced Manufacturing & Prototyping Integrated to Unlock Potential (AMP-IT-UP) supported by National Science Foundation Award #1238089 through Georgia Institute of Technology's Center for Education Integrating Science, Mathematics, and Computing (CEISMC).

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