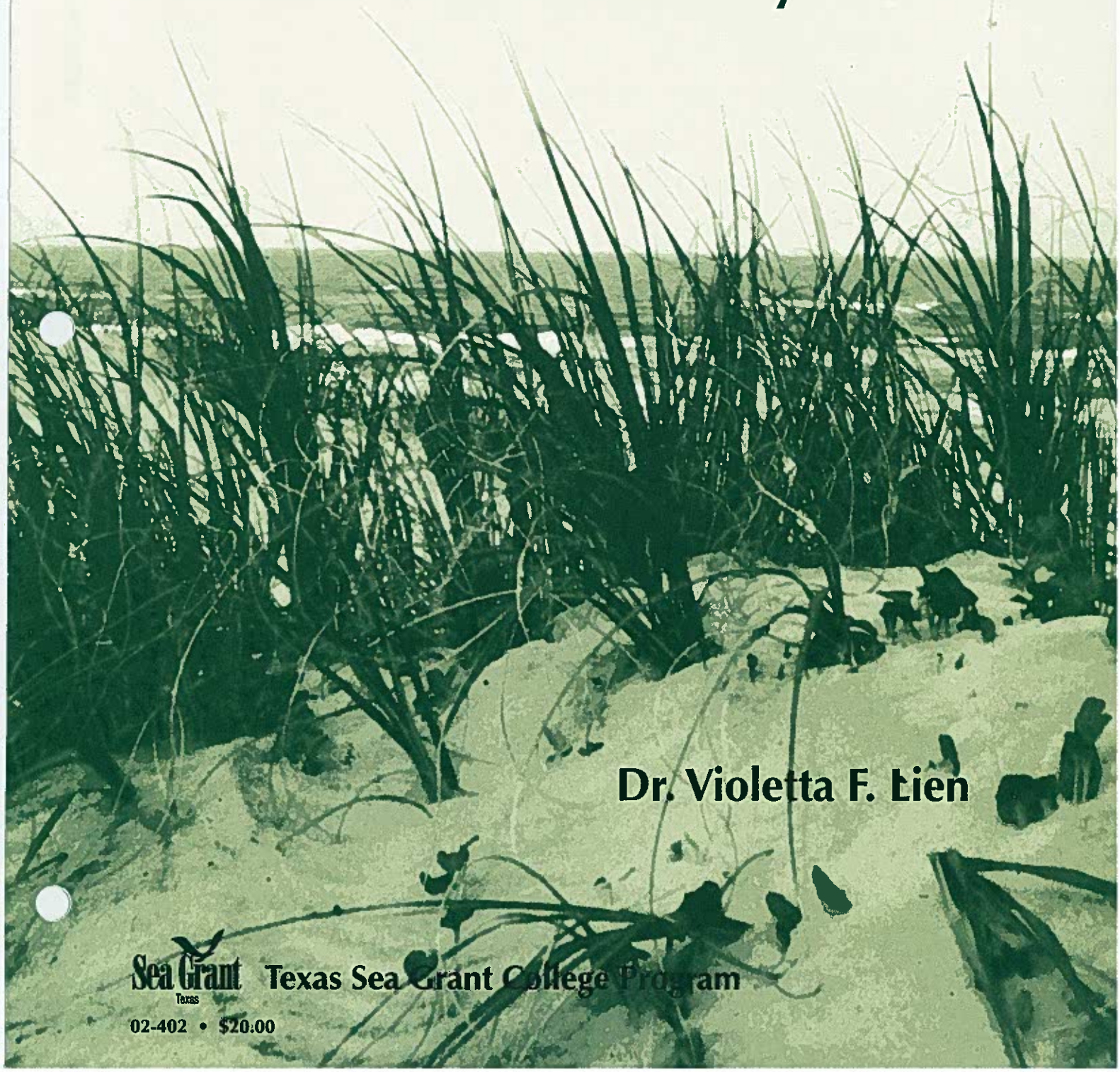
Investigating the Marine Environment in the 21st Century



Dr. Violetta F. Lien

Sea Grant Texas

Texas Sea Grant College Program

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Investigating the Marine Environment in the 21st Century

by
Violetta F. Lien
Department of Curriculum and Instruction
Southwest Texas State University

illustrated by
Regina Kubelka

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Preface

The living ocean drives planetary chemistry, governs climate and weather and otherwise provides the cornerstone of the life-support system for all creatures on our planet, from deep-sea starfish to desert sagebrush. That's why the ocean matters. If the sea is sick, we'll feel it. If it dies, we die. Our future and the state of the oceans are one.

—Sylvia A. Earle

The Apollo moon missions gave us a picture of our home, Planet Earth, for the first time in human history. When the astronauts saw the earth they called it "the blue planet." Our planet is primarily a world of blue water partly concealed by pattern of white vapor clouds that mark the movement of weather systems. The continents are actually islands in an enormous global sea.

Life on earth is water-based. Water runs through the bodies of living organisms as it does throughout the earth. Water actually gives the earth its features from caverns, valleys, canyons, deltas and beaches. It modifies the climate and is the source of extraordinary climatic events such as tropical storms and hurricanes.

The oceans are a fascinating and vital part of our world. The water draws us, capturing our attention and imagination. From prehistoric times to the present, the sea has been an important theme. The sea has inspired myth and legend, classic works of art, music and literature, and numerous television shows and movies. Many terms and expressions of the sea have become part of our language today. In countless ways, large and small, the resources of the sea touch our lives from food to oil and gas in our automobiles, as well as, recreation.

When we examine the history of people and nations, we see that their movement has quite often been in response to presence or absence of water. Only 10 of the 50 states do not have contact with the sea directly or indirectly through inland waterways. Our country has always been a maritime nation and even our major population centers are near water. More than half of our population lives only an hour's drive from the sea. The ocean offers military, recreational, economic, artistic and intellectual outlets of unlimited scope.

Texas is legendary in its ties to the land. Most people think of Texas as a land of ranches, cows, cowboys and oil wells rather than a land of windswept beaches and soaring seagulls. However, coastal Texas is of fundamental importance to the state. Texas has a coastline of more than 360 miles, which is one of the longest coastlines in the United States and is one-twelfth of the coastal United States. The Gulf of Mexico, the world's ninth largest body of water, is an important resource for both the United States and Texas. The Gulf waters supply more than 50 percent of the nation's seafood, and the coastal wetlands serve as a nursery and refuge for 70 percent of all Gulf species of fish and shellfish. More than 400 species of birds spend time in the Texas coastal zone. Of the United States' offshore oil and gas production, 90 percent comes from the Gulf of Mexico and 40 percent of the total United States refining capacity is located along the Gulf. The Texas portion of the Gulf shore alone has 65 percent of the nation's petrochemical capacity. The importance of the Gulf coast today and for the foreseeable future is evident by the fact that more than one-third of the state's population and economic activity is concentrated in that one-tenth of Texas that is the coastal plain, within 100 miles of the Gulf Coast.

Despite the importance of the Texas coastal zone and the fact that our planet is largely covered with salt water, the public and students know very little about what science has discovered, or has yet to discover, about the sea. Today, we recognize the importance of the sea as an integral and sustaining part of our planet, yet we are not "literate" about the marine environment and its resources. Wise interaction with the marine environment depends upon an informed public that is literate about the oceans. Studies on students' knowledge of marine and aquatic related topics indicate a critical need for an increased emphasis on the marine environment.

The purpose of this marine education resource manual is to fill the void in available marine education materials. The activities are designed to help students become more knowledgeable about the marine environment and its resources through emphasis on the Texas coastal zone and the Gulf of Mexico. The activities are designed for use in both traditional and integrated science courses, but also provide marine activities for social studies, language arts and mathematics courses or for interdisciplinary thematic units. The book provides current, in-depth information for classroom use and is correlated to the Texas Essential Knowledge Skills in science, mathematics, social studies and language arts. It also will meet national standards in science, mathematics, social

studies and language arts. It provides marine activities to incorporate in the teaching of systems; form and function; constancy and change; and properties, patterns and models.

Being a resource manual for teachers, this book contains many more activities than a teacher can use in a year. Each teacher is encouraged to select those activities most applicable to the individual's objectives. The book can be utilized in a variety of ways.

- Lessons can be used separately or can be incorporated into existing lessons to provide marine examples.
- Lessons can used as a basis for a unit.
- The book can be used for a semester-long course.

Although the manual was designed for middle school, the activities can be adapted and incorporated into upper elementary and high school classes as well.

This marine resource manual is designed not only to contribute to teachers' and students' knowledge of the marine environment but also to skills that are needed. Process skills, higher-order thinking, sound reasoning, problem-solving, interactive communication skills and inquiry are stressed. According to the enGauge project[1] on 21st century skills, the core skills are:

1. Digital-Age Literacy
   - Basic scientific, mathematical and technological literacies
   - Visual and information literacies
2. Inventive Thinking
   - Adaptability/ability to manage complexity
   - Curiosity, creativity and risk taking
   - Higher-order thinking and sound reasoning
3. Effective Communication
   - Teaming, collaboration, and interpersonal skills
   - Personal and social responsibility
   - Interactive communication skills
4. High Productivity
   - Ability to prioritize, plan and manage for results
   - Effective use of real-world tools
   - Ability to create relevant, high-quality products

The book provides activities that can be used to develop these skills with your guidance. However, as the teacher you are the key to the use of the activities. You will facilitate and guide the students' learning and thinking. The activities are not designed to be worksheets or cookbook laboratory activities, but as guides to inquiry or problem solving. Use the questions as your guide to facilitate the students' thinking and problem-solving skills through discussions, activities, projects and presentations. Encourage the students to work in cooperative groups to conduct inquiries on the marine topics and use the available technology in their research and presentations of their findings.

The activities are designed so that equipment and materials should not be a limiting factor. However, if you have technological tools, equipment and software (computers, graphing calculators, CBLs, probes, interfacing equipment, scanners, digital cameras, Pagemaker, Powerpoint, Excel, Inspiration, Hyperstudio, etc.) available incorporate their use in the activities.

Use this book as a resource to take your students on a voyage to Earth's final frontier and to facilitate their becoming marine "literate" and developing skills for the 21st century. Remember much of the ocean remains a mystery, from currents and hurricanes to its many amazing creatures. Our study of the sea has unlocked an unimaginable wealth of knowledge and resources, yet much remains to be learned. Your students can be the future discoverers. As many have noted, what we do or do not do today will determine the fate of this water planet, and of humankind.

We've made the investment needed to venture into the skies, and it has paid off mightily. We've neglected the oceans, and it has cost us dearly. This is the time to do for the oceans in the 21st century what our predecessors did for space.

—Sylvia Earle

[1](Lemke, C. 2001. *21st Century Skills.* Naperville, Ill: NCREL. http//www.ncrel.org/enguage/skills/skills.htm.)

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Topic 1 — Introduction

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Topic One: Introduction

Each learner must construct meaning for himself or herself. The only learning that can take place is that which is connected to the individual's existing knowledge, experiences and conceptualizations. What students learn is not a copy of what they observe in their surroundings, but the result of their own thinking and processing. These activities are designed to enable the students to review their experiences and analyze their thinking about the marine environment. Learners use what they already know as the basis for making sense of the experiences they will have. This will provide you, the teacher with the basis that the students will be using to make sense of their experiences in marine education. This topic also addresses our limited exploration and knowledge of the marine environment compared to our exploration of space.

Use the internet to locate the most recent information. The National Oceanic and Atmospheric Administration web site (www.noaa.gov) is an excellent resource. The following are also excellent resources for additional information on ocean exploration:

Ballard, Robert D. with McConnell, M. 1995. *Explorations: A Life of Underwater Adventure.* New York: Hyperion.

Broad, William J. 1997. *The Universe Below: Discovering the Secrets of the Deep Sea.* New York: Simon & Schuster.

Earle, Sylvia A. 1995. *Sea Change: A Message of the Oceans.* New York: Random House, Inc.

Activity 1: What are Your Experiences with the Sea?

TEKS: Science: 7.5, 6.5, 6.8, 7.8, 8.10, 6.10, 7.12, 6.12

Math: none

Language Arts: 6.24, 7.24, 8.24

Social Studies: 6.22, 7.21, 8.30

Learner outcomes: After completing the activities the students will be able to:

- recall and evaluate their personal experiences with the sea
- communicate their experiences with the sea by drawing a picture of their image of the ocean and writing a descriptive narrative of their ocean experiences

Background:

1. This activity will provide insight into the students' experiences and perceptions of the ocean which need to be considered in developing your lessons. Students can begin their thinking about the sea by completing the statements in number 1a-e. You might read the introductory paragraph and put these statements on a transparency or on the board. Allow the students 5-8 minutes to complete their responses individually, before having students share their responses in their group. Discuss similarities and differences in their responses. Ask them to note any patterns among their responses. Have the students analyze why their responses differed and the relationship of their personal experiences to their responses.
2. To help the students focus on their images and experiences with the ocean, have them close their eyes and listen as you read the questions in number 4. Allow 30-60 seconds after each question for the students to focus on their mental images. Stress using all their senses - seeing, hearing, smelling, tasting, touching - to relive or bring to life their images of the oceans. You might play a tape or CD of ocean sounds for background during the activity.
3. After completing the imaging experience, have the students draw a picture of their ocean image and/or write a descriptive narrative of their ocean experience. In order to develop good communication skills, students need ample opportunity to practice communicating effectively with others. Have each student pair with a partner. The partners should read each other's narratives and describe what they experienced or visualized as they read the narrative. Have students discuss how accurately they communicated their experiences and how to improve their communication.
4. Use questions 6-9 to help students trace sources of their beliefs and perceptions about the ocean. Discuss the relationship of experiences in developing one's perceptions.
5. To assess the students knowledge of the sea, have each team complete the first three columns of the KWOL Chart of the Sea. Use their responses to assist in developing the students' inquiry into the marine environment and its resources. At the end of your marine unit have the teams complete the last column, "What have you learned about the sea?" as an informal assessment of what the students learned and what was important to them.

Activity 2: How has the marine environment influenced us?

TEKS: Science: 6.5, 7.5, 6.6, 6.8, 6.9, 8.10, 7.12, 6.14, 8.14

Math: none

Language Arts: 6.24, 7.24, 8.24

Social Studies: 6.7, 7.10, 6.1, 7.7, 6.20, 7.20, 8.29

Learner outcomes: After completing the activities the students will be able to:

- recall, through brainstorming, ways the marine environment has influenced people
- classify ideas into topic areas
- communicate the influence of the marine environment by constructing a web or concept map

Background:

1. Have the students use markers and newsprint to generate their list of ideas. These lists can then be posted and used to compile a class list.
2. List the topics in number 3 on a transparency or on the board. Ask the students to classify their ideas into these categories. They may add ideas to list.
3. Have the students work in pairs or in groups of 3 or 4 to develop a concept map or web. Use the following steps:
   - Write each idea on small slip of paper. Write only one idea or word on each piece of paper.
   - Group concepts that are related.
   - Arrange the pieces of paper on a table or desk in a two-dimensional hierarchical order so that:

     (a) the most important topic or topics are at the top;

     (b) less important topics are underneath;

     (c) examples are at the bottom; and equally important topics are at the same level.
   - When the arrangement is completed to each group's satisfaction, have them copy the arrangement they have made onto a sheet of blank paper or newsprint. Put an oval around each word to separate it from the others, just as the pieces of paper were separated.
   - Draw lines connecting the concepts.
   - Write in the words on the lines describing the relationships.
   - Draw in linking lines.
   - Write in the linking words.
4. Have the groups post their maps on the board or wall and share their constructions with the rest of the class. Stress that each map reflects their thinking and represents the way they relate the given concepts. Remember the maps are an assessment tool. They are a vehicle for looking into the students' heads and see how they are constructing information. The maps may show misconceptions. Ask questions to determine if they are really misconceptions, if so use activities in this manual to help correct them.
5. By having the students check and rank the topics by interest, you can plan your activities based on their interests.
6. Extension: Each team may select a topic to further investigate using the internet. The team would be the experts on the topic and may present a poster session to the class.

Activity 3: How do the land and marine environments compare? (A Model)

TEKS: Science: 8.5, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.1, 7.7, 6.20, 7.20

Learner outcomes: After completing the activities, the students will be able to:

- construct a model to compare the exploration of land and ocean environments
- evaluate exploration of land and ocean environments
- evaluate a model of the ocean

Background:

1. Ask the students what they know about our exploration of the ocean and how it compares to exploration of the land. Each group can do the activity or it may be used as a demonstration to introduce: 'How can we use a graphic model to compare land and ocean exploration?"
2. Tell the students they are going to create a model of the earth and the oceans to compare the exploration of land and the oceans. Show the students an apple or provide an apple for each team of students. Consider that this apple represents the earth. Slice the apple into quarters, setting one quarter aside. This one quarter represents the land area of the planet. Ask, "What fraction of the earth is left?" (3/4)
3. The remaining three-fourths (71%) represents the water environment. Now place 12 push pins or tacks (use 12 for large apples; 10 for medium size apples; 8 for small ones) into these pieces of the apple. Put all but one of them along the edges and place one in the center of a piece of the apple. These push pin or tacks represent the amount of the ocean that has been explored. Ask, "How much of the area of the apple is not covered by pins and what does this represent?" It represents the unexplored area of the ocean which is approximately 95%. In other words, only 5% of the ocean has been explored. Ask, "Why are most of the tacks along the edge?" These are on the continental shelf next to the continents, the location of most of the exploration of the ocean.
4. Stress that the one tack or push pin in the center of the apple represents the less than one tenth of one percent of the deep ocean that has been explored.

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Point out that more has been mapped and generally probed with electronic devices, but it has not been observed, touched, sampled, or understood.

5. Slowly pull the tacks or push pins out. As the pins are removed asked if they are still exploring the ocean. Discuss how exploring the ocean is like pushing pins in and pulling them out of the apple. All exploration of the ocean has been for short periods of time. Much of this exploration has been through collection of data from small points over short periods of time. Despite all of the advances in knowledge about the earth in recent years, the fact remains that below the depth where most divers can venture (about 150 feet) little of the ocean has been seen. Instruments can be lowered to obtain samples; a few submersibles briefly travel to great depths. Recently there has been an increase in visits of a few hours in submersibles to areas of the ocean vents and the use of cameras on remotely operated vehicles or ROV's has increased. The recent use of ROV's is rapidly increasing our knowledge of the ocean. In 1960 two men spend half an hour in the deepest part of the ocean; however, no visits to this depth have occurred since that time. So actually very little is known about the deepest parts of the ocean floor. The apple and push pins are used to provide an illustration. The push pins represent not only the amount of the ocean that has been explored but also that most exploration is either done through sampling or very short periods of observation. The majority of the exploration has been on the continental shelf. Discuss the limitations of these brief visits and our knowledge of the ocean, as well as the relationship of our knowledge of the ocean and the type of exploration used.
6. To help improve students' analysis and evaluation skills, discuss the strengths and weaknesses of the apple as a model.

Extension: Encourage the students to use the internet to learn more about current ocean exploration.

Activity 4: How can we use a graphic model to compare land and ocean exploration?

TEKS: Science: 8.5, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.1, 7.7, 6.20, 7.20

Learner outcomes: After completing the activities, the students will be able to:

- construct a graphic model of land and ocean environments
- calculate and graph the amount of the marine environment which has been explored
- compare the exploration of the land and ocean

Background:

1. The students will be doing calculations (calculators may be used) and using graph paper to represent the earth and to compare the exploration of ocean and land environments. Rounded percentages are used in the activity. 25% or 250 squares will be colored green to represent land and 75% or 750 squares will be colored blue to represent the ocean. 3% or 22.5 squares of the blue (water) are fresh water and they will have a black dot. 72% or 727.5 of the 750 squares are salt water. Only 5% (36 squares) of the ocean (727 squares) has been explored. Most of this exploration is near the land area. Only one tenth of one percent of the deep ocean has been explored. This is less than one full square.
2. This illustrates the limited ocean exploration that has occurred. Discuss the possible impact of so little knowledge of the ocean.

Activity 5: How does our exploration of the land and oceans compare?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 7.12

Math: 6.4, 7.3, 6.3, 7.2, 8.2

Language Arts: 6.24, 7.24, 8.24

Social Studies: 6.2, 7.2, 8.29, 6.1

Learner outcomes: After completing the activities, the students will be able to:

- analyze the information obtained through different methods of observation
- discuss the limitations of different methods of exploration and data gathering
- compare the methods used to study land and marine environments
- summarize the relationship between methods of exploration and the knowledge obtained

Background:

1. Ironically, on a planet extensively covered with water, our knowledge of the majority of the water environment is very limited. Our knowledge of the oceans is based on lowering instruments to collect samples in selected areas. Submersibles have only traveled briefly to areas beneath the seas. The activities in this section are designed to emphasize the limitations of this type of exploration of the marine environment.
2. Set up each aquarium so it has a large number of different objects of varying sizes. The aquariums can include non-living objects rocks, marbles, toys, cups, plastic plants, etc.) or as freshwater aquariums. The students at Station A will be using nets; if

animals are used, povide rocks and other objects so they can escape the net.

3. After completing the activity, discuss what we would know about the earth if our explorations of deserts and rain forests were limited to instruments being lowered from above to collect data or to brief trips with an air supply on carried on the backs of the observers. Or suppose that our knowledge of land plants and animals was based on blindly dragging a net through forests or grasslands from above the earth and that the specimens collected are banged up and crushed by the net. These methods are the basis of our knowledge of the marine environment. Our knowledge of marine organisms and their interactions is very limited. Have the students discuss the following statement: "No one really understands the impact of ocean dumping, over-fishing, oil spills, pollution, or agricultural runoff on the ocean systems." Discuss why understanding and protecting our marine environment is crucial to the survival of the planet.
4. Point out that based on our past explorations of the ocean, it was assumed that at one mile and half down in the darkness no life existed. Today samples taken using small submersibles and quick samples taken near the vents in the ocean floor are indicating that there is abundant life on the ocean floor. One quick sample taken at the base of a chimney, a mineralized mound that grows atop volcanic vents on the ocean floor, had a total of 236 animals of 14 different species. These included worms, limpets, copepods, snails, sponges, and sea spiders all in one quick sample. Given these numbers and diversity, one can only wonder what a more leisurely sample or close examination of several days would have yielded.
5. Encourage the students to use the internet to locate information about the recent discoveries and studies of the ocean floor and life in the ocean.

Activity 6: How does our exploration of land, space, and the oceans compare?

TEKS: Science 6.3, 7.3, 8.3

Math: none

Language Arts: 6.10, 7.10, 8.10

Social Studies: 6.7, 6.22, 7.20,

Learner outcomes: After completing the activities, the students will be able to:

- hypothesize about why space exploration appears to be more important than exploration of the oceans
- compare the problems and methods in the exploration of land, oceans, and space
- evaluate the interest in space exploration versus exploration of the ocean depths

Background:

1. When Sylvia Earle, a distinguished marine biologist, was the chief scientist of the National Oceanic and Atmospheric Administration, she found many people who really did not see the relevance of the ocean to their everyday lives. This included intelligent and influential people. Without the ocean, Earth would be a lot like Mars. The ocean drives Earth's chemistry, governs the climate and weather, and provides the basis of the life support system of all organisms on the planet. If the ocean is sick, the Earth will feel it. However, people are more interested in exploring Mars than learning about the ocean. In this activity the students will compare ocean exploration with space exploration.
2. Discuss the problems of living in space and living in the ocean. Stress the similarities of the adverse conditions due to pressure and temperature. Discuss the importance of special vehicles, suits and equipment needed in each.
3. Have the students discuss and hypothesize why the exploration of outer space is more popular when understanding the ocean is crucial to life on Earth. Then create and conduct a survey to determine how people feel about ocean exploration and the basis for their feelings.
4. There may be hundreds of new species in the ocean that have not been discovered. The oceans not only provide food but medicines and other potentially useful products. However, we spend much more to investigate space. Discuss why space exploration and not ocean exploration receives the largest portion of support.

Activity 7: What is the connection between the land and sea?

TEKS: Science: 6.3, 7.3, 8.3, 7.14, 8.14

Math: 6.4, 7.3, 8.5

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- analyze the relationship between the land and the sea
- calculate and graph the connection between the land and water environments
- rate the interactions of people with the land and marine environments
- summarize the impact of the oceans on the Earth

Background:

1. Only a small amount of the land area is able to produce food compared the area of the ocean.

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However, the activities of people on land have a major impact on the ocean environment. Discuss and evaluate the impact of the activities of people as to whether the activities are negative or positive.

2. Again, discuss the importance of the ocean to the survival of life on Earth. Point out that without the oceans, Earth would be more like Mars or Venus. Could life as we know it survive on Mars or Venus?
3. Encourage the students to use the internet to learn more about the impact of human activities on the marine environment.

Activity 8: What can we learn from exploring terra?

TEKS: Science: 6.10, 6.12, 7.12

Math: none

Language Arts: 6.24, 7.24, 8.24, 6.13, 7.13, 8.13

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- make inferences about the adaptations of the human body if people had been marine animals instead of land animals
- make inferences about life under the sea
- analyze how information would be obtained about an unknown land environment from the ocean
- discuss the problems humans adapted to living in marine environment would have living in a land environment

Background:

1. In this activity, to develop thinking skills, the rules are changed. Instead of humans living on land, the students are to imagine that humans are marine people instead. Discuss how humans would differ and how they would live under the ocean.
2. Using a Texas highway map, simulate exploration of a land environment by a marine people. Discuss how they can learn about an alien land environment and what they need to know to survive.
3. Discuss the problems of dropping a piece a paper as a probe to learn about the land environment. Some of the problems include: probes not landing where intended, only providing information about the spot were they landed, and only providing information at a particular time. Compare this to dropping instruments into the ocean to learn about the marine environment. Relate their findings about the land environment to our knowledge of the ocean environment.

Activity 9: What do you know about the Texas coast and the Gulf of Mexico?

TEKS: Science: 8.10, 7.14, 8.14

Math: 6.4, 7.3

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11

Social Studies: 6.7, 7.1, 6.2, 7.2, 8.29, 8.12

Learner outcomes: After completing the activities, the students will be able to:

- conduct a survey to determine people's knowledge of the Texas coast and the Gulf of Mexico
- analyze the results of the survey
- summarize what they learned about the Texas coast and the Gulf from the survey

Background:

1. The Gulf of Mexico is often America's forgotten sea. People do not realize its importance, not only to Texas but also to the United States. This survey is designed to increase awareness of the many areas in which the Gulf of Mexico is a major factor. After the class has taken the survey and discussed the results, each student could survey 3 to 5 additional people outside of class. The survey results can be analyzed to determine if age, economic level, education level, etc. are factors that might make a difference in the response of individuals.
2. Statements 3, 4, 8, 16, 17, 21, 23, 26 and 28 are false. All of the other statements are true. Below is the correct information.

   #3 Four of the United States' busiest ports are in the Gulf of Mexico: New Orleans, Houston, Corpus Christi, and Tampa. Six Gulf ports are among the top ten in handling crude oil.

   #4 The Texas Gulf coast is home to 65% of the nation's petrochemical activity.

   #8 About 66% of the oil imported into the United States comes through Texas.

   #16 The U.S. Gulf coast is longer than the U.S. Pacific coast from California to Washington.

   #17 Discovery of the Gulf of Mexico was recorded by Europeans in 1517.

   #21 The Gulf of Mexico hosts five of eight of the world's species of sea turtles, all of which are threatened or in danger of extinction.

   #23 Thirty-three percent of Texas' economic activity is located within 100 miles of the coastline.

   #28 One billion pounds of fin fish are accidentally caught in shrimp nets and tossed overboard each year.

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1. What are Your Experiences with the Sea?

Name _____ **Team** _____

Most globes depict the ocean as a blank blue area. Many peoples' perception is very similar. Their picture of the sea is based on scattered images. These include beach scenes from family visits, a relative's experience on a ship, storms, sunken treasure, pirates, whales. . . . The reservoir of images, real or imaged, is mixed. Each one's images and perceptions of the marine environment will differ based on their personal experiences. These may be negative or positive depending on the circumstances. Yet, these images haunt us. They have a beauty and a power that have and still affect our lives.

Materials: none

Procedure:

1. Complete the following statements:
   a. When I hear the word "ocean" or "sea", I think of ...
   b. What I like most is about the ocean is ...
   c. What I like the least about the sea is ...
   d. The most worthless part of the ocean is ...
   e. The most priceless part of the sea is ...
   f. Share your responses with your group. How are your responses alike?
   g. How did they differ?
   h. Discuss the differences. Why do you think that your responses differ?

2. To prepare for the activities you will be doing, get comfortable and relax. Now take a few minutes, close your eyes and picture yourself at the ocean. Picture what you are doing, seeing, hearing, smelling and feeling.

3. As you pictured yourself by the ocean, what were you doing?
   a. Who were you with?
   b. What did you see? Hear? Smell? Feel?
   c. Describe the waves and the sky.
   d. What animals did you see? What were the animals doing?

4. Now draw a picture of your image of the ocean. After you have completed your drawing, write a descriptive narrative of your experiences at the ocean on a separate page. Be sure to include the information you listed in number 3.

5. Is your description based on a visit to the ocean or what you have read about or seen in movies or on TV or heard about? Explain.

6. Compare your images of the ocean based on your visit(s)to the images of the oceans that are depicted in the stories in literature, movies and television programs. How are they alike and how do they differ?

7. Which images were negative and which were positive?

8. Discuss the relationship between a person's experiences (your experiences and your classmate's) and one's perception (how one thinks) of the marine environment.

9. As a team, construct a chart based on the following format. You will answer the last question at the end of the unit.

Name _____

KWOL Chart of the Sea

What do you know about the sea?	What do you want to learn about the sea?	How can you find out what you want to know about the sea?	What have you learned about the sea?

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2. How has the Marine Environment Influenced Us?



Name:_____
Team: _____

For most of us, when we think of our planet we think of land. It was not until the Apollo moon missions that we saw a picture of our home planet. When the astronauts saw the earth for the first time they called it "the blue planet." From the perspective of space, our earth is primarily a world of blue water partly concealed water vapor clouds. Our continents are actually islands in a global sea. You already have experiences and knowledge of the oceans. You and your team are going to take a few minutes to list what you know about the oceans, our marine environment.

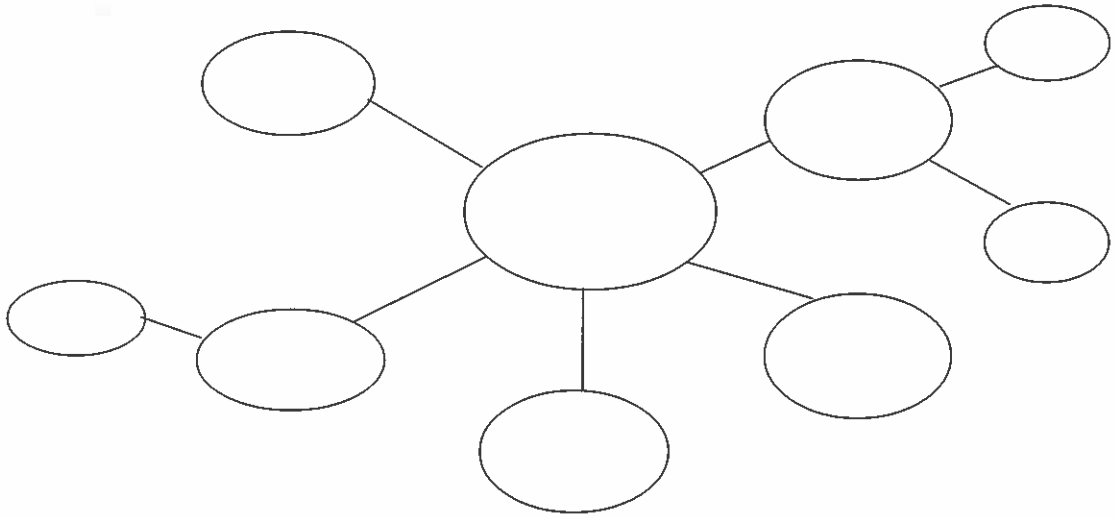
Procedure:

1. In your group, the principal investigator is to make sure the group stays on task. The recorder's task is to list each item suggested on paper. These should be recorded on newsprint or paper that can be posted on the wall or chalkboard for sharing at the end of the brainstorming session.
2. The rules for brainstorming are: Everyone shares/lists all ideas of which they think. All ideas are welcomed. No idea needs to be explained. Expand on others' ideas. Listen to each other. Others ideas may trigger something in your mind. Work to get as many ideas as possible. Try to be the group that gets the longest list.

   You will brainstorm all the ways that the marine environment has influenced or influences people. List your ideas as rapidly as possible without discussion. Brainstorm for five minutes.
3. Examine the list below. See if you have included ideas related to each topic. Add to your list any new ideas related to the topics in the list below. Ask how does or has the marine environment influenced the following:
   a. the arts - visual arts, music, dance, drama, creative movement, etc.
   b. the language arts - language, literature, poetry
   c. the social sciences - history, economics, geography
   d. health and medicine
   e. recreation
   f. transportation
   g. resources
   h. technology

i. man-made environment
j. natural environment
k. day-to-day experience

4. Use the list of your group's ideas to create a brainstorming web. List the question, "How has the marine environment influenced us?" in an oval in the center of the page. Use lines to link related ideas. Each idea should be enclosed in an oval.



5. Write a sentence or two that summarizes how that marine environment has influenced us.

6. Go over your list and put a check mark by the areas that you want to learn more about.

7. Select and rank in order (1, 2 .... 5) the top five you want to study.

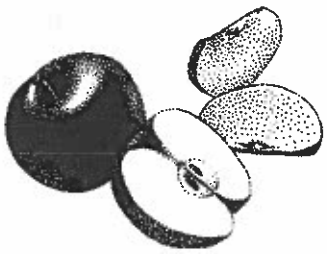
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3. How do the Land and Marine Environments Compare? (A model)

Name:_____ **Team:** _____

The oceans are an important part of planet Earth and essential to supporting life. However, the serious work of deep sea exploration is just beginning. It will take decades, if not centuries, to explore and map the ocean depths. You will be creating a model to help you compare our knowledge of the land and marine environments. You and your team will create a model of the earth and the oceans to compare the exploration of land and the oceans.
Materials: apples (one per group), knife, marker, push pin tacks or thumb tacks, masking tape

Procedure:



1. Get an apple to represent the earth. Use the marker and divide the apple into four quarters. Very carefully slice out of the apple a one quarter section, put one quarter aside. One quarter represents the land area of the planet. What fraction of the earth is left? What will it represent?

2. The remaining three-fourths represents the water environment. Place 10 push pins in a medium size apple along the edges of the three quarter section of the apple. Put nine pins along the edge. Put all but one of them along the edges and place one in the center of the apple. These tacks represent the amount of the ocean that has been explored. Estimate how much of the area of the apple is not covered by pins and what does this represent?

3. Why were most of the tacks placed along the edge which represents the area of the continental shelf along the edge of the continents?

4. The one tack or push pin in the center of the apple represents the less than one tenth of one percent of the deep ocean that has been explored. More has been mapped and generally probed with electronic devices but it has not been observed, touched, sampled or understood. Why have we explored so little of the deep part of the oceans?

5. Slowly pull the tacks or push pins out. Explain how exploring the ocean is like pushing pins in and pulling them out of the apple. How does this represent the time we spend exploring the deep parts of the ocean? Explain.

6. All exploration of the ocean has been for short periods of time. Much of this exploration has been through collection of data from small points in the ocean. Despite all the ad-

vances about the earth in recent years, the fact remains that below the depth where most divers can venture (about 150 feet) little of the ocean has been seen. Instruments have been lowered to obtain samples. A few submersibles have briefly traveled to great depths. In 1960, two men spent half an hour in the deepest part of the ocean. In your group, discuss the limitations of these brief visits. How have these brief visits affected our knowledge of the ocean? List the limitations you discussed below.

7. Discuss the strengths and weaknesses of the apple as a model of the earth.
   a. List the strengths of the model.
   b. List the weakness of the apple as a model.

8. Write your conclusion about our exploration and knowledge of the ocean.

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4. How can we use a Graphic Model to Compare Land and Ocean Exploration?



Scientist(s) _____
Team _____

Ironically, our planet is covered with water, most of the water is salty. Our knowledge of the majority of the water environment is very limited. Our knowledge of marine organisms and their interactions is very limited. Understanding and protecting our marine environment is crucial to the survival of our planet. You are going to create a graph representing the exploration of the ocean and investigate why we know so little about the oceans.

Materials: graph paper, colored map pencils or markers

Procedure:

1. Take one sheet of graph paper and cut a piece that has 1,000 squares. Color 25 percent of the paper a green color. This represents the land area of the earth. How many squares are colored green?

2. Color the remaining part blue. This represents the water of the planet. What is the size of the part that was colored blue?

3. Three percent of the water on earth is fresh water, place a black dot in 3 percent of the blue squares. How many squares should have a black dot?

4. The blue squares without black dots represent the marine waters. What percentage is salt water?

5. Only 5 percent of the ocean has been explored. How many blue squares would represent 5 percent of the ocean?

   Draw diagonal lines across the blue squares next to squares representing land areas to represent the areas that have been explored. Why do you think most of the area of the ocean that has been explored is next to land?

6. Only one tenth of one percent of the deep ocean has been explored. That is observed, touched, sampled or understood. Color over these blue squares that have the diagonal lines with a black color. How many squares represent the amount of the deep ocean that has been explored?

Why do you think we have explored so little of the ocean?

7. Summarize below what your graphic model illustrates about the exploration of the land and ocean?

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5. How does Our Exploration of the Land and Oceans Compare?

Researcher(s) _____ **Team** _____

The first major expedition in history to explore the ocean was the *Challenger* expedition of 1872. The scientists used nets, dredges, bottles and instruments lowered from the deck of a rolling ship. This is still the method most often used by modern scientists exploring the ocean. You and your team are going to conduct investigations in the methods of studying the land and ocean environments. You will visit four different stations to conduct investigations.

Materials: Four aquariums (three covered so contents cannot be observed), a variety of objects to place in the aquariums, vial with string attached, and a small aquarium net.

Procedure:

1. Four aquariums have been set up to model different methods of exploration. Each aquarium will contain a variety of objects to study. At each station, one or two members of your team need to act as the investigators who are making observations; one person needs to act the investigation time manager, and another needs to record the data collected.

2. At each station, follow the instructions for that station.

Station A

This station represents the conditions that oceanographers face in exploring the ocean. Use the dip net and make two different sweeps, keeping your hands above the water. Then use a string to lower the vial into the aquarium to collect two samples. What did you collect?

Based on what you collected, describe what was present in this study site.

Station B

This station represents scientists using diving in their investigation of the ocean. Scuba diving rules would make possible 20-minute trips into the study area. These trips could only be made once or twice.

Uncover the half of the aquarium labeled A and observe for one minute and 30 seconds. Place the cover back.

What did you observe?

Based on what you observed, describe what is present in the aquarium.

Station C

This station also represents scientists using diving in their investigation of the ocean. This time the visit is 60 meters from the edge of the study area. This visit can only be for five min-

utes. This visit will also need a longer time for decompression after the dive. Uncover the entire aquarium and observe for 30 seconds. Put the cover back. What did you observe?

Based on your observations, describe what is present in the aquarium.

Station D

This station represents a field study on land. In land investigations, a scientist can spend an unlimited amount of time studying the entire area or one tree, animal, etc. Spend five minutes studying this site.

What did you observe?

1. Based on your observations, describe what is present in this site.

2. Analyze your team's experiences at each of the stations. How were they alike? How did they differ?

3. Summarize your comparisons of the stations below.

4. How do we get information about life in the oceans?

5. Compare the ways we study the oceans to the ways in which we have studied the land environment such as forests, prairies, etc. Set up a table titled **Methods Used to Study Land and Ocean Environments** on a separate piece of paper. Label one column **Land Environments** and a second column **Ocean Environments**. List ways in which we study the land and ocean areas and the plants and animals that live in them.

6. Analyze the table and write a sentence summarizing your comparison of the exploration of the land and the ocean.

7. Suppose our knowledge of land plants and animals was based on dropping a net into the forests or grasslands from above earth or only dropping down from above to observe an area for short time. This is the way that we have studied the oceans. How would this have affected our knowledge of these land areas if we had explored land areas like we do the ocean?

8. How has this type of investigation of the ocean affected our knowledge of the ocean?

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6. How does our exploration of land, space and the oceans compare?

Researcher(s)_____ **Team**_____

Most of our information about the ocean is from using nets, dredges and instruments. Since 1970, a few underwater laboratories have been put into the sea to use for scientific exploration. The small underwater laboratory has been used in the Bahamas and U.S. Virgin Islands by several hundred researchers for two decades. Remote controlled underwater cameras and instruments are "flown" from the end of a wire. These have been used to explore hundreds of meters into the ocean. Underwater vehicles that hold two or three persons have been used to explore areas of the ocean. These vehicles are limited in the time and area that they can explore. In recent years the U.S. National Oceanic and Atmospheric Administration (NOAA), the U.S. Navy, several universities and other institutions are using new techniques to map the ocean floor. However, what lives in these areas is not known. The oceans contain 97 percent of the Earth's water and make up more than 95 percent of the biosphere, the area of the earth where life is found. Why do you think we have explored so little of the ocean and know so little about it?

Materials: none

Procedure:

1. You and your Team will analyze the exploration of the ocean and land. What do you think has kept people from exploring the sea even though it is so important to life? List your hypotheses below:

2. Humans are not adapted to living in outer space or in the ocean. Outer space and the ocean depths are both dangerous environments. Construct a table like the following example, listing the problems that humans must overcome to live and work in each area (land, ocean, space).

Table 1. Comparison of Exploration of Land, Ocean and Space

Exploration and Problems	Land	Oceans	Space
Ways each is explored			
Problems/Factors affecting explorations			
Methods used to overcome problems			

3. If you had the opportunity, which would you want to explore — outer space or the ocean? Explain.

4. In spite of the dangers, people seem more comfortable with going to the Moon, or Mars, or living on a space station than descending into the ocean depths. Why? What are some possible explanations?

5. Hundreds of species of plants and animals live in the ocean. There are probably organisms that we have not even discovered or seen. A large number of species are a valuable source of food for people around the world. We know almost nothing about the habits of these commercially valuable species. We do not know what their role is in the ocean ecosystems, their importance to the health of the sea, their place in the food web, or their adaptations. Do you think we should spend more on learning about the ocean or space? Explain.

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7. What is the Connection between the Land and Sea?

Scientist(s) _____ **Team** _____

Despite the advances in knowledge about the earth itself, we still know very little about the ocean. As important as the oceans are to life on earth, it seems logical that people should care about the oceans and should be driven by a strong desire to know more about the interactions of the land and sea. No one really understands the long term impact of land activities (land development, pollution, agricultural runoff, etc.) on the ocean systems. You are going to gather information on the connection between the earth's land areas and the oceans.

Materials: Graph and Chart from "How does Exploration of the Land and Ocean Compare?," colored map pencils or markers

Procedure:

1. Use the graph and chart you created from "How does Exploration of the Land and Ocean Compare?" The green colored squares represent the earth's land area, which is one-fourth of the total earth. Use your pencil to divide the green squares on your graph into two equal sections. How many squares are in each half?
   What percentage of the land does each half represent?

2. Place black horizontal lines across the squares in one section of green squares. This represents the land area that is not a good habitat for people. These are the polar region, deserts, swamps, high or rocky mountains.
   How many solid green squares remain?
   What percentage does this represent?

3. Use a pen and divide the remaining green colored squares into four equal sections. Place black dots in each of the squares of the three sections. Those three parts represent the areas where the soil is too poor to produce food. These also include the cities, suburban areas, highways, shopping centers, factories, parking lots and all areas where people live, but food cannot be produced. The remaining section, which is colored green, represents the land area that produces the food for the human population. What is the percentage of the land area that produces food?

4. How much larger is the ocean area than the parts of land were people live and produce food?

5. Construct a table like the one below. List ways in which the things people do where they

live and work interacts with the marine environment or affects the marine environment. Under the column on the left list the activities of people in the land area; under the column on the right side, list the interaction on the marine environment. Once you have completed the chart decide whether the interaction has a positive (P) or negative (N) impact on the marine environment by placing a P or N in the column next to the impact on the marine environment.

Table 2. Coomparison of Activities

Activities of People on Land	Impact of Activities on the Marine Environment	Type of Impact



6. Why do we need the oceans? Make a list of your reasons below.

7. Suppose the oceans dried up tomorrow. Why should you care? Give your response and your reasons in a paragraph below.

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8. Exploring Terra

Scientist(s) _____ **Team** _____

Humans, as well as, many other animals are adapted for survival on land. Marine organisms are adapted for survival in the ocean. Have you ever thought about what it would be like to live in the ocean. In this activity you will investigate living in the ocean and exploring land.

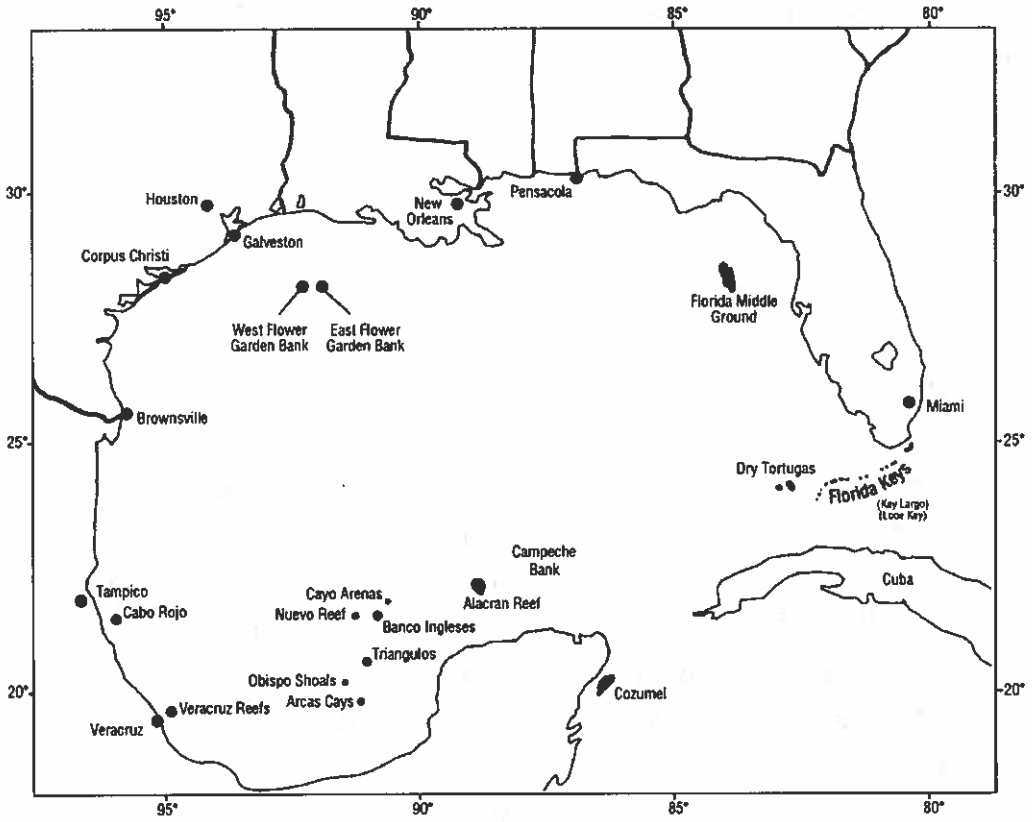
Materials: Texas map (available free of charge from Texas Department of Transportation) or United States map and pictures of the environment in the different regions of the state, Texas Almanac, Texas State Travel Guide (available from Texas Department of Transportation), one-inch square pieces of paper, Texas Parks and Wildlife web site on internet: http://www.tpwd.state.tx.us

Procedure:

1. Try to picture in your mind the things that are described as you read each section of the narrative below. After reading, pause and close your eyes to picture it in your mind in more detail. Then write a brief description and sketch your picture.

Imagine the following situation:

2. Instead of living on land, imagine that people have always lived in the ocean. You are a marine person instead of a land person. Your body is adapted to breathing, eating, sleeping and moving in the ocean.



What would you look like?

How would you breathe?

How would you eat? What would you eat?

How would you move? What would your appendages be like?

What senses would you use to survive?

What would type of body covering would you have?

What would your head look like?

3. On a separate sheet of paper, write a description and sketch how a marine person might look. Explain each structure and how it is adapted to living in the ocean.
4. Imagine that through centuries of living under the sea as a marine people, you have built cities, factories, farms, etc., under the water. What would your homes, cities, etc., be like? Describe and sketch.
5. Through centuries of living under the sea, your marine people have developed vehicles for moving people and goods from one underwater location to another. Describe and sketch what types of vehicles they might be using.

6. As marine people, you have never explored or seen the environment above the water surface or the area of land between the bodies of water. Now your marine people are looking for new areas for possible expansion and colonization. The two areas that are know are the land areas called "Terra" and the area above the water. Your marine country has just developed the technology to explore the land area and the area above the water. What are some of the questions you would need find out about this environment if you wanted to visit it? or live on it? Explain.

7. How would you explore the area to answer your questions without visiting it?

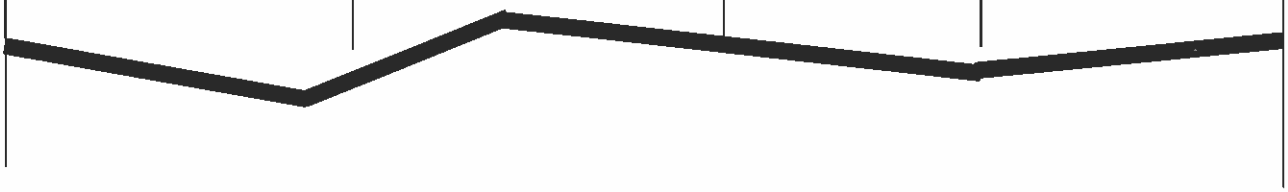
8. Your scientists have developed the technology to launch a craft through the surface of the water to probe and visit the surface of the area known as Terra. A one-inch square piece of paper will represent the probe that you are going to launch. Place a map of Texas (or map of the United States may be used) on the floor. Your first probe is designed to land on Terra, the area we know as Texas. Hold the paper in your hand with you arm raised, then drop the paper above Texas. This represents the launch of your first probe. Conduct four additional probes. Construct a table similar to the following example and record the data for each probe. **Remember that no person has been on Terra so there will be no buildings, highways, etc.**

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(If you are not sure what the area your probe landed on is like, use the Texas Almanac to look up the county for a general description).

Table 3. Data from Probes

Location (name of city or town near probe landing	Description of Terrain Observed (flat, hilly, land, water, etc)	Plants/Animals Observed	Weather, Season Observed (temperature, cloudy, etc.)



5. Use only the data from your probes and describe Terra.

6. How accurate is your description compared to what is known about Texas or the United States? Explain the difference.

7. What would be the effect of sending probes at different times of the year or times of the day? How would this affect the results of a probe?

8. Suppose the probes landed in a lake or landed in rain. What data would be sent back and how would this affect the description of Terra?

9. What must scientists do to get a better description and data?

10. Compare your probes of Terra to our present-day exploration of the ocean. How is it alike and how does it differ?
    How does it affect our descriptions of the ocean floor and the organisms living in the depths?

11. Eventually your marine people hope to land a person on Terra using a landing craft and a specially designed Terra suit. Discuss the problems that must be solved for a person who can live and breathe in water adapting to living on land. (Remember to consider such factors as climate, weather, gravity, moving on land, altitude, soil surface, land vegetation, changing terrain.)

12. Describe a design and the features that must be include in the Terra suit for a person's survival on land.

13. Select an area of Texas or the United States that you know well. Write a short story or interview the Terranauts as they return to the undersea country to report on their experiences in your selected area that they explored. Remember they would find no structures, only the land, plants and animals and weather of the area.

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9. What Do You Know About the Texas Coast and the Gulf of Mexico?

Contestant _____ **Team** _____

You are a contestant for a quiz program. The topic is the Texas Coast and the Gulf of Mexico. Complete the contestant quiz to determine your knowledge level on this topic. Are you an expert or not?

Materials: Copy of Texas Coast and Gulf of Mexico Quiz

Procedure:

1. Complete the Contestant Quiz.

2. Check your answers.
How many questions did you answer correctly?
What percentage did you answer correctly?
Are you an expert on the Gulf? Why or why not? Explain.

3. Check the statements about the Gulf that surprised you. List the five that surprised you the most.

4. Compare and discuss your results with your team and class.

5. Explain why you think the Gulf of Mexico is sometimes referred to as "America's Forgotten Sea."

6. Think about what you have learned about the Gulf. Write a paragraph summarizing what you have learned about the Texas coast and the Gulf, its importance and its problems.

Contestant_____

Texas Coast and Gulf of Mexico Quiz

Instructions:

The questions are true (T) or false (F). Place the letter of your answer in the blank preceding each question.

___ 1. The Gulf of Mexico is a small ocean basin except for an opening to the Atlantic Ocean and one to the Caribbean Sea.

___ 2. Approximately one-third of the Texas population lives within 100 miles of the Gulf shoreline.

___ 3. There are nine major ports, including four of the 10 busiest and 10 smaller ports along the Texas coast.

___ 4. The Texas Gulf Coast is home to 50 percent of the nation's petrochemical activity.

___ 5. Nearly half of all U.S. import/export tonnage passes through Gulf waters.

___ 6. Texas refines about 25 percent of the nation's petrochemicals.

___ 7. There are more than 400 miles of major navigational channels along the Texas coast.

___ 8. About 50 percent of the oil imported into the United States comes through Texas.

___ 9. About two-thirds of the area of the continental United States drains into the Gulf as does half of the area of Mexico.

___ 10. The 21 major estuaries along the Gulf coast account for 24 percent of all estuarine area in the 48 contiguous states and 55 percent of the marshes.

___ 11. The Texas coast alone is the wintering ground for about two-thirds of the waterfowl using the Central Flyway.

___ 12. Padre Island is the nation's longest barrier island.

___ 13. The Gulf of Mexico includes three of the top five states in terms of value of fish landed.

___ 14. About 98 percent of the fishes and shellfish caught in the Gulf depend on the estuarine and marsh habitats of the Gulf Coast.

___ 15. The Gulf of Mexico leads all other regions in marine recreational fishing.

___ 16. The U.S. Gulf coast is shorter than the U. S. Pacific coast from California to Washington.

___ 17. Discovery of the Gulf of Mexico was recorded by Europeans in 1617.

___ 18. Agriculture is one of the mainstays of the Gulf Coast region.

___ 19. The third major type of pollution of Gulf waters is dredged material.

___ 20. The Gulf of Mexico's marine mammals consists of Cetaceans (whales and dolphins) and Sirenians (manatees).

___ 21. The Gulf of Mexico hosts all eight of the world's species of sea turtles, all of which are threatened or in danger of extinction.

___ 22. Twenty-five percent of the non-Texans who visited the state, visited somewhere along the Texas coast.

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___ 23. Twenty-five percent of Texas' economic activity is located within 100 miles of the coastline.

___ 24. The Gulf states annually contribute over $20 billion dollars to the U. S. economy in tourism dollars alone.

___ 25. The Gulf's economic value is second only to the total U. S. federal income tax.

___ 26. Beach erosion has taken away 60 percent of the Gulf shoreline at rates of 1 to 50 feet per year.

___ 27. Each acre of coastland land that is developed costs the taxpayers roughly $50,000 in tax money to build the roads, sewage and water lines, etc.

___ 28. One million pounds of finfish are accidentally caught in shrimp nets and tossed overboard each year.

___ 29. Texas coastal wetlands are disappearing at the rate of about 1,600 acres each year.

___ 30. The average number of shark attacks in North America is 23 per year and in Texas two per year.

___ 31. Oil and gas from the Gulf accounts for 90 percent of America's offshore oil and gas production.

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Topic 2 — Words, Poems and Books of the Sea

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Topic Two: Words, Poems, and Books of the Sea

Words are created, flourish and then fade away as need for them disappears. Words that were common in the day of the sailing ships are no longer needed or used. The language from the sailing ships moved onto land and became a part of land activities. Sometimes the meanings were related and sometimes the words or phrases would take on new meanings. Today's exploration of the ocean depths is adding new words to our vocabulary. With each new type of technology and exploration into the depths of the ocean, new words are needed for the equipment used, the processes developed, and the objects and organisms that are seen. Also, as explorers view new organisms and features, they use existing words to describe the new, which leads to new uses for the words.

Poetry and music have been influenced by the sea. Even today poets and composers are discovering new sources of motivation in the realities of the undersea world. Writers and playwrights have long been fascinated by the mysteries of the ocean. This section will further explore the influence of the marine environment on words, letters, poems, and stories of the sea. These activities may be integrated into any class or conducted in a Language Arts class or as part of a thematic unit in which teachers from the different subject areas are team teaching.

Activity 1: Are You a Marine Word Detective?

TEKS: Science: 7.12, 6.10

Math: none

Language Arts: 6.6, 7.6, 8.6, 6.9, 7.9, 8.9

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- infer word meanings of marine terms by applying the meanings of root words and affixes
- identify the meanings and derivations of unfamiliar marine words using dictionaries and other sources

Background:

1. Have the students generate possible ways to discover the meaning of a word that is new to them. Discuss the role of root words, prefixes and suffixes in discovering the meaning of a word. Have the students read the text and use the list to discover the word for the definition given. When each student has completed Part I, have the students discuss the words in their groups. Each group can work together to add other prefixes, root words, and suffixes to the list.
2. Have a contest to determine which students are the best word detectives. Each group can compile five to ten definitions for words that they want the other groups to solve. The words must be found in the dictionary or another reference. When each group has completed their list of definitions, have the groups exchange lists to be solved. The group that correctly discovers the words for the most definitions is the winner of the word detective contest.
3. For the second part of the contest, have the groups complete number 3. The group that has the most correct wins. You might also have each group prepare a list of five marine related words for the other groups to determine from which Greek, Latin or Anglo-Saxon words the word was derived.
4. To help learn the new words and concepts and to avoid confusion, encourage the students to develop their own dictionary or word list. They could keep a section of their notebook or journal for recording new words and their definitions. Another option is to list the new words on 3 x 5 index cards and begin a card file of new words.

Activity 2: Have Marine Words of the Sea Come Ashore?

TEKS: Science: none

Math: none

Language Arts: 6.6, 7.6, 8.6, 6.9, 7.9, 8.9

Social Studies: 6.1, 7.7

Learner outcomes: After completing the activities, the students will be able to:

- use word origins as an aide to understanding historical marine influences on the word meanings
- analyze how words associated with the marine environment have changed from the days of the sailing ships and how they will continue to change
- write sentences to illustrate the usage of words and phrases

Background:

1. Emphasize that in the past there were many instances where the words that we used were borrowed from the sea. "Sea Language Ashore" lists some of the words and phrases from the sea and their marine meaning. Have the students select 10 words from the list and complete the chart. Encourage the students to use the dictionary and other resources to determine today's use and meaning.
2. Compare today's use of the word or expression to

that of the marine use in the past. Discuss the similarities between the meaning of the words and phrases in the past and today's usage.

3. Have the students write a sentence using the word or phrase as an example of its use today. Students can then share and evaluate the sentences.

Activity 3: How Have Words from the Sea Changed?

TEKS: Science: 8.12

Math: none

Language Arts: 6.6, 7.6, 8.6, 6.9, 7.9, 8.9

Social Studies: 6.1

Learner outcomes: After completing the activities, the students will be able to:

- discuss the changes in the meaning and use of words over time
- compare the use of words in the past with their use today

Background:

1. Provide copies of "Words from the Sea" to the students and have them write today's meaning for the words. Encourage them to use a dictionary or other resources as needed. Compare the words' use today with their usage in the past and determine similarities in their use.
2. Ask the students to select four words or phrases to include in sentences. Have the students write sentences using each word or phrase in today's context. Encourage the students to search for other words or phrases from the sea that we use today in a similar context.

Activity 4: Are There New Marine Words?

TEKS: Science: 8.10

Math: none

Language Arts: 6.6, 7.6, 8.6, 6.9, 7.9, 8.9, 6.11, 7.11, 8.11

Social Studies: 6.20, 8.29

Learner outcomes: After the completing the activities, the students will be able to:

- conduct research to locate new marine words
- classify marine words by their development
- predict and discuss the formation of new marine words in the future

Background:

1. After the students have read "New Marine Words," discuss the causes for the occurrence of new marine-related words.
2. Encourage students to conduct their own research to see if they can find words that:
   a. are initials for the words that makeup the name. For example, have the students see what they can learn about the word "scuba."
   b. are a result of new technology or exploration processes.
   c. are used in a new context different from their past context.
3. After discussing the reading, have the students list their predictions about the sea language and the future.

Activity 5: How Has the Sea Influenced the Writing of Books?

TEKS: Science: 7.12

Math: none

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.24, 7.24, 8.24

Social Studies: 6.1, 7.7 when applicable (depends on the book)

Learner outcomes: After completing the activities the students should be able to:

- summarize the influence of the sea on writers
- read and review a book about the sea
- relate the influence of the sea on an author and the writing of a book

Background:

1. The sea has been an influence on many writers. Many early American writers wrote at least one book about the sea. After the students have read "Letters of the Sea", discuss the influence of the sea on writers.
2. Encourage the students to read and prepare a review of a book about the ocean using the questions in the activity as a guide.

Activity 6: Has the Sea Influenced Legends and Fairy Tales?

TEKS: Science: 8.10, 6.12, 7.12

Math: none

Language Arts: 6.11, 7.11, 8.11, 6.24, 7.24, 8.24

Social Studies: 6.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- analyze and evaluate a legend or fairy tale of the sea
- write and present a fairy or legend about the sea
- generalize about the basis for legends and fairy tales

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- explain why legends and fairy tales seem to be more a part of earlier time periods than today

Background:

1. Almost all cultures have their own legends and tales about the sea. Many cultures have their own stories explaining the formation of the sea or why the water is salty or other ideas. These activities can be used in Language Arts classes or as a part of an integrated thematic unit on the sea. This activity consists of three parts and each may be a separate lesson. Part I is locating legends and tales about the sea. Encourage the students to locate legends from different cultures. Discuss why there are so few present-day tales or legends.
2. Use Part II as a way to have the students analyze stories to determine what a tale or a legend is and what can be learned from them.
3. Discuss why legends and fairy tales were used for explanations of things or events in all cultures in the past while present-day legends and fairy tales are almost non-existent. Discuss the connection between lack of explanation for a thing or event and the development of a legend or fairy tale.
4. In Part III, the students use what they learned about tales and legends to develop their own. Prior to the activity, discuss the components of tales and legends. This could be used as a culminating activity at the end of a marine unit. If possible, provide an opportunity for the students to make presentations of their creations to the school, to lower grade levels, to another elementary school, or to parent groups or community organizations.

Activity 7: Has the Sea Influenced Poetry?

TEKS: Science: 8.10, 6.12, 7.12

Math: none

Language Arts: 6.11, 7.11, 8.11, 6.24, 7.24, 8.24

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- analyze a poem about the sea
- make a prediction about poetry about the sea that might be written in the future
- write their own poems and present them to the class

Background:

1. This activity may be used in Language Arts classes or as a part of an integrated thematic unit on the ocean.
2. To involve the students in locating poetry about the sea, set up a contest. Each team would have to find a certain number of poems about the sea, a designated number by well-known authors, etc. The librarian and Language Arts teacher could assist with the planning.

Activity 8: Can We Use Fairy Tales to Write Poetry?

TEKS: Science: 8.10, 6.12, 7.12

Math: none

Language Arts: 6.11, 7.11, 8.11, 6.24, 7.24, 8.24

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- use tales or legends of the sea to create poems
- use syntu, free verse, haiku, senryu, tanka, cinquain, diamente, rhymed verse, triplets, or quatrains to communicate information about the sea

Background:

1. Team with Language Arts teachers to work with the students in learning to use the various forms of poetry to communicate about the sea. These forms can be used by the students to communicate what they have learned about a marine topic. Use poetry as a way to summarize or communicate information about any marine topic. Writing poetry requires more thinking skills than simply summarizing a topic.
2. Post the students' poetry on school bulletin boards, publish them in the school paper or create a book of poetry about the sea. Have a contest to determine the best poem in each category. Contact a local business to display the winners.

Activity 9: Can You Write a Poem, Sonnet, Limerick and a Song About the Sea?

TEKS: Science: 8.10, 6.12, 7.12

Math: none

Language Arts: 6.11, 7.11, 8.11, 6.24, 7.24, 8.24

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- communicate information about the sea using poems, sonnets, limericks or songs

Background:

1. The sea is a rich source of ideas for writing and communicating. Students can use any marine topic, research it and use the information as a basis for a poem, sonnet, limerick, or song. Team with Language Arts teachers to develop the students' skills in using these means of communication. Use

these with any marine topic or series of marine activities.

2. Again a contest or another public means for teams or individuals to showplace their communication and illustrating marine concepts is recommended.

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1. Are You a Marine Word Detective?

Word Detective_____ **Team**_____

Are you a word detective? Detective is from the Latin words *detectus,* which means to discover, find out, reveal, uncover. A scientific word often has the definition of the word hidden within it. This is true in the ancient languages of Greek or Latin that make up its parts. An example is the word *photosynthesis.* It seems like a difficult word until you use your detective skills. If you know that *photo* is Greek for light, and *synthesis* in Greek means put together. Put the words together and in Greek it means putting together with light. To expand on the definition of photosynthesis, it is the process where light energy is used to put together smaller chemicals to make larger chemicals.

Below is a list of Greek and Latin prefixes, suffixes or root words that make up scientific terms:

1. Root words are written without a hyphen; (for example: plankton).
2. Parts written with a hyphen at the end are prefixes (for example, photo-) and appear only at the beginning of a word.
3. Parts written with a hyphen at the beginning are suffixes (for example,- ology) and appear only at the end of a word.

Prefixes	Root Words	Suffixes
a-: gives the root word a negative meaning	benthos (benthic): depth of sea or bottom	-ogy: study of
arthro-:	joints	
bio-: life or living	cetus: large sea animal	-ped: foot
chemo-: having to do with chemicals	culture: cultivate, take care of, grow	
e-: out of, from	fauna: groups of animals; Fauna was the sister of the god of agriculture	
epi-: upon, on	flora: groups of plants; Flora was the goddess of flowers	
hydro-: water	meter: to measure	
in-: same as the English word in	merge: to plunge	
mari-: sea or ocean	nekton: swimming or swimmer	
micro-:little, small, minute	phone: voice, sound	
pinna-: feather	plankton: wandering, drifting	
photo-: light	scope: to view	
phyto-: plant	synthesis: to put together or make	
sub-: under		
zoo-: animal		

1. Using the list of prefixes, root words and suffixes, can you discover the words whose definitions (which are clues) appear below? Match the words listed below to their definition. Write the word from the list next to its definition.

Arthropods	Mariculture	Pinnapeds
Benthos	Microfawna	Submarine
Biology	Microscope	Submerge
Chemosynthesis	Nekton	Zooplankton
Hydrometer	Phytoplankton	

Growing or farming animals in saltwater.
Animals that swim or live in ocean waters.
To dive or plunge underwater.
A boat that moves deep under the ocean.
Animals that have jointed feet.
Animals that have feathery appendages(flippers)for feet and live in saltwater.
Animals that drift or wander with the ocean currents and waves.
Very small animals that can be seen through a microscope.
An instrument used to look or view very small plants and animals.
Plants that drift near the surface with the currents and waves.
The study of life and living organisms.
The process of using chemicals dissolved in seawater to make food.
An instrument used to measure the density of water.
Animals that live at the bottom of the ocean.

2. Use the chart of prefixes, root words and suffixes to define the following words:

abiotic -
biotic -
hydrophone -
photosynthesis –
microphone –
zoology –

3. See if you and your group can add two prefixes, two root words and one suffix to the list in number one.

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4. Write two definitions for others to solve. See how many other prefixes, root words, and suffixes you and your group can add to the list above. Write definitions for others to detect or solve.

5. Using your word detective skills and a dictionary, find out which Greek or Latin or old English (Anglo-Saxon) words the name was derived from and the definition.

Cetaceans
Octopus
Sea anemone
Abyss
Mollusca
Crustacea
Petroleum
Echinoderm
Barometer
Bathysphere

2. Have Words of the Sea Come Ashore?

Word Detective_____ **Team**_____

Words are created, flourish and fade away as their need disappears. Words that were common in the day of the sailing ships are no longer needed or used. With each new type of technology and explorations into the depths of the ocean, new words are needed for the equipment used, the processes developed and the objects and organisms that are seen. The language from the sailing ships moved on land and became a part of land activities. Sometimes the meaning was related, and sometimes the words or phrases would take on new meanings. Today's exploration of the ocean depths is adding new words to our vocabulary. As explorers view new organisms and features, they use existing words to describe the new that which leads to new uses for the words.

Materials: dictionaries, copies of Sea Language Ashore

Procedure:

1. There were many instances where the words that we use were borrowed from the sea. "Sea Language Ashore" lists some of the words and phrases from the sea and their marine meaning. Select 10 words or phrases from the list and prepare a comparison table similar to the one below. List the word or phrase selected in the left hand column (first column). In the second column, list the marine meaning or use. In the third column, write its current meaning or use. You may use the dictionary and other resources to determine today's use and meaning.

Table 1. Past and Present Meaning of Marine Words

Marine Word or Phrase	Words Marine Meaning	Todays Meaning or Use

2. Write a sentence for each of five words or phrases to demonstrate its use and meaning today.

3. Share your words and sentences with your team.

4. How does today's use of the word or expression compare to that of the marine use in the past? Discuss the similarities or differences between the meaning of the words and phrases in the past and today's usage.

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5. Select two of the words or phrases from number two and hypothesize how the words or why the meanings of the words or phrases might have changed over time.

6. Summarize what you have learned about language, how it can change over time, and the meaning or origin of words and phrases.

Sea Language Ashore

There are many instances where words that we use are borrowed from the sea. Our common speech has many examples, but in using them most people are not aware of the connection. Other terms originated by seamen are no longer relevant to seafaring and have vanished from the sailor's tongue. Antenna is one of these words. To the Roman sailor, the spirit or yard on which he set his sail was an antenna.

The terminology of trade and transportation on land owes a heavy debt to the sea for its language. The railroads coined some new words, but others were borrowed outright. These included ballast, run, stateroom, aboard, shipping, fare, freight, berth, cabin, tender, caboose and crew. Other terms borrowed by various occupations included charter and fleet (taxis or buses); dogwatch (newspapers); on deck and in the hole (baseball); wrecking crew (construction); double deckers (soda fountain); pilot and skipper (airlines). This list could continue. A brief dictionary of some of the sea language that has come ashore is given below:

A

A-1: first-class; rating given to British naval vessels and merchant vessels for insurance purposes.
Aback: a ship being unmanageable due to a sudden shift of wind striking the sails from the side opposite to which they are trimmed.
Aboard: inside the bulwarks, on deck or in collision.
Act of God: used with marine insurance meaning due to causes beyond human control.
After: the portion of ship behind mainmast where officers have their quarters.
Antenna: the spirit or yard on which a sailor set his sail.
Arrive: to come to shore.
Articles: a written agreement by the crew signed before a government official before sailing.

B

Barge: a heavy, clumsy craft, with or without sails.
Beachcomber: a runaway sailor.
Bear down: to approach another vessel from the windward.
Beat: to make progress in the direction from which the wind is blowing.
Below: beneath the deck.

Blanket: to cut off another vessel's wind by sailing close to windward of her.
Bring up: come to a sudden stop, due to grounding.

C

Cabin: living accommodations aft for officers and passengers.
Caboose: cabin or deckhouse on a small vessel.
Call: summon from below decks.
Cast about: to try different courses when in doubt about the ship's position.
To make a clean sweep: of a sea breaking over the rail and wash overboard all moveable objects.
Coast: make short trips from port to port.
The coast is clear: originally referred to a blockading squadron.
Come down upon: to attack from the windward.
Cut out: attacking a ship at anchor by means of a small boat.

D

Dead: word used to denote exact bearings like dead ahead.
Deck: horizontal sections of a ship's hold.
Derelict: a ship abandoned but still afloat and a menace to navigation.
Dragnet: a net used by fishermen for bottom fishing.
Driver: a shipmaster given to carrying soil.
Dungarees: working clothes made of blue jean material, first applied to sailors' clothes.

E

Ease off: to steer less closely into the wind.

F

Fairway: a straight course down a channel.
Fare: a fisherman's catch of fish.
Fender: a buffer of wood or braided rope hung over a vessel's sides to prevent injury to her hull.
Figurehead: carving on a ship's bow.
Filibuster: to run contraband of war to revolutionaries.
First-rate: an official rating of warships in the British Navy of old.
Fleet: a group of ships in company.
Freight: goods transported by ship.

G

Galley: an old-time vessel.

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Glass: in the old days at sea, was half-an-hour measured from the sandglass or a spy-glass.
Greenhorn: a person making his first voyage.
Ground: to run a vessel ashore or aground.

H

Hail: to call out from one part of a ship to another.
Hand: a common sailor.
Hard up: the rudder is as far over as it will go, so nothing further can be done.
Haul: a catch of fish.
A clean bill of health: certificate given by the port health officer to a departing vessel.
High and dry: aground too far to be lifted by the tide.
Hold: cargo space in a vessel.

I

Irons: sea name for handcuffs.

J

Junk: worn-out rope and ship's fittings.

K

Keep: to steer.
Knock off: to go off duty.

L

Landmark: a prominent object on the coast, recognizable from the sea at a considerable distance.
Lash: to tie securely.
Launch: to set a newly built ship afloat.
Lay off: steer away from the wind.
Lay up: to take a ship out of service to make repairs.
Log: the distance covered by a vessel.
Libel: to place a lien on a vessel or cargo.
Light out: go or carry out orders.
Lines: the design of a ship.
Locker: a compartment for storage aboard ship.
Look up: to head a vessel closer to the wind.
A total loss: a shipwreck where the hull cannot be saved.
At loose ends: rope cast off the pin and dangling idly.

M

Manhandle: move cargo by sheer manpower.
Mate: first or chief mate of a vessel.

O

Off and on: a ship tacking toward and away from land, waiting for daylight or the tide.
Open and shut: alternate spells of clear and cloudy weather.
Overhaul: to overtake another vessel.
Overwhelm: bury in heavy seas.

P

Papers: a ship's documents on hull and cargo.
Payoff: to discharge and pay accumulated wages to the crew.
Pile up: running a vessel aground.
Pipe down: sea slang meaning shut up.
Push off: to leave.

R

To rate: from ranks in the Navy.
Reckoning: calculation of a ship's position.
Ride: to lie at anchor.
Rostrum: bronze beak ram on early Mediterranean warships.
Rover: a pirate.
Run: distance covered by a vessel in a given time.
Rundown: to collide with another ship by running into her.

S

Sailed down: saved or hoarded.
Salvage: a claim on the value of a vessel and cargo abandoned at sea by the vessel which towed them to safety.
Scuttle butt: a cask of drinking water located on the deck of old-time vessels for the crew's convenience.
Shake a leg: used in calling the watch below.
Sheeroff: to change course away from an object.
Sheet: first meant sail.
Shove off: push a boat away with oars.
Skyscraper: a small, triangular sail carried on some ships above or in place of the skysail.
Sleep in: to sleep through one's watch on deck.

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Slush: waste fat from the kitchen used to grease the masts.

T

Tally: to keep track of cargo items by means of four upright strokes and a fifth diagonal stroke linking them together.
Tender: a small boat serving a larger vessel.
The old man: sailor's name for the captain.
Trip: a short voyage.
Turn in: to go below at the end of one's watch.
Turn out: to go on duty.

U

Underwrite: to share the risks among subscribers called underwriters, first used for vessels at sea.

V

Vamoose: get out of here.

W

Way: progress of a ship or boat through water.
A whale of: something large and important.
Wreck: the remains of a ship or to wreck a vessel is to cast her away.

Y

To spin-a-yarn: in making spun yarn from untwisted yarns of rope, it took two sailors to operate the winch.

3. How Have Words from the Sea Changed?

Word Sleuth_____ **Team**_____

Many terms and expressions of the sea have become part of our language today. The meanings have changed over the years and they may not be used in the same way today. As a word detective you will determine if you can find the meaning for words and phrases from the sea.

Materials: copies of Words from the Sea, dictionary

1. As a team, complete the "Words from the Sea" chart by filling in today's meaning for the words from the sea. You may use a dictionary or use the internet to locate these nautical terms and phrases. You may need to ask a librarian to assist you in finding the idiomatic expressions.

Words from the Sea

Word(s) or Phrases	Marine Meaning or Use	Today's Meaning or Use
A-1	used to denote ships found to be in first class condition	
Average	first designated an equitable division among all participants of a loss incurred in a shipment at sea	
cut and run	to "let run" the furled sails of a ship by cutting the yarns that secured them	
clean bill of health	a certificate stating whether there was an infectious disease aboard a ship or in the port of departure; it was given to the captain for him to show at the next port	
crew	all men working on a ship	
cranky	liable to lurch or capsize	
freight	a method of transporting goods by water	
first rate	a ship in first class condition	
haul	to change the course of the ship by trimming sail, usually to travel closer to the wind	
haul off	to change a ship's course to draw away from something	
haul up	to sail nearer the direction of the wind	

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Word(s) or Phrases	Marine Meaning or Use	Today's Meaning or Use
junk	a worthless rope	
laid up	a ship that is dismantled and out of use	
out of commission	a ship not in fit condition for use	
overhaul	pull a ship's rope through a block or lead to ease or slacken	
on the rocks	a ship being ruined when it was grounded on rocks	
son of a gun	a reminder of the days when women lived on board the king's ships either in the harbor or at sea	
taken aback	in an unmanageable condition because of the sudden shift of the wind striking the sails from the side opposite that to which they are trimmed	
to the bitter end	the bitter end is the part of a cable that remains within the pool	

2. How does the use of the words today compare with their usage in the past?

3. Are there similarities in the use in the past and today's meaning? Explain.

4. Each member of your group should select four different words or phrases to include in a sentence using the word or phrase in today's context.

5. See if you can find other words or phrases from the sea that we use today.

6. Write your conclusion about marine terms and expressions and their changes over time.

4. Are there New Marine Words?

Word Detective_____ **Team**_____

Words are created, flourish and fade away as their needs disappears. A hundred years ago, the Nantucket whaler spent his free time doing scrimshaw work. Today, the Nantucket whaler is gone, so there is little need for the word. Scrimshaw, is a word meaning etching on ivory. As a detective, you will investigate new marine words.

Materials: Copies of New Marine Words

Procedure:

1. As a team, discuss how new marine words might come into existence. List some of your ideas below.

2. Read the article "New Marine Words." Write a sentence that summarizes the article.

3. Based on the article, what are some causes for the occurrence of new marine words.

4. Look up "scuba" in the dictionary. How was this word developed?

5. See if your team can find marine words that fit the following categories.

   a. are initials for the words that makeup a name.
   b. are a result of new technology or exploration processes.
   c. are used in a new context from the past.

6. Use the internet to locate new marine terms. You might use a "search engine" to locate additional information from organizations that are listed. Some sites to check out are:
   http://www.noaa.gov/
   http://www.onr.noaa.gov/education/
   http://www.seaworld.com
   http://www.yahoo.com/science/oceanography
   http://www.fws.gov
   gopher://esdim1.esdim.noaa.gov/11/NOAA_system/education/
   http://www.yoto.com

7. What conclusions can you draw about the role of technology and exploration in the development of new marine words? Use an example to support your conclusions.

8. What are your predictions about the creation of new marine words? Explain why you made these predictions.

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New Marine Words

Today, there is a need for new words. A large number of people are discovering, inventing and doing new things related to the ocean. The surfer and oceanographer create new words to describe what they observe. The geologist needs new words to describe the sea floor, and it's spreading. As technology increases in all areas of the marine environment, new words are needed to describe the technology and the new knowledge it produces. The need for terms related to the ocean depth has also increased as we begin to explore the depths.

Another area is the ships that move across the oceans. These vessels have gradually changed over the centuries as capabilities have increased and needs have changed. The oil tanker has grown and changed to the point where it has a new name, very large crude carrier or VLCC or supertankers. As we have increased our ability to do things underwater, now we have aqualungs, hydrophones, submersibles with names like Sealab, Tekite, Alvin and Tiburon.

As new techniques for exploring are developed, new words must be created. One new exploration technique is having a ship tow a miniature laboratory that scans the water for chemicals, temperature and particles. The ship tows the device so that it moves up and down a 1,000 feet or so above the seafloor in a pattern like a yo-yo. Because of this motion, the process is called, "Tow-Yo."

Another way words are formed is by the initials for the words that make up the name of an object. Vehicles operated through remote control are called ROVs (Remote Operated Vehicles). Another is AUV, which is the name for Autonomous Underwater Vehicle, which can map the ocean floor, track schools of fish or deep diving whales or tracing a pollution trail to its source. The SWATH, Small Waterplane Area Twin Hull, is a ship developed by the Navy. This ship is extremely stable in rough seas because of its two submarine hulls that ride under the water. CURV is the Cable-controlled Underwater Recovery Vehicle. The CURV is equipped with robotic arms and cameras that allow items to be collected from deep water. Currently, shrimpers are required to install Turtle Excluder Devices or TEDs in their nets to prevent turtles from being captured.

A group or organization's name may also be made that of its initials. Some examples are: National Aeronautics and Space Administration (NASA), United States Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) and Marine Spill Response Corporation (MSRC).

The use of words in a new context often leads to confusion. People many use them in different ways, or there may be several words to describe one thing, the meaning of that word may change or words used in context can be adapted for use in another. This is especially true in the exploration of the depths of the ocean. Chimney is used by deep sea explorers to identify the immense stone towers that form above the hot springs on the sea floor. The openings or cracks in the sea floor from which hot mineral waters flow are called vents. Floc is the

term used to describe the plume of hot water that is filled with white microbes and minerals that rise from deep fissures on the seafloor.

The discovery of new organisms in the ocean also requires new names. It also takes time for words to meet the standard to be added to the dictionary. Some words are out of date by the time they are placed in dictionaries.

In reading about the marine environment, whether it is for leisure reading or research, one finds new words. Listening to the conversations of fishermen or shrimpers, boaters, surfers or scientists, they seem to be using a new language mixed with the English language. New words will come with each new development whether it is in marine recreation or research. Learning the new language is a part of learning about the marine environment.

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5. How has the Sea Influenced the Writing of Books?

Book Reviewer_____



For centuries the sea has been a source of fascination to land dwellers. The resources from the sea touch our lives in many ways. One of the many treasures of the sea is books. You are going to review a book about the sea.

Materials: a copy of "Letters of the Sea," books about the sea or access to a library

Procedure:

1. Read "Letters of the Sea." Summarize the influences of the sea on writers.

2. Visit the library and locate a book about the sea that you want to read. Read the book and complete the information form on the book.

3. Pretend you are a book reviewer for a newspaper or magazine. Use the information about your book, to write a 200- to 250- word book review of the book. Attach your review to this information sheet.

Letters of the Sea

Restless and changing, awesome and mysterious, the sea has gripped our imagination throughout the ages. Writers and playwrights have long been fascinated by the mysteries of the ocean and their visions are expressed in literature. Homer of ancient Greece wrote the first great sea epic, the **Odyssey**. In his epic, the sea is portrayed as full of danger and peopled with monsters.

Writing about the sea continued with the American writers. James Fenimore Cooper, the first great American story teller, is remembered as the author of novels about Indians and pioneers. He also wrote of the sea. His first story, **The Pilot** based on John Paul Jones and the cruise of the Ranger, was the first American sea novel when published in 1823. One of his last books also was a sea story, **Afloat and Ashore** (1844).

Richard Henry Dana, Jr., sailed around the Horn and the story of his adventures became one of the great classics, **Two Years Before the Mast** (1840). Herman Melville sailed on a whaling ship and wrote his first book of the sea, **Typee**, followed by several others. He ended with his masterpiece, **Moby Dick**, a complex book with many levels — like the sea itself. It was Melville's attempt to wrestle with the meaning of the seas and continents of the moral world. Among the papers Melville left when he died was the unpublished novel, **Billy Budd**.

Henry David Thoreau did know Melville's **Typee**, but he disliked fiction and did not read **Moby Dick**. In **Walden**, published in 1854, Thoreau did not share the enthusiasm for expedi-

tions exploring the seas. Even before he published **Walden**, he began his own experience with the sea. He died before he could put his book together. The book, **Cape Cod**, (1858), composed of his essays, was compiled after Thoreau's death. It is about his walks, the people and the flotsam and jetsam of Cape Cod.

When Melville died, young Jack London was beginning to explore the waterfront. He wrote one great sea story, **The Sea Wolf**, in 1904. In the 1930s Charles Nordhoff wrote a number of books about the sailor's life and about whaling and fishing. These were the Bounty triology, **Mutiny on the Bounty** (1932), **Men Against the Sea** (1934) and **Pitcairn's Island** (1934). These books inspired motion pictures and did much to remind American readers of their own seagoing past.

Two of our best known writers, John Steinbeck and Ernest Hemingway, wrote of the sea - Steinbeck in **The Pearl** (1945) and Hemingway in **The Old Man and the Sea** (1952). As a youth, Steinbeck wanted to go to sea as Jack London had but was not able to get a job. He wrote **The Sea of Cortez** (1941), which deals with man's interaction with the sea. In **Cannery Row** (1945), Steinbeck presented the image of a marine biologist who is the opposite of an establishment scientist.

The most widely read book about the sea in more recent times has been Rachel Carson's, **The Sea Around Us** (1951) which deals with man's continuous confrontation with the sea. She also wrote, **Under the Sea Wind** (1941) and **The Edge of the Sea** (1955). You may have enjoyed reading, **The Eyes of the Amaryllis Island of Blue Dolphins**, **The Cay** or other children's books of the sea.

There are many other books about the sea available today. Undoubtedly, the sea will continue to intrigue people and serve as the creative catalyst as they write more of their feelings and observations in the future.

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Book Reviewer_____

Name of the Book Reviewed _____

Author(s) of the Book_____

Type of Book (Check one)

Fiction (Check the type below)

____Realistic Fiction
____Historical Fiction
____Fantasy
____Mystery
____Science Fiction

____**Information Book**
____Autobiography
____Biography
____Other (Explain)

A. General Questions for All Books

1. What is the author(s) background?

2. Did the author's background influence the writing of the book? Explain.

3. Would you recommend this book to your classmates? Give two reasons why or why not they should read the book.

4. Discuss the influence on the role of the ocean on the author and its impact on the writing.

5. Answer those questions below that match the type of book you read.

B. Questions for information book

1. What was the topic and purpose of the book?

2. Was the book interesting? Explain what made it interesting or why it was not interesting.

3. Is the language easy to understand or did you have difficulty? Explain.

4. Evaluate the use of illustrations.

5. Describe three things that you learned that you did not know before reading the book.

C. Questions for fiction book.

1. How does the author establish the time and setting of the story?

2. How does the time and setting influence the action, characters or theme?

3. Who tells the story?

4. Is the plot believable? Explain.

5. Briefly describe the plot.

6. Describe the main characters. Are they realistic?

7. Is there a moral or lesson to the story? Explain.

D. Questions for a Biography or Autobiography.

1. Who is the book about?

2. Where was the person born? Where did the person live? When (dates)?

3. What part of the person's life does the book cover?

4. For what is the person well-known or famous?

5. What were the person's strengths and weaknesses? How did they affect his or her life?

6. Discuss three things that you learned about the person that you think are important for others to know.

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6. Has the Sea influenced Legends and Fairy Tales?

Reviewer _____ **Team**_____

Every part of the world has its legends and tales of the sea. The very creation of the seas is explained in mythology and in the Bible. Fish also appear early in myth and religion. The Carthaginians worshipped the fish as a symbol of strength; the Egyptians regarded the eel as sacred; and the Chaideans worshipped the fish- god Cannes.

Stories of great floods are found in most cultures, the most familiar of which is that of Noah and the Ark in the Bible. The ancient Greeks created sea nymphs in their imaginations. There also are the legends of Atlantis, the lost continent, and those of Odysseus from Homer's epic, the **Odyssey**.

Other imaginary tales or legends include Jason and the Argonauts; Gilgamesh; How the Fish Got in the Sea; Why the Fish Do Not Speak; Why Fish Have Gills; Why Jellyfish Have No Shell; Why the People of Raiatea Have No Fear of Sharks; The Boy Who Was Caught by a Clam; Why the Sea is Salt; The Origin of the Coconut; The Gratitude of the Fish; Mermaid of the Magdalens; and Jules Verne's famous **20,000 Leagues Under the Sea**.

The world of the sea suggests legends, images and inspirations. These tales and legends provide you the opportunity to read about the brave people of heroic courage or maidens with inner strength. At the same time, they present the importance of the sea to different cultures and heritages.

Materials: Access to a library or books with legends and tales of the sea or **Fairy Tales of the Sea** (Texas Sea Grant College Program, TAMU-SG-81-402)

Procedure:

Part I: What is the tale or legend of the sea about?

1. Visit the library and find a legend or fairy tale of the sea.
2. Evaluate the legend or tale by using the questions below:
   a. Name of the legend or tale.
   b. Where did you find it? (book, etc.)
   c. What is the origin of the tale? People or country?
   d. What is the setting and mood of the tale?
   e. Briefly summarize the tale.
   f. What is the theme or main idea of the tale or legend?
   g. What can you learn about the sea from a story?

Part II: What can we learn from the tale or legend?

1. Since all tales or legends are make believe, pay close attention to the factors that allow

you to predict that it is fiction. There are several things that can be considered as clues.

a. What in the title is a clue that you are reading fiction?

b. How does the language of the tale indicate that the characters are real or fiction?

c. How does the language of the tale refer to people, places or events? Does this help determine whether it is real or fiction?

2. Compare factual material with the marine topics of the tales. For example, read about the marine topic in an encyclopedia or other reference book. Compare the language and description of the topic in the tale to the language and description in a reference book. How does it differ?
   a. Is there a moral or lesson to the story? Explain.

   b. Would you recommend the tale to your classmates? Give two reasons why or why not.

Part III: Can we Present or Create a Tale of the Sea?

1. In your group, share the legends or tales that were read by each member. Select one to present to the class. Plan a short presentation of the tale or legend for the rest of the class. Your group may want to present it as a skit, play, TV episode, radio program or puppet show. Outline the plans for your presentation below. Include each person's responsibility for completing the presentation and the materials you will need.

2. As a group, create your own tale or legend of the sea. Select a marine topic you know about. List which topic. Outline your tale or legend.

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7. Has the Sea influenced Poetry?

Reviewer _____ **Team** _____

The sea itself provides images, inspiration and poetry for humans. Many writers have used poetry to describe their experiences in the marine environment. Locate a poem about the sea to evaluate and share with your team.

Materials: Access to a library; books of poems

Procedure:

1. Visit the library and find a poem about the sea.

2. What is the name of the poem and who is the author?

3. What is the setting (time and place) of the poem?

4. Is the poem about a real or imaginary situation? Explain.

5. What does the poem do?
   a. Tells a story about
   b. Presents a picture of
   c. Expresses emotions of
   d. Teaches a lesson about

6. What does the poem tell you about the sea?

7. From the poem, what would you infer or conclude about the writer's feelings about the sea?

8. How does the poem make <u>you</u> feel?

9. Would you recommend this poem to a classmate? Give two reasons why or why not?

10. Would this poem be written the same if it were written today? Explain.

11. Would the author write the same poem if he or she were writing about the sea in the year 2015? What would be the same? What would differ?

12. In your group share your poems. Which one did your group like the best? Explain why?

8. Can we use fairy tales to write poetry?

Poet_____ **Team** _____

Writing poetry will give you a chance to express your thoughts in a condensed fashion. To the careful observer there is poetry in nature. The sea itself is poetry to some. Poetry can extend concepts you have learned and your concerns into the realm of your imagination. You will use freedom of expression to use a variety of poetry. You can become a poet.

Materials: copy of **Fairy Tales of the Sea** (Texas Sea Grant College Program, TAMU-SG-81-402) or copies of Tales or Legends about the Sea.

Procedure:

1. The content of tales or legends or information on a marine topic you and your team select can be used to write poems. The topic or theme you select can range from an animal to coral reefs to the ocean itself. Any topic is fine. Or, you may select a tale, legend, story or novel as a basis of your poetry. You and your team members (individual or as a group) will create a poem using each of the forms of poetry listed below. Write, type or print each poem on a page. Illustrate the area on the page around your poem. Use these to create your teams book of poetry. Use the computer and publish your book of poetry. Illustrate your book.

2. Select a tale and use its content to write poetry. This will require you to describe fairy tales or legend events in a new way.

   A **syntu** is a Japanese poem consisting of five lines that do not have to rhyme.
   The lines are as follows:

   In line 1 use one word, a noun—the name of an organism, object, event or phenomenon.
   In line 2 write an observation of the noun you named in line 1 using one of the five senses.
   In line 3 write a feeling about the item named in line 1.
   In line 4 write another observation of the noun in line 1 using another of the senses (not the one used in line 2)
   In line 5 write a one-word synonym for line 1.

   a. Select a person, animal, object, event or phenomenon from a fairy tale or legend to write your syntu.

   b. Now select a marine topic and write a syntu using it.

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3. **Free verse** is unrhymed and unrestricted in length or rhythmic patterns. It is one of the simplest verse forms. The poet may use whatever form best expresses the intended feelings.

   An example from **The Serpent's Bride**:
   A princess and a Serpent were wedded.
   It was not a comforting arrangement.
   But the princess had trust.
   And kept loving her bridegroom.
   Until love transformed her serpent into a king.

   a. Select a tale and use it to write free verse.
   b. Now select a topic about the sea and write free verse about it. Write your free verse on a separate page.

4. **Haiku** is a form of Japanese poetry. Each poem is made up of three lines expressing a quick picture of nature. It should not rhyme, but flow easily from the first to the third line. The correct number of syllables is desirable but not necessary.

   Format
   Line 1 5 syllables
   Line 2 7 syllables
   Line 3 5 syllables

   An example from **The Little Mermaid**
   Mermaids flit softly,
   Traveling blue water trails
   Quiet disappearance.

   a. Select a tale and use it to write a haiku. Write it on a separate page.
   b. Now select a picture of the sea that you can visualize and write a haiku about it. Write it on a separate page. Vary the shape of the poem to your liking.

5. A **senryu** is a three-line form resembling a haiku without the syllable requirements.

   An example using the **The Fisherman and His Wife** fairy tale:
   The fisherman's wife wished and wished
   And was never happy
   She was returned to her beginning.

   a. Select a tale and use it to write a senryu.
   b. Select any marine topic and write a senryu about it.

6. **Tanka** is extended haiku. In addition to the first line with five syllables, the second with seven and the third with five, the tanka has fourth and fifth lines with seven syllables each.

   An example using **A Fish Story** is:
   Fish living on the earth
   Hunting tribe, walking and talking
   Warming under the sun.
   Tumbling down into the sea
   Finding comfort in their lives.

a. Select a tale or legend to use to write a tanka.
b. Now select a marine topic to write about using a tanka.

7. **Cinquain** (pronounced sin-cain) is a five-line poem that describes something. It resembles the haikus and tankas. It usually occurs in one of two formates.

Format I
line 1 noun
line 2 two adjectives
line 3 three action verbs
line 4 four feeling verbs
line 5 a restatement of line 1

Format II
line 1 2 syllables that name the subject
line 2 4 syllables describing the subject
line 3 6 syllables showing action about the subject
line 4 8 syllables showing feeling about the subject
line 5 2 syllables using another word for the subject

An example of a cinquain using the tale **Why the Ocean is Salty** is:
Ocean
Blackness, darkness
Bamboo bridge from the caves

a. Select a tale or legend and write your own cinquain.
b. Select a marine object to describe. Write a cinquain to describe it.

8. The **diamente** is a seven-line contrast poetry arranged like a diamond.

Format
line 1 one noun (subject)
line 2 two adjectives
line 3 three verbs ending in "ing"
line 4 four nouns related to subject
line 5 three more verbs ending in "ing"
line 6 two adjectives
line 7 one noun (opposite of subject)

An example using **The Little Mermaid** is:

Mermaids
Lovely, quiet
Swimming, singing, dreaming
Fairies of the sea
Walking, talking, living
Lively, active
Mortals

a. Select a tale or legend and write your own diamente.
b. Now select a marine topic and write a diamente about it.

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9. **Rhymed** verse forms can be used to convey messages about the sea and tales of the sea. After reading and discussing a tale or a topic, make a list of rhyming words. Couplets or triplets and quatrains can be a product of this.

   a. A two-line **couplet** is the simplest rhymed verse form.

      An example using the **Raven and the Lobster** would be:
      The raven wasn't very smart,
      For with his lobster he did part.

      Use your list of rhyming words to write couplets about the topic you selected.

   b. **Triplets** are three-lined, rhymed verses. The rhyme may be carried in two or three of the lines.
      An example using **The Sea of Gold** would be:
      Hikoichi fed the fish his rice,
      Those who watched called him a fool.
      When he was rewarded, the others did drool.

      Use your list of rhyming words for a topic to write triplets.

   c. **Quatrain** is a four-line verse form with numerous possibilities for rhyming schemes—first and second, third and fourth (aa, bb). Other rhyming schemes are abab, abba, abca.
      An example for **The Story of Tremsin** is:
      There was an impossible feat,
      Which Tremsin was to complete.
      Overwhelmed, he became tearful
      But was told, "That's not a task, but a trifle.

      Use your list of rhymed words to create a quatrain.

   d. Longer rhymed forms may be produced by combining couplets, triplets and quatrains in various ways. As a group, select a topic or a tale and compose a poem by having each person contribute a couplet, triplet or quatrain to the poem.

10. Summarize your experience in writing poetry. Would you rather write a paragraph on a topic or create a poem? Explain.

*Adapted from **Fairy Tales of the Sea**, Teacher's Guide, Texas A&M University Sea Grant College Program, 1981*

9. Can you write a poem, sonnet, limerick and a song about the sea?

Writer(s) _____ **Team** _____

The sea is a treasure chest of ideas for writing. You will use what you know about the sea and express your thoughts about it using poems, sonnets, limericks and songs. Use your imagination to freely express what you know about the sea.

Materials: none

Procedure:

Part I: Can you write a poem about the sea?

1. Select a topic, object, event, phenomenon from the sea to write a poem about. Select a topic that you like. Learn more about it and take notes.

2. Reflect on your notes. Visualize it. Write about it just as you visualize it. Choose words that suggest the season, location, time of day, the feelings, etc. Select a form of poetry from "Can you use fairy tales to write poems?" Write your poem below. Work on each poem until it suggests exactly what you want others to visualize. Be patient, it takes time to develop ideas into writing.

Part II: Can you write a sonnet about the sea?

1. Writing a sonnet. Select a topic. Learn about it and take notes. Focus on the main idea you want to present. What do you want to tell people? Visualize it.
2. Write a sonnet about it. Sonnets are composed of 14 lines with most lines having a rhyming word at the end of every other line. This rule does not have to be followed exactly. Your expression is more important. Use the unstructured sonnet below as an example.

Tropical rain forests will soon be gone,
and with them all the birds so bright.
Never more to hear their song
or strange animals to see through filtered light.
The trees are burned so cattle graze
to serve our fast-food chains
with a quick-made hamburger craze.
Some call it progress on the range,
without knowing the land won't last.
For poor soil there is the norm
so more trees must be slashed
believing more jobs will be born.
Such futility escapes all reason,
there won't be jobs with all the trees gone.

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Part III: Can you write a limerick?

1. Again select a topic, learn about it and take notes. Visualize it. Write a limerick about it. A limerick is a poem of five lines, usually with the rhyme scheme of aabba, the first, second and fifth lines have three stresses (feet), the third and fourth, two. This form was made popular by Edward Lear. As with other forms of poetry, you do not need to follow the format exactly. See the example below.

   There once was a botanist named Linnaeus,
   Who sought to bring order to chaos.
   Who said to claim it,
   You have to name it.
   Hoorah for the good Swede, Linnaeus.

   Write your own limerick.

Part IV: Can you write a song about the sea?

1. Primitive societies recorded their customs and beliefs in song-like chants. Modern society records its customs, beliefs, history and events in song. To write a song, choose one of your favorite songs for the tune or make up a tune. Substitute marine words for the regular words or write music to fit some of the poems that you and others have already written. Write your song below.

Part V: Show Time

As a group select a poem, sonnet, limerick and a song to present to the class.

Source of sonnet: ***Connections: Science by Writing****, by Robin Lee Harris Freedman, 1990, Serin House Publishers.*

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Topic 3 — Geology of the Gulf

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Topic Three: Geology of the Gulf Coastal Zone

Coastal zones are some of the fastest changing parts of the Earth's surface. Any single coast is the result of processes at all three time scales: the slow geological processes of mountain formation and erosion that require millions of years, the gradual sea level changes requiring thousands of years, and superimposed over these are the day-to-day and year-to-year combinations of the long-term and short-term actions of waves, currents and tides. The activities will investigate the processes of the first two time scales.

The economic aspects of the Texas coast—the production of oil and gas, shipping, agriculture and sprawling industrial complexes—are certainly important. However, the geology of this area is the key to understanding these factors as well as the natural environment. The geologic history of Texas, as recorded by rocks, began more than a billion years ago. The Gulf of Mexico did not exist until 300 million years ago. Approximately 65 million years ago, the coast of Texas was along the Balcones fault. Streams flowed eastward draining areas to the north and west. This resulted in extensive seaward building by broad deltas, marshy lagoons, sandy barrier islands and embayments. Thick vegetation covered the areas between the streams. Coastal plains were taking shape, under the same processes still at work today. During the North American Ice Age, the state's climate and sea level underwent major changes with each period of glacial advance and retreat. Sea level during periods of glacial advance was 300 to 450 feet lower than during the warmer interglacial periods. The climate was more humid and cooler. The major rivers carried more water and more sand and gravel to the sea. These deposits lie under the outer 50 miles or more of the Gulf coastal plain.

Approximately 3,000 years ago, the sea level reached its current position. The geologic legacy is the mineral wealth and varied soil and land. The geology of Texas, including the Texas coast, has been the subject of intensive study since the first Spanish explorers visited in the early 1500s and this continues today. Understanding the geologic story of the region is critical to understanding the region itself. These activities will focus on the connection between the geology and the other aspects of the region.

Activity 1: How was the Gulf of Mexico formed?

TEKS: Science: 8.14, 7.14, 6.14, 6.6, 7.5, 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5

Math: 6.8, 7.9, 8.8 (measurement)

Language Arts: 6.11, 7.11, 8.11

Social Studies: 6.1, 7.7 (history)

Learner outcomes: After completing the activities, the students will be able to:

- summarize the geologic events that lead to the formation of the Gulf of Mexico
- construct and evaluate a model of the formation of the Gulf of Mexico

Background:

1. To introduce Part I, have the students look at the geologic map in Figure 1 or at a geologic map of Texas and ask what patterns they see. Ask for possible hypotheses or explanations of the patterns. Discuss how they could determine if their explanation was correct.
2. Read the guided imagery to the students rather than having them read it themselves. Read slowly and pause after each section so they have time to visualize the events. Discuss the events and create a time line.
3. To develop students' thinking skills in Part II, do not give them the instructions. Instead give each group 10 minutes to discuss and develop their ideas for a model to demonstrate the formation of the Gulf.
4. Provide materials for each group to test its model. Each group may then share the model with the class. Models can be evaluated and each group can use what was learned to improve on its own

Activity 2: How was the Gulf coastal plain formed?

TEKS: Science: 7.5, 6.6, 7.12, 6.14, 7.14, 8.14

Math: (timeline 6.11, 7.13, 8.14)

Language Arts: 6.11, 7.11, 8.11 (if a timeline is required – 6.24, 7.24, 8.24)

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.23, 7.23, 8.32, 6.1, 7.7

Learner outcomes: After completing the activities, the students will be able to

- compare the shoreline at the end of the Cretaceous to today's shore
- construct a chart describing the events that formed the present Gulf coastal plain

Background:

1. Instead of having the students read the guided imagery, read it to the students. Have the students close their eyes and relax. Read slowly and pause after each section so they have time to visualize the events. Discuss their visualization of the events. Complete a time line chart of the events.

2. Use the geologic map to discuss the events that occurred that filled in the Gulf and developed the present day coastal plain. Discuss the types of soils and materials that will be found in the coastal plain.

Activity 3: Can a model demonstrate the development of the Gulf coastal plain?

TEKS: Science: 8.14, 7.14, 6.12, 6.6, 7.5, 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5

Math: 6.8, 7.9, 8.8

Language Arts: 6.24, 7.24, 8.24

Social Studies: 6.6, 7.9, 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- create and evaluate a model to demonstrate how the Gulf coastal plain formed
- construct a cross section of a model of the Gulf coastal plain
- compare a cross section model they constructed to the work of geologists.

Background:

1. For Part I, discuss how scientists use the information from geological processes occurring today to determine what happened in the past. Stress that geologists assume that the physical and geological forces are the same today as in the geologic past. Ask the students what the effects would be if this assumption were not true.
2. Instead of giving the students the instructions for creating the model, ask them to use what they learned from the figures and narrative in the activity "How was the Gulf coastal plain formed?" to develop a model to demonstrate the events. After each team has developed its plans, provide the students with the materials to experiment with their design for the model. Encourage them to test and revise their model.
3. Part II is designed to help students develop their understanding of geologic cross sections by creating a cross section. Discuss and compare the students' cross sections with those of geologists. Discuss the geologists' use of core samples to develop cross sections. Ask why core samples may not enable the geologists to develop an accurate, detailed cross section. (The area from which a core sample was not taken may differ from the area of the core sample.)

Activity 4: Where was the Texas coast in the past?

TEKS: Science: 6.5, 7.5, 6.12, 7.12, 7.11, 6.14, 8.12, 8.14

Math: 6.4, 7.3

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.1, 7.7, 6.3, 7.8, 8.10, 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- use maps to make inferences about environmental conditions of the past to explain the fossil remains, soils, and minerals found in the Texas coastal region
- summarize how understanding the biological, physical, and chemical forces which exist today helps explain the geologic history of the Texas coastal region

Background:

1. Discuss how understanding the biological, physical and chemical forces that exist today help explain the geologic past.
2. Provide students with copies of the maps depicting the Texas shoreline from the Cretaceous to the present. Tell students they will be role playing geologists rather than just answering questions. They will be developing explanations and presenting their explanations at a scientific conference. Their team of geologists is to use what it knows about plants, animals, soils and minerals to explain past environments. Encourage them to use other resources, including the internet, to gather information about plants, animals, etc. Assign each team several of the examples from the activity. Each team is to prepare an explanation and support it. The team will then present its explanations to the class at a "conference." Other teams may pose questions or provide additional information to either support or refute the explanation given.
3. End the conference or activity with the students developing a conference report or summary of the explanations.

Activity 5: What prehistoric marine organisms were present in Texas?

TEKS: Science: 6.5, 7.5, 6.10, 7.9, 8.11, 7.11, 7.12

Math: 6.8, 7.9, 8.8, 6.4, 7.3

Language Arts: 6.10, 7.10, 8.10, 6.9, 7.9, 8.9, 6.20, 7.20, 8.20

Social Studies: 6.1, 7.7, 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- complete a table of the major events and fossils found in the Texas coastal zone
- use knowledge about organisms and the environment in which they live to make inferences

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about the past
- discuss the effect of environmental changes and the survival of organisms

Background:

1. Discuss how understanding the biological, physical and chemical forces that exist today help explain the geologic past. In groups, have the students list examples. Use questioning to guide the students to identify some of the following. The deposition of sediments that form the soils is related to particle size and the flow of the water. As rapidly moving water slows, the largest particles are deposited first and the smallest last. The finest particles may not be deposited until the water stops moving. More organic material present in sediments indicates the presence of more plants and animals. Hard parts, such as bones and shells, are more likely to form fossils. If only marine fossils are found, then the area was probably a sea or ocean. Climatic conditions affect the type of environment and the type of environment affects the type of vegetation found. A mild, humid climate will have more vegetation than a drier or colder climate. The climate and environment also affect animals. Amphibians need water or a moist environment while reptiles can survive in drier conditions. Animals and plants are adapted to their environments. Large grasslands support large grazing animals and rodents.
2. After the discussion, have the students read "Prehistoric Organisms in the Texas Coastal Zone" and complete the chart. Discuss the relationship between the organisms and the environments of the past and environmental changes. Include a discussion on the impact that global warming could have on the present organisms and the environment.

Activity 6: How were salt domes formed?

TEKS: Science: 6.3, 7.3, 8.3, 7.5, 6.6, 6.7, 6.14, 8.12, 8.14

Math: none

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9

Learner outcomes: After completing the activities, the student will be able to:

- examine and interpret figures to develop a hypothesis for the formation of salt domes and subsidence over salt domes
- use a model to explain the formation of salt domes
- design an experiment to test the hypothesis that large salt lakes or seas in hot, dry climates must have existed to form salt layers

Background:

1. Discuss the idea that the outside appearance or surface of an area may appear "boring" although there might be many interesting features and stories underneath the surface. Each rock and mineral has a history and a story. This is the situation with the Gulf coast of Texas. To conduct this lesson as an inquiry, use the questions to guide the students' inquiry. Begin by showing the students Figure 1 and ask them where the salt domes are located. What do they notice? What patterns do they see? What would be needed to form a salt deposit? What must have existed to form these deposits? What type of climate must have existed? Ask each team to develop a hypothesis about how the salt domes were formed.
2. Provide each team with the series of cross sections of the Gulf of Mexico. Tell them that under heat and pressure salt becomes soft and will flow. Note the thickness of the salt layer. Ask what conditions would have had to exist for this deposition of salt to occur. Ask them to use this information and the cross sections to continue to develop or refine their hypotheses.
3. Provide the students with "silly putty" and point out that it has a consistency similar to that of salt under pressure. Tell them to use it to create a model to demonstrate their hypotheses for the formation of salt domes. After the teams share their models, develop a class model and explanation.
4. In teams, have the students design their experiment or a model to support the hypothesis that large salt lakes or seas must have existed in hot dry climate to form the salt layer.

Activity 7: How has geology influenced the Gulf coastal zone?

TEKS: Science: 6.3, 6.14, 7.3, 8.3, 8.14

Math: none

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.1, 6.3, 6.6, 6.22,7.8, 7.9,7.12,8.10,8.30

Learner outcomes: After completing the activities, the students will be able to:

- analyze maps and identify patterns and relationships
- explain the relationships between geology, natural scenery, soils, vegetation, aquifers, and agriculture of the Gulf coastal plains

Background:

1. Rather than assigning the activity as a worksheet, have the students use inquiry to engage in thinking processes as geologists. Tell each team that they are geologists and are examining maps of the Texas coastal plains.
2. Provide each team with copies of Texas maps that show the following: geology, physiography, soils, vegetation and aquifers. Explain that the geology map provides the geologic history that is recorded in the rock strata. The physiographic map shows the natural scenery divided into regions. Each region is distinguished by a characteristic geologic structure, landforms, rock and soil types, vegetation and climate. The soil map shows the soil types in each region. The aquifer map shows the location of the major aquifers in the state. Tell the students to study the maps and determine if they observe any patterns. Ask them to summarize and explain any relationships they noted between the different maps.
3. In closing, stress that the geology or the rock strata determine the soil, the soil determines the vegetation and these give rise to the physical features and natural scenery. The rock strata and soils are related to the location of aquifers.

Activity 8: What is the connection between the geology and the petroleum resources of the Gulf Coast?

Activity 9: What is the connection between the geology and non-petroleum energy resources?

Activity 10: What is the relationship between the geology and minerals of the coastal zone?

TEKS: Science: 6.6, 6.7, 6.14, 7.14, 8.12, 8.14

Math: 6.10, 7.11

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.1, 7.7, 6.3, 7.8, 8.10, 6.6, 7.9, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- analyze figures and maps to gather data and form conclusions
- summarize the relationship between the geology and petroleum and non-petroleum energy sources and minerals in the Texas Gulf Coast
- explain the importance of the geology of a region to the resources

Background:

1. Rather than requiring each team of students to complete Activities 8, 9 and 10 individually, assign one of the activities to one or two different teams. Challenge the teams to use their knowledge from Activity 7 to analyze the figures and maps to determine the connection between geology and the energy and mineral resources.
2. Have each team present its findings using maps and figures to illustrate its presentation just as scientists would do at a conference. Encourage other class members to participate in the "conference" by asking questions and offering their own interpretations. Stress that scientists always ask questions, demand verification, search for data and meaning, and long to know and understand. Each group should help everyone understand what they learned.

Additional Resources:

The following are available from: Bureau of Economic Geology, The University of Texas at Austin, University Station, Box X, Austin, Texas 78713-8924
Web: http://www.beg.utexas.edu

List of Publications:

Environmental Geologic Atlas of the Texas Coastal Zone (7 atlases): Bay-City-Freeport Area; Beaumont-Port Arthur Area; Brownsville-Harlingen Area; Corpus Christi Area; Galveston-Houston Area; Kingsville Area; Port Lavaca Area. Each atlas has 9 multicolored geological and environment maps of the area with text of additional figures and tables.

Guidebook 2, Texas Fossils: An Amateur Collector's Handbook

Guidebook 11, Recent sediments of Southeast Texas—A Field Guide to the Brazos Alluvial and Deltaic Plains and the Galveston Barrier Island Complex

Guidebook 12, Uranium Geology and Mines, South Texas

Guidebook 17, Padre Island National Seashore—A Guide to the Geology, Natural Environments, and History of a Texas Barrier Island

Guidebook 20, Modern Depositional Environments of the Texas Coast

State Maps (multicolored page-size map and text) approximate cost $0.25:

Geologic (SM0002); Tectonic (SM0004); Physiographic (SM005); River Basin (SM006); Land Resources (SM007); Wall size: Energy Resources (ER001); Mineral Resources (ER002); **Geologic Atlas of Texas** (Multicolor on a topographic base, scale 1:250,000); Beaumont Sheet, Houston Sheet, Beeville-Bay City Sheet, Corpus Christi Sheet, McAllen-Brownsville Sheet (Approximate cost $6 each)

Other Resources: Texas Almanac

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1. How Was the Gulf of Mexico Formed?

Geologist _____ **Team**_____

Have you ever wondered whether the Gulf of Mexico has changed over time? Actually 300 million years ago the Gulf of Mexico did not exist. You and your team will be investigating when and how the Gulf of Mexico was formed.

Materials: Stream table or large trays, different types of sand (different colors) or soil, large flat rocks or wood blocks, water

Procedure:

Part I – How and when was the Gulf of Mexico formed?

1. For an overview of the geology of Texas, look at the geologic map of Texas (Figure 1). This map shows the ages of the surface rocks. The patterns that you see are clues about the geology of Texas. Examine Figure 3.1, what patterns do you observe?

2. Follow the rock formation running from Dallas-Ft. Worth, through Waco, past Austin and San Antonio, then westward toward the Big Bend of the Rio Grande. This forms an 'S' curve through the center of the state. What is the pattern of the rock formations to the east and south of it?

3. The 'S' line was the edge of the North American continent in Cretaceous time (60 to 100 million years ago) when the Gulf of Mexico formed as the continents of North and South America separated during a period of sea floor spreading and continental drift. This curved line also follows the buried Ouachita Mountains that crossed Texas in the past. The folded, metamorphosed rocks indicate that there may have been two mountain ranges. During the Paleozoic about 300 million years, these mountains may have been as tall as the Alps or even the Himalayas. Locate Austin on the map. You are going to use guided imagery try to imagine the things you hear described by your teacher.

   Now we are ready to begin. Get yourselves comfortable. Close your eyes. Just do your best to imagine the things that will be described. Your teacher will read aloud:

   Imagine you are moving back in time to a period to 350 to 300 million years ago. You are viewing the state from above an area between Austin and the Texas coast. As you look closer, you notice the edge of the North American continent is in front and below you. As you are watching, the North American continent slowly collides with another continent, which is located to the south and over what is now the Gulf of Mexico. They are forming a super continent called Pangaea. As the continents collide, layers and layers of rocks are pushed up. This is the Ouachita mountain range beginning to rise on the North American continental edge. The rock layers move up to the height of the Alps or more. To the west of these mountains, the continent's crust is sinking and forming basins. Seas and sediments

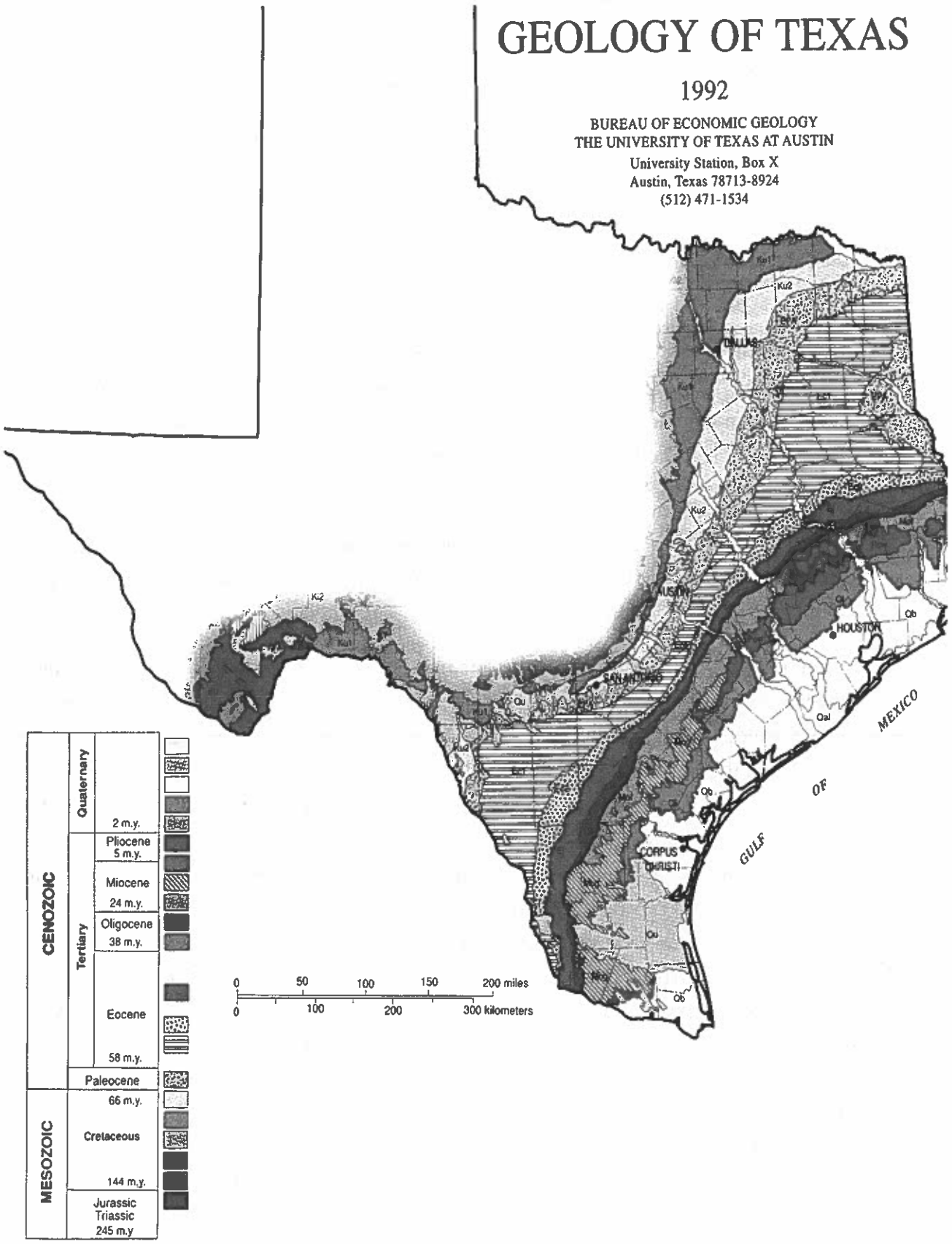


Figure 3.1

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begin filling the basins. From 286 to 245 million of years ago during the Permian, marine reefs and banks are growing in the shallow waters in west Texas to the west of the Ouachita Mountains.

As you continue watching the mountains, you notice that they are being quietly eroded away. At the end of 200 million years, this erosion has worn them nearly flat. You notice rumbles of change are beginning again. The super continent, Pangaea, is beginning to split apart. The opening occurs just to the south and east of the Ouachita Mountains. It is breaking apart on the southern edge of the Ouachita mountain range. You realize that the two continents that you see moving apart are North and South America. A depression begins to form between them.

During the Jurassic period (208 to144 million years ago), the breakup of Pangaea continues. Far to the northwest you see that the Rocky Mountains are rising. The Gulf of Mexico is beginning to form below you as the other continent (South America) moves away. At the beginning, the Gulf is a shallow sea that is not well connected to the other oceans. As a result, it dries up often and layers of salt are deposited. By late Jurassic, it has widened into a small ocean, the Gulf of Mexico.

You see dinosaurs roaming the area, and some leave tracks and trails in the slimy mud flats bordering the shallow waters. As you look closer, you see the first kinds of flowering plants appear. Some small rodent-like animals appear. These are the first mammals.

Time continues to move and you are now in the Cretaceous Period (144- 66 million years ago). The continents continue to move apart to the west, and shallow seas fill the area below you to the current area of the Gulf of Mexico. The seas spread over the area were land was. The Ouachitas were quietly eroded nearly flat and now you see Cretaceous seas cover the area. These seas reach all the way to the foot of the Rocky Mountains that are moving up. The shallow seas are filled with calcareous-shelled organisms, and thick deposits of limestone are forming. The warm Cretaceous climate results in the formation of light-colored, flat-lying limestone from north of Dallas through Central Texas to the Big Bend. These seas spread sediments that will become limestone, sandstone, marl and mudstone over much of Texas. Slowly thousands of feet of limy rock are laid over the old Ouachita mountain range. On the sandy shorelines and mudflats of these seas, dinosaurs are roaming freely, leaving evidence that will become fossilized footprints and trackways across Texas. Although you see dinosaurs everywhere, marsupials and bats appear. The number of flowering plants is increasing. The warm shallow waters are not completely quiet. In the shallow water near Austin, a volcano erupts as well as several near Uvalde.

Your view goes blank for a time. Think about what you heard and visualized. Examine Figure 3.2. Mark the location of Texas. Note the configuration of the continents. Next to each figure explain what is happening in Texas and the Gulf of Mexico and why it is happening.

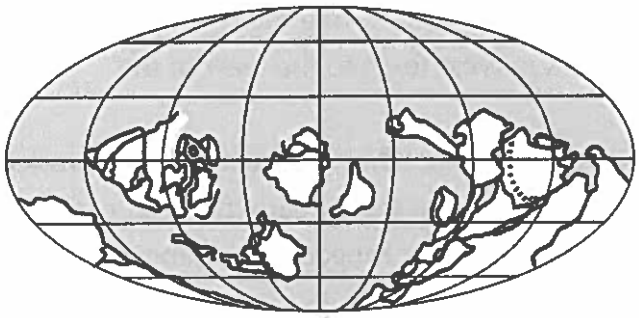


Fig. 3.2a. 540 million years ago

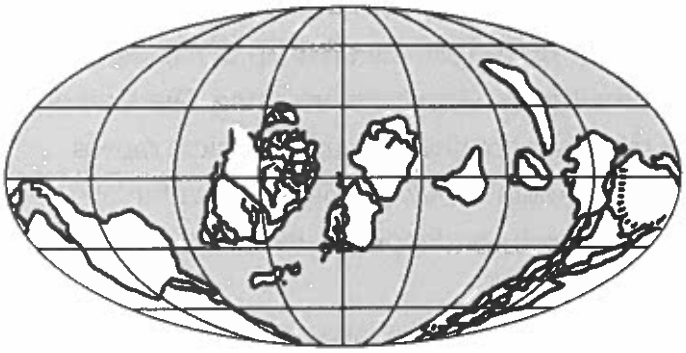


Fig. 3.2b. 480 million years ago

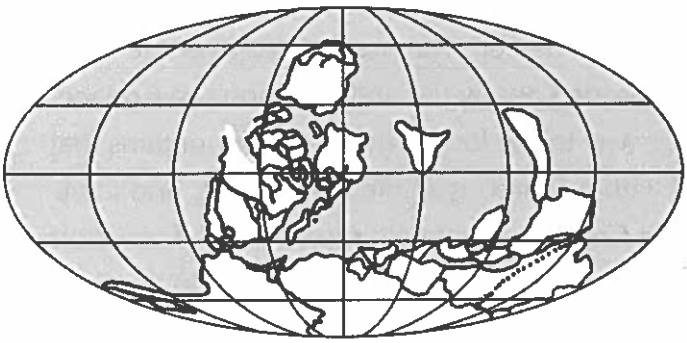


Fig. 3.2c. 420 million years ago

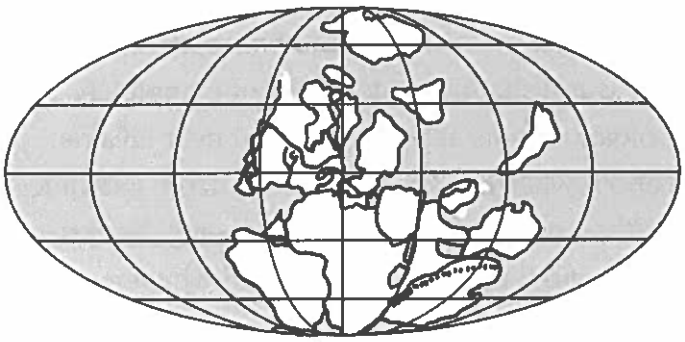


Figure 3.2d. 360 million years ago

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Fig. 3.2e. 300 million years ago

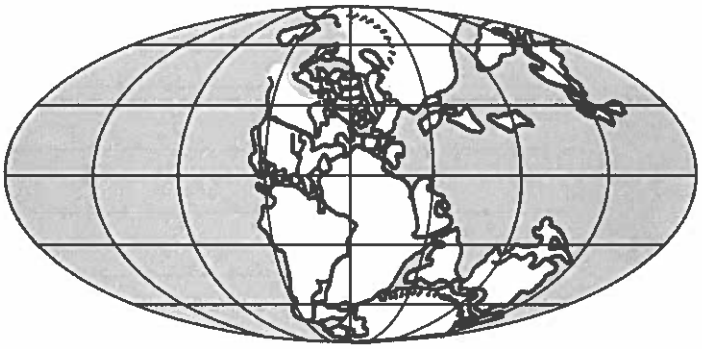


Fig. 3.2f. 240 million years ago

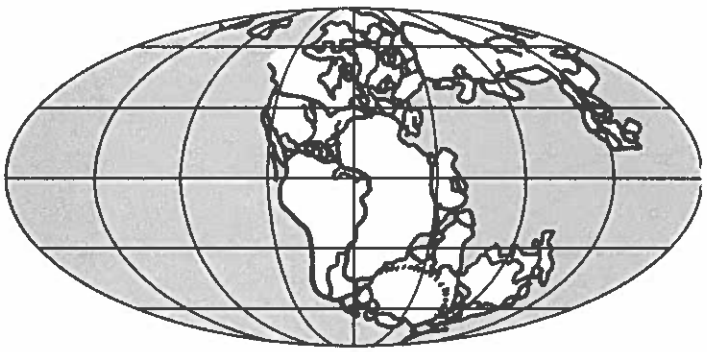


Fig. 3.2g. 180 million years ago

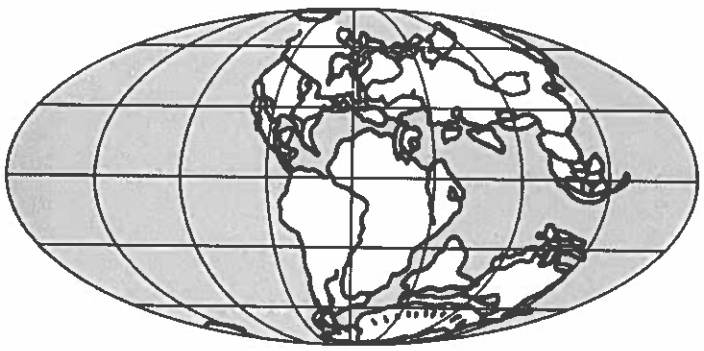


Fig. 3.2h. 120 million years ago

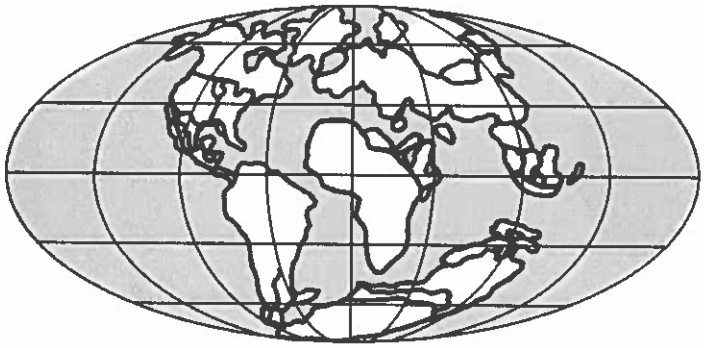


Fig. 3.2i. 60 million years ago

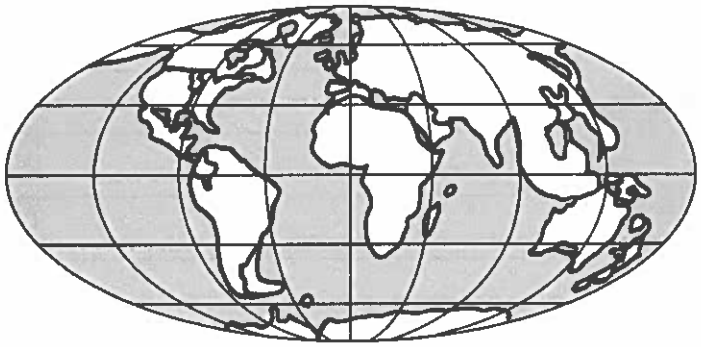


Fig. 3.2j. Present

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Part II - Can you make a model of the formation of the Gulf of Mexico?

1. Using Figures 3.1 and 3.2e-3.2j, and also narrative from Part I, your team is going to create a model to demonstrate the formation of the Gulf of Mexico. Set up a stream table or a large pan on a table. Obtain two boards or large flat rocks. They will represent two continents (North and South America). Place them in the center of the tray next to each other so they touch. Obtain a moist mixture of different soils, sand and gravel (aquarium gravel). Place these in layers to cover the "continents" to a depth of 5 to 8 cm. Add water to a depth 2 cm around the "continents".

   This represents Pangaea around 200 million years ago when erosion has flatten the Ouachita Mountains at the edge of the North American continent.

2. Slowly move the rocks or blocks apart to represent Pangaea breaking and moving apart. Describe and sketch what happens to the area between the continents as they pull apart.

3. Continue to move the "continents" until they are 20 cm apart. Add water until the depth of the water is 4 cm. Describe what happens.
4. Reread the narrative of the formation of the Gulf of Mexico. Does your model support the narrative what geologists believe happened? Explain.

5. How does your model differ from the narrative?

6. What could you do to improve your model?

7. Test your improvements. Evaluate and describe the effects.

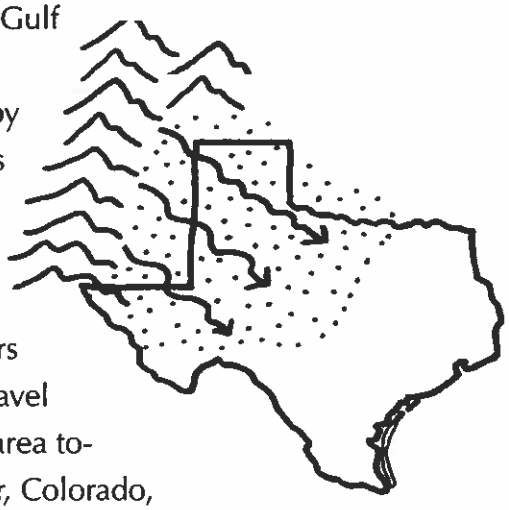
2. How Was the Gulf Coastal Plain Formed?

Geologist_____ **Team**_____

On the surface, the Gulf coast does not appear to have a very interesting geologic history. It is appears to be a flat plain. Looking under the surface geologists have found that spectacular events have occurred under the flat cover. You and your team will be investigating what is beneath this area to learn its geologic history.

Procedure:

1. For an overview of a trip through time you are about to take, look at the geologic map of Texas. Figure 3.1 (page 72) in the "How was the Gulf of Mexico Formed?" Note the pattern of the formations to the east and south of the 'S' curve from Dallas-Ft. Worth, through Waco, past Austin and San Antonio. You are going to travel back in time to see how the shoreline moved from this 'S' curve to its present location.
2. Now we are ready to begin your travel back in geologic time again. Get yourself comfortable. Close your eyes. Just do your best to imagine the things that will be described. Imagine you are moving back in time to a period 66 million of years ago when your view went blank. You are again viewing the state from above an area between Austin and the Texas coast. The dinosaurs are gone. The plant life continues unchanged as do the birds.



It is the Tertiary period (58 million years ago), the Gulf of Mexico begins to fill. Layer upon layer of gravel, sand, silt and clay are being deposited into the Gulf by large rivers. You wonder from where all the sediments are coming. Something big must be eroding to produce that much sediment. As you look west to the Rocky Mountains, you notice that from the very tall Rocky Mountains in Colorado and New Mexico, rivers have carried a huge apron of gravel and sand. This gravel and sand is spread over Texas from Dallas-Ft. Worth area towards the Rockies. As you are watching the Red River, Colorado, Brazos and other smaller rivers are eroding back this apron of Rocky Mountain sediments. The rivers deposit these sediments in the Gulf of Mexico. The deposits form inclined wedges of sediments that are arranged like a tipped stack of books. These wedges of sediment have grown for 10 million years and continue today.

During this time period, grasses appear on the sediments that have been deposited. You see primates, rodents, elephants, horses, pigs, hippos, cattle and deer grazing on the grasses.

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Now it is 10 to 20 million years ago. As you are watching the Dallas to Austin-San Antonio area, you see the earth move upward. Earthquakes are causing the Cretaceous block of rock west along the line from Dallas to Waco, then Austin to San Antonio and on to Uvalde to move up nearly 2,000 feet as one mass. This fracture follows the line of the buried Ouachita Mountains and is known as the Balcones Fault.

The scene below you continues and moves to recent times, erosion continues. The rivers cut across this block of limestone and continue to bring sediments from the high plains to the Gulf. The Red, Sabine, Brazos, Colorado, Pecos and Rio Grande Rivers continue eroding and filling in the Gulf of Mexico. So much sediment is deposited that the weight pushes down on the crust underneath. This causes the rock to crack forming faults. The filling does not stop, and you realize that it has filled past today's shoreline. The shoreline is 50 to 140 miles further than the present-day shoreline. The rivers continue to flow across this shelf of the Gulf. Upstream these rivers are cutting deep valleys, some more than a 100 feet deep, into the coastal plain so they can flow with a smoother slope to a more distant shoreline.

Now you notice that the sea level is rising. The river currents also slow as the sea level rises, so more sediments are deposited and the valleys are filled. You wonder why this is happening. You realize that the climate is much cooler and it is the end of the Ice Age, 18,000 years ago. Because of the large amount of the earth's water that is frozen in the ice sheets sea level is 300 to 450 feet lower. Rhinoceroses, elephants, wooly mammoths, camels, horses, saber-tooth cats and dire wolves are the animals that you notice.

Now it is around 9200 B.C., 40 to 50 miles from the shoreline (today this is McFaddin Beach), you see your first humans. They are camped on a ridge top site overlooking a tributary of the old Sabine River. They are hunting the mammoth and other Pleistocene animals.

Now the scene moves to around 8000 B.C., the Pleistocene or Ice Age has ended. The climate, plants and animals are very similar to those that you see today. You also see tribes and bands of hunters and gathers moving across the area. This warming of the earth's climate has caused the ice sheets to melt. The water is returning to the oceans and the sea level begins to rise. It rises to within 15 feet of the present sea level. As the sea moves landward, you watch the shelf and river mouths flooding. The river mouths are slowly drowning as the shoreline moves 30 to 35 miles inland. Upstream the rivers drop their sediments to adjust to their slope to meet a higher sea level. The rising sea level is covering the sandy beaches of the past. It is 2800 years ago, and the sea level is now the same as it is today. As you are watching, you notice that the waves are moving this sand on the higher submerged land between the old Ice Age rivers. These are becoming small segments of barrier islands. These segments continue to grow and merge to form the long barrier islands of today's coast.

As you review what has happen over the last 200 million years, you notice that thick layers of over 15,000 meters (50,000 ft) of sediment have been deposited in the Gulf. Each layer is different because of the kind of sediment washed down from the continent or formed by dead marine life. At times, the deposits were sand, forming sandstone; at other times, fine grains of silt and clay formed shale rock. In addition, salt was deposited by water evaporating in shallow areas of the Gulf. In other places, marine plants and animals built on sediments forming reefs. Where marine life was plentiful, limestone was deposited. Your quick trip through time ends at this point.

2. Think about what you heard and visualized. Examine Figure 3.1 again. Notice how rocks east of the sweeping 'S' curve line are parallel to the line. All are also younger than the Cretaceous and get younger toward the Gulf of Mexico. Use Figure 3.1 and the narrative to explain this pattern.

3. Examine Figure 3.4, the map showing how the shoreline of North America has built towards the Gulf. Compare the shoreline at the end of the Cretaceous to that of today.

4. Notice the location of the shoreline 18,000 years ago. How did it differ from the shoreline location today?

5. What is the explanation why the shoreline location 18,000 years ago differs from today's location?

6. Construct a Time-Line Chart similar to the example below by citing the significant events for each period.

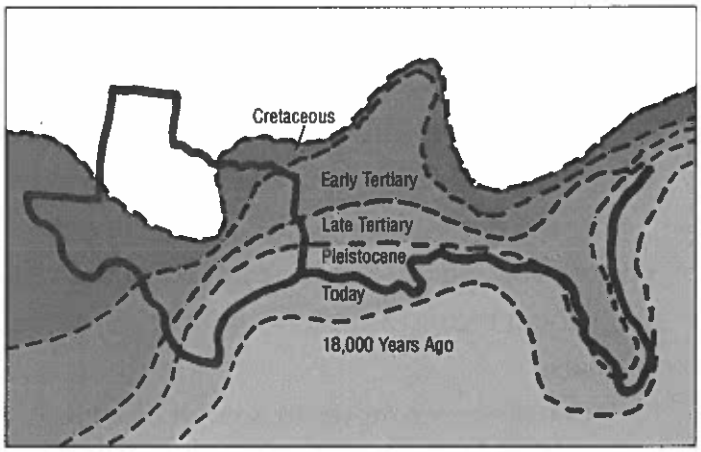


Fig.3.4 Progression of shoreline into the Gulf of Mexico.

Years	Geological Period or Era	Events

7. Summarize what has happened to the shoreline of Texas and the southern United States.

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3. Can a Model Demonstrate the Development of the Gulf Coastal Plain?

Geologist_____ **Team**_____

To learn about the history of the Gulf coastal plain, geologists assume that physical and geological forces that occurred in the past are the same today. They study processes as they are happening today. Geologists also study core samples from wells that have been drilled into the Gulf coastal plain. From this information they have developed a picture of the formation of the coastal plain. You and your team will used a stream table to create a model to see if it fits the geological narrative of the formation of the coastal plain.

Materials: ruler, stream table or large aluminum or plastic pan, different types or colors of sand and soil, small aquarium gravel, large flat rock or block of wood or plaster mold, water, plastic cup

Procedure:

Part I: How did the Gulf Coastal Plain form (model)?

1. Using the figures and narrative from the "How was the Gulf Coastal Plain Formed?" activity, your team is going to create a model to demonstrate how the Gulf coastal plain formed and changed over time. Refer to the narrative in "How was the Gulf Coastal Plain formed?" as needed. Set up a stream table or a large clear plastic pan on a table. Obtain a large flat board or rock, to represent the core of the continent in north of the 'S' curve line in Texas. Place it near one end of the stream table or pan. Obtain different types of soil, sand (different colors) and small aquarium gravel. Moisten each type of soil and sand. Place the seven to 10 different types of soil, sand and gravel as layers on top of "continent" to cover it to a height of 10 to 15 cm. Fill in the area from the 'continent to the bottom of the pan or "Gulf" to form a gentle slope. Create some river valleys from the "continent" to the Gulf. Use another wooden block to raise the end of the stream table or pan slightly under the continent. Add water to the bottom of the Gulf until it is 2 cm deep. Sprinkle water over the "continent" so it begins to run into pan.

2. Construct Table 1 (Changes over Time) and record your observations. How is the model like the Gulf Coast at the end of the Cretaceous?"

Table 1. Changes Over Time

Time Period	Land Area	River and River Valley	Shore Line	Continent Edge	Gulf of Mexico
End of Cretaceious 66 million years					
Tertiary Period 58-30 million years					
Balcones Fault 10-20 million years					
Balcones Fault to Ice Age					
Ice Age					
End of Ice Age to Present					

3. How does the model differ from the Gulf Coast?

4. Slowly sprinkle water over the continent so that the water runs to the end of the pan (the Gulf). Record the changes that occur on the land surface, the river, the shoreline and the Gulf itself. Keep sprinkling water until two to three layers have eroded from the top of the "continent" (use a cup to remove water from the end of the pan if it fills up). Record the changes in Table 1. (Tertiary Period)

5. What depositional features formed? Describe and sketch them.

6. Did the rivers form deltas? Was there a pattern? Explain and sketch their formation.

7. Was there a pattern to the deposition of the different size particles (silt, clay, sand and gravel)? Where and when were they deposited? Explain and sketch.

8. About 10 to 20 million years ago, the cretaceous block of rock west of the 'S' curve line moved up 2,000 feet. Demonstrate this by carefully raising the block about 1 cm. Be careful to disturb as little of the soil, sand and gravel as possible. Then sprinkle water (rain) on the land surface so that water runs into the Gulf. Continue sprinkling water until two to three more layers have eroded. Record the changes in Table 1 (Balcones Fault). What was the effect of this fracture and uplifting?

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9. Record in Table 1 (Balcones Fault to Ice Age), continue sprinkling water until two or three layers have eroded. Use toothpicks to mark the shoreline. What is happening in the Gulf of Mexico basin? What is happening to the shoreline? Explain and sketch.

10. Measure the depth of the water in your model of the Gulf of Mexico. Measure the location of the shoreline. To determine what happens during the Ice Age when water from the oceans froze and form ice sheets, use a cup to remove water to lower the water depth by 2 to 3 cm. Sprinkle water on the land surface until one layer is eroded. Record in Table 1 (Ice Age) what happened during the Ice Age. Use a toothpick to mark the shoreline. Where was the shoreline located? What happened to the rivers and the river valleys?

11. Around 8,000 B.C. the Ice Age ended and water is returning to the oceans as the ice sheets melt. The sea level begins to rise. To model this add water to the raise the water depth by 1.5 cm. Sprinkle water over land to erode another layer and the water level of the Gulf is raised another 1.5 cm. Record what happened in Table 1 (End of Ice Age to Present).

12. Compare the narrative and the data in Table 1. How is the model like the narrative? Explain.

13. How does the model differ from the narrative?

14. Examine the patterns in Figures 3.1 and 3.2 in "How was the Gulf of Mexico formed?" Does your model explain the patterns? Explain.

Part II: What is a Cross section of the Gulf Coastal Plain Like?

1. Remove the water from the table or pan. Make two lines (4 cm from the edge on each side) the length of the pan from the original continental edge (the wood block) to the shoreline. Place a piece of cardboard or clear plastic along each line. Carefully work the piece to the bottom of the stream table or pan. Then remove the sediment between the cardboard and the sides of the table or pan. Describe and sketch the cross section of the deposited layers on each side.

2. How were the sediment layers alike? How did they differ?

3. Based on your observations, predict what a cross section of the sediments through the center of the stream table or pan would look like? Make a sketch of your prediction.

4. Use a piece of cardboard or plastic to divide the pan in half. Remove the sediments from one side to observe the cross section. Describe and sketch the cross section. Was your prediction correct? Explain.

5. Figure 3.5 is a cross section of the Gulf of Mexico from the work of geologists. Compare it to the cross section that your model formed. How are they alike? How do they differ?

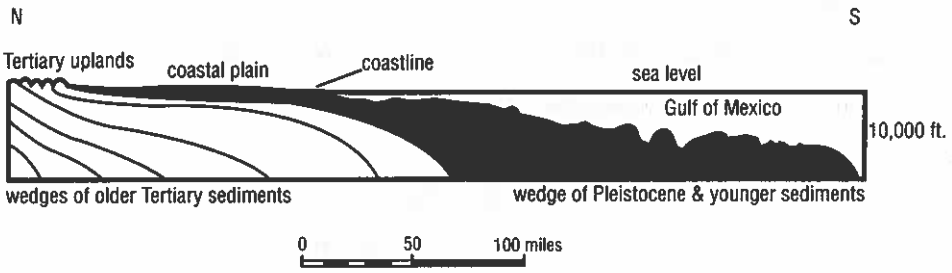


Fig. 3.5. Cross section of the Gulf Coast

6. Evaluate your model. How well does it demonstrate the processes that formed the Gulf Coast over time? Explain.

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4. Where Was the Texas Coast in the Past?

Researcher _____ **Team**_____

Geological history is known only by understanding the biological, physical and chemical forces which exist today. We know that certain types of animals live in the sea; therefore when we find fossils of similar animals in inland rocks, we know that the rocks had a marine origin.

Oysters, for example, live primarily in brackish water. If we find a large number of oysters in rocks we can logically interpret the ancient environment as brackish. Conversely, if fossils of land animals are found in rocks, then the environment was land. If fossil land animals are found with brackish snail and clam shells, however, then the dead land animals were carried by streams from the areas where the animals lived and died. Maps of the geologic history of Texas have been constructed based on this knowledge and fossil discoveries.

You are going to analyze maps of Texas from the Lower Cretaceous to the present to learn more about the Texas coast in the past.

Materials: Maps of Texas (Cretaceous to present)

Procedure:

1. Examine the maps of Texas from the Lower Cretaceous to the present. How has the Texas coast changed from the Cretaceous to today?

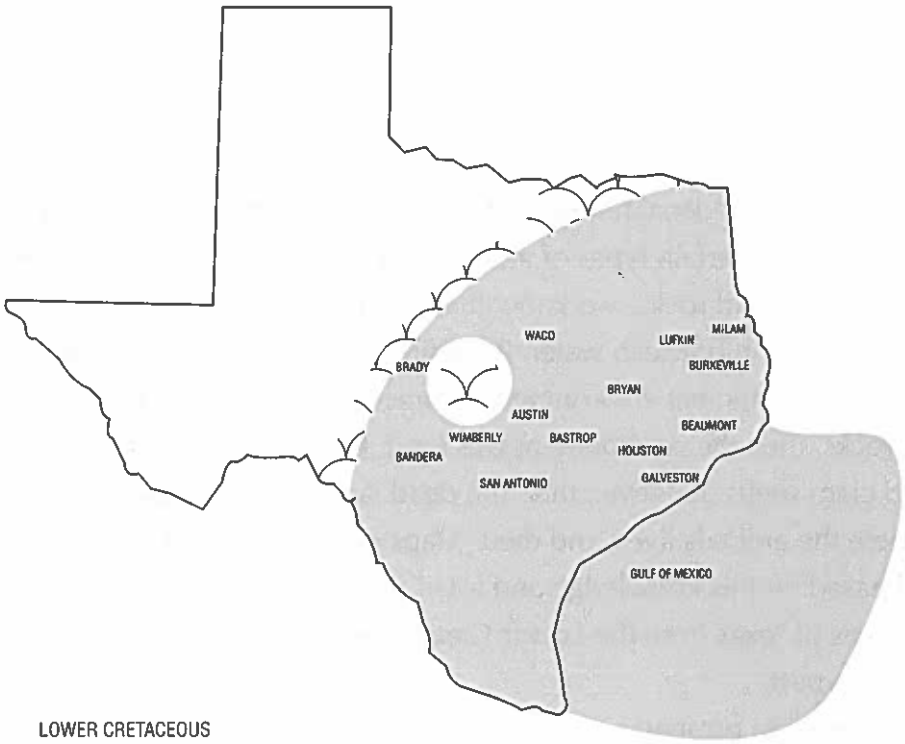
2. Use the maps to construct a table similar to the one on page 89.

3. Use the table and the maps to answer the following:
   a. Explain why fossil sea urchin, oyster, clam and other sea shell fossils are found around Austin?

   b. What cities would have been on the shoreline of the Gulf of Mexico during the upper Cretaceous?

   c. Dinosaur tracks and trails of a giant Sauropod are found in the bed of the Blanco River (west of Austin) and in the Paluxy River at Glen Rose (south of Dallas). A fossil mosasaur was found in Onion Creek near Austin. What possibly were the environmental conditions when they formed in the Cretaceous?

   d. Clay used to make bricks is found east of Austin in the Bastrop area. Explain why clay deposits are found there and when these were probably deposited.

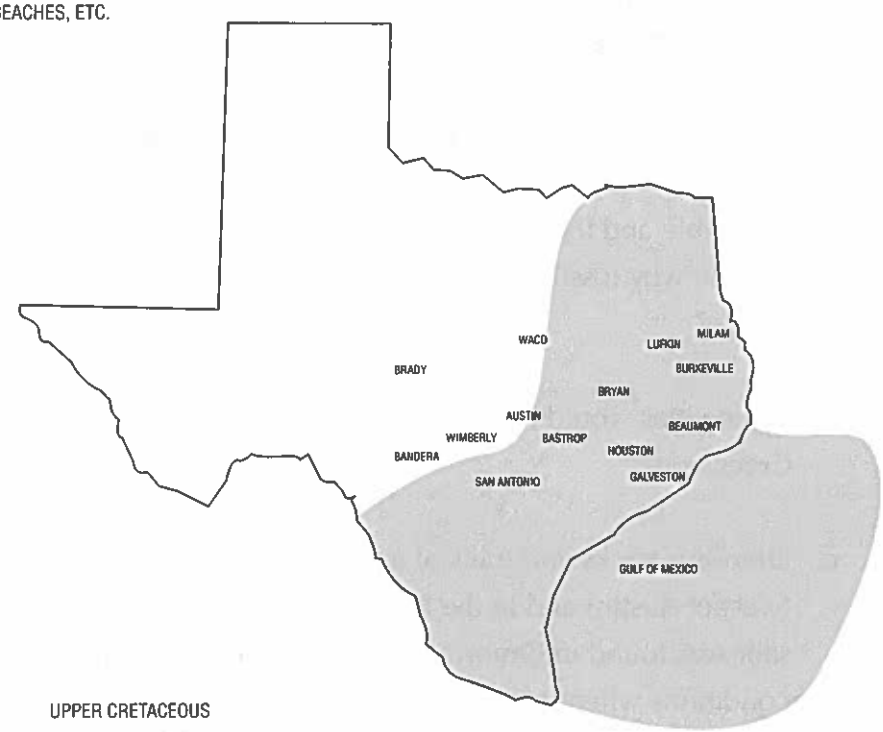


LOWER CRETACEOUS

LAND

TRANSITION ZONE -COASTAL BAYS, LAGOONS, MARSHES, DELTAS, BEACHES, ETC.

SEA



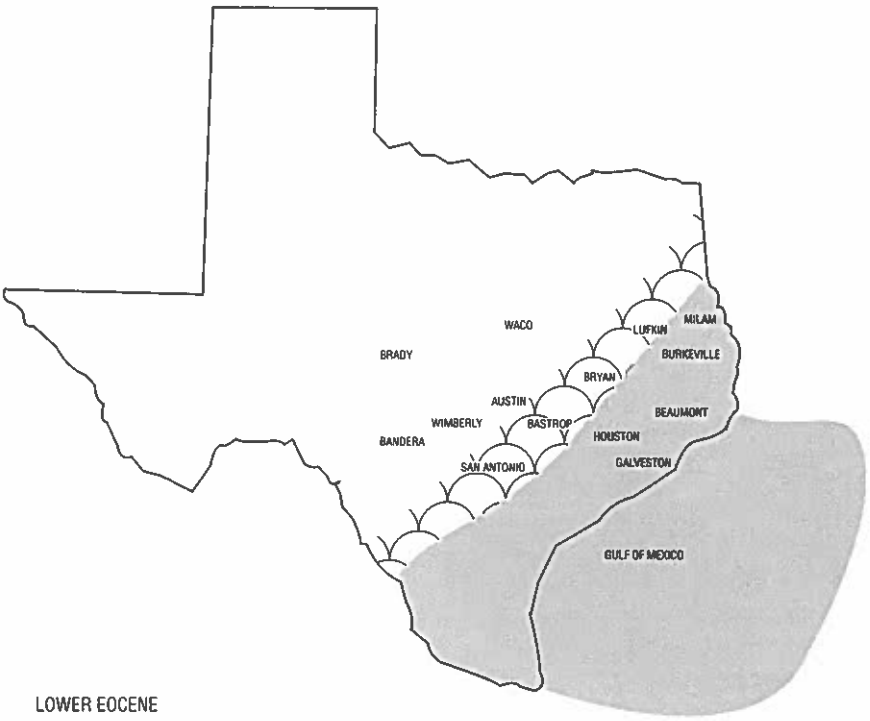
UPPER CRETACEOUS

LAND

TRANSITION ZONE -COASTAL BAYS, LAGOONS, MARSHES, DELTAS, BEACHES, ETC.

SEA

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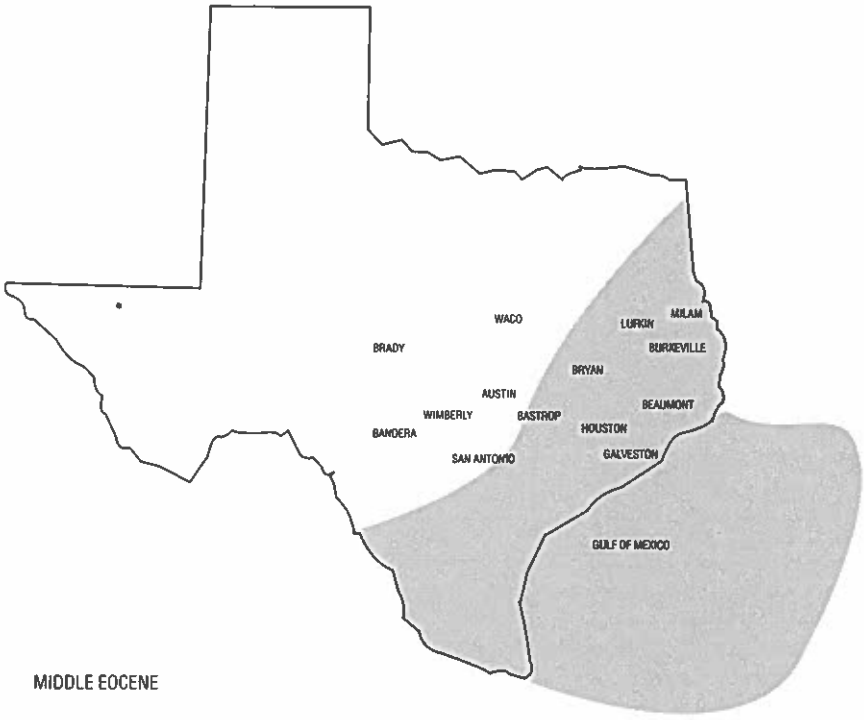


LOWER EOCENE

LAND

TRANSITION ZONE -COASTAL BAYS, LAGOONS, MARSHES, DELTAS, BEACHES, ETC.

SEA

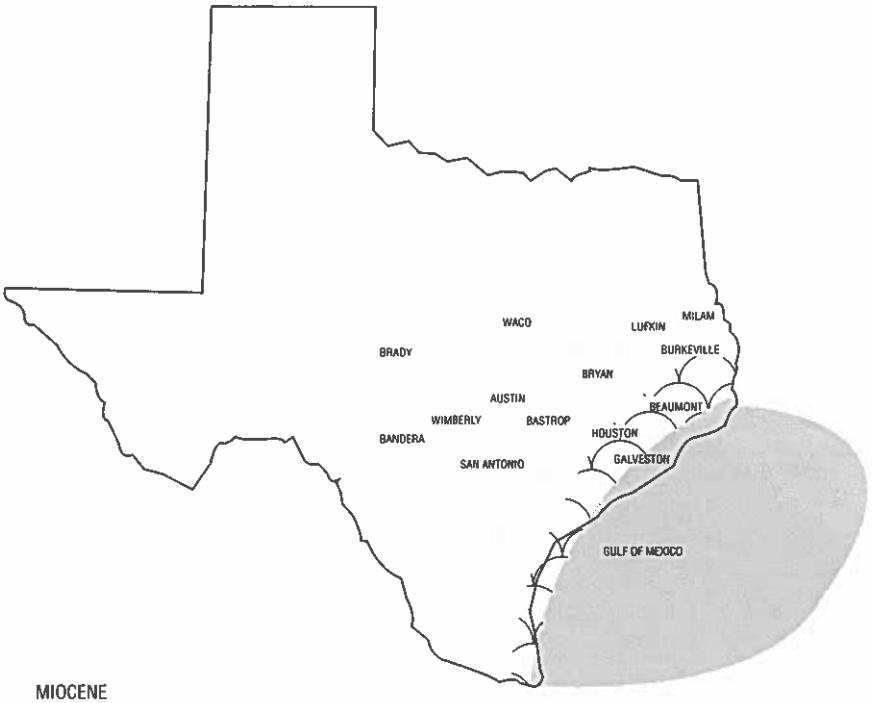


MIDDLE EOCENE

LAND

TRANSITION ZONE -COASTAL BAYS, LAGOONS, MARSHES, DELTAS, BEACHES, ETC.

SEA



MIOCENE

LAND

TRANSITION ZONE -COASTAL BAYS, LAGOONS, MARSHES, DELTAS, BEACHES, ETC.

SEA



PLEISTOCENE

LAND

TRANSITION ZONE -COASTAL BAYS, LAGOONS, MARSHES, DELTAS, BEACHES, ETC.

SEA

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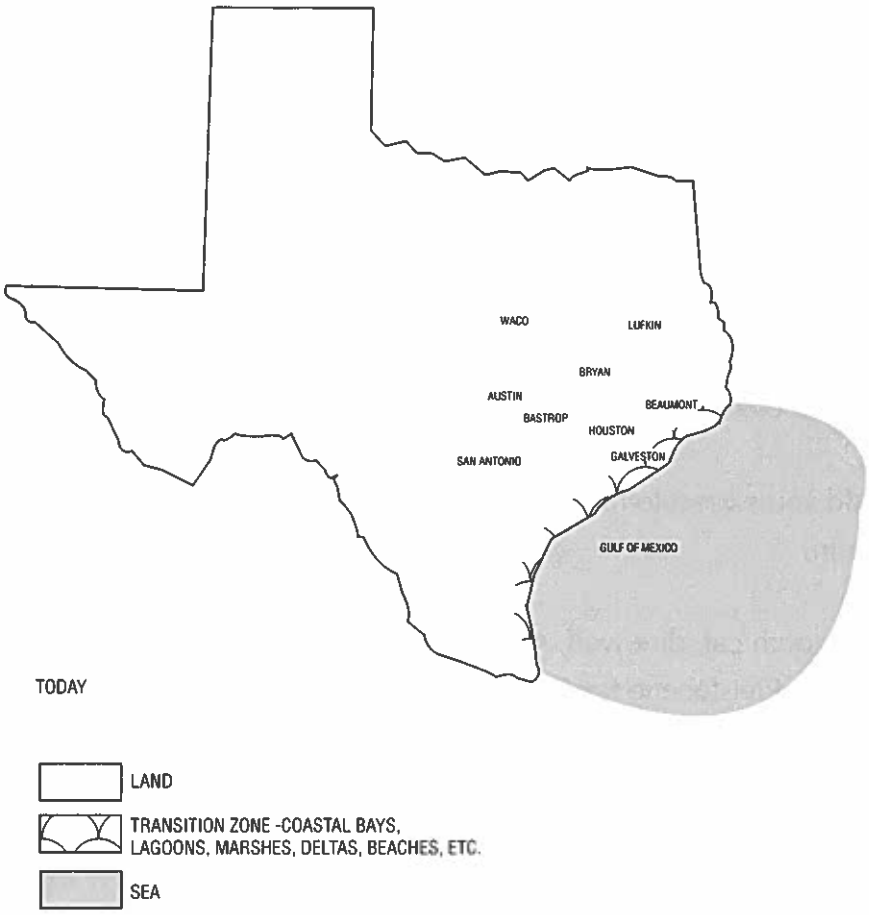


Table 1. Changes Over Time

Geologic Period	Age in Millions	Location of Transition Zone	Area under the Sea
Recent — Today			
Pleistocene	1		
Miocene	15 - 25		
Middle Eocene	45 - 50		
Lower Eocene	50 - 60		
Upper Cretaceous	65-90	Waco, Austin, Wimberley	East of Waco, all areas south of Austin, including San Antonio
Lower Cretaceous	90 - 144		

e. Bastrop State Park has sand and clay outcrops. Under what conditions were these deposited and when?

f. In an area 60 miles from Austin towards Bryan, fossilized Palm wood logs are found. Explain what the environment must have been like in the past when the Palm trees were growing.

g. Giant pig-like artiodactyl fossils were found in the Miocene formations of the Texas Coastal Plain. Where was the coastal plain at the time?

h. What kind of fossils would you expect to find in the Miocene deposits between Beaumont and Houston? Explain.

i. The giant land sloth, saber-tooth cat, dire wolf, mastodon, wooly rhinoceros, horses and camels were some of the Pleistocene fossils that were found. These were often found in the sand and gravel pits of the Gulf Coast Plain. Explain why.

4. Lignite, which is compressed plant material, is found in a wide band in Eocene deposits. It was deposited in muddy areas between river channels where plants grew abundantly in these swampy areas. Where is this band of lignite located?

5. Examine the map of the Pleistocene time. Where was the shoreline of Texas located?

6. Archeological evidence has revealed that the first people came to the Texas coastal region about 12,000 years ago during the ice ages. If you were looking for shoreline campsite remains where would you have to look?

7. How does the Texas shoreline during the Pleistocene differ from the Texas shoreline today?

8. Use the maps to explain why sand and gravel are readily available in all areas.

9. Rich, organic sediments are associated with the oil and gas deposits found in northeast Texas, central Texas, south Texas and the coastal zone. Use the maps to explain why oil and gas are found in these areas.

10. Summarize the relationship between the Texas coastal plain and the fossil remains that are found.

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5. What Prehistoric Organisms Were Present in Texas?

Paleontologist _____ **Team**_____

The origin of life was perhaps the greatest of all events in biology. The processes involved were numerous and extraordinarily complex. The Earth's beginning occurred 4.6 billion years ago. The transition from nonliving to living occurred at some point in time beyond 3.5 billion years. Our knowledge of this ancient time is very sketchy. The Earth's processes of plate tectonics, erosion and deposition have destroyed much of the early rock record. Paleontologists study the prehistoric forms of life through the study of plant and animal fossils. You will analyze and organize data to learn more about prehistoric life.

Materials: copy of **Prehistoric Organisms**, **Texas Fossils, Guidebook 2** (Bureau of Economic Geology), or **A Guide to Fossils of Texas** (Texas Monthly Field Guide Series)

Procedure:

1. Read Prehistoric Organisms in the Texas Coastal Zone. Use the information from the reading and complete Table 1. List the major events and ages and the fossils found in Texas. Use reference books (**Texas Fossils** and **A Guide to Fossils of Texas**) to add additional details about Texas fossils to each period.

2. From the reading, you noted that early organisms in the Precambriam did not have hard parts. How would this affect fossils that one would be able to find? How does this affect the fossil record and what we know about that time?

3. Explain why the development of hard parts, such as shells, was important to the animal. Give examples of the benefits.

4. Explain why only fossil marine organisms are found up to the late Devonian.

5. Explain the advantages and disadvantages of fish that had both gills and lungs.

6. What is the difference between amphibians and reptiles? Relate these differences to the environment best suited for each to live.

7. The Paleozoic ended with the Permian Period. By the close of the Permian Period, 75 percent of the amphibians and large numbers of plants had become extinct. Some indicate the cause may have been a climate change. What would support this?

Table 1.

Era	Period	Million years	Epoch	Events	Fossils found in Texas
Cenozoic	Quarternary	0.01	Holocene		
		1.6	Pleistocene		
		5.3	Pliocene		
	Tertiary	23.7	Miocene		
		36.6	Oligocene		
		57.8	Eocene		
		66.4	Paleocene		
Mesozoic	Cretaceous				
	Jurassic	144			
		208			
		245			
	Triassic	245			
Paleozoic	Permian	286			
	Pennsylvanian	320			
	Mississippian	-360			
	Devonian	-408			
	Silurian	438			
	Ordovician				
	Cambrian	505			
		570			
	Precambrian	4600			

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8. The Mesozoic environment was drier, and the shell egg developed. Explain the importance of the eggs with shells to domination by the reptiles.

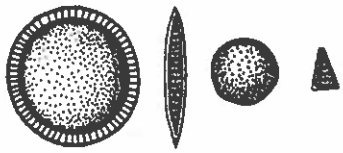
9. What are some possible explanations for development of grasslands, large plant-eaters and meat-eaters in the Tertiary?

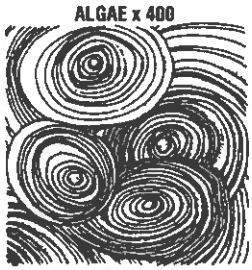
10. Explain why marine fossils are not found in Texas during all time periods.

11. Summarize the relationship between the organisms and the environments of the past. What is the effect of environment changes? Which organisms survive and which become extinct?

Prehistoric Organisms in the Texas Coastal Zone

Where did life begin? There are good reasons for thinking that it originated in the sea. The sea contains the salts important to the health and growth of organisms. In addition to providing nutrients the oceans moderated the temperature. The oceans also shielded delicate living tissue from deadly rays and protected life as it began.


DIATOMS x 900

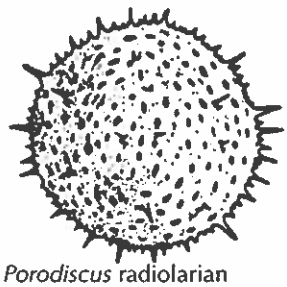


The most common Precambrian fossils are stromatolites. These are not actual organisms, but are materials deposited by algae. Stromatolites are indirect evidence of algae because they look like deposits made by algae today. The actual remains of tiny organisms have been discovered in rocks older than 3.5 billion years. These early remains are bacteria and blue-green algae that lack a nucleus. More advanced organisms that have cells with an organized nucleus are found in rocks that are a billion years old. During the Precambrian, life-forms did not have hard parts such as shells, scales, bones or teeth. The late Precambrian does include evidence of marine algae, radiolarians, worm burrows, sponge spicules, brachiopods and coelenterates.


Typical radiolarian (*Actinomma*)

Life in the early Paleozoic time was restricted to the seas. Vertebrates did not exist. An abundance of marine invertebrates is found in the Cambrian period, which began 600 million years ago. These included radiolarians, worms, coelenterates, sponges, bryozoans, brachiopods, cephalopods, mollusks, echinoderms and arthropods. There were many unfamiliar forms that did not have shells or skeletons. It was the golden age of *trilobites*. They were seldom larger than 30 centimeters. More than 600 genera of these mud-burrowing scavengers lived worldwide.

The beginning of the Cambrian period brought an important change. This was the first time that animals appeared that had hard parts, such as shells. The hard parts had many useful purposes. They could grow larger. The hard parts protected the soft parts and they could function in a more controlled environment.


Porodiscus radiolarian

In Texas, many invertebrates were present in the Cambrian Age and are abundant as fossils in marine formations. These include foraminifera, radiolarians, sponges, jellyfish, corals, sea anemones, bryozoans, brachiopods, chitons, tusk-shells, gastropods, crinoids, pelecypods, cephalapods and echinoderms.

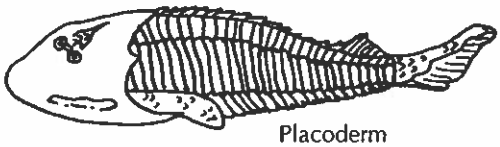
By Ordovician times (505-438 million years ago), brachiopods outnumbered the trilobites. The brachiopods were no larger than 20 centimeters. During this time period, the cephalopods were abundant. They were mobile and highly developed mollusks that were the major predators. They were the ancestors of today's squid, octopus and

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nautilus. They were the first large animals. One species reached a length of nearly 10 meters. Also armor-plated fishes began to evolve.

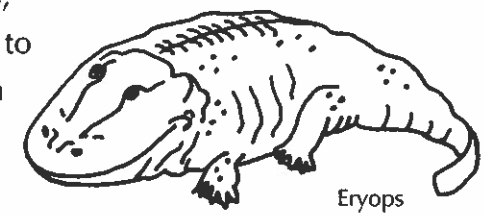
During the late Paleozoic, the animals greatly diversified. About 400 million years ago, plants that were adapted to living at the water's edge began to become land plants. These early plants were small leafless spikes that were only about 6 - 8 centimeters tall.

It was during the Devonian Period (408-360 million years ago) that other fishes evolved. This included primitive sharks that had skeletons of cartilage and the bony fishes. These are the groups to which most modern fishes belong. Because of this it is often called the "age of fishes." In Texas, the cartilaginous fishes include the sharks, skates, rays and Rat fishes. Shark teeth are found in Texas from the Pennsylvanian formations to the Miocene. These are probably the most common vertebrate fossils in Texas.

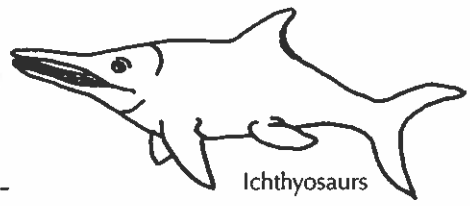

Placoderm

The bony fish, however, are the most numerous, successful and varied of all aquatic vertebrates. They have adapted themselves to all kinds of water. The bony fish have an internal bony skeleton, well-developed jaws, an air-bladder and typically, an external covering of scales. The remains of bony fish have been collected in many places in Texas. Osteolepis is one of the early bony fish. Coelancanths were once thought to be extinct since the Cretaceous Period (128 million to 62 million years ago), but in 1938 and 1972, and even more recently, living specimens were captured in the deep water off Madagascar.

By the late Devonian time, two groups of bony fishes, the lung fish and the lobed-finned fish became adapted to land environments. They had primitive lungs in addition to their gills. Over time, the lobed-finned fish began to use their lungs more than their gills. By the late Devonian time, they had evolved into true air-breathing amphibians with fishlike heads and tails. Insects were already on land so there was plenty of food. There was no competition from other land animals. So the amphibians took on roles and forms that are similar to modern reptiles such as crocodiles. During the Mississippian (360-320 million years ago) and Pennsylvanian (320 –286 million years ago) large tropical swamps existed across North America. This was the "Age of Amphibians."


Eryops

The ichthyosaurs, short-necked marine reptiles that were fish-like in appearance, were the most abundant carnivores of the Mesozoic era (225 to 62 million years ago). They resembled modern dolphins and some reached lengths of 25 to 40 feet. The average length was about seven feet. Well-preserved fossils show they gave birth to live young. Many different species of


Ichthyosaurs

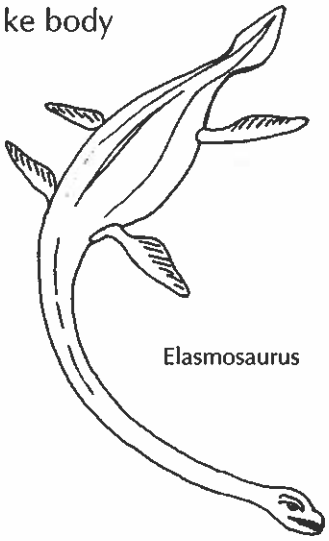
ichthyosaurs lived in the Mesozoic seas. One of the most interesting was the Eurhinosaurus, which had toothed jaws of unequal length. Their upper jaw was nearly twice the length of their lower jaw. Although the ichthyosaurs resemble fish or dolphins, there is no relationship between them. The similar appearance is only because of a very perfect adaptation to live in water.

The Mosasaurs are another group of extinct marine lizards. Some of these reptiles grew to be as much as 50 feet long and their gaping jaws were filled with many sharp, recurved teeth. They were present in the great Cretaceous (128 to 62 million years ago) seas, which covered many parts of Texas.

The Paleozoic ended with the Permian (286-245 million years). By the end of the Permian, 75 percent of the amphibian families had disappeared. Plants had also declined in number and variety. At least 80 to 90 percent of the marine life disappeared. This included all the trilobites, some types of coral and brachiopods.

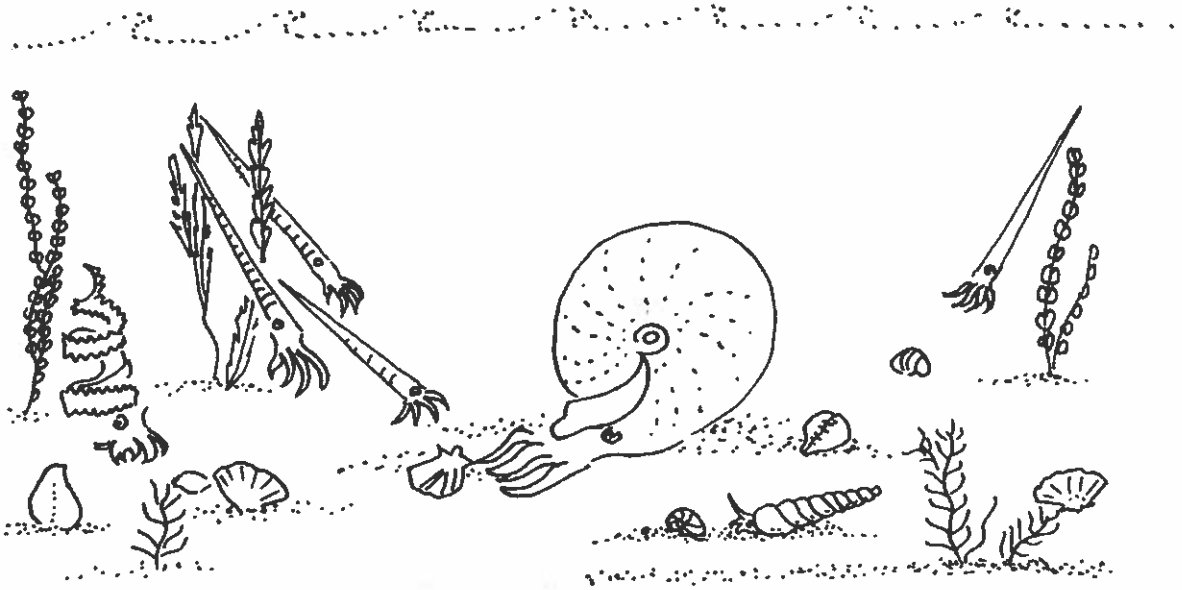
The Mesozoic Era was the breakup of the supercontinent, Pangaea. This era is divided into three periods: Triassic (245-208 million years), Jurassic and Cretaceous. This became the "Age of Dinosaurs." The environment became drier and the shelled egg developed. This meant that a water-dwelling stage was no longer a part of the life cycle of animals. With the development of the egg, the reptiles became dominant. The most awesome reptiles were the dinosaurs. During the Jurassic Period (208-144) is when most of the huge dinosaurs such as Apatosaurus, Brachiosaurus and Stegosaurus lived. The gymnoperms (cycads, conifers, ginkgoes) quickly became the dominant plants. During the Cretaceous (144-66.4 million years) shallow seas covered much of North America and the Gulf Coastal region. Great swamps existed during this time. Tylosaurus was the largest Texas mosasaur. Giant turtles, Archelon, which reached a length of 12 feet, also were present in these areas.

The Plesiosaurs were marine reptiles that had a broad turtle-like body and paddle-like flippers. Some were long-necked with small heads and long tails; others were short-necked and long-headed. They ranged in length from 15 to 40 feet. These reptiles were not streamlined or well-equipped for swimming as the ichthyosaurs or mosasaurs, but the long serpent-like neck and small head with a mouth full of sharp teeth were probably very useful in catching other small animals for food. The Elasmosaurus were long-necked Plesiosaurs. They were swimming reptiles, often 40 feet long, with four nearly equal-sized, paddle-like appendages.



Elasmosaurus

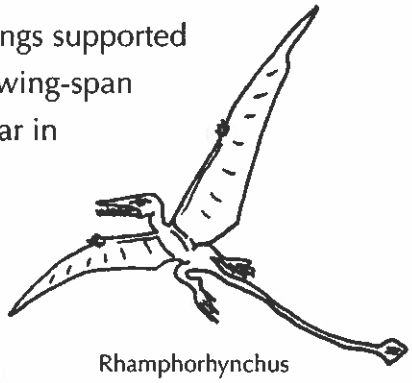
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Cretaceous Sea Floor (Source: Lien, 1979, Investigating the Marine Environment and Its Resources. © Texas Sea Grant)

The Trinacromerum was a pliosaur found in Texas during the Cretaceous Period. Ichthyosaurs and plesiosaurs were the carnivorous masters of the oceans. Hosts of ammonites (some up to six feet in diameter) were in the seas with gastropods, pelecypods, squids, echinoids, crinoids and foraminifera.

The Pterosaurs were the Mesozoic reptiles with bat-like wings supported by arms and long, thin "fingers." The huge Pterandon, with a wing-span of more than 26 feet, had a large skull that extended to the rear in a long, bony comb. The long pointed snout was toothless and excellently adapted to hunting fish and mollusks. The life of the Pterandon can be compared with that of the present-day albatross that inhabits the open sea. The Pterandon was a passive flyer, moving mainly in gliding flight, like the albatross that is able to move rapidly in the air without flapping its wings. The phytosaurs were a group of crocodile-like reptiles that ranged in length from six to 25 feet. Although resembling crocodiles both in appearance and habitat, they were a separate group and lived in Texas during the early mesozoic era (Triassic Period).



Rhamphorhynchus

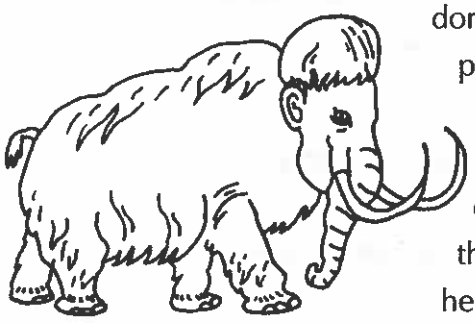
Alligators first appeared in the Tertiary Period while crocodiles appeared in the Cretaceous. They were much larger and more abundant during Cretaceous and Cenozoic times than they are today. The remains of both are found in Texas. In fact, the remains of the largest crocodile ever discovered were found in the state. It probably had an overall length of 40 to 50 feet, and its massive skull was six feet long with exceptionally strong jaws.

During the Mesozoic, the reptiles made some major adaptive changes. One group, the pterosaurs, developed huge membrane wings that allowed them to fly. Another group of

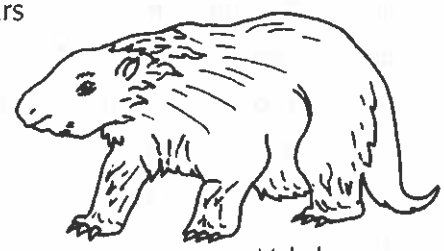
reptiles led to more successful flyers, the birds. Some reptiles returned to the sea. The included the fish-eating plesiours and ichthyosuars. These reptiles became good swimmers but they breathed using lungs and had reptile teeth. At the close of the Mesozoic, more than half the species, including many reptile groups, became extinct. This included the dinosaurs as well as numerous marine organisms. This mass extinction appears to have affected all land animals larger than dogs.

The remains of the extinct whale-like form Basilosaicrus or Zenglodon are found in the Eocene of the Cenozoic. This marine mammal attained a length of over 40 feet, and its body form was well-adapted to speed and maneuverability in water. The true whales are found in later marine deposits.

During the Cenozoic Era of the past 66 million years, the mammals replaced the reptiles as the dominant land animals. Flowering plants (angiosperms) replaced the gymnosperms as the dominant land plants. The development of the flowering plants, birds and mammals evolved rapidly. During the middle of the Tertiary, grasses developed and spread over the plains. This fostered the development of large plant-eating mammals. This led to the development of carnivores that could prey on them. Many of these large animals were here as recent as 11,000 years ago. In the Pleistocene epoch in Texas, there were large (often five feet tall) armadillo-like mammals with "bong" shells. The wolves were twice as large as today's wolves. Other mammals of this epoch were the saber-toothed cat, jaguar, tapir, giant ground sloths, rhinos, pigs, llamas, camel, giant bison and elephant relatives. A wave of Pleistocene extinctions eliminated these huge relatives on the North American continent.



Wooly Mammoth



Mylodon

The fossilized remains provide us with information about past life. From this, we can learn when, where and how organisms lived. These remains are important in tracing the development of plants and animals on earth. However, we must remember that the fossil record is incomplete.

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6. How Were Salt Domes Formed?

Geologist _____ **Team** _____

The Gulf Coast appears to be a strip of flat land next to the Gulf of Mexico. However, it does have a geologic story to tell. Below the surface are salt domes. They do not reach the surface but they are an important part of the subsurface geology of the coast. You and your team will examine the story the salt domes tell.

Materials: "silly putty" or mud, dish

Procedure:

1. One exciting discovery has been that of the numerous oval-topped hills that extend above the ocean floor along the continental margins of the Gulf of Mexico. Drilling has shown that many of these are domes of salt. These salt domes have pushed up through the sediments covering the ocean floor. Examine Figure 6.1. Where are many of the Gulf of Mexico salt domes located?

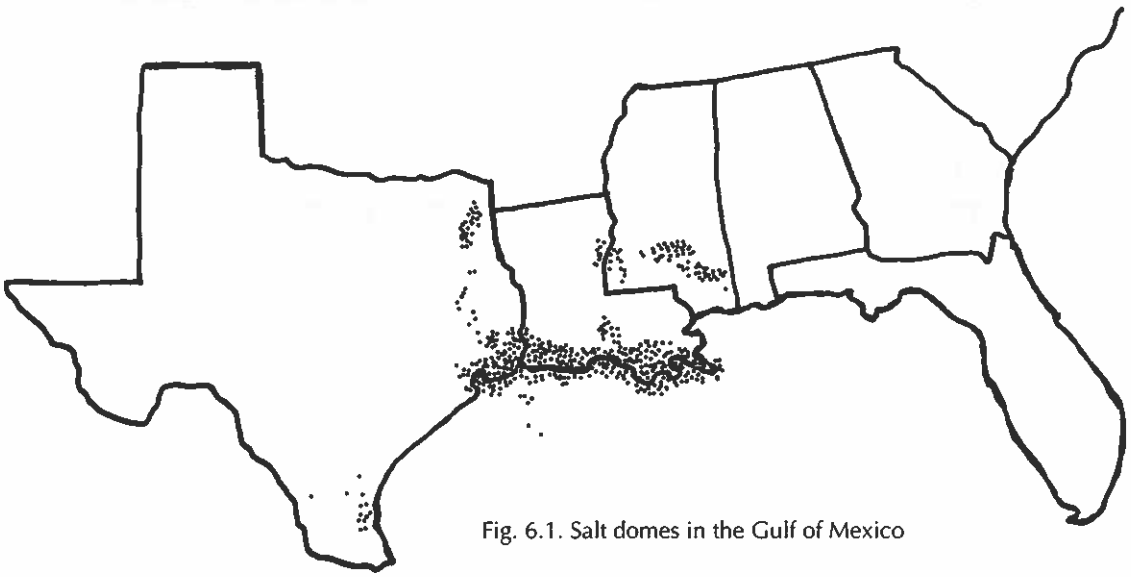


Fig. 6.1. Salt domes in the Gulf of Mexico

2. Geologists have been studying the salt domes to determine how they formed. The salt domes are thousands of feet thick and cover a large area. Geologists have hypothesized that huge salt lakes or seas must have existed in a climate that was hot and dry. This salt was deposited on the bottom in thick layers. Salt deposits are formed when water evaporates. Explain why they hypothesized that large salt lakes or seas must have existed.

3. Why did they hypothesize that the climate was hot and dry?

4. Salt has some unusual properties. When salt is subjected to heat and pressure, it becomes soft and can be molded. The salt will even creep and flow. Examine the series of figures below on the history of development of the Gulf and especially the salt domes. Use the figures to explain what is happening in each stage.



Fig. 6.2 — Jurassic — Cross Section of Gulf of Mexico

a. What was probably happening during the Jurassic?

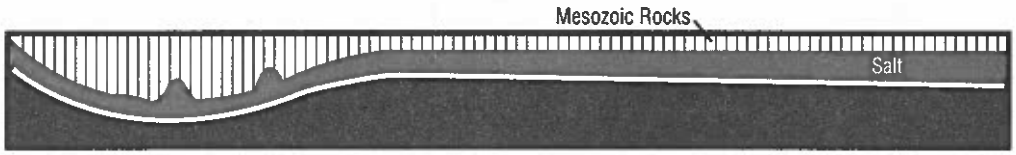


Fig. 6.3 — Early Cretaceous — Cross Section of Gulf of Mexico

b. What probably happened during the Cretaceous?

c. What might be a possible explanation for the depression that was formed during the Cretaceous? To find out, place a layer of "silly putty" on the table. Place your thumb on the layer. Slowly press down on the putty. Remove your thumb. What happened to the putty? What caused a depression in the putty?

d. Based on what happened when you pressed your thumb on the putty, what is pressing down to cause the depression in the sediments?

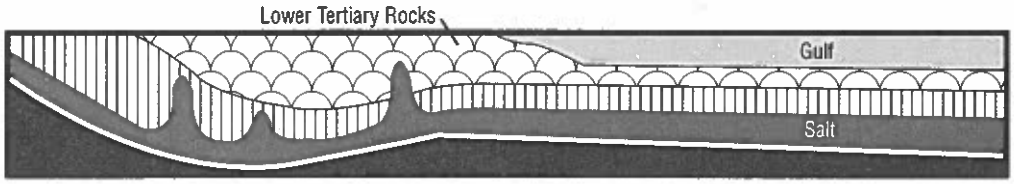


Fig. 6.4 — Mid Tertiary — Cross Section of the Gulf of Mexico

e. Examine the figure depicting the mid-Tertiary. What has happened since the early Cretaceous time?

f. What might be an explanation of what has happened?

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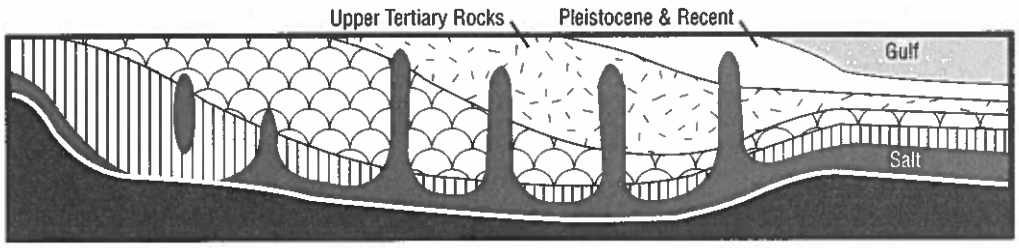


Fig. 6.5 — Pleistocene – today - Cross Section of Gulf of Mexico

g. Some geologists estimate that the main layer of salt may be 30,000 to 50,000 feet beneath the surface of the Gulf Coast. Examine the figure that shows the time from the Pleistocene to today. What has happened since the mid-Tertiary?
h. Use mud or "silly putty" to represent sediments. Can you demonstrate how the salt moved as the weight of the sediments pushed down. Push down on a layer or mud or "silly putty" with two fingers that are four centimeters apart. As you push down, what is happening to the mud or "silly putty" between the two fingers?
i. Why would the property of salt and the layers of sediments provide an explanation for the formation of the salt domes? Explain.

5. When the top of a salt dome is only a few thousand feet below the surface, ground water enters the dome. The water helps form gypsum, calcite, anhydrite and sulfur. These minerals form a "cap rock" over the top of the salt dome. Salt, sulfur and gypsum are mined from the cap rock of many east Texas salt domes. The minerals are removed from the salt dome below the surface. Over the years, subsidence has occurred over salt domes and sink holes have formed. Why?

6. Design an experiment or model to demonstrate that large salt lakes or seas must have existed in a hot and dry climate to form the salt layer that has formed the salt domes.
   a. What are your variables?
      (1) Manipulated or independent variable (what you change).
      (2) Responding or dependent variable (what you measure).
      (3) Controlled variable(s) (what stays the same).
   b. List of materials you will need.
   c. Procedure (Explain the steps you are going to take to investigate the problem).

7. How Has Geology Influenced the Gulf Coastal Zone?

Geologist _____ **Team** _____

The basic geology patterns have a direct effect on the topography or physical features of the coastal zone. You and your team are going to determine if there are other connections. Connect between the geology of the Gulf Coast and its natural resources.

Procedures:

1. Look at the geologic map of the state (Figure 7.1) that show the ages of the main rocks at the surface. What patterns do you notice to the south and east of the "S" curve through the state?

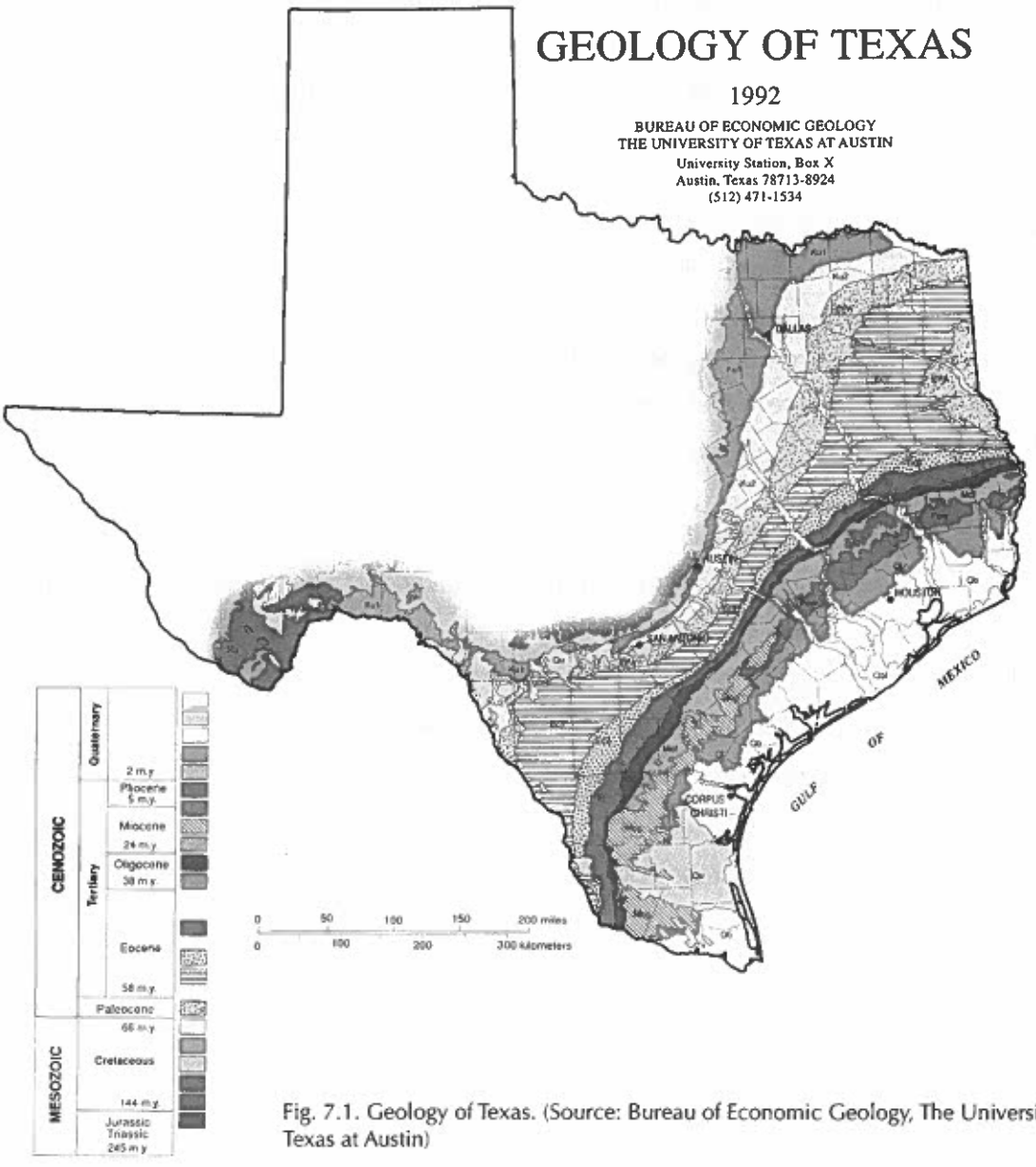
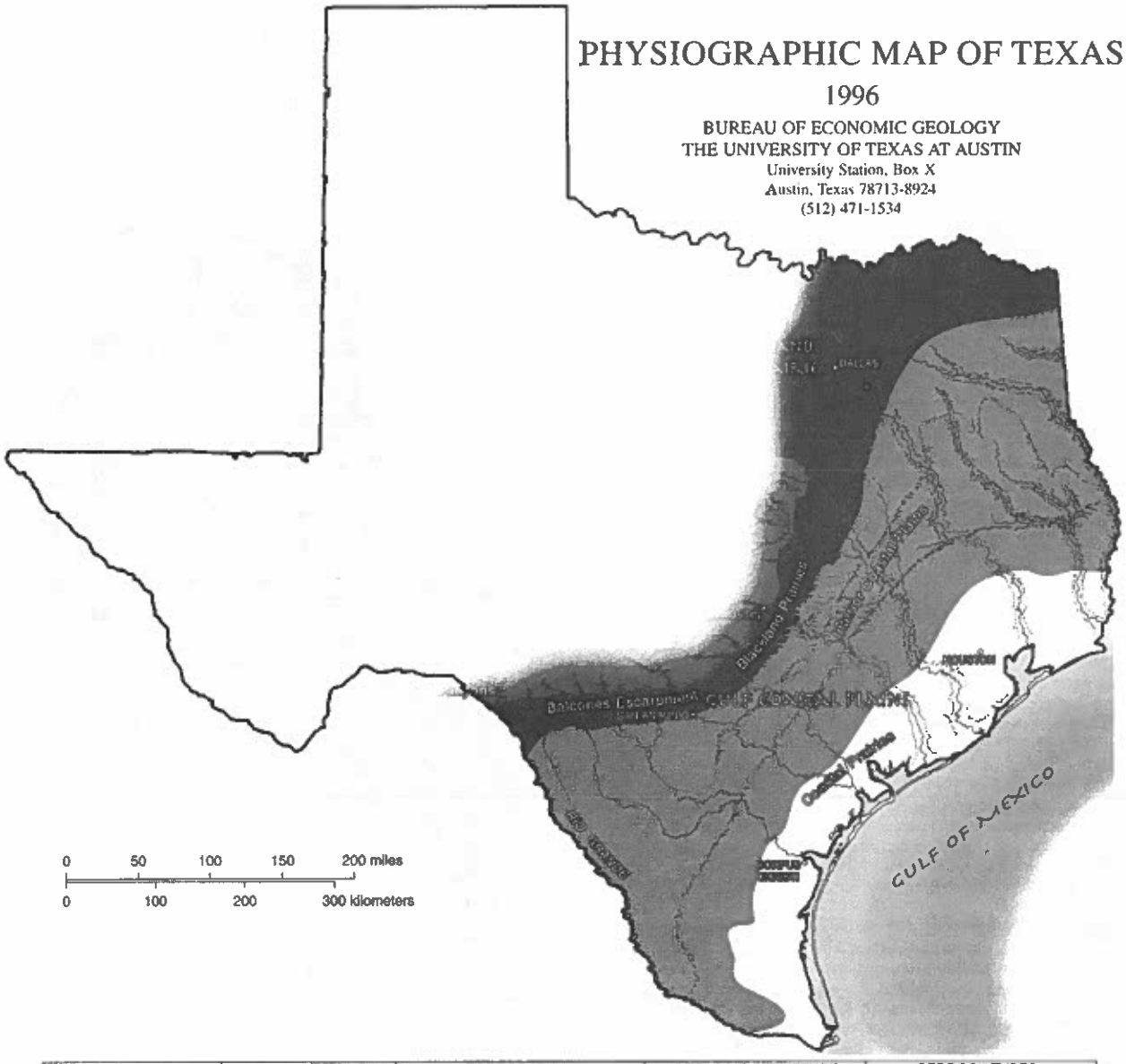


Fig. 7.1. Geology of Texas. (Source: Bureau of Economic Geology, The University of Texas at Austin)

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2. Compare the geology of the coastal zone to the physiographic map (Figure 7.2) of Texas. Note the patterns. Why would the patterns be similar?



PROVINCE	MAX. ELEV. (ft)	MIN. ELEV. (ft)	TOPOGRAPHY	GEOLOGIC STRUCTURE	BEDROCK TYPES
Gulf Coastal Plains					
Coastal Prairies	300	0	Nearly flat prairie, <1 ft/mi to Gulf	Nearly flat strata	Deltaic sands and muds
Interior Coastal Plains	800	300	Parallel ridges (questas) and valleys	Beds tilted toward Gulf	Unconsolidated sands and muds
Blackland Prairies	1000	450	Low rolling terrain	Beds tilted south and east	Chalks and marls
Grand Prairie	1250	450	Low stairstep hills west; plains east	Strata dip east	Calcareous east; sandy west
Edwards Plateau					
Principal	3000	450	Flat upper surface with box canyons	Beds dip south; normal faulted	Limestones and dolomites
Pecos Canyons	2000	1200	Steep-walled canyons		Limestones and dolomites
Stockton Plateau	4200	1700	Mesa-formed terrain; highs to west	Unfaulted, near-horizontal beds	Carbonates and alluvial sediments

Fig. 7.2. Physiographic Map of Texas. (Source: Bureau of Economic Geology, The University of Texas at Austin)

3. Figure 7.3 is a Land Resource map of Texas. Compare the pattern of the geology and soils. Explain the relationship.

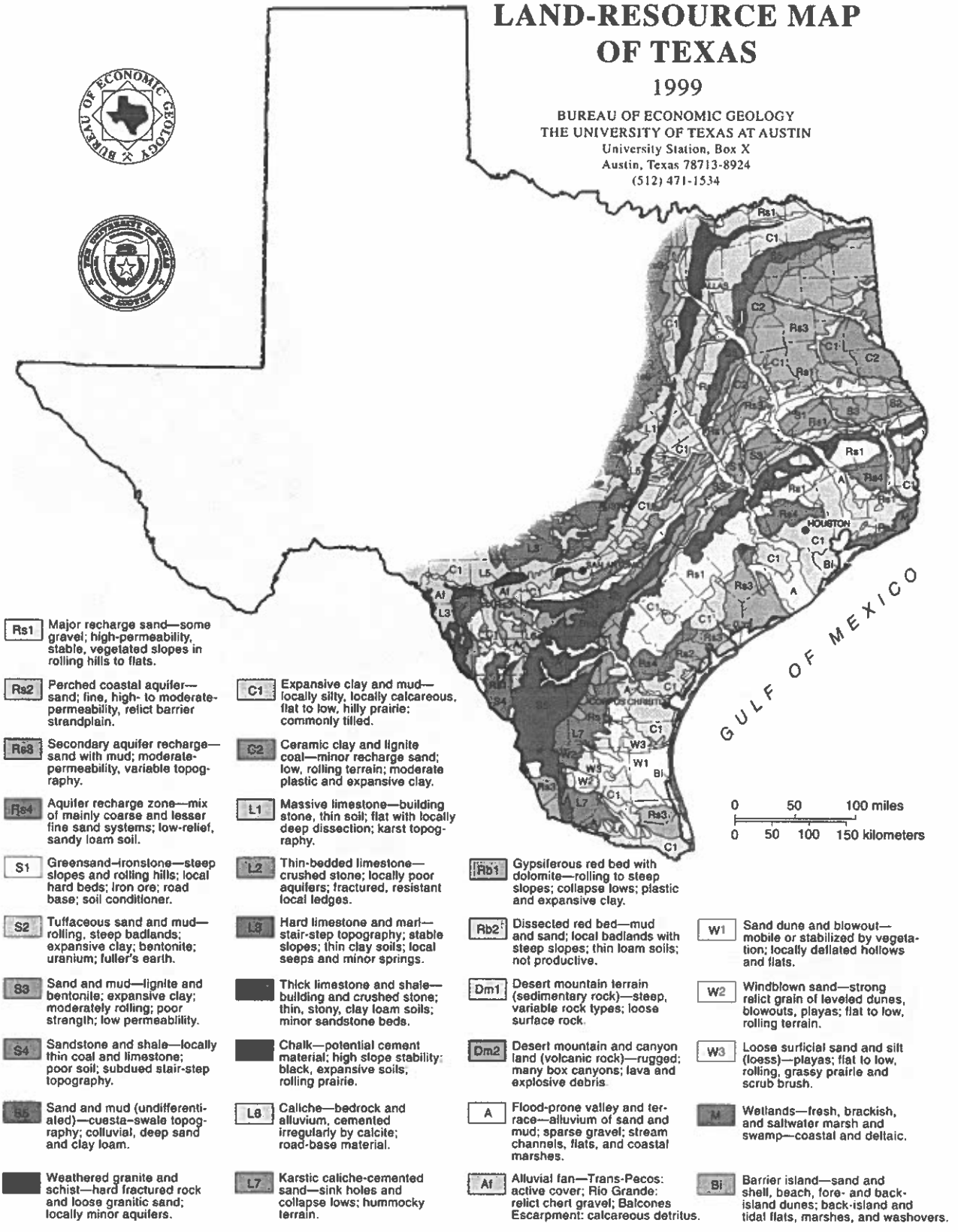


Fig. 7.3. Land-Resource Map of Texas (Source: Bureau of Economic Geology, The University of Texas at Austin)

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4. Compare the Texas vegetation areas shown in Figure 7.4 with Figures 7.1 and 7.3. What is the pattern? Explain the connection.

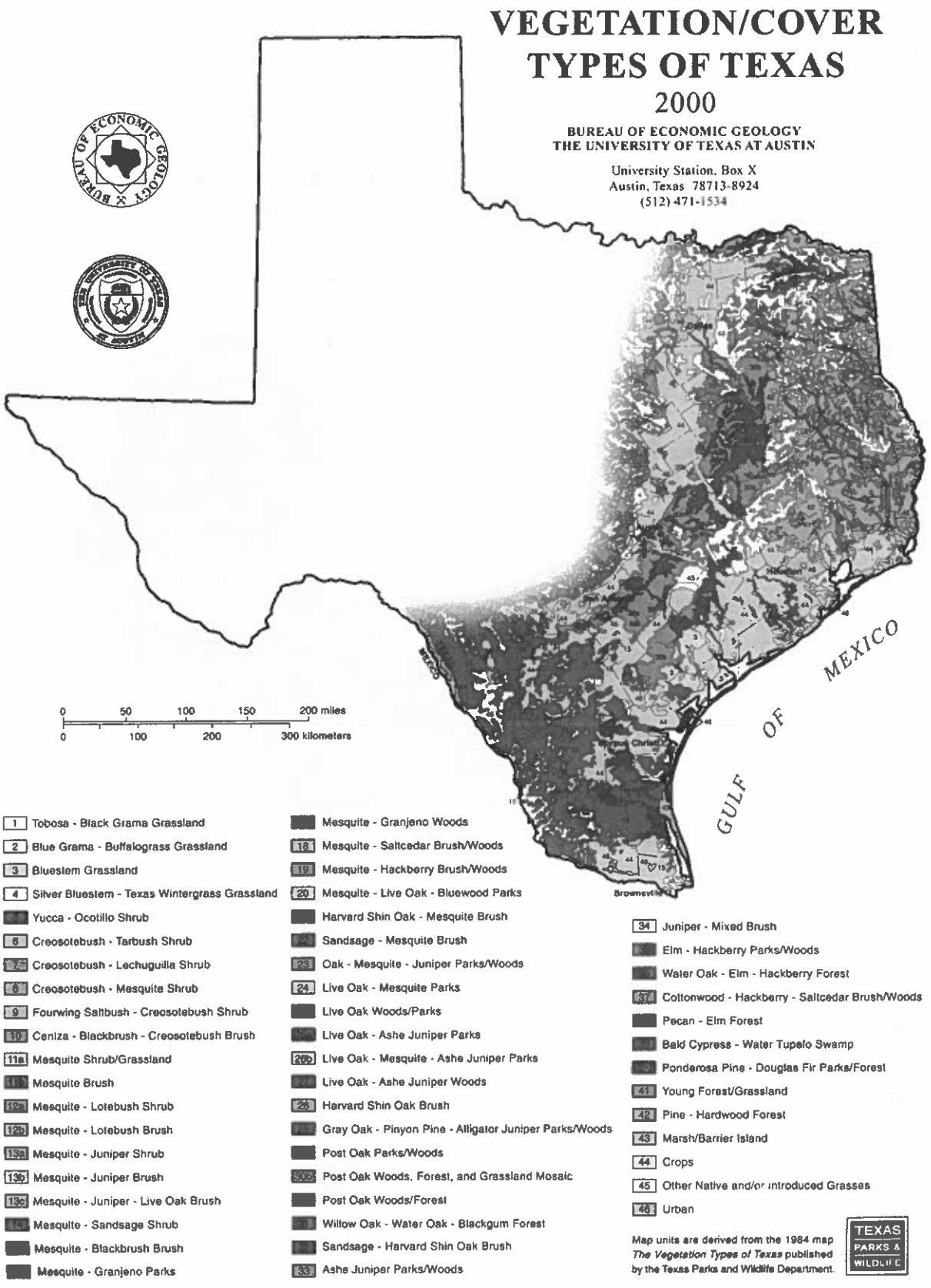


Fig. 7.4. Vegetation/Cover Types of Texas (Source: Bureau of Economic Geology, The University of Texas at Austin)

5. How do the geological and the soil formations relate to the agricultural products grown in the Gulf coastal zone? What evidence would support this?

6. Fifty-six percent of the water being used in Texas is from aquifers. The major aquifers are shown in Figure 7.5. What are the two major aquifers found in the region south of the "S" curve?

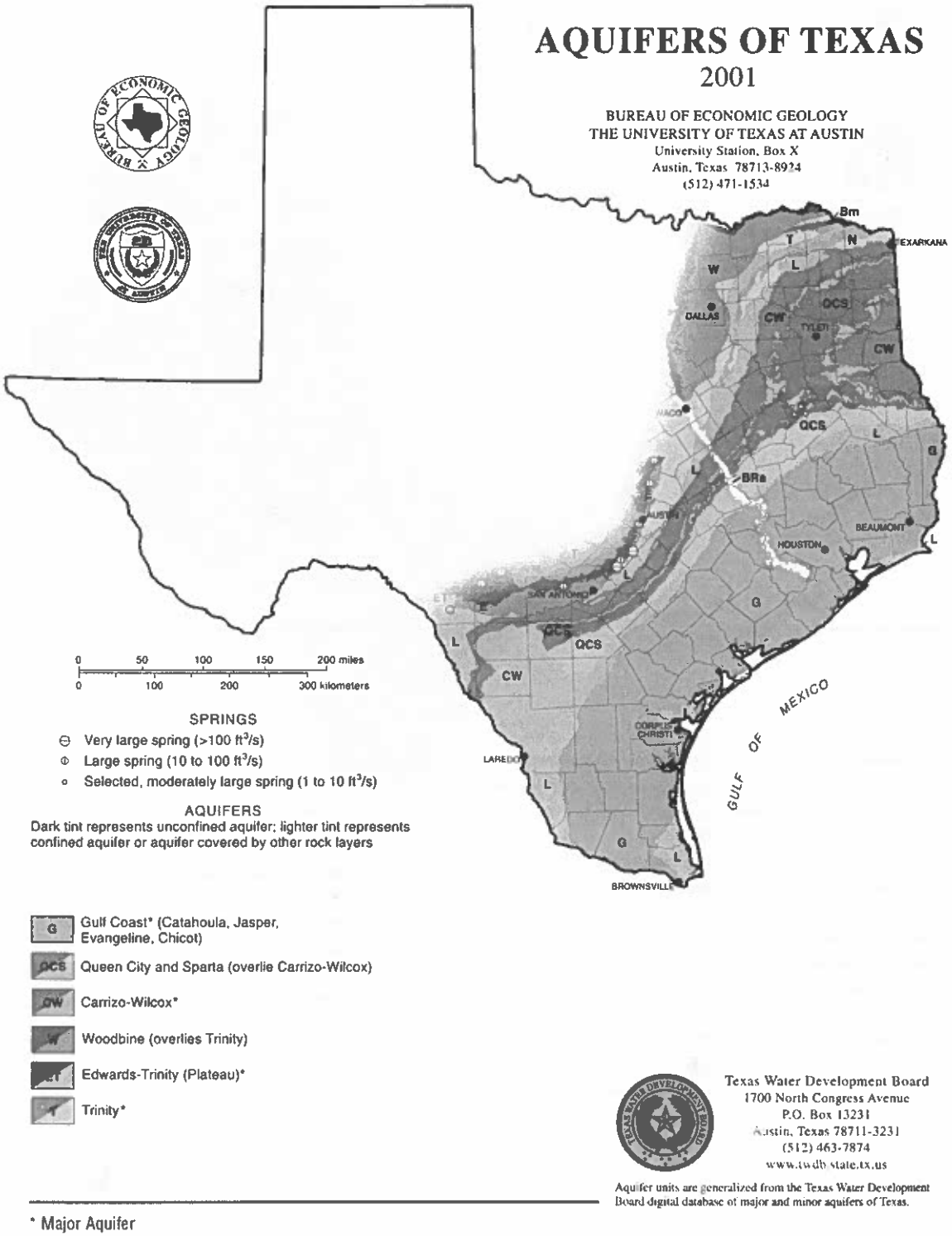


Fig. 7.5. Aquifers of Texas (Source: Bureau of Economic Geology, The University of Texas at Austin)

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7. The sandstone of the Carrizo-Wilcox Aquifer furnishes water to all or parts of 61 counties. These sands were deposited in the early Cenozoic time (Eocene) from large rivers to deltas that were then the Texas coast. Why does this aquifer parallel the Gulf of Mexico? Use Figure 7.1 to explain the pattern.

8. Note the pattern of the Gulf Coast aquifer. How does the pattern of the aquifer shown in Figure 7.5 tie in with the geology of Figure 7.1?

9. Use Figure 7.1 to help explain the conditions under which the clay, silt, sand and gravel of the Gulf Coast aquifer were deposited.

10. What is the connection between the geology, physical features, soils, vegetation areas and aquifers of the Coastal Zone? Explain.

11. Water is being removed from the porous sand layers of the sand-clay sequences of the aquifers. What effect will this have on the surface?

8. What Is the Connection Between the Geology and the Petroleum Resources of the Gulf Coast?

Geologist _____ **Name** _____

Any review of the geology must include a survey of Texas' natural resources. The coastal zone, both onshore and off, has enormous natural resources. Texas has produced 55 billion barrels of petroleum – nearly 40 percent of the nation's historic production. You are going to investigate why there is so much oil, gas and other resources in this region.

Materials: none

Procedure:

1. Oil has flowed abundantly from wells in the East Texas Basin and from the Texas Gulf coastal province, both on and offshore. Texas has a great amounts of oil and gas because of its geological history. About 200 million years ago, Pangaea's pull apart resulted in the Earth's present continents and ocean basins. The Gulf of Mexico began to form as North America and South American separated. The separation occurred along the "S" curve shown on Figure 8.1. So all the land area east and south of the "S" curve was formed by sediments pouring into the Gulf basin. These sediments were mainly organic-rich mud. Compare the patterns of Figure 8.1 to the location of the oil and gas fields of the coastal region in Figure 8.2. Is there a connection between the two? Explain.

2. Petroleum means "rock oil" and is called crude oil. It is a mixture of many liquid hydrocarbons that are made of the elements hydrogen and carbon. Petroleum is formed from the remains of sea life (organic material) buried by sediments of mud on the ocean floor. The remains decay over millions of years into the liquid hydrocarbons. As more sediments are deposited on top of the mud, petroleum and water are squeezed out of the mud by the weight of the sediments. The petroleum may enter porous rocks or rocks that have many tiny open spaces like sandstone and limestone. Eventually the petroleum is trapped between layers of impermeable rock. Natural gas is made up mostly of methane, a gaseous hydrocarbon. When it is found with petroleum, it is trapped between the petroleum and a layer of impermeable rock. Natural gas can be found in porous rock by itself. The processes that form natural gas are the same as those for petroleum. Four geologic elements are needed to form an oil or gas field. These are: a trap, a seal, a source and a reservoir. See Figure 8.3. How does the formation of oil and gas tie in with the geology of the coastal zone? Explain.

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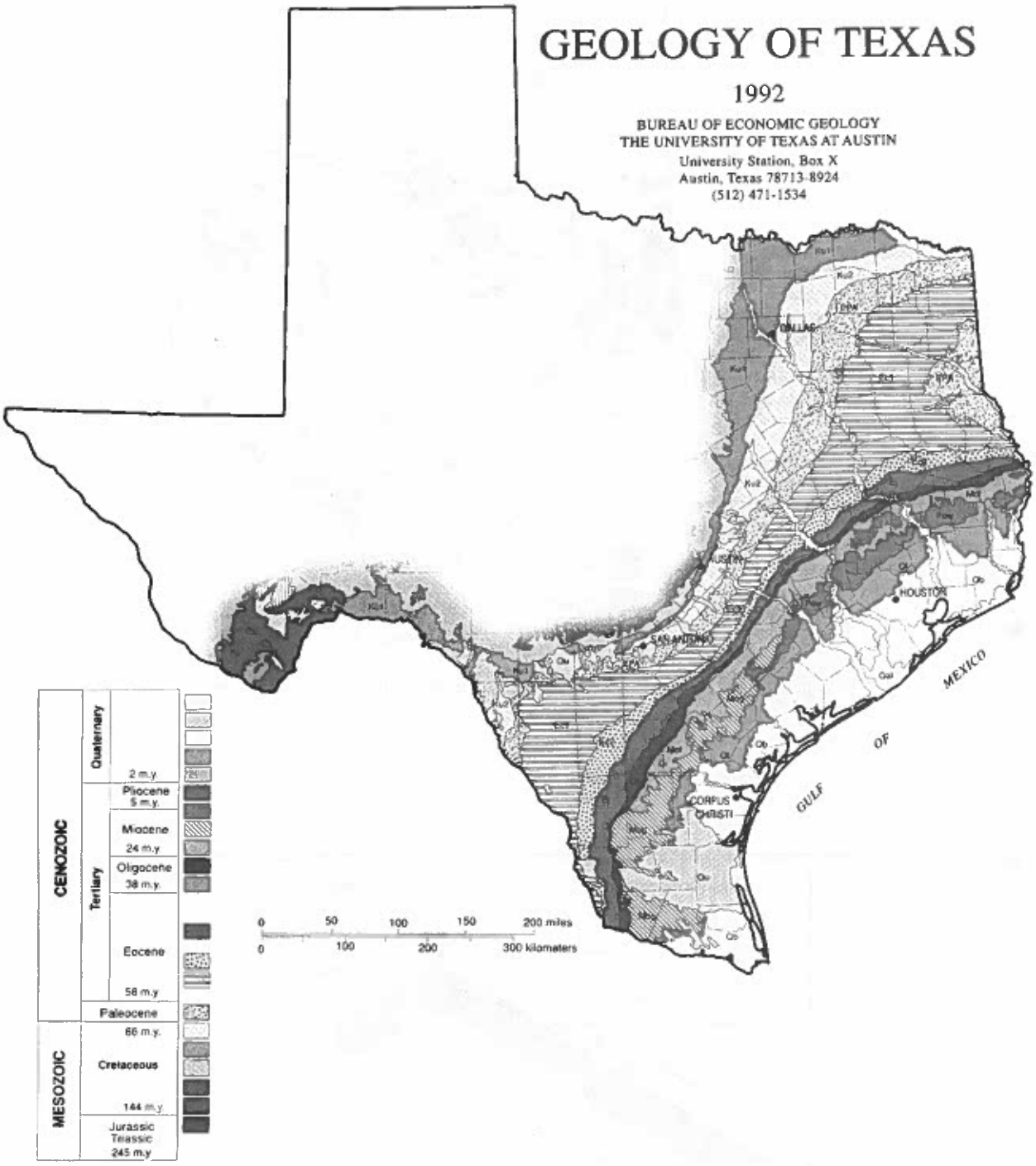


Fig. 8.1. Geologic Map of Texas (Source: Bureau of Economic Geology, The University of Texas at Austin)

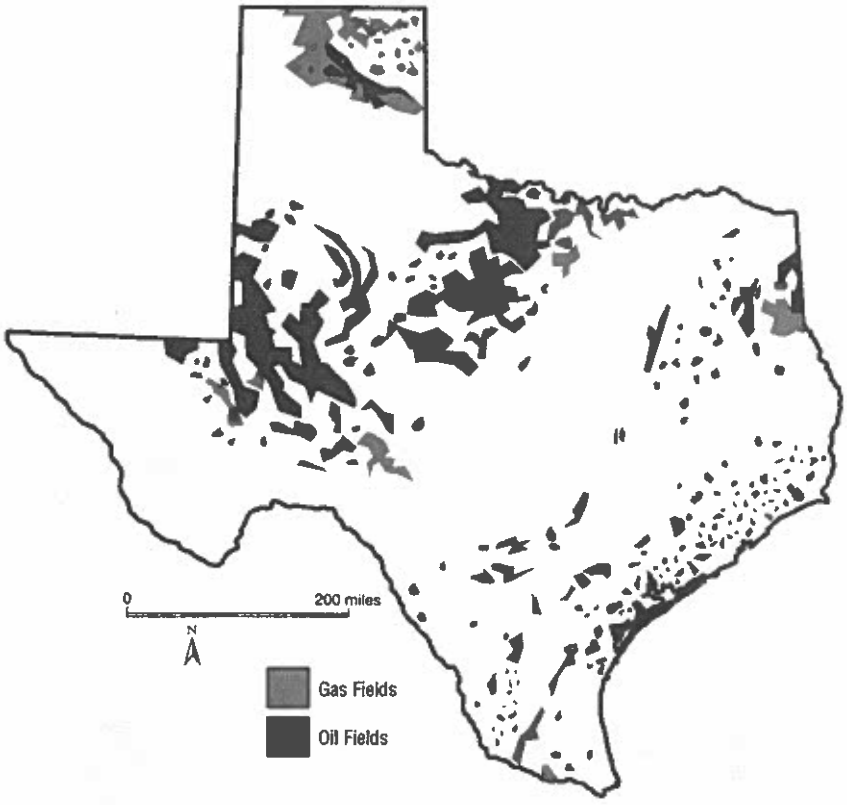


Fig. 8. 2. Oil and gas fields of Texas. (Source: Roadside Geology of Texas)

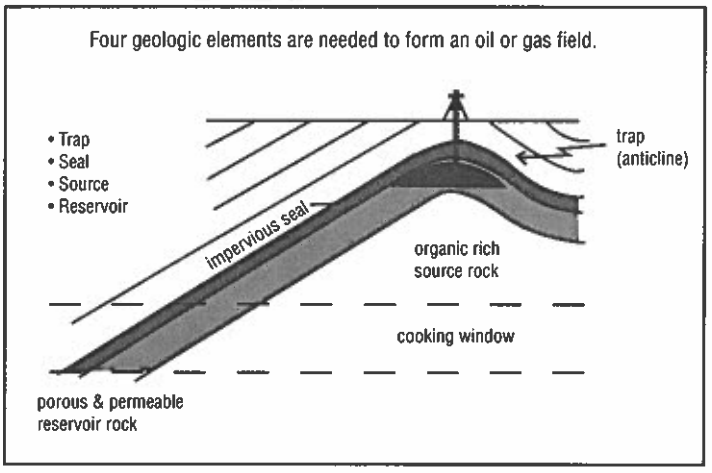


Fig. 8.3. Four geologic elements are needed to form an oil or gas field. (Source: Roadside Geology of Texas)

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3. Examine Figure 8.4, which shows the major oil and gas reservoirs in Texas. In what type of rocks are these reservoirs located? Explain why.

4. Under what conditions did these rocks form? How is this connected to the formation of petroleum and gas?

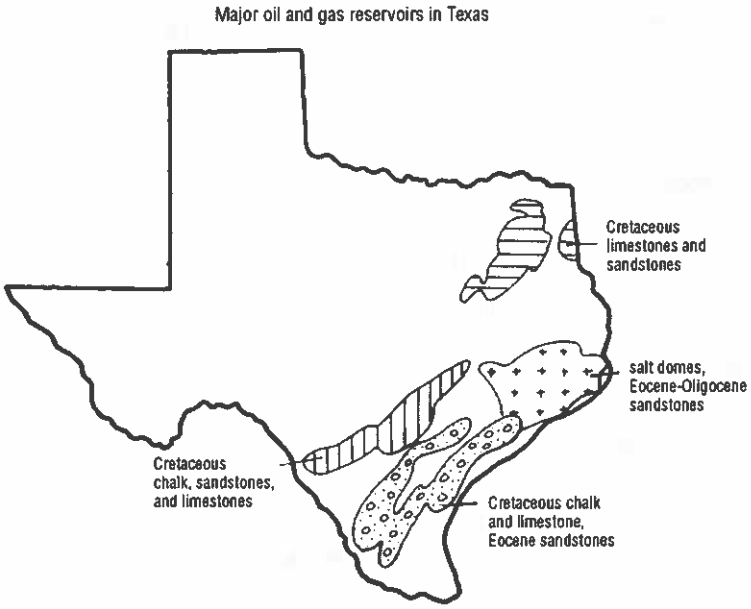


Fig. 8.4. Major oil and gas reservoirs in Texas. (Source: Roadside Geology of Texas)

5. Rocks at the top and along the sides of salt domes have produced billions of gallons of oil in the coastal zone. Spindletop, near Beaumont, is one of the earliest, largest and most famous oil fields in Texas. The oil came from cap rock reservoirs of a large salt dome near Beaumont. Examine Figure 8.5 of the types of oil traps and Figure 8.6 of a cross section of the Spindletop field. Use the figures to explain how the oil was formed and trapped.

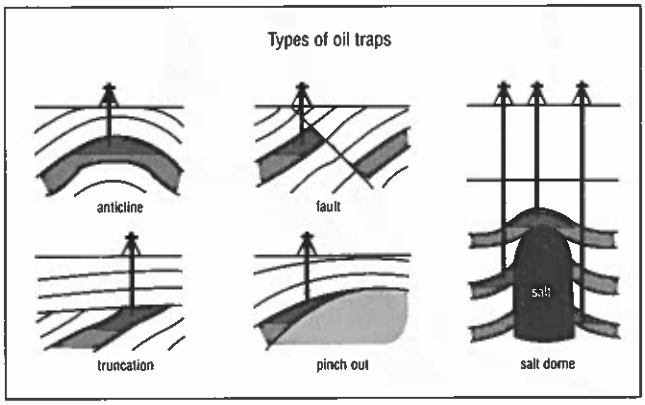


Fig. 8.5. Types of oil traps. (Source: Roadside Geology of Texas)

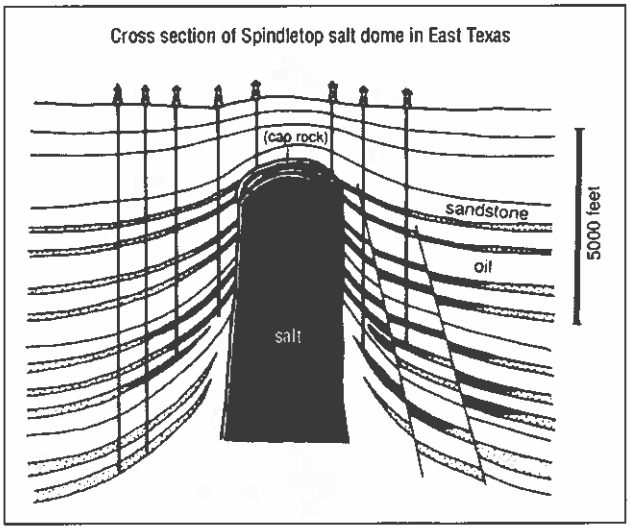


Fig. 8.6. Cross section of Spindletop salt dome in East Texas. (Source: Roadside Geology of Texas)

6. List the characteristics of the geology of the coastal zone that were ideal for the formation of oil and gas.

9. What Is the Connection Between the Geology and Non-petroleum Energy Resources?

Researcher _____ **Name** _____

There are more natural resources than petroleum and natural gas. These include coal and uranium. You are going to investigate why coal and uranium are found in the coastal zone.

Materials: none

Procedure:

1. Figure 9.1 shows the energy resources located in the Texas coastal zone excluding oil and gas. What are these energy resources?

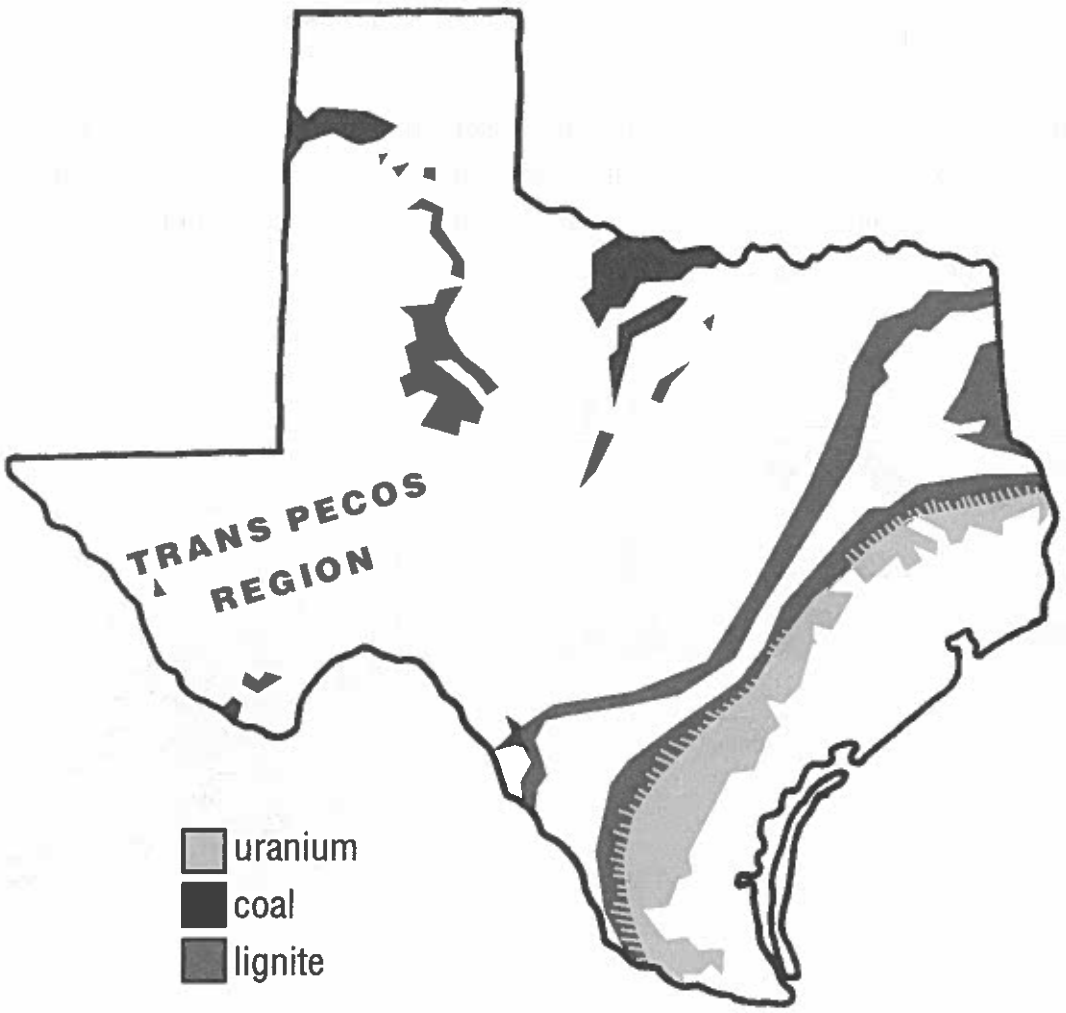


Fig. 9.1. Energy resources in Texas. (Source: Roadside Geology)

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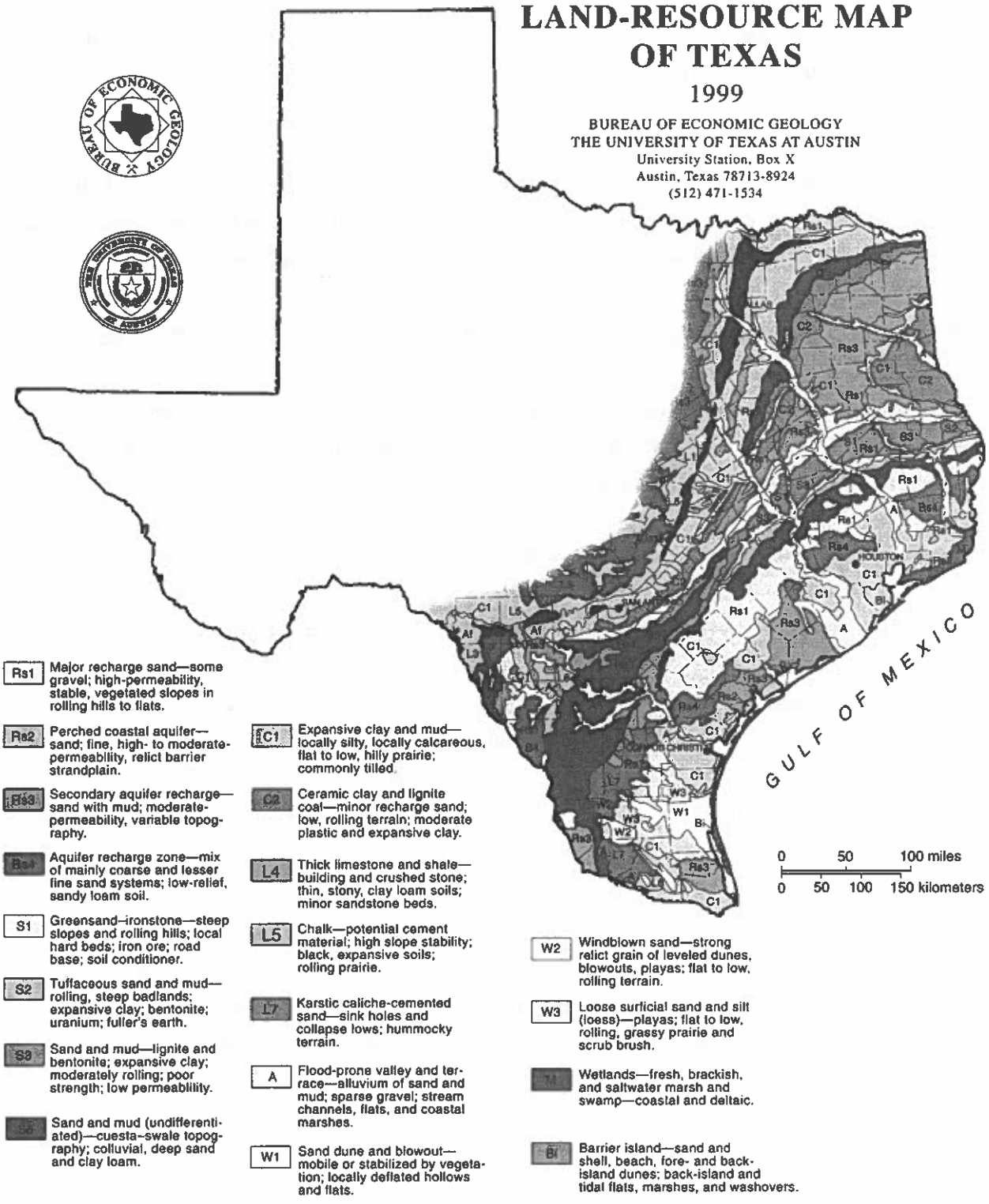


Fig. 9.2. Land Resource Map of Texas (Source: Bureau of Economic Geology, The University of Texas at Austin)

2. Lignite coal is a brownish-black coal which is lower in grade than bituminous or anthracite coal. Lignite is formed from abundant organic material. This is formed from organic material that was deposited in ancient river, delta and coastal lagoon environments. Using Figures 9.1 and 9.2, when was lignite formed? What does this tell you about this area in the past?

3. Lignite is mined when it is found near the surface in seams three to ten feet thick. It is mined by stripping methods using huge buckets and drag lines. The lignite is removed by large shovels. What happens to the land and water when strip mining occurs?

4. What effect could this have on the aquifers and Gulf if mining occurs without restrictions?

5. Lignite was not a major energy source as long as there was plenty of inexpensive oil and gas available. In the 1970s, the available oil and gas became more limited and expensive. What are implications of this for lignite mining?

6. Examine Figure 9.1 and 9.2. Where are the uranium deposits located in the coastal zone?

7. The Gulf Coastal Plain uranium deposits occur mostly with sandstone and clay in a layer that contains volcanic ash. The uranium was dissolved in water and carried from the volcano as sediments. It was then deposited in the sandstone and clay. What were the conditions at the time of this deposit that helped form the uranium?

8. The original source of the uranium is Trans-Pecos volcanic ash. Locate the Trans-Pecos region of West Texas. What is a possible explanation for volcanic ash from far West Texas being deposited in the Gulf Coastal Plain?

9. In general, the quality of the uranium was low. However, the area was actively mined from 1959 to the mid-1970s . Competition from foreign sources and a smaller demand for uranium have almost shut down the mining. The mining was by stripping and open pit. What are possible problems that could have resulted in the coastal zone because of the mining?

10. In a paragraph, summarize the connection between the geology and the energy resources of the Gulf coast.

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10. What Is the Relationship Between the Geology and Minerals of the Coastal Zone?

Researcher _____ **Team** _____

There are more resources than energy resources. The non-fuel resources include industrial metals, rocks and minerals. The Texas non-fuel mineral production is over 1.5 billion dollars and ranks sixth among the fifty states. The Gulf coast is a large source of these minerals. You are going to investigate why there are so many mineral resources in this region.

Materials: none

Procedure:

1. Believe it or not we still live in a "Stone Age." An average of 11 tons of rocks is processed annually for each person in the United States just to produce things our lifestyle demands. These stone produces include: paved streets, insulated homes, glass, paper, soap and even the kitchen sink. Modern agriculture would not be possible without the fertilizer, lime and pesticides made from rocks. Examine Figure 10.1, which shows the areas of these mineral resources. What industrial rocks are found in the coastal plains south of the "S" curve?

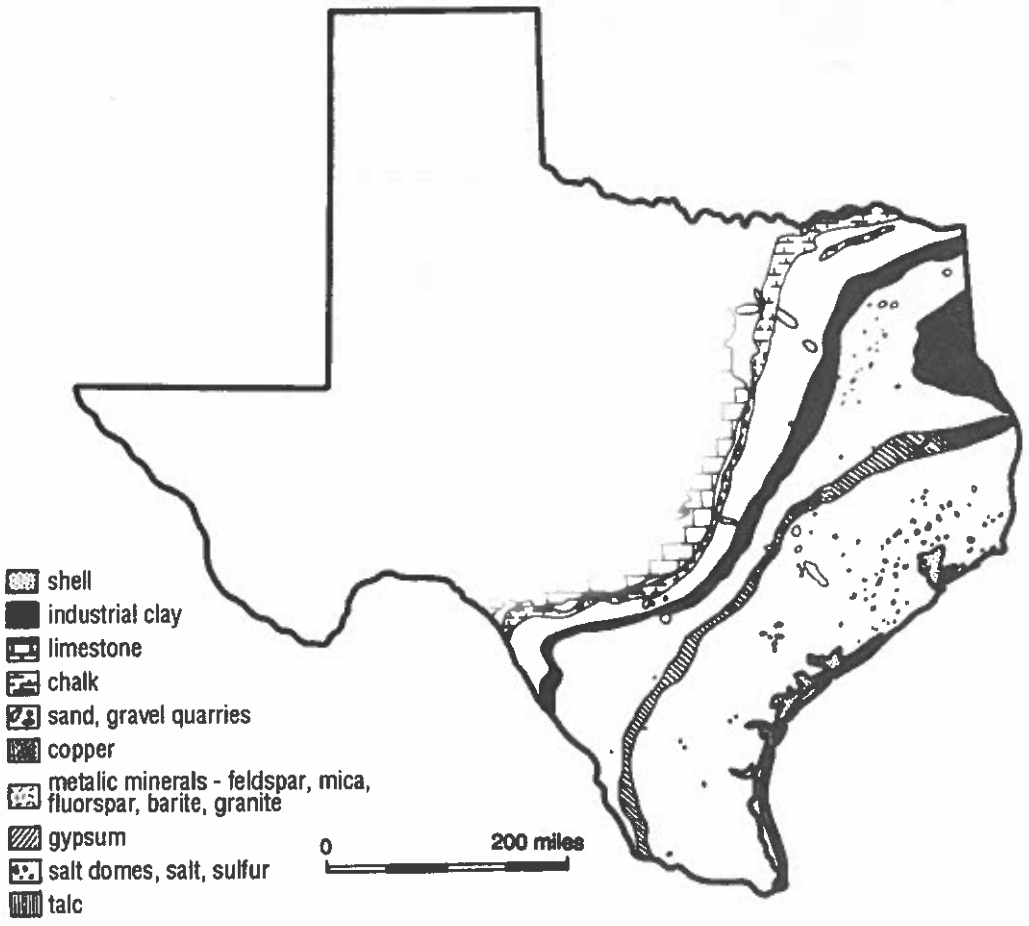


Fig. 10.1. Mineral resources in Texas. (Source: Roadside Geology of Texas)

2. Use Figures 10.1 and 10.2 to explain why these industrial rocks are found in the coastal plain. What is the relationship to the geology of this region? Explain.

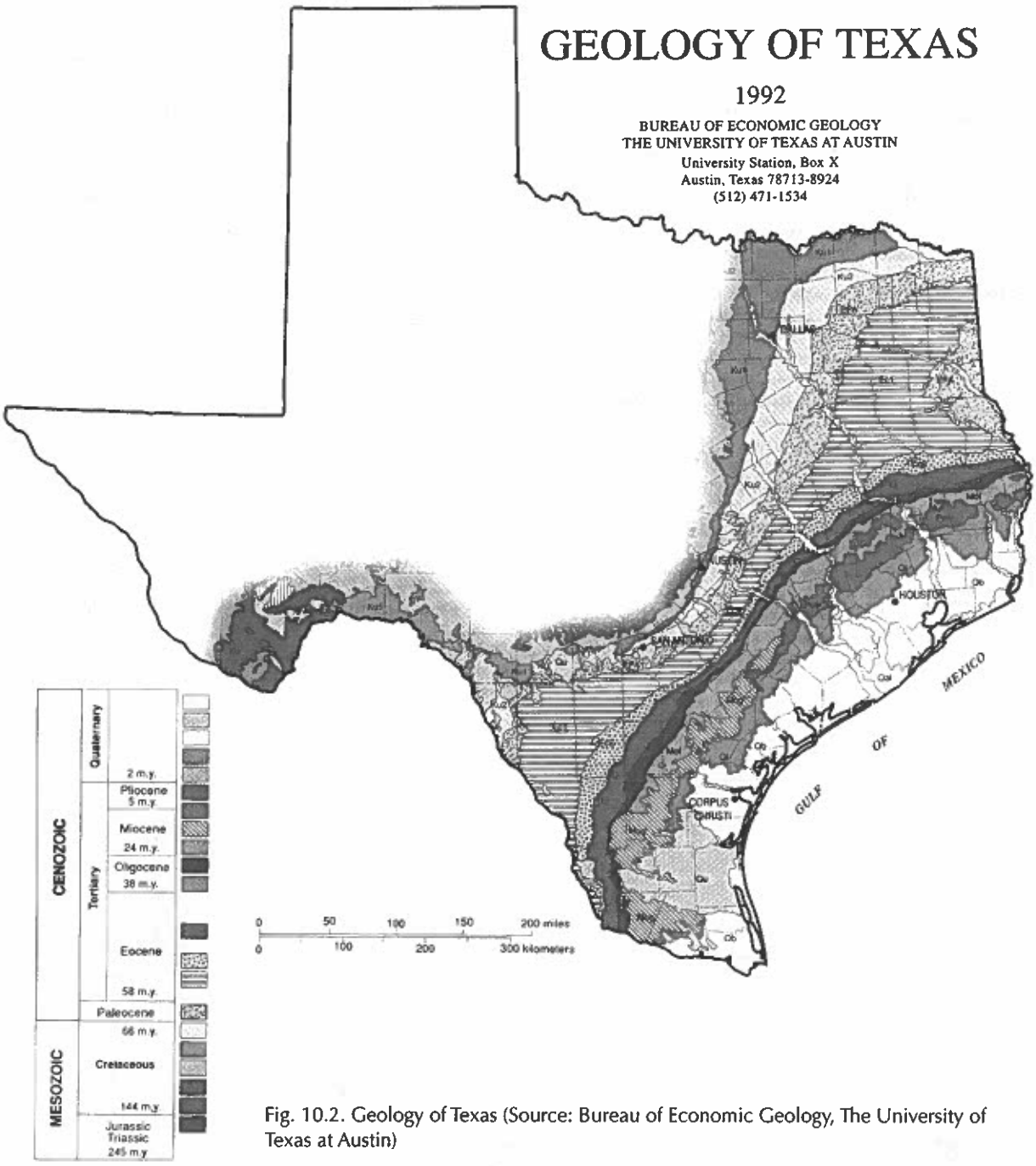


Fig. 10.2. Geology of Texas (Source: Bureau of Economic Geology, The University of Texas at Austin)

3. Five tons of sand, gravel and clay are used yearly for each U.S. resident. Sand and gravel are combined with cement to make the artificial rock, concrete. Building a house requires an average of 50 tons of concrete. An average mile of four-lane highway requires 85,000 tons. Sand and gravel are readily available in the coastal zone. Explain why.

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4. If sand and gravel would not be available, how do you think this would impact the coastal zone?

5. Clay is used to make bricks, tile, pottery, drilling mud and is a filler in fertilizers. Texas ranks third in clay production. It is mined in Bastrop and Guadalupe counties east of Austin and San Antonio. Ft. Bend County near Houston is another location of clay mining. Under what conditions is clay deposited?

   How is the formation of clay connected to the geology of the coast?

6. From the past to the present, salt is one of the world's most traded minerals. Explain why?

7. The United States is the world's largest salt-producing nation. Texas produces about 20 percent and is second in salt production. Louisiana is first and produces twice as much as Texas. Most of the salt in Texas is mined in the coastal region. Explain why Texas and Louisiana produce so much salt? How does this relate to the geology?

8. Salt is not the only product mined from the domes. Some domes produce oil and sulfur. Sulfur is brimestone or is the rock that burns. It is often the caprock of Texas salt domes. About 85 percent of all the sulfur mined is converted to sulfuric acid. The sulfuric acid is used making fertilizers, leaching copper from copper ore, making rubber, paints, rayon, film, paper, dyes and thousands of other products. About 300 pounds of sulfuric acid are used per person in the United States. Texas is the nation's leading sulfur producer. What is the connection between the geology and sulfur production in Texas?

9. As salt and sulfur are removed from below the surface, what will happen to layers of sediments above the domes?

   What types of problems has this caused along the Texas coast?

10. Magnesium is the third most abundant element in sea water. Dow Chemical's plant in Freeport, Texas extracts a magnesium compound from the water. Then it uses electrolysis to produce magnesium metal. How is this related to the geology of the coast?

11. Summarize the relationship of the Gulf Coast geology and the formation of industrial rocks.

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Topic 4 — Recent Geology of the Gulf Coast

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Topic Four: Recent Geology of the Gulf Coast

Throughout the world, coasts are zones of transition between the ocean and land, where waves, currents and tides act to mold the landforms. These in turn influence the movement of water. Energy from waves can change a coastline in a brief span of geological time (a few thousand years). However, coastal processes can act faster still, in years or even days. Hurricanes can destroy a beach within a day and swift tidal currents can create a shallow channel in months. Coasts are some of the fastest changing parts of the Earth's surface. Any single coast is the result of processes at all three time scales: (a) the slow geological processes of mountain formation and erosion that require millions of years; (b) the gradual sea level changes requiring thousands of years; and (c) the day-to-day and year-to-year combinations of long term and short term actions of waves, currents, and tides.

Natural processes are constantly changing and shaping the coastal regions. These processes include: stream runoff, sediment deposition, storm surge, flooding, ground sinking, faulting, sand dune movement, and wind, wave and tidal action. These processes result from the natural interactions of climate, soil and water systems and they result in the continuous change of coastal regions. These changes occur not only in shorelines, but also in bays, marshlands and river courses. Some changes are vital to the survival of the ecosystems. Floods flush bays and, although this might seem to have a bad effect on organisms, it is followed by an increase in productivity. Marsh changes ensure the continuous cycling of nutrients needed for marine organisms.

Some of these changes conflict with our use of the land. These conflicts usually occur where we have gotten in the way of natural processes or unknowingly upset their balance. This section will focus on the effect of gradual sea level changes and the day-to-day or year-to-year processes and on the impact of human activities today and in the future.

Activity 1: What are the shoreline features of the Gulf Coast?

TEKS: Science: 7.5, 8.6, 6.6, 8.10, 8.12, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.9, 7.9, 8.9, 6.10, 7.10, 8.10, 6.20, 7.20, 8.20

Social Studies: 6.6, 7.9, 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- use a Texas highway map to locate and describe barrier islands, inlets or passes, lagoons, estuaries, deltas, spits, and peninsulas
- compare the different types of shorelines along the Gulf and describe how they were formed
- explain the statement that parts of the Texas coast have "two shorelines"

Background:

1. Provide each pair of students with a Texas highway map on which to locate the features of the shoreline. Contact your local Texas Department of Transportation office or the Texas Department of Transportation, Travel and Information Division, P.O. Box 5064, Austin, Texas 78763-5064 for a classroom set of Texas highway maps. Review how to locate points on the map using coordinates.
2. Extension: Use a map of the United States and locate other shorelines and shoreline features that are similar to areas of the Gulf coast.

Activity 2: How has the Texas shoreline changed in recent history?

Activity 3: What are some short-term changes in the shoreline?

TEKS: Science: 7.5, 8.6, 6.6, 8.10, 8.12, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.7, 7.2, 8.12

Learner outcomes: After completing the activities, the students will be able to:

- analyze diagrams and summarize the shoreline changes that occurred
- hypothesize about the impact of change (natural or human) on marine life
- describe the role of storms such as hurricanes on shoreline changes

Background:

1. Point out that the Matagorda Bay area of the coast is a good location to observe and study shoreline changes. This area of the coast has been the least affected by human activities; therefore, the changes that occur are due to natural processes in most cases.
2. Provide each team of four with the two activities. Two of the students can analyze the figures in Activity 2 and the other two can analyze the figures in Activity 3. When each pair has completed its analysis, they can discuss their findings as a team.

3. Ask the students to list ways that these changes might impact the living organisms. Have students use a Texas highway map to locate similar areas along the shoreline and predict what changes might occur naturally over time and during a hurricane. Discuss factors people should consider in developing these areas of the coast.
4. If your school is located in the coastal zone, have the students interview people to learn about changes that they have seen. A group of students might conduct a search of the local newspaper files to locate photographs that depict the changes, both natural and human.

Activity 4: What is the effect of different shoreline slopes?

TEKS: Science: 8.5, 6.4, 7.4, 8.4, 6.6, 8.10, 8.14, 8.12

Math: 6.6, 7.6, 8.7, 6.8, 7.9, 8.8, 6.11, 7.13, 8.14, 6.4, 7.3, 8.5

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- construct a model to investigate the relationship of slope and flooding along the coast
- analyze the impact of storm surges on the Texas coast
- compare a graphic and actual mode.

Background:

1. Discuss the creation of models to study events in nature. Include a discussion of computer modeling and its potential.
2. The slope of the Texas coast is very gentle, averaging about 1 meter of elevation change per kilometer (1 km is approximately 0.6 miles). Storm surges and hurricanes have a major impact on the coast and can cause serious flooding and damage. To demonstrate this, measure a distance of one kilometer along the street in front of or along side the school. Point out that a storm surge of 1 meter or 3.3 feet would flood an area of that distance. If your school is within 48 kilometers or 30 miles of the Gulf, contact county or city officials to determine the elevation of your school or city. Determine the slope and use it to determine how far inland a storm surge of 1 m, 1.5 m, 2 m, 3 m, 4 m, 5 m and 6 m would travel. A major hurricane may have a storm surge of 6 meters (20 feet). Have the students determine how close the floodwaters would reach for a storm surge of this magnitude. Discuss the impact of this type of flooding on wildlife and people.

Activity 5: Is the sea level rising?

TEKS: Science: 6.5, 7.5, 8.10, 7.14, 8.12, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3, 8.5, 6.8, 7.9, 8.8

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.24, 7.24, 8.24

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.7, 7.10, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- list causes of changes in sea level
- analyze figures and describe sea level changes along the Texas coast from 17,000 years ago to the present
- develop hypotheses about temperature changes and sea level
- explain how tidal gauges help determine sea level changes
- predict the impact of sea level changes on the coastal zone

Background:

1. To enable the students to develop their thinking skills, use the activity questions to guide their thinking and the discussion. Show the students a transparency of Figure 1. Ask the students to summarize their observations. Have the students discuss the figure in their groups and list the impacts of the changing sea level on the coastal zone over the last 17,000 years. Ask the students for possible explanations of the change in sea level and what data would be needed to support their hypotheses.
2. Show the students Figure 2 of the sea level on the Texas coast since 1920. Ask for possible explanations of the sea level changes. Ask students to predict what will happen if the global temperature rises and polar ice begins to melt. Show the students Figure 3 and ask what patterns they observe and what they can conclude from the data.
3. Share the differences in the rate of sea level rise in the Gulf of Mexico. Ask for possible explanations of the variations.
4. Use the questions to guide the students' discussion of the impact of the sea level rising.

Activity 6: How did the barrier islands form?

TEKS: Science: 6.4, 7.4, 8.4, 8.5 (models), 6.5, 7.5, 8.12

Math: 6.3, 7.2, 8.2

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the

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students will be able to:

- interpret data from figures of the history of the Texas coast
- analyze the data and theories of barrier island formation
- develop hypotheses about the impact of a rise in sea level and the building of dams on rivers on barrier islands
- construct a model to test the theories of barrier island development

Background:

1. The barrier islands are very young geologic features when compared with the Earth. Their origin has been debated, yet it is obvious that barrier islands form and are modified by different processes and combinations of processes. Rather than giving the students the activity, show them a transparency of Figure 1, the stages in the history of the Texas coast and Figure 2 of the river valley. Allow the groups 8 minutes to study the figures and list their observations, their interpretations of the data and their conclusions. Discuss their findings using the questions to guide the discussion.
2. For Part II, provide each group with the figures and information on the formation of barrier islands and allow each group 8-10 minutes to analyze the data and develop hypotheses. Each group should present its conclusions to the class for discussion.
3. Ask the groups to develop hypotheses about the effect of global warming on the barrier islands and the building of dams on rivers.
4. Provide each team with the materials to construct models to evaluate the theories of barrier island development.

Activity 7: What can a model of a barrier island tell us?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 7.5, 8.12, 8.14

Math: 6.3, 7.2, 8.2

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- use a map to construct a model of a barrier island system which includes the mainland and bay or lagoon
- use a model to investigate where water and wind erosion and deposition is occurring
- use a model to determine the effect of waves on barrier islands
- use a model to investigate the impact of a hurricane
- conduct an investigation to determine the impact of salt spray on barrier islands

Background:

1. Stress the importance of constructing models to investigate geologic processes. Allow teams to conduct their own inquiries to determine where water, wind and wave erosion and sediment deposition take place. Each team may construct models of barrier islands from different areas of the coast and compare the findings to determine if erosion and deposition differ. When the teams have completed their investigations, have each present its findings to the class.
2. Ask the teams to hypothesize about the impact of hurricane winds and waves on the barrier islands. Again, have the teams use their models to check their hypotheses.
3. Have each team use its model to investigate the impact of salt spray and relate its findings to plants and animals on the island. Discuss special adaptations of organisms to survive in parts of the island.

Activity 8: Do seawalls help?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 7.5, 8.5, 6.6, 8.12, 8.14, 8.10

Math: none

Language Arts: 6.10, 7.10, 8.10, 6.24, 7.24, 8.24

Social Studies: 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- construct a model to determine the impact of waves on an island prior to and after building seawalls
- design an experiment to test and evaluate sand dunes as a means of protecting barrier islands
- compare seawalls and sand dunes as means of protecting barrier islands

Background:

1. Divide the teams into three groups. Group A will construct a barrier island model to determine the impact of waves on the shoreline. Group B will construct a model to determine the impact of building seawalls. Group C will use a model to investigate the use of sand dunes for protection of the island.
2. After each group has presented its findings, have the class analyze each method and decide which

method provides the best protection.

Activity 9: What is the saga of a seawall?

TEKS: Science: 6.5, 7.5, 6.6, 7.14, 8.14, 8.10

Math: none

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.6, 7.9, 6.20, 7.20

Learner outcomes: After completing the activities, the students will be able to:

- analyze diagrams and determine the effects of the presence of a seawall on buildings, dunes, beach, shoreline slope, and what happens to the seawall itself over time
- summarize possible long term impact of a seawall

Background:

1. Discuss the impact of the 1900 hurricane on Galveston and the building of a seawall to protect the city. Ask each team to discuss the impact of a seawall and hypothesize about what might happen to it over a period of 75 years and what must be done to maintain a seawall.
2. After this discussion, provide the students with the series of figures, the saga of a seawall, and have them make observations as to what is happening to buildings, dunes, beaches, shoreline slope and the seawall itself over time. Discuss what can be done to prevent the loss of land, buildings and the seawall.

Activity 10: How would you develop a barrier island?

TEKS: Science: 6.5, 7.5, 8.6, 8.10, 7.14, 8.12, 8.14, 8.10

Math: none

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.6, 7.9, 6.7, 7.10

Activity 11: How should barrier islands be developed?

TEKS: Science: 6.5, 7.5, 8.10, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.7, 7.10, 6.22, 7.21, 8.30

Activity 12: Which "Rules of the Sea" do you favor?

TEKS: Science: 6.6, 8.10, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.23, 7.23, 8.32, 6.6, 7.9, 6.7, 7.10

Activity 13: What is "ideal" barrier island development?

TEKS: Science: 6.5, 7.5, 6.6, 8.10, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20 (6.24, 7.24, 8.24 if you add on creating the brochure)

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.7, 7.10 (6.23, 7.23, 8.32 if you add on creating brochure)

Activity 14: What should be the policies for protecting our coastal islands?

TEKS: Science: 6.6, 8.10, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10, 6.6, 7.9, 6.23, 7.23, 8.32

Learner outcomes: After completing Activities 10-14, the students will be able to:

- compare and evaluate plans for development of barrier islands
- formulate explanations as to the possible impact of a hurricane on developed barrier islands
- examine the effect of using various structures to rebuild an island after a major storm
- compare different methods of rebuilding the island after a major storm
- discuss the pros and cons of the ideas presented in "Rules of the Sea"
- explain the reasons for rebuilding using "Rules of the Sea"
- prepare a brochure explaining several of the ideas from "Rules of the Sea"

Background:

1. Activities 10, 11, 12, 13 and 14 can be used as an integrated series of activities or used as single activities or only some of the activities may be used.
2. Begin with Activity 10. Provide each team with a drawing of an undeveloped barrier island. Each team is to develop its island for people to live and work on. Each team can present its plans with an enlarged sketch of the planned development on newsprint to the class.
3. Provide the teams with copies of Figure 2 to use for comparison with their plans. Have the stu-

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dents use the checklist to evaluate their development plan. Ask students who have visited barrier islands to share what type of development they observed.

4. After evaluating the plan, ask each team to predict what will happen if a major hurricane crossed its planned development. Provide each team with a copy of Figure 3 to check the accuracy of this prediction. Ask the teams to discuss and present changes that they could make to reduce the damage to their planned development. Ask who should pay for the changes or rebuilding after major storm damage to an island.
5. Begin Activity 11. Discuss the fact that federal relief money that is sent to storm damaged areas is often used to build larger and more elaborate structures. Ask students to evaluate this proposal in terms of what is positive, negative and interesting. Then ask the students to give their proposal for what should be done.
6. After each team has assessed the impact of a major storm (Activity 11, Figure 1), analyze two different ways to rebuild the island (Activity 11, Figures 2 and 3). Have the students read "Rules of the Sea to Live By" and use it to evaluate each method in rebuilding. This can be set up as a community hearing on how to rebuild their island after a major storm or on creating a plan for the development of their island. Divide the class into three groups. Group A will represent the island government that must decide how to rebuild an island; Group B will represent the people who favor rebuilding using various structures (groins, jetties, seawalls, beach replenishment); and Group C will represent the island residents who favor rebuilding using the "Rules of the Sea." Depending on the class size, you may want to have one government group, two or more groups (businesses and home owners) that favor rebuilding using the various structures and two or more groups that favor rebuilding using "Rules of the Sea."
7. The government group (Group A) will need to plan the questions they will ask each group to determine the impact of their suggestions (cost, loss of property, impact of future storms, etc). Group A is not to take sides but should ask questions of both sides (A and B). The groups representing the two plans (Groups B and C) will need to plan their presentations at the hearing and be prepared to answer questions from the government group or the opposition group. Provide Groups B and C with copies of activities 12 and 13 to use in planning their presentations. They can use the activities to determine what their group will favor and what they will oppose.
8. After the presentations and discussions, Group A should think about what will be best for their community and should develop a plan in response to the presentations. Challenge the three groups to reach an agreement on a plan for the island (this may not be possible). Conduct a discussion of how the decision was reached or not reached. Point out that decisions are usually made by consensus and discuss the effect of a consensus agreement in planning development of the coastal zone. Also discuss the impact if no agreement can be reached in an island community for several years or if action is only taken on major problems as they happen, meaning there is no long range plan for decision-making.
9. New issues or problems continually arise. Activity 14 can be used to represent additional issues that the groups must address, evaluate and make decisions about. Discuss the problem(s) this presents if no long-range plan is in place. Discuss the problems and frustration of developing long-term plans for the development of an island. The students may feel frustrated because there is no correct answer that resolves all the problems or issues. Ask them for suggestions on how to improve the decision making process and what goals should be the focus in planning developments on barrier islands or elsewhere.

Activity 15: Do islands move? Or how do you stop an island from moving?

TEKS: Science: 6.6, 8.10, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.1, 7.7, 6.3, 7.8, 8.10, 6.6, 7.9, 6.23, 7.23, 8.32

Learner outcomes: After completing the activity, the students will be able to:

- use data to explain how inlets and barrier islands move and change
- use information about inlet and island movement to formulate explanations on the impacts of building jetties

Background:

1. To guide the students in inquiry and formulating explanations, show the students Figure 1 and ask each team to list its observations and inferences. Use the activity questions to guide inquiry and thinking. Repeat this with Figure 2.
2. Provide each team with numbers 7, 8, and 11 and ask students to formulate explanations.
3. As a class summarize the impact of inlet and island movement before and after jetties are built. Discuss the impact of these natural processes on the development of coastal zones.

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1. What Are the Shoreline Features of the Gulf Coast?

Name _____ **Team**_____

If you look at a map of the coastline of the United States, you can see different shorelines. There are even differences along the Gulf coast. Perhaps you are familiar with the sandy beaches along the Gulf. Do you realize that the areas of the Earth that undergo the most change are where the sea meets the land? This boundary between the land and sea is called the **shoreline**. On sandy beaches, the waves sweep sand along the shoreline or out to sea. Where ocean waves meet steep rock cliffs, the waves pound the walls of the cliff. They wear away huge slabs of rock. You are going to analyze the shoreline along the Gulf to determine what features the waves have created.

Materials: Texas Highway Map (1 per group), Map of United States (optional)

Procedure:

1. The long islands, called barrier islands, appear to be the most obvious features of the Texas coast from the air and on maps. The best known barrier island is Galveston Island while Padre Island is the longest. The barrier chain along the Gulf is the world's largest. The islands average about 30 miles long and two miles wide, and consist primarily of fine sand extending to a depth of 30 feet. The barrier islands are separated from each other by tidal channels (passes) through which water moves during high tide. The islands are separated from the mainland by shallow bays.

   Obtain a Texas highway map that shows the Gulf of Mexico shoreline. Locate the barriers islands on the map. Name the barrier islands you found.

   Between the barrier islands there are inlets, or passes. Water moves between the Gulf and the bays and lagoons through the passes. The water flow through these passes is caused by tides. Locate the tidal passes. List the location of the passes below. Include the map coordinates.

2. Along the Texas Gulf Coast, the waves break a distance from the shore due to the gentle slope of the shelf. The sand is pushed up, forming sandbars. Centuries of this formed long, sand islands – the barrier islands. These islands were widened by sand from their seaward side until they were miles across. They also were partially built up by the winds, which picked up the sand and formed sand dunes. Barrier islands may be connected to the mainland, at least on one end. Some are wide enough that cities have been built on them. Identify cities built on barrier islands of the Gulf Coast.

3. As you look at the map, you will notice that there are two kinds of bays. One is long, narrow, and parallel to the coast behind the barrier islands. This type of bay, called a lagoon, separates the barrier island from the mainland. The lagoons average three miles wide, 20 miles long and six feet deep. They usually have a mud bottom. Much of the Gulf Intercoastal Waterway has resulted from dredging the lagoons behind the barrier islands. Locate the lagoons. Include their map coordinates. Along what part of the Texas coast are lagoons located?

4. What might be a possible explanation for more lagoons in one area than another?

5. Locate the intercoastal waterway. Why was this area behind the barrier islands dredged for a waterway instead of using the Gulf for shipping?

6. The second kind of bay is also longer in one direction than in the other, but its length is at right angles to the coast. This is the estuary bay. An example is Galveston Bay and its continuation as Trinity Bay. The estuary bays average eight miles wide, 25 miles long and 10 feet deep and generally have mud bottoms like the lagoons.

7. Locate the estuary bays. Which are estuary bays? Include their coordinates.

8. How do the estuary bays differ from the lagoon bays?

9. How does water enter the estuary bays and what kind of water (fresh, salt or brackish) is found in these bays?

10. How does water enter the lagoons and what kind of water is found in the lagoons? Explain.

11. Look at the shoreline. Notice that Texas really has two shorelines — one along the Gulf of Mexico and another along the bays. The Gulf shoreline is on the seaward side of the barrier islands with broad, sandy beaches. The bay shoreline is different. It is very irregular, generally flat and marshy without sandy beaches. Why would the beaches be different?

12. As the water from a river flows into a body of water, the flow of water is slowed and the sediments in the water are deposited. This deposit of sediments that forms at the mouth of a river is called a delta. The deltas built by the rivers are another feature of the Gulf Coast. Most deltas occur near the tops of the estuary-type bays. Rivers that carry large sediment loads have filled their estuaries. They now flow directly into the Gulf. Which Texas rivers flow directly into the Gulf?

13. The Mississippi River carries sediments from a large part of the United States. The Mississippi and other major rivers are very slowly filling the Gulf with sediment. A few million

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years ago the Mississippi River emptied into the Gulf as far north as Cairo, Illinois. Today, it has filled in the entire area and is emptying into the Gulf. See Figure 1.1 — Mississippi River Delta. Note how much area the Mississippi has filled in since 1838.

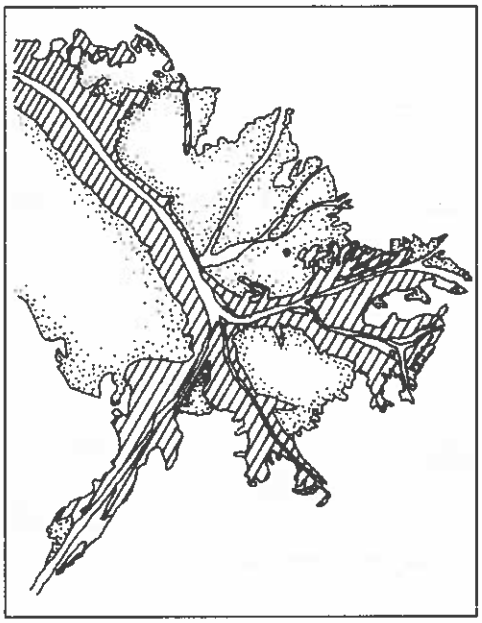


Fig. 1.1. Mississippi River Delta

14. Use Figure 1.2 to determine what kind of delta the Mississippi formed. Is it an arcuate or birdfoot delta?

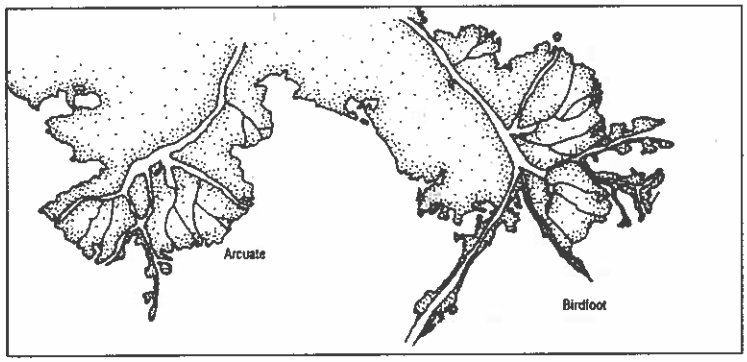


Fig. 1.2. Gulf of Mexico Deltas

15. The waves usually do not come straight into the shore. Instead, they hit the beach at an angle. As a result, water near the shore is pushed along the shoreline, forming a current called a longshore current. These currents can carry large amounts of sand along the shorelines. This current may act like a conveyor belt carrying sand. In places where the shoreline changes directions, the current slows down and deposits sand. In bays, the currents leave a deposit of sand called a "spit". A spit is a bar of sand with one end attached to land. The other end is across the open water of a bay. Identify where spits are located along the Texas shoreline. Include the map coordinates for the spits.

16. Another feature of coastlines is a land area that extends out into the water and is almost entirely surrounded by water. This is a **peninsula**. Identify the peninsulas found along the Texas coastline. Include the map coordinates.

17. There also are areas along the Gulf coast built by plants and animals. The Florida Keys are a coral-reef coast formed by coral during a period between glaciers when the sea was about 20 feet higher than it is today. Many islands and projections of the mainland along southwestern Florida have been formed by mangroves. They can grow in saltwater. A seed pod falls from a mangrove tree overhanging the shoreline and starts a new plant on the

bottom. The seed also might drift out to a shoal and become rooted. Currents are slowed by the mangrove roots and deposit their sediments and, eventually, islands and projections develop along the shoreline.

Figure 1.3 is a shoreline formed by Mangroves. Examine Figures 1.1, 1.3 and 1.4. These figures represent the shorelines of the Gulf of Mexico. Summarize their differences below.

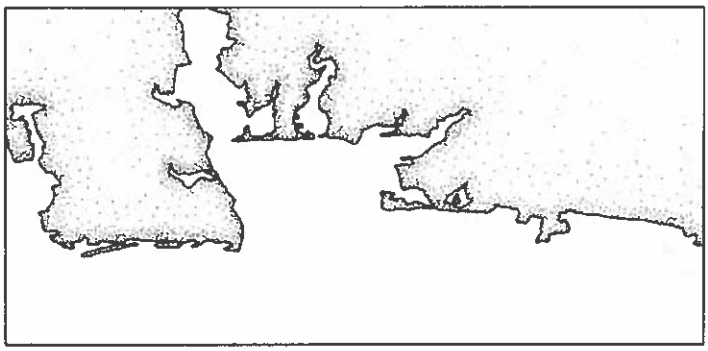


Fig. 1.3. Shoreline formed by mangroves.

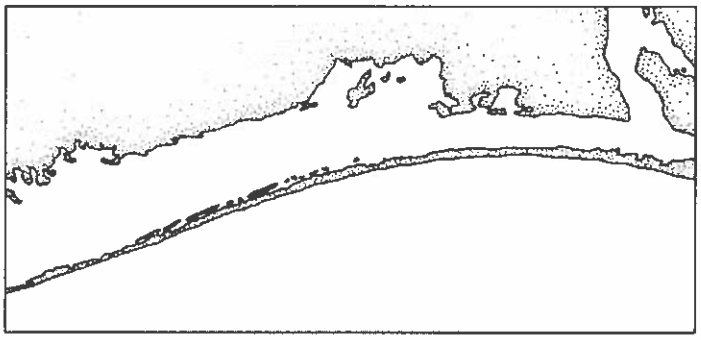


Fig. 1.4. Barrier Island shoreline.

18. Obtain a map of the Gulf of Mexico that includes Florida. Compare the Florida and Texas shorelines.

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2. How Has the Texas Shoreline Changed Over Time?

Geologist _____ **Team** _____

Natural processes are constantly changing and shaping the coastal region. These processes include stream runoff, sediments being deposited, wave erosion of the shoreline, storm surge, flooding, ground sinking, faulting and sand dune movement. These processes result from natural interactions. You and your team are going to examine how nature changes the shoreline.

Materials: Texas highway map

Procedures:

Part I: How has the Colorado River Delta changed?

1. Examine how nature changes the shape of the coastal region. If we go back in time, we find that Matagorda Bay was one bay in 1856. See Figure 2.1. Figure 2.2 shows the effect of a log jam at the mouth of the Colorado River in 1929. What was the effect of the log jam?

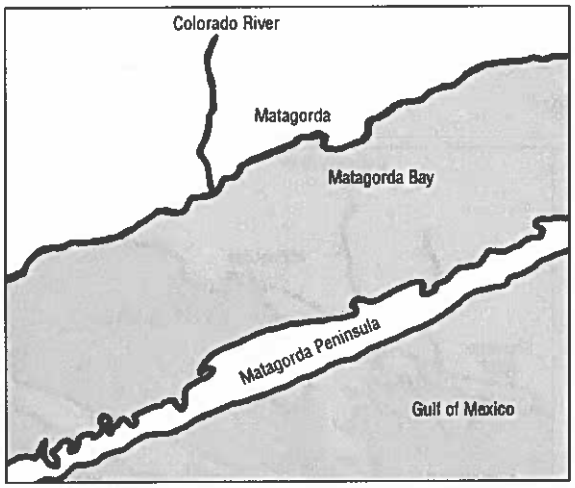


Fig. 2.1. Colorado River 1856

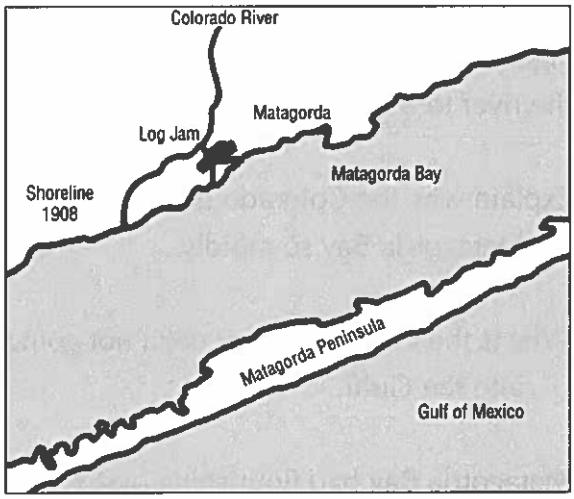


Fig. 2.2. Colorado River in 1929, before log jam was moved.

Illustrations in this section from Lien: Investigating the Marine Environment and Its Resources, p. 277 ©1979 Texas Sea Grant College Program.

2. Examine Figures 2.3 and 2.4 to see what happened after the log jam was removed. What happened to Colorado River delta from 1930 to 1936?

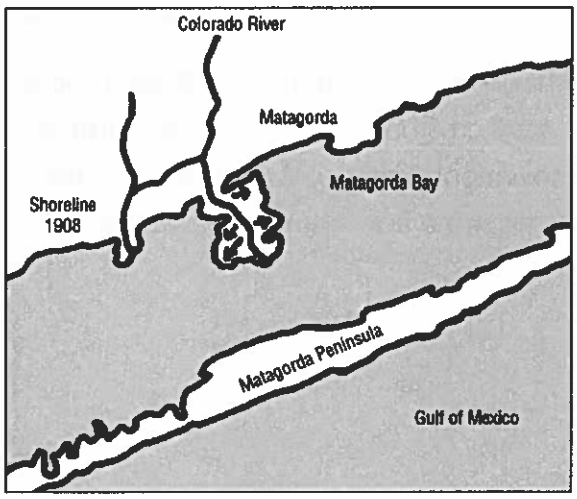


Fig. 2.3. Colorado Delta 1930

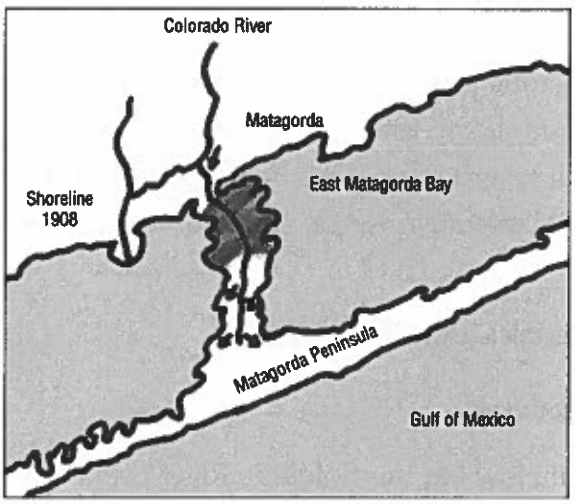


Fig. 2.4. Colorado Delta 1936

Examine Figure 2.3 and describe what is happening.

3. Examine Figure 2.4 and describe the changes that occurred in the six years. What has happened to Matagorda Bay?

4. Figure 2.5 shows the Colorado delta in 1941, five years later. How many years did it take the river to build a delta five miles across the bay?

Explain why the Colorado delta is filling in Matagorda Bay so rapidly.

Why is the Colorado River delta not going into the Gulf?

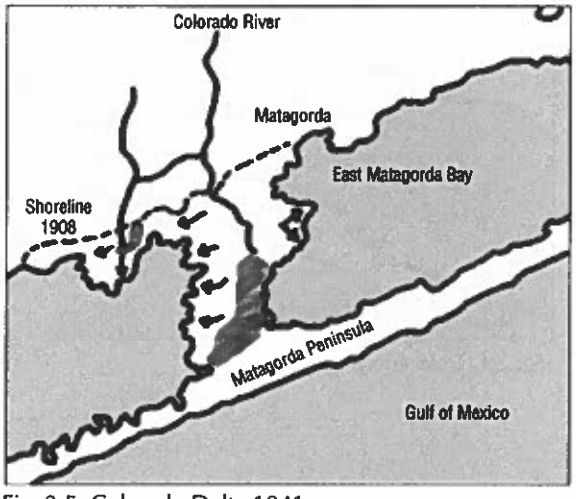


Fig. 2.5. Colorado Delta 1941

5. Matagorda Bay had flourishing oyster reefs. How would this natural change of the delta forming in Matagorda Bay affect the marine life?

6. The U.S. Corp of Engineers cut a ditch through the islands to allow water to flow into the open Gulf. What would have happened if they had not cut this ditch through the barrier island?

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7. Use the Texas highway map and examine the shoreline. Which river's deltas may have filled in a bay? Explain.

8. Figure 2.6 shows the Colorado River mouth today. Water from the river enters the western bay and the Gulf of Mexico. Marshes occupy the low-lying areas along the shore of the mainland and the bay side of the barrier islands and peninsulas. The mainland marsh areas are directly related to the river.

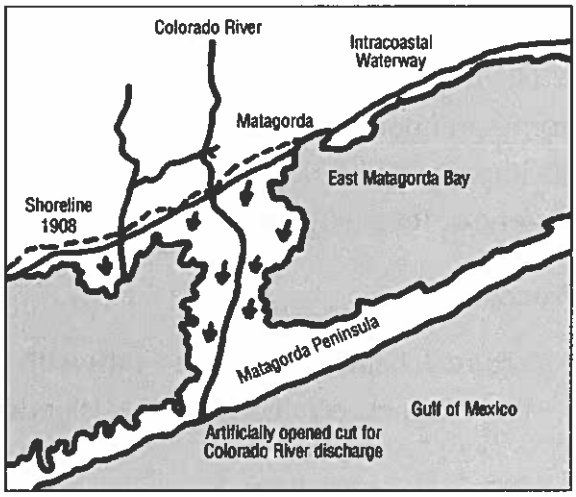


Fig. 2.6. Colorado River today

Grassflats occur in many areas, but are best on the western side of the delta. Here the water is a few inches to about four feet deep and the bottom is sand and muddy sand. Oyster reefs also once flourished in several areas of this bay. What is happening in the western bay so that oyster reefs are dying?

9. Compare East and West Matagorda Bay. Explain their differences. How would these differences affect marine life?

10. People's activities can affect the natural processes of change and marine organisms. For example, how might dredging a cut through the Matagorda Peninsula affect marine organisms?

11. The Colorado River now flows into the open Gulf. It would be expected that a new delta would form in the Gulf. However, there is not a sign of a new delta forming in the Gulf. What are some possible explanations?

3. What Are Some Short-term Changes in the Shoreline?

Geologist _____ **Team**_____

Natural processes are changing and shaping the shoreline. Natural processes such as storms and hurricanes can cause rapid changes in the shoreline. You are going to investigate the impact of a hurricane.

Materials: Texas Highway Map

Procedure:

1. Figure 3.1 shows the Texas Coast with the barrier islands. How might a hurricane change the coast, especially the barrier islands?

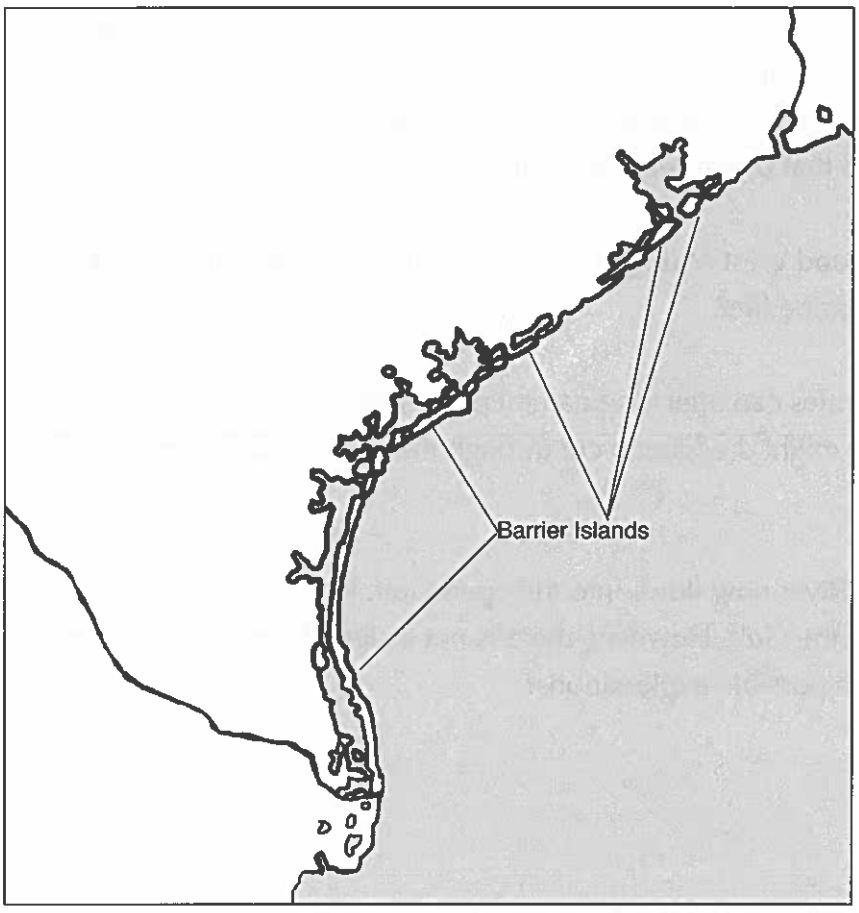


Fig. 3.1. Texas Coast

2. On the Texas Highway Map, locate the Matagorda Peninsula. Where is it located? Include the coordinates.

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3. Figure 3.2 shows the Matagorda Peninsula in 1960. Describe the Peninsula.

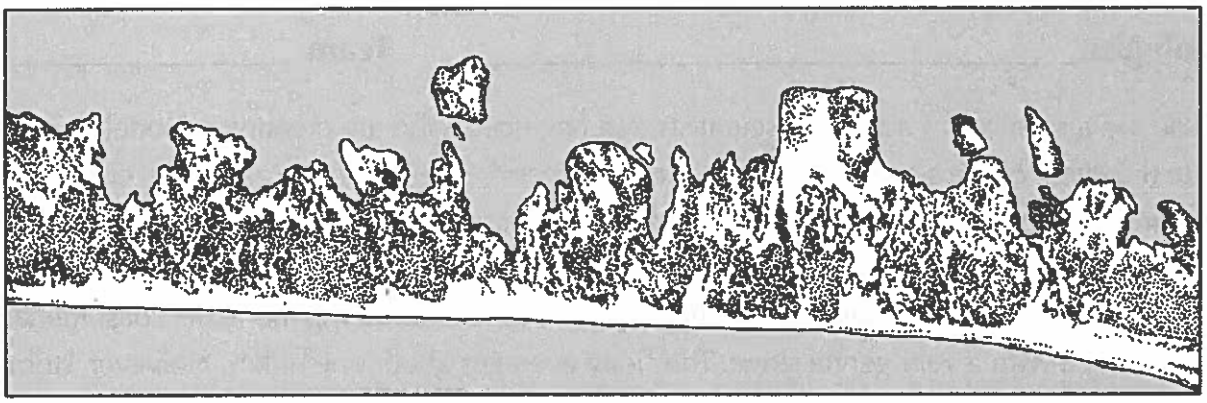


Fig. 3.2. Matagorda Peninsula 1960 (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

4. In 1961, Hurricane Carla had winds of more than 175 miles per hour (mph). The winds along the entire coast were more than 75 mph. Figure 3.3 is after Hurricane Carla. What changes do you see on the Matagorda Peninsula as a result of Hurricane Carla?

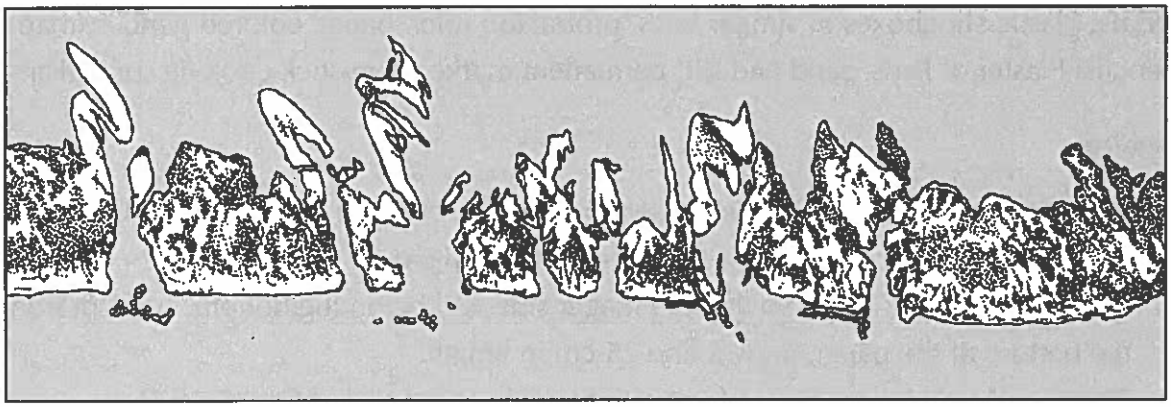


Fig. 3.3. Matagorda Peninsula (after Hurricane Carla 1961) (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

5. What effect could these changes have on the marine environment and on marine organisms?

6. What do you think will happen to the islands several years after a hurricane? For example, is Matagorda Peninsula the same as it was after Carla (Figure 3.3)? Explain.

7. Records for the past 100 years show that hurricanes have made landfall on the Texas coast at an average rate of about four to six per decade. The information on coastal erosion is only available for more recent storms. Hurricane Alicia in 1983 removed 54 million cubic feet of sand from the western part of Galveston Island. In 1980, Hurricane Allen had winds of 115 mph. It caused 6 to 100 feet of shoreline erosion along Padre Island. It also opened 38 channels across the island. These were moderate hurricanes. Explain why the most obvious short-term coastline changes are found on the barrier islands.

4. What Is the Effect of Different Shoreline Slopes?

Geologist _____ **Team** _____

You are a member of a team of scientists and engineers who are creating a model to investigate the effect of the slope of the shoreline. Your team's role is to learn about the effect of the slope in order to make predictions to protect the coastal zone. The shoreline and beach is the first line of defense that protects the land from the sea. The way tides, waves or storm surges affect a beach depends on the physical nature of the shoreline. Along the Texas coast the land meets the sea with a very gentle slope. The slope averages about one m/km. However, storm surges and hurricanes have a major impact on the coast.

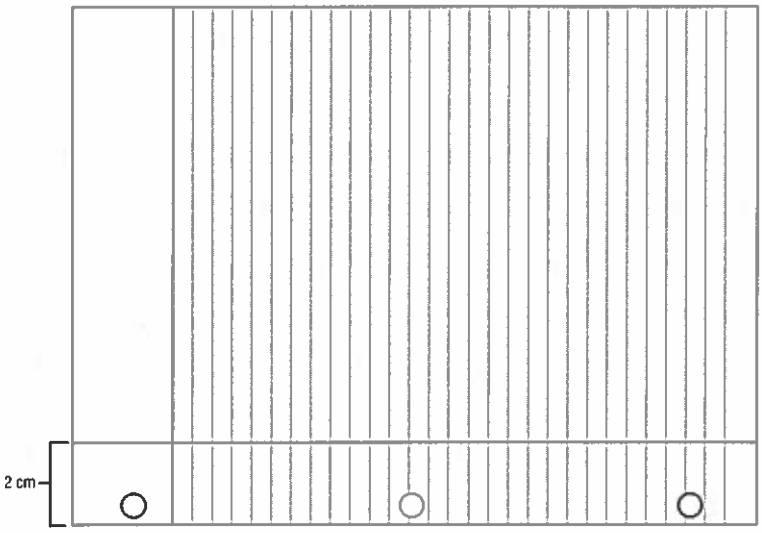
Scientists and engineers often create models to study events in nature. Why build an elaborate model? A real model is better than a computer generated model. Models save money. One advantage of using models is that changes can be made and the effect of the changes can be immediately observed.

Materials: Plastic shoeboxes or similar trays, protractor, ruler, paper, colored pencils (map pencils) Plaster of Paris, sand and silt, permanent marker, non-stick cooking spray (Pam)

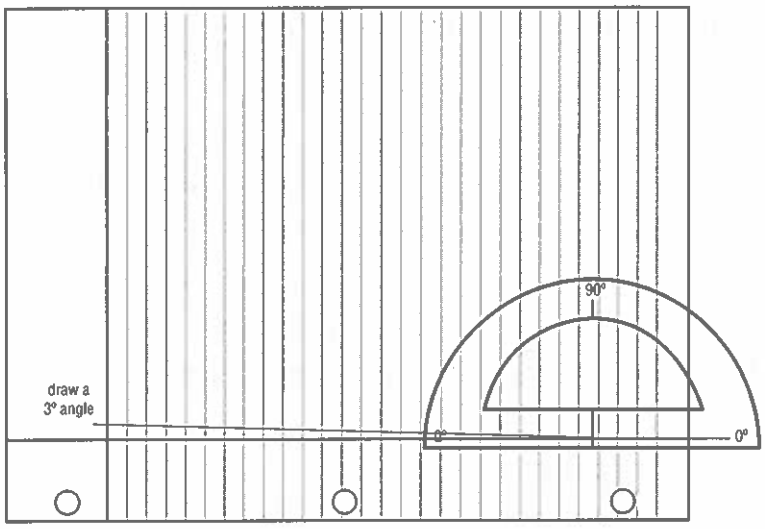
Procedure:

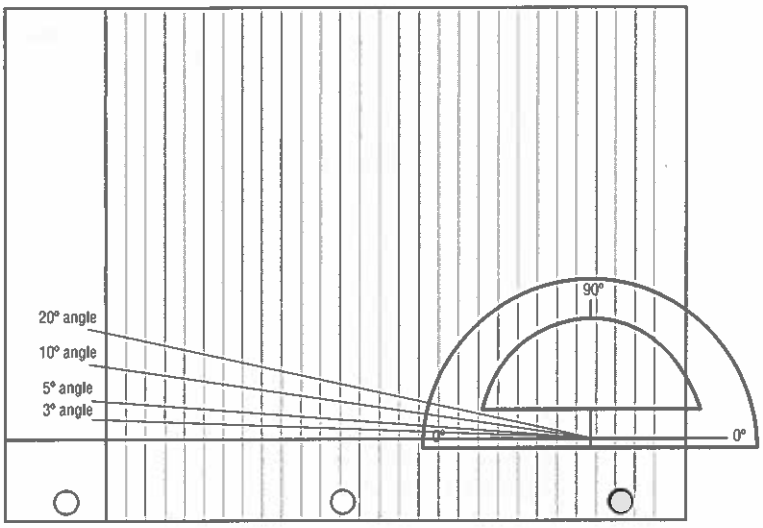
Part I: Can you make a graphic model to demonstrate the effect of different shoreline slopes?

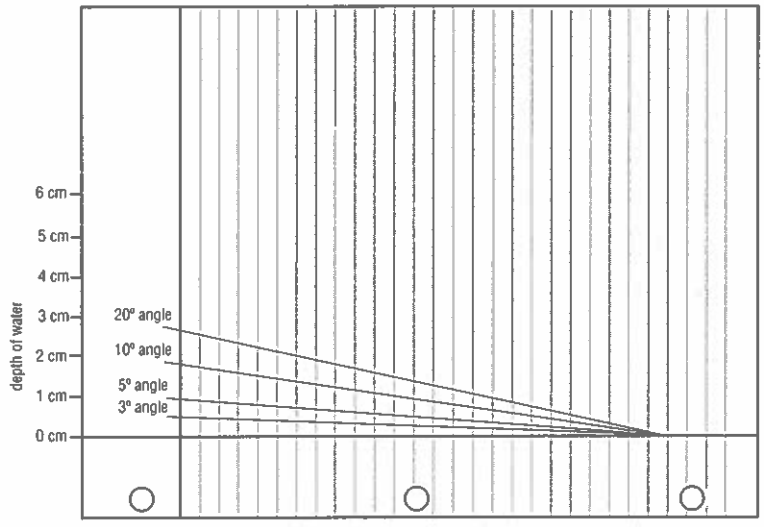
1. First create a model of the slope of the coastal zone on paper.
   a. Turn the notebook paper so that the longer side will be on the bottom. Two cm from the bottom of the paper, draw a line 25 cm in length.
   b. Draw an 8 cm vertical line to form a right angle at left end of the 25 cm line.



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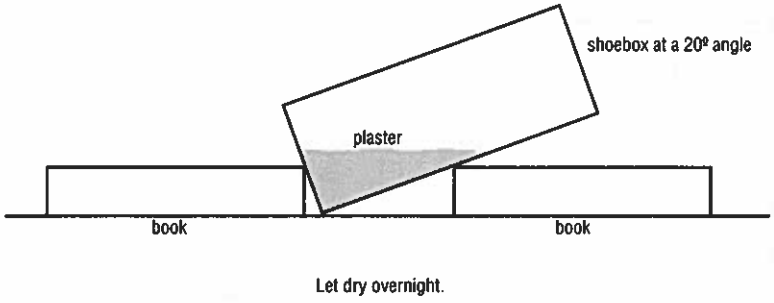
c. Place a mark 10 cm from the right end of the horizontal line. This mark will represent the vertex of the angle and the point where the beach begins.
d. Place the protractor at the 10 cm point. Use the protractor to draw a 3° angle. Use a ruler to extend the left to the right to form a slope.
e. Repeat the above procedure to form slopes of the following angles: 5°, 10° and 20°. Use a different colored map pencil for each slope.
f. Mark a scale of 1-cm intervals on each side (right and left) along the vertical axis. Draw horizontal lines across. Shade the area beneath the horizontal lines in different colors. The horizontal lines represent the level of water.

3. What happens to the land area as the water level rises? Is more land covered with water? Explain.

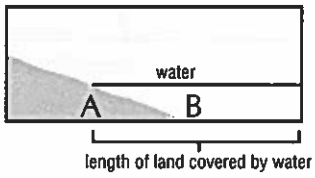
4. Does the degree of slope influence or change the amount of land area covered by water? Explain.

Part II: What can a model tell about the effect of different shoreline slopes?

1. Obtain a plastic shoe box or similar container for each different slope.
   a. Set the container on the table so that the longer side is facing you.
   b. Place a mark 10 cm from the right end of the container. This mark will represent the beginning of the slope of the land, the point where the beach begins.
   c. Place the protractor at the 10 cm point on the side of the container. Use a marker and place a dot at this point. Use the protractor to draw a 3° angle on the side of the container. Use a ruler to extend the line from the left to the right to form a slope. Make a second dot where the line ends.
   d. Spray the container with non-stick cooking spray.
   e. Follow the directions for mixing the Plaster of Paris and mold the plaster to make the 3-degree slope beginning at the 10-cm point.
   f. Repeat the above procedure to form slopes of the following angles each in a separate container: 5°, 10° and 20°.
   g. Use two books to hold the container at an angle until the plaster hardens. Allow the Plaster of Paris slopes to dry overnight.



Let dry overnight.



   h. The next day, add water to a depth of 1 cm. Measure the area of land (Plaster of Paris) covered by water. Measure the length of the plaster covered by the water. See the figure, the measurement from A to B will represent the length of land covered by water. This length times the width of the container is the area covered by water.
   i. Add water to a depth of 2 cm, measure the amount of land covered and record the data in the Table. Repeat this for 3cm, 4 cm, 5 cm and 6 cm.
   j. Repeat steps g and h for the 5°, 10° and 20° slopes. Construct a table similar to the following example and record the measurements.

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Table 1: Distance of Land Covered by Water Depths of 1 cm to 5 cm for Different Slopes of Lands

Water Depth	3° Slope cm of land covered	5° Slope cm of land covered	10° Slope cm of land covered	20° Slope cm of land covered
1cm				
2cm				
3cm				
4cm				
5cm				

2. Analyze the data you collected. Summarize the findings.

3. How much more distance does the water cover for each 1 cm the level of the water is raised?

4. Does the degree of slope make a difference? Explain.

5. How does your graphic model (Part I) compare to the actual model? Were the results similar? Explain.

6. The 3° slope is the more common slope found along the Texas coast. What is the impact of a tidal surge or storm surge in which the water level in an area of the coast is raised 5 or more feet above sea level?

7. Hurricanes may bring a storm surge that increases the level of the water from 10 to 20 feet. What will be the effect of a storm surge of this type along the Texas coast?

8. Many waste disposal sites along the Texas coast are located less than 10 to 20 feet above sea level. What problems can result?

9. Summarize what you have learned about the effect of the slope on the coastal zone.

5. Is the Sea Level Rising?

Geologist_____ **Team**_____

The lowering of the mean global temperature in an ice age freezes a large amount of water into polar icecaps and glaciers. This lowers the sea level. When the mean global temperatures increase, the glaciers melt and this water runs back into the oceans. The sea level rises. During these times, the sea level may change by more than 100 meters. In investigating the changing sea level, scientists would like to determine the following facts: When did the rise in the sea level begin? How fast has it happened? How long will it last? How high will it go before it reverses? You are going to investigate what is happening on the Gulf Coast. Is the sea level rising on the Gulf Coast? Is it rising faster or slower than in the past?

Materials: none

Procedure:

1. Examine Figure 5.1. It shows 17,000 years of sea level change along the Texas shoreline. What conclusion can you reach about the sea level on the Texas coast?

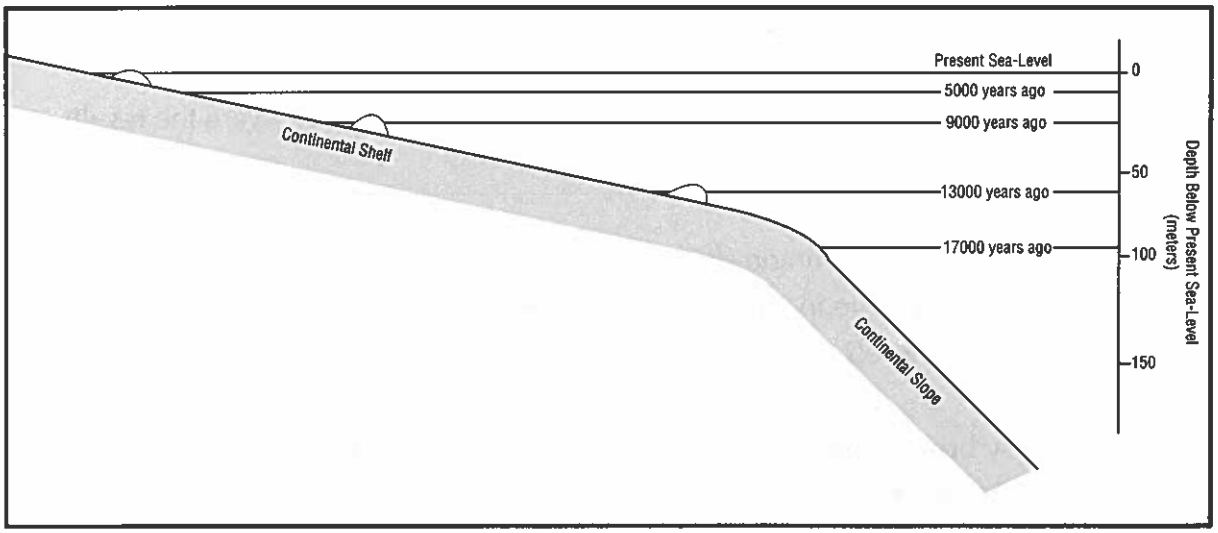


Fig. 5.1. 17,000 Years of Sea Level Change on the Texas Coast. (Source: Morton et al, 1983: Living with the Texas Shore)

2. When was the sea level at its lowest point?

3. How many meters below present sea level was the lowest point?

4. When did the sea level rise the fastest?

5. When did the rapid rise in sea level slow down?

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6. Figure 5.2 shows the sea level rise since 1920. What generalization can you make about the sea level since 1920?

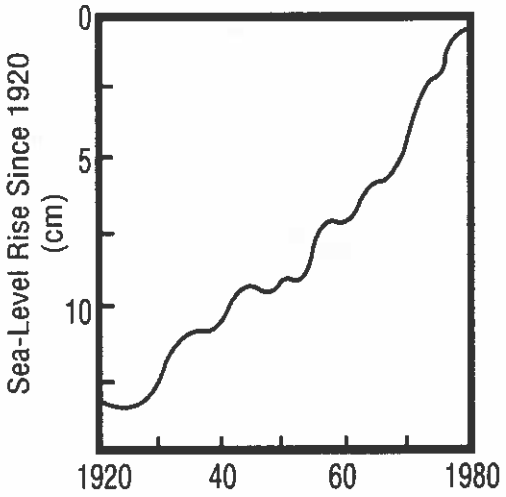


Fig. 5.2. Sea Level Change on Texas Coast Since 1920 (Source: Morton et al, 1983)

7. When the volume of water changes, it causes a change in the sea level. If the volume increases, the sea level rises, or, if it decreases, the sea level is lower. A global change in sea level occurs in three ways:
   a. by adding or reducing (Ice Age) the amount of water in the oceans, or
   b. changing the volume of the ocean basins (plate tectonics, sediments filling a basin, etc.), or
   c. by changing the mean temperature of the oceans so that its volume increases or decreases as saltwater expands or contracts.

   A rise or fall in the mean annual temperature of only 1-2° C can have a big effect. The last ice age was produced with only a 2-3° C lower mean temperature than today. Predict what will happen if the trend toward a warmer global climate continues and the mean annual temperature increases only a few degrees. Explain.

8. There is approximately 100 years of reliable data from tide gauges. Examine Figure 5.3. It gives the average sea level curve as determined by tide gauge data. Compare the global average with that of the east coast of North America and the Gulf of Mexico. What is the pattern of the sea level curve? What can you conclude from the data?

9. The ozone layer in the Earth's atmosphere is being reduced and global temperatures appear to be rising. What is your hypothesis about its effect on the sea level?

10. Figure 5.4 is of the tide gauge records for New York and Galveston, Texas. Compare the two rates. How are they alike? How do they differ?

11. The New York record (Figure 5.4) is close to the global average of 3 mm. The Galveston rate of rise is higher than the global average. Sea level change is affected by local changes. For example, the mean annual rate of sea level rise for Port Isabel is 3.6 mm; Galveston is 6.2 while Grand Isle, Louisiana is 9.5 mm per year. Could the depositing of sediments from the rivers or subsidence (sinking of land) cause this? Explain.

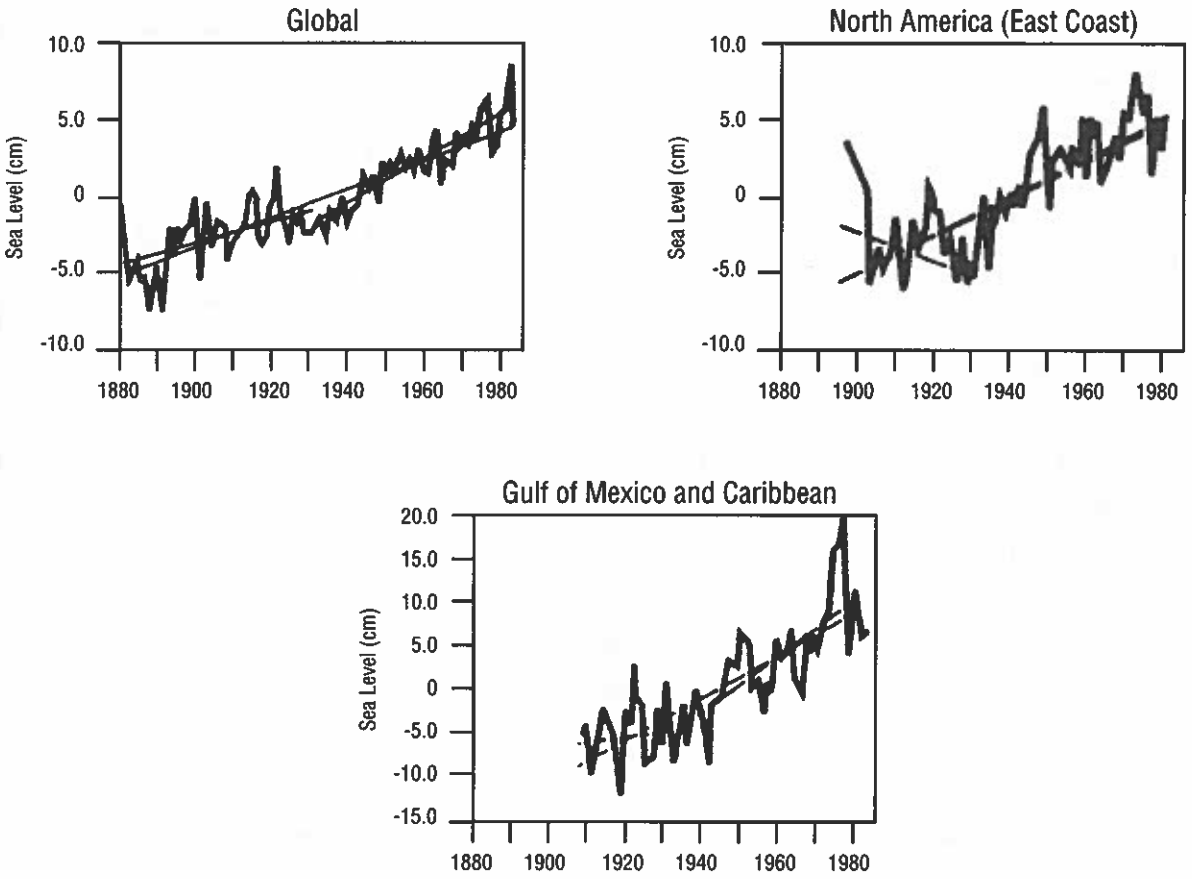


Fig. 5.3. Sea level curves determined by tide gauge data. (Source: Davis, 1997: The Evolving Coast)

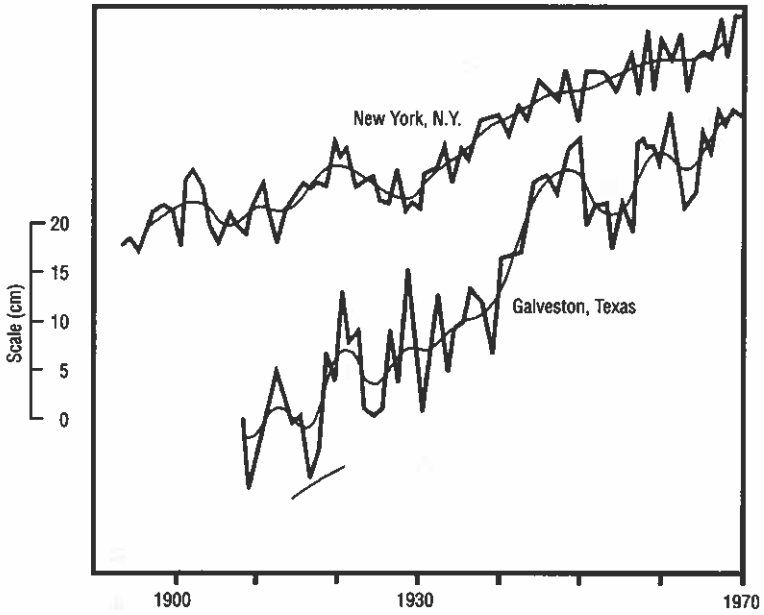


Fig. 5.4. Tidal gauge records for New York and Galveston. (Source: Davis, 1997: The Evolving Coast)

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12. The reason for the differences is that in parts of the coastal zone in East Texas and the Mississippi River delta in Louisiana, the sea level is rising 9 to 10 mm because the land is sinking. About 6 to 7 mm of this annual rise is due to subsidence (sinking) caused by a combination of sediments compacting and the removal of fluids from the coastal zone. The natural process of compaction has been occurring for millions of years along the Gulf coast. However, part of the sinking is more recent and is due to human activities. Nearly 100,000 wells have removed large amounts of oil and natural gas from the coastal zone of the Gulf of Mexico. In addition, large quantities of water have been removed for home and industrial use. As a result of these activities, some of the land near Galveston has sunk nearly 2 meters in the last 100 years. How does a rise in sea level affect an area? What will happen if an area of the coast sinks 2 meters or over 6 feet?

13. If the sea level is rising approximately 6 mm per year in the Galveston area, how many years will it take for the sea level to rise 30 cm, or 1 foot?

14. The slope of the coastal zone is gentle. A rise in sea level of 30 cm, or 1 foot, could result in the shoreline moving between 100 and 1,500 feet further inland. Some project that a 3° rise in annual temperature could result in a 90-cm or 3-foot rise in the sea level of the Texas coast. What will happen if the shoreline/water moves further inland?

    How will the rise in sea level affect the cities on the coast?

15. On a separate sheet of paper, create a cartoon to show what might happen as the sea level rises.

16. In the Mississippi River delta region, an annual rise in the sea level of 9 mm causes a loss of more than 40 acres of coastal land a month. What effect does this have on the area?

17. What might be done to prevent the sea level from rising more rapidly?

6. How Did the Barrier Islands Form?

Geologist _____ **Team** _____

The great age of most geologic features is often emphasized. However, the barrier islands are very young. The oldest deposits are only several thousand years old. These barriers of sand, shell, and gravel exist on all coastlines of the United States. Most of the theories of barrier island formation are related to the changes in the sea level during the ice ages. You are going to analyze the data to determine how the barrier islands might have formed.

Materials: Texas Highway map, stream table or large shallow pan, sand, and water

Procedure:

Part I: Has the location of the shoreline changed?

1. Examine Figure 6.1 (next page), sketches representing stages in the history of the Texas coast. Where was the shoreline at the end of the Ice Age?

2. Where did the rivers empty into the Gulf of Mexico at the end of the Ice Age?

3. As the massive ice sheets that covered the Midwestern part of the United States melted, where did the water from the melting ice end up?

4. Where was the Texas shoreline 4,500 years ago after most of the large glaciers or massive ice sheets had melted? Explain.

5. Where is the shoreline today, compared to its location during the Ice Age?

6. In Figure 6.2, the sketches represent the same river valley 20 miles inland during the Ice Age and today. How do the valleys differ and why?

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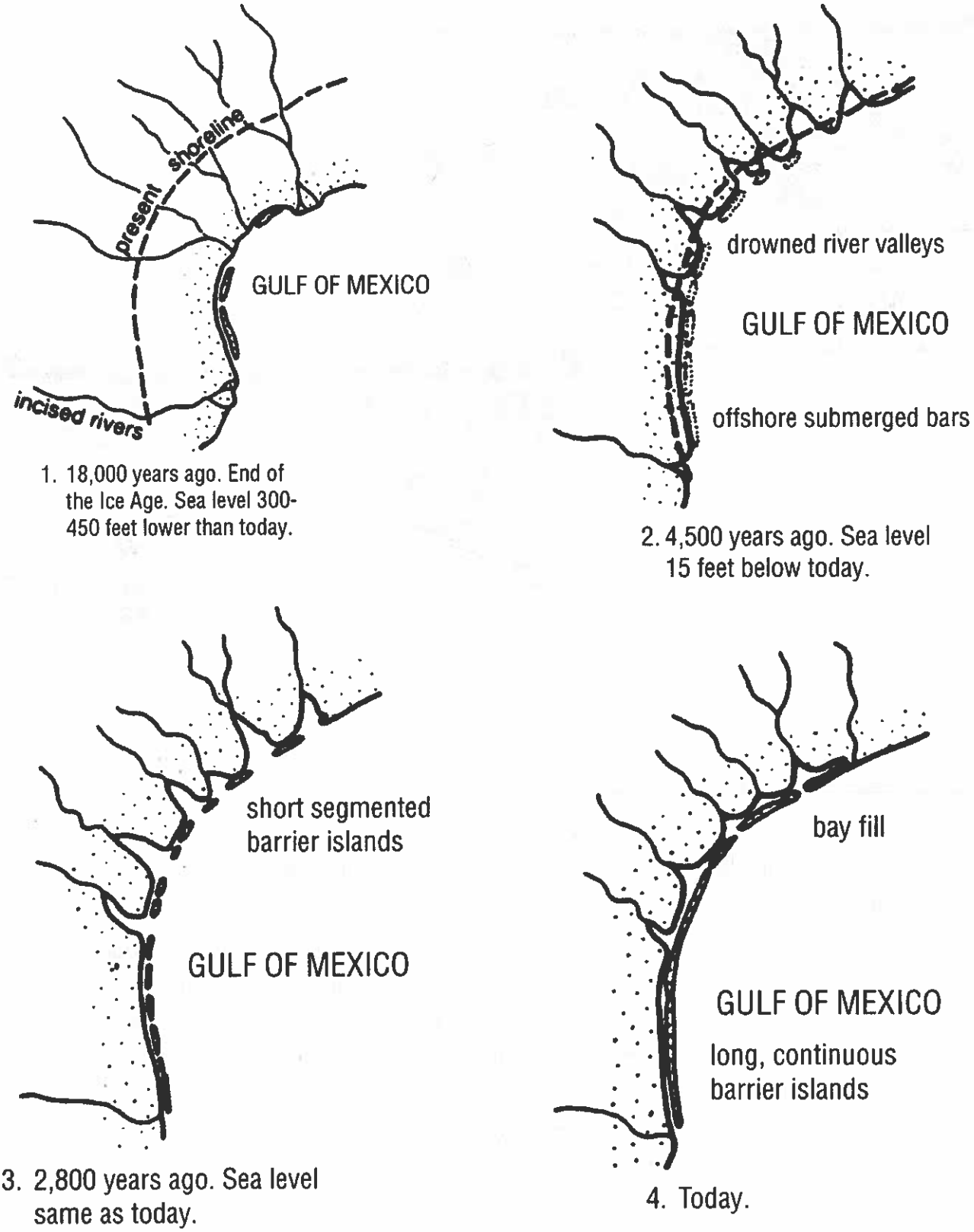


Fig. 6.1. Geologic history of Texas barrier islands. (Source: Roadside Geology)

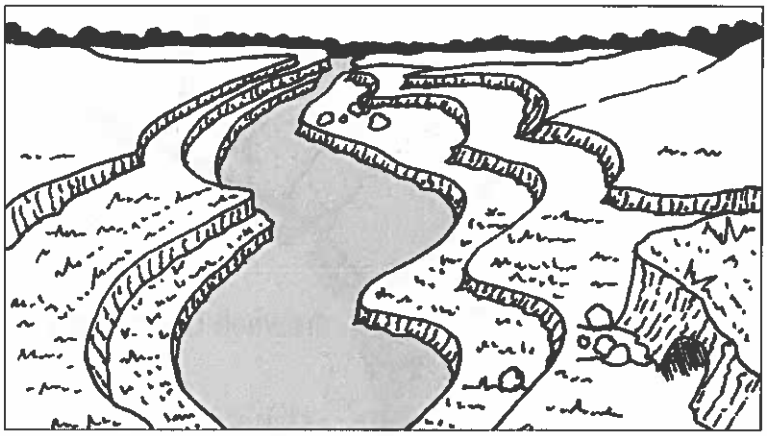


Fig. 6.2a. River valley during Ice Age.

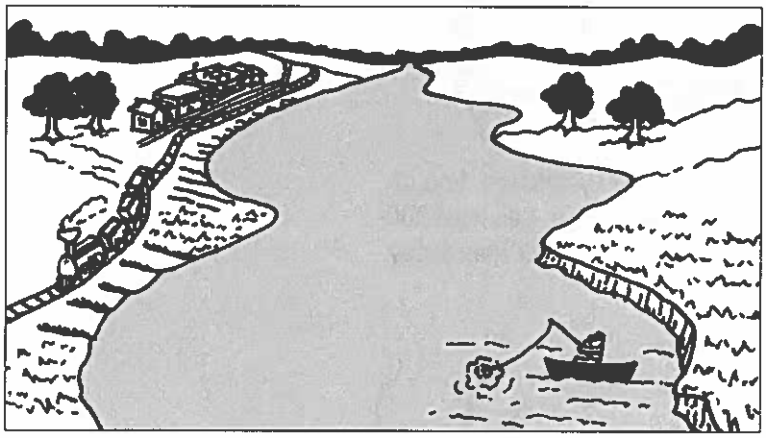


Fig. 6.2b. River valley today. (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

Part II: How were the barrier islands formed?

1. The actual process of the barrier island formation is still debated by geologists. Most of the theories of how the barrier islands formed are related to the freezing and melting of the great ice sheets.

   About 18,000 years ago, near the end of the last Ice Age, the shoreline was about 40 to 50 miles further into the Gulf. The sea level began to rise as the Ice Age glaciers melted. The sea level rose about 300 to 450 feet as the ice sheets melted. It reached today's level several thousand years ago. One theory is that as the level of the sea rose more than 400 feet, the shoreline moved inland. Storm waves from the rising water would wash over the ridges of sand dunes originally formed by windblown sand. The lowland between the ridges and the mainland were flooded. The ridges became the barrier islands. See Figure 6.3. What happens to the dunes in this theory as the sea rises?

2. Another theory is that barrier islands may have formed from sandbars that were submerged. As the water rose the waves carried the sand to the shoreline (Figure 6.4). Eventually, as sand was added to the ridge, it was built up so that the surface of the barrier island

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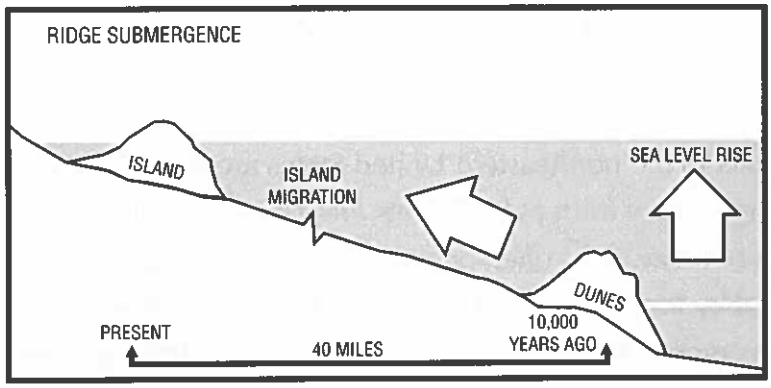


Fig. 6.3. Barrier Island Formation: Ridge submergence

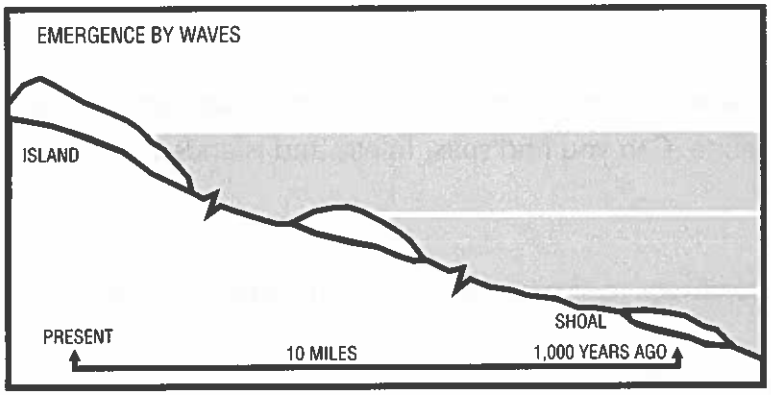


Fig. 6.4. Barrier Island Formation: Emergency by waves.

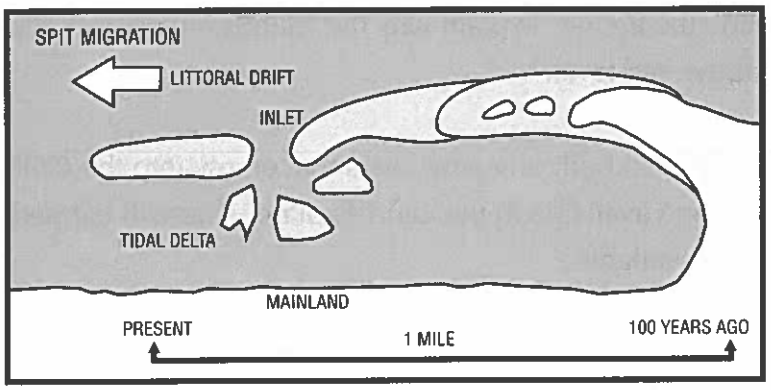
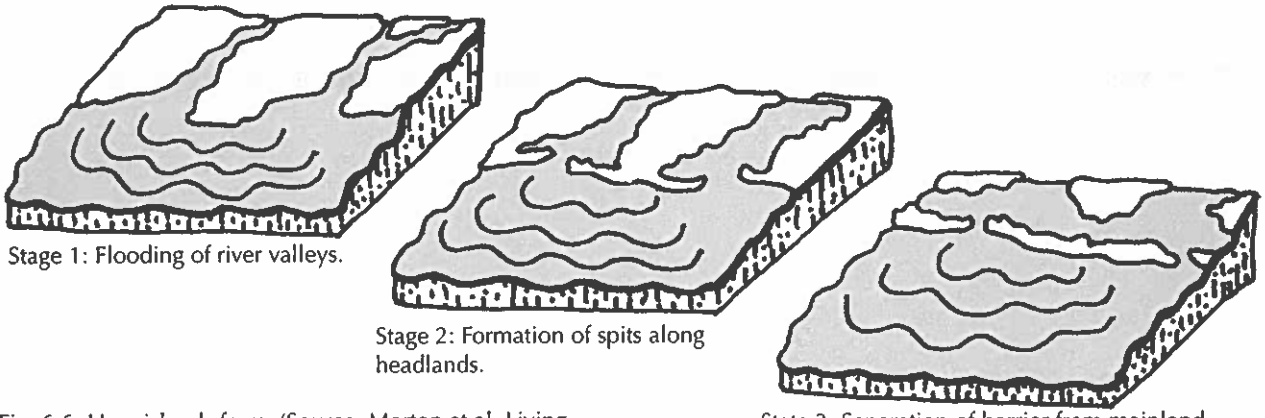


Fig. 6.5. Barrier Island Formation: Spit Migration



Stage 1: Flooding of river valleys.

Stage 2: Formation of spits along headlands.

State 3: Separation of barrier from mainland.

Fig. 6.6. How islands form. (Source: Morton et al. Living with the Texas Shore)

was above sea level. How does this theory (Figure 6.4) differ from the previous one in Figure 6.3?

3. Many of the barriers in the northeastern United States are spits. They are attached to the mainland at one end. They form as sediments are moved by currents across open water or across the mouth of a bay. Spits often become barrier islands after storms separate them from the mainland by forming inlets (Figure 6.5). The river valleys were flooded as the ice melted. The waves moved the sand forming spits along the land between the flooded river valleys. Erosion and flooding separates the spit from the land so it becomes an island. Figure 6.6 shows this sequence.

   If this is how the islands formed, what evidence would support this theory? Examine a map of the Texas shoreline. Can you find spits, inlets, and islands along the coast that support this? Explain.

4. As the sea level continues to rise, predict what will happen to the barrier island. Explain.

5. It has been stated that the barrier islands are moving and movement is essential to their survival. For every 1-foot rise in sea level, coastal barriers islands must move 100 to 1,000 feet inland. Examine the figures. Explain why the islands must move inland if they are going to remain above sea level.

6. Dams and lakes have been built on many rivers that empty into the Gulf of Mexico. How does this affect the sand available in the Gulf? Explain what will happen to the barrier islands if less sand is available.

Part III: Can a model show how barrier islands may have formed?

1. Use a stream table or a large pan with sand and water to create a model of coastal barrier islands from spits (Figure 6.6). Use wave action to create the spit and barrier islands.

2. Were you able to use a model to test the theory? Discuss what you learned from the model.

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7. What Can a Model of a Barrier Island Tell Us?

Geologist _____ **Team** _____

The most dynamic environment is along the Gulf shoreline. This is where air, water and land meet and interact. Gulf waves are produced by the wind. The waves reach the beach where they interact with the sand. The winds also carry salt spray and move the sand on the beaches. Often scientists create models to determine how certain features may have formed. You are going to create a model of a barrier island to investigate these interactions among the water, sand and wind.

Materials: Texas highway map, markers, large tray (aluminum foil) with shallow sides, dark-colored Plastalene modeling clay or Plaster of Paris (white and colored), sand and soil, a small fan (blowing by mouth can be substituted), pieces of evergreen cedar or juniper or small leafy branches, spray bottle filled with water, small sprinkling can, cups, plastic ruler

Procedure:

Part I: Where does erosion and deposition take place on barrier islands?

1. Use the Texas highway map and sketch an area of the coastal system on the tray using he marker. Include part of the mainland, a river, a lagoon or bay, a barrier island and part of the Gulf.

2. Make a thick Plaster of Paris and water mixture or use Plastalene clay. Use it to build up the outlines of the coastal features. Build the model so that it has a gently sloping mainland, a river which empties into the bay or lagoon, a barrier island with a gently sloping beach, higher dunes and a lower area behind the dunes for shrubs.

3. When the plaster is nearly dry, insert the cedar or small branches inland behind the dunes just so the tops are even with the dunes or above the dunes. Place some further back on the mainland. These can be placed in the model immediately if clay is used.

4. Fill up the tray so that water fills up the bay or lagoon and the Gulf. Place some sand, soil and clay on the mainland.

5. Using a sprinkling can or a cup of water, simulate river runoff. Slowly wash the soil into the bay. On a sheet of paper, sketch the model and record the areas were each type of sediment is deposited. Where was the clay deposited? Where was the soil deposited? Where was the sand deposited?

Part II: Where does wind erosion and deposition take place on barrier islands?

1. Place some fine sand on the barrier island. Place a small fan or have a person blow hard on the seaward side of the model barrier island.

2. Blow the sand for approximately five minutes (students will need to take turns blowing across the island).

3. Observe the movement of the sand over the island and its deposition on the far side. On a sheet of paper sketch the model then add the patterns in which the sand is deposited.

4. Explain where the sand was eroded and deposited.

5. Explain the ways that these processes could affect the shape of the land as well as the water depth.

Part III. What is the effect of waves on the barrier islands?

1. Fill the tray with water so that the water fills in the bay and Gulf. Again cover the barrier island with sand so that the sandy beach extends into the Gulf. Use a thin board, a clean Styrofoam meat tray or a plastic ruler that will cover the width of the Gulf area in your tray to create waves that move into the barrier island.

2. Record the deposition and erosion patterns on a separate sheet of paper. Where does the erosion occur? Where is the sand removed? Where is the sand deposited?

3. Place several grains of colored sand in the water in the front of the barrier island. Use the Styrofoam to create waves that hit the beach straight on. Watch the movement of the colored sand grains. Sketch the model, add in the waves, and use arrows to show the movement of the colored grains of sand. How are the waves affecting the Gulf shoreline?

4. Examine Figure 7.1 of the movement of waves on shore along the Texas coast. Do the waves hit the beach straight on or at an angle? Explain how the waves approach the coast and from what directions.

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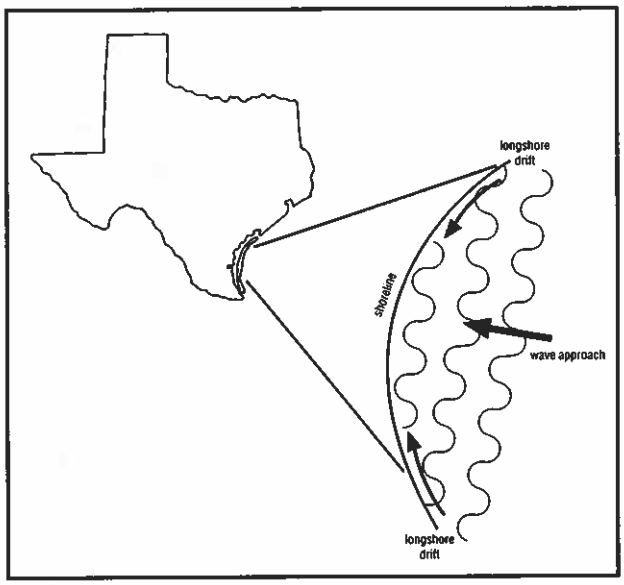


Fig. 7.1. Convergence of longshore drift along the Texas coast. (Source: Roadside Geology)

5. Again place several grains of colored sand in the water in the front of the barrier island. Use the Styrofoam tray to create waves that hit the beach at an angle as they do along the Texas coast. Sketch the model, add in the waves and use arrows to show the movement of the colored sand grains.

6. Compare your sketch of the movement of the sand grains from number 5 above to Figure 7.2 below. How are they alike and how do they differ?

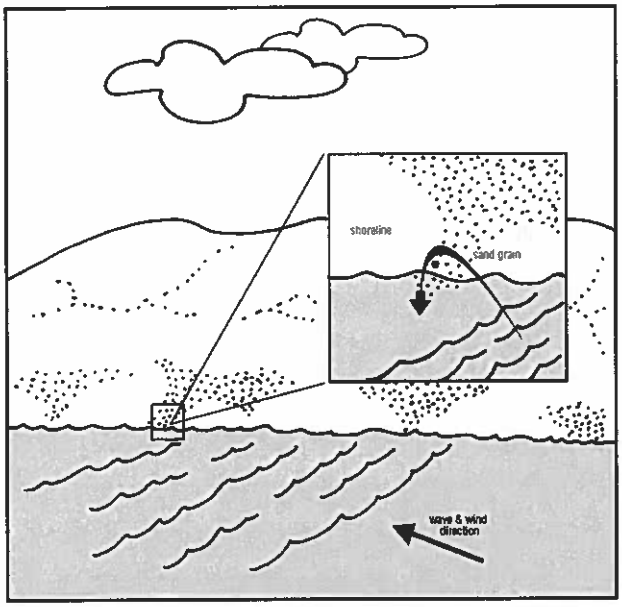


Fig. 7.2. Movement of waves and sand toward the beach. (Source: Roadside Geology)

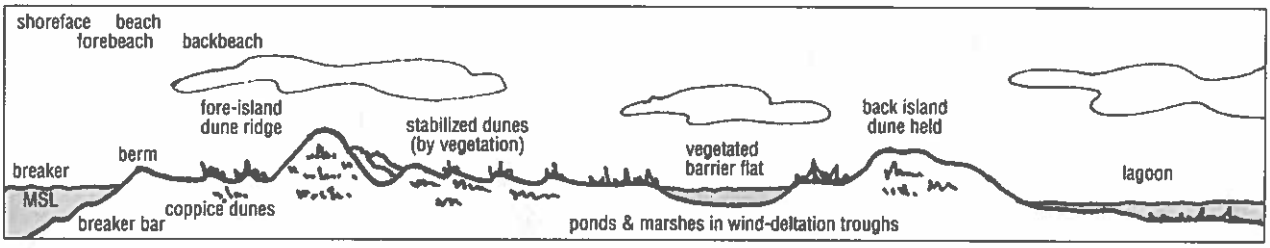


Fig. 7.3. Profile of Padre Island

7. The direction of the waves on the beach changes during the year. Change the direction of the waves. Sketch the pattern on your paper. Explain what happens.

8. Reexamine Figure 7.1. Notice that the curve of the Texas barrier islands has an impact on the long shore current that carries the sand. Waves approach the Texas coast from different angles depending on the seasons and wind patterns. Near the center of the barrier island curve on Padre Island is a zone of convergence. In this zone the sandy beaches change to shell beaches. The shells on Little Shell Beach (small shells) come from the north. The large shells on Big Shell Beach come from the south. Using your data and Figure 7.1, explain why this is a zone of convergence.

9. A hurricane can produce very high waves and storm surges of 10 to 20 feet above normal high tide. To investigate the impact of a hurricane, create a wave of water that is twice as high as the previous ones. Repeat this, increasing the level of water four to five times higher than normal. On a sheet of paper, sketch the model and record the level of the high waves and storm surges. Explain the impact of a hurricane on the barrier islands.

10. Examine the profile of a barrier island (Figure 7.3). Explain the impact of a hurricane on the barrier island, lagoon or bay and mainland.

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Part IV: What part of the barrier islands absorb most of the salt spray?

1. To investigate salt spray over the island, hold the spray no higher than the highest part of the beach area. Spray the area until it is wet. Sketch the model on a separate sheet of paper. Indicate the area that was wet.

2. Hold the spray slightly higher and spray again. Add this area to your sketch of the model (this would simulate normal salt spray coming from breaking waves and the sea breeze and the effects of storms).

3. What part of the island absorbs most of the salt spray?

4. What type of plants could grow on the dunes? What special adaptations to wind and salt would they need?

5. Observe the effects of spray on the trees. What happened to the taller trees?

6. Salt can kill some plant leaves and stems. What would happen to the shape of the tree?

7. Explain which places on the island or the mainland would receive the least amount of spray and why. Discuss how this would affect the plant and animal life.

8. Examine the profile of the environments of a barrier island (Figure 7.3). What area would be least affected by the salt spray? Explain.

8. Do Seawalls Help?

Shoreline Engineer _____ **Team** _____

Galveston Island is the best known barrier island in the United Sates. On Sept. 8, 1900, a hurricane hit Galveston, which at that time was the fourth largest city in Texas. It had a population of more than 37,000. The storm flooded the island and washed away two-thirds of the buildings. Six thousand people were killed in Galveston and as many as 2,000 in nearby coastal areas.

This disaster marked the beginning of America's concern with coastal hazards. The people of Galveston decided to raise the height of the island. Block by block the buildings were raised and sand was used to fill in the area under them. In addition, a 17-foot high seawall was built. At the time that the seawall was built, a wide beach was present. Even as late as 1965, cars were driven on the beach in front of the western end of the seawall. Today, the beach has completely disappeared. You are going to investigate why this happened.

Materials: stream table or shallow pan, sand, small blocks of wood (to represent buildings), ruler or small strip of wood to represent a seawall, small flat board (for creating waves), water.

Procedure:

1. You are going to investigate what happens when seawalls are built on a shoreline. Create a model of the shoreline of a barrier island in a stream table or shallow pan. Place the sand in one end of the pan. Create a gentle slope of the beach toward the water. Add some sand dunes. Use the small pieces of wood to represent buildings. Place some of the small pieces of wood on the dunes, others behind the dunes and some in front of the dunes. Add water to the pan to cover part of the sand. Take a separate sheet of paper. Divide it into four sections (quadrants). In the top left section (quadrant) of the page, draw a diagram of your model. Label it: Barrier Island Shoreline.

2. Use a board to create waves that will wash upon the beach for 3 to 4 minutes. Make sure your waves always move in the same direction. Observe what happens as waves wash upon the beach. On the separate page in the top right section, draw a diagram to illustrate the effects of waves over time. Label it: Barrier Island Shoreline Over Time.

3. Describe the effect of wave action on each of the following:
   Beach:
   Dunes:
   Buildings in front of dunes:

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Buildings on the dunes:
Buildings behind the dunes:

4. Change the size and strength of the waves. What happens?

5. People often believe that building a seawall will prevent the erosion. Recreate your model again. Place the ruler or strip of wood that will represent the seawall in the sand parallel to the water's edge. Leave sand in front of the seawall to represent the beach. On the separate page in the lower left section (quadrant), draw a diagram of your model. Include the location of the seawall. Label it: Barrier Island Shoreline with Seawall.

6. Use the board to create waves that wash upon the beach. Observe what happens as waves wash upon the beach. In the lower right quadrant of the page, draw a diagram to illustrate the effects of waves on the barrier island. Label it: Barrier Island Shoreline with Seawall Years Later.

7. Describe the effect of wave action on each of the following after a seawall has been built:
   Beach:
   Dunes:
   Buildings in front of dunes:
   Buildings on the dunes:
   Buildings behind the dunes:

8. Change the size and intensity of the waves. What happens?

9. Describe the effect of building a seawall on a coastal shoreline. Does it help or not? Explain.

10. Should seawalls be built or not? Explain.

11. Some shoreline engineers suggest that instead of building seawalls, the dunes should be increased instead. Also, no buildings should be allowed on the first two rows of dunes. Design experiments to test each of the variables.
    A. Experiment 1 - Dunes with buildings behind them
    B. Experiment 2 - Larger dunes with buildings behind them
    C. Experiment 3 - Two rows of dunes with buildings placed behind the second row of dunes.

    On a separate page for each experiment describe or sketch the design. Test the impact of the waves. Record your results.

12. Summarize your findings from the three experiments.

13. What method is best for protecting the coast? Explain.

9. What Is the Saga of a Seawall?

Researcher _____ **Team** _____

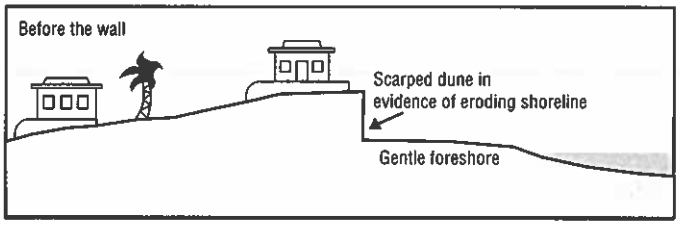
Seawalls are designed to receive the impact of the waves during storms. They have been built in almost every highly developed coastal area. Seawalls are not common on the Texas coast except in Galveston. In Galveston, the natural shoreline has retreated well beyond the ends of the seawall. It seems that each year the seawall and the buildings it protects are sticking a little further out on the beach. In some areas there is no longer a beach. What is the story of a seawall?

Materials: none

Procedure:

1. A researcher has studied the effect of building seawalls. Figure 9.1 A-D, the saga of a seawall, shows the results of the study. Study each of the four diagrams. Beside each diagram, describe the buildings, dunes, beach, shoreline slope and the seawall. Note that each diagram represents a different situation, and note the relation to the absence or presence of a seawall.

A. Before the Seawall



Buildings:

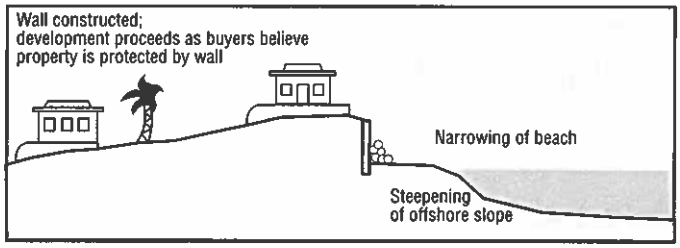
Dunes:

Beach:

Slope of Shoreline:

Seawall:

B. Seawall is Built



Buildings:

Dunes:

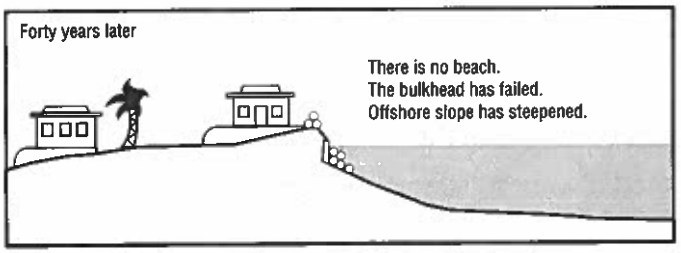
Beach:

Slope of Shoreline:

Seawall:

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C. Two to 40 Years Later



Buildings:

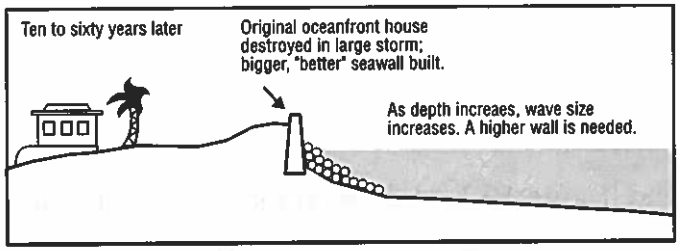
Dunes:

Beach:

Slope of Shoreline:

Seawall:

D. Ten to 60 Years Later



Buildings:

Dunes:

Beach:

Slope of Shoreline:

Seawall:

(Source: Bush et al: Living by Rules of the Sea)

2. Based on the saga of a seawall, summarize the long-range effect of a seawall.

3. A town building inspector of Monmouth Beach, New Jersey, told of the town's seawall history. "There were once houses and even farms in front of that wall. First we built small seawalls and they were destroyed by storms that seemed to get bigger and bigger. Now we have come to this huge wall which we hope to hold. There is no beach in front of the seawall, only the remains of old seawalls, groins, and bulkheads for hundreds of yards of sea." Groins and bulkheads are walls similar to seawalls built to protect land from the sea. Explain why this happened.

4. Could it happen along the Texas shoreline? Explain.

10. How Would You Develop a Barrier Island?

Real Estate Developer _____ Team _____

In recent years, more and more people are attracted to the Texas coast. They enjoy its natural beauty, and the more who have visited it want to stay. Although it is not recommended to live on barrier islands, the pressure for new homes and businesses is growing. Building and living on any coast is a risk. Some people will always be willing to risk the loss of life or personal property in order to live near the beach. You are going to plan the development of a barrier island.

Materials: colored markers, copies of Figure 10.1

Procedure:

1. Your company has bought a barrier island (Figure 10.1) to develop for people to live and work on and for visitors. This is a typical undeveloped barrier island. No two barrier islands are the same but this one has most of the features found on barrier islands. You are the team responsible for planning the development of the island. Decide what you will build on the island. List these below. This might include highways, streets, hotels, condominiums, shops, businesses, houses, docks, restaurants, canals for waterfront homes, etc. Next to each item, list where they will be located on the island.

2. Use the colored markers and sketch in on Figure 10.1 what and where your team will recommend that your company will build on the island. Remember that the only way to the mainland will be by ferryboats or a bridge. Traveling to the mainland for materials and supplies is not a quick trip. Add any additional structures, roads, etc. that are needed to support the people living on and visiting the island.

3. Development has occurred on many barrier islands. Figure 10.2 represents the typical development that occurs. Dunes are flattened for buildings and parking lots; straight roads are constructed through the dunes; canals are cut on the lagoon side. Many barrier islands are more developed with more hotels, condos, housing and restaurants near the water. There may also be additional shops and businesses on the island. Compare your plans for developing an island (Figure 10.1) to the development on many barrier islands (Figure 10.2). How is your development similar to that of Figure 10.2?

4. How do your plans for development differ from that of Figure 10.2?

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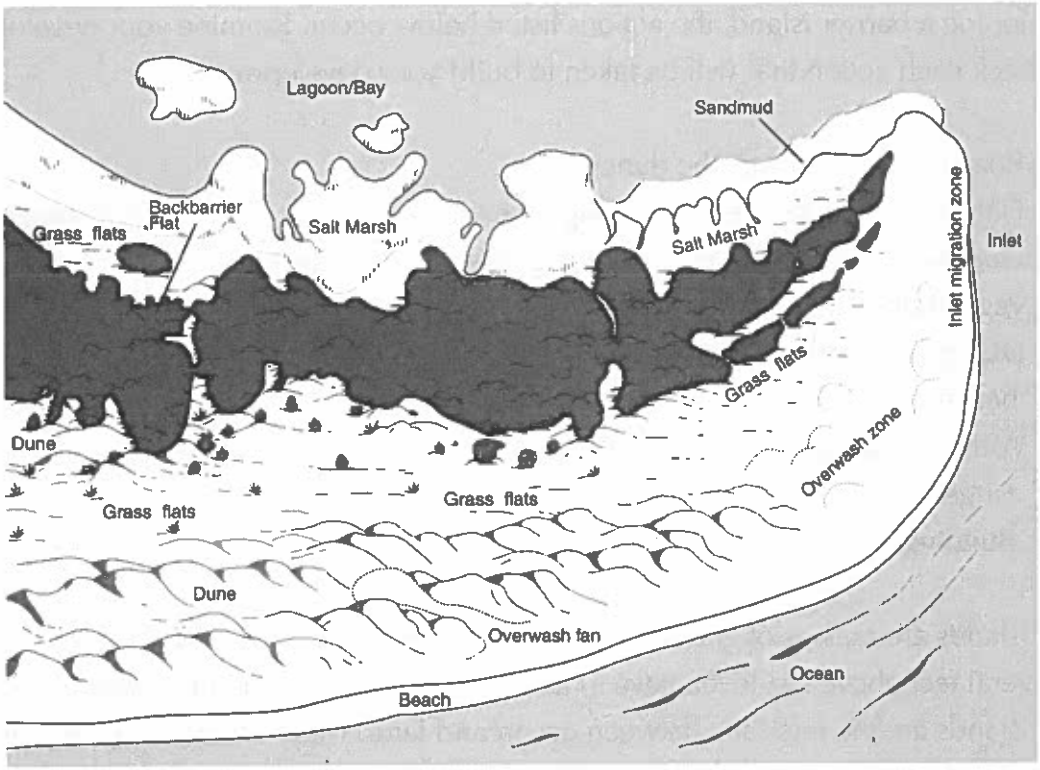


Fig. 10.1. Typical undeveloped barrier island. (Source: Bush et al: Living by the Rules of the Sea)

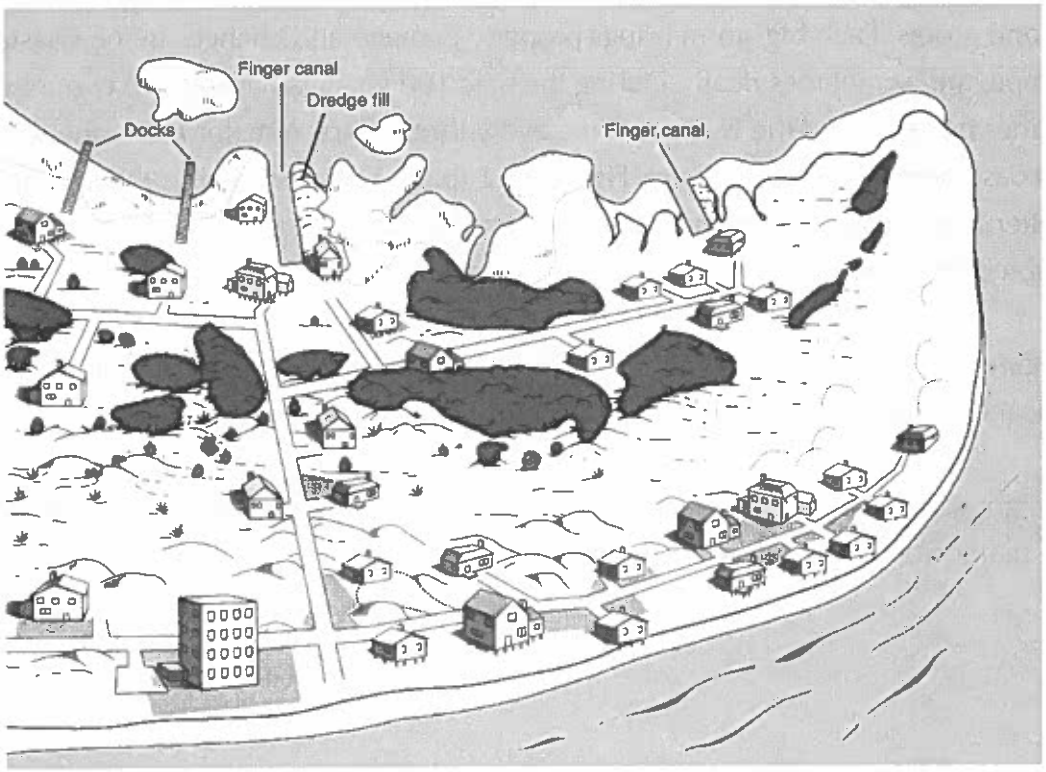


Fig. 10.2. Typical barrier island development. (Source: Bush et al: Living by the Rules of the Sea)

5. In developing a barrier island, the actions listed below occur. Examine your development plan, check each action that will be taken to build your development.

_____ Roads are cut through the dunes.
_____ Flat, straight roads are built through the dunes.
_____ Dunes are flattened to form building sites and parking lots.
_____ Vegetation is removed.
_____ Dunes are removed so buildings (hotels/condos/houses) can be placed near the beach
_____ Walkways are cut through the dunes.
_____ Finger canals are cut on the lagoon or bay side.
_____ Buildings are built at the edge of the beach.

6. Barrier islands are masses of gravel, sand and mud, surrounded by water. The islands are only several feet above sea level, have a narrow width and have fragile vegetation cover. Barrier islands are the interface between ocean and land. They receive the biggest impact from storms, hurricanes, storm-surge flooding and waves. As a result, the islands have wave erosion, overwash (water washing over the land during storms), flooding, erosion by flooding, wind damage and dramatic sand movement during storms. These hazards are increased by people changing the island by flattening dunes, removing protective vegetation, constructing roads and buildings, dredging channels and finger canals and building jetties and groins. Each big storm brings property damage and changes in the coastal landscape, and sometimes death. During the past 100 years, an average of two major hurricanes have crossed the U.S. coastline every three years. A major hurricane strikes the Texas coast every 20 years. Examine Figure 11.1 (page 161), which illustrates what happens after a major storm crosses a developed barrier island. List what has happened to the development below.

7. Use Figure 11.1 and examine your development plan to determine what would happen if a hurricane crossed your development. Describe what could happen below.

8. How might you change your development plan to reduce some of the possible damage from a major storm? Explain why you made the changes.

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11. How Should Barrier Islands Be Developed?

Coastal Management Engineer _____ Team _____

When a storm strikes a barrier island, the typical reaction is to clean up and rebuild. After a hurricane hits, many island communities focus on coming back "bigger and better." The community focuses on engineering and land-use planning. You and your coastal management team are to determine how the island should be rebuilt.

Materials: copies of "**Rules of the Sea to Live By"**

Procedure:

1. Relief money after an island has been hit by a hurricane often increases the redevelopment. Often in redevelopment, cottages are replaced by duplexes, duplexes by condominiums, low-rise by medium-rise if not high-rise buildings. But is this better? What do you think? Explain.

2. You and your team are to determine which type of comeback is really better. Examine Figure 11.1 to analyze the impact of a major storm. Figure11. 2 shows the rebuilding of the island using various structures (groins, jetties, seawalls) and beach replenishment as part of the rebuilding. Examine Figure 11.2 to determine the effect of each.

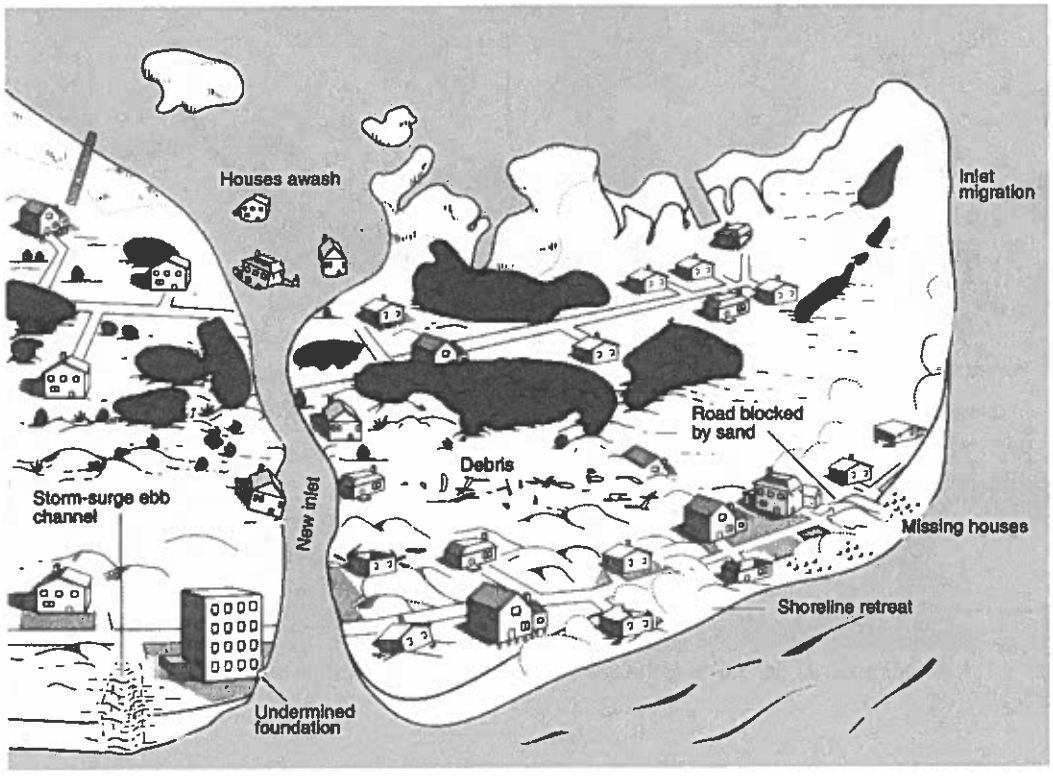


Fig. 11.1. Barrier island after a major storm. (Source: Bush et al. Living by the Rules of the Sea)

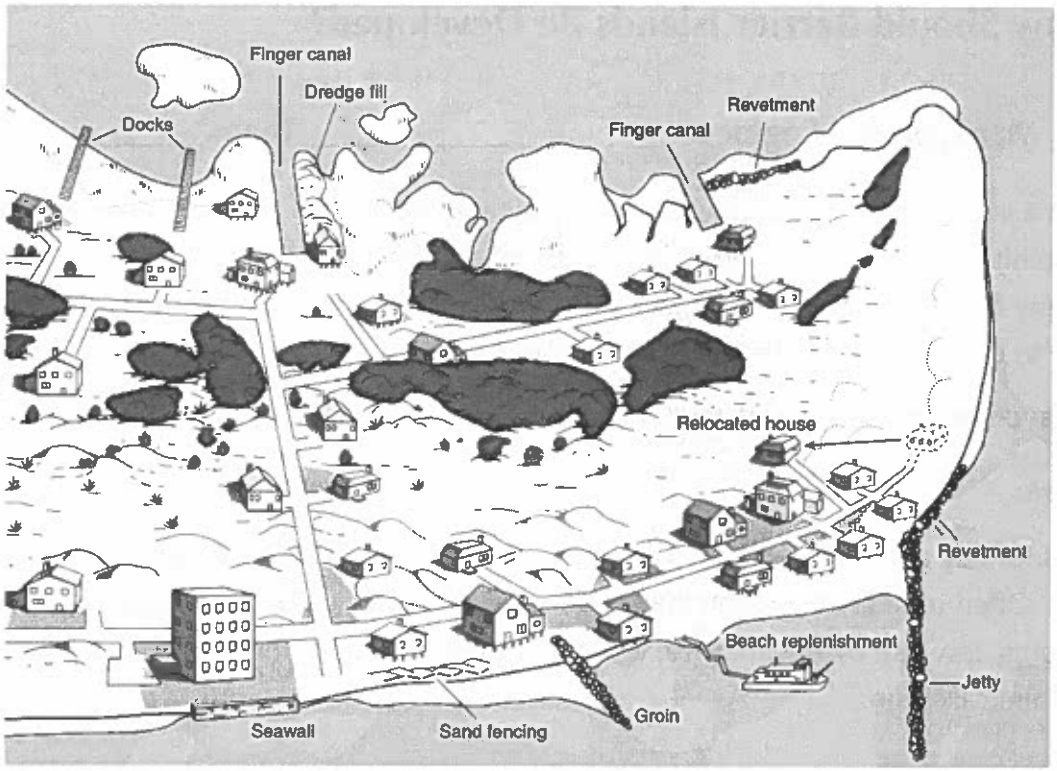


Fig. 11.2. Rebuilding using structures. (Source: Bush et al: Living by the Rules of the Sea)

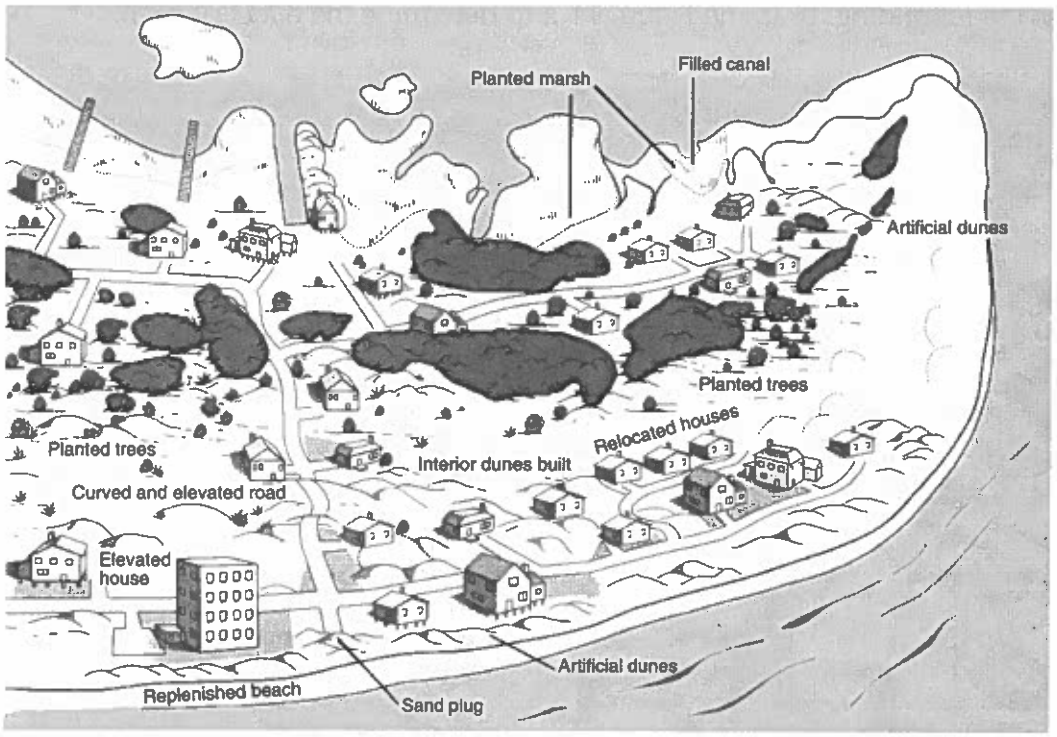


Fig. 11.3. Rebuilding based on "Rules of the Sea to Live By." (Source: Bush et al: Living by the Rules of the Sea)

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(a.) What is the impact of building groins and jetties? (Are they widening the beach or not?)

(b.) What is the effect of the seawall?

(c.) How is the beach being widened?

(d.) What is the impact of relocating homes?

3. Figure 11.2 demonstrates rebuilding based on the processes active within the coastal environment. Describe below what has been done to rebuild using this process.

4. Read **"Rules of the Sea to Live By".** Determine whether Figure 11.2 or Figure 11.3 represents rebuilding that is better. Evaluate these figures.

5. Construct a table similar to the following and list how the island would be rebuilt using the two different methods.

Table 1: Barrier Island Rebuilding

Rebuilding Using Structures	Rebuilding Using "Rules of the Sea"

6. Which one best represents the generalizations presented in **"Rules of the Sea to Live By"?** Explain why.

7. Rebuilding a beach is costly, so why is it recommended?

8. Explain why the dunes should be rebuilt in front of all the shoreline buildings.

9. Why is it important to build roads over and around the dunes, not through dunes?

10. Buildings are set further back from the beach. Why?

11. Explain why it is important to replant native grasses on the dunes and shrubs of the island.

12. Why should finger canals not be built on an island?

13. Have you visited a coastal island, did it meet the **"Rules of the Sea to Live By"**?

14. Select one or more of the ideas of "Rules of the Sea to Live By." Prepare a brochure that explains the rule. You may say what happens if the rule is followed and what happens if it is not followed. Be creative – you want to get the attention of your readers. Include artwork in your brochure!

Rules of the Sea to Live By

David M. Bush, Orrin H. Pilkey, Jr., and William J. Neal have studied and researched the U.S. Atlantic Ocean and Gulf of Mexico coasts. They have experienced up close coastal processes such as storms and shoreline retreat. Over the years they have mapped and studied most of the barrier islands in the United States. In recent years, they have taken a first-hand look at hurricanes and their impact on developments. They do not recommend that people live on barrier islands. The hazards are numerous and are difficult to avoid even by evacuation. Development on these islands destroys the ecosystem. They have written a book, **"Living by the Rules of the Sea**." The book provides rules of the sea for people to live by if they insist on developing and living on barrier islands. Below are conclusions based on the rules of the sea.

1. Wide beaches protect property.
   There is more beach to absorb and spread out the storm wave energy. This reduces the damage to buildings. Wide beaches need to be maintained.

2. Dunes protect property
   Sand dunes are often referred to as the "barrier" in barrier island or "nature's shock absorber." The dunes absorb and scatter storm wave energy. This protects buildings located behind the dunes. The dunes rather than the buildings absorb the storm's energy. Dunes also provide sand to the beach for rebuilding after a storm. Dunes also prevent washovers where water washes over an area during a storm surge. Removing dunes may lead to property loss and damage that could have been prevented if they had not been removed.

3. Vegetation protects property.
   Killing or removing plants growing on the dunes leads to the movement of the dunes by wind. Vegetation stabilizes and traps sand. Once newly built dunes are stabilized with grasses, then shrub growth can be encouraged.

4. Shore-perpendicular roads act as overwash and storm-surge ebb conduits.
   Roads provide a cut in the dunes that allows storm waters to flow through and cause flooding and erosion. Gaps in dunes should have sand plugs built across them. The roads should be curved and elevated, not straight and flat.

5. Notches in dunes create overwash passes.
   Notches cut in dunes to reach the beach or for beach views, or construction sites allow water to flow through and erode the dunes. Notches should be plugged.

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6. Overwash and storm-surge ebb is intensified when funneled by structures.
   Buildings should not be placed close together. Also, paved roads, drives, and parking lots between buildings prevent water from filtering into the ground. They also funnel the water into channels that cause more erosion.

7. Seawalls can protect buildings, but they can also cause narrowing of the beach, reducing both recreation and storm protection value.
   Large seawalls may protect shoreline buildings, however, the beach in front of the seawall will narrow or disappear. This loss of the beach results in more erosion and flooding.

8. Setbacks protect.
   A beachfront building placed back from the sea is the easiest and least costly method or reducing property damage. As erosion threatens, buildings should be moved or demolished and rebuilt in another location.

9. Elevation protects.
   Elevation, whether it is natural or from filling in a construction site, or by building on pilings, may be one of the most important factors in protecting property.

10. Proper community governance offers a degree of self-protection.
    Development where building codes are enforced results in less property damage. The code may be as simple as keeping the area below stilt houses free of materials so water can wash through without damaging the building.

12. Which "Rules of the Sea" Do You Favor?

Citizen _____ **Team** _____

David M. Bush, Orrin H. Pilkey, Jr., and William J. Neal have studied and researched the U.S. Atlantic Ocean and Gulf of Mexico coasts. They have experienced up close coastal processes such as storms and shoreline retreat. Over the years they have mapped and studied most of the barrier islands in the United States. In recent years they have taken a first-hand look at hurricanes and their impact on developments. They do not recommend that people live on barrier islands. The hazards are numerous and are difficult to avoid even by evacuation. Development on these islands destroys the ecosystem. They have written a book, "Living by the Rules of the Sea." The book provides rules of the sea for people to live by if they insist on developing and living on barrier islands. Every hurricane has provided a lesson that we should be living by the rules of the sea. You will evaluate how to live by the rules of the sea and decide what actions you would support.

Materials: none

Procedure:

The following conclusions are the basis of the rules of the sea. Read each conclusion and explanation. A proposal is listed for each. List reasons for supporting and opposing the proposal. Then list your decision.

1. Wide beaches protect property

There is more beach to absorb and spread out the storm wave energy. This reduces the damage to buildings.

As a citizen, would you support when beaches narrow and erosion threatens to move buildings?

Reasons for supporting:

Reasons for opposing:

Your decision:

2. Dunes protect property.

Sand dunes are often referred to as the "barrier" in barrier island or "nature's shock absorber." The dunes absorb and scatter storm wave energy. This protects buildings located behind the dunes. The dunes rather than the buildings absorb the storm's energy. Dunes also provide sand to the beach for rebuilding after a storm. Dunes also prevent washovers where

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water washes over an area during a storm surge. Removing dunes may lead to property loss and damage that could have been prevented if they had not been removed.

As a citizen, would you support a law that no dune on any part of a barrier island should ever be removed and if a dune is moved it must be restored?

Reasons for supporting:

Reasons for opposing:

Your decision:

3. Vegetation protects property.

Killing or removing plants growing on the dunes leads to the movement of the dunes by wind. Vegetation stabilizes and traps sand.

As a citizen, would you support a $5,000 fine if any native plants are removed from the dune area, and the plants must be replaced at the expense of the person(s) who removed them?

Reasons for supporting:

Reasons for opposing:

Your decision:

4. Shore-perpendicular roads act as overwash and storm-surge ebb conduits.

Roads provide a cut in the dunes that allows storm waters to flow through and cause flooding and erosion.

As a citizen, would you support the requirement that all roads on the barrier island must be raised higher than the surrounding area and must curve so that they reach the beach at an angle?

Reasons for supporting:

Reasons for opposing:

Your decision:

5. Notches in dunes create overwash passes.

Notches cut in dunes to reach the beach or for beach views, or construction sites allow water to flow through and erode the dunes.

As a citizen, do you support a law requiring wooden elevated walkways to be built over the dunes for people to walk to the beach and that any notches should be closed by the landowner?

Reasons for supporting:

Reasons for opposing:

Your decision:

6. Seawalls

Seawalls can protect buildings, but they can also cause narrowing of the beach, reducing both recreation and storm protection value.

As a citizen, would you support a law that prohibits the building of seawalls on open ocean shorelines?

Reasons for supporting:

Reasons for opposing:

Your decision:

7. Setbacks protect.

A beachfront building placed back from the sea is the easiest and least costly method of reducing property damage. As erosion threatens, buildings should be moved or demolished and rebuilt in another location.

As a citizen, would you support zoning laws that would require that all buildings be placed a specific distance from the beach and if they are too close they must be moved or demolished?

Reasons for supporting:

Reasons for opposing:

Your decision:

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13. What Is "Ideal" Barrier Island Development?

Coastal Management Engineer _____ **Team** _____

The majority of the coastal communities have grown haphazardly without long-term planning. Development proceeded without studying the island or the risks. If a barrier island is developed, in the best of all worlds, development would be based on preventing damage from natural processes. You are going to evaluate the "ideal" development of a barrier island.
Materials: none

Procedure:

1. If one wants to develop a barrier island or live on one, Figure 13.1 represents the ideal development. Figure 13.2 represents the typical development on a barrier island. Compare the two types of development in the table below.

Table 1: Comparison of Types of Island Development

Structures	Ideal Development	Typical Development
Roads		
Walkway to Beach		
Dunes		
Beach		
Hotels, High-Rises, Condos		
Houses		
Finger Channels		
Evacuation Route		
Seawalls/Groins		

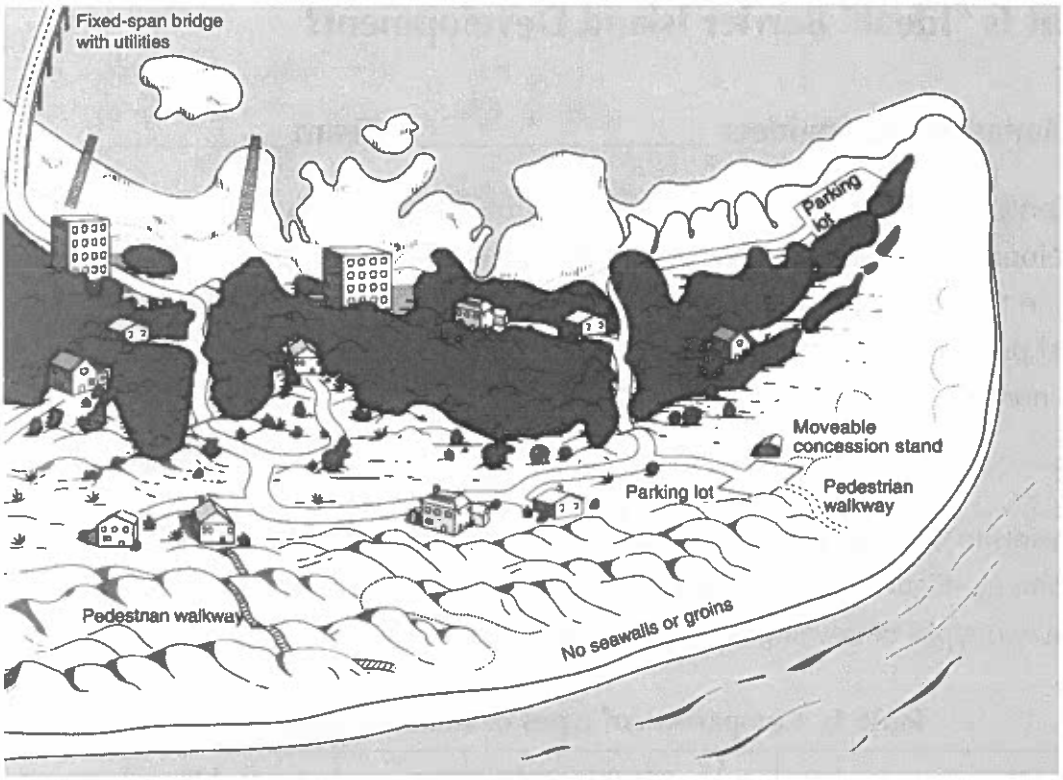


Fig. 13.1. "Ideal" developed barrier island. (Source: Bush et al: Living by the Rules of the Sea)

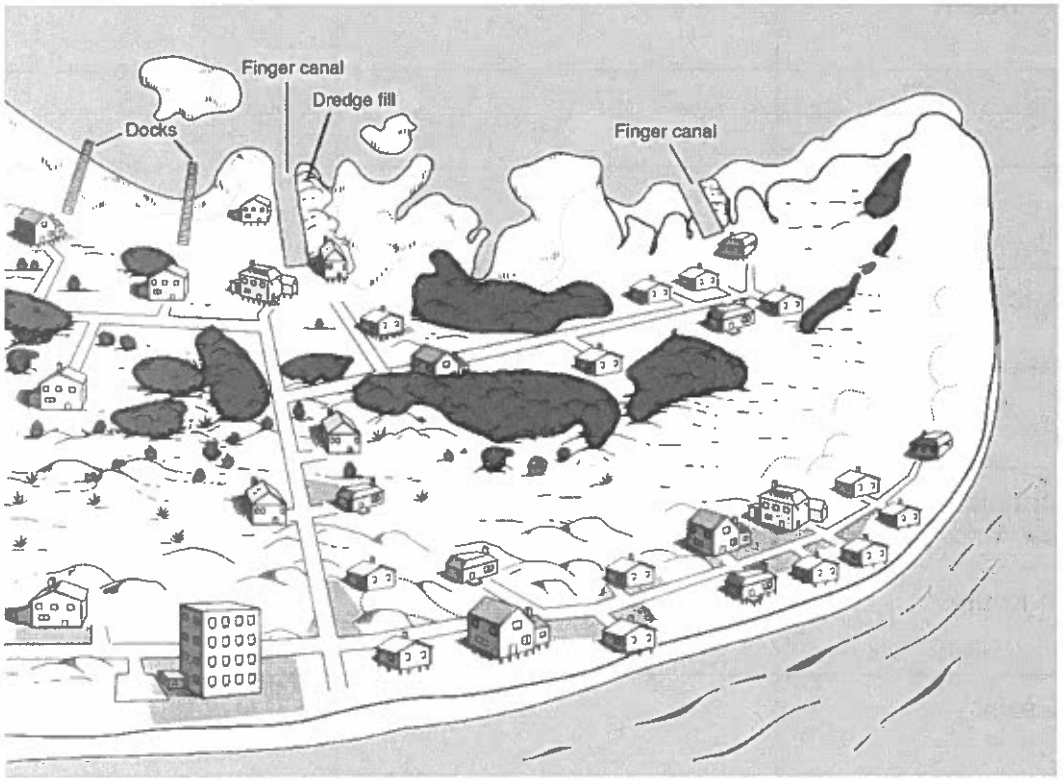


Fig. 13.2. Typical barrier island development. (Source: Bush et al: Living by the Rules of the Sea)

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2. Consider the positive, negative, and interesting results that would occur if all the barrier islands were developed like the "ideal" one. List them below.

Positive Results

a.

b.

c.

Negative Results

a.

b.

c.

Interesting Results

a.

b.

c.

3. How would you propose to develop a barrier island? On a separate page, make a sketch of the island and the structures. Explain what you will want on this island and where you will place it. Explain why you made the choices you did.

14. What should be the policies for protecting our coastal islands?

Citizen _____ **Citizens Group** _____

The coastal barrier islands protect the mainland form storm waves and surges. They buffer the waves so that marshes and estuaries can form. This creates habitats for fish and shellfish, shorebirds, water birds, and migrating songbirds. They are areas for sunbathing, swimming, surfing, bird-watching, painting, fishing, boating and photography. Like many locations valued for their natural beauty, the coastal barrier islands are threatened by increased human activity. People are moving to barrier islands and building vacation or retirement homes. This development is destroying the beauty that attracted people. One of the most damaging aspects of development is the removal of dunes to build houses, condominiums, hotels, shopping centers, and even roads. This development will need protection. This means expensive engineering projects most of which will only provide short-term protection. As a citizen, you will need to decide which policies you support and do not support.

Materials: none

Procedure:

For each of the following items decide the positive, negative, and interesting aspects. Then decide whether you support the stated policy.

1. The use of an area for a disposal site should be prohibited if it would affect municipal water supplies, fishery or shellfish areas, wildlife or recreational areas.

Positive Negative Interesting

a.

b.

c.

Your decision:

2. The state or federal government should not pay the costs of rebuilding after storms.

Positive Negative Interesting

a.

b.

c.

Your decision:

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3. No federal assistance for the construction of sewer systems, highways, water supply systems, airports, bridges, and jetties should be provided.

Positive	Negative	Interesting
a.		
b.		
c.		

Your decision:

4. All barrier islands should be parks, wildlife refuges, and sanctuaries.

Positive	Negative	Interesting
a.		
b.		
c.		

Your decision:

4. State and federal tax laws should not promote and underwrite the costs of barrier island development by offering tax credits for business investments or losses of property.

Positive	Negative	Interesting
a.		
b.		
c.		

Your decision:

15. Do islands move? Or how do you stop an island from moving?

Geologist_____ **Team**_____

The shoreline is constantly changing. Inlets are located between islands. The inlets connect the backwaters (bay or lagoon) to the ocean. Inlets, particularly tidal inlets, are not fixed features. They can move in one direction or another, reverse direction, open or close, narrow or widen or any combination of these patterns. You are going to investigate how inlets and barrier islands move and change.

Materials: none

Procedure:

1. Examine Figure 15.1. It shows Aransas Pass, which is located between Mustang Island and San Jose Island.

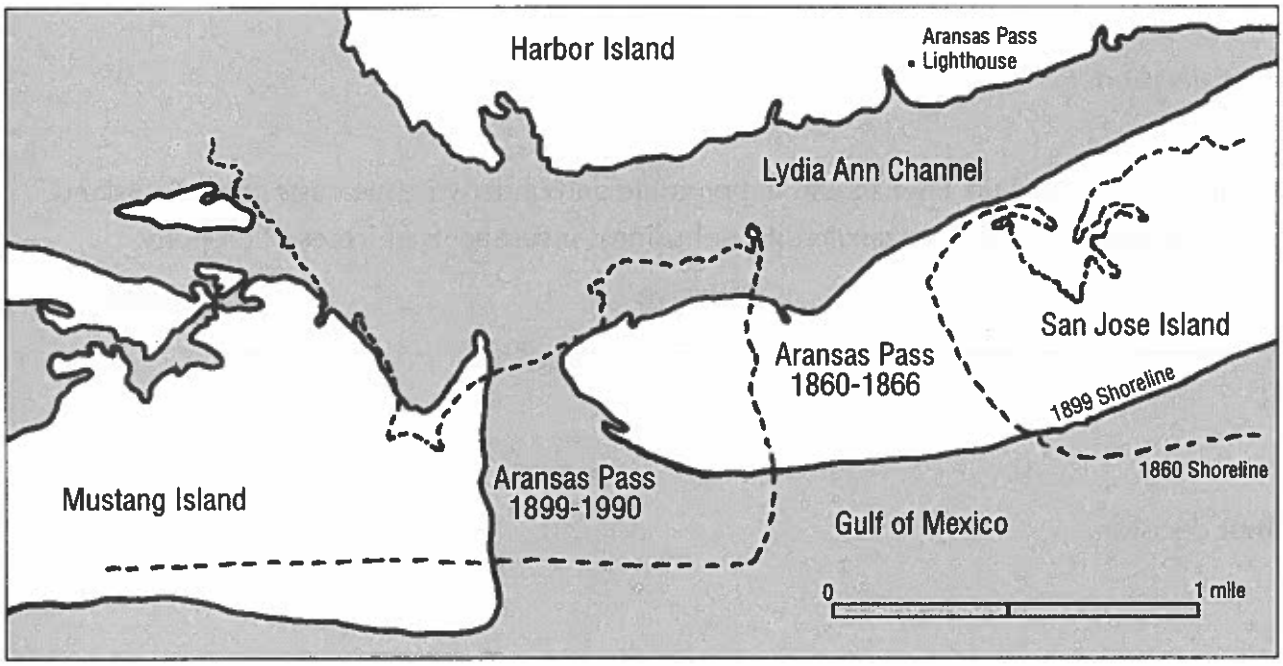


Fig. 15.1. Migration of Aransas Pass. (Source: Martin et al: Living with the Texas Shore)

A. What has happened to the pass?

B. What has happened to the islands?

2. During what time period did the lighthouse on Harbor Island behind San Jose shine its beacon straight through the inlet? Is the lighthouse still useful? Explain.

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3. During this period before the jetty was built, Aransas Pass was unstable. It migrated up to 260 feet per year.

   A. What do you think caused this movement?

   B. Where do you think the erosion was taking place?

   C. Where do you think sand was being deposited?

4. Figure 15.2 shows the sequence that occurs between an inlet and its islands. The channel carries the water into the Gulf between the islands (stage 1-initial growth). The sand in the longshore current flows into the channel. This forces the channel to bend (stage 2 extension). During this phase, where is erosion taking place? The left or right island?

5. At stage 3, which island is eroding? Left or right?

On which island is sand being deposited? Left or right?

6. Explain the statement, "Sand is just moving from one island to the next, so islands migrate."

7. The present pair of Aransas Pass jetties was completed about 1910, Jetties are rock walls built on each side of the pass into the Gulf. This stopped the movement of islands. Draw

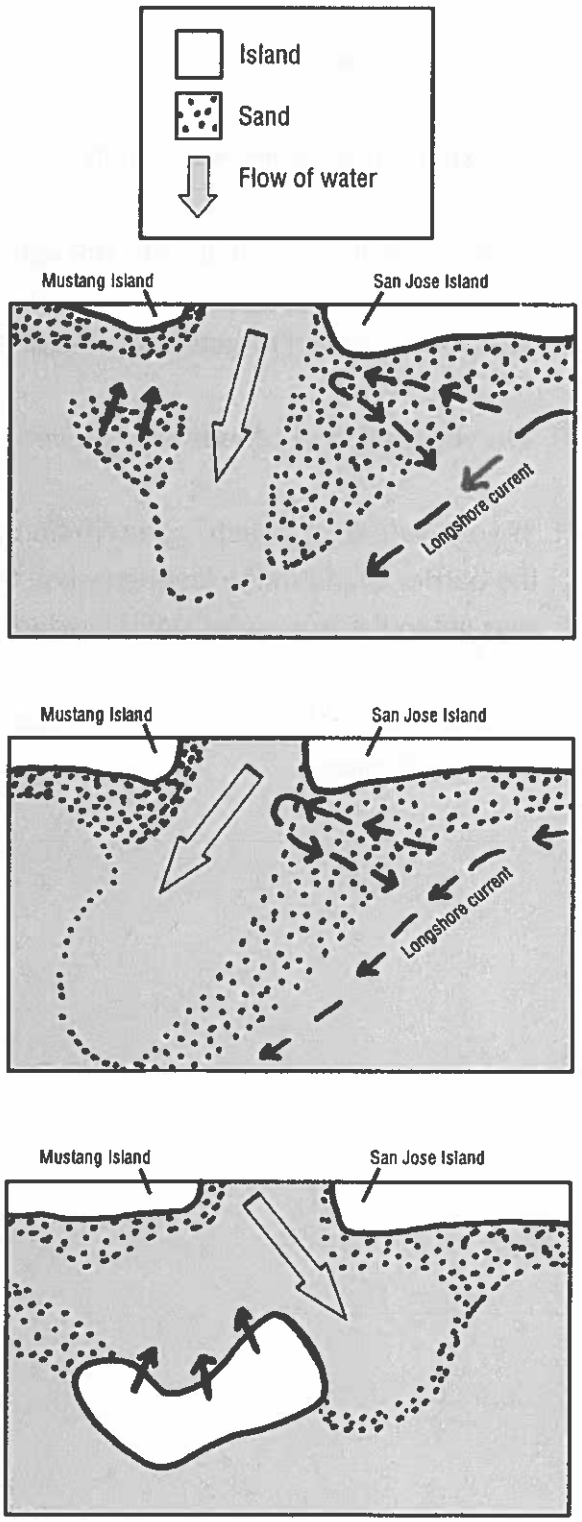


Fig. 15.2. Sequence of events between an inlet and barrier islands.

lines on each side of the channel in Figure 15.2, stage 1. Make sure the lines extend out into the Gulf.

A. What happens to the sand the longshore current is carrying?

B. What happens to the sand on the island on the left of the jetty?

C. Explain how jetties keep inlets and islands from moving.

8. Explain why many sailing ships ran aground in passes along the Texas coast before jetties.

9. Discuss the impact of jetties on shipping along the coast.

10. Do you think that islands have moved or are moving towards the mainland? Explain.

11. If you walk on a beach, you will find oyster, clam or snail shells that once lived behind the barrier island in the lagoon or bay toward the mainland. How did shells from the back side get to the front side? What is your hypothesis?

12. Would finding the shells from the lagoon on the beach indicate that the islands have moved? Explain.

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Topic 5 — Watershed of the Gulf of Mexico

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Topic Five: Watershed of the Gulf of Mexico

Humans discard a large variety of substances in the ocean. These substances include natural (sewage, for example) and artificial (plastics, for example) materials. It is estimated that humans are disposing of 20 billion tons of waste each year and that most of it ends up in the ocean. Many of these effluents, particularly heavy metals, are very toxic or even lethal in very small amounts. Others, like raw sewage, promote the growth of disease-causing organisms including viruses, bacteria and parasites in coastal waters. These can cause diseases in humans who come in contact with them.

These wastes can be broadly categorized as sewage, metals and artificial biocides. Municipal sewage consists of a sludge of organic and inorganic chemicals. One of the main ingredients of sewage is human waste. It is a mixture of organic matter, nutrients such as nitrates and phosphates, and microorganisms such as viruses and bacteria. A great deal of sewage, some of it untreated, is discharged into rivers or waters in the coastal zone.

The term heavy metal is applied to elements such as lead, mercury, cadmium, arsenic and copper. These elements are naturally found in trace amounts in the environment due to the weathering of rocks and volcanic eruptions. These heavy metals are needed for biological processes including photosynthesis and cellular metabolism. However, at high levels they are extremely toxic and become lethal to organisms. Human activity is responsible for adding large amounts of these metals to the environment. These metals are usually a waste product of manufacturing or industrial processes.

Mercury, in the form of methyl mercury, is one of the heavy metals found in nearshore waters (bays and estuaries) of the Gulf. Mercury damages the nervous system of higher organisms and is a deadly poison because it accumulates in cells over time. It can remain in the environment a very long time because microorganisms do not break it down. Humans produce most of the mercury in the environment. It is a byproduct of paper-pulp and chlorine-alkali industries, a component of anti-fouling paints used on ship hulls, and a chemical ingredient in pesticides and some pharmaceutical products. Once in the water, mercury attaches to the surface of solid particles and settles to the bottom where it becomes part of the bottom sediment. Small organisms in the sediments and oysters can ingest and build up mercury in their tissues. This process is called bioaccumulation. As smaller organisms are eaten by larger organisms, the metal is concentrated in ever greater amounts in each step of the food chain in a process called biomagnification. Herbivores have low quantities of mercury in their tissues, first order carnivores have much more and second order carnivores have even more. People eating shellfish and fish containing mercury can develop neurological disorders or kidney malfunctions and, in some extreme cases, may even die.

It is estimated that more than 70,000 chemicals are used by industries all over the world and about a 1,000 or more new chemical substances are introduced every year. Their molecular structure, biodegradability, effects on organisms (including humans), and the effect on the environment vary tremendously. For example, chemicals such as DDT and PCBs are highly toxic and remain a long time once released into the environment. DDT usage is outlawed in western countries but there is little regulation in the rest of the world. As a result, its production has increased substantially. There are more than 200 separate chemical compounds called PCBs used in the manufacture of electrical equipment, paints, plastics, adhesives, coating compounds and many other products. PCBs are found everywhere in the ocean. PCB production was banned in the United States in 1979. However, bioaccumulation and biomagnification of DDT and PCBs occur so the poison builds up in tissue as they are passed up the food chain. Mussels can have concentrated and biomagnified DDT and PCBs levels 690,000 times higher than the measured quantities in the surrounding water.

Because of high population densities along rivers and their use as a convenient disposal for wastes, a large portion of the contaminants found in bays, estuaries, wetlands and the nearshore area is from river discharge. The rivers are polluted with solid and dissolved material from the wastes of farmland, towns, cities and industrial complexes and they in turn pollute the coastal habitats that receive the water. The entire watershed of the Gulf contributes to composition and quality of the water.

A watershed is composed of all the land that drains or has water run off into one body of water. The Gulf of Mexico watershed includes not only Texas but also a large portion of the United States and such other countries as Canada, Mexico, Cuba and Guatemala. Guatemala drains in the extreme north through Mexico. Two-thirds of the United States drains into the Gulf of Mexico. This is the area between the Rocky Mountains and Appalachian Mountains and includes states as far away as Montana and New York.

Water that falls on the land may sink into the ground or it may runoff. It will flow off the ground, flowing downhill into flowing streams or creeks that join to form rivers. Ponds or lakes form where rivers

are dammed naturally or by humans. The river may flow into the ocean. Water dissolves chemicals that it contacts as it flows over the surface. In the natural world, these chemicals are essential mineral nutrients for organisms. However, humans have changed the natural world in ways that can greatly increase the amount and kinds of chemicals dissolved as well as suspended in water. These chemicals or pollutants can have a serious impact on living organisms in the water. Water pollutants can be divided into two categories, depending how they enter the water. Point source pollutants are chemicals that come from a specific identifiable source that can be measured and regulated. Non-point source pollutants are chemicals that cannot be measured and do not come from a specific identifiable source. Chemicals can be both point source and non-point source pollution. The non-point source pollution is a major problem and North Americans are pouring pollutants and nutrients into bays, estuaries and the Gulf at an alarming rate. Most people typically think of water pollution as coming from factories. However, the area in which water pollution has not improved is the kind that everyone contributes to, non-point source pollution. Since everyone cannot be constantly monitored, education is needed. The activities in this section address these watershed problems.

Activity 1: What is the watershed of the Gulf of Mexico?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.6, 7.6, 8.7, 6.7, 6.14

Math: 6.3, 7.2, 8.2, 6.8, 7.9, 8.8, 6.4, 7.3

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- construct watershed models to demonstrate what happens when rain falls on impermeable surfaces and runs off in the watershed
- use a map to determine the watershed of the Gulf of Mexico and to analyze its impact

Background:

1. In Part I, a simple model of a watershed is constructed to develop an understanding of what a watershed is and how it functions. Have the students compare the model and a real watershed.
2. In Part II, a map is used to determine the size and location of the Gulf of Mexico's watershed. Have the students list factors that affect the amount of water entering the Gulf and why the amounts from the rivers differ.

Activity 2: What happens when a chemical enters the Gulf of Mexico watershed?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 6.6, 6.7, 8.14, 8.5

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- construct watershed models to demonstrate what happens to chemicals entering the watershed
- develop hypotheses and plan, design, and conduct experiments to investigate questions about the watershed and pollutants

Background:

1. Have the students write their hypotheses about what will happen to a chemical that enters the watershed. Challenge the students to use their watershed model to plan an investigation. Review hypotheses, writing procedures, identifying and controlling variables, gathering and recording data, and reaching conclusions. Have the students plan and write the instructions for their investigation. Have them evaluate their communication skills by exchanging their instructions with another group. Each follows the instructions as written. Discuss their findings and the quality of a group's instructions for conducting the experiment.
2. For each of the suggested investigations, have the students plan their investigations and then conduct them. Discuss their findings but also evaluate the investigative procedure that was used. Ask students if there are ways to improve their investigations.
3. Discuss the impact of chemicals (sewage, heavy metals and artificial biocides) from all parts of the watershed entering the Gulf.

Activity 3: Are you an NSP polluter?

TEKS: Science: 7.14, 8.14

Math: 6.3, 7.2, 8.2

Language Arts: 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10, 6.20, 7.20, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- identify non-source point pollutants
- evaluate themselves to determine if they have ever been non-source point polluters

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- conduct and analyze the data from a survey on non-source point pollution
- plan and create a brochure informing others about non-source point pollution

Background:

1. First ask the students to explain exactly what pollution is. The definition of pollution adopted by the United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution in 1982 was:

   "Pollution is the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in deleterious effects such as harm to living resources, hazards to human health, hindrance of marine activities, including fishing, impairing quality for use of sea-water and reduction of amenities." Have the students compare their definition with this one. Note that the definition assigns pollution specifically to the activity of humans.
2. Have the students individually complete the non-source point questionnaire, then tally the results and discuss their findings. Ask the students to explain how each pollutant enters the watershed and its impact on the Gulf. Were they aware that their activities contributed to pollution in the Gulf?
3. After the students have conducted their survey of non-source point pollutants, discuss their results and summarize their findings.
4. Before preparing a brochure on non-source point pollution, discuss why education is needed on the subject and how to best communicate the information in a brochure. Display the brochures. Ask the students to select the brochure that best communicates the problem.

Activity 4: Cattle, corn, and cars — How do they affect the Gulf?

TEKS: Science: 6.12, 7.12, 6.14, 7.14, 8.14

Math: 6.3, 7.2, 8.2

Language Arts: 6.24, 7.24, 8.24

Social Studies: 6.7, 7.10, 6.20, 7.20, 8.29, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- analyze the effect of increasing nutrients in the Gulf waters
- explain the relationship of the population growth of people, cattle, corn, and cars on the Gulf waters

Background:

1. Begin Part I by discussing the information about eutrophication. Students may create a drawing to illustrate the concept or it may be created a part of the class discussion. To make this an inquiry activity in which the learners formulate explanations, provide each team with the questions. Ask the students to use the eutrophication illustration that they developed to formulate a hypothesis that describes the effects of oxygen depletion, thick layers of phytoplankton, wind and tides.
2. Use the same procedure for Part II. Provide each team of students with 2 of the 6 questions to formulate explanations from using their illustration of eutrophication. Ask each group to create an illustration to share that illustrates the impact of population growth. Ask each group to provide suggestions for resolving or reducing these problems.

Activity 5: How do you affect the Gulf?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5, 6.5, 7.5, 6.12, 7.11

Math: 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20, 6.13, 7.13, 8.13

Social Studies: 6.3, 7.8, 8.10, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- identify substances which they add to water and their effect on the Gulf of Mexico
- design and conduct an experiment to investigate the effects of various substances on plankton and algae
- discuss ways that they could reduce their impact on the Gulf of Mexico and how they will implement their ideas

Background:

1. After the students have listed substances that they add to water during a day, make a class list of substances. Discuss the impact of their class, then the multiplication factor of their entire school and community (town, city, state, states in watershed). Discuss additional chemicals that are added by businesses, manufacturing, industry and services.
2. Review the general pathway of domestic effluents from all businesses, schools and homes. Divide the class into teams and assign each team several businesses (manufacturing, services, industrial, agricultural) to identify the substances that they add to their wastewater. For example, restaurants will add human wastes, food wastes, soap, grease, cleaning solutions, etc. Each team will add its information to the class list. Contact the local

wastewater treatment plan and the governmental agency that supervises the wastewater to learn what happens to the substances added to the water and what substances cannot be added to the wastewater by businesses, etc.

3. A field trip to the local wastewater treatment plant can be scheduled to learn more about what happens locally to the substances that are added to water. Or invite an individual from the wastewater treatment plant or government office in charge of water treatment to visit the class to discuss the treatment of substances that are added to the water.
4. Rather than providing instructions, have the students design and conduct their own investigations to determine the effect of substances that they add to water on plankton and algae or fish. These would be on-going investigations that would last several months.
5. Have students generate proposals that could be adapted by their family, school and community to reduce their impact on the water of the Gulf.

Activity 6: Where is the "Dead Zone" in the Gulf of Mexico?

TEKS: Science: 6.5, 7.5, 7.11, 7.12, 7.14, 8.14

Math: 6.4, 7.3

Language Arts: 6.11, 7.11, 8.11, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- conduct research to locate information on the businesses, industrial and manufacturing complexes, agricultural production, and population centers located in the Mississippi River watershed
- formulate hypotheses describing the cause of the "dead zone" or hypoxic bottom water along the Louisiana continental shelf
- interpret data concerning the causes of the "dead zone"
- develop a proposal to provide a solution to the problem of the "dead" zone that is fair to all

Background:

1. To present this as an inquiry for each team, indicate the location of the "dead zone" on a map and describe what happens. Ask each team to discuss it and formulate hypotheses. Each team will need to identify the data needed to prove their hypotheses.
2. After the teams have formulated their hypotheses and identified the data needed, have them locate the Mississippi River drainage basin and use an atlas, the internet or other resources to determine the population centers, agriculture, businesses, and manufacturing and industrial complexes that are located in the watershed. The teams may change or refine their hypotheses and the data that they will need.
3. Provide teams with the data in questions 7, 9 and 10. The teams may share their conclusions on the causes of the "dead zone."
4. Ask the teams to respond to questions11 and 12. End the activity by having each team present its proposal for a solution to the problem (question 13) that avoids a "farmer vs. fisherman" confrontation. Discuss the solutions presented and develop a class proposal. Discuss how teams can ensure that their proposals are carried out. Additional information is available in **Scientific American**, (Nov. 1997) pp. 19-20.

Activity 7: Why should we care about nitrogen in the watershed?

TEKS: Science: 6.5, 7.5, 6.7, 7.7, 8.10, 7.11, 7.14, 8.12, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.10, 7.10, 8.10, 6.24, 7.24, 8.24, 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- analyze how human activity has impacted the nitrogen cycle
- describe the effect of nitrogen compounds on humans
- gather data on the water quality of streams and rivers in their community

Background:

1. Provide each team with newsprint and markers to diagram the nitrogen cycle. Depending on the level of the students, you may read and discuss one step and then have the team create its illustration. Repeat this with each step until teams have completed the diagrams.
2. Discuss the ways that humans affect the cycle. After the discussion, each team can add these factors to the nitrogen cycle diagram.
3. Use the information in Part III to compile a list of the impacts of nitrogen compounds and ask students to identify and explain which ones may affect them directly.
4. Obtain a map of your local community or of coastal areas of Texas. Assign each team to an

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area to gather data on its water quality. Obtain several copies of **Texas Water Quality, A Summary of River Basin Assessments** or use the internet to consult the water quality evaluation from the Clean Rivers program at http://www.tnrcc.state.tx.us/water/quality. This site provides information on the nutrient level, dissolved minerals, dissolved oxygen, acidity/alkalinity (pH), dissolved metals and fecal coliform bacteria levels. It also indicates if fish caught in the waterway can be consumed and if the water is safe for contact recreation.

5. If nitrogen test kits are available, use a community map and assign teams of students to collect water samples from the creeks, streams, ponds, rivers or lakes in the area. Conduct the nitrogen tests and record the findings on the map. If the amount of nitrogen compounds is high, ask the students to infer the cause or source.
6. After discussing Part IV, one project might be to develop plans to reduce the nitrogen if any local areas had elevated amounts. Encourage the students to involve individuals and the local government.

Activity 8: What should be our policy about nutrients and the Gulf?

TEKS: Science: 6.5, 7.5, 7.7, 6.8, 7.14, 8.14

Math: 6.3, 7.2, 8.2

Language Arts: 6.10, 7.10, 8.10, 6.20, 7.20, 8.20

Social Studies: 6.6, 7.9, 6.7, 7.10, 6.23, 7.23, 8.32, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- analyze the pros and cons of a proposal and make a decision to agree or disagree with the proposal

Background:

1. One strategy to promote thinking is to have students analyze a proposal by identifying the reasons in support of or in opposition to before they make a decision. Assign each team one or two scenarios to analyze. The team will discuss it and determine its position after each student has individually analyzed the assigned scenario.
2. Each team can present its analysis of the assigned scenarios to the class. The class members then decide or vote whether they agree or disagree with the team's decision.

Activity 9: How does your watershed impact the Gulf of Mexico?

TEKS: Science: 6.8, 6.6, 6.14, 7.14, 8.14

Math: 6.3, 7.2, 8.2

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- use data sources to evaluate the water quality of a watershed and determine the sources of point source pollution
- use data sources to make inferences about possible non-point source pollution in a watershed
- assess the cost and benefits of improving water quality and propose solutions

Background:

1. This activity will provide students the opportunity to assess the water quality of Texas river basins to determine point source contamination and make inferences as to possible non-point source pollution. Assign each team a watershed to assess and have the team present its findings to the class. Discuss the quality of the state's watersheds and their impact on the Gulf.
2. Have the teams use the same data sources to determine the point source contamination in the area of the school district and their community. After the students have identified non-point source pollutants, discuss what should be done locally about the water quality. Invite a local government official (city or county) to discuss the community's problems, plans, costs and benefits.
3. Texas River Basin maps (8 1/2 x 11) are available from: Bureau of Economic Geology, The University of Texas at Austin, University Station, Box X, Austin, Texas 78713-8924. Website: http://www.utexas.edu/research/beg/ (cost $0.25 each).

Activity 10: What should be our policy for protecting the waters of the Gulf coastal zone and the Gulf of Mexico?

TEKS: Science: 7.14, 8.14, 6.12, 7.11, 7.12

Math: none

Language Arts: 6.20, 7.20, 8.20, 6.23, 7.23, 8.32

Social Studies: 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- analyze the positive, negative, and interesting aspects of a state policy and decide on their own position

Background:

1. To develop thinking skills, each student should analyze the proposal individually. The teams can then discuss the proposal and reach a group decision.

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1. What Is the Watershed of the Gulf of Mexico?

Scientist(s) _____ **Team** _____

A **watershed** is the area of land from which water drains into a specific body of water. The Gulf of Mexico watershed is all of the water from the surrounding land areas that drains into the Gulf. It is fed by rivers from a very large area. Five countries are a part of the watershed of the Gulf. Three of these—the United States, Mexico and Cuba—are obvious. The other two are Guatemala and Canada. Guatemala drains in through Mexico into the southern Gulf and Canada drains through the Missouri-Mississippi River system into the northern part of the Gulf. You will investigate the watershed of the Gulf of Mexico.

Materials: aluminum foil, pan, cups, waste paper or cardboard, sprinkler, plastic tray (or a stream table), sand, cups, rocks, and water, calculator (optional)

Procedure:

Part I: Can you make a model of a watershed?

1. You can make your model using either aluminum foil, recycled waste paper and plastics, or the stream table and sand. If using the stream table, set the table so that one end is raised at a 20- to 30-degree angle. Use rocks or cups (different sizes) and place them under the sand to create hills, mountains and valleys for streams and rivers at the upper end. Add the Gulf at the lower end. See Figure 5.1.
   If using the aluminum foil to create a model, first use waste paper/cardboard or parts of plastic bottles to make the raised areas for mountains at the raised end of the pan. You can use different inverted cups under the aluminum foil. Use the aluminum foil to cover the hills, mountains and valleys. Make valleys for rivers and streams and set it up so the flow into the Gulf is at the lower end.



Fig. 5.1

2. Now make it rain. Tip the sprinkler so that the rain falls in the upper part of the tray. Watch what the water does when it falls on the land. Where does it go?

3. Test your model to see what happens if the rain falls hard as in a downpour instead of a slow light sprinkle.

4. What would happen if it rained for a long period of time?

5. How would the type of surface (rocks vs. sand) in a real watershed affect the water running off the land and into the drainage system?

6. What type of surface in a real watershed would keep the water from sinking into the ground?

7. Compare your watershed model to a real watershed. How are they alike?

8. How does your model differ from a real watershed?

Part II: What is the watershed of the Gulf of Mexico?

1. The Gulf's watershed covers almost two million square miles. Of this vast area, about 1.6 million square miles are in the United States and Canada. Use the Gulf of Mexico watershed map (Figure 5.2) to analyze the watershed. How many states are part of the Mississippi River drainage?
2. Which is the most northwestern state that drains into the Gulf?

3. Which is the most northeastern state that drains into the Gulf?

4. How many states are part of the non-Mississippi Gulf drainage?

5. Which states are part of the non-Mississippi Gulf drainage?

6. Some 33 major rivers drain into the Gulf, as do numerous small rivers, creeks and streams. The greatest of these is the Mississippi River. This immense river has an average flow into the Gulf of 12,600 cubic meters per second. A cubic meter is about the same as 35.5 cubic feet and a cubic foot is about 7.5 gallons. How many gallons of water per second does the Mississippi empty into the Gulf?

7. All of the rivers that flow into the Mississippi River ultimately flow into the Gulf. These are important in American history and commerce. List some of these rivers.

8. Of the other rivers that empty into the Gulf of Mexico, the Rio Grande is probably the best known. It begins in Colorado and flows across New Mexico before it becomes the boundary between Texas and Mexico. The western part of the United States receives less precipi-

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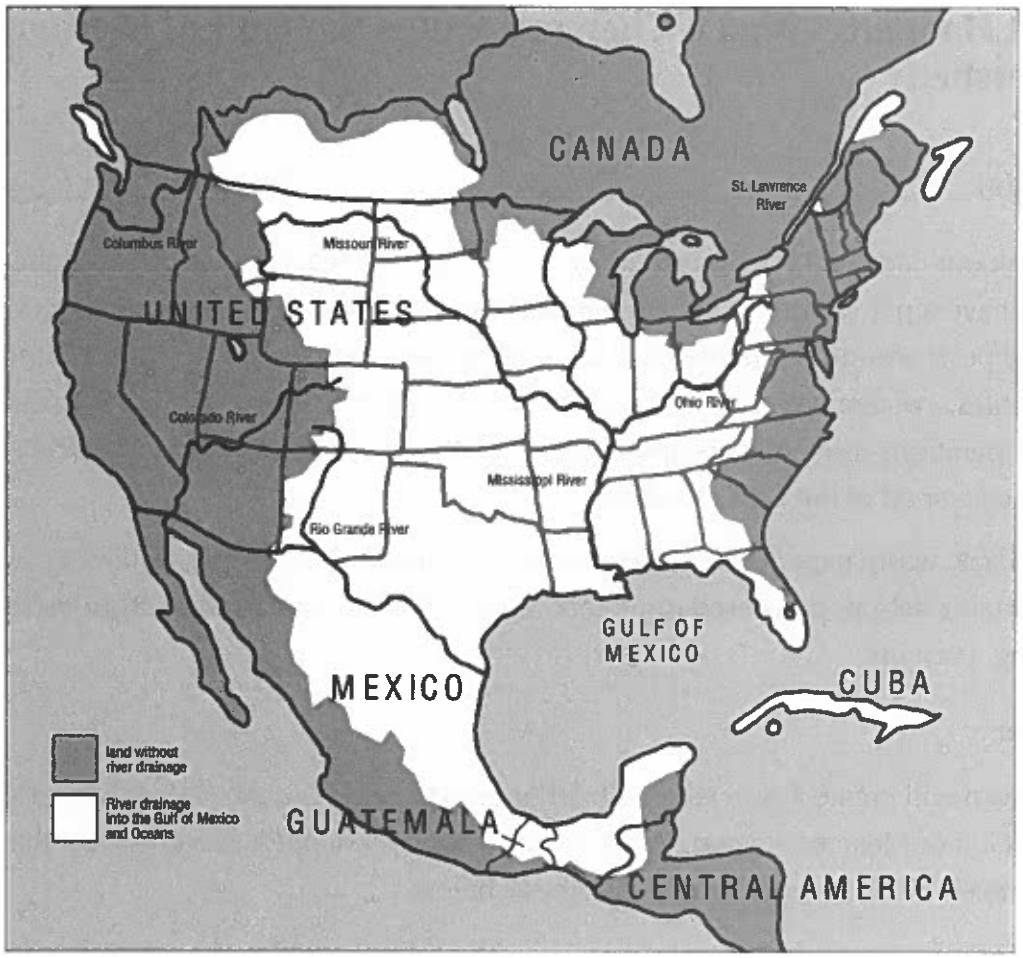


Fig. 5.2. Gulf of Mexico watershed. (Source: Environmental Protection Agency, Region 6)

tation than the eastern side. How does this impact the drainage basin of the Mississippi River and the Rio Grande River?

9. Much of the water of the Rio Grande is used for irrigation. How does this affect the amount that enters the Gulf?

10. The mean discharge rate at the mouth of the Rio Grande is only about 15,000 gallons per second. How does this compare to the Mississippi rate?

11. Write a statement summarizing the factors that affect the amount of water that drains from a watershed into a body of water.

2. What Happens When a Chemical Enters the Gulf of Mexico Watershed?

Scientist(s)_____ **Team**_____

We back our cars out of the driveway or parking lot and leave a spot of oil on the pavement. We have a pet whose wastes are deposited in the yard. We use chemicals to kill the weeds and pests around our homes and we fertilize our lawn and garden. At construction and industrial sites, contaminated soil is carried into drainage ditches by rainfall. Farming and ranching operations use fertilizers and chemicals. What happens to these chemicals if they enter the watershed of the Gulf of Mexico?

Materials: tray, waste paper and or plastic cups, aluminum foil, water, sprinkler or waterer, or stream table set-up, powdered drink mix (KoolAid), small pieces of sawdust or Styrofoam packing, corn oil.

Procedure:

1. Your team will create a watershed model or use the one from the "What is the Watershed of the Gulf of Mexico?" lesson. What do you think will happen to a chemical that enters the watershed? Write your team's hypothesis below.

2. List the steps you are going to take to investigate the question (use a very small amount of powdered drink mix to represent the chemicals).

3. Construct a table similar to the example below in which to record your data. Conduct your investigation. Make observations of the watershed during your investigation.

Table One: Observations of Chemicals in Watershed

Chemical	Watershed Before Adding Chemical	Watershed While Chemical is Added	Watershed After Chemical was Added
Water Soluble			
Insoluble			

4. Analyze your findings. Explain how your findings answer the question.

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5. Plan and conduct investigations to answer the following questions:
   a. What is the effect of heavy versus light rainfall on the pollution?
   b. What is the effect of larger amounts of chemicals (powdered drink mix)?
   c. What is the effect if small amounts of chemicals (powdered drink mix) are added to several of the small rivers and creeks of a watershed?

6. Plan and conduct an investigation using your model of the watershed to find out what happens when trash (paper, cups, bottles, etc.) enters the watershed. Use small pieces of sawdust or small Styrofoam packing pieces to represent pollutants that float on water. Summarize your findings:

7. Plan and conduct an investigation using your model of the watershed to find out what happens if a chemical that does not dissolve in water enters the watershed. Add some corn oil to water in a plastic bottle. Shake it, then pour into your watershed. Record your observations in Table One. Summarize your findings.

8. What are some of the chemicals that dissolve in water that the powdered drink mix could represent?

9. What is the effect of these chemicals on the watershed?

10. What are some chemicals that the corn oil represents?

11. What is the effect of chemicals that do not dissolve in water on the watershed?

12. If the powdered drink mix represents pollutants that dissolve in water that enters the watershed of the Gulf of Mexico, where are the pollutants collecting? What is the effect of this? Explain.

13. What is your team's recommendation for preventing the collection of pollutants in the Gulf of Mexico?

3. Are You an NSP Polluter?

Investigator(s)_____ **Team**_____

Non-point source pollution (NSP) has been a concern but not a top priority over the past 30 years. However in the past 20 years NSP has become the leading cause of pollution of our lakes, rivers, coastal waters and underground sources of drinking water. The Texas Commission on Environmental Quality (TCEQ) annually lists the bodies of water that have a major problem. Of the 140 on the list in 1998, 105 are affected by non-point source pollution. The problem is that both industry and landowners view this as "out of sight, out of mind." In other words, many people feel if the pollutants are not visible (washed down a drain), they are not a problem.

Are you one of 18.5 million Texans who is unintentionally poisoning your water supply?

Materials: NSP Pollution Questionnaire

1. Complete the questionnaire to determine if you or your family is helping to pollute our water supply. Check the yes or no column to indicate those activities done by you or your family. **NSP** is pollution of an unknown origin that ends up in the watershed. Unlike pollution from industrial and sewage treatment plants, NSP pollution comes from many widely scattered sources. Did you check yes for any of the activities? Which ones?

2. If you checked yes for any of the activities above then you have helped to pollute the watershed of the Gulf of Mexico with non-point source pollution or NSP. To find out why you are a NSP polluter and how to avoid being one, read the article, "What is NSP Pollution?"

3. Based on the reading, which types of NSP pollution occur in your neighborhood?

4. What possible solutions would you suggest to stop the NSP pollution of our lakes and the Gulf of Mexico?

5. To find out how many people are NSP polluters, use the NSP questionnaire to interview others. Find eight other people outside of your class to complete the questionnaire. Interview two people from each of the following age groups: below 18, 19-30, 31-50, more than 50. Combine your team's data and analyze your findings. Tally the data for the class.
   a. Which questions were answered with "yes?"
   b. Which were answered "no?"

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6. Calculate the percentage of "yes" and "no" responses for each age category.

7. As a team, discuss ways to get the word out that we do not want non-point source pollution of our water. Help others be a part of the solution rather than part of the problem. List your ideas.

8. Work with your team and plan a way to get the word out in your school and community. You might design brochures or posters, or plan a radio or television presentation.

Non-point Source Pollution (NSP) Questionnaire

Age:_____

ACTIVITY	YES	NO
Use herbicides to kill weeds in your yard		
Spray pesticides on your yard or around your house		
A car leaves a oil spot on the pavement or driveway		
Use fertilizer on the lawn and garden		
Have a pet whose wastes are deposited in your yard		
Pour used motor oil from the car on fire ant nests or along the fence to kill grass		
Wash out paint cans and brushes in the yard		
Put used oil filters in the garbage		
Put empty cans or bottles of floor wax, furniture polish, varnish, paint thinner, turpentine or oil-based paint in the garbage		
Put empty containers of pesticides in the garbage		
Put empty cans or bottles of lighter fluid, oil, or batteries in the garbage		
Dropped a gum or candy bar wrapper on the ground		
Dropped a drink bottle or can on the ground		
Dumped tires, old furniture or other trash along a road or beach		

What is NSP Pollution?

What is non-point source pollution (NSP)? It is commonly referred to as rainfall run-off pollution. It is pollution of unknown origin that ends up in the watershed. It is primarily caused by rainfall running over and through the ground. This runoff picks up and carries away natural and man-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters and underground sources of drinking water. These pollutants include the spot of toxic oil that leaks from cars onto the driveways or parking lots; the fertilizer used on the lawns and gardens; the deadly chemicals used to kill the weeds (herbicides) and pests (pesticides) around the home and yard clippings. These pollutants, along with pet wastes, are washed by the rainfall into streets and storm drains. Street and storm drains carry the pollutants to nearby streams, rivers, lakes, estuaries and eventually into the Gulf. Even oil, grease, gasoline, paints and other household chemicals carelessly dumped on lawns, in streets and in storm sewers end up in the watershed. The biggest threat is non-point source pollution.

Some research shows that the adding of sediments, chemicals and other things to the watershed occurs as much during dry weather as when it rains. This means that people are watering their lawns a lot. The water is going down the gutters and it takes fertilizers, pesticides and pet wastes with it.

Construction and agriculture are also sources of NSP pollutants. Tons of soil, trash and chemicals wash from construction sites each year and end up in waterways. An overuse of fertilizers or their incorrect application causes them to drain into waterways. This has the most immediate impact on wildlife. The fertilizers and wastes from animals wash off fields. The extra nutrients in the water result in an increase in algae and plant growth. The algae can have a large bloom, then die and decay. When the algae decay, they take the oxygen out of the water. These changes in the dissolved oxygen level in the water can cause fish kills and the death of other organisms. Increased algae growth and more cases of red and brown tides are occurring in the bays and estuaries of the coastal zone.

Used motor oil is made of toxic metals and other compounds, which make it a very hazardous material. Large numbers of people change the oil in their cars. This means that they have four to five quarts of used motor oil to get rid of. What do most people do with it? If it is poured along the yard fence to kill grass, it will end up being washed into the waterways. In Texas it is against the law to pour used motor oil on the ground. It must be taken to a recycling center. Even if everyone would dispose of used oil and oil filters at recycling centers, there is still the oil you see in every parking lot. When it rains this oil is carried in the water runoff. It ends up in the water and sediments where it kills the organisms.

A worn-out tire, piece of furniture and other trash that is dumped can end up in the waterways, the bays, estuaries and on the beaches. These affect the organisms living in the water, including oysters, crabs, fish and other seafood that we eat. Non-point source pollution is a serious problem.

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Some of the consequences are:

- degrading of water supplies
- pesticide contamination of the food chain having long-term effects on wildlife and human health
- degrading of recreational swimming and fishing areas
- destruction of aquatic habitats, affecting the reproduction of some aquatic organisms.

In the past 20 years NSP pollution has become the leading cause of pollution of our lakes, rivers, coastal waters and underground sources of drinking water. The Texas Commission on Environmental Quality (TCEQ) annually lists the bodies of water that have a major problem. Of the 140 on the list in 1998, 105 are affected by non-point source pollution. The problem is that industry, landowners and nearly everyone else thinks "out of sight, out of mind." In other words, if they do not see what happens, they do not think there is a pollution problem.

Previous pollution control efforts by the government focused mainly on point source pollution. These sources are easy to see and measure. Most of these have already been identified and dealt with. The TCEQ, Texas General Land Office, Texas Soil and Water Conservation Board, Texas Department of Agriculture and Texas Parks and Wildlife are the major state agencies working on this problem. They are trying to help people learn more about NSP pollution and what they need to do to prevent it in the local community. Remember it is people, not government agencies who are responsible for decreasing the pollutants.

NSP pollution is everyone's responsibility because everyone causes it. You and your family can practice these habits to decrease this pollution:

In the Home and Garden:

- Keep pet wastes, leaves and trash out of gutters and storm drains.
- Apply lawn and garden chemicals sparingly, following directions, or use natural pesticides.
- Control soil erosion by planting ground cover in erosion-prone areas.

Household Hazardous Waste:

- Dispose of antifreeze, paints and other household chemicals properly.
- Floor wax, brake fluids, furniture polish, weed killer, varnish, batteries, moth balls, glues, pesticides, car wax, solvents, paint thinner, rat poison, lighter fluid, turpentine, shoe dye, oil-based paint and primer all require special disposal by citizens. Call (512) 239-4747 or 1-800-64-TEXAS for more information.

Used Oil and Used Oil Filters:

- Dispose of used oil and oil filters at recycling centers. Many gas stations, oil changers and auto parts stores will accept used oil.

4. Cattle, Corn, and Cars — How Do They Affect the Gulf?

Oceanographer_____ **Teams**_____

An excess of nutrients flowing from the land into the sea has created serious environmental problems in many coastal waters. You and your team will analyze why ocean waters around the world are becoming greener, browner and redder.

Materials: none

Procedure:

Part I. What is the effect of enriching the Gulf?

1. When nutrients such as fertilizer are added to water, the phytoplankton multiply in an explosive manner. The water turns shades of green, brown and red with the pigments of the plankton. These blooms or explosive growths of plankton increase the amount of organic matter in aquatic ecosystems. This process of adding organic matter to the ecosystem is called **eutrophication**. Why is this growth of plankton a problem? The phytoplankton live only a short time. The organisms constantly die and sink to the bottom. On the bottom, bacteria use oxygen to digest the dead plankton. When more nutrients are added, more organic matter sinks to the bottom and more oxygen is used up. Oxygen becomes scarce or even exhausted. Animals that cannot move to zones with more oxygen die. These dead animals litter the bottom providing more organic matter for more bacteria to grow. The dead animals also wash up on beaches. On a separate page create an illustration to explain the process described above.

2. How does the oxygen depletion affect the rich fishing grounds in the bays and estuaries?

3. The increase of nutrients causes the increase in phytoplankton. The phytoplankton can form thick layers on the coastal waters. This affects the depth to which sunlight penetrates. How does this affect the sea grasses and seaweeds that typically grow in coastal waters and the animals that live there?

4. Until 40 years ago, it was thought that the oceans would not be affected by the forces of nutrient enrichment and oxygen depletion. Scientists now know this is wrong. The fertilization of coastal waters is a major threat to the Gulf of Mexico, Chesapeake Bay, the North Sea, the Baltic Sea, and many other estuaries, bays and lagoons. Why would these regions that do not experience strong winds or tides be more likely to be affected? How do winds and tides prevent water from becoming oxygen starved?

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Part II: What is the effect of people, cattle, corn, and cars on the Gulf?

1. The impact of urban sewage systems on water began in the mid-1800s and has only increased. Both nitrogen and phosphorus are essential for human nutrition, therefore the increasing human population consumes and excretes larger and larger amounts of both elements. This factor alone almost doubled the amount these nutrients released from human wastes between 1950 and 1985. How has this affected the water including the Gulf?

2. The human diet is becoming richer in protein. This protein contains nitrogen. How is the increase to a protein rich diet affecting the water? Explain.

3. As the human population increases, the need for food increases. The number of animals raised for food increases. The number of livestock, animals that consume and excrete large amounts of nitrogen and phosphorus, has grown by 18 percent in the past 20 years. How is this affecting the water?

4. Farmers have been adding large amounts of fertilizer to their fields since the 1950s to produce the large amount of crops to feed both humans and livestock. The main ingredients of fertilizers are nitrogen and phosphorus. Rain carries them to streams and rivers. How does this nitrogen and phosphorus get into the bays, estuaries and the Gulf of Mexico?

5. Use of nitrogen fertilizer increased more than fivefold between 1960 and 1980. In the following decade more fertilizer was spread on the land than had been applied throughout the entire history of agriculture. What is the impact of this on our lakes and oceans?

6. The burning of oil, gas and coal at high temperatures in engines and electric powered generators produces nitrogen compounds. This produces about 18 percent of the nitrogen that human activities add to the world every year. Rain and wind carry these compounds to the earth. How will this affect the coastal waters? Explain.

7. On a separate page, create an illustration to explain the effect of population growth and cattle, corn and cars on the Gulf.

5. How Do You Affect the Gulf?

Oceanographer _____ **Team** _____

Millions of people learned the joys of running water between about 1850 and 1920, as towns throughout North America and Europe threw parties celebrating the completion of their first public water supply. As clean water flowed through the taps and flush toilets, it freed people from back-breaking trips to wells and visits to out houses. Unfortunately homeowners did not think about how their new toilets would change the makeup of the oceans including the Gulf of Mexico. In the United States about 35 percent of all municipal sewage ends up basically untreated in marine waters. You and your team are going to investigate the impact of running water and toilets on the oceans.

Materials: Texas Highway Map, 2 or 3 liter bottles, water from a natural source that contains algae, substances (shampoo, soap, water from cooking, etc. that are added to water)

Procedure:

Part I What substances are you adding to water?

1. On a separate sheet of paper, list all the ways that you use running water during a day. Your list should begin with your waking up and end with your going to sleep at night.

2. Place a check next to each activity on your list in which you added something to the water and indicate what substance (soap, shampoo, tooth paste, water from cooking vegetables, grease from dishes, food wastes, human wastes, etc.) was added to the water. How often do you add substances to the water you use?

3. The water you used and that ran down the drains will find its way to your local wastewater treatment plant. Contact your water treatment plant to learn what happens to the substances that you added to the water. Which are removed and which are not?

4. After the water is treated in the wastewater treatment plant, where does the water go? (Call your local wastewater treatment for this information) Does it flow into a body of water?

5. If the wastewater flows into a body of water, use a Texas map to determine if it is part of the watershed for the Gulf of Mexico. Where does it enter the Gulf of Mexico?

6. How might the water you used affect the Gulf water?

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Part II. How do the substances you used affect the plankton and algae in water?

1. Conduct an investigation to determine the effect of various substances in the water on the microscopic single-celled organisms called plankton and algae.
   a. Obtain 2 or 3 plastic liter bottles. Cut and remove the top portion of the bottles.
   b. Add water from a natural source (pond, lake, creek, river, etc.) that contains microscopic algae (pond scum) until the bottle is filled up to 10 cm from the top.
   c. Do not add any other substance to the first bottle; this bottle will be your control. Add 15 ml of a substance (shampoo, soap, water from cooking, etc.) you have selected to test to each of the other bottles.
   d. Place the bottles near a window for light or under lights for growing plants.
   e. Observe the bottles each day for the next two or three weeks.
   f. Record your daily observations in your science journal.

2. Every gardener knows, nitrogen and phosphorus are essential ingredients of plant fertilizers. Plants that live underwater often respond to these nutrients just as tomatoes and roses do — they grow faster. Conduct an investigation to determine the effect of various fertilizers on the plankton and algae. Repeat steps a-f in number 1. In step c add a teaspoon of fertilizer to the bottle. You may wish to add different fertilizers to each bottle or you may want to add different amounts of the same fertilizer to the different bottles.

3. After two or three weeks what conclusions can you reach about the impact of adding different substances to water? How did it affect the plankton and algae in your water?

4. Although you conducted the investigation using fresh water, do you think the results would be similar if you were using salt water and plankton found in saltwater? Explain.

5. How do the substances you add to water affect the Gulf? Explain.

6. What can you do to reduce your impact on the Gulf waters?

6. Where is the "Dead Zone" in the Gulf of Mexico?

Scientist _____ **Team** _____

The Mississippi River is one of the ten largest rivers in the world. It empties 580 cubic kilometers of water into the Gulf of Mexico each year. Its drainage basin or watershed is made of 40 percent of the land area of the lower 48 states. A watershed is defined by the U.S. Environmental Protection Agency as "a geographic area in which water, sediments and dissolved materials drain into a common outlet." In this case you are going to investigate all of the area of the Mississippi River basin that drains into the Gulf of Mexico. You are going to analyze the relationship between the Mississippi River watershed and what is happening in the Gulf of Mexico.

Materials: United States Map (includes drainage basin of rivers that drain into the Mississippi River drainage basin), Atlas of the United States

Procedure:

1. Draw a line on the map (Fig.6.1, next page) around the area from which the Mississippi River, and rivers that run into the Mississippi, carry water to the Gulf of Mexico. What is the drainage basin of the Mississippi River?

2. What (agriculture, business, industry, population centers) is located on the land in the Mississippi River basin? Use an atlas or the internet to obtain additional information.

3. Every spring something goes wrong with the water in a large portion of the Gulf of Mexico. The amount of oxygen in the water near the bottom of the Gulf floor drops to very low levels. Sometimes it drops so low that there is almost no oxygen present. This area of low oxygen acts like a blanket that is killing or driving away some fish and most bottom dwellers, such as shrimp, snails, crabs and starfish. In the worst areas, the sediment turns black. Examine Figure 6.2. Where is this zone of low oxygen located?

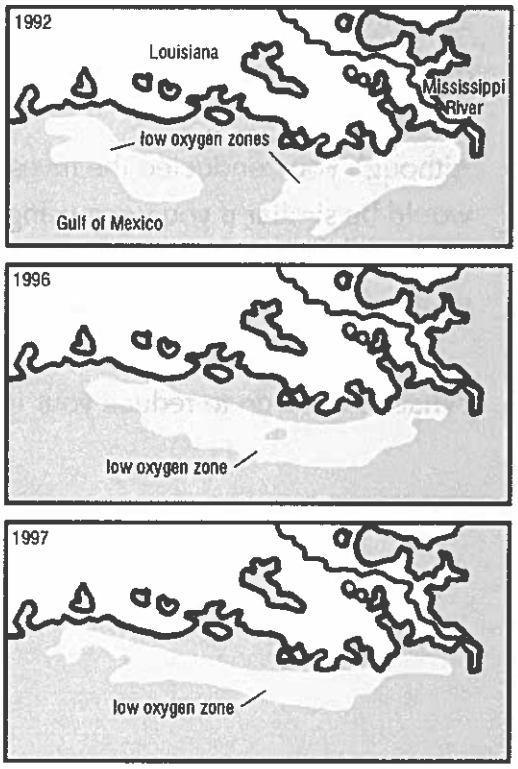


Fig. 6.2. Low oxygen zones in the Gulf of Mexico. (Source: Scientific American, Nov. 1997, p. 20)

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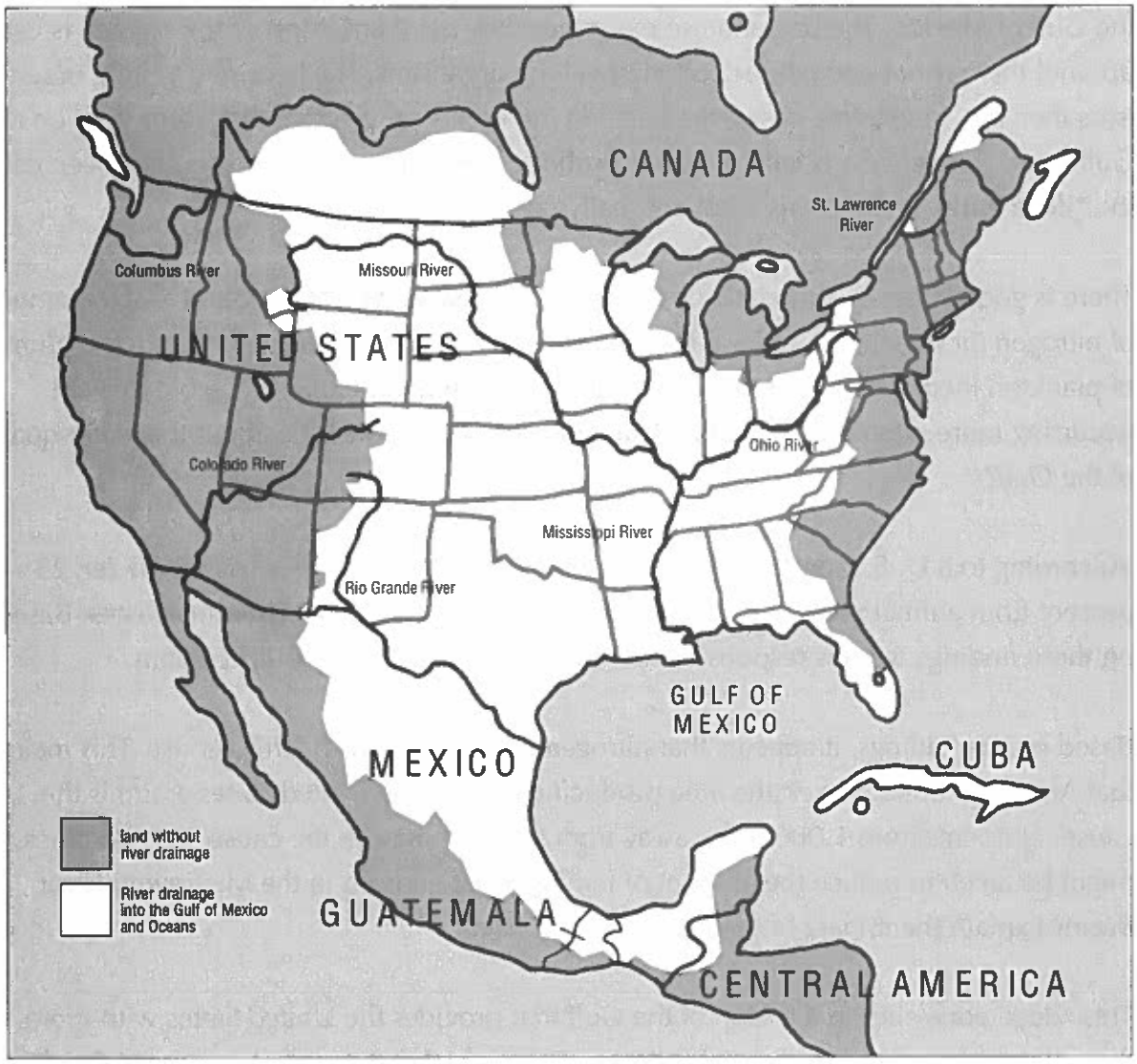


Fig. 6.1. Major rivers feeding into the Gulf of Mexico.

4. From Figure 6.2, what has happened to this zone since 1992?

5. What is causing this problem? Write your hypotheses below.

6. What data would you need to prove that your hypothesis is correct?

7. Studies of water samples, sediments from the sea floor, and other data show that the amount of dissolved nitrogen in the outflow of the Mississippi has tripled since 1960. Phosphorous levels have doubled. What might be the cause of this increase?

8. Nitrogen and phosphorus can be used by single celled organisms. This causes an increase in the growth of phytoplankton near the surface. The phytoplankton are eaten by the one-celled organisms. The remains of the phytoplankton and the wastes then fall to the floor of

the Gulf of Mexico. The bacteria use oxygen as they eat them. Most of the oxygen is used up until there is not enough for bottom dwelling organisms. The bottom dwelling organisms then die. In extreme cases, the bacteria increase so much that they form mats on the Gulf floor. This process is called **eutrophication**. This region of low oxygen has been called the "**dead zone**." Why is this label not really correct?

9. There is good water-quality data for Gulf since the 1950s. Scientists found that the amount of nitrogen increased; the ratio of the amount of nitrogen to silicate increased; the number of plankton increased; the amount of oxygen decreased; and toxic algae blooms are occurring more often. Based on the data what could you conclude about the water-quality of the Gulf?

10. According to a U. S. Geologic Survey, 56 percent of the nitrogen is from fertilizer, 25 percent from animal manure, and 6 percent from municipal and domestic wastes. Based on these findings, who is responsible for the "dead zone" in the Gulf? Explain.

11. Based on the findings, it appears that nitrogen has gone up with fertilizer use. This means that America's breadbasket (the area producing most of the United States grain) is the cause. Nutrients from 1,000 miles away from the Gulf may be the cause. What actions might be taken to reduce the amount of fertilizer that ends up in the Mississippi River Basin? Explain the impact of your suggestion actions.

12. This "dead zone" lies in a region of the Gulf that provides the United States with more than 40 percent of its commercial fisheries. Some say that this zone has caused the decline in the fish and shrimp catches. Others say that the decrease in fish and shrimp is due to over fishing. Which argument do you support? Explain.

13. What are some solutions to the problem of the "dead zone?" Remember that the best solution should be a win-win solution for the farmers, fishermen and the citizens.

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7. Why Should We Care About Nitrogen in the Watershed?

Citizen _____ **Group** _____

The increase in nitrogen content of our natural ecosystems has occurred more rapidly than any other human-caused change. People have changed the global nitrogen cycle. You are going to analyze the impact of changes in the nitrogen content.

Materials: Nitrate test kit (optional), **Texas Water Quality, A Summary of River Basin Assessments**, or the internet

Procedure:

Part I: What is the nitrogen cycle?

1. Read the description of the nitrogen cycle below.
   Living organisms need nitrogen to make proteins, DNA, RNA and other organic compounds. Nitrogen gas makes up 78 percent of the volume of the atmosphere. However, neither plants nor animals can use the nitrogen in that form. You inhale nitrogen with every breath you take, but you exhale it unused. Nitrogen cycles back and forth from the abiotic (nonliving) to the biotic (living) parts of the ecosystem.
   a Plants (producers) get their nitrogen-bearing compounds from the soil or the water in which they grow.
   b Living in the soil or in the roots of certain plants (legumes) are nitrogen-fixing bacteria. They can "fix" the nitrogen, converting it to a form they or other organisms can use. Nitrogen fixers convert nitrogen gas to ammonia (NH_3).
   c The ammonia produced by the nitrogen-fixing bacteria can be used by the legume plants or can spill into the ground and be used by bacteria or other plants.
   d Decomposers in the soil break down the complex organic compounds in dead plants and animal bodies. They use the energy from these compounds and convert them into simpler substances. The chief nitrogen-containing substance is ammonia. Ammonia is a gas, and some of it will escape into the atmosphere. However, it dissolves in water. In soil water, ammonia reacts chemically with hydrogen ions to form ammonium ions (NH_4^+).
   e In the form of ammonium ions, nitrogen may be absorbed by the roots of plants. It is then used by the plants.
   f Other specialized bacteria then convert these inorganic forms of nitrogen back into nitrite (NO_2^-) and nitrate (NO_3^-) ions in the soil and then into nitrogen gas. The nitrogen gas is released to the atmosphere to begin the cycle again.

2. Create a diagram of the nitrogen cycle on a separate sheet of paper or newsprint.

3. Look at the diagram of the nitrogen cycle (Figure 7.1). Compare your diagram to it.

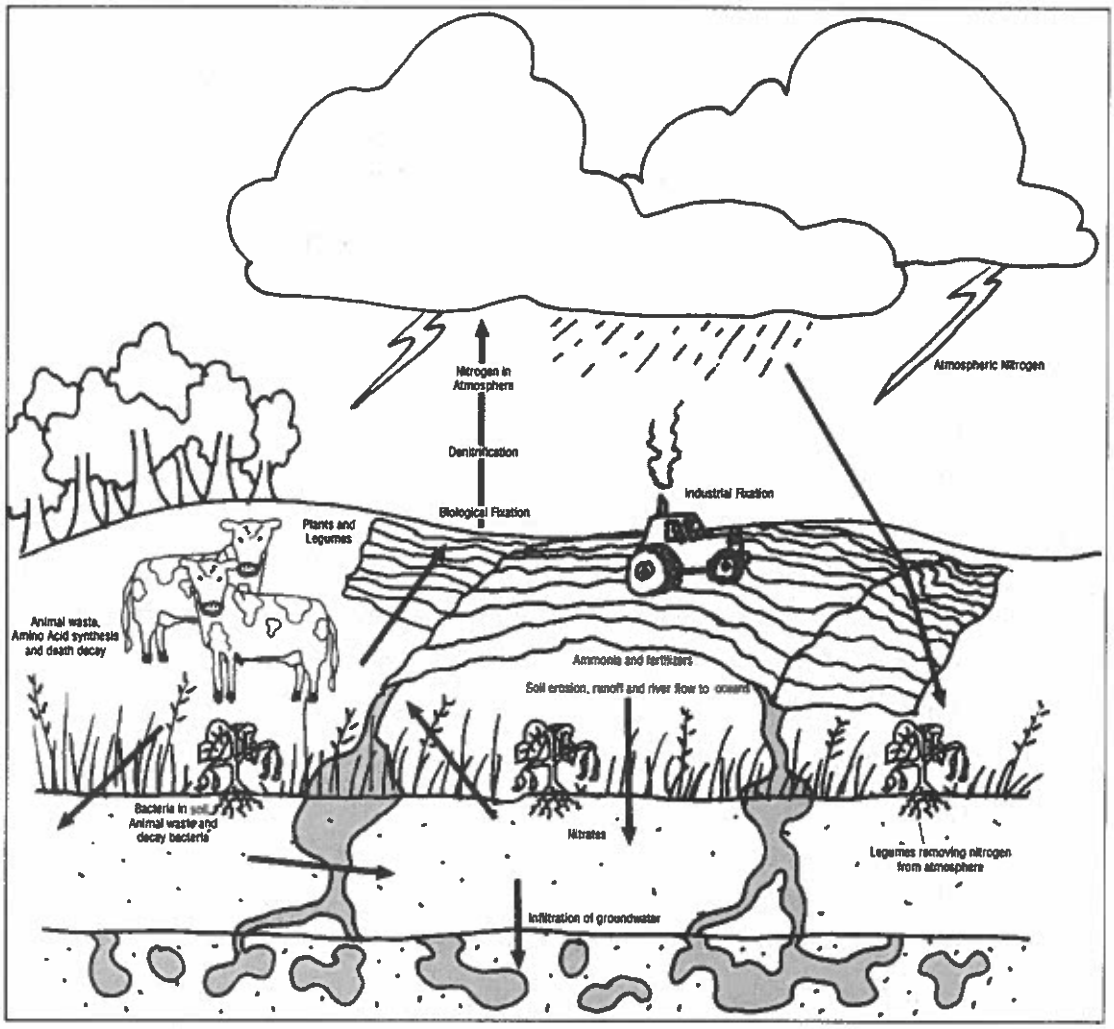


Fig. 7.1. Nitrogen cycle.

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Part II. How do we affect the nitrogen cycle?

1. Read and discuss the ways listed below that humans interfere with the nitrogen cycle:
   a. Burning forests, grasslands and fossil fuels releases nitric oxides and other gases to the atmosphere. These cause acid rain and photochemical smog.
   b. Mining mineral deposits containing nitrate and ammonium ions for fertilizers.
   c. Nitrous oxide gas is released into the atmosphere by bacteria breaking down livestock wastes and fertilizers applied to the soil.
   d. Removing nitrate and ammonium ions from the soil by growing nitrogen-rich crops.
   e. Excess nitrate and ammonium ions enter aquatic ecosystems from agricultural runoff of fertilizers and livestock wastes.
   f. Extra nitrogen ions are added to the aquatic ecosystem from sewage wastewater.

2. Add the ways that humans impact the cycle to the diagram of the nitrogen cycle (Figure 7.1).

Part III. Why should we care?

1. Read about the impact of nitrogen compounds below.

Nitrates in drinking water can be dangerous for young animals, including humans. Babies have a less acid stomach than adults so their stomachs convert nitrates to nitrites. The hemoglobin in the red blood cells of fetuses (unborn babies) and infants is different than that of adults. The fetal hemoglobin combines with the nitrites which prevents it from carrying oxygen. For this reason the U. S. Environmental Protection Agency (EPA) sets a limit of 10 parts per million (ppm) of nitrates for public drinking water. In Europe, where levels of 2000 ppm have been measured, some babies have died. Brain damage and miscarriages are also possible. American farm animals have been affected. Reproductive failure of cows and sheep has been traced to their drinking water that had high nitrate levels.

In grassland areas where a lot of fertilizers were used, the number of species that grow there has been reduced. In some cases, a single grass begins to dominate. These types of changes can also occur in aquatic systems too.

Nutrient enrichment from nitrogen has caused red tides and the recent *Pfiesteria* outbreaks. These toxic dinoflagellates are naturally occurring. However, the increase in nutrients caused a huge population growth over a short period of time, causing fish kills. In spring 1996, Florida manatees died when they inhaled the toxic compounds from a red tide. Toxins from *Pfiesteria* produce nervous system problems in humans. The *Pfiesteria* itself attacks fish and human flesh. So the increase of nutrients causes problems ranging from a loss of biodiversity to fill kills and human health problems.

The addition of nitrates may change an entire estuary. An estuary is the partially enclosed coast at the mouth of a river where its fresh water, carrying sediments and runoff from the land, mixes with seawater. The nutrients cause a population explosion of phytoplankton. The phytoplankton growth is so thick in the summer that it blocks out the sunlight. Sea grasses do not get enough light to grow so they die. As phytoplankton and seagrasses sink to the bottom, they are decomposed by bacteria that use oxygen. So the oxygen is depleted in the bottom waters during calm weather. It becomes a dead zone. The dead zone that forms in the Gulf of Mexico during the summer probably results from excess fertilizer washed down the Mississippi River watershed into the Gulf. The nutrient increase in coastal waters may be even dangerous.

2. List the ways that nitrogen compounds are dangerous. Check each way that may affect you directly. Explain how.

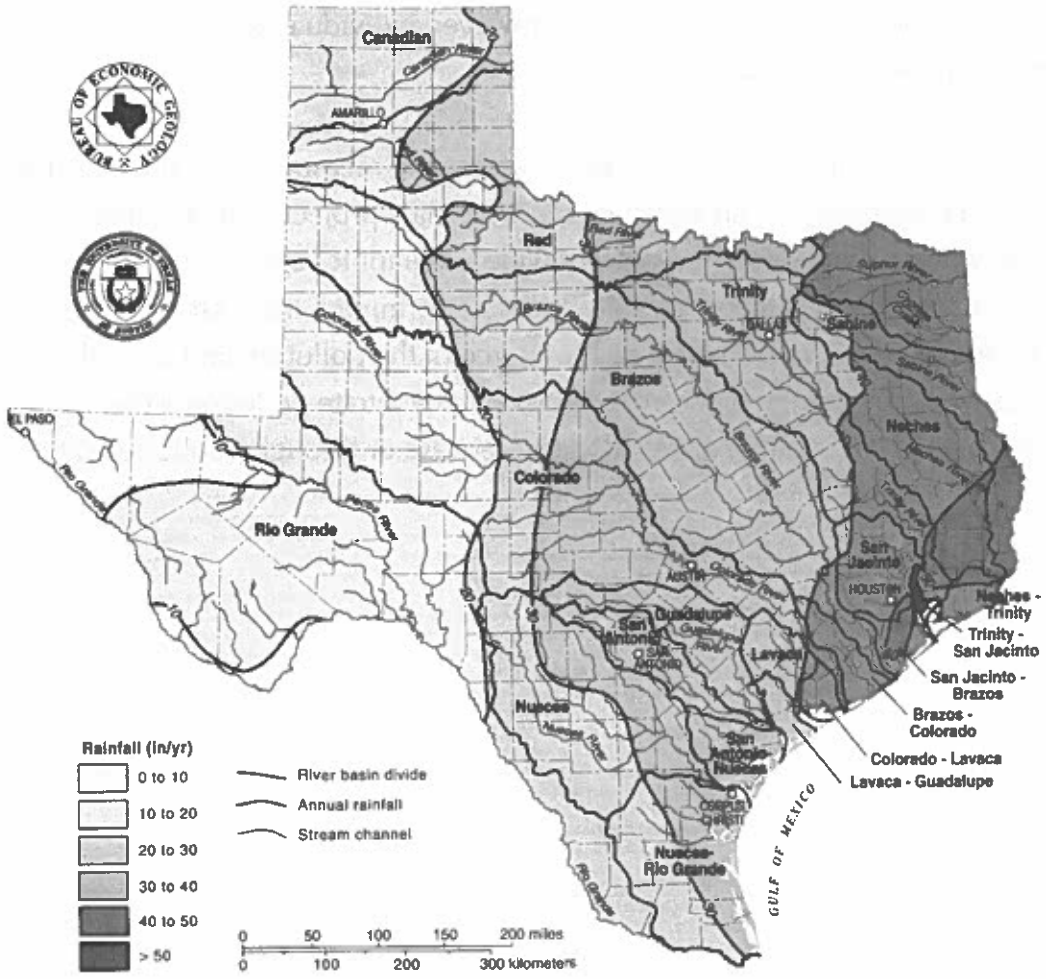
3. Obtain a copy of **Texas Water Quality, A Summary of River Basin Assessments** from the Texas Clean Rivers Program, Texas Commission on Environmental Quality, P.O. Box 13087, Austin, Texas 78711-3087 or use the internet to consult the updated water quality evaluation from the Clean Rivers program at http://www.tnrcc.state.tx.us/water/quality. Determine if the nutrient level in streams, rivers and lakes in your area is of concern. Are there any nutrient problems in your local area? Explain.

4. Use the information prepared by the Texas Clean Rivers Program (book or internet) to determine the nutrient level of such coastal areas as Lower Sabine River, Lower Neches River, San Jacinto-Brazos Coastal, Lower Brazos River, Brazos-Colorado Coastal, Lower Colorado River, Guadalupe River, San Antonio-Nueces Coastal, Nueces-Rio Grande Coastal and the Arroyo Colorado Watershed (See Figure 7.2). Which ones have nutrient problems?

5. How do the nutrient levels of the coastal basins compare to those in your local area? Explain.

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RIVER BASIN MAP OF TEXAS



Fi tin)

River basins	Texas length (miles)	Texas area (sq mi)	Number of major reservoirs*	Conservation storage (acre ft)*	Storage (acre ft/sq mi)
Brazos	840	42,800	19	3,322,880	75
Canadian	200	12,700	2	560,900	44
Colorado	600	39,893	11	3,803,900	95
Guadalupe	250	6,070	2	420,000	70
Lavaca	74	2,309	1	157,900	68
Neches	416	10,011	4	3,455,500	345
Nueces	315	16,950	2	931,640	60
Red	680	30,823	7	4,593,460	149
Rio Grande	1,250	48,259	3	3,772,000	78
Sabine	360	7,426	2	6,041,300	814
San Jacinto	70	5,800	2	570,400	102
Trinity	550	17,696	14	6,969,710	388

*Data from Texas Water Development Board.

Part IV. What can we do?

1. Nitrogen that enters systems from a specific source such as a smokestack or sewage can be addressed with regulations and technological solutions. Most nitrogen sources are not currently regulated. For example, no one measures how much fertilizer homeowners, farmers or golf courses use. Discuss how we could decrease fertilizer use through education, incentives or taxes.

2. Use what you have learned about the nutrient level in your local area and nitrates to prepare a brochure or poster to educate people about the problem.
   Nitrate pollution is a large - scale problem. Each of us plays some role. Governments may have a major role in solving the problem. However, individual education and action are essential to improve the situation.

3. (Optional) Because nitrate in water is easily and safely measured and since its presence is a widespread problem, it is an excellent topic for class projects. Since nitrate is stable, you can make water collections that represent wide geographic regions in your city, community or rural area and test the water for nitrates. Determine if there are nitrate-enriched environments in your area. Determine the source of the pollution and possible solutions. As a class, you may plan and do projects that reduce nitrate pollution either through direct action such as planting buffer zones along waterways or through public education.

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8. What Should Be Our Policy About Nutrients and the Gulf?

Citizen/Legislator _____ **Team** _____

North Americans pour nutrients into bays and estuaries at alarming rates. Many coastal areas are being affected. What can and should be done about it? You and your team are going to evaluate possible solutions and decide what action should be taken.

Materials: none

Procedure:

Analyze each of the following proposals. For each list reasons for supporting the proposal, reasons for opposing it and, finally, your team's decision.

1. The first way to decrease amount of nutrients is effective sewage treatment. Nitrogen can be removed from wastewater. Wastewater treatment plants can enable microbes to break down the nitrates and give off nitrogen gas, which is harmless. This process of **denitrification**, or the removal of nitrates, can be cost effective as well as good for the environment. Some wastewater treatment plants have already implemented this process even though they aren't required to do so. It would cost about $ 1 million to update a modern wastewater treatment plant and up to $20 million for a complete redesign of an older plant. This additional microbial treatment reduces the time that fans must run to aerate the sewage. This process also reduces the acidity of the wastewater. As a result, some chemical additives are no longer needed. This additional microbial treatment also reduces the amount of sludge that must be disposed of. Savings in operation and maintenance costs in the updated plant over the long term would be close to the cost of updating the plant. Would you support legislation that required that all wastewater plants be updated in the next five years?

2. Only 25 percent of the nitrogen comes from sewage, much of the rest is runoff from farmland. Better land management can help solve this. Farmland can be graded or sloped and plowed so that runoff is reduced. Leaving a border of plants or plant materials around fields and planting forests or artificial wetlands between the fields and streams can reduce runoff. These borders would provide a place for sediments to settle from runoff and plants to take up the dissolved nutrients. Should legislation require better land management of fields, the planting of forests and artificial wetlands between fields and streams, and provide funds to support these programs?

3. Fertilizer-reduction strategies are designed to give crops as much nutrient as they need but no more. These methods include simple soil testing to using computerized tractors that use satellite-based navigation equipment to direct the application of fertilizer. (a) Should legislation require all soils to be tested before any fertilizer can be applied? (b) Should large farming operations (more than 1,000 acres) be required to use the computerized and satellite-based equipment to apply fertilizer? (c) Should government funds be used to pay for part of the costs?

4. One of the toughest problems is that with the increase in population, there has been an increase in livestock feedlots. Hundreds of livestock are fed in pens. This results in large amounts of manure. The large amounts of phosphorus in manure may overload the phosphorus in the soil even though the nitrogen is not high. The problem is what to do with all the manure. Should legislation fund research to answer the question of what to do with all the manure?

5. The burning of fossil (oil, gas and coal) fuel in engines and electric-power generators accounts for 15 percent of the nitrogen that human activities add to the earth each year. Should legislation require that the amount of nitrogen compounds produced by cars, trucks, power plants, etc. be reduced even though this means an increase in the cost of cars, trucks and power plants?

6. The richer nations like the United States and parts of Europe can afford the high tech solutions to reducing nitrogen. However, the United Nations Population Fund estimates that 80 percent of the rise in global population is taking place in the urban areas of Africa, Asia and Latin America. The nations in these continents do not have the technology or the money to pay for solutions for reducing the nitrogen that enters the oceans. Should all countries be required to reduce the nutrients (nitrogen and phosphorus) in the water and should the wealthier countries help pay for this?

7. Summarize the impact on the oceans if each proposal is adopted and implemented.

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9. How Does Your Watershed Impact the Gulf of Mexico?

Hydrologist _____ **Team**_____

Hydrologists are scientists who study water. Some study watersheds to determine their environmental quality. Point source pollution is from contaminants that come from a single pipe or plant or single source. You are going to use data to investigate the environment and environmental health of a watershed. You will also determine how the watershed's health affects the Gulf of Mexico.

Materials: Texas Highway Map and/or map of Southwestern United States, page size River Basin Map of Texas, Texas Commission on Environmental Quality (TCEQ) contamination case map, **Texas Almanac**, overhead transparency and transparency marker, ruler, internet access

Procedure:

1. Your team will be assigned a watershed that empties into the Gulf of Mexico to investigate. Place a clear transparency on the page-size River Basin Map of Texas (Figure 9.1). Mark the state outline so that you can later place the transparency on another map as an overlay. Trace the boundaries and major rivers in your assigned watershed. The headwaters of a river are where the streams that form the beginning of the river start. Use the Texas Highway map or a map of the southwestern United States to locate the headwaters or the beginning of the major river in your watershed. Where are the headwaters?

   Where does its water flow into the Gulf?

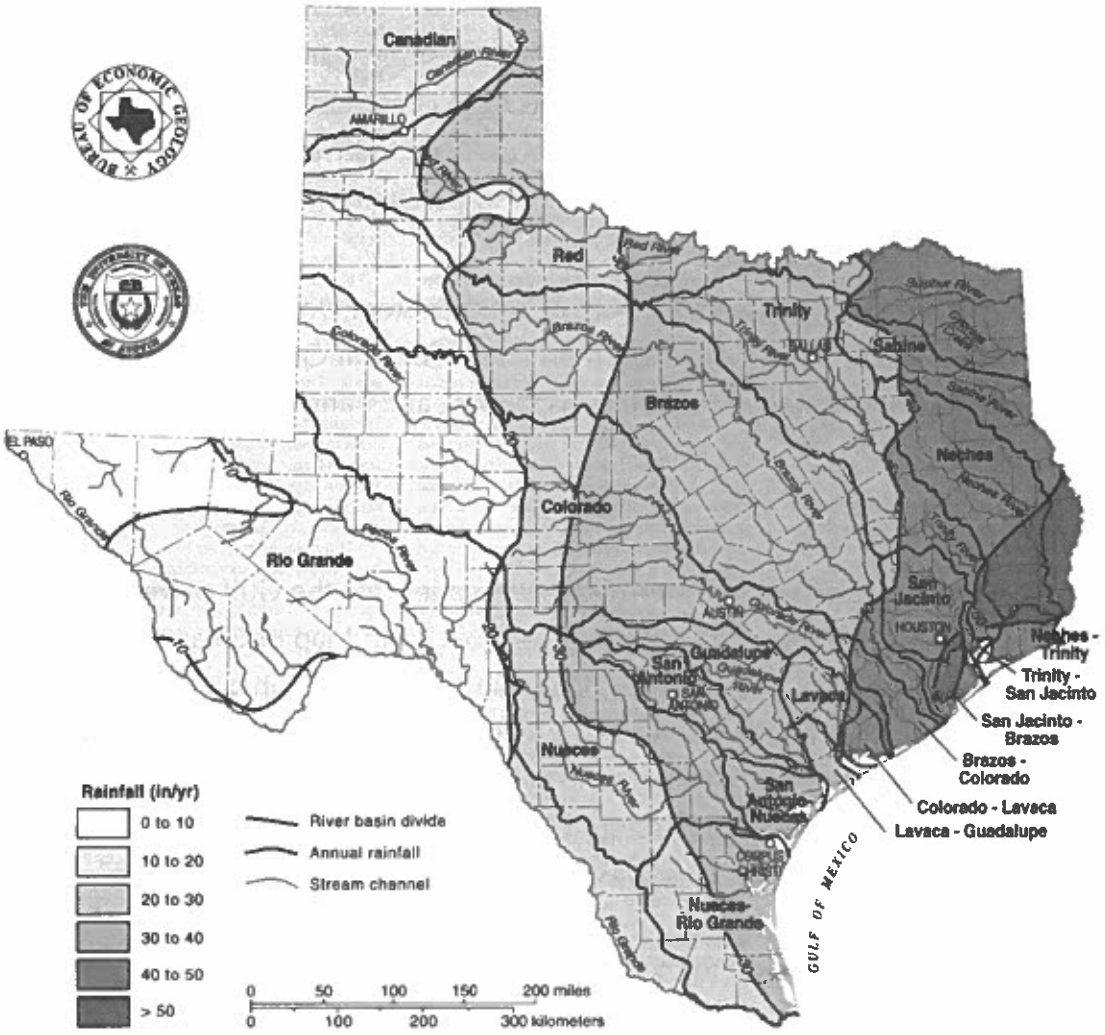
2. Using the data from the table on the River Basin Map of Texas, what is the length square miles of area of your watershed?

3. Construct a table similar to the example. Use the River Basin Map (Figure 9.1) and a Texas Highway map to complete the table. Add the data from your classmates' watersheds.

Table 1: Watershed Data

Watershed	Major River(s)	Major Cities	Agriculture	Industry

RIVER BASIN MAP OF TEXAS



River basins	Texas length (miles)	Texas area (sq mi)	Number of major reservoirs*	Conservation storage (acre ft)*	Storage (acre ft/sq mi)
Brazos	840	42,800	19	3,322,880	75
Canadian	200	12,700	2	560,900	44
Colorado	600	39,893	11	3,803,800	95
Guadalupe	250	6,070	2	420,000	70
Lavaca	74	2,309	1	157,900	68
Neches	416	10,011	4	3,455,500	345
Nueces	315	16,950	2	931,640	60
Red	680	30,823	7	4,593,460	149
Rio Grande	1,250	48,259	3	3,772,000	78
Sabine	360	7,426	2	6,041,300	814
San Jacinto	70	5,600	2	570,400	102
Trinity	550	17,696	14	6,969,710	388

Data from Texas Water Development Board.

Fig. 9.1. River Basin Map of Texas. (Source: Bureau of Economic Geology, The University of Texas at Austin)

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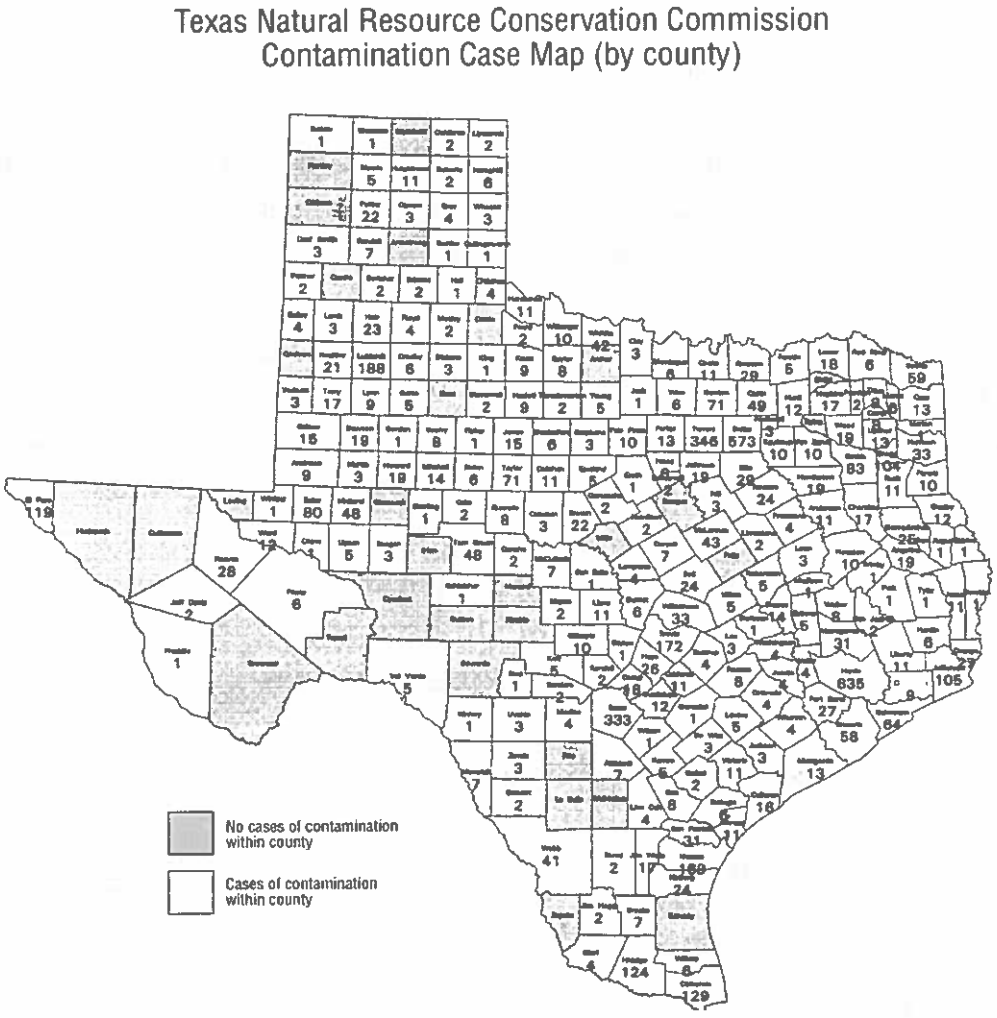


Fig. 9.2. Contamination Case Map (by county) (Source: Texas Commission on Environmental Quality Joint Groundwater Monitoring and Contamination Report 1994)

4. Place the transparency of your watershed on the Texas Commission on Environmental Quality Contamination map (Fig. 9.2). How many cases of contamination are found in your watershed?

5. Which counties in your watershed are the sources of most point source contamination?

6. To determine the water quality in your watershed check for your watershed at http://www.tnrcc.state.tx.us/water/quality/tmdl/1966_tmdl_list.html for the point source contamination. What are the sources of the contamination?

7. Use the highway map and the Texas Almanac to determine possible sources of non-point-source pollution. **Non-point-source pollution (NSP)** is contamination that comes from several sources. Identify the population centers, agricultural areas, and industry that are likely sources for this type of pollution.

8. Discuss the quality of your watershed. Is it good? Bad?

9. Explain how your watershed is impacting the Gulf of Mexico.

10. What do you think should be done about the water quality of your watershed?

11. Who should do something about the water quality in both your watershed and the Gulf of Mexico? Explain.

12. What would be the costs and benefits of increasing the water quality in your watershed and Gulf?

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10. What Should Be Our Policy for Protecting the Waters of the Gulf Coastal Zone and the Gulf of Mexico?

Citizen _____ **Citizen Group** _____

As a citizen you will be asked to make decisions about policies that impact the water quality of the watersheds and the Gulf of Mexico. In order to make good decisions, you will need to analyze both the positive and negative aspects. Then you can decide whether to support a particular policy.

Materials: none

Procedure:

1. Indicate the positive, negative and interesting aspects of each of the following items on a separate sheet of paper. Divide the paper into three columns: Positive, Negative and Interesting. List the positive aspects under the Positive heading and the negative aspects under the Negative heading. Those aspects that are neither positive nor negative should be placed in the Interesting column. Then decide whether or not you support the stated policy.
   A. An advance disposal fee of five cents will be levied on every glass, plastic or metal container and one cent on every paper container. This money will be used to fund recycling of these containers and to remove them from the watershed. Decision good or bad?

   B. States should require that anyone who purchases and/or uses pesticides, herbicides or fertilizers be trained in their use. This training should occur before the purchase is made and should emphasize the correct method of application and ways to ensure the chemical does not enter the watershed. Decision good or bad?

   C. Cities should be required to treat run-off to prevent watershed contamination from animal wastes, oil from streets and driveways, lawn fertilizers and pesticides, and other pollutants. Decision good or bad?

   D. Farmers and ranchers who have land bordering rivers and streams should be required to fence cattle and other livestock away from the water. They should be required to prevent fertilizers from washing into the streams and rivers. Decision good or bad?

2. Discuss these with your team after you have completed A - D. Did all your team members have the same responses?

3. After discussing the statements, complete A - D as a team.

4. Your team will be assigned one statement from A - D and either a positive or negative position to debate with another team. Each team will only have two minutes to present its position.

5. Summarize what you learned.

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Topic 6 — Sand, Sediments and the Coastal Zone

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Topic Six: Sand, Sediments and the Coastal Zone

The sands and sediments found along the Texas coast or on the floor of the Gulf of Mexico have a story to tell. They contain a great variety of particles. These grains were carried to the Gulf from land or produced by a variety of biological or chemical processes. Careful study of the properties of these sands and sediments by trained geologists gives valuable clues about the region's geological history, the marine life over time, the past climates, variations in the flow pattern of water currents, fluctuations of sea level, occurrences of mass extinction and many more events. These stories can be read from the record found in the sand and sediments of the coastal zone and the Gulf of Mexico.

The sands and sediments differ in mineral composition and grain size along the Texas coast. Texas beach sands are derived from erosion on land and delivered by rivers to the sea. The river runoff and incoming tidal currents provide sediment from both the landward and the seaward directions. River-deposited sediment tends to be a mixture of sand and mud, while sediments brought in from the sea generally consist of sand mixed with marine shell gravel. The sediment deposits at the edges of estuaries, lagoons, and bays are sheltered from wave action, resulting in very fine mud being deposited.

The type of deposition material, whether gravel, sand, a mixture of sand and silt or primarily fine sediments, is a factor in determining the organisms that live in an area, color of the water, erosion, flooding, and impacts dredging and construction projects. The deposition patterns of the past determine the location of today's oil and gas deposits. The characteristics of the sediments in an area impact both the abiotic and biotic aspects.

For all of the activities use two different types of sand and two different sediment samples. If possible, obtain a sample of sand from the dunes and another from a beach area. The sediment samples should contain silt or fine mud or clay and can be collected from the bay and estuarine areas. If this is not possible, obtain different types of sand from a local sand and gravel or cement company or collect it locally. The sand sold for use in children's sandboxes will work as one sample. Sediment samples collected from local creeks or rivers can be substituted for sediment from a bay or estuary. Samples can be made by mixing silt, clay and sand. One sediment sample should consist of more silt and clay than sand. Dry samples are needed for the activities. Dry them by spreading each sample in an aluminum pan and placing in an oven set at 300°F for 15-30 minutes and stir several times while it is heating. Sand or sediments dried in this manner may be stored in plastic bags after cooling.

Introduce the activities by telling the students that they will be scientists or detectives who are studying samples of beach sand to determine the properties of each sample. They will use this knowledge to analyze unknown samples. Ask them why a scientist might want to identify unknown samples. Then discuss the possibilities that the sample could be from a crime scene and they might want to know whether or not the suspect was at the scene of the crime. Scientists also study samples to determine where the sand originated or what conditions created it. Studying the sand can help scientists understand how the beaches were formed and how they are changing. It will help scientists understand geologic processes in order to predict what will happen in the future, such as where erosion will occur and where materials will be deposited. These are important issues as the coastal zones continue to be developed.

Have the students work in teams of four. Encourage them to work as a team of scientists. Within a team, they may work in pairs to test the samples and share their results. If you have more types of sand and sediment samples available, each team may test different samples and report on its findings to the class.

Activity 1: What can we learn about mystery sand samples by using our senses?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.7

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- investigate the properties of sand using their senses (sight, smell, hearing, touch) to describe and compare samples
- communicate the characteristics of sand samples and use them to identify the sample
- use their observations of sand samples to write descriptive paragraphs

Background:

1. Prepare 2 to 4 different samples of sand or sediments for each group by placing 1 to 2 teaspoons of the sample in a snack-size plastic bag. Using a permanent marker, label each bag with the number of the sample. Use sand samples from the dunes, different beach areas and different beaches if possible. If these are not available, obtain different types of sand from a local sand

and gravel or cement company or collect samples from local streams or rivers to use. Keep one sample to use as your sample for the evaluation of the students.

2. Provide each group of students with the samples of sand. Before beginning Part I, ask what they notice about the samples. Do any of these seem similar? Are they different? How do they differ? Ask the students to observe the samples and see what they can learn. After 5 to 10 minutes, ask the groups to share what they learned. Ask what information their samples might provide. The following activities can be used to help the students develop their observation, communication and thinking skills. The time for the activities will depend on the students' observation and communication skills.
3. Begin Part I by telling the students that they will be using sight to observe the sand samples. After completing the activity, they should be able to identify each sample by sight alone. They should be able to write a description of each sample so that another group could use their description to identify the sample described. You might want to have each group describe each of its samples on separate index cards (some samples should be different among the groups). When they have completed their descriptions, the groups can exchange the index cards with the description and the samples. The groups will then attempt to match the description card to the sample described. Discuss the problems they had and how they can improve. Discuss which words are better scientific descriptors. The discussion could also focus on adverbs and adjectives as descriptors. This activity will help reinforce the importance of good observation and communication skills.
4. Provide hand lenses for the students to use. Have the students place a small sample on a piece of white paper and another small sample on black paper. Discuss their observations using the hand lens. Review the use of the microscope before students observe the samples. The students could place a piece of transparent tape that is sticky on both sides on the slide and then place a small sample on it for viewing under the microscope.
5. Have the students compare their observations and discuss the role of tools (technology) such as hand lenses and microscopes in observations. If possible show the students a picture of sand photographed using an electron microscope as part of the discussion.
6. Begin Part II by asking the students if they could distinguish among the samples and identify each by touch alone. Challenge the students to practice this skill and see if they can do it with their samples. Discuss what is meant by texture. Have the students write their descriptions of how each sample feels.
7. Have the groups exchange descriptions and examples to check their ability to communicate. Each group can determine how successfully another group in used descriptions to identify the sample by touch.
8. Discuss what the students have learned. Point out that we often overlook our sense of touch. An individual who is blind can use this sense to read Braille, so the students should be able to develop the skill to "read" sand samples.
9. Begin Part III by stressing that the students follow the proper procedure for smelling. Stress how students can use their hands to move the air from above the sample to their noses. Discuss their findings. The grains in the sand alone will not have an odor. If there is an odor, it is a result of organic particles or other chemicals that may be present in the sample. Discuss possible causes of the odors and how the smell can be used to detect impurities or pollutants in the sand.
10. Begin Part IV by asking the students if the sand samples would sound differently. Then have the students investigate this in different ways, by pouring the sample into a container (film cans) or onto paper and by placing the sample in a container and shaking it. Have the students shake the container at different rates and observe similarities and differences. Discuss the causes for differences in sound. Determine if there is a relationship between the sample particle size and the sound.

Activity 2: What can the shape, sorting, and size tell us about our mystery sand?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.7, 6.14, 7.14, 8.14, 6.6

Math: 6.3, 7.2, 8.2, 6.4, 7.3

Language Arts: 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.23, 8.32, 7.23

Learner outcomes: After completing the activities, the students will be able to:

- classify the sand particles by size, shape, and degree of "sorting"
- use their observations of sand samples to write descriptive paragraphs
- use the data gathered about each sample to infer the history of the sample

Background:

1. For Part I, ask the students what they observe about the shape of the sand grains in Activity 1.

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Discuss what inferences they could make about the shape of the grains (from round to angular) and what causes the grains to be more rounded than angular. Sharp edges are worn as particles rub against other particles. The more rounded the grains, the more the grains have been moved and exposed to water and air. Ask the students why all the grains in a sample are not the same (hardness varies).

2. Provide each group with copies of the chart Six Classes of Roundness. Glue the chart to an index card and laminate it for repeated use in the classroom or in the field.
3. Discuss why three groups of each sand sample are used. Make sure the students know how to determine percentage and average.
4. Ask the students if their samples are primarily angular or rounded. Discuss how they could determine what degree of roundness is found in their samples. Stress the importance of using quantitative measurements in place of qualitative. Ask the students to create a title for their data table. Point out that the title needs to cite the variables about which data is collected.
5. Begin Part II by asking the students what sorting is. Discuss how particles are sorted. Provide the students with copies of the Sorting Chart. If the chart is placed on an index card and laminated, it can be used repeatedly both in class and in the field.
6. Have the students compare their samples to the Sorting Chart and record their data. Ask the students what inferences they can make about the samples.
7. In Part III, ask the students why the samples have particles of different sizes. (Harder minerals weather more slowly so the particle size will be larger.) Have the students determine the size of particles in their samples using the Sand Size Chart. Have the students record their findings in the table and label the table.
8. Discuss the relationship between particle size and the duration of erosion and weathering. (The longer the particles are exposed to the erosion process, the more rounded and smaller the particles.) The harder the rocks or minerals which formed the sand, the larger and the more angular the particles will be. Ask if it is possible that some of the minerals or particles have disappeared. (Softer minerals such as mica, which is found in granite, are so soft that often no mica particles are found because the particles have been broken down.) Discuss what inferences they can make about their sand based on the particle size.
9. Before beginning Part IV, stress keeping the sand in the bag and using the magnet on the outside of the bag so that if iron particles are present they will not collect on the magnet. Also it is easier to see if particles collect on the inside of the bag next to the magnet. Explain that sand that has formed from the erosion of iron ore may have particles that are like iron filings and will be attracted to a magnet.
10. Discuss what the students have learned about their sand samples and what inferences they can make. The students should make inferences about the source and history of the sand grains in the sample based on the size, shape and sorting of the particles.
11. For Part V, have the teams summarize their findings in a table. The students could use the information to participate in a descriptive writing activity about the samples or to write a story about the history of the sand sample.
12. Provide the students with unlabeled samples and ask them to determine whether or not it is one of the known samples. If it is a known sample, have them indicate which one.
13. Create sand samples for the mystery. Samples W, X, Z should be similar and should be sand from a river or inland area. Sample Y should be sand from a beach, which would have very small shell fragments. You can have each team collect sand samples and create their own mystery. In class, the teams can exchange sand samples and the mystery to solve. They will need to provide data to support their solutions.

Activity 3: Is the mass of sand and sediment samples the same?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.7, 6.14 7.14, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- predict whether the same volumes of sand will have the same mass
- measure the mass and volume of sand and sediment samples
- conduct an investigation to determine the relationship between the particle size and mass of sand samples

Background:

1. Ask the students to predict whether the samples will have the same mass or different masses and why? Would equal amounts of gravel and sand have the same mass? Any type of balance may be

used to determine the mass of the samples.

2. Stress that mass is the quantity (how much) of matter in an object. Volume is the space that the matter or the sand occupies. The mass of the samples will not be the same even though the volume will be the same. The size of the particles affects the mass. Evenly sorted coarse sand may have more pore space filled with air and therefore have less mass. In some coarse sands, the pore spaces may be partially filled with smaller particles, producing sand that has a greater mass. A sediment sample of very fine particles may have the greatest mass.
3. Discuss density (mass/volume). Density is the mass of matter in a given space or volume. Ask the students if there is a relationship between the porosity and density and how they could construct an investigation to determine the relationship. Ask the students to explain their reasoning. Stress that an important property of matter, whether it is in the solid, liquid, or gaseous phase, is the measure of density or compactness. Samples of very fine particles are denser than samples of coarse particles. Ask students to suggest ways in which they could measure the density. Have the students measure the density of their samples and determine the relationship between particle size and density.
4. Before conducting the investigation, have the students formulate hypotheses describing the relationship between density and the water holding capacity of sand and sediments. Then have them make predictions about the water holding capacity of the samples. In planning the experiment, stress identifying the variables and determining which ones will be controlled and how to control them.
5. Discuss the results and the relationship between porosity and the water holding capacity of different soils. Discuss the use of this information by farmers, contractors, builders and engineers. Ask students why this information is important.

Activity 4: What affects the settling of sediments?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 7.5, 8.6, 6.7, 8.10, 7.14, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- make predictions about the settling rate of sediment particles
- measure the settling rate of sediment particles
- design and conduct experiments to investigate factors affecting the deposition of sediments
- summarize how geologists use this information to explain what happened in the past

Background:

1. Show the students containers of different types of sediments (sand, clay, silt, gravel) and different size particles. Explain that the different types of sediments are deposited in separate areas. In most cases they are not mixed together. Ask each team to formulate hypotheses to explain this.
2. To focus on inquiry, have each team design and conduct experiments to test their hypotheses. (1- or 2-liter plastic soda bottles can be used.) After they have conducted their investigations, discuss the variables and how they were controlled in their investigations. Have the students analyze their data and assess their hypotheses. Compare the investigation in Part I to their investigations here to determine if one is more effective than the other.
3. Have the teams design and conduct an experiment to determine the effects of the rate of water movement on the settling of particles. Identify the controlled variables. Ask each team to share their findings and explain the relationship of the speed of water movement to the deposition of the sediments. The larger particles settle faster if the density is similar. More dense particles settle faster if they are the same size. Faster moving water has more particles suspended in it than slower moving water. Larger particles (gravel) settle first as the water slows and the finest particles (silt) may only settle to the bottom when the water is still. Faster water slows the settling process. Particles settle fastest in nonmoving water.
4. Have the teams use what they learned to make inferences about past environments using sediments found in an area today.

Activity 5: What can we learn from sediment layers?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5, 6.5, 7.5, 6.7, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.6, 7.9, 6.22, 7.21, 8.30, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- construct a model of sediment layers

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- interpret the data from sediment layers and explain the type of environment in which each layer was deposited

Background:

1. Provide each team with materials and ask them to create a series of sediment layers and an explanation of the conditions under which they would have been deposited. Create the model in a container so that the layers can only be viewed from the top.
2. Each team will exchange models with another team to analyze and infer how the layers were deposited and under what conditions. Each team will use straws (jumbo straws work best) to extract core samples to use in making its inferences about the environment under which the deposition occurred and the history of the core sample. Use the questions (9-12) to discuss and compare the samples to the real sediment layers and the processes that occurred.

Activity 6: How much space is there between sand and sediment particles?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.6, 6.7, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3, 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- conduct an investigation to determine the pore space in sand or sediments
- measure the particle size, density and porosity of samples
- formulate and test a hypothesis describing the relationship between particle size, density and porosity

Background:

1. Ask the students which is more dense: gravel, sand or mud. Have the students predict which sample has the greater amount of space or pores between the particles. Rank the samples in order from the most pore space to the least based on their observations. Ask the students to predict which sample is the most dense and which is the least dense. Based on their observations and data, the students should conclude that less pore space corresponds to a more dense sample. Have the students prepare a statement relating density, particle size and porosity.
2. Have the students conduct the investigation to gather quantitative data to verify their predictions. One point of this activity is to show that there are pores between sand and sediment particles. Sometimes the pores are large and easy to see and sometimes the pores are not obvious until you fill them with water. The porosity, the ratio of open pore space to the total volume of a sample, is an important property in water movement and water-holding capacity. The more pore space it has, the more water the soil can hold.
3. Using the information from previous activities, have the students determine the relationship of particle size and density to porosity.
4. Ask the students how pore space can be important to organisms. The pore space can provide a place for organisms to live as well as providing water for organisms. If pore space is filled with air, it can provide oxygen for organisms. Pore space enables the roots of plants and organisms in the soil to get oxygen and water. Soils must be loose to increase porosity in order to increase plant growth. If soils have a low porosity, water does not readily enter the soil and the possibility of flooding increases, as well as erosion.

Activity 7: How can a model be used to demonstrate porosity in sand and sediments?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5, 6.6, 6.7, 8.10, 8.14, 8.12, 7.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3, 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.6, 7.9, 6.7, 7.10, 6.20, 7.20, 8.29, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- construct a model to illustrate differences in porosity
- design and conduct an experiment to compare pore space

Background:

1. Provide students with the materials and ask them to design a model to demonstrate porosity in sand and sediments. After they have developed their design, they are to conduct their investigation and determine the percentages of pore space. Have them compare their model to sand and sediments.
2. Have the students hypothesize about the effects of filling the pores between the marbles with sand rather than water. Then design and conduct an investigation to test their hypotheses.
3. Use information from "How much space is there between sand and sediment particles?' to determine the percentages.

4. Have the students hypothesize about what will happen if large amounts of water are pumped out of the pore spaces. Discuss how this can result in land subsidence or sinking. When water or air is removed from the pore spaces, the sediments do not require as much space and become more compact or compressed so that at the surface they appear to be sinking.

Activity 8: How fast does water move through sand, soil, or sediments?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.6, 6.7, 6.14, 7.14, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3, 6.8, 7.9, 8.8, 6.11, 7.13, 8.14

Language Arts: 6.9, 7.9, 8.9, 6.20, 7.20, 8.20

Social Studies: 6.23, 7.23, 8.32, 6.22, 7.21, 8.30, 6.20, 7.20, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- formulate and test a hypothesis describing the relationship between permeability and porosity
- conduct an investigation to determine permeability
- relate the permeability of sediments to the location of aquifers
- relate soil permeability to the placement of landfills

Background:

1. Ask the students to predict which sample will absorb water the fastest and to explain the basis for their prediction. Discuss how they could quantitatively determine in which sample the water is absorbed or infiltrates more rapidly. How would they control the variables? Then conduct the investigation to determine the relationship of particle size, porosity and permeability flow rate.
2. Stress that the composition of the sample is one factor that affects the rate at which water is absorbed. Sand, soil or sediments vary in composition, from being loosely packed to being brick-hard. Loose sand may absorb water at the rate of 10 cm per minute while baked soil may require several hours to absorb 10 cm. The quantity of water that can be stored depends on the porosity of the sample (the percentage of the total volume of rock or sediment that consists of pore spaces). Sand or sediments may be very porous and still not allow water to move through them. The permeability of a material indicates its ability to transmit water through the interconnected pore spaces. The smaller the pore spaces, the slower the ground water moves. If spaces between the particles are too small, the molecules of water will bind to the particles and the water will be held in place. Clay provides an example of this. Although the ability of clay to store water is often high, its pore spaces are so small that water is unable to move though it. So we say that clay is impermeable.
3. Point out to the students that, on the other hand, samples with larger particles (such as gravel) can have larger pore spaces. Water can move through the large pore spaces with relative ease. They transmit groundwater freely and are referred to as aquifers or "water carriers." Sand that was deposited and buried in the past can be a water-bearing layer today that well-drillers seek. A good aquifer can provide water for many wells, homes, cities, irrigation and industries.
4. Ask the students to explain the need for placing landfills in impermeable soils. Include a discussion of the potential problems if the landfills or waste disposal sites are located in permeable soils. As water moves through a landfill, materials will be dissolved or suspended in the water. If the materials are hazardous, they can be carried into streams, rivers and even the Gulf.

Activity 9: How much water can different sand, soil and sediments absorb and hold?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 7.5, 6.7, 7.14, 8.14

Math: 6.3, 7.2, 8.2, 6.4, 7.3, 6.8, 7.9, 8.8, 6.11, 7.13, 8.14

Language Arts: 6.9, 7.9, 8.9, 6.10, 7.10, 8.10, 6.20, 7.20, 8.20

Social Studies: 6.6, 7.9, 6.7, 7.10, 6.22, 7.21, 8.20, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- conduct an experiment to measure the water-holding capacity of soil
- identify the variables that affect the water absorption rate of soils
- relate the water-holding capacity of soils to the location of solid waste sites, flooding and erosion, and crop production

Background:

1. The sand and sediment samples used in this activity should be dry. Have the students predict which sample will hold the most water and present their explanation. Both the size of the particles and the amount of organic material in the sample affect its water-holding capacity.
2. Discuss how the water-holding capacity of a

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sample makes a big difference in the intake of water. If sand or sediments absorb most of the rain, it means that there will be less erosion. Any water that is not absorbed will remain standing on top (if the land is not sloping) or will run off if there is a slope. This results in flooding and erosion. The more moisture that enters the sand, sediments or soil, the more productive the area will be since soil high in water-holding capacity provides more moisture for plant growth. Stress to the students that if their samples were soil, the water that passed through the soil would not drip out into a beaker—it would continue sinking deeper into the subsoil toward the water table where it would recharge the groundwater supplies.

Activity 10: How does the gulf coastal aquifer work?

TEKS: Science: 6.5, 7.5, 6.6, 6.14, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20

Social Studies: 7.7, 6.1, 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- relate porosity and permeability as factors in determining aquifers
- construct a model to demonstrate how an aquifer works
- make inferences as to the conditions for the formation of the Gulf Coastal and Carrizo-Wilcox aquifers
- use the model to explain how subsidence or salt water encroachment could occur

Background:

1. Have each team construct a model of an aquifer and demonstrate how it works, with emphasis on porosity and permeability. Discuss the idea that formations that allow for a faster rate of water movement could produce problems because a faster rate of movement allows less time for the water to be purified in an aquifer before it is pumped to the surface. When the aquifer is composed of sand or permeable sandstone, water can sometimes be purified after traveling through it for great distances. There is a balance as the openings between the sand grains are large enough to permit water movement, yet the movement of water is slow enough to allow plenty of time for its purification.
2. Have the students locate the Gulf Coast Aquifer on the map. What type of materials was deposited to form this aquifer? Have them use the properties of sand and sediments to support their explanation. The Gulf Coast Aquifer covers all or parts of the 53 counties along the Gulf Coast, from the Sabine River to the Rio Grande. It was formed by deposition during the late Cenozoic period. These clay, silt, sand and gravel deposits are both fluvial and deltaic and formed in shallow marine conditions. These deposits are the source of fresh water for the coastal zone.
3. Ask the students to hypothesize about why excessive pumping from this aquifer is causing land-surface subsidence and allowing subsurface encroachment of salt water from beneath the Gulf of Mexico. Discuss how the removal of water results in sediment compaction that can result in land-surface subsidence. As water is pumped out, the salt water located in the pores of nearby sands and sediments will move into the spaces that were emptied as water was removed.
4. Have the students locate the Carrizo-Wilcox Aquifer, one of the most extensive in Texas. It supplies water in a 61-county area that extends from Arkansas and Louisiana to the Rio Grande River. Ask the students to hypothesize as to the type of sediments present and how and when they might have been deposited. These formations were deposited in very early Cenozoic time (Eocene) from large rivers forming deltas in this area. At that time this areas was the Texas coast. This aquifer is recharged directly by precipitation and from streams crossing the outcrop area today.
5. Ask each team to use their aquifer model to explain how this aquifer works and how it was formed. Discuss the role of the past coastlines in the development of the Carrizo- Wilcox aquifer and the Gulf Coast aquifer.

Activity 11: How does groundwater become contaminated in the coastal zone?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 7.5, 8.5, 7.14, 8.14

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10, 6.6, 7.9, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- construct a model of an aquifer to demonstrate how contamination can occur
- formulate ways to prevent aquifer contamination

Background:

1. Refer the students to the location of the Carrizo-Wilcox and Gulf Coast aquifers and ask them to predict what would happen if pollutants entered

the aquifer at one point. Ask the students to use their aquifer model to demonstrate the entering of contaminants into the aquifer.

2. Discuss the impact on the state if these two major aquifers of the coastal zone became contaminated. Ask the students to propose ways to prevent this, especially in areas where there are large numbers of abandoned oil wells. Discuss requiring all companies to properly close wells when they are abandoned.

Activity 12: What is the relationship of the properties of sand, soil, sediments, and groundwater contamination?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 7.5, 8.5, 6.8, 6.7, 7.14, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.7, 7.10, 6.22, 7.21, 8.30, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- formulate hypotheses describing the relationship of properties of sand and sediments to groundwater contamination
- conduct an experiment to investigate the relationship of soils and sediments to groundwater contamination

Background:

1. Discuss how water that enters the ground reaches the aquifer. Have the students brainstorm about what substances could enter the ground and cause contamination and the sources of these contaminates. Ask the students to hypothesize about which properties of sediments would increase the potential for contamination.
2. Point out that in coastal zone aquifers there is a saltwater zone under the freshwater deposits. Excessive removal of water lowers the water table. As the bottom of the freshwater zone rises, the saltwater will also move up, thus contaminating the freshwater supply. Deep wells and wells near the shore are usually the first to be affected by this.
3. Have the students work in teams to propose ways to correct and prevent future contamination of groundwater in the coastal zone. If the school is in this region, encourage the students to learn what is being done, then extend their research and develop a plan to present to local, regional or state agencies and legislative and governing bodies.

Activity 13: What are some sand and sediment problems in the coastal zone?

TEKS: Science: 6.5, 7.5, 6.7, 7.14, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.20, 7.20, 8.20

Social Studies: 6.22, 7.21, 8.30, 6.23, 7.23, 8.32, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- relate properties of sand and sediments to problems in the coastal zone
- propose action that can be taken to prevent problems

Background:

1. Have each team discuss the scenarios of coastal problems and use their knowledge of the properties of sand and sediments to explain the causes of each. They should also propose solutions to the problem. Have each team present its analysis.
2. The problem with the soil on Galveston Island and other coastal areas is that it does not drain well. In areas where the sediments are heavy clays, they do not drain well and remain saturated with water for long periods of time. The clays are more porous and have a greater water holding-capacity than sand, but the pore spaces are so small that these soils have a low permeability. Because little water can infiltrate to lower levels, the upper layers can easily become too waterlogged for most crops. Water will remain on top, resulting in flooding. The clays are also sticky when wet, which creates additional problems for farming or development. This creates land use problems like those of Camp Wallace.
3. Discuss the problem of flooding in the coastal zone due to slow filtration rates and the lack of a large slope. Point out that the sediments found in the wetlands, estuaries and bays have a slow infiltration rate. Ask the students to discuss what problems this could present if they are drained and developed or if there are large amounts of rain from tropical depressions or hurricanes moving inland in this area. Soils with a slow filtration rate will have water remaining on top, resulting in the soils becoming waterlogged and flooding. The water will not drain off due to the gentle slope. As the soils become waterlogged, crops and organisms in the soil will die since the pore spaces will be filled with water and air will not be available for organisms or plant roots.
4. Point out that the natural process of compaction of layers of sediments has been occurring for

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many millions of years. However, a significant part of the northern coast of the Gulf of Mexico has been subsiding because of the withdrawal of large volumes of fluid through various human activities. More than 100,000 wells have removed huge amounts of oil and natural gas from the Mississippi delta and the nearby coastal zone of the Gulf of Mexico. This is also occurring along other areas of the Gulf Coast. Large quantities of water have been withdrawn for domestic and industrial use. As a result, some of the land near Galveston has sunk nearly 2 meters in this century. Point out that to lessen the threat of subsidence, water is now being pumped into the ground rather than out of the ground.

5. Discuss the fact that regional subsidence in parts of the coastal zone in east Texas and in the Mississippi River delta in Louisiana is causing the sea level to rise 9 to 10 mm per year because the land itself is sinking. Point out that this rate of sea level rise in these areas is the highest in the United States and approximately three times higher than the global average. About 6 to 7 mm of this annual rise is due to subsidence caused by a combination of compaction of delta sediments and the withdrawal of fluids from the coastal zone. In the lower Mississippi River delta, huge amounts of fine sediments (as much as 1.6 million metric tons per day) reach the mouth of the river. These sediments trap water as they settle to the bottom. The resulting mud may be up to 90 percent water by volume in this delta region. The weight of all this mud will compress the sediments below and eventually squeeze out the water, just as one squeezes the water out of a sponge. As the water leaves, the land surface sinks. This leads to a rise in sea level. The subsidence of the Mississippi River delta and other delta areas has been increasing during the past decades. This is a result of the many dams and other controls that people have placed on the rivers. The dams and other controls have slowed and reduced the amount of new sediments coming in while the old sediments are being compacted.

Activity 14: How do soils affect the waste disposal on the Texas coast?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.5, 7.5, 8.5, 6.7, 7.14, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.7, 7.10, 6.22, 7.21, 8.30, 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- predict the suitability of soils for waste disposal
- construct a model to determine which soil types are best for waste disposal sites

Background:

1. Provide each team with different soil types to examine and ask them to predict which are most suitable for waste disposal sites.
2. After they have completed their predictions, have the students prepare a model of a waste disposal site to test their predictions. Ask each team to determine the relationship of soil permeability, porosity, and water-holding capacity for effective waste disposal. Have each team develop the criteria for soils in which waste disposal sites should be located to decrease the leakage of wastes into the surrounding soil and water.

Activity 15: How safe are the solid waste disposal sites in the Texas coastal zone?

TEKS: Science: 6.2,7.2, 8.2, 6.3, 7.3, 8.3, 6.14., 7.14, 8.14

Math: 6.8, 7.9. 8.8, 6.11, 7.11,7.13, 8.14

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20. 8.20

Social Studies: 6.7, 7.10, 6.20, 7.20, 8.29, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- interpret data concerning the location of waste storage sites in the coastal region
- infer the reasons for the locations of the waste storage sites
- recommend policies for placement of waste storage sites

Background:

1. Now, as in the past, industrial facilities are usually located with little, if any, consideration for the impact on people and the environment even though these facilities usually produce hazardous wastes. In the past, some of the problems were due to lack of knowledge about the serious health hazards that could result. Today the health hazards are known and information about the soils and coastal environments is available, so there is no reason for these problems to continue. The technology of waste storage has also changed. Data are available so that placing waste disposal sites in unsafe areas can be avoided. In the past, toxic industrial wastes were sometimes placed in municipal landfills. In other cases, they were stored indefinitely on a side lot by the plant. As more wastes were added, accidental leakage occurred and environmental risks increased. These existing waste storage sites are a problem.

Unless they are cleaned up, they will release toxic materials. Not only do landfills leak down and up, chemicals in them also mix and form new toxic materials. Discuss the characteristics of poor and good waste disposal sites.

2. Divide the students into teams, and assign each team an area of the Texas coastal zone. Tell each team that they are to evaluate the location of existing solid waste disposal sites. This includes determining if they are located in wetlands or within a mile of water and the permeability of the soil. Discuss how each of these factors impacts the quality of the site for waste disposal.
3. Each team will present its results to the class and mark the location of the unsafe waste disposal sites. Each team's results will be compiled to prepare a report on the safety of the waste disposal sites of the Texas coastal zone. Note the location of the sites in relation to cities and waterways. Discuss the problems that can occur. Discuss what policies the students would recommend for the placement of waste disposal sites.
4. As an extension, obtain soil maps of your city or county. The local United States Department of Agriculture Natural Resources Conservation Service Office is a resource for information on local soils. It is listed in the telephone book under U.S. Government, Department of Agriculture or visit the website (http://www.nrcs.usda.gov) or contact the Soil Science Society of America (http://www.soils.org). Contact the local governmental offices for information on the location of waste disposal sites. Evaluate the location of solid waste disposal sites to determine the type of soil in which they are located. Also examine the location to determine if it is in a wetland and its proximity to water (marshes, creeks, streams, lakes, etc.). Prepare a report on the safety of the sites.

Activity 16: Is there danger on the Texas coast?

TEKS: Science: 8.14, 7.14, 7.11

Math: 6.4, 7.3, 8.5

Language Arts: 6.10, 7.10, 8.10, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- interpret data concerning chemical-producing counties and health problems
- formulate and evaluate hypotheses describing the relationship of chemical production and health problems
- graph data on health problems

Background:

1. After completing Activities 14 and 15, discuss how students might conduct an investigation to determine if there are possible health problems.
2. Provide each team with Figures 1 and 2. Ask what patterns the team observes and for students' interpretations of the data. Point out that Texas has 1,500 chemical-producing plants and one-third of these are located in four coastal counties. Ask each team for possible hypotheses concerning the relationship of the plants and the health problems of these counties. Discuss the data they would need to test their hypotheses.
3. Provide the teams with Table 1 to examine and use to evaluate their hypotheses. Discuss their findings. Provide each team with Tables 2-4 to construct bar graphs of the data.
4. Ask each team to interpret the data in their graphs, note the patterns and summarize their interpretations for the class. Discuss the differences in data between Tables 3 and 4. Point out that data will vary from year to year, but the pattern is important. Is the pattern from year to year similar? Discuss the differences between the coastal counties and the state death rate average. The cancer death rate is higher for the coastal counties, particularly those with chemical plants. The male death rate is greater than that of females. More males than females were employed by the refineries and chemical plants. Discuss the idea that smoking is a factor and that more males smoke than females. Discuss the implications for coastal residence based on the data. Contact the Texas Department of Health or the Texas Cancer Registry for more recent data.

Activity 17: What is the impact of building high-rise centers in the coastal zone?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5, 6.6, 6.7, 7.14, 8.14

Math: 6.4, 7.3, 8.5, 6.8, 7.9, 8.8

Language Arts: 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.23, 7.23, 8.32, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- design and construct experiments to investigate the effect of building cities on unstable sediments of the coastal zone
- communicate the results of experiments to the class

Background:

1. Stress that the practice of building high-rise centers on unstable sediments has caused settling

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in parts of inland port cities such as Houston and New Orleans. New Orleans is now below sea level. Dikes and levees have been constructed to keep seawater out. Could the buildings in the area be a cause? This could be a major problem in the future. Ask the students for their hypotheses. Discuss the data needed to test their hypotheses.

2. Tell the students that their team of scientists has been contracted to conduct an investigation to provide information that can be used to determine the future development of cities along the coastal zone. Discuss the following questions. Should high-rise buildings be allowed? How many buildings can be safely built in an area? Should there be regulations on building in the coastal zone? Should the buildings be designed in a specific way to avoid compacting the sediments? Or can buildings be designed to prevent compacting the sediments on which they are built?
3. Tell each team that they are to plan an investigation to determine the impact of building high-rises of stone, concrete and steel on the coastal sediments. Have the students use the Investigation Forms to plan their investigations.
4. When the students have completed the designs of their investigations, have the students conduct their investigations. After the students have completed their investigations, ask each group to analyze its investigation to determine what can be improved upon and what was done well. The students may revise their investigative plans and redo their investigation. Stress that scientists always revise and repeat their investigations.
5. Conferences are held to bring together scientists to discuss what is known about a problem. Each shares what they have learned about the problem. Hold a conference on The Impact of High-Rise Construction on Coastal Zone Sediments. Each team should be given 4 minutes to present its findings. Encourage the students to use charts, graphs, drawings, etc. to present their findings. After the conference, each team should meet and discuss the findings of the other teams. They should then determine what they would investigate next or how to redesign their investigations. Each team could make recommendations about construction in the coastal zone.

Activity 18: What is the relation of the Texas coastal zone problems and the sediments?

TEKS: Science: 7.14, 8.14,

Math: none

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.7, 7.10, 6.20, 7.20, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- interpret data on the physical properties of sand and sediments and relate it to problems and issues (flooding, subsidence, saltwater intrusion, groundwater contamination, etc.) in the coastal zone
- summarize the effects of soils and sediments on environment problems in the coastal zone
- analyze the coastal soil and sediment problems and prepare an informative article
- prepare a brochure informing the public of problems, causes, possible solutions, and regulations related to soil and sediment related environmental problems

Background:

1. As closure to this topic, have the students review their data to summarize the relationships of the properties of the sand and sediments. The students can apply what they learned about the properties of sand and sediments by creating a chart that lists in the left hand column all of the problems or issues or water resources associated with the sand and sediments deposited in the coastal zone. In the right column, have the students list the properties of the sand and sediments that are related to the problem or resource.
2. Each student will select a problem to research in greater detail in preparation for writing an informative article. Encourage the students to contact state agencies for additional information and to use the internet. If your school is located in the coastal zone, encourage the students to also conduct interviews. Stress that they will need to present all sides of the issue and that their article should be based on facts not opinions. Check with the local newspaper to see if they will print the best articles.
3. Each team can use its members' articles as a resource to prepare a brochure for dissemination to citizens. It should be an informative presentation about the problems associated with the coastal zone deposits and what can be done to prevent these problems. Encourage the students to use computer software to create a brochure on 8 1/2 x 11 paper.
4. Discuss what guidelines or regulations are needed to prevent these problems in the coastal zone. Have the students conduct research to learn what regulations currently exist and what agencies are responsible. Suggest that they see if the Clean Water Act regulations include the problems they have studied. Two state agencies dealing with

these issues are the Texas Commission on Environmental Quality (website: http://www.TCEQ.texas.gov/), P. O. Box 13087, Austin, Texas 78711-3087 and the Texas General Land Office, Coastal Division, (website: http://www.glo.state.tx.us), 1700 N. Congress Ave., Austin, Texas 78701-1495. Encourage the students to use the internet to obtain information from these and other agencies. If you are located in the Texas coastal zone, encourage the students to locate regional and local agencies that relate to these issues.

Other Resources:

Goldsteen, Joel B. **Danger All Around: Waste Storage Crisis on the Texas and Louisiana Gulf Coast**. (1993) The University of Texas Press, Austin.

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1. What Can We Learn About Mystery Sand Samples by Using Our Senses?

Scientist(s) _____ **Team** _____

Today you will be studying sand like scientists do. You will use your observation skills to observe the properties of sand and identify it. Not all sand is alike. Not all sandy beaches are the same. You will observe the sand using your senses of sight, touch, smell and hearing. You will also learn more about the properties of each type of sand help you identify the samples.

Materials: ziplock (snack size) bags of sand samples for each group, hand lens, microscopes and slides (if available), 35mm plastic film canisters, index cards.

Procedure:

Part I: What Can You Learn about Sand by Using Your Sense of Sight?

1. Construct a table with the headings shown below. Describe each sample in this table, so that you or someone else can use your description to identify it. Make a sketch of each sample.

2. Use a hand lens to observe the samples and add to your descriptions. If a microscope is available, place some sand on a microscope slide (do not use a cover slip) and observe under low power. Describe and sketch your observations of the sand under the microscope. Record your descriptions and sketches in your table.

3. How are the samples alike? How do they differ? Complete the chart to answer these questions.

Similarities	Differences

4. On a separate sheet of paper, write a paragraph comparing your observations of the sand samples.

5. Can you tell the difference in the samples by using sight only?

6. How did the observations using your sight differ from those using tools?

7. What is the effect of using tools (hand lenses, microscope) to make observations?

Part II. What Can You Learn about Sand Using Your Sense of Touch?

1. Place a pinch of the sand sample on a piece of paper. Place your finger on it. How does it feel? **Texture** is the way materials feel. Take a pinch of the sand sample between your thumb and finger. Rub it between your finger and thumb. Construct a table similar to the follow exampe and record your observations.

Table 1: Observations of Sand Samples Using Sight

Sample Number	Description of Sight: Using Eyes Only	Sketch: Using Eyes Only	Description of Sight: Using hand lens	Sketch: Using hand lens	Description of Sight: Using microscope	Sketch:Using microscope
1						
2						
3						
4						

2. Can you tell the differences in the sand samples by touch? Which words are best for describing the sand samples' texture? Explain why you chose those words.

3. How does the size of the particles affect the texture?

4. Can you identify the samples by using only your sense of touch?

Part III. What Can You Learn about Sand Using Your Sense of Smell?

1. To smell the sample, use your hand to move the air from above the sample to your nose. **DO NOT** put your nose to the sample and inhale. Construct a table similar to the one below and escribe how each sample smells.

2. Can you tell the differences between the samples by smell?

3. If the samples have different odors, what do you think are possible causes?

Table 2: Observations of Sand Using Senses of Touch, Smell and Sound

Sample Number	Touch	Smell	Sound
1			
2			
3			
4			

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Part IV. What Can You Learn about Sand Using Your Sense of Hearing?

1. Listen as you pour a small amount of each sample on a tray or piece of paper. Do they sound the same?

2. Put a teaspoon of the sand in a plastic 35mm film canister. Move and shake it. Record your observations in Table 2. Do the samples sound the same? Explain.

3. Why do you think the samples might sound different?

2. What Can the Shape, Sorting and Size Tell Us About Our Mystery Sand?

Scientist(s) _____ **Team** _____

As you use your senses to observe each sand sample remember that observations are facts learned directly through your senses. Observations are not interpretations or explanations of what you observed. Once you have made your observations then you can use them to make inferences about the sand samples. An **inference** is an interpretation or explanation based on what you already know and your observations. You will observe the shape, size and how well the mystery sand samples are sorted to identify the samples.

Materials: snack size plastic bags of sand samples for each group, hand lens, small pieces of black and white paper, small magnet, "Charts of Roundness, Sorting and Size".

Procedure:

Part I: What Does the Shape of Sand Grains Tell You?

1. How can you determine if a grain of sand is round or angular?

2. Determine the roundness of the sand particles in your samples by comparing them with those in Figure 2.1, Six Classes of Roundness. Randomly separate part of the sample into three groups of ten grains. Use a hand lens. Construct a Data Table 1 similar to the example and record the number of each type of grain for sample A.

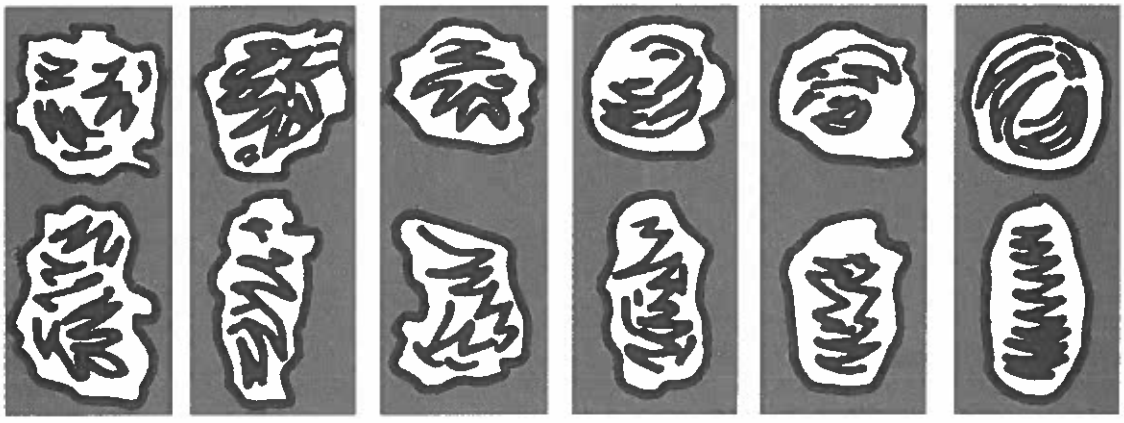


Fig. 2.1. Six Classes of Roundness

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Data Table 1: Roundness of Sand Samples

	Very Angular		Angular		Sub-angular		Sub-rounded		Well-rounded	
	No.	%	No.	%	No.	%	No.	%	No.	%
Sample A Group #1										
Group#2										
Group#3										
Average % of each Type	N/a		N/a		N/a		N/a		N/a	
Sample B Group #1										
Group#2										
Group#3										
Average % of each Type	N/a		N/a		N/a		N/a		N/a	
Sample C Group #1										
Group#2										
Group#3										
Average % of each Type	N/a		N/a		N/a		N/a		N/a	

3. Repeat this for each of your samples. Determine the percentage of each type of grain in the sample. Round the percentage to the nearest whole number. Use this to determine the average of the types in each sand sample. What type of roundness is found in the largest percentage?

4. What is the percentage of each class of roundness in Sample A? Sample B? Sample C?

5. Are the averages the same for each sample?

6. What do you think causes the particles to be rounded? Write a sentence that explains why you think some samples are more rounded than others.

7. What do you think causes some grains to be more rounded than others?

8. If you had one sample in which 90 percent of the grains were very angular or angular, what conclusion could you reach about the sample?

Part II. What Can the Sorting of Particles in the Sand Sample Tell You?

1. **Sorting** refers to the range in sizes of particles in a sample. If a sample has big and little pieces it is not well sorted, but if all the particles were the same size it would be very well sorted. Sorting is due to the way sand particles settle. If settling occurs in quiet water the sample will be well sorted. If the conditions are turbulent or violent then the particles will not be well sorted. Sand dunes tend to be well sorted, meaning that the particles are uniform or similar in size.

2. Obtain four different samples to examine sorting. Spread a small amount of each sample on a piece of paper. Use the Sorting Chart (Figure 6.2) to classify the sorting of your samples. Examine your samples. Construct Table 2 and record the data. Write a title for the table. Summarize your data.

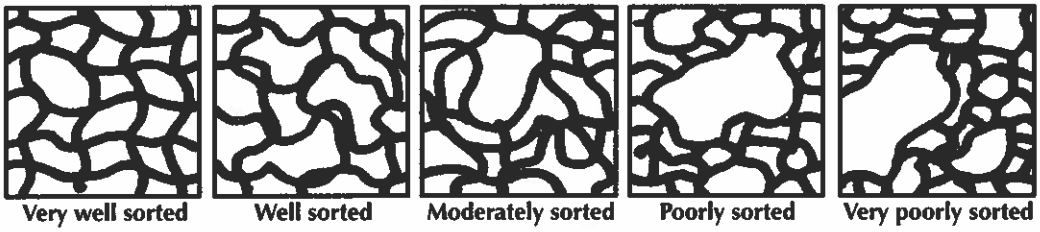


Fig. 2.2. Sorting Chart

Data Table 2: Title:_____

Sample	Type of Sorting
A	
B	
C	
D	

3. What does it mean to say a sample is a "well-sorted" sand?

4. If you had a sample that has some very-rounded particles and some that are not, what do you think happened?

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Part III. What Can the Size of the Sand Particles Tell You?

1. Use the Sand Size Chart (Figure 2.3) to determine and classify the size of the particles in the sand samples you used in Part II. The chart has two circles with dots that are the size that is noted along the side of the circle. There is a dark circle and a lighter one. Use the dark circle for light sands because they are seen better on darker backgrounds. Darker sands are seen better on the lighter backgrounds. Sprinkle a little of the sand sample you are measuring on the paper and find the size that the particles fit into. In many cases there will be a range of sizes. Construct a table similar to the example and record the size of your samples. List the range of particle sizes from smallest to largest particle in the first column of the table. Record the particle size that seems to appear more frequently in the sample.

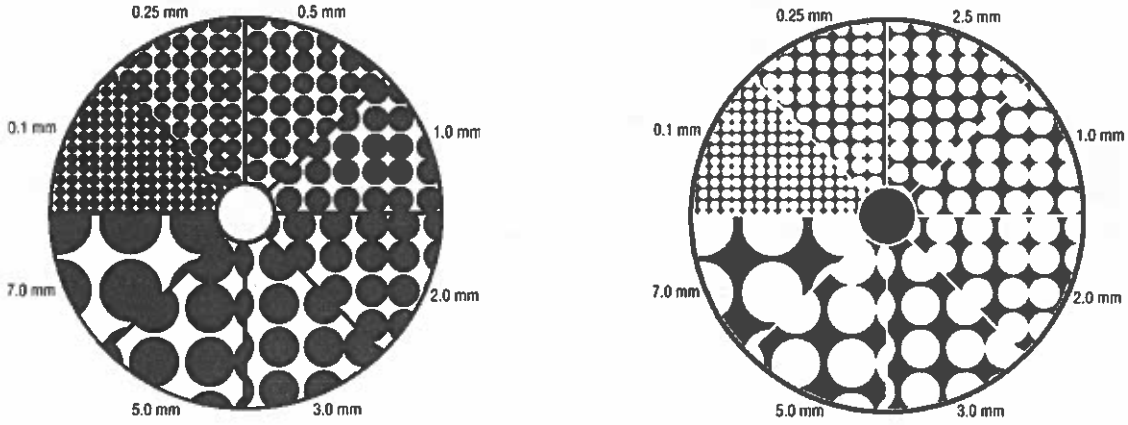


Fig. 2.3. Sand Size Charts

Table 3: Particle Size of Sand Samples

Sample	Range of Size	Most Frequent Size
A		
B		
C		
D		

2. Erosion breaks rocks into particles. What can size tell you about the length of erosion of the sand particles? Explain.

3. The hardness of a rock determines how it erodes. Harder rocks erode slower. What do you think is the relationship of the hardness of the rock from which the sand was formed and the particle sizes you found in your samples?

Part IV. Does Your Sand Contain Magnetic Particles?

1. Close your plastic bags containing the sand samples. Place a magnet on the outside of the plastic bag. Slowly move the magnet. If sample contains rock particles that are magnetic, you will see particles follow the movement of the magnet. Test each sample and record your results in a new table (Table 4).

2. Did any of the samples contain magnetic particles?

3. Explain why the sand might have magnetic particles.

Part V. Summary of Characteristics of Sand Samples

1. Summarize your findings from Parts 1, 2, 3 and 4 in a table constructed like the one below.

Table 4: Roundness, Sorting, Particle Size and Magnetic Particles of Sand Samples

Sample	Roundness	Sorting	Size	Magnetism
A				
B				
C				
D				

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2. Based on your observations, what do you think is the story or history of each of your samples? What happened to it along the way? Describe the sample and what inferences you can make based on your observations in Table 4. Construct another table and record these inferences.

Table 5: Description and Inferences About Sand Samples

Sample	Description Based on Table 4	Inferences Based on Descriptions
A		
B		
C		
D		

3. Obtain an unknown sand sample and determine which of your samples it is. Which sample is the unknown sample?

4. What evidence did you use to identify the unknown sample?

5. Select one of the samples for a story. Use your observations to tell the story or history of the sample, using the information in Tables 4 and 5. What can color, texture, smell, shape, roundness and sorting tell you about what has happened to the sample? Write your story on a separate page. Use illustrations to explain what happened.

6. Use your knowledge of sand to solve a mystery. A beach home was broken into. The vandals destroyed some furniture and left the home in a mess. It appeared that someone broke in and had a party. A couple of middle school students with sand on their shoes, backpacks and clothes are picked up by the police. The students said that they had been at the river and were not at the beach or the beach house. You believe the students and think you can prove that they were not at the beach. The police agree to let you try. They provide you with the following sand samples:

   Sample W – Sand taken from the students' shoes.
   Sample X - Sand taken from the students' backpacks.
   Sample Y – Sand taken from outside the beach house window where the intruders had entered the house.
   Sample Z – Sand taken from the sandbar on the river where the students said they had sat down.

7. Explain how you would use the samples provided by the police to prove whether or not the students were there.

8. What would you look for in the samples and what would you do to compare the samples?

9. Create a table (similar to Table 4) that can prove or disprove the students' innocence.

10. What were your findings? Were the students innocent? Explain.

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3. Is the Mass of Sand and Sediment Samples the Same?

Scientist(s):_____ **Team:**_____

Is all sand alike? Are all sediments alike? Do all samples have the same physical properties? How do the physical properties affect the use of the land? You and your team are going to be scientists and begin a series of investigations into the properties of sand and sediments to determine if you can use this information to answer coastal land use problems. The first property you will analyze is the mass of the samples. You will also determine what factors affect the mass of a sample. Does particle size make a difference?

Materials: two different sand and two different sediment samples, 100ml graduated cylinder, balance, small plastic cups

Procedure:

Part I: What is the mass of the samples?

1. Obtain your team's sand and sediment samples. Examine them. Will each sample have the same mass if the volume of each is the same? What do you think and why? Write your prediction and explanation below.

   Discuss the problem in your group. Is everyone's prediction the same?

2. Scientists do not always agree so they conduct investigations to determine what the answer is. How could you find out?

3. One way to find out if your prediction was correct is to conduct the investigation below.
   a. Observe the samples. Rank them in order of particle size, Number 1 being the smallest and 4 the largest. Construct a table similar to the following example and record the ranking.

Table 1: Mass of Sand Samples

	Sample 1	Sample 2	Sample 3	Sample 4
Particle size rank (#1 is smallest)				
Mass of graduated cylinder and 50 ml of sample				
Mass of empty graduated cylinder				
Mass of sample				

b. Use a balance to determine the mass of a graduated cylinder. Record the mass for each sample in the second row of the Table 1.
c. Add your dry sample of sand or sediment to the 50 ml mark. Determine the mass of the graduated cylinder and the sample. Record the mass for each in the first row of Table 1.
d. Subtract the mass of the graduated cylinder to determine the mass of 50 ml of sand or sediment. Record the mass in the third row of Table 1. (Save the samples for the next activity.)

4. Was your prediction correct? Is there a relationship between particle size and the mass of the sand or sediment sample? Record your conclusion.

Part II: What is the Density of the Samples?

Another important property of matter, whether in the solid, liquid, or gaseous phase is the measure of compactness: density. We think of density as the "lightness" or "heaviness" of material of the same size. Density is a measure of how much mass is squeezed into a given space.

1. Do you think all the sand and sediment samples have the same density? What is your prediction and why?

2. How can you find out if your prediction is correct?

3. You can find out if your prediction is correct by using the mass of each sample that you recorded in Table 2 to calculate its density. Remember density is the amount of matter per unit of volume, so density = $\frac{\text{mass (grams)}}{\text{volume (ml)}}$

   To calculate the density of your samples, you would use the following:

   $$\text{Density} = \frac{\text{mass of sand}}{50 \text{ ml}}$$

   Construct a table similar to the following example and record the density of each sample in Table 2.

Table 2: Mass and Density of Sand and Sediment Samples

Sample Number	Description of Sample	Mass of Sample	Density of Sample
1			
2			

Was your prediction correct?

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4. Is there a relationship between particle size of the sand and sediment samples and the density of the sample? Write your conclusions below.

5. Is there a relationship between the density of the sediments and the amount of water they can hold? What do you think? Explain.

6. Conduct an experiment to determine if your prediction is correct.
   a. Obtain a plastic soda or water bottle (12, 16 or 20 oz.).
   b. Cut the bottle with scissors to make a funnel and beaker.
   c. Invert the top into the bottom. Do not remove the cap.
   d. Pour the 50 ml of sand sample into the inverted top.
   e. Fill a graduated cylinder with 50 ml of water. Slowly add water until it no longer enters the sample.

7. How much water did each sample hold?
   a. Sample 1 _____
   b. Sample 2 _____
   c. Sample 3 _____
   d. Sample 4 _____

8. Was your prediction in number 5 correct? Explain.

9. What is the relationship between density of the sediments and the amount of water it can hold? Explain.

10. Why might this information be useful to farmers, etc.?

11. Who uses or can use this information?

12. Would the mass of sand or sediments affect the subsidence or sinking of land in the coastal zone? Explain.

4. What Affects the Settling of Sediments?

Scientist(s) _____ **Team** _____

Sediments come from all parts of Texas and also the Mississippi River drainage basin which covers 27 states in the central part of the United States. These sediments have formed the Texas Coastal Zone. It includes Montana on the northwest across the northern states to Pennsylvania and a portion New York state in the northeastern United States. What determines when and where sediment particles are dropped? What do you think?

Materials: sediment and sand samples of different size particles (organic and inorganic), 100ml graduated cylinder, stop watch or clock, water, stirring rod (pencil may be substituted), plastic soda bottles (12 oz or larger)

Procedure:

Part I: What determines when sediments settle?

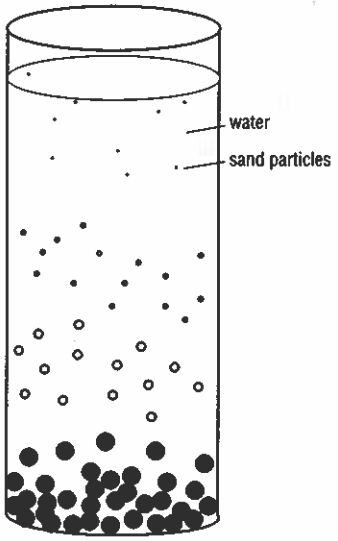
1. Your team is going to determine how the size of a particle affects the rate at which it sinks in water. Obtain samples of different size particles, including both inorganic and organic particles. Write your prediction for which particle will sink the fastest. The slowest? What is the reason for your prediction?

2. Construct a table similar to the example and record the size of each particle you are testing by drawing each particle to size.

Table1: Sediment Size and Time Particle Settles

Sample Number	Observation-Sketch (actual particle size)	SettlingTime (seconds)	SettlingTime in Moving WaterTime (seconds)

3. Fill a 100 ml graduated cylinder with water. Wet your finger. Put the particle on your finger. Use a stop watch or clock to determine the time it takes a particle sink. Then at "go" release the particle by touching your finger with the particle to the water's surface in the graduated cylinder. Record the time it takes the particle to sink in Table 1. Repeat this for each particle you are testing.



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Part II: What is the effect of water movement on the settling rate?

1. Your team is going to determine the effect of water movement on the settling rate. Write your prediction below:

2. Use particles that are the same size as the ones you used in Part I. Fill a 100ml graduated cylinder with water. Stir the water so that it is moving. Wet your finger. Put the particle on your finger. Use a stop watch or clock to determine the time it takes the particle to sink at "go." Release the particle by touching your finger with the particle to the water's surface in the graduate cylinder. As soon as the particle is released, stir the water again. Record the time it takes the particle to sink in Table 1. Repeat this for each particle you are testing.

3. Was your prediction correct?

4. Is there a difference between the effect of non-moving and moving water? Write a sentence summarizing your results.

5. Based on your results, how would the rate of sinking effect sediment size at the mouth of a river? Where would the smaller particles settle? Explain.

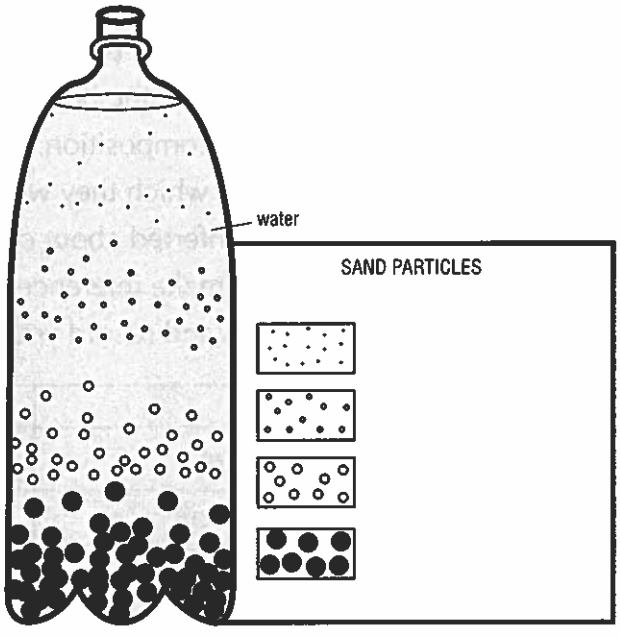
6. How do you think the surf settling rate would affect the sediments in the surf?

7. Explain the relationship between settling rates and the sediments deposited on a beach?

Part III: What type of sediments settle first?

1. How does settling occur? Examine several sand samples of different sizes, small gravel and silt. Which sample would you expect to settle first? Explain why?

2. Fill a plastic soda bottle (12 oz or larger) 2/3 full of water. Pour in several samples of different size particles, including various sizes of gravel, sand and silt until the bottle is almost full. Replace the cap and shake it vigorously.



3. Set the bottle aside and observe immediately. Repeat your observations after 10 minutes, 20 minutes, 30 minutes and 40 minutes. Divide a separate sheet of paper into four sections. Label each section with the time observed. In making each observation, hold an index card against the side of the bottle and draw a diagram showing the different layers. Also record your observations. Continue daily observations for the next four days on a separate sheet of paper, divided into four labeled sections to record your observations.

4. What happens as the movement of the water slows down?

5. Which particles settle to the bottom first? Explain why.

6. Which settled last? Explain why.

7. How does this activity represent what may be happening in the estuaries, bays and the Gulf of Mexico when rivers deposit sediment?

8. If a geologist only finds very fine mud and silt in the estuary, what inferences could he make about the following:
   a. Is the water moving fast or slow? Explain.
   b. Where would the heavier particles like coarse grained sand be found? Explain.

9. Summarize what you learned about particles settling or sinking in a sentence.

10. How could this information be used by geologists? a sand and gravel company? a construction company?

11. Sedimentary rocks form as layer upon layer of sediment builds up in various conditions. This would be like stacking all the bottles of sediment in the class. Each layer is unique. The layers vary in texture, composition, and thickness. These differences are a result of the different conditions under which they were deposited. As a geologist examines sedimentary rocks, much can be inferred about conditions that formed it. Use your knowledge of sediments and settling to make inferences about the environment in which each was formed. Construct a chart and record your inferences.

Rock Type	Environment during deposition
Conglomerate made of gravel	
Shale formed from mud and silt	
Sandstone formed from sand	

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5. What Can We Learn from Sediment Layers?

Scientist(s) _____ **Team** _____

All things in water, whether a particle of dust from the land, a decaying piece of marsh grass or a fish, eventually end up on the bottom of an estuary, bay or the Gulf of Mexico. Sediments collect like particles of "rain" falling down to the bottom. Sediment is predominately composed of sand and silt that has eroded from the land. If there are shallow seas, then salt and other minerals are deposited. Sometimes the sediments are mostly from the land that is being eroded and other times from dead marine animals, plants and minerals. Depending on where you collect you will find additional materials in the sediments. Beach sediments often contain broken shells (carbonates) while marsh sediments often have more decayed plant material. Each layer of sediment contains a story about the earth's history of that region. Over the last 200 million years, thick layers of more than 15,000 m (50,000 ft.) of sediment have been deposited in the Gulf. Each layer is different because of the kind of sediment washed down from the continent or formed by dead marine life. To learn about the past, scientists study the layers of deposits. The sediment layers provide the clues to the past. Scientists collect sediments by punching a pipe or corer into the sediments and pulling it up. Coring keeps sediments in the order in which they were deposited.

Your team of scientists is going to make a model of sediment layers and then examine the sediment layers in a core sample to make inferences about the history of the layers.

Materials: Different kinds of possible sediments (clay, sand, different types of soil, small gravel, ground up leaves/grass and shells, etc.), jumbo clear plastic straws or cork borers, index cards

Procedure:

1. Your team will create a model of sediment layers. Use the collection of possible sediments (clay, different types of soil, different size sands, small gravel, ground up shells, ground up leaves/grass, etc.) provided to create your model of sediment layers. Plan the order of layers you will create. Write an explanation of how the layers got there and the source of each layer. Draw a diagram of the layers.

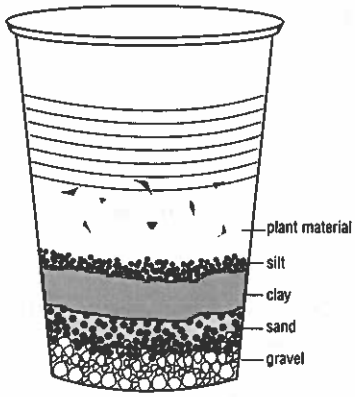
   Describe the kind of environments each layer will represent. For example:
   a. sand means deposited by wind in dunes or waves on a beach or by a steam
   b. gravel means steep slopes or very strong rivers or waves
   c. leaves means plants and animal remains were deposited in a swamp
   d. clay and silt means very slow-settling in quiet water of deep ocean, river flood plains, or lagoons.

   Construct Table 1 similar to the example and record this information.

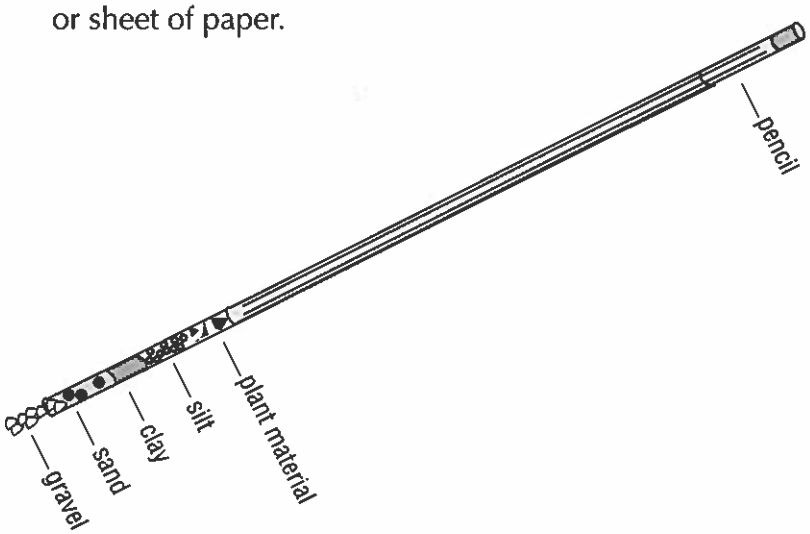
Table 1: Sediment Layers and Formation Environment

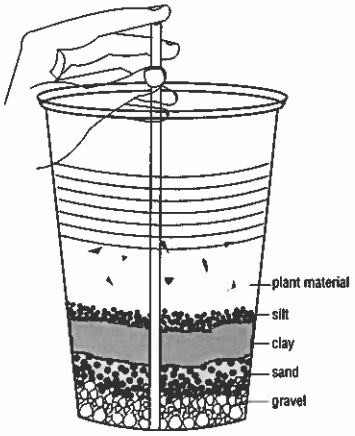
Layer	Sediment Make-up	Formation Environment
1		
2		
Bottom of cup		

2. Make a model of sediment layers you described and diagramed using the collection of materials provided. Place the materials in layers in a 9 oz clear plastic cup. Saturate the layers with water.



3. When you have completed your model, you will exchange models with another group as directed by your teacher. You will now act as scientists and core the model your group was given. Use a straw as a "corer." Push the corer into the container, hold the top tight with your fingers and pull the "core." Using a stirring rod or pencil, push the sediments out one end onto a creased index card or sheet of paper.





4. Analyze your core sample. Record the number and contents of each layer of sediments in a table constructed similar to the example. Make inferences as to where the sediments came from and the conditions of the environment of the sediment's deposition.

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Table 2: Sediment Layers, Composition and Source

Sediment Layer	Composition of Layer	Possible Source	Environment of Deposition
1			
2			
3			
4			

5. What might cause the layers of sediments to be different?

6. Which observations support your inference?

7. Write a paragraph summarizing your conclusions about the layers of this model.

8. Meet with the group that created the model your team examined and compare your findings with their plans of the model. Were your findings the same as those intended? Why or why not?

9. How is the model of sediment layers like the layers of sediments that are deposited?

10. How does the model differ from layers of sediments that are deposited?

11. Discuss some of the problems that your team had and that scientists might have in taking core samples and interpreting them.

12. As a team, discuss the following and write your explanation.
    a. When and why might layers be missing?

    b. Why would the thickness of the layers differ?

    c. Why are all the sediments deposited not the same?

    d. Why are cores useful tools in locating oil and gas deposits?

    e. Why are cores useful tools for determining the history of the coastal area?

6. How Much Space Is There Between Sand and Sediment Particles?

Soil Scientist(s)_____**Team**_____

As you observed the sand, soil and sediment samples closely, you probably noticed some spaces between the particles. All sand, soil and sediments contain spaces or pores. Are the size and number of pores in all the samples alike? What is the effect of the pore space on sand, soil or sediments? Your team will be conducting investigations to find out.

Materials: sand, soil and sediment samples (from "What can the shape, sorting and size tell us about our mystery sand? Part III What can the size of particles tell you?"), plastic soda bottles (24 oz. or larger), nylon hose, rubber bands, graduated cylinder, water, scissors, plastic cups

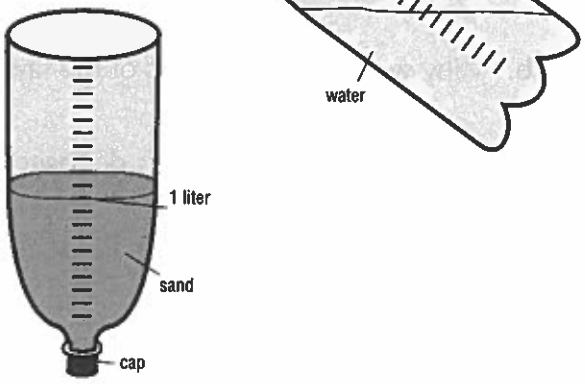
Procedure:

1. Do you think that there is the same amount of space between the particles in all the samples? Why or why not?

2. How could you find out if your answer is correct?

3. One way to check your answer is to see if there is space for another material to fit in between the sand and sediment particles. The easiest way to find out is to see if there is space to fit water molecules between the particles. Will the sand and sediment samples hold different amounts of water? Or the same? What is your prediction and why?

4. Find out if your prediction is correct.
   a. Obtain two 24 oz. (or larger) plastic soda bottles (if possible use one bottle for each sample to be tested plus one to serve as the collection bottle). Select one bottle to become the sample bottle with the bottom cut off (be careful as you cut the bottles). Cut the bottle, 3 cm up from the bottom. Cut off the top of the bottle 3 cm below the ring on the other bottle, the collection bottle. See drawing below. To make a measuring scale on each bottle, use a permanent marker to mark the level as each 10 milliliters of water is added. Continue until you reach 500 ml. This will be your measuring scale.



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b. Place two squares from nylon hose with a rubber band over the opening of the bottle. Put the cap on the bottle.
c. Fill your sample bottle with sand or sediment to the 250 ml mark. Fill the collection bottle with water to the 250 ml mark. This is the start volume.
d. Slowly pour water from the collection bottle into the sample bottle until you have a thin layer of water standing on the surface of the sample.
e. Read the current volume on the collection bottle and record it as the finished volume. Record your data in a table similar to the following example.
f. Remove the cap from the sample bottle and let the water drain and the sample dry.
g. Repeat the steps for each sample to be tested. When you have finished, clean up.

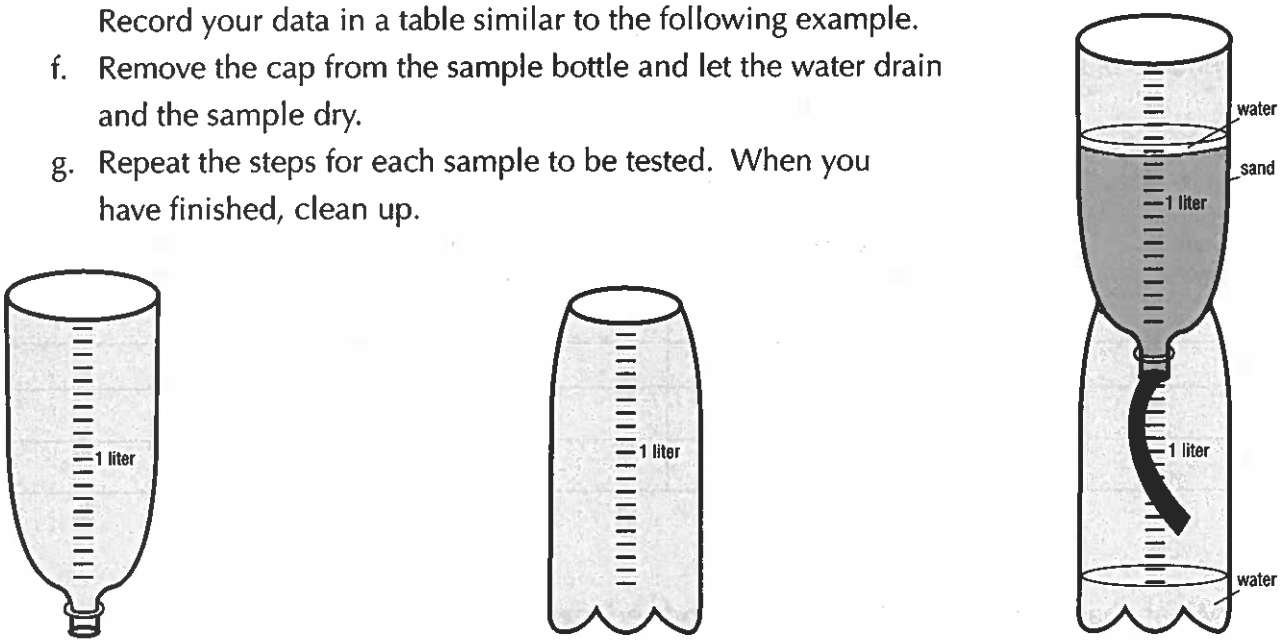


Table 1: Volume of Water to Fill Spaces in Samples

Sample #	Starting Volume	Finished Volume	Volume to Fill Space
1			
2			
3			
4			

5. Observe what happens as you add the water. Record your observations on a separate piece of paper.

6. Often there are references to the "empty space" between soil particles. Based on your observations, was this space (pores) really empty space? Explain.

7. Was your prediction correct?

8. Compare the amount of water needed to fill the pore spaces. Was it the same for each sample? Explain.

9. **Porosity** refers to the open spaces or pores through which water can move. Porosity is measured as the ratio of open pore space to the total volume of a sand or sediment sample. Use your data (Volume to fill pore spaces) from Table 1 to determine the porosity for each sample.

Percentage of Porosity = $\frac{\text{Milliliters of water to fill pores}}{\text{Milliliters of sample (250 ml)}} \times 100 = ___\ \%$

Table 2: Density, Particle Size and Porosity

Sample Number	Particle Size (small, medium, large, etc.)	Density(gm/ml) mass/volume	Porosity (Percentage)
1			
2			
3			
4			

10. What characteristics of the sand, soil and sediments affect porosity?

11. Determine the density of each sample (See Activity: Is the Mass and Density of Sand and Sediment Samples the Same?) Record the particle size (See Activity: What Can the Size of Sand Particles Tell You?) and density for each sample in Table 1. If you used the same samples as you used in the above activities, then record the data from these activities in a table similar to the example labeled "Table 2."

12. Is there a relationship between porosity, particle size and density? Write a paragraph explaining your findings.

13. You have already noted that beach sand is composed of grains of various sizes and shapes. Although sand may be coarser or finer in different areas of the beach due to wave action, it stated that the space between the grains (pore space) is constant, averaging about 20 percent of the total volume. Compare this statement with your results. Is the statement true or not? Explain.

14. Why is the information about porosity important? How can this information be used? In building homes or roads? In gardening or farming?

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7. How Can a Model Be Used to Demonstrate Porosity in Sand and Sediments?

Soil Scientist(s) _____ **Team** _____

You have conducted the investigation "How Much Space Is There Between Sand and Sediment Particles?" to investigate the relationship between particle size, density, pore size and water-holding capacity of sand, soil and sediments. Once scientists complete an investigation they communicate what they have learned. They may create a model to demonstrate their findings. Your team will be designing a model to demonstrate porosity.

Materials: 7 small, clear plastic cups, marbles or pebbles, fine dry sand to fill 3 cups, water, graduated cylinder.

Procedure:

1. Fill the 7 cups with the materials listed below. Fill each cup to 2 cm from the top.
   - 2 cups with marbles or pebbles
   - 2 cups with fine dry sand
   - 3 cups with water.

   Use the graduated cylinder to measure the volume of water needed to fill the cup.

2. Plan a demonstration that will compare the amount of water needed to fill the pores between the marbles or pebbles with the amount of water needed to fill the pore space between the sand. Record the directions for your group's demonstration.

3. Conduct the demonstration. When you have completed this comparison demonstration, write a statement that best describes the amount of pore space between the grains of sand and the marbles or pebbles. Use percentages of pore space to compare each sample. (See Activity: "How Much Space Is There Between Sand and Sediment Particles" for instructions to determine the percentage.)

4. Suppose that you fill the pores between dry marbles with sand rather than water. Will you need the same volume, a smaller volume or a greater volume of dry sand than water to fill the pores? What do you think?

5. Write the procedure to test your group's demonstration.

6. Write a statement that best describes your results when your team has completed the demonstration.

7. Design a demonstration to find out the porosity in a cup of marbles and sand. Determine how much water is needed to fill the pore space in marble and sand mixture.

8. Based on your demonstrations which has the least amount of pore space and which has the most pore space?
   a. the cup of sand
   b. the cup of marbles, or
   c. the cup of sand and marbles

   Indicate the percentage of pore space for each. Refer to "How Much Space Is There Between Sand and Sediment Particles?" for instructions to determine the percentages.

9. If you have been on a beach after a rain you may have noticed how quickly the beach dries after a rainfall. How does porosity affect this?

10. The pores of the sand and sediments under the coastal zone are filled with water. When this water is removed from the sediments in many areas of the coast, land subsidence or sinking occurs. The Brownwood subdivision in Baytown is an example. Oil and chemical facilities along the Houston Ship Channel, as well as domestic water supplies, were pumping groundwater out faster than natural forces could replace it. Explain the relationship of the removal of water from the pores of the sediments and land subsidence or sinking of the land.

11. In the parts of the coastal zone in east Texas and the Mississippi River delta in Louisiana, the sea level is rising 9 to 10 mm per year because the land itself is sinking. About 6 to 7 mm of this annual rise in sea level is due to the subsidence or sinking caused by a combination of compaction of delta sediments and the removal of fluids from the coastal zone. Explain how this relates to the sea level rising.

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8. How Fast Does Water Move Through Sand, Soil or Sediments?

(How does this affect aquifers and solid waste disposal in the coastal zone?)

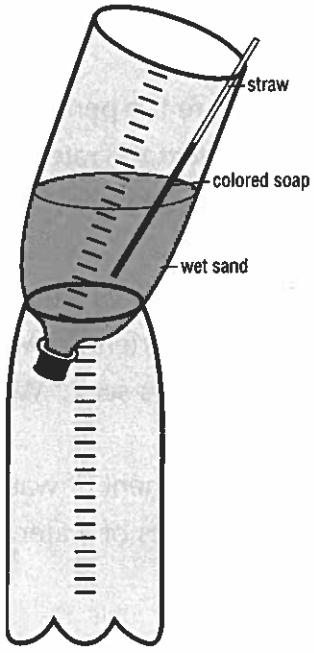
Scientist(s) _____ **Team** _____

The nature of the surface and subsurface materials of the coastal zone varies in composition. It may vary from the loose sand of the beach and sand dunes to brick-hard clay in inland areas. Most materials lie between the two extremes. The composition of the materials affects the movement of water or pollutants. You will be investigating sand, soil and sediments to determine some areas the water moves through the materials. When pollutants are dissolved in water and water moves through the rock, soil or sediments, the pollutants can move with it. How does water move through materials such as rocks, soil and sediments? The questions is partly answered by permeability. **Permeability** is the measure of how easily water can move through materials. Your team will be investigating permeability to learn how it affects water and pollutant movement.

Materials: soil (clay and sand) and sediment samples, 3 plastic soda bottles (20 or 24 oz.), pieces of nylon hose, rubber bands, stop-watch, graduated cylinder and water.

Procedure:

1. Will the water move through the sand and sediment samples at the same rate or do all sediments have the same permeability? Or will it move through one sample faster than another, that is, can water flow through one material more easily than another? Which one and why? What is your prediction and why did you choose it?



2. Your team will try to find out if your prediction was correct. You may use the sample and collection bottles you made in a previous activity, "How Much Space Is There Between Sand and Sediment Particles?"
   a. Put the nylon hose over the end of the sample bottle. See the diagram.
   b. Put 250 ml of the sample to be tested into the sample bottle. Use only dry samples. Insert the screened end of the sample bottle into the collection bottle.
   c. Slowly pour water into the sample bottle. Try to keep the water level 25 ml above the sample.

d. When the water starts to come out of the sample bottle and into the collection bottle, start timing. Continue to add water to the sample bottle, keeping all the sand wet.
e. When the collection bottle reaches 500 ml, stop pouring water, stop the timing and record the time.
f. To determine the rate of flow through the sand, divide the amount of water that flows through in milliliters by the time period in seconds:

$$\text{rate of flow} = \frac{\text{500 ml of flow through water}}{\text{amount of time (seconds)}}$$

g. Repeat the steps for each sample. Record your data in a table similar to the following example..

3. Permeability flow rate is expressed as a volume per time or liters per minute. Convert your ml/sec rate to liters/per minute. Record this in a table similar to the example.

Table 1: Porosity and Permeability

Sample Number	Description of Sample (particle size, pore space)	Permeability Flow Rate (ml/sec)	Permeability Flow Rate (liters/minute)

4. Record your observations and the rate of flow for each sample in Table 1. Was your prediction correct? Record your conclusions.

5. Compare the permeability of the sand, clay and sediment samples. What variables (factors) affect the rate? Is it the percentage of pore space, size of the pores, or both? Write a statement that best describes your results.

6. Permeable rock strata or sediments that transmit groundwater freely are called **aquifers** ("water carriers"). Aquifers are important because they are the water-bearing layers that well drillers seek. Which of your samples were the most permeable?

7. The movement of water through a soil, permeability, has a predictable rate. Some approximate values of water flow are given in Table 2.

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Table 2: Soil Type and Rate of Water Flow

Type of Soil	cm/hour	m/day
Sand	.36 – 36+	8.6 – 860+
Loam	.036 – 3.6	.86 – 86
Clay	.0036 – 036	.086 - .86

a. Which soil type is the most permeable?

b. Which is the least permeable?

c. Explain how your results compare to the results in Table 2.

8. Sediments and soils that are impermeable (slow or prevent water movement) are the best sites for landfills. Explain.

9. Which types soils are the best for placing landfills? Explain.

10. It has been estimated that over the next 25 years, the equivalent of over 3,000 Astrodome stadiums will be needed to hold the compacted wastes, trash and garbage of the Houston region alone. In New Orleans, it is estimated that enough wastes will be generated to fill the area of about 2,200 Superdomes in the next 25 years. Explain why the permeability of the substrata and overlying soils is critical in providing good sites for waste disposal.

9. How Much Water Can Different Sand, Soil and Sediments Absorb and Hold?

(How does the infiltration rate and water-holding capacity affect the coastal zone?)

Scientist(s) _____ **Team** _____

In some areas water enters the soil very quickly after a rain. In other areas the water forms puddles or ponds and enters the soil very slowly. How quickly sand, soil or sediments absorb water is called **infiltration** or **percolation**. Infiltration is the entrance or flow of water into the soil, sediment or the rocks of the earth's surface. You will be investigating the infiltration rate and the water-holding capacity of sand and soil.

The amount of water that sand, soil and sediments absorb is its water-holding capacity. Do you think that sand and sediments have the same ability to absorb water? Why or why not? Which will hold more water, sand, soil or sediments? What is your prediction?

Materials: Sand, soil and sediment samples, 20 or 24 oz plastic soda bottles, screen or nylon hose, rubber bands, graduated cylinder, timer and water

Procedure:

1. To check your predictions, obtain four dry sand, soil and sediment samples.
   a. Use the sample and collection bottles from "How much space is there between sand and sediment particles?" and "How fast does water move through sand, soil or sediments?" Put a screen or fasten squares of nylon hose with a rubber band over the sample bottle.
   b. Fill each sample bottle with 250 ml of the sand or sediment sample and invert over the collection bottle. Pour 500ml of water in a beaker or other empty collection bottle.
   c. Construct a table similar to the following and record the time. Begin pouring 500 ml of water into each sample bottle. As the water moves into the sand or sediment sample, add more water to the sample. From the original 500ml, record the time dripping begins and the time dripping stops in Table 1. Repeat the procedure for each sample.

Table 1. Water Absorption Data

	Samples			
	#1, Sand	**#2, Soil**	**#3, Soil**	**#4, Sediment**
Time when water is added				
Time when dripping begins				
Time when dripping stops				

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d. Fifteen minutes after you began adding water to the samples, determine the amount of water that **was not** absorbed.

1. For each sample, pour any of the water you could not add to the sample bottle into a graduated cylinder. Add the amount of water left standing on top of the sample into the same graduated cylinder. The water left standing on top would be "run-off." Try to avoid disturbing the sand or sediment sample as you pour the water off its surface. These two combined amounts are the total volume of water that did not enter the soil. Construct a second table and record this amount for each sample.

2. Determine the volume of water that passed through each sample. This is the water that dripped into the lower beaker "bottle." Enter this volume in Table 2.

3. Calculate the amount of water that was not absorbed by each sample by adding the volume of water that did not enter the sample and the volume of water that passed through the sample. Enter the sum in Table 2. Repeat the above steps for each sample to be tested.

4. Calculate how much water each sample absorbed by subtracting the volume of the unabsorbed water from 500ml (the starting amount) for each sample. This is the water holding capacity of the sample

   Water absorbed by the sample = 500 ml -_____ ml = _____ ml

   Record amount of water absorbed (water-holding capacity) of each sample in Table 2.

Table 2. Unabsorbed Water Data (after 15 minutes)

	Samples			
	#1, Sand	**#2, Soil**	**#3, Soil**	**#4, Sediment**
Volume of water that did not enter the soil ("run-off")				
Volume of water that passed through the soil				
Total unabsorbed water				
Total water absorbed ("Holding capacity")				

5. Compare the water-holding capacity of the sand, soil and sediment samples. Why do you think that the sand, soil and sediments hold different amounts of water? What variables affected this? Write your conclusion.

6. Compare the water **absorption rate** of the samples from Table 1 (the **absorption rate** is how fast the water moved through the sample and began dripping from the bottle). Which sample absorbed the water faster?

7. Write a statement that best explains the relationship between the rate of absorption or infiltration and the amount of water that runs off?

8. From which sample would the water run off and cause the greatest erosion?

9. Which sample has the greater water-holding capacity? The least?
   What is the relationship between water-holding capacity and flooding? On which type of soil or sediment would flooding occur?

10. Discuss the importance of the water infiltration and water-holding capacity of the samples and growing crops.

11. According to The University of Texas at Austin, Bureau of Economic Geology, only 30 percent of land used for solid waste disposal is capable of secure containment of wastes. A good solid waste disposal site or landfill should be located in soils that are impervious. This means that water cannot pass through the soil into the wastes. Water moving through solid wastes carries hazardous chemicals with it. This can contaminate surface water bodies and aquifers that supply drinking water. Twenty percent of the landfills are in poor sites while the other half are sites that are of only marginal suitability. In other words, 70 percent of the solid waste storage sites in the coastal zone are ineffective and/or unsafe. Explain the effect of the soil's water infiltration rate and water-holding capacity on a solid waste disposal site.

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10. How Does the Gulf Coastal Aquifer Work?

Hydrologist:_____ **Team:** _____

From your previous investigations you have learned that **porosity** and **permeability** are factors that determine if sediments or rock strata will form an aquifer. Aquifers are important because they are the water-bearing layers that well drillers seek. A good aquifer can provide water for homes, cities, irrigation, and industries. The Gulf Coast Aquifer is a very important aquifer in the Texas coastal zone. In the densely populated areas like Houston, water withdrawal from the aquifer has caused problems. Your team is going to create a model of an aquifer to demonstrate how an aquifer works.

Materials: clear plastic container that is at least 6-8" deep (a plastic shoe box, small aquarium or 3 liter bottle), Modeling or floral clay, felt, white play sand, aquarium gravel (natural color), jumbo drinking straws, or plastic tube, plastic spray bottle, tape

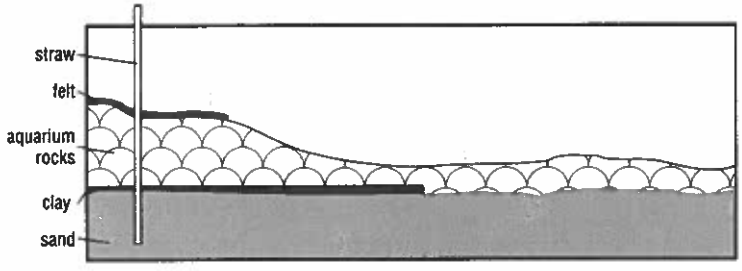
Procedure:

1. Tape the straw or plastic tube directly against the longer side of the container. Fasten the straw approximately 1 cm from the bottom of the container. This will represent a well. Slowly pour a layer of sand completely covering the bottom of the clear plastic container. Making it 4 cm deep. Pour water into the sand, wetting it completely. Make sure that there is no water standing on top of the sand. Note how the water is absorbed in the sand, but remains around the sand particles as it is stored in the ground or aquifer.

2. Flatten a piece of clay like a pancake and cover one-half of the sand with clay. Press the clay against the three sides of the container in the area covered. Pour a small amount of water onto the clay. What happens to the water?

   Why does the clay represent what is called a "confining layer"?

3. Use aquarium gravel to form the next layer of earth. Place the gravel over the sand and clay, covering the entire area. To one side of your container, slope the rocks forming a high hill and a valley (see diagram below). Place a piece of felt on top of the hill to represent the topsoil layer.



side view of container

Now slowly spray water on the top of the hill until the water in the valley is even with your hill. Observe and record your observations of what happens to the water and where it is found.

4. On a separate sheet of paper describe the role of porosity and permeability in how an aquifer works. Illustrate your explanation.

5. Examine Figure 10.1. Locate the Gulf Coast Aquifer. What parts of the state does it cover?

6. For which major population centers does it serve as a source of water?

7. As water is pumped out of the aquifer, more water will flow in to take its place during recharge. Recharge adds water to the groundwater system when rainfall, surface water, or water from a creek or lake soak in through the soil and rocks. Since water flows slowly in rock, recharging the aquifer takes time. What will happen if more water is removed from the aquifer than enters it by recharge? Explain.

8. What factors would lead to more water being removed from the aquifer than is being replaced through recharge?

9. Pumping water from the Gulf Coast Aquifer has led to salt water from beneath the Gulf of Mexico moving into the aquifer. Explain how you think this might happen.

10. The Gulf Coast Aquifer was formed during the late Cenozoic period from river and delta deposits, as well as shallow marine deposits. What specific types of particles were deposited to form the aquifer? Explain.

11. Where was the Texas coastline during the late Cenozoic period when the Gulf Coast Aquifer was being formed? Explain.

12. Use Figure 10.1 to locate the Carrizo-Wilcox aquifer. What parts of the state does it cover?

13. The Carrizo formation and the underlying Wilcox Group were deposited during the very early Cenozoic time from large rivers flowing to form deltas. What specific types of particles were deposited to form this aquifer?

14. Where was the Texas coast during the formation of the Carrizo-Wilcox Aquifer? Explain.

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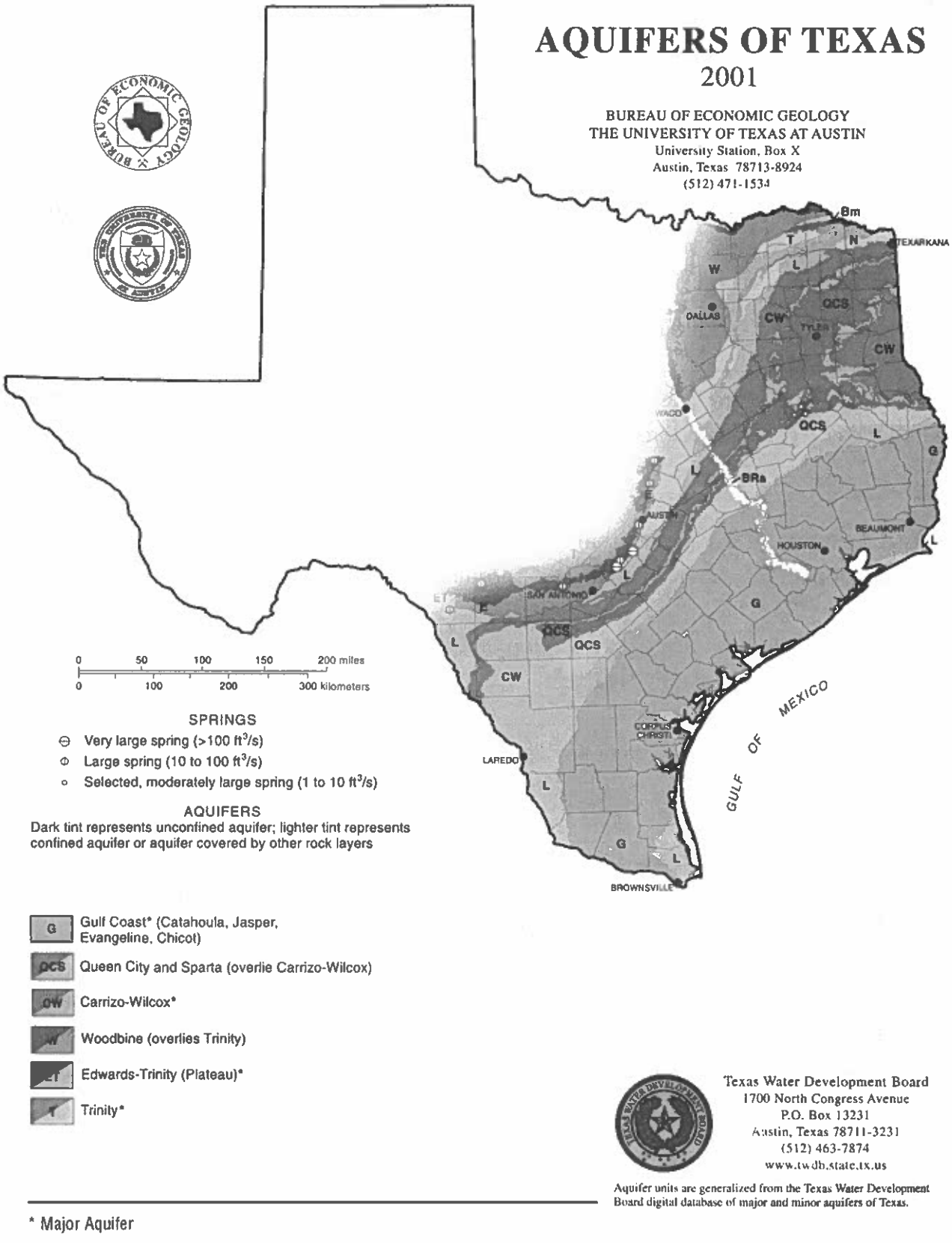


Fig. 10.1. Aquifers of Texas. (Source: Bureau of Economic Geology, The University of Texas at Austin)

11. How Does Groundwater Become Contaminated in the Coastal Zone?

Hydrologist: _____ **Team:** _____

The Gulf Coast Aquifer is a very important aquifer in the Texas coastal zone. In the densely populated areas like Houston, water withdrawal from the aquifer has caused problems. Your team is going to create a model of an aquifer to gather data to determine how what happens above the ground can affect what happens below the ground.

Materials: a 6"x8' clear plastic container that is at least 6-8" deep (a plastic shoe box, aquarium or 3 liter bottle, modeling or floral clay, white play sand, aquarium gravel (natural color), jumbo drinking straws or plastic tube, plastic spray bottle, 3"x 5" piece of green felt, l/4 cup cocoa or colored Kool Aid mix, red food coloring, water, tape

Procedure:

1. Use the model of the aquifer from "How Does the Gulf Coastal Aquifer Work?" or use the instructions (1-3) to create a model of an aquifer. See the diagram below.

2. Place the small green piece of felt on top of the hill. If possible use a little clay to securely fasten it to the sides of the container.

3. Use the food coloring and put a few drops into the straw. What happens to the food coloring?

4. The food coloring represents pollutants. Old wells are sometimes used to dispose of chemicals, trash, used motor oils. What happens to materials that are dumped into old wells? What is the effect on the aquifer?

5. Using the cocoa or Kool Aid, sprinkle some on top of the hill. Fill the spray bottle with water and use it to make it rain on top of the hill. What happens to the cocoa or Kool Aid?
6. The cocoa or Kool Aid represents the use of lawn chemicals or fertilizers, etc. How could these affect the aquifer?

7. Explain how could this contamination be prevented.

8. Take another look at the "well" you contaminated. What has happened to the food coloring or pollutant now?

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9. What would happen in an aquifer that has been contaminated from old wells over time?

10. Remove the top of the spray bottle and insert the stem into the straw. Depress the trigger to pull up the water from the well. What color is the water in the stem of the sprayer that represents a water well?

11. Should the water drawn from this well represented by the straw be used for drinking? Explain.

12. Write a statement that best describes how an aquifer can become contaminated over time.

12. What Is the Relationship of the Properties of Sand, Soil, Sediments and Groundwater Contamination in the Coastal Zone?

Scientist(s): _____ **Team** _____

The pollution of groundwater is a serious matter, particularly in areas where aquifers provide the drinking water. The Gulf Coast Aquifer is the main source of water for the Texas coastal zone. One common source of pollution is sewage. The sources include an increasing number of septic tanks as well as inadequate or broken sewer systems and farm wastes. Other sources and types of contamination also threaten ground water supplies. These include fertilizers and pesticides. Even when you fertilize your lawn or spray insects in your yard, some of these may go into the groundwater. Animal wastes from pets are a major source of bacteria contamination. In addition, a variety of chemicals and industrial materials may leak from pipelines, storage tanks, landfills and holding ponds. Some of these are classified as hazardous. This means that they are either flammable, corrosive, explosive or toxic. You and your team are going to investigate how a contaminant or pollutant moves through the sand or sediments.

Materials: Sand, soil and sediment samples, plastic soda bottles, straw, dark food coloring, graduated cylinders, liquid dish detergent, plastic spoon, teaspoon, clear plastic cup.

Procedure:

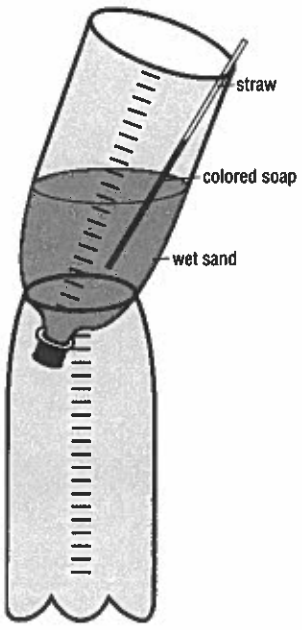
1. Do you think that the properties of the sand or sediments are a factor in groundwater contamination? Explain your hypothesis.

2. To determine if your hypothesis is correct conduct the following investigation using a model of an aquifer.

   a. Use the sample and collection bottles from the previous activities. Put the screen or nylon squares into the sample bottle. Fill one sample bottle (Sample A) with sand to the 400 ml mark. Add water to the sample bottle until all the sand is wet. If the sand were an aquifer, what condition does this represent?

   b. Place the sample bottle into the collection bottle. See the diagram.

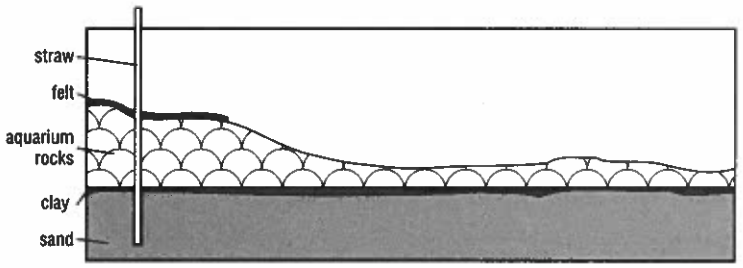
   c. In a clear plastic cup, mix 1 teaspoon of liquid dish soap



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and drops of food coloring. Make sure the solution is a dark color so it can be seen. Fill a plastic drinking straw half way with the soap/food coloring mixture. This will represent the contaminant.

d. Holding your finger over the top of the straw hole, insert the straw into the sand near the edge of the sample bottle. Tip the sample bottle so that the sand the straw is in is higher than the rest of the sand. Remove your finger from the straw once the straw is inserted into the sand.



side view of container

e. Wait 10 to 15 minutes.

f. When a contaminant gets into the groundwater it will produce a plume, an area of the water that is contaminated. The plume's shape is determined by the type of contaminant and the conditions around it. Using a plastic spoon, slowly remove a 50 ml layer around the colored soapy water of sand. Then draw the "contaminant plume" by looking at the sand left in the bottle. Label this line by the volume on the side of the bottle.

g. Remove another 50 ml of sand and add this shape to your drawing. Continue removing 50 ml volumes of sand and adding to your drawing until you no longer see the plume.

h. Repeat the steps for a sample of soil sediments (Sample B and Sample C). Clean up.

3. Construct a chart similar to the example below. Compare the shape of the plume in the sand sample (Sample A) with the shape in the soil sample (Sample B) sediment sample (Sample C). How are they alike and how do they differ?

Table 1: Contamination of Samples

Sample	Shape of Plume	Size of Plume	Similarities	Differences
A				
B				
C				

4. What can you conclude about the properties of sand, soil and sediment and contamination? Is the rate of pollutant movement and size of the plume the same? Explain your findings.
5. What are some possible solutions to prevent pollution of soil and water in the coastal zone?

6. Using what you have learned, explain why contaminants in the Gulf coast aquifer may go undetected for a long period of time. Unfortunately most contamination is discovered only after the drinking water has been affected and people become ill. Explain why.

7. In coastal areas there is often a layer of saltwater below the layer of fresh ground water. Often the groundwater resource is being threatened by saltwater moving into the fresh water area. This occurs when fresh water is pumped out and there is not enough rainfall to replace it. Use what you have learned about the properties of sand and sediments to explain why this happens.

8. What do you think can be done to correct and prevent the problem of saltwater contamination of groundwater resources along the coastal zone?

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13. What Are Some Sand and Sediment Problems in the Coastal Zone?

Scientist(s) _____ **Team** _____

Sand is super! You play and build with it in sand boxes. You can build castles on the beach with it. It feels gritty as it dries on your bare feet. You sprinkle it on icy sidewalks and roads to make them less slippery. Mixed with gravel and cement in water, it adds strength to walls and sidewalks. Winds carve it into beautiful and grotesque shapes in cliffs and dunes. Sand is very important in the world. However, some of the properties of sand and sediments can result in problems in the coastal zone. You and your team will read each scenario about a coastal problem. Then use your knowledge of the properties of sand and sediments to determine possible causes of the problems and action that can be taken to solve the problem.

Materials: none

Procedure:

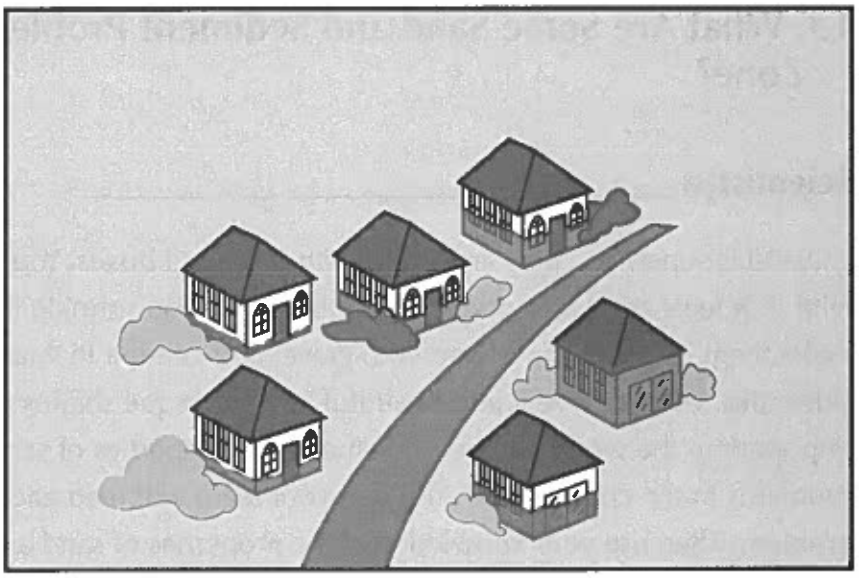
1. In 1940-1941 the federal government built an Army base, Camp Wallace on Galveston Island. Camp Wallace was built close to the established base of Ft. Crockett that had been built in 1897. It used the water supply and electricity from Ft. Crockett. The camp consisted of 1,600 acres, 161 barracks and a payroll of $150,000 per week in 1941. It had almost 400 buildings and room for 12,000 men. During construction in November 1940 it rained nine inches and the site was flooded with three feet of water. The engineers had ditches built around the site. In December, a six-inch rain flooded the site again. Ditches were built throughout the camp. They also built shell roads with materials dredged from Galveston Bay. These roads became a problem. Clumps of mud would drop off the tires of the trucks and stick to the shells. In May 1941, a six-inch rain left only mud, no flooding. In 1943, the Army left the site.

   a. What properties of sediments were the cause(s) of the problem?

   b. What action could have been taken to prevent the problem?

2. The City of Baytown, 20 miles east of Houston along the Houston Ship Channel, includes a peninsula surrounded on three sides by Galveston Bay. Almost 400 homes were built on this 500-acre peninsula that was the Brownwood subdivision in the 1940s and 1950s. The neighborhood was considered so prestigious it was known as the "River Oaks of Baytown" (referring to an upper class Houston neighborhood). During the 1960s and 1970s, Brownwood, like much of the Texas coast, began to sink. Unlike other areas of the coast,

the Brownwood subsidence, or sinking, reached a total of 10 to 15 feet. This resulted in homes being flooded during high tides and storms and, ultimately, led to a government buyout of the property. Today, Brownwood has been transformed into the Baytown Nature Center.



a. What caused the subsidence or sinking?

b. What action could have been taken to prevent the problem?

3. The Boling Dome, southeast of Houston, was the largest producer of sulfur in the United States. In 1983, a sinkhole 25 feet deep and 250 feet in diameter formed along F.M. Road 442, directly over the crest of the dome.

   a. What caused the sinkhole to form?

   b. What action could have been taken to prevent the problem?

4. The Gulf coast region has thick layer of saline aquifers. These are popular for underground disposal of liquid industrial wastes. In 1973, there were 56 municipal and industrial waste disposal wells in the southeastern Gulf coast. These handled an estimated total of 18 billion gallons of liquid wastes. A large part of these wastes contain toxic substances. Liquid wastes pumped underground during the early 1970s and before, are seeping into the soils. This is causing serious, irreversible environmental damage.

   a. What is causing wastes to seep into the soils?

   b. What action could have been taken to prevent the problem or solve the problem?

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14. How Do Soils Affect Waste Disposal on the Texas Coast?

Researcher(s) _____ **Team** _____

Safe waste disposal is affected by several environmental conditions. One of these factors is the nature of the soil. A company is investigating sites for locating a waste disposal site. You and your team of researchers are going to use a model to investigate soils to determine which land area is the most suitable for waste disposal.

Materials: different types of soil (sand, clay, loam, silt, combinations, etc.) 32 oz., 1 or 2 liter bottle with the top cut off, ruler, plastic spoon, paper or plastic cups, food coloring, "Easter Egg" dye tablets, glycerin or cooking oil, used coffee grounds, corn starch

Procedure:

1. Examine the soil types. Construct a table similar to the example below. List the soils and predict which will be suitable for a waste disposal.

Table 1: Analysis of Soil Types for Waste Disposal

Soil Sample	Description of Soil	Prediction of Suitability for Waste Disposal	Distance Wastes Leaked from Site (mm)
1			
2			
3			

2. Prepare a model of a waste disposal site for each soil type.

   a. Fill the tray or 3 liter bottle to a depth of 8 cm with the dry soil type to be tested.

   b. Press the soil into the container.

   c. In the center of the container, use a spoon to dig a waste disposal area that is 5 cm x 5 cm and 4 cm deep.

3. In a paper or plastic cup, mix the "wastes" to put in the waste disposal site. Mix in food coloring or the dye tablets to represent chemicals; cooking oil or glycerin to represent oil; coffee grounds or cornstarch to represent solid wastes. Add water since water is used to remove wastes. Pour the "wastes" into the waste area to fill the hole.

4. Wait 15 minutes. Then use the spoon to remove the "wastes" from the site.

5. Slowly remove the soil below the site. Determine if the "wastes" leaked out of the site into the soil.

6. Measure the distance that the "wastes" leaked into the soil. Record the observations and distance in Table 1.

7. Explain which type of soil is the best for waste disposal and which is most unsuitable.

8. Is there a relationship between the suitability of a soil for waste disposal and soil permeability, porosity and water holding capacity? Explain.

9. Explain why waste disposal sites should be placed in impermeable soils such as clay.

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15. How Safe Are the Solid Waste Disposal Sites in the Texas Coastal Zone?

Health Department Investigator (s) _____ Team _____

The problem of where to store waste has grabbed a lot of headlines. People have been slow to realize that the environmental damage and problems caused by storage sites is even greater. The location of waste storage sites along the Texas coast is a problem. You and your team are investigators surveying and evaluating solid waste storage sites. You are determining which ones (if properly built) are in safe locations.

Materials: none

Procedure

1. Examine the maps of the distribution of solid waste disposal sites in the following areas: Beaumont-Port Arthur, Galveston-Houston, Bay City-Freeport, Port Lavaca, Corpus Christi and Brownsville-Harlingen. Determine which solid waste disposal sites are not in suitable locations. These may be in wetlands or in highly permeable soil, or they are located next to water (a mile or closer) where flooding is a problem. Circle these in red on the map.
2. Examine the map to determine which waste disposal sites are actually located in suitable locations. Circle these in blue.
3. Construct Data Table 1. Use the maps of each area and complete the table.

Data Table 1: Location of Solid Waste Sites in Texas Coastal Zone

Area	Total Sites (number)	Wetlands (marshes swamps)	Highly Permeable (sand, shell)	Moderately Permeable	Impermeable (mud or clay)
Beaumont-Port Arthur					
Galveston-Houston					
Bay City-Freeport					
Port Lavaca					
Corpus Christi					
Brownsville-Harlingen					

4. How many or what percentage of sites in each area are in good locations where the soil is impermeable?

5. Summarize the results of your examination of the waste disposal sites in this area.

6. What do you think caused the placement of waste disposal sites in unsuitable locations?

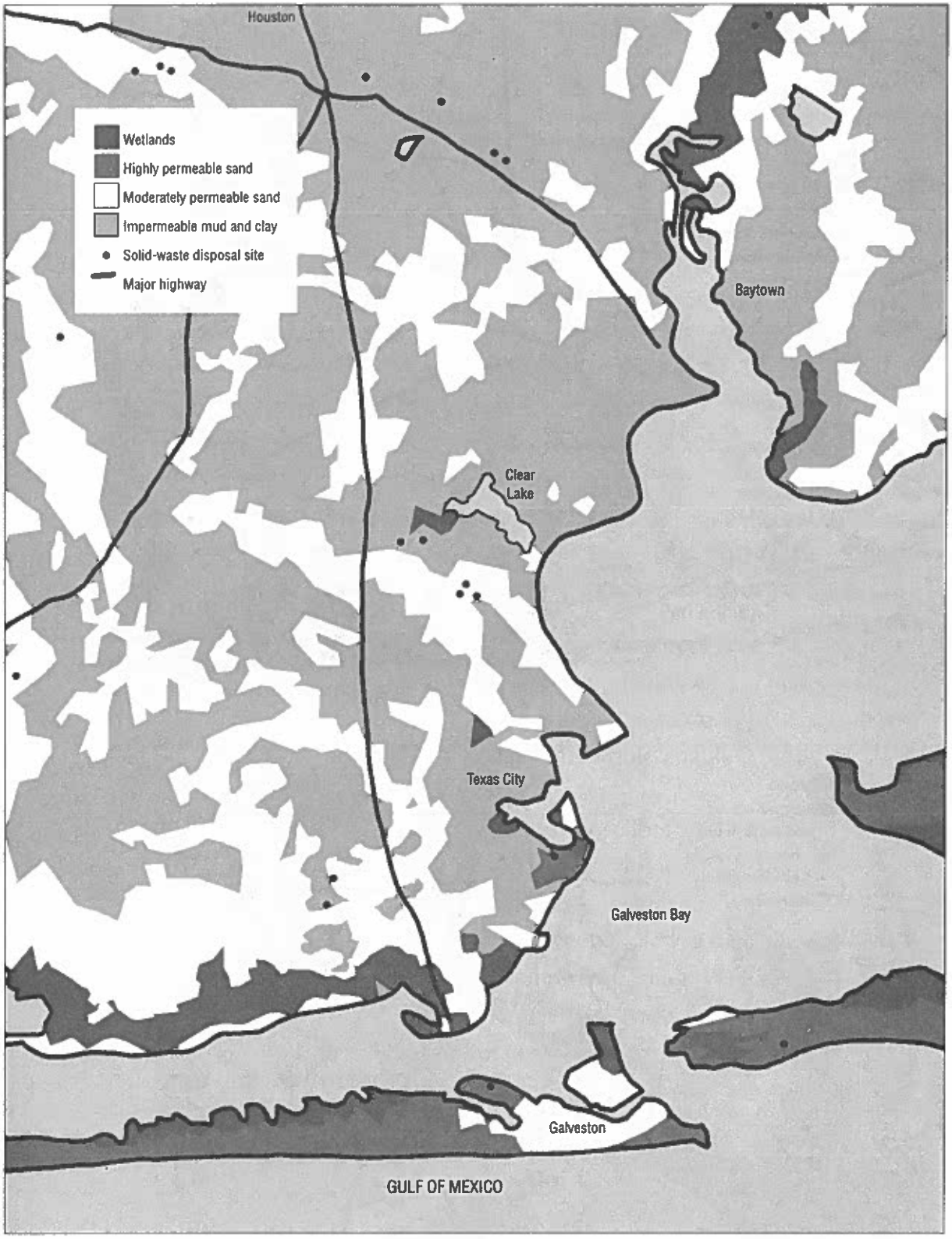
7. What types of problems can result from the placement of waste disposal sites in unsuitable soils?

8. What policies would you recommend for placement of waste disposal sites?



Beaumont-Port Arthur

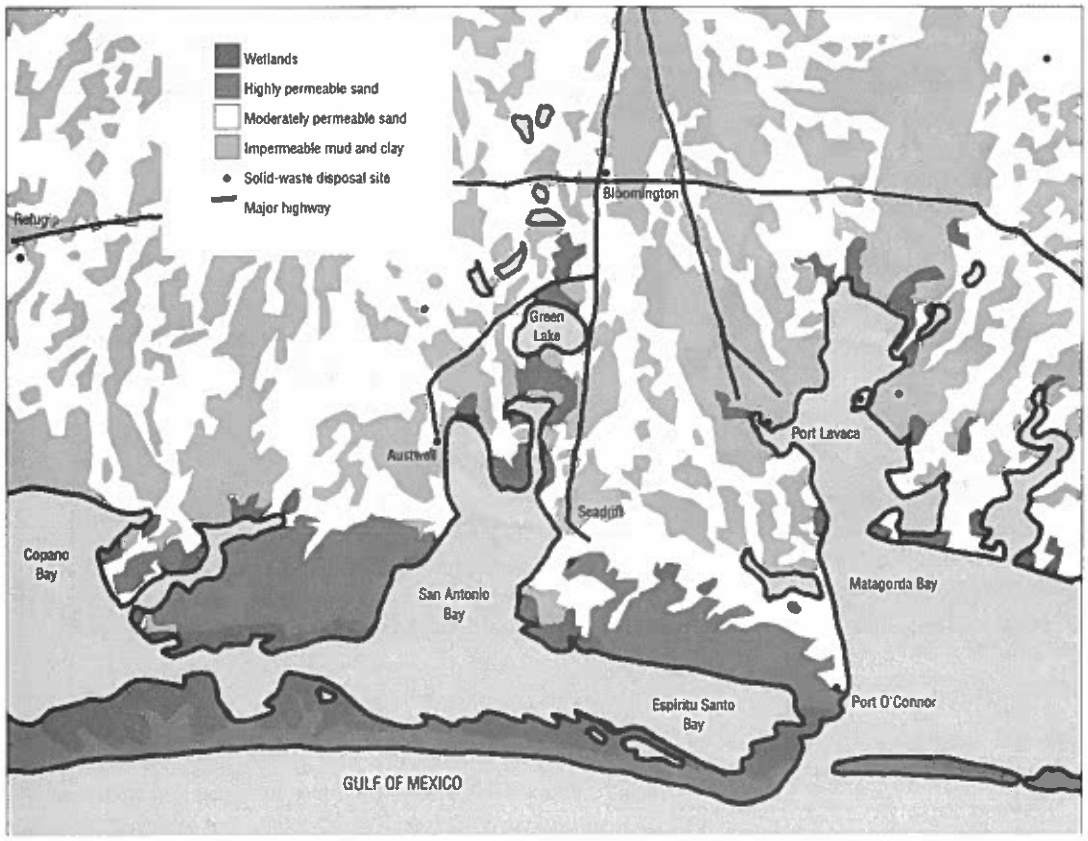
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Galveston-Houston

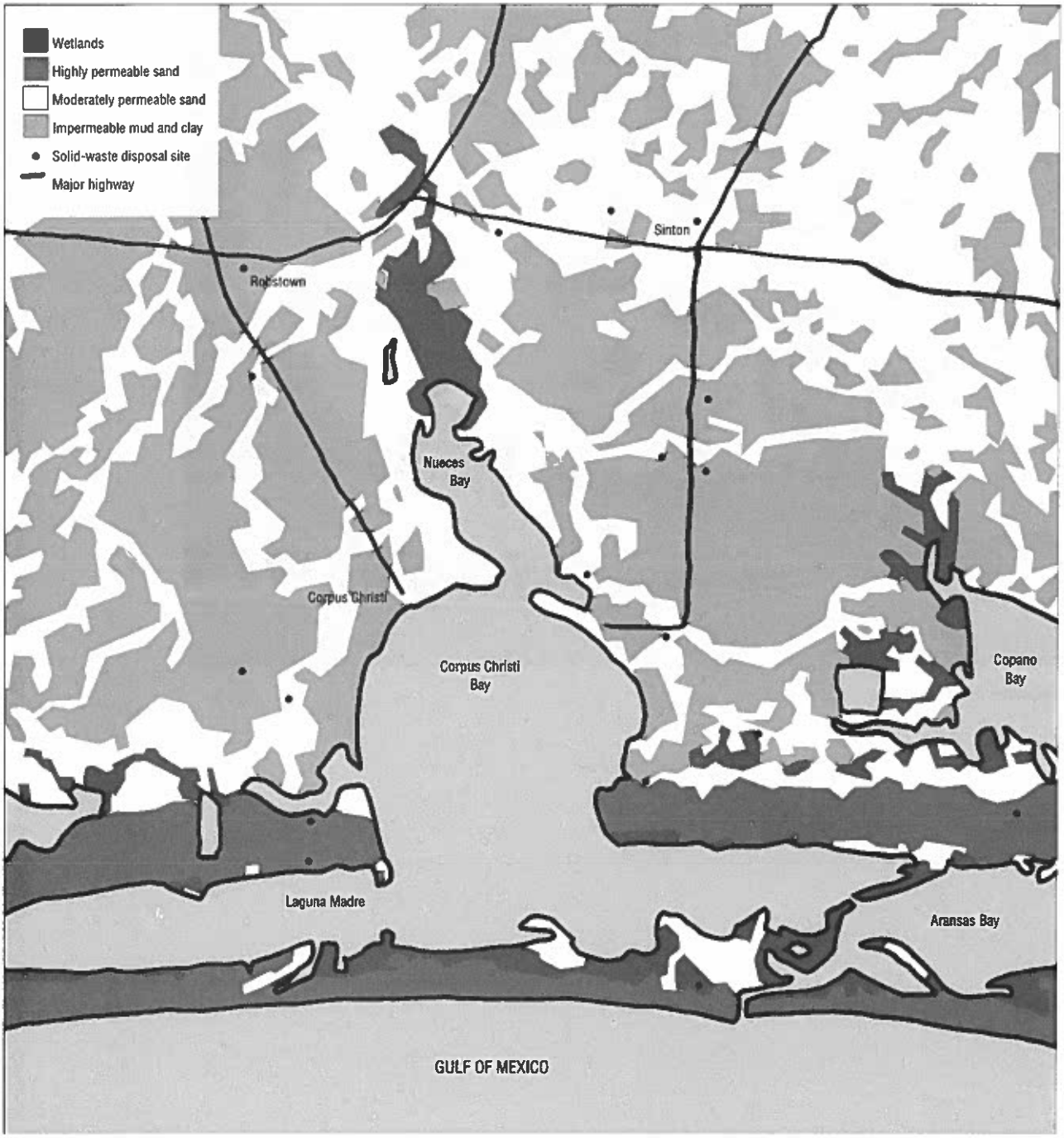


Bay City-Freeport

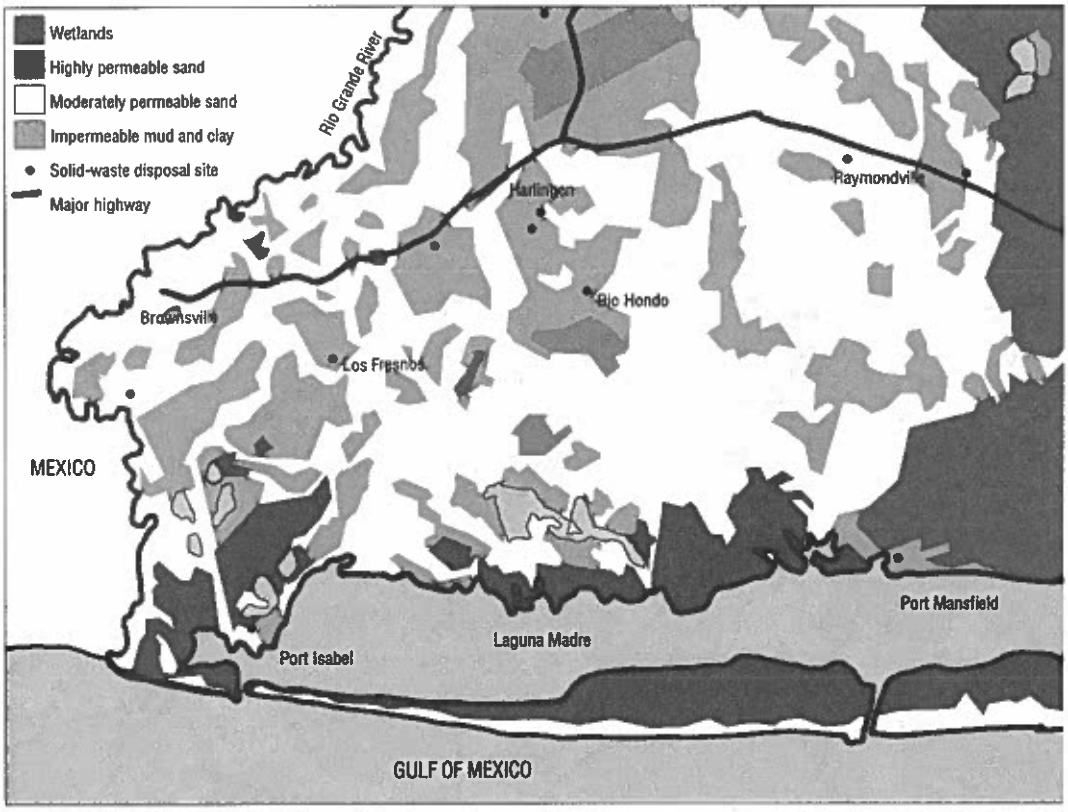


Port Lavaca

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Corpus Christi



Brownsville-Harlingen

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16. Is There Danger on the Texas Coast?

Health Department Investigator_____ **Team** _____

Since the discovery of oil on the Gulf Coast at the turn of the century, waste disposal was not a planned activity. Land was considered a disposable and practically limitless resource. Much of the land was unpopulated. Companies drilled and pumped oil. When the well ran dry, they just moved. Oil mixed with brine water was regularly dumped on the surrounding land. Solid wastes that were by-products of the petrochemical industry were ignored and not disposed of properly. Waste streams from petrochemical plants have also been found to contain toxic substances. They can also be significant sources of air pollution.

In 1980, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) created a tax on the chemical and petroleum industries. The tax money collected, the "Superfund" is used to clean abandoned or uncontrolled hazardous waste sites. The sites are called "Superfund Sites." In 1987, there were 60 sites in Jefferson county and 246 in Houston and Harris County while Galveston County had 39 and Brazoria County had 52 sites. Four counties in the southeastern Texas coast had 397 sites listed. Releases of contaminants have been shown to be common and repeated for these sites. These counties seem to have poor air quality, unsafe surface and ground water, contaminated soils and aquifers, and regular dangers from contamination. Contamination is a constant threat to public health. Some believe that there is a cancer epidemic in this southeast Texas Coastal zone. You and your team are going to analyze the data to determine if there is a problem.

Materials: none

Procedure:

1. In 1979, the Environmental Protection Agency (EPA) released a study that included maps showing the locations of chemical producing counties (CPCs) and counties of high trachea, bronchus and lung cancer death rates from 1950-1969. Examine the maps (Figure 16.1 and Figure 16.2, next page). Compare the CPCs and the high cancer death rate areas. What patterns do you notice?

2. Texas has about 1,500 petroleum refineries and chemical plants. About one-third of these are located in four coastal counties: Chambers, Galveston, Jefferson and Harris. Based on Figures 16.1 and 16.2, what is your hypothesis about the cancer death rate of these four counties?

3. Examine the cancer deaths from 1976-1985 in Table 1 for the four counties. What patterns do you notice?

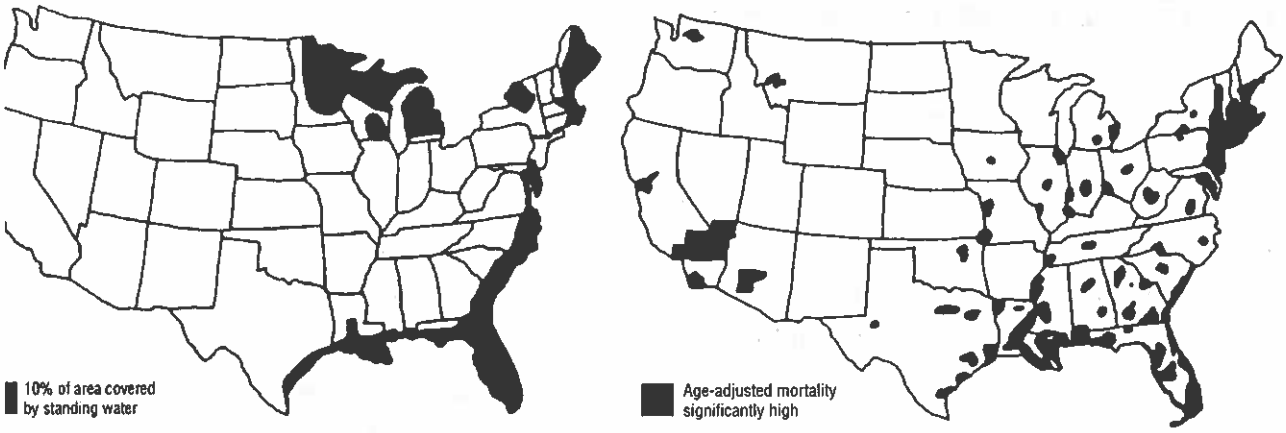


Fig. 16.1. Correlation of respiratory cancer and wetlands residency. (Source: Goldsteen, 1993: **Danger All Around: Waste Storage Crisis on the Texas and Louisiana Gulf Coast**)

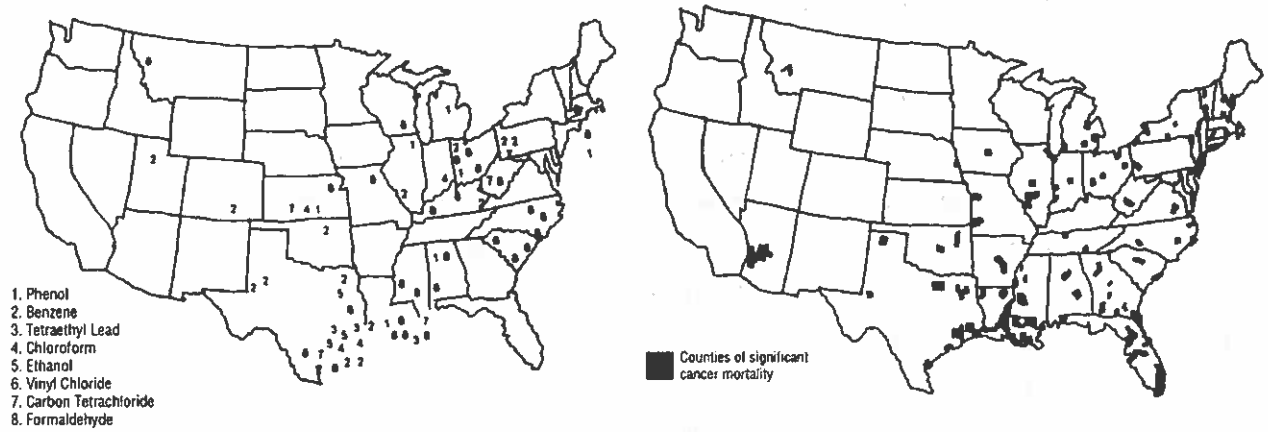


Fig. 16.2. Comparisons of CPCs and high cancer mortality rates. (Source: Goldsteen, 1993: **Danger All Around: Waste Storage Crisis on the Texas and Louisiana Gulf Coast**)

4. Does the data in Table 1 support your hypothesis or not? Explain.

5. Refineries and chemical plants are found in the coastal zone from the Texas-Louisiana border to Corpus Christi. The total cancer death rates per 100,000 people for 1995 for the coastal counties is in Table 2. Construct a bar graph of the data on a separate sheet of graph paper.

   a. Label the horizontal axis with the names of the coastal counties.

   b. The vertical axis is the number of cancer deaths per 100,000.

   c. Plot the data for the male death rates including the state average in bars. Color these bars blue.

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Table 1: Total Cancer Incidence Rates in Selected Texas Counties, 1995

	Male		Female		Male and Female	
	# Cases	Rate*	# Cases	Rate*	# Cases	Rate*
Aransas	76	477.36	53	345.99	129	406.98
Brazoria	392	459	382	378.2	774	408.02
Calhoun	49	462.29	40	341.66	89	391.35
Chambers	39	355.02	28	228.9	67	289.81
Galveston	539	482.02	474	342.68	1,013	402.31
Harris	4,978	446.38	4,832	329.22	9,810	377.17
Jackson	41	498.61	25	264.62	66	356.2
Jefferson	606	451.77	556	321.62	1,162	372.04
Kenedy	^	^	^	^	^	^
Kleberg	51	384.09	53	294.76	104	328.01
Matagorda	89	469.66	88	390.5	177	415.21
Nueces	591	437.1	552	309.36	1,143	362.16
Orange	208	484.06	175	332.62	383	394.76
Refugio	20	400.2	20	348.31	40	362.22
San Patricio	129	430.02	107	290.64	236	352.46
Willacy	38	417.88	29	262.84	67	326.32

*Rates are per 100,000 and age-adjusted to the 1970 U.S. standard.
^Statistics not displayed due to less than 5 cases.
Prepared by: Texas Cancer Registry
October 13, 1999
Data Request # 99374

Table 2: Total Cancer Incidence Rates per 100,000

Texas	Male Rate*	Female Rate*	Male and Female Rate*
All counties	443.13	313.53	367.08
Aransas	477.36	345.99	406.98
Brazoria	459	378.2	408.02
Calhoun	462.29	341.66	391.35
Chambers	355.02	228.9	289.81
Galveston	482.02	342.68	402.31
Harris	446.38	329.22	377.17
Jackson	498.61	264.62	356.2
Jefferson	451.77	321.62	372.04
Matagorda	469.66	390.5	415.21
Nueces	437.1	309.36	362.16
Orange	484.06	332.62	394.76
Refugio	400.2	348.31	362.22
San Patricio	430.02	290.64	352.46
Willacy	417.88	262.84	326.32

*Rates are per 100,000 and age-adjusted to the 1970 U.S. standard.
Prepared by: Texas Cancer Registry

d. Next to the male death rates plot the data for the female death rates. Color these bars red.

e. Next to the female death rate bar, plot the data for the combined male and female death rate. Color this bar black.

f. Label the horizontal and vertical axis.

g. Title the graph.

6. Analyze your bar graph. What patterns do you notice?

7. Compare the county death rates to the average for the state of Texas. What do you notice?

8. Compare the male and female cancer death rates. If there is a difference, what might cause the difference?

9. Tables 3 and 4 give the respiratory and thoracic cancer death rate for 1995 and 1996 for the coastal counties. Construct a bar graph of each table on separate sheets of graph paper. Refer to the steps in number 5 above to make your bar graphs.

Table 3: Respiratory and Thoracic Cancer, 1995 Death Rates per 100,000

Area	Male Rate, Deaths	Female Rate, Deaths	Male and Female Rate, Deaths
All of Texas	77.3	34.1	52.5
Aransas	114.0	27.9	68.4
Brazoria	75.1	43.2	56.4
Calhoun	85.5	37.4	59.3
Chambers	52.6	36.3	43.0
Galveston	93.3	45.1	66.1
Harris			
Jackson	86.4	41.2	59.8
Jefferson	102.8	39.8	66.0
Matagorda	113.3	45.3	74.5
Nueces	79.1	37.2	54.8
Orange	96.1	41.2	65.4
Refugio	48.3	0.0	18.0
San Patricio	76.6	27.4	49.8

*Rates are per 100,000 and age-adjusted to the 1970 U.S. standard.
Source: Texas Department of Health

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Table 4: Respiratory and Thoracic Cancer, 1996 Death Rates per 100,000

Area	Male Rate, Deaths	Female Rate, Deaths	Male and Female Rate, Deaths
All of Texas	75.1	35.0	52.5
Aransas	58.8	72.6	65.6
Brazoria	106.1	44.4	72.8
Calhoun	79.4	59.8	68.2
Chambers	105.7	25.1	62.8
Galveston	90.2	39.1	61.8
Harris			
Jackson	102.6	38.2	64.3
Jefferson	89.3	45.6	63.6
Matagorda	64.2	35.6	48.2
Nueces	68.4	41.6	52.8
Orange	120.8	67.5	90.0
Refugio	96.3	15.7	51.4
San Patricio	89.9	35.6	60.4

*Rates are per 100,000 and age-adjusted to the 1970 U.S. standard.
Source: Texas Department of Health

10. How does the death rate in the coastal counties compare to the state average? What patterns do you observe?

11. Compare the male and female respiratory and thoracic cancer death rates. If there is a difference, what might cause the difference?

12. Is there danger on the Texas Coast? Explain.

17. What Is the Impact of Building High-rise City Centers in the Coastal Zone?

Scientist(s) _____ **Team** _____

The coastal zone makes up 17 percent of the land area of the United States and is the home to 25 percent of the population. Many of the people live in inland port cities of Houston, New Orleans and the surrounding areas. In Texas more than one-third of the population is located in the coastal zone. With the increase in population, more buildings are constructed including high-rise buildings. What is the impact of constructing buildings of steel and concrete on sediments in the coastal zone? Plan an investigation to determine the effect of building high-rise buildings on coastal sediments. Use the Investigation form as a guide in planning your investigation, reporting data and summarizing your results.

A. Problem: (State your problem or describe the problem to study.)

B. Question: (State your problem as a question.)

C. Hypothesis: (Write an if...then...statement that explains what you think will happen in your investigation.)

D. Design for your Experiment:
What are your Variables? (What will you change and what will you measure?)
1. Manipulated Variable (what you will change)
2. Responding Variable (what you measure)
3. Controlled Variable(s) (what stays the same)

Materials: (Make a list of the materials you will need in your investigation)

Procedure:

Explain the steps you are going to take to investigate the question.

E. Data Collection: (Make observations and take measurements. Organize Data into charts or tables.)
Title: _____

F. Data Interpretation (Show the data collected in a graph.)
Title: _____

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G. Results (Analyze your data. Think about the data. Explain how your findings answer your question.)

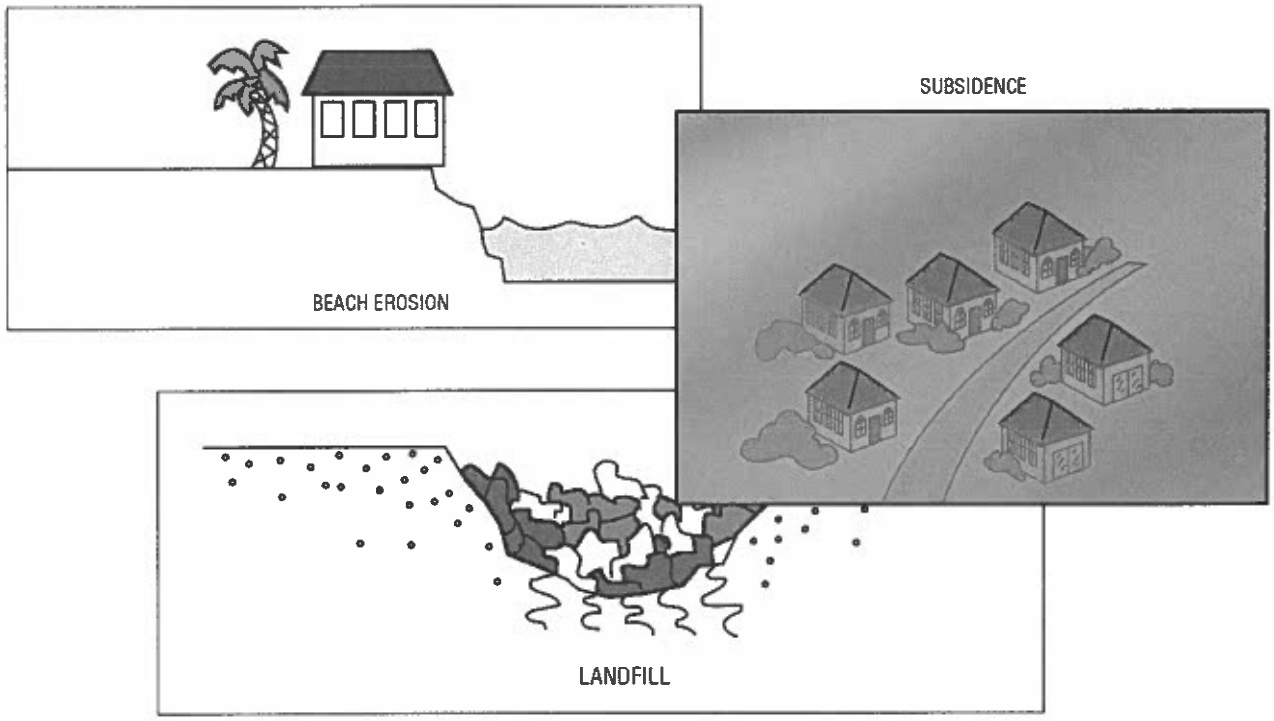
H. Conclusion: (Compare your results to your hypothesis. Explain if your results support or refute your hypothesis. Summarize your findings.)

I. Applications: (Relate or connect your results to another situation. Tell how this information can be used.)

18. What Is the Relation of the Texas Coastal Zone Problems and the Sediments?

Reporter _____ **Team** _____

The soils and sediments of the coastal zone affect the environmental problems. A reporter's role is to learn all about a topic and then prepare an article that informs the public about the problems, their causes and possible solutions. Many of the landowners and citizens of the coastal zone understand the importance of this region to the state. It is important in maintaining both a healthy economy and natural environment. You and your group will prepare an article to inform people of the issues.



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Materials: none

Procedure:

1. Using what you have learned about sediments, prepare a table of the problems related to the sand and sediments in the coastal zone. List the problems in the left column and the properties that are associated with it in the column on the right side.

Table Title:_____

Problem	Properties that are a Factor

2. Write a title for the table.

3. Use this table to create a short article to inform people about the issues in the coastal zone. Include diagrams to explain what happens.

4. In addition to informing people about the issues, what type of regulations does your team propose to prevent problems associated with the coastal zone? Research what regulations exist. Are there regulations under the Clean Water Act that apply to these problems? Contact state agencies for information. Two of the state agencies that relate to these issues are Texas Commission on Environmental Quality (TCEQ) and Texas General Land Office. The internet is a resource for information and for contacting these agencies. List what you learned about existing regulations below.

5. Use the information you have gathered and prepare a brochure which could be disseminated to citizens to inform them of the problems, causes, possible solutions and the regulations that exist.

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Topic 7 — Beaches and Dunes

Lesson Page

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   Part 1: Can the particles of sand and sediments be identified? 297
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Topic Seven: Beaches and Dunes

When one thinks of the coast, the beach is often the first coastal feature that comes to mind, closely followed by the dunes that are landward of the beach. Both beaches and dunes are found on the mainland and on barrier islands. Their features differ in each location and they serve as protection for the coast in general. The beach is the most actively changing part of the coast. Each wave moves sediments while the wind moves the sand.

People love the beach and dunes; however, this can result in problems for this fragile environment. Human activity, if not carefully regulated, tends to damage the beaches and dunes very quickly. The various ecosystems of barrier islands are best protected by limiting recreational activities that destroy dune grasses, by preventing building and general development along the dunes, by not allowing the removal of sand, and by limiting foot and vehicle traffic through the dunes to the beach. The activities in this section will investigate the composition and sources of beach sand, the formation of sand dunes, and the adaptations of organisms to live in this harsh environment. The problems arising from human activity will be addressed, as well as ways to protect and restore the beaches and dunes.

Activity 1: What is the composition of the beach sand?

TEKS: Science: 6.1, 6.2, 6.3, 6.4, 7.1, 7.2, 7.3, 7.4, 8.1, 8.2, 8.3, 8.4, 6.7, 6.14

Math: 6.4, 7.3, 6.8, 7.9, 8.8

Language Arts: 6.24, 7.24, 8.24, 6.13, 7.13, 8.13

Social Studies: 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- observe beach sand and identify the minerals and animals parts
- infer the identity and source of the particles forming the beach sediments
- measure the percentage of each type of particle in a sample
- infer the reason for differing combinations of particles on different beaches
- make inferences about the history of the samples
- apply their knowledge of sediments to solving a puzzle or mystery

Background:

1. The prior experiences of the students should include lessons on observing minerals and rocks, distinguishing between minerals and rocks, using the physical properties of minerals to identify them and identifying the different types of rocks. If the students have not had the experiences and skills listed above then plan several lessons to provide these experiences.
2. Have the students work in teams. Demonstrate and discuss the sand and sediments formed by the different rocks and minerals, including those rocks and minerals that are completely broken down and do not form sand or sediments. Ask the students what would cause the rocks and minerals to break up (weathering, wind, water, animals, wind and currents).
3. The sediments that make up the beaches, bottoms of lagoons, bays, inlets and the ocean may come from many sources. Nearly any material that can be transported by waves can form a beach. These sources include parts of living organisms such as plankton (floating plants and animals) and the benthos (bottom dwellers). The organic fragments will help identify the organisms that were present. Sources of sediments also include nonliving materials such as rock fragments and minerals from rocks. Along rocky coasts, one finds pebbles and rocks from glacial deposits and stream accumulations or rock fragments that have eroded directly from the bedrock. Rock beaches are found where few other sediments are available. The sand beaches are mainly composed of quartz. Quartz is the more resistant to being broken down than softer minerals like mica and calcite, and even feldspar will break down before quartz. The rock or mineral fragments are a key to determining the source of the sediments that form a beach, a dune, or fill in an estuary. The source of the particles can be determined by identification of the particles. The size of the particles is determined by the wave action. The higher the wave action, the smaller the particles. The composition of these sediments can provide information as to whether they are from river deposits or another source.
4. Have the students identify the animal specimens (exoskeletons, shells, skeletons, etc.) that are available. As the specimens are broken into smaller pieces, make sure that the students can identify the specimen using the smaller pieces. Discuss their descriptions and the characteristics that are critical to identification. Have the students exchange the broken specimens with other teams so that the students learn to recognize as many specimens as possible. Have the students use hand lenses to help with identification. Use stereomicroscopes or dissecting microscopes if

they are available. Encourage the students to draw and describe each specimen.

5. Provide the students with sample mixtures of rocks and animal specimens in plastic bags so they can practice their skills. Encourage the students to use their notes and drawings. Discuss how the identification of the sample could be given in percentages of each type of particle rather than just with a description.
6. You might have the teams compete to determine which team has the best skills in identifying the make-up of sand and sediment samples. Have the winning teams explain how they were able to identify the make-up of the samples.
7. Ask the students some reasons why a scientist or detective would want to know the make-up of the samples? The reasons include wanting to know the original source of the materials, where they came from, the direction of transportation and the mineral resource. All of these would help a scientist locate mineral deposits. Ask to the students to determine where the materials came from and how to use this information in determining the history of the sediments or in predicting future events.
8. Tell each group that they represent a team of detectives who will analyze the samples and use that information to determine if an individual or vehicle or object has been in a particular area. Provide the students with two samples labeled A and B. Sample A represents sand from a beach area and sample B should be from another area. Have the students examine the samples and compare them to sample X, which is the sample from the floor mat of the suspect's car and shoes. You can have sample X be the same as sample A or B or sample X could be different. Have the students use the results of their analysis to write up and present their findings about whether or not the suspect's car was at the location. You might have the students write short stories in which this information and skill at identifying the sand and sediments are the keys to solving or resolving the problem or puzzles of their stories. Or each team may create their own scenarios with samples for the other teams to solve.

Activity 2: From where did the beach materials come?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.7, 6.8, 8.10, 6.14, 7.14, 8.12, 8.14

Math: none

Language Arts: none

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- use observations to make inferences about the sources of sediment samples

Background:

1. Introduce this activity with the scenario that as scientists, students are observing the sediment samples and making inferences about the sediments. Their inferences should include information about the make-up of the sediments, original source of the sediments, and the direction from which they were transported. Discuss the differences between sediments from the rivers (contain detritus or decaying material) and those from the surf (heavier sands) or from the dunes (fine sand). The river deposits may bring in gravel or sand consisting of rock and mineral fragments from inland rock outcrops. The river deposits may also include mud and silt, depending on the river's drainage basin
2. Stress to each team that their observations should support their inferences about the samples that they observed. Have each group identify the observations that support its inferences.
3. Using a Texas highway map, have the students locate the Llano region, the Llano and Colorado Rivers, the mouth of the Colorado River, and Matagorda Island. The sediments from the Llano region would include quartz and feldspar. The currents in this area flow from the east to the west so the sediments to the south or west of the cut through which the river flows would include those from Llano, while those to the north or east would be finer and contain more silt and organic materials. The currents are carrying sediments from the Mississippi River and other rivers along the coast. The driftwood would have been carried down a river from an inland area.
4. Discuss the ways that knowledge of the make-up of sediments can be used. Mud beaches occur where there is low wave action and large quantities of fine sediments are deposited by rivers. These beaches may have a consistency much like that of yogurt. Beaches with silt and mud erode more easily. At the other end of the spectrum are gravel beaches. Most are located in northern climates and consist of pebbles and cobbles from glacial deposits or rock eroded directly from the bedrock on the shore. Sand is the main component of most beaches, and most of it is quartz. However, there are black and green sand beaches from volcanic rock. In the Bahamas and southern Australia the beaches are made of fine white shells.

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5. Have each team create a sample with a scenario for the other teams to solve. The written scenarios can be exchanged and each team would then write its explanation for the scenario. Their explanations should be based on the data provided and could also include "what if" situations if the team does not have enough data.

Activity 3: What is the effect of building seawalls and groins along the beaches?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5, 6.5, 7.5, 8.6, 6.6, 8.7, 8.10, 7.14, 8.12, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.9, 7.9, 8.9

Social Studies: 6.3, 7.8, 8.10, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- construct a model of a beach to investigate how water and sand interact
- use a model to investigate the effects of building groins and jetties on the beach and shoreline
- communicate, using diagrams, the effects of wave action on beaches and on beaches with groins and jetties
- evaluate the pros and cons of building groins and jetties

Background:

1. Have the students work in teams to create a model of the beach. First have the students analyze the wave action on the beach. A small amount of colored sand can be added to the beach sand. This will help students to observe the movement of the sand particles on their model beach better. Encourage the teams to repeat the activity until they can explain and sketch the wave interaction on the beach. They should try to answer the following questions. Where do the waves have the greatest energy? Where do the waves have the least energy or impact? How do the currents move? Where is erosion occurring? Where is deposition occurring? Each team can present its findings and an explanation can be developed through class discussion about wave interaction on a beach.
2. Humans try to impose their will on the coastline by (1) interfering with the longshore current's transportation of sand, and (2) by redirecting wave energy striking a stretch of shore. This intervention occurs by building jetties and groins perpendicular to the shoreline. Jetties are built to prevent or, at the very least, to slow the deposition of sediments at the mouth of harbors, estuaries and tidal inlets. Groins are smaller and cheaper to build than jetties. They are positioned on eroding beaches to trap sand and to increase the buildup of sediments. A second strategy to control shorelines and protect beaches, roads and bluffs from erosion is to redirect wave energy away from sites that are eroding by building seawalls on shore. Breakwaters are barriers built in front of harbors or shorelines. They are built offshore and parallel to the beach or harbor mouth.
3. Discuss how groins, jetties and seawalls are built along the beaches. Divide the class into teams and have each team construct a model to analyze the effect of building one of the following: groins, jetties, seawalls or breakwaters.
4. Encourage the teams to repeat their investigation of the effect of their constructions on the beach and answer the questions in number one. Each team will present its findings to the class using diagrams and actual demonstrations with the model. Class discussion should include some of the following information.

   Groins are positioned on eroding beaches to trap sand artificially and to promote the buildup of sand. They are dams that trap sand instead of water. They trap sand on the updrift side (the side on which the current flows against or into the groin) and increase erosion on the downdrift side (the side on which the current flows away from the groin). They can be dangerous to swimmers since deep holes are scoured out on the seaward ends. They also deflect the longshore current, causing rip tides. Jetties are built to decrease or prevent the buildup of sediments at the mouth of harbors, estuaries and tidal inlets due to the longshore drift of sand. The flow is channeled between jetties, which increases the current speed at the inlet. This prevents the deposition of sediments and can result in a deepening of the channel. Jetties will cause a buildup or accretion of sand on one side of the jetty and erosion on the other side of the inlet. The side on which the sand builds up may exceed the length of the jetty and spill into the inlet. The inlet then must be dredged to remove the sand. Breakwaters are designed to absorb the pounding of the waves and to reflect the waves back to the sea. However, the quiet water behind the breakwater stops the flow sediments and causes sediments to build up. Further down current from the breakwater, erosion takes place since the sediments are not being replaced. The turbulence of the water increases in front of seawalls. This increases the erosion of sand and causes the beach at the base of the seawall to become narrower. Eventually there is no beach and the water begins to erode the seawall. All

of these structures are expensive to build and maintain.

5. Discuss the pros and cons of building structures on the beach. Challenge the students to suggest alternative solutions.

Activity 4: Open beaches vs. gas drilling?

TEKS: Science: 8.14

Math: none

Language Arts: 6.11, 7.11, 8.11

Social Studies: 6.20, 7.20, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- evaluate the pros and cons of drilling for oil or gas on a Gulf beach
- make a decision on the issue of whether or not to drill on the beach

Background:

1. Oil and gas reserves are found under the Gulf of Mexico and some are so close to shore so that the wells can be drilled on land. Have the students read individually about the problem. Have them list the pros and cons of supporting the proposals. Then ask them to decide what their position would be.
2. Discuss the problem as a class. Stress that there are many problems related to the beach and there are no easy answers. Have the students search for other problems to present to the class. Then present them, identify the pros and cons, and make decisions.

Activity 5: How do sand dunes form?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 8.5, 6.6, 8.6, 8.7, 7.14, 8.12, 8.14

Math: 6.6

Language Arts: 6.6, 7.6, 8.6, 6.9, 7.9, 8.9

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- formulate and test a hypothesis describing the relationship between particle size and sand dune formation
- construct a model to investigate sand dune formation and identify the parts of sand dunes
- construct a model to show the effects of the types of wind on sand dunes
- design and conduct experiments to investigate the effects of plants, construction, and waves on sand dunes
- identify and control the variables involved in investigating sand dune formation and the effects of factors on dunes

Background:

1. Note that sand dunes are an important part of many coastal areas. They are large piles of sand that have accumulated by processes, shapes and patterns similar to those of dunes found in inland deserts. All dunes require wind and a supply of sediment. On the coast, the limiting factor may be an inadequate supply of sediments. Coastal dunes are not restricted to barrier islands. Coasts without barrier islands can have large dune fields. Before each team creates its model of a sand dune, ask members to predict which factors affect sand dune development. Each team can create models of dunes to determine which sediments work best. Also have the team determine whether sand can be moist or whether it must be dry to form dunes.
2. Have the students compare sand dune formation to running water. Like running water, wind drops its load of sediment when its velocity drops and the energy available for transport drops. The sand begins to accumulate where an obstruction across the path of the wind slows the movement of the air. The sand is deposited in mounds or ridges that form dunes. When the moving air encounters an object, such as a clump of vegetation or a rock, the wind sweeps around and over it. This leaves a shadow of more slowly moving air behind the obstacle as well as a smaller zone of quieter air just in front of the obstacle. Some of the sand grains come to rest in these zones. As the accumulation of sand continues, it forms a barrier to trap even more sand. If there is a sufficient supply of sand and if the wind blows steadily, the mound of sand becomes a dune. Wind causes the sand grains to move by rolling, skipping, bouncing and jumping along the ground. The particles are driven up the gentle slope of the windward side of the dune. Sand that accumulates beyond the crest slumps down the steeper leeward side. The angle of the leeward side of the dune is about 34 degrees. If it is steeper, gravity causes the sand to slump. Continued sand accumulation with slides down the leeward side result in the slow migration of the dune in the direction of the wind movement. As the sand slides down the leeward side, or slip face, it forms layers inclined in the direction the wind is blowing. When dunes are buried under layers of sediment and become part of the sedimentary rock record, these cross beds remain. The cross beds provide geologists with the wind direction when they were formed.
3. Using the information from the investigations of sand dune formation, have each team create a model of a series of sand dunes along a shoreline.

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This model will be used to design and complete an investigation to determine the impact of various factors on the dunes. Assign each team one of these factors to investigate: the presence of plants, the absence of plants, construction of buildings and existing sand dunes. Each team will present its findings to the class using diagrams or a demonstration.

Activity 6: What is the effect of wind on sand?

TEKS: Science: 6.2, 6.3, 6.4, 7.2, 7.3, 7.4, 8.2, 8.3, 8.4, 8.6, 6.6, 7.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.10, 7.10, 8.10

Social Studies: 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- formulate and test a hypothesis describing the relationship between the size and movement of sand particles
- formulate and test a hypothesis describing the relationship between wind types and the movement of sand
- make predictions about the effect of wind blown sand on sand dunes, plants, animals, people, and structures built by people

Background:

1. Have each team develop its hypotheses about the relationship between particle size and the distance particles are moved. Then have teams conduct their investigations and summarize their findings.
2. Create a three-column table. List the different types of wind in the first column of the table. In the second column, students will write their hypotheses about the effect of each type of wind on the sand and sand dune. In the third column they will list the results of their experiment with each type of wind. Coastal dunes are best developed along shores that have moderately strong winds of 15-30 knots, persistent onshore winds and gradually sloping beaches. Hurricane force winds can move and scatter the sand, destroying dunes. Under storm conditions, dunes can be eroded by waves. Coastal dunes act as natural "sea walls" that effectively prevent widespread flooding of the interior of barrier islands during severe storms or extreme high tides.
3. Ask students to predict the impact of the wind's movement of sand on beaches, sand dunes, plants, animals, people and structures. Each team can design and conduct an experiment to determine whether its prediction was correct.

Activity 7: Why are dunes along the Texas coast different?

TEKS: Science: 7.5, 6.6, 8.10, 7.14, 8.12, 8.14

Math: 8.5, 6.10, 7.11

Language Arts: 6.9, 7.9, 8.9, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- formulate a hypothesis explaining the variation of sand dunes along the Texas coast
- use climatic data to explain the difference in sand dunes

Background:

1. Have each team develop its hypotheses to explain the differences in sand dunes along the coast. Graph the climatic data and determine if any climatic factors are related the differences in dune formation.
2. In the counties closer to Louisiana, the sediments consist of more silt and mud. More vegetation is found in the beach areas, protecting the sediments from being moved by the wind. The amount of sand for dunes is limited. Also the rainfall is higher, so the sand is wet and wet sand isn't readily carried by the wind. As one moves along the coast from Galveston to Port Isabel, the climate becomes drier, so the sand can be moved by the wind and there is less vegetation to prevent the wind from transporting the sand. The larger dunes are found in the dry areas where there is limited vegetation.

Activity 8: Does water move in sand dunes?

TEKS: Science: 6.3, 7.3, 8.3, 6.2, 7.2, 8.2, 6.4, 7.4, 8.4, 8.5, 6.7, 7.11, 8.8, 6.12

Math: 6.8,7.9,8.8

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20, 6.9, 7.9, 8.9

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- conduct an experiment to determine if water moves in sand dunes
- measure the rate of movement of water in sand dunes
- communicate through drawings how water

moves in between sand particles

- use the concepts of capillary movement, adhesion and cohesion to explain the movement of water in sand dunes

Background:

1. Ask each team to develop its hypotheses about how plants and animals survive in sand dunes. Students should then conduct the investigation to determine if water moves up in sand to provide water for plants and animals.
2. The pore space is determined by the degree of particle packing. This affects the water level in the sand. The level is highest in fine sand. Capillary action enables the water in the sand to be above sea level. Sand above the water level is damp due to the adhesion of water to the sand particles and to the presence of water vapor in the spaces between particles. The presence of a water table in the sand is important to animals living away from the surf zone. By burrowing, they can reach wet sand to protect themselves from desiccation (drying out).
3. Have each team share its sketches of the movement of water in sand with the class. Two or three teams can work together to prepare a skit to illustrate the movement of water through the sand. In their presentation they will need to explain and demonstrate capillary movement, adhesion and cohesion. They might include information on how these help animals to survive and plants to grow in the dunes.
4. As an extension, have the teams test different types of sand to determine the rate at which water moves in each.

Activity 9: How do organisms survive the sandy beach and dunes?

TEKS: Science: 6.2, 7.2, 8.2, 6.3, 7.3, 8.3, 6.4, 7.4, 8.4, 6.9, 8.10, 6.10, 6.12, 7.11, 7.12

Math: (if graph is made, then 6.10, 7.11)

Language Arts: 6.9, 7.9

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- hypothesize how animals can survive harsh conditions on the beach
- conduct an experiment to investigate the effect of temperature on the beach
- measure the temperature in different depths of sand
- conduct an experiment to determine how animals burrow into the sand
- analyze the adaptations of organisms that live in the beach sand

Background:

1. After describing the conditions on the beach, ask each team to determine how members might survive if they were a clam or a crab on the beach. Each team can conduct the investigation to determine the temperature on the surface and under different depths of sand. Even a few millimeters of sand will protect animals against the hazards of exposure to the sun's rays. An animal can burrow a few centimeters into the sand and survive intolerable surface temperatures. With the pore space averaging 20 percent of the total volume of the sand, it is a good insulator. The salinity is relatively constant a few centimeters beneath the surface. Therefore an organism can survive a period of runoff after a rain or a drought.
2. Ask the students during what time of the day would they expect to see animals if they were walking on a beach. Discuss their reasons. Ask students who have been to the beach if their observations support this.
3. Since burrowing in the sand is how animals survive, ask the students what type of effort this would take. Investigate burrowing into sand. A phenomenon called thixotropy is a physical aspect of sand that is important to burrowing animals. Thixotropy is the ability of a gel to become liquid when stirred. So seemingly solid wet sand in the surf zone will "liquefy" if agitated. An animal's burrowing movements are all that is needed to liquefy the sand and allow an animal to quickly dig into the sand.
4. Ask the students to sketch a crab and a clam that would be designed to burrow into the sand. Compare their sketches to those of a bean clam and a mole crab (both are burrowing animals). Their bodies are streamlined and smooth for burrowing into the sand. Discuss how the streamlined and smooth surface is beneficial to burrowing.
5. Point out that some animals make permanent burrows in the beach sand of the surf zone. Ask the students to design a burrow that would survive in the surf. Provide students with small pieces of materials (plastics, sand, crushed shells, etc.) to make their burrows and test them. The few animals that make permanent burrows do so by building tubes or using mucous to strengthen the sand.
6. Ask the students if they have been to the beach and seen a vehicle get stuck in the sand. Ask them to describe what happened. Explain why, as the

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vehicle's wheels moved in wet sand, it became more stuck. Discuss how to get a vehicle out if they get stuck in wet sand.

Activity 10: How do beaches and dunes protect the Texas coast?

TEKS: Science: 6.5, 7.5, 8.6, 6.6, 6.8, 8.11, 6.12, 6.14, 7.14, 8.12, 8.10

Math: 6.8, 7.9, 8.8

Language Arts: 6.9, 7.9, 8.9, 6.6, 7.6, 8.6, 6.10, 7.10, 8.10, 6.24, 7.24, 8.24

Social Studies: 6.3, 7.8, 8.10, 6.6, 7.9, 6.7

Learner outcomes: After completing the activities, the students will be able to:

- identify the different areas of the beach and dunes
- identify the areas which are "public" and the dune protection line
- diagram the water and sand cycle on the beach
- interpret data to explain the effects of storms and human activities on beaches and dunes
- propose action that should be taken to prevent beach and dune destruction

Background:

1. Discuss why an understanding of the natural processes of the beaches and dunes is needed. Ask why scientists, landowners, county and city officials, industry, businesses and citizens must understand the natural processes and must all be involved in planning.
2. Divide the two readings (The Beaches and Dunes, The Water and Sand Cycle) among the teams. The team reading "The Beaches and Dunes" can concept map or outline the key points in the article and create a skit to demonstrate the main points of the article. The team reading "The Water and Sand Cycle" can concept map the cycles or create a role-play to illustrate the movement of the water and sand on the beach. Other teams may be assigned to communicate and demonstrate the impact of storms or hurricanes, including washovers and washouts. Another team will be assigned the demonstration of a blowout, while another is to demonstrate the impact of human activities. These demonstrations can be presented to the class. Create a cross section of the beach and dunes on newsprint or the chalkboard for the teams to refer to during their presentations.
3. After the presentations, each team will discuss what happened to the beach and dunes as a result of human activities. In Part III, assign one action for each team to analyze. The team should sketch what will happen as a result of the activity and develop a proposal for action that should be taken. Each team will present its findings and proposal to the class. The class can approve, modify or reject the proposal.
4. Human activity, if not carefully regulated, tends to damage the dunes. Foot traffic can destroy grass that stabilizes the dune and thus make it susceptible to wind erosion. Dune buggies are particularly harmful, because they destroy the vegetation cover that keeps the sand in place. This can lead to large blowouts. Blowouts are breaks or deep depressions in the dune ridge that occur when the dune's vegetation cover had been destroyed. The blowouts can deepen and widen rapidly and lead to the destruction of the dune itself. Also, storm water can surge through the blowouts, transporting sand from the beach and forming washover fans in the backshore area of the barrier island.

Activity 11: How can sand dunes be protected?

TEKS: Science: 6.2, 7.2, 8.2, 7.3, 8.3, 7.4, 8.4, 9.4, 8.5, 6.6, 7.5, 7.14, 8.12, 8.14

Math: none

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.24, 7.24, 8.24

Social Studies: 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- design and conduct experiments to investigate dune stabilization
- construct a model of sand dunes to investigate the best method for rebuilding dunes

Background:

1. Discuss the problems of dune and beach erosion. Each team will be a task force to investigate the effect of different items in the stabilization of the beach. Encourage the teams to conduct a series of investigations, trying the items in different locations to determine where they work best.
2. Each team will analyze its findings and make recommendations that include sketches for stabilizing the dunes. Each team will create a model to test its recommendations for stabilizing and rebuilding dunes.
3. After conducting the tests to determine what works best, ask each team to create a Beach Access and Dune Protection brochure. A contest might be held to determine which teams create the best brochure.

Activity 12: Which plants should be used to restore Texas coastal dunes?

TEKS: Science: 7.14, 8.14, 8.11, 7.11

Math: none

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.22, 7.21, 8.30, 6.23, 7.23, 8.32, 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- analyze and explain the purpose of the rules for planting in sand dune areas
- use data concerning plants for coastal dunes to develop a plan for planting in a selected coastal county

Background:

1. Assign each team a rule or two to analyze and ask members to explain the importance of the rule to the class. Because of the fragile sand dune environment, federal, state and local laws and regulations have been developed to guide beach and dune rebuilding. This is to avoid more damage to this environment. Before beginning any beach or dune restoration, one needs to be aware of all laws and regulations. Dune and marsh plants are not available commercially in Texas and must be transplanted from nearby natural areas. Permission must be obtained to harvest plants. The best time to transplant the plants will vary because the climate varies along the coast. The best time is in cooler weather. When plants are transplanted they should only be taken from natural areas where erosion will not occur. Taking plants from an area susceptible to erosion will only create another area with problems. To prevent erosion in the harvest area, the plants should be removed in a scattered pattern and should not be removed in less than two-foot intervals. The plants should be dug out with a shovel so that the roots remain intact. Pulling out the plants often leaves part of the plant behind or results in damage to the plant. To prevent the plants from drying out, they should be planted after a rain or else the dunes will need to be watered before transplanting. Mulch should be placed around the transplanted plants to retain the moisture in the sand and to prevent wind from eroding the sand. Cutting dune grasses can result in their being buried by the sand, in addition to damaging them. Vegetation has a profound influence on the development of dunes. Dune plants are salt tolerant, have a deep root system in order to tap ground water, and have the ability to withstand being buried in sand. Grasses and bushes tend to cause the windblown sand to be deposited. This promotes the growth of dunes. Problems occur when the natural vegetation cover had been destroyed.
2. Assign each team one or two counties and ask members to develop a plan for replanting the dunes in that area. Stress the use of plants adapted for the county and the need to plant them in the appropriate region of the beach or dune for which they are adapted. Each team will present its plan to the class along with the basis for their plant selection.

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1. What Is the Composition of Beach Sand?

Scientist(s) _____ **Team** _____

You are going to be a detective. You will analyze sand and sediments found in the coastal zone. These samples may be from the beach, dunes, bays or soils of the coastal zone. Each sample has its own story. A detective uses observation to learn the story of each sand or sediment sample. The sand and sediment that makes up beaches, bottoms of bays, estuaries and oceans may come from many different sources. It may consist of different combinations of organic (shells, skeletons) and inorganic (quartz, feldspar) materials. Anything that does not decay can be deposited in the sand and sediment layers. In analyzing sand and sediment from different places, you can learn a lot about the organisms and the area. The challenge is to be able to identify the make-up of the sediment from the bits and pieces. Can you use your observation skills to detect pieces that came from animals from those that came from rocks and minerals? Scientists learn this skill by making their own samples to compare with the unknown samples they are studying. A detective in an investigation will use the same skills to determine if the sand found in a car or on a suspect's shoes is from a crime scene. You are going to make your own samples to use to help you develop this detective skill.

Materials: shells, dried starfish, sea urchins, crabs, fish bones, fish scales and other similar marine organisms which would leave some "hard parts" when dead; rocks and minerals, rock hammer, goggles, ruler, hand lens, dissecting microscope, graph paper, petri dishes, socks or pieces of material

Procedure:

Part 1: Can the particles of sand and sediments be identified?

1. Obtain small samples of different minerals (quartz, feldspar, etc.) and rocks (granites, gneiss, schist, marble, sandstone, limestone, etc.). Observe each mineral and rock sample. Break the samples into smaller and smaller parts. Make sure that you can identify the specimen using the smaller pieces. Record your observations in your data table. Use a hand lens as needed. Always wear goggles when breaking the rocks into smaller pieces. Wrap the item to be broken in a piece of material or in a sock. Use the rock hammer to break it into smaller pieces.

2. Obtain animal specimens (dried shells, crab shells, fish bones, fish scales, any organisms that have hard parts that do not decay). Break the specimens into smaller and smaller parts. Make sure that you can identify the specimen using smaller pieces. Construct a table similar to that on the next page and record the descriptions. Use a hand lens as needed.

3. Break the samples into even smaller parts and use a dissecting or stereomicroscope to observe the small parts of each sample. Record your observations in Table 1. Determine ways to distinguish between the living parts and the nonliving parts using your observations.

Table 1: Observations of Pieces of Organisms and Minerals

Organism, Rock or Mineral Samples	Description of smaller pieces	Sketch of smaller pieces	Sketch of smaller pieces with hand lens
1.			
2.			

4. Practice testing your observation skills by combining specific specimen pieces, rock and mineral specimen pieces as a mixture in a small cup to practice your skills. Report each specimen not just by description but also in percentages. To determine the percentage by placing the pieces in a petri dish which can be placed over graph paper. Sort each type into a group together to determine what number of the squares are covered. To determine the percentage divide the squares covered by a particular type of rock or mineral by the total squares covered.

Part II. What can we learn from the composition of sediments?

1. What would cause shells, skeletons, and other hard animal parts to break up?

2. What is the smallest size piece from which you could identify a specimen? Does the type of specimen (shell, skeleton, etc.) make a difference in your being able to identify the smaller pieces? Explain.

3. What would cause the rocks and minerals to break up?

4. What is the smallest size piece of rock or mineral you could identify?

5. Which is more difficult to identify, the rock or mineral pieces? Explain why.

6. How do you distinguish between organic (materials which were once alive) and inorganic pieces (which were never alive)?

7. Why does the percentage of shells and inorganic materials differ along the beaches?

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8. What would be some reasons why a scientist or detective would want to know the make-up of the sand and sediments? What information could the samples provide?

9. Obtain the sample of sand from the unknown beach. Examine it carefully. Use your skills to describe the specimens which make up the unknown sand. Determine the percentage of each specimen present in the sample. Construct Table 2 and record your results

.

   a. What inferences can you make about the source of the materials?

   b. The history of the sample?

Table Two: Observations of Mystery Samples of Sand

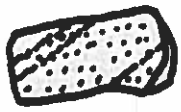
Sample	Description of Sample	Specimens in Sample	Percentage of each Specimen
Unknown sample			
Sample A			
Sample B			
Sample C			

10. Obtain samples A, B and C. Your team has been asked to analyze these samples: A whooping crane was found dead on a beach, presumably hit by a car. Sample A is from the site where the whooping crane was killed. Sample B is taken from the suspect's car floor mats and Sample C is from the floor of the trunk of the suspect's car. Make your observations and record the data in Table 2. Use this information to make your case to a jury as to whether the suspect had been to the beach where the dead bird was found. Write up your presentation.

2. What Is the Source of the Beach Materials (Sand and Sediments)?

Scientist(s) _____ **Team** _____

You have used your skills to determine the make-up of sand and sediments. Nearly anything that can be transported by waves can form a beach. The materials that are available will be included as long as they can be carried to the beach and remain there, at least temporarily. For example, mud is not a common component of a beach. If it is the dominant sediment available from the rivers when the wave action is low, then the mud can collect in large quantities on a beach.


Sandstone


Breccia


Shale


Gravel

Given the right conditions, gravel particles of any size and composition can be a common beach component. All that is needed is an easily available source of rock fragments and high wave action. These generally occur along rocky coasts and in the northern latitudes. Many of the gravel beaches related to barrier islands are composed of gravel-sized shells.

Remember the heavier sands will stay in the surf; lighter ones are carried up to the dunes; sand with pieces of detritus (decaying materials or leaves) may come from a river; mud and very fine sediments are from very muddy slow moving rivers; and pure sand that is bought is already sorted. The waves and related processes arrange the sediments on a beach in such a way that at any one place the sediment particles are more or less the same size. This phenomenon is called good sorting. Try your detective skill and observe each sample closely for clues as to its source.

Materials: samples of different types of sand and sediment, hand lens, or dissecting microscope

Procedure:

1. Closely examine each sample. Construct Table 1 and record your observations.

2. Use your observations to make an inference about the source of each sample. An inference is an explanation or interpretation of what you observe. Record your inference in Table 1.

3. Look at the inferences you made. Think about which observations, prior knowledge and experiences are supported by your inference. List these in Table 1 next to the inference.

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4. Using your observations and inferences, identify a possible source for each sample of sediments.

Table One: Observations and Inferences about the Sand

Sample Number	Observations	Inferences	Observations that Support Inference Listed	Possible Source

5. What conclusions can you make about the sources of your samples?

6. What are some ways the knowledge of the make-up of the sand and sediments could be used? How could this information be used by each of the following:
   a. Police detectives –

   b. Builders –

   c. Oil company geologists –

   d. City planners –

   e. Beachfront home owner –

   f. Others –

3. What Is the Effect of Building Seawalls and Groins along the Beaches?

Engineers(s) _____ **Team** _____

Like many areas valued for their natural beauty, the dunes and beaches are threatened by increased human activity. It is ironic that by moving to an attractive location, people often end up destroying much of what attracted them there in the first place. There is no greater threat to the coast than development. Dunes are removed to build houses, condominiums, hotels, shopping centers, and even roads. Dunes are not only removed for construction but also to provide access to the beach or a better view of the water. As dunes are destroyed, the normal beach development is interrupted. Erosion problems develop. Engineering solutions are sought. Protective walls of concrete, steel, or rock are often built to try to solve the problem. The Galveston seawall is an example. Seawalls and groins are often built to protect the beach and dunes behind them. You and your group of engineers are asked to investigate the effect of building sea walls, jetties, and groins along the beach. Can you explain why the Galveston seawall protects the city but the sandy beaches have disappeared?

Materials: Plastic tray or pan or stream table, sand, water, board or cookie sheet, small pieces of wood or metal (popsicle sticks or strips of hard plastic)

Procedure:

1. Create a model of a part of the coast. At one end of the pan or stream table, add sand to create a beach that slopes to the water. Add water to the pan, deep enough to cover half the sand.. Now take the board and place it near the end of the pan so that it touches the bottom of the pan. Gently move the board back and forth to create small waves. See Figure 3.1.

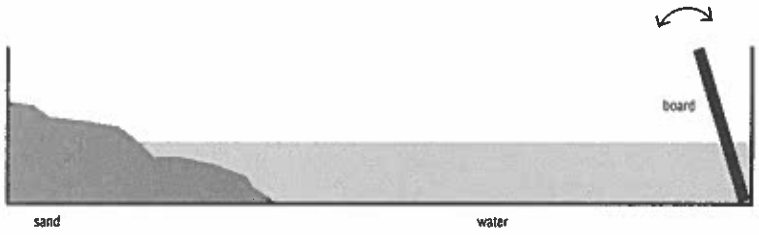


Fig. 3.1.

2. Observe how the water and sand interact. Describe what happens.

3. Reread "The Water and Sand Cycle on the Beach," which is in the activity "How Do the Beaches and Dunes Protect the Texas Coast?" Do the sand and water interact as described in the reading? Explain.

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4. Place two pieces of wood or metal perpendicular to the shoreline in the pan to represent groins. See Figure 3.2. Place the board in the corner of the pan so that when it is moved it will move the water perpendicular to the shoreline. The flow of water along the shore creates littoral drift. The littoral drift is the movement of sand caused by water as it moves back into the Gulf. Gently move board back and forth. Observe and sketch what happens to the sand along the groins. Does the sand remain in place or move?

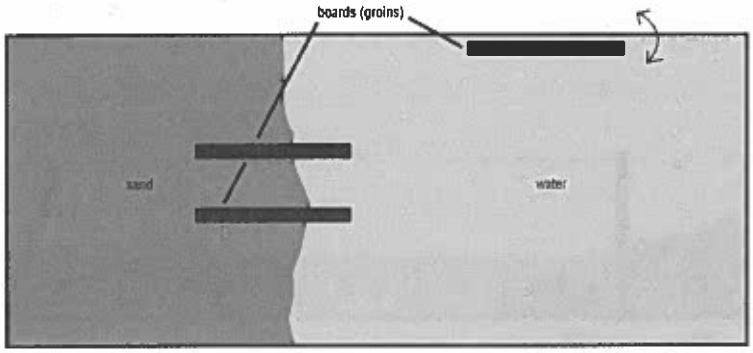


Fig. 3.2

Where is sand being deposited? Or where is a beach being built? Where is sand being eroded away?

5. Using the pan or stream table, create a model of an inlet with jetties built on both sides to keep the inlet open for shipping. Create an inlet to a bay or the mouth of a river in the sand. Place two pieces of wood or metal on each side of the inlet perpendicular to the shoreline in the pan. These will represent jetties. See Figure 3.3. Place the board in the corner of the pan so that when it is moved it will move the water perpendicular to the shoreline to demonstrate the littoral drift along the shoreline. Gently move the board back and forth. Observe and sketch what happens to the sand along the jetties.
Where is sand being deposited? Or where is a beach being built? Where is sand being eroded away?

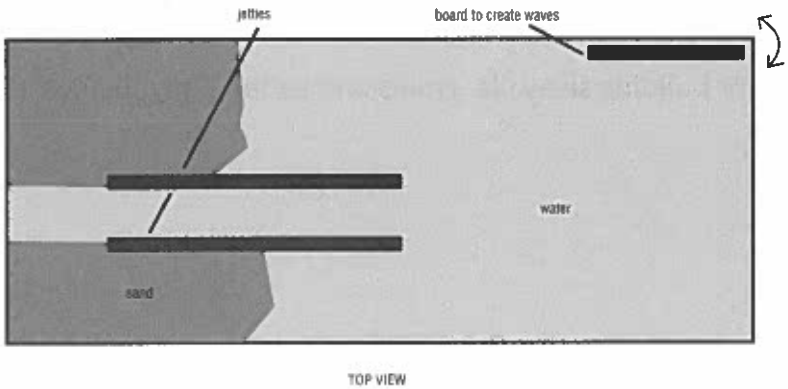


Fig. 3.3

6. The most drastic measure to protect property is the construction of seawalls, rigid masses of rock and concrete built parallel to the shoreline to take the impact of waves. To study the effect of s seawall on erosion, use the pan or stream table. Smooth the sand into a gentle slope to create a beach on one end. Place the strip of wood to make the sea wall in the sand 5 cm to 7.5 cm from the edge of the water to make a seawall. See Figure 3.4. Now take the board and place it near the end of the pan (parallel to the beach) so that it touches the bottom of the pan. Gently move the board back and forth to create small waves.

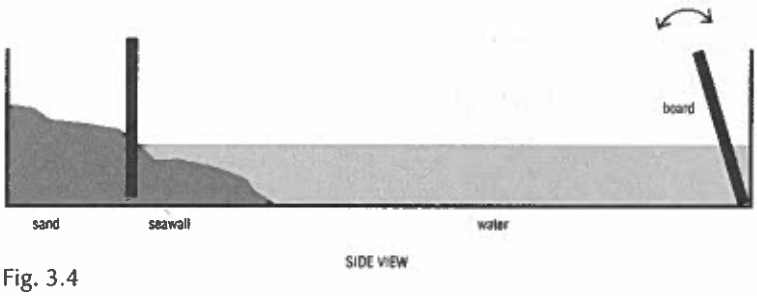


Fig. 3.4

7. Observe and sketch what happens to the sand in front of your seawall.

8. The Galveston seawall was built after the 1900 hurricane that submerged the island and claimed 6,000 lives. The seawall has protected the city, but the sandy beach in front the seawall is gone. Why? Use your findings to explain what will happen where seawalls are built.

9. Prior to 1900, the residents of Galveston Island removed the sand dunes for a better view of and access to the water. Explain the statement "Sand dunes are much better protection from erosion than sea walls." Do you agree or disagree? Why?

10. List three pros for building seawalls, groins and jetties along the coast.

11. List three cons for building seawalls, groins and jetties along the coast.

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4. Open Beaches vs. Gas Drilling?

Citizen(s) _____ **Group** _____

Boca Chica Beach is a seven-mile stretch of sand that extends south from South Padre Island to the mouth of the Rio Grande River. See Figure 4.1. Cameron County has banned heavy commercial trucks from the beach, which stops 18-wheelers from driving on the beach. Cars and pick-ups are still allowed to drive on the beach. The county says that big trucks are too dangerous for people using the beach. This is a beach that is used by families. They also believe that the trucks will damage the beach. The county claims there is an exception in the open beaches law if public safety is at stake.

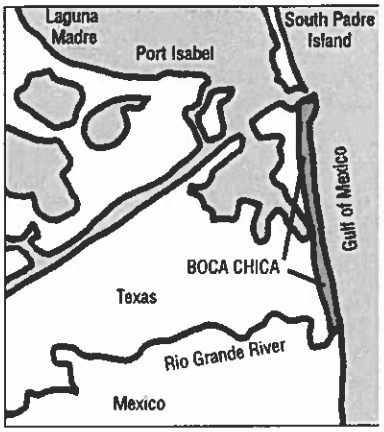


Fig. 4.1. Boca Chica (Source: Based on Austin American-Statesman, Feb. 23, 1999)

An oil company is planning to drill for natural gas near the popular South Padre Island Beach. The company won the bid for the state gas lease. The company wants to use "directional drilling" to drill at an angle. They would drill from the shore to what the company hopes is natural gas below the floor of the Gulf of Mexico. They plan to build the drilling rig away from the beach. The company claims the best way to reach the drilling rig is to drive along the beach. The oil and gas royalties from the leases under the Gulf of Mexico go into a trust fund for the public schools. Therefore, the company stresses that school children of Texas would benefit from the gas well.

Some state officials believe the Texas Open Beaches Act allows public access to Texas beaches and that the county's banning of heavy trucks is against the law. They feel the county does not have the right to restrict traffic on the beaches.

Another group of citizens opposes the company's drilling for gas. They feel that drilling and 18-wheelers will damage the beach and the dunes. This could affect the vegetation, wildlife and the dunes and could result in beach erosion. In addition, opposing groups do not want to see drilling rigs affecting the view from the beaches and sand dunes.

1. Should a county should be allowed to ban heavy commercial trucks, vehicles or equipment on beaches in their county?
   a. List reasons for supporting the banning of vehicles.

   b. List reasons for allowing commercial vehicles on the beaches:

   c. Write your decision on a separate piece of paper.

2. Should oil and gas companies be allowed to build drilling rigs behind the sand dunes along the Texas coast?
   a. List your reasons for supporting the building of drilling rigs.

   b. List your reasons for banning the building of drilling rigs within sight of the beaches and sand dunes along the Texas Coast.

   c. Write your decision on a separate sheet of paper

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5. How Do Sand Dunes Form?

Scientist(s) _____ **Team** _____

Have you ever been to the beach and seen the sand dunes? Have you climbed a sand dune? What were dunes like? Sand dunes are an important part of many coastal areas including the Texas coast. They are large piles of sand that have accumulated. The processes, shapes, and patterns of coastal dunes are similar to those of dunes found in inland deserts. How do they form?

Materials: sand, very fine sand and silt, shoebox or tray, straws or small fan, toothpicks, yarn or string, plant pieces, goggles, protractor

Procedure:

Part I: Which particles form the best dunes?

1. As scientists do, you will conduct investigations to learn the mysteries of sand dunes. How do they form? What affects their shape? Why are some larger than others? What will your team need to form sand dunes and discover how they have formed?

2. How can you create a model of a sand dune? What factors will affect the development of sand dunes?

3. Wear your goggles as you conduct your investigations. Create your sand dunes by placing a small quantity of fine sand in plastic shoebox or tray. Blow through a straw or use a small fan to simulate the wind. Blow the sand into a dune shape. Add more sand. What was the most effective way to create a sand dune?

4. Use a small quantity of silt. Blow the silt into a dune shape. Describe what happens.

5. Use sand of different size particles to make sand dunes. What type of sediment is needed to form sand dunes on a beach? Why?

Part II: How does a dune form?

1. While one person blows to create the sand dune, watch what happens from eye level? What happens as the dune gets higher?

2. Observe what happens to the sand on each side as you blow across the dune. Draw the dune's shape in profile below (side view). The side you are blowing towards or the side the wind is blowing against is called the windward slope. The opposite side is called the

leeward side. The top of the dune is the crest. Label the crest, windward and leeward slopes on the drawing of your sand dune.

a. What happens to sand grains at the top of the crest?

b. Which side has the gentle slope?

c. Which side has the steeper slope?

d. The leeward side is known as the slip face. Observe what happens to the sand, why do you think it is called slip face?

e. Where does the wind-blown beach sand accumulate? On the seaward or landward side?

3. Determine the angle of the dune by placing a protractor at the base of the dune and measuring the angle of the windward side and the angle of the leeward side.
   a. What is the angle of the windward side?

   b. What is the angle of the leeward side?

   c. What happens when the dune is steeper than 34°, its critical angle?

4. Sketch a series of drawings in sequence to illustrate how a dune is formed.

5. How would you create a row or series of dunes?

6. What is your inference about the effect of the type of wind on sand dunes?

7. What type of wind would help build the sand dunes and what type would erode away sand dunes?

8. On a separate page, write a paragraph summarizing what is needed for the formation of sand dunes and how they form. Include sketches.

9. What do you think will happen if the wind changes directions?

10. To find out, add another colored fine sand at the base of the dune and blow across the dune. Record your observations below. Blow sand on to the dune from a different direction. Blow from another side. What do you notice? Can you tell the direction of the wind from the way the sand was deposited?

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Part III: Can you apply your knowledge of dune formation?

1. Since wind-deposited layers are angled, how could a scientist use this information to determine the direction of the winds in ancient sedimentary rock formed from cemented sand dunes? Use sketches to illustrate your explanation.

3. It has been stated that sand dunes are a natural barrier to the destructive force of wind and waves. They are the least expensive and most efficient defense against storm-surge flooding and beach erosion. Explain why this is true.

4. Conduct an investigation to determine the effect of plants on the sand dunes. Place one or two pieces of string or yarn (representing plants) on your dune and pieces of plants to represent planted beach grass. Blow sand across the dune. Note the effect of plants on dune movement. Describe what you observed.

5. What will be the effect of any type of obstruction, including plants, existing sand dunes or human construction such as buildings or seawalls on the movement of sand? Plan an investigation to determine the effect.
   a. Question:
      (State your problem as a question.)

   b. Design your experiment:
      What are your variables? (What will you change and what will you measure?)

   c. Materials:
      (Make a list of the materials you will need in your investigation.)

   d. Procedure:
      (Explain the steps you are going to take to investigate the question. Use illustrations.)

   e. Data collection:
      (Observations and measurements made.)

   f. Results:
      (Analyze your data. Explain your findings.)

   g. Conclusion:
   (Summarize your findings.)

h. Applications:
(Tell how this information can be useful.)

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6. What Is the Effect of Wind on Sand?

Scientist(s) _____ **Team** _____

Sand dunes are a natural barrier to the destructive forces of wind and waves. In order for scientists to understand beaches and sand dunes they must understand the mystery of the interaction of the wind and sand. As a scientist, you could begin by asking: Are some sand samples affected by the wind more than others? Which type of sand forms dunes? Do all types of sand form dunes?

Materials: sand samples, straws or small fan, ruler, goggles

Procedure:

1. To learn about the relationship of the wind, types of sand, and sand dunes, place 100 ml of the sand sample on a piece of paper. Wear goggles when conducting the experiment. Place a line at the front edge of the sand sample. Use straw or small fan to blow air (wind) across the sand samples. Measure the distance the different sand particles moved by blowing. Construct a table based on the following example and record your observations and measurements.



Table 1: Title_____

Size of Sand Particles (mm)	Distance Sand Particles Moved (cm)

2. Does the wind affect the sand particles differently? Write a sentence explaining the relationship of particle size and the distance the wind can move the sand.

3. What else did you observe about the wind and the movement of the sand?

4. Now see what you can learn about the movement of the sand and different types of wind. Blow across the sand to simulate different types of winds, a breeze, mild winds, strong winds, short gusts of wind, severe sustained winds, hurricane winds, etc. Decide how would you simulate each type of wind. Be sure to wear your goggles. Conduct your tests

of the effect of the wind. Record your observations and measurements of the movement of the sand in a table similar to the following example. Write a title for the chart.

Table 2: Title_____

Type of Wind	Movement of the Sand

5. What is your conclusion about the type of wind and the movement of the different types of sand?

6. Now see what you can learn about the movement of sand and wind from different directions. Blow across the sand from one direction, then change to another direction. Change directions several times. Record your observations and include drawings to illustrate what you observe. Compare the effect of wind from one direction to the effect of wind from a different direction.
7. How might this affect each of the following:
   a. beach —

   b. sand dunes —

   c. plants —

   d. animals —

   e. people —

   f. human-designed structures (roads, buildings, etc.) —

8. How would living organisms (plants and animals) need to adapt to survive in an area such as the beach and dunes where the wind is moving the sand?

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7. Why Are Dunes along the Texas Coast Different?

Scientist(s) _____ **Team** _____

If you travel along the Texas coast, you will notice that there are very few sand dunes between the Texas-Louisiana border and Galveston. There are only sand ridges and many of these are covered with plants. In Aransas and Calhoun counties, the dunes are 15 to 20 feet above sea level. The most highly developed dunes are in Nueces and northern Kleberg counties. The foredunes in this area average 20 to 25 feet with very few plants. The largest dunes are as high as 40 feet. In Kenedy, Willacy and Cameron counties, the foredune ridge is poorly developed and is also broken by washovers and blowouts. The dunes are much smaller in size on the southern end of Padre Island and also migrate or move. What causes these differences in the sand dunes? The climatic conditions differ among the coastal counties. Is there a connection between the dunes and the climate? Does climate affect the plants that grown on the dunes? How would the plants on dunes affect the size of the dunes? Is there another explanation? As a scientist, you will see if you can find the answer to the puzzle of why the dunes on the Texas coast differ.

Materials: graph paper

Procedure:

1. As a team think about possible explanations or hypotheses that the sand dunes along the coast are different. List your reasons.

Table 1: Average Yearly Rainfall in Texas Coastal Counties

County	Average Yearly Rainfall (inches)	January Mean/Minimum Temperature, °F	July Mean/Maximum Temperature, °F	Growing Season (days)
Aransas	36.9	45	92	312
Brazoria	52.3	42	92	268
Calhoun	42.2	44	93	300
Cameron	24.5	51	93	341
Chambers	51.6	41	91	261
Jefferson	52.8	42	93	250
Kenedy	29.7	45	95	319
Kleberg	27.5	46	95	314
Matagorda	43.2	46	91	296
Nueces	30.2	46	94	309
Willacy	27.5	47	96	331

2. Your team will now analyze data to determine what might cause the differences in the dune size. To determine if climate is part of the reason, create a bar graph of the counties and the rainfall. Use the information from Table 1.

   a. On a sheet of graph paper on the horizontal axis, list the counties in order from the Texas/Louisiana border to the Texas/Mexico border. List the rainfall data along the vertical axis. Plot the data on the graph to create a bar graph.

   b. On another sheet of graph paper make a bar graph of the January and July Mean Temperatures. On the horizontal axis, list the counties in order from the Texas/Louisiana border to the Texas/Mexico border. List the temperatures scale from 40°F to 100°F on the vertical axis. Plot the bars for the January temperature data for each county in blue. Next to the bar for the January temperature, plot the July temperature data for each county in red. Label the graph.

   c. On another sheet of graph paper make a bar graph of the length of growing season for the coastal counties. Place the counties on the horizontal axis and the length of the growing season on the vertical axis. Complete and label each column of the graph.

3. Analyze and interpret the data on the graphs. What relationships do you notice between the location of the county and each climatic condition?
   a. Where is the average rainfall the highest?

   b. Where is the average rainfall the lowest?

   c. What is the relationship of the location of a county and its mean January and July temperatures?

   d. What is the relationship of the location of a county and its growing season?

4. What inferences can you make about the location of the counties and the type of dunes? What is the pattern? Write a generalization explaining the relationships.

5. Based on the data, what factors appear to affect the type of dunes?

6. Use the climatic data. Could these factors explain the puzzle of why the dunes differ? Explain why.

7. Write a one- to two-sentence generalization explaining your answer to the puzzle.

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8. Does Water Move in Sand Dunes?

Scientist(s) _____ **Team** _____

Sand dunes are an important part of many coastal areas. They are large piles of sand. They have formed by processes and in shapes and patterns similar to the dunes found in deserts. Are sand dunes just a pile of dry sand? How do plants get water to grow? How do animals live in the sand dunes? What happens to water in the sand dunes?

As a team you will discuss and investigate these questions.

Materials: clear plastic cups or clear plastic soda bottles, aluminum pie plate, sand, water, scissors, metric ruler, graph paper

Procedure:

1. As a team discuss the questions above. What are your hypotheses?

2. Investigate the question of what happens to water in sand dunes.
   a. Make a cylinder that is open at both ends, carefully cutting the bottom out of a plastic cup or both ends of a plastic soda bottle with scissors. Wipe the inside of the cylinder with a paper towel to make sure it is completely dry.

   b. Place the cylinder in an aluminum pie plate. Fill it completely with dry sand. Now you have a column of dry sand sitting inside the cylinder in the pie pan.

   c. Slowly pour water directly into the bottom of the pie pan to a depth of 1 cm. Do not pour the water directly on the sand. Be careful not to move the cylinder or the sand.

   d. Begin timing as soon as you have poured the water in the pan. Use a metric ruler to measure how many centimeters the water rises in the sand, measuring the distance from the bottom of the cylinder to the top of the line of dampness in the sand. Construct a table similar to the following and record your measurements every two minutes (2, 4, 6...).

Table 1: Height of Water Movement

Time after water added (in minutes)	Height of water (cm) in sand

3. On a sheet of graph paper, graph the height of water movement and time. Summarize your findings.

4. Describe what happens when the water is poured in the pan at the base of the cylinder containing the sand.

5. Use a hand lens and observe a section in the sand where the water is moving up in the sand. How would you describe its movement through the sand?

6. Create a chart similar to the one below. Sketch the sand grains below to illustrate how the water molecules move up through the sand. In the first frame, sketch 20 grains of dry sand stacked together. In the second frame, sketch the sand grains immediately after water has been added to the bottom. In frame three, sketch what happens after two minutes and frame four, after eight minutes.

Frame 1: Dry Sand Grains	**Frame 2: Immediately after water is added**	**Frame 3 Two minutes after adding water**	**:Frame 4: Eight minutes after adding water**

7. After the water has moved through all the sand, carefully pick up the cylinder and observe what happens. Does sand pour out as individual grains or in a lump? Describe.

8. Scientists use concepts and principles that are known to explain new observations and data that they have collected. Read the following and use it to explain the movement of water in the sand that you observed.

   Water molecules can move through sand or soil in all directions, even against gravity. This movement of water is called **capillarity** or **capillary movement** or **capillary migration**. Both adhesion and cohesion are at work when water rises through dry sand or soil. **Adhesion** is the attraction between molecules that causes matter to cling or stick to other matter (like adhesive tape). For example, water molecules adhere or stick to some surfaces. **Cohesion** is the ability of a substance to stick to itself. In this case, water molecules stick together so water will form droplets.

   Did you observe the forces of adhesion and cohesion in the sand and water? Explain.

9. Discuss how you would demonstrate the movement of water through the sand using six to eight of your classmates to represent the sand molecules and four to represent the water. Explain or sketch your sequences.

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10. What will happen when capillary water moves to the surface?

11. Discuss the relationship of water movement in sand and an organism's ability to live in the upper beach area or the backshore and dune area.
    a. How does this enable plants to grow in the dunes?

    b. The only permanent animal residents in the dune area are rattlesnakes, earless lizards, six-lined racerunner lizards and ghost and mole crabs. These animals live in a harsh environment of blowing sand, periods of wetness and dryness, intolerable hot surface temperatures in the summer and harsh cold in the winter. Most survive by burrowing. How does the water in the sand enable these organisms to survive?

12. You conducted your investigation with one type of sand. Do you think the results would be the same or different with different types of sand and soil? As an extension, plan and conduct an investigation to determine how water moves in different types of sand and soil. Use the report form as a guide.

REPORT FORM

Scientist(s) _____ **Team** _____

A. **PROBLEM**

(State your problem or describe the problem to study.)

B. **QUESTION**

(State your problem as a question.)

C. **HYPOTHESIS**

(Write an if...then....statement that explains what you think will happen in your investigation.)

D. **DESIGN FOR YOUR EXPERIMENT**:

What are your variables? (What will you change and what will you measure.)

1. Manipulated Variable (what you will change)
2. Responding Variable (what you measure)
3. Controlled Variable(s) (what stays the same)

Materials: (Make a list of the materials you will need in your investigation)

Procedure: (Explain the steps you are going to take to investigate the question.)

E. **DATA COLLECTION**

(Make observations and take measurements. Organize Data into charts or tables.)

Title:_____

F: **DATA INTERPRETATION**

(Show the data collected in a graph.)

Title:_____

G: **RESULTS**

(Analyze your data. Think about the data. Explain how your findings answer your question.)

H. **CONCLUSION**

(Compare your results to your hypothesis. Explain if your results support or refute your hypothesis. Summarize your findings.)

I. APPLICATIONS

(Relate or connect your results to another situation. Tell how this information can be used.)

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9. How Do Organisms Survive on the Sandy Beach?

Biologist(s) _____ **Team** _____

Think about the conditions on a beach. What animals are permanent residents on the beach? Imagine you are an animal living on the beach in the area between the dunes and high tide, the supralittoral zone. When the wind is blowing you are hit by salt spray and blowing sand. On a summer morning the breeze is cool but as the day progresses, the temperature on top of the sand becomes intolerable. In the winter, the wet winds are harsh and cold. How can you survive the periods of wetness and dryness; the extreme hot and cold temperatures? How will you hide from the birds that come into the area looking for food? What might you do to survive? You and your team will be investigating how organisms live in these harsh conditions.

Materials: sand, water, ice, plastic cups, thermometers, lamp with 100 watt or greater bulb, pan with depth of 15 cm or greater

Procedure:

Part I: How do organisms survive the temperatures on the beach?

1. Suppose you are an animal living in the surf zone between the high and low tides. What are the conditions like? The waves are constantly pounding you with sand and shell fragments. The surf washes you around. There is nothing solid to hold onto to prevent being washed by the wave action or washed in and out by the tide. When it is high tide you are covered by the surf, but during low tide you may be uncovered. Waves crash down and the water moves back leaving you exposed. Birds are waiting to grab you for their lunch. What might you do to survive this horrible situation?

2. The only safe place is in the sand. As a result, most animals, except those that can swim well or crawl fast, burrow in the sand. Set up the following activity to determine if burrowing helps animals avoid the extreme temperature changes.

   a. Fill two 16 oz or larger cups with sand to a depth of 12 cm.

   b. Place the bulb of one thermometer 10 cm below the sand's surface in each cup. Place another thermometer 5 cm below the surface, a third 1 cm below the surface and a fourth on the surface of the sand.

   c. Place one cup under a lamp with a 100-watt or higher light bulb. Make sure that the light is directly above the cup. The light should be 20 cm above the surface of the sand.

d. Fill a small plastic sandwich bag with ice and place it on the surface of the second cup.

e. Allow these to set for 30 minutes or longer. Continue with Part II of this investigation.

f. If possible read each thermometer without removing it from the sand. If this is not possible, quickly your place your finger at the temperature and then determine the temperature. Record the temperature readings in a table similar to the following. Complete the title for the chart.

Table 1: Title:_____

Thermometer Location	Exposure to Heat, °C.	Exposure to Cold, °C.
Surface		
1 cm below		
5 cm below		
10 cm below		

3. On a sheet of graph paper, make a graph of the depth versus the temperature. Use a red color to graph to exposure to heat and a blue color to graph the exposure to cold. Compare the graphs.

4. Analyze your data. Summarize your results.

5. Based on your results, if you were an animal living in the sand dunes what would you do to survive the extreme cold and hot temperatures? Explain.

6. If you were walking in the sand dunes, during what time of the day would you expect to find animals moving about? When would you expect to find animals moving about during the winter? Explain.

Part II: How do organisms burrow in the sand?

1. What is it like to burrow in the sand? Investigate the burrowing of an animal into the sand. Obtain two plastic cups. Fill one cup 3/4 with dry sand and the other cup 3/4 with wet sand. Push your finger down into the cup of dry sand. Move it around. Note what happens.

2. Now push your finger into the wet sand sample. Move your finger around slowly. Note what happens. Move your finger rapidly. Describe what happens.

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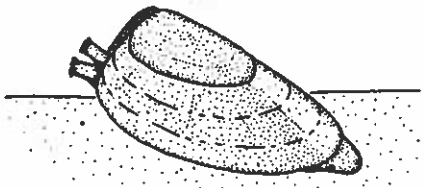
3. This phenomenon demonstrated by wet sand is called thixotrophy.
   a. Based on your observations, write a definition for this physical aspect of sand.

   b. Find the definition of thixotrophy in the dictionary. How is your definition like the one in the dictionary?

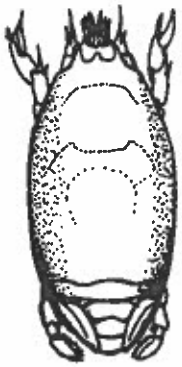
   c. How does it differ from the dictionary?

4. In which sand, wet or dry, would it be easier to burrow into or move around in? Why?

5. One of the common animals of the intertidal zone is the coquina or bean clam. Look at the drawing of the bean clam.
   Note that it has a smooth streamlined shell.
   How does this help the clam once it is uncovered?
   See how rapidly you can burrow your finger into wet sand. What did you do to burrow more rapidly?
   What was the effect?



Bean clam



Mole crab

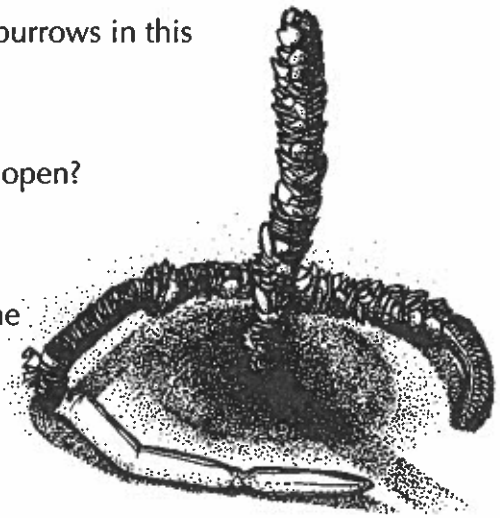
6. The mole crab is another inhabitant of the surf zone. Look at the drawing of the mole crab. What adaptations would enable it to burrow quickly and to live in the sandy surf?

7. What happens when you pull your finger out of the burrow you created in the wet sand? the dry sand?

8. The burrows are in the surf zone where water would wash across them. What happens to burrows in this area?

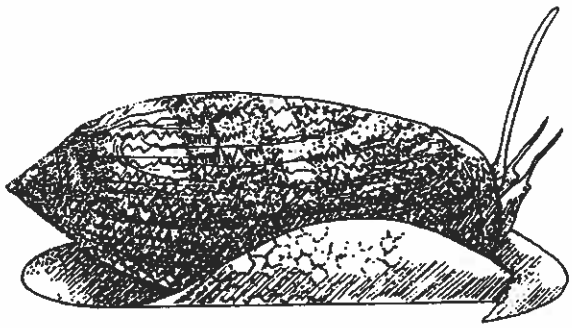
9. How would you design a burrow so that it would stay open? Sketch your burrow.

10. A few animals actually make permanent burrows in the surf zone. The tube-building worm, *Diopatra cupraea* is a common inhabitant of the surf zone. Look at the drawings of these animals and their burrows. What does it do to make its burrows permanent?

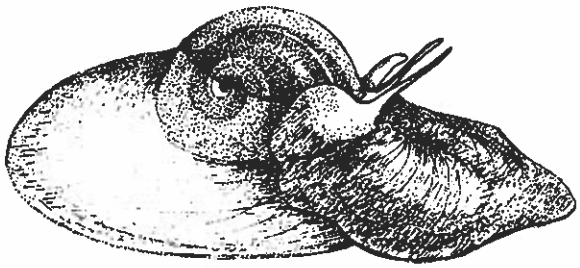


Diopatra cupraea (tube-building worm)

11. Those animals that do not make permanent burrows, but move or burrow constantly in the surf sand, are generally streamlined and smooth-surfaced. Two snails, the lettered olive and moon snail are common burrowers in the intertidal zone. Explain why they have smooth and streamlined shells.



Lettered olive, *Oliva sayana*



Shark's eye, *Polinices duplicatus*

12. People who drive on the beach in or near the intertidal zone sometimes get their vehicles stuck. Their reaction is to move the wheels to get out.

    a. What will happen as they move the wheels in the wet sand? Explain.

    b. What should they do to get out if they are stuck in wet sand on the beach?

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10. How Do the Beaches and Dunes Protect the Texas Coast?

Scientist(s) _____ **Team** _____

Scientists use journal articles to communicate to others what they have learned. Others read the articles to learn more about an event, object or organism. They use the information to explain an event or predict what might happen. You are a scientist working with landowners, county and city planners, industry and citizens to help people understand the natural processes and the impact of natural and human interaction. Use the articles to learn about the structure of a typical Texas barrier island where the beaches and dunes are located and the natural cycling of water and sand on the beach. As a scientist you will need to explain the natural processes to others and make predictions about the impact of natural or human interaction on the beaches and dunes.

Materials: Copies of "The Beaches and Dunes" and "The Water and Sand Cycle on the Beach"

Procedure:

Part I: The Beaches and Dunes

1. Read "The Beaches and Dunes" and study the diagram of the beach and dunes. Identify the different areas of the beach described below by placing the letters in the correct area of the beach in Figure 10.1.

   a. The part of the beach that is only covered by water during a tropical storm or hurricane.
   b. The part of the beach that is covered by water during the daily high tides
   c. The part of the beach that is not covered by water during the daily low tides.
   d. The location on the beach where you would put a tent if you were camping on the beach.
   e. The area that is the first to slow the storm waves.
   f. The area you would place materials to trap sand to build dunes.
   g. The part of the dunes that is most effective in blocking waves from flooding inland areas.

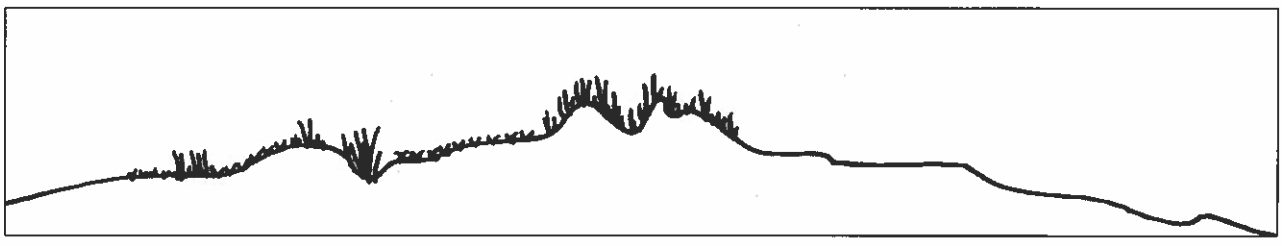


Fig. 10.1. Cross-section of beach and dunes.

2. The Open Beaches Act passed by the Texas Legislature, guarantees the public's right of free and unrestricted access to the "public beach." This is the area from the line of mean low tide to the line of permanent vegetation on the shoreline bordering the Gulf of Mexico. Use a colored map pencil and color the area that is public beach.

3. The Dune Protection Act amended by the Texas Legislature in 1991 requires the commissioner's court of any county which borders the Gulf of Mexico to establish a dune protection line on the Gulf shoreline. Place the letter X where you would place the dune protection line.

Part II: What is the Water and Sand Cycle

1. Read "Water and Sand Cycle on the Beach." As a scientist, use the article and list in sequence the steps of the water and sand cycle.

2. Now use the steps of the sequence to create a graphic diagram of the water and sand cycle.

3. At times the height of storm waves may be higher than the lowest part of dunes ridge. What will happen? Use Figure 10.2, "Washover from Storm Surge," to explain what happens. Where does the water overflow? This is called a washover. Use the article and diagrams to define washover.

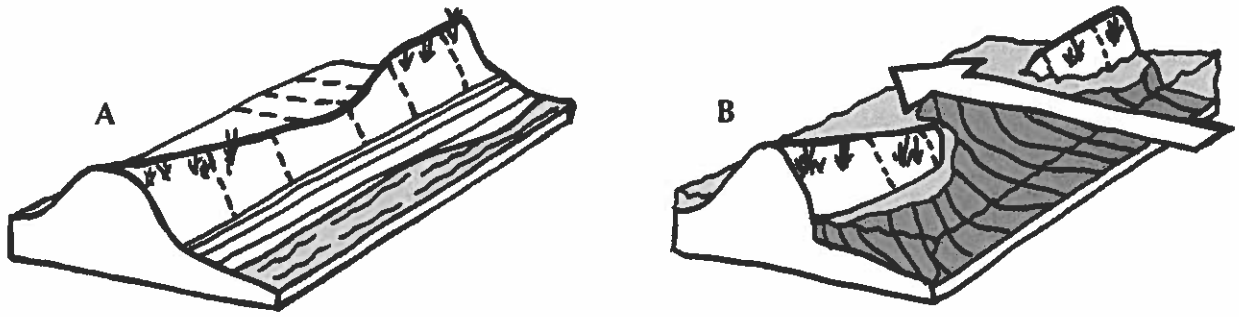


Fig. 10.2. Washover from storm surge. (A) dune before storm (B) during storm

4. Where is the eroded sand carried and deposited?

5. Study Figure 10.1, the cross-section of a typical Texas barrier island. What happens if the storm or hurricane is severe and the washover continues into the interior?

6. What will be the effect of the water and sand on the interior habitats and organisms?

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7. Storms may also produce washouts in dune areas. These result from rain from storms or retreating bay waters that can be piled up by slow moving hurricanes. Use Figure 10.3, "Washout in a Dune Ridge," to explain what happens.

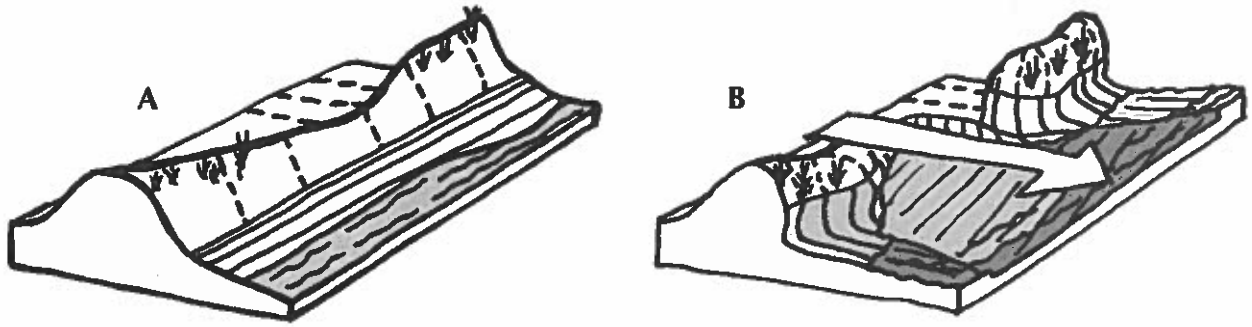


Fig. 10.3. Washout in a dune ridge from retreating bay waters or stormwater runoff. (A) Before storm (B) After storm

8. Use the diagrams to help you define washout.

9. Compare and contrast washover and washout.

10. The wind can also cause erosion of dunes. Blowouts or breaches in the dunes may form as a result. See Figure 10.4, "Formation of a Blowout." Explain how disturbances of dunes by vehicles, people, construction work or grazing animals can cause the formation of these breaches.

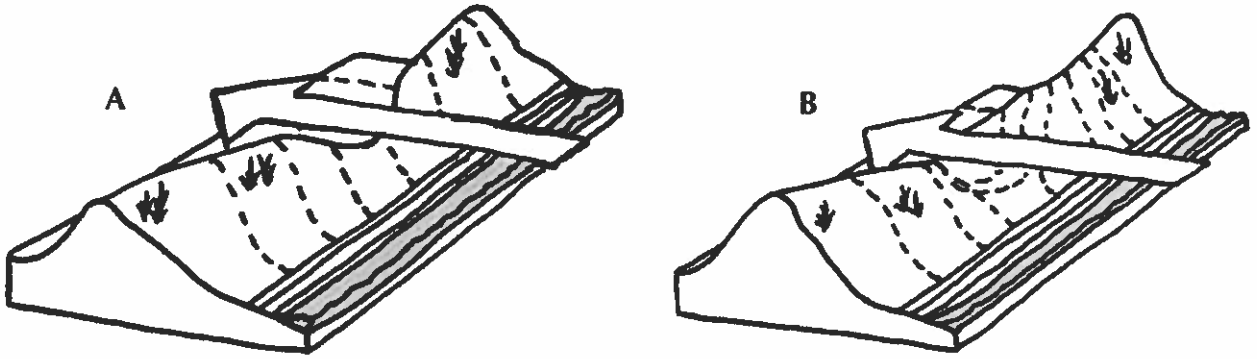
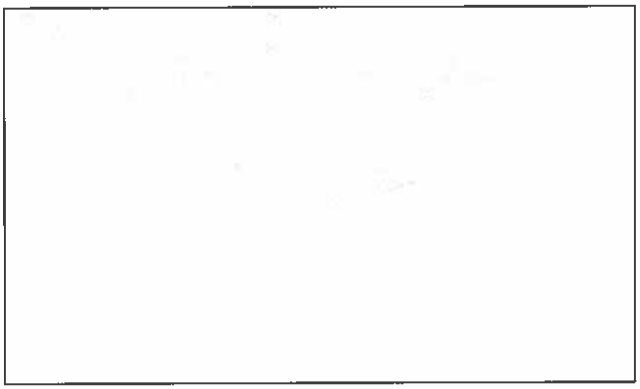


Fig. 10.4. Formation of a blowout. (A) Onshore wind (B) Increased erosion caused by onshore wind

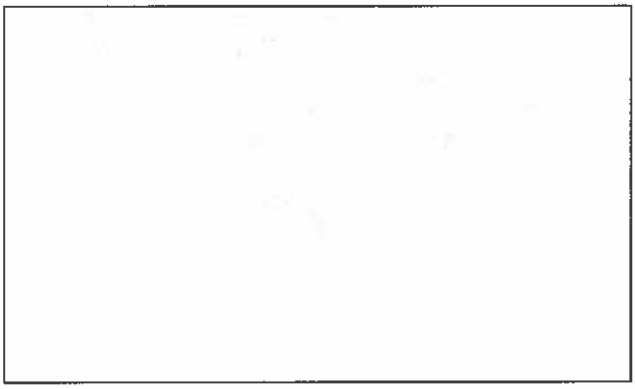
11. Explain how during storms, blowouts may become channels for storm-surge waters from the Gulf.

12. Removing plants from sand dunes can be as damaging as removing the sand. The plants are often removed from a large area when a construction site is cleared. Plants are also trampled and destroyed by pedestrian traffic, motor vehicles, horses, and grazing cattle. As

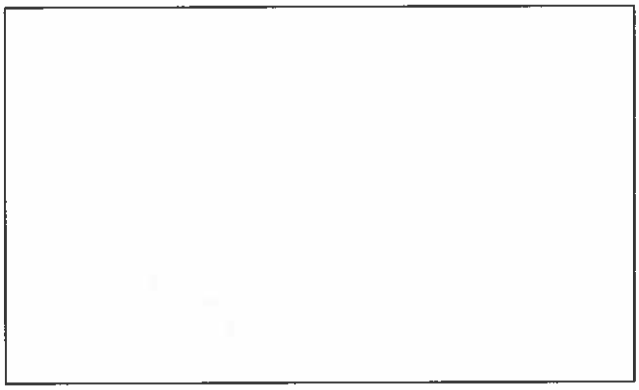
trails through the dunes are used, the plants are destroyed. The wind then begins to carry sand from the area. As the sand is carried away, the trail gets deeper and wider. Draw a series of sketches to illustrate what happens to the dunes. Explain what can happen during a storm or very high tides.



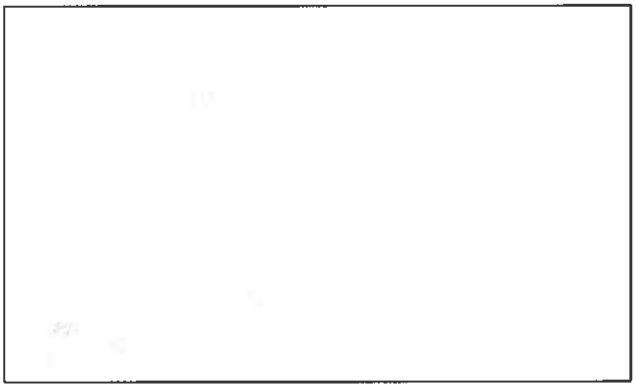
1. Before A Trail



2. Trail Created by Cows



3. Trail After Use by Motor Vehicles, Horses, Peope



4. Trail Area After High Tide

13. Explain how the damage from vehicles has affected the area between the dunes and how this can lead to a blowout, washout, or washover.

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Part III: What action should be taken?

As a scientist, you are asked to explain what will happen to the beach and dunes if certain human activities take place. Use the information from the article and diagrams to prepare your responses. For each of the activities below explain what the impact of the action will be and what proposed action should be take to protect the beach and dunes. You may include sketches.

a. Cattle grazing
   Impact of action
   Proposed action

b. Bulldoze dunes for construction site or to lay pipelines
   Impact of action
   Proposed action

c. Use of 4-wheel vehicles in dunes for off road driving
   Impact of Action
   Proposed Action

d. Trails over the dunes to Beach homes
   Impact of Action
   Proposed Action

e. Construction of elevated wooden dune walkovers to walk over the dunes to the beach
   Impact of Action
   Proposed Action

f. Construction of roads through the dunes to the beach
   Impact of Action
   Proposed Action

The Texas Coastal Management Plan has recommended beach traffic lanes, off-beach parking, and dune walkovers.

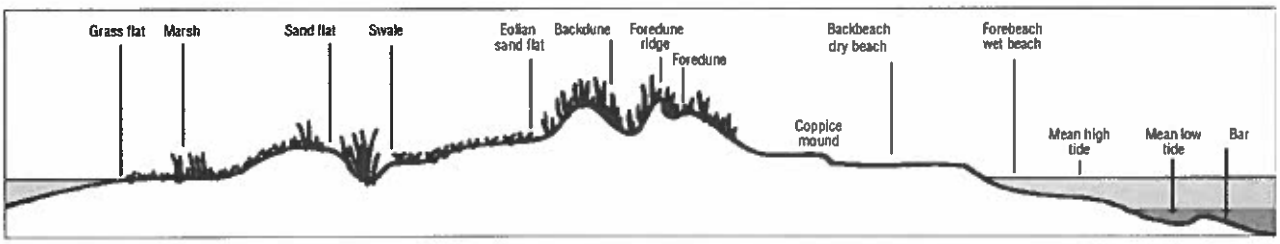
Impact of Action
Proposed Action

The Beaches and Dunes

The beach is a great place for picnicking, camping, swimming, fishing, surfing, collecting shells, birding or just relaxing. These are things that most people think of when they think of the beach. The beach and dunes, however, are much more than just a place for beauty and recreation. This is the first line of defense that protects the land from the sea. Dunes help prevent loss of life and property by absorbing the impact of storm surge and high waves, stopping or delaying the intrusion of water inland, slowing shoreline erosion, and replenishing eroded beaches after sotrms. The dunes also serve as a habitat for organisms (including threatened or endangered species). With an understanding of how the beach performs its protective role, people can use and enjoy the beach without destroying it.

The are two features of the beach that help it protect the land. First, it has a sloping surface that gradually scatters the energy of a wave as the wave flows up the slope. Second, since it is made of sand, the beach is flexible and the slope caqn change as the waves change.

The beach is the area that extends from low tide to the line of vegetation along the shoreline. The forebeach, or wet beach, is the area affected by normal daily tides. The backbeach, or dry beach, is only covered by water when there are storm tides or high spring tides. Note the coppice mounds. This is where dunes begin to grow. These mounds are formed as sand collects by plants and other structures on the beach. The mounds are where the sand from offshore sandbars is deposited. The mounds may become covered with plants. Slowly the plants will collect and trap more sand and the mounds will increase in height. Eventually the mounds form foredunes.



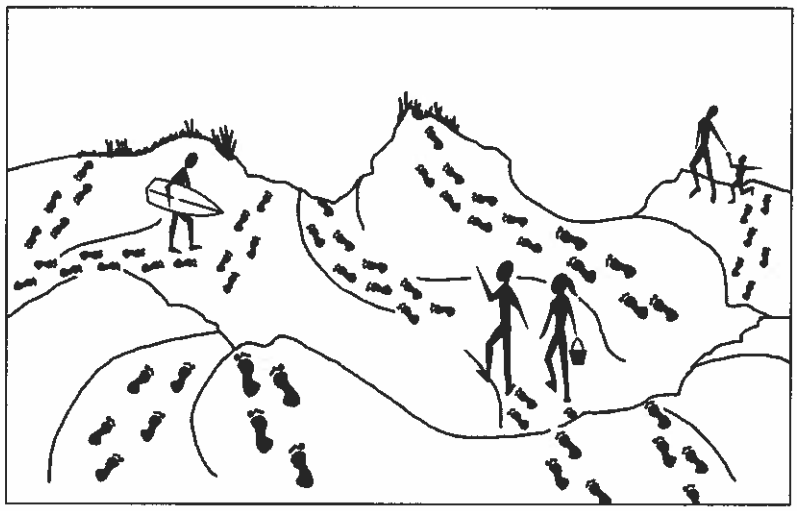
Cross-section of a Typical Texas Barrier Island

The foredunes are those covered by plants and are closest to the water or landward of water. They are first to scatter the storm wave and current energy. The foredune ridge is high, continuous and well-stabilized with plants. This ridge rises behind the foredune area. The foredune ridge helps block storm surge and prevents the waves from washing inland.

The main problems are caused by human interaction and can partially or completely destroy the dunes. The first problem is human interaction that causes a loss of vegetation that holds the dunes in place. These include people killing vegetation by creating footpaths over

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the dunes. This creates weak areas in the dunes that can be eroded by wind or water. Simple foot bridges over the dunes can prevent these weak areas. Dune buggies, dirt bikes or other vehicle traffic will also kill vegetation and erode the dunes.



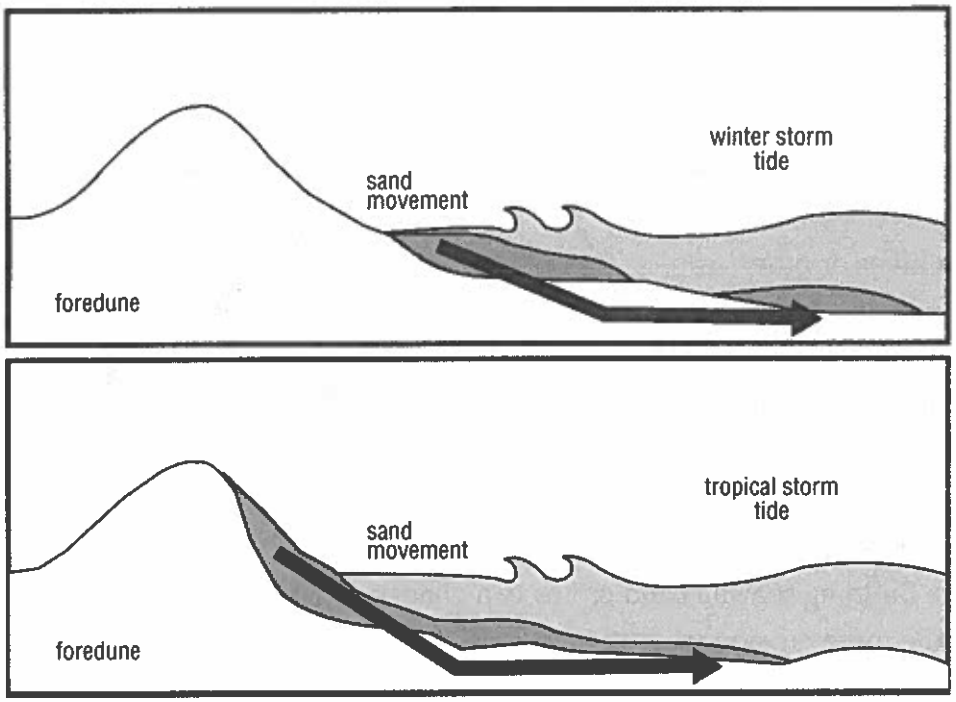
Another problem is construction too close to the water. Dunes may be flattened for building sites or buildings are placed seaward of the dunes. Building seawalls and groins can change the cycle and cause more deposition in one area while more erosion in another. Where dunes are well developed, it is usually possible to build more structures on stilts behind the center of the dunes. This allows people to enjoy the ocean front without interfering with the natural cycles of the beach. If people work with the natural processes of the beach, the beach can be used and enjoyed without interfering with the beach's role of protecting the land from the sea.

The Water and Sand Cycle

Beaches and dunes are necessary parts of a dynamic environment where water helps to constantly exchange sand. This results in the interaction of a water and sand cycle. As a wave approaches the beach, the water becomes shallower and shallower due to the slope of the shoreline. When the wave reaches water that is about 1.3 times deeper than the wave is high, the wave will break. The coarsest particles on the beach collect just below the breaking waves. The medium and fine particles are suspended by the waves breaking. These sand particles are then moved up or down the shore.

During the calm conditions that exist most of the year along the Texas coast, waves average 2 to 4 feet in height and are not very close together. Each wave follows a sequence. The wave breaks and, in doing so, stirs up the sand on the bottom. Part of this sand remains temporarily suspended in the water as the wave flows on the beach. Now three things happen to scatter the energy of the wave. First, the wave is flowing up a slope, slowing down as it moves uphill. Second, the sandy beach is rough, which helps to slow the water down. Third, some of the water from the wave soaks in to the sand. This leaves some of the grains that went into suspension when the wave broke on the beach. Each new wave leaves a few more grains of sand on the beach. Gradually the beach builds up and, in time, the sand is blown into the foredune where it is trapped by plants and stored until a storm removes it.

During a storm, the waves are higher with more energy and they hit the beach in rapid



succession. The beach cannot soak up much of the water from each wave so more water is left on the beach to wash back down after each wave. Each new wave carries a little sand with it as it washes back. The beach erodes. These high-energy waves also wash against the base of the sand dunes. This undermines and erodes sand from the base of the dunes until they collapse. In severe storms, the dune face may erode several yards inward; in hurricanes, this erosion may be more than 100 meters. Sometimes dunes are destroyed.

The retreating waves carry the sand offshore and deposit it seaward of the surf zone in large sand bars. These sand bars become important because they change the depth of the water, which, in turn, make the waves break sooner. This erosion by the breakers reduces the storm waves' energy. As the beach erodes, the area becomes flatter so waves move farther up the beach and scatter their energy more. A wave has less energy so little or no sand is carried off the beach. The sand bar does not get any higher and waves keep coming in without causing appreciable changes in the beaches.

Assume that the water level does not change (no tides), the waves do not change and there is plenty of sand on the beach. When the slope of the beach, the height of the sand bar and the amount of wave energy is divided between the sand bar and the beach, the system is balanced. If the supply of sand remains constant, the natural exchange between the beach, dunes and offshore areas will repair and rebuild dunes to a height and width determine by local conditions.

What will happen if the waves and beach are the same but the water level changes (the rise and fall of the tide)? With a rising tide, there is more erosion and with a falling tide there is

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less erosion. The situation becomes more complicated if the waves and the tide change in a storm. If a storm extends over one or more tidal cycles, the rise and fall of water levels makes the interaction more complex. The general cycle, however, is the same. The storm waves erode the beach, the sand forms a bar or several bars that cause the waves to break further from shore and this reduces the rate of erosion on the beach.

11. How Can Sand Dunes be Protected?

Scientist(s) _____ **Team** _____

As a Park Ranger you have noticed that on the beaches people interact with the natural processes that operate in the beach and dune area. You and your fellow Rangers have noticed over several years that the interaction works two ways: (1) people affect the environments and natural processes and (2) the environments and natural processes affect people and their activities. One way that people interact is when they build a structure, house or road along a beach. Any structure that interferes with the natural cycle of the sand can lead to beach erosion. Once the beach begins to erode towards their beach house, people build groins or seawalls to control the erosion. They are immediately happy since their beach is no longer eroding and their property is saved. However, their neighbors who live down current are unhappy since their beach is beginning to erode.

You have also noticed that the beaches where people drive are different from the beaches where no vehicles are allowed. On beaches where traffic is allowed, vegetation cannot live long enough to trap sand. As a result the beach is much smoother, flatter, and broader. Beaches that do not have traffic have vegetation and dunes closer to the beach.

People walking also affect the plants and dunes. When they hike up the dunes to get a better view of the island or walk across the dunes to get to the beach, deep trails develop in the dune ridge. People also cut roads across the dunes to reach the beach. The wind erodes these areas even more because there is no vegetation to slow wind erosion. After storms you have found that these are the areas where water has surged across. As water flows through these areas it erodes more sand and destroys the vegetation of adjacent areas causing even more erosion.

From reading reports on coastal problems, you have learned that the coastal ecosystems are in a delicate balance in nature and human interaction has resulted in many changes along the Texas coast. Erosion has taken away 60 percent of the Gulf shoreline at rates of between one and 50 feet per year. The average annual erosion rate is 8.25 feet per year. More than 45 acres of land are lost each year to erosion in Chambers County. At Sargent Beach in Matagorda County, erosion has claimed more than 2,000 feet of beach at an average rate of 25 to 33 feet per year in some places. A storm or hurricane will claim even more in one or two days. Hurricane Allen in 1979, eroded an average of 12.21 feet in 48 hours. In one area alone, Allen eroded 75 feet. Hurricane Alicia in 1983 was not a big hurricane, it was barely a 3 on a 5 point scale. The damage was extensive, aerial photos indicated that erosion was from 20 to 145 feet and averaged 80 feet along Galveston Island. It eroded more than 2 million cubic yards of sand from West beach alone.

How can Texas keep from losing beaches? The first line of defense against a storm is the

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sand dunes. The dunes may grow slowly but they are very strong. Many coastal specialists believe that Texas dunes are being destroyed not by hurricanes, but by increased development and traffic.

Along the Texas coast, and especially in your coastal area, population growth is leading to an increase in development and recreational use of your beaches and dunes. All the construction and heavy recreational use of the beaches is causing the conditions of the beach and dunes to get worse. Plants that hold the sand are being destroyed so sand is lost. The dune line is broken by roads, trails, and storm runoff. Human activities are speeding up the damage naturally caused by wind and wave erosion. If the beach and dunes are destroyed, your community's beauty will be lost and people will no longer come to the beach. Many businesses will lose money. Also in the case of a severe storm, damage to property will be much greater, therefore more costly.

A task force of concerned citizens has asked your team to investigate several methods that are used to construct, improve and repair sand dunes. You have been asked to determine how each method works and which one works the best. Based on your investigation, your team is asked to make recommendations for protecting your community's beach and dunes and to prepare a brochure informing others.

Materials: sand, straw or small fan, toothpicks, yarn or string, and plant pieces to be "planted beach grass" or pieces of cedar to represent discarded Christmas trees and brush, safety goggles, tray or lid from paper ream box.

Procedure:

1. To conduct your research, you first must make a model of the sand dunes to test your ideas. Place the sand in the form of dunes in the lid of the cardboard box or in a tray.

2. Investigate several different types of dune stabilization. Keep your goggles on during your investigation. Place each item below in a sand dune and note the effect on the dune as wind blows. Use a straw or a small fan to blow across the dune. Try each item in different parts of the dune.

   a. Use plant pieces (blades of grass) to simulate beach grasses

   b. Use pieces of yarn or string to simulate plants that vine.

   c. Use pieces of cedar to represent discarded Christmas trees.

   d. Use toothpicks to represent "fences."

3. Record your findings for each item in a chart similar to the following example. Write a title for the chart.

Title:_____

Item for Dune Stabilization	Effect of Item on Sand Dunes
A.	
B.	
C.	
D.	

4. What is the effect of each item on the dunes?

5. What happens to the sand grains when they hit the "grass, vines, cedar, or fences?"

6. Where is the best location for the items? Where should they be placed on the beach?

7. As the investigator use what you have learned from your investigation to summarize and sketch your recommendations for improving or stabilizing sand dunes.

8. Create a row of sand dunes. Place a breach (break) or a road through the row of sand dunes. Now use what you learned to rebuild the break in between the dunes. Try to repair it several different ways. Describe and illustrate what you did and learned.

9. Now as a task force use what you have learned to develop Beach Access and Dune Protection brochure for your coastal community. Use what you have learned to prepare a brochure with illustrations that includes the following:
   a. Why protect sand dunes?
   b. What can be done to protect the beach and dunes?
   c. What laws, rules, and regulations should there be to protect the dunes?
   d. What can be done to promote dune growth?
   e. Describe items that can be used to stabilize sand dunes.
   f. Describe how and where to erect the structures.

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12. Which Plants Should be Used to Restore Texas Coastal Dunes?

SOBA Planner _____ **Team** _____

A number of years ago in Brazoria County marine advisory agent Charles Moss, and Eddie Seidensticker, district conservationist for the U. S. Soil Conservation Service, decided to do something about the erosion problem on the beach. They organized a group to line up discarded Christmas trees from landfills and secured the trees with stakes to keep them in place. In a few weeks, the trees were completely covered with sand and beginning to form a dune that provided additional storm protection, slowed erosion and prevented sand from filling the lagoons, which are valuable fish spawning areas. Mr. Moss found that January is the best time to do this, not only because of the availability of Christmas trees but also because it is a good time to build dunes because of the northerly winds. The strong southeast winds that usually precede northerly winds uncover the sand and speed up the forming of dunes.

Moss and Seidensticker's project has grown far beyond Brazoria County until, today, volunteer groups repeat this process not only all along the Texas coast but along many other beachfronts in the United States.

Your county is losing valuable property along beachfront to erosion. A local Save Our Beach Association (SOBA) was created to save the county's dunes and beaches. The sand was just blowing away and the beaches were becoming barren. The SOBA is planning to build dunes in January and then help stabilize the dunes by planting the appropriate vegetation during April. You are to outline the plans for your county SOBA beach and dune rebuilding project.

Several methods may be used to increase dune size, increase the stability of existing dunes, and repair damaged dunes. However, plantings of native vegetation should be the main method for dune construction, improvement and repair. Where fresh sand deposits collect around obstructions such as grass clumps, plantings of native vegetation or structural barriers can be used to start and speed up the building up of sand. Structures such as slatted wood or plastic sand fencing can be used to help trap sand. These structures can also be used to encourage sand accumulation closer to the beach or establish dunes where a low sand supply has stopped dune formation or where dunes have been destroyed. They should be removed when the vegetation is established. In areas where the local sand is not available, dunes can be artificially constructed with imported sand and then planted with vegetation.

Materials: copies of Plant Ranges of the Texas Coast, Texas Coastal Dunes and the Chart of Plants for Coastal Dunes, typing paper, map colors or markers.

Procedure:

1. Several rules need to be remembered when planting in the dune area. Analyze each of the rules.

   Rule 1: Before undertaking a dune protection or improvement project on the Texas coast one should be aware of federal, state and local laws, and regulations that may apply to the proposed activity. Check with the Texas General Land Office or the Texas Attorney General's Office. Explain why this is required.

   Rule 2: Dune and marsh plants are not available commercially in Texas. They are usually transplanted from natural stands that are nearby. A permit from the county commissioners' court or from a city may be required if the harvesting or planting site is seaward of a dune protection line. The dune protection line may be 1000 feet inland from the high tide line.

   Explain why this is a requirement.

   Rule 3: The best time for transplanting south of Corpus Christi is January or February. For transplanting north of Corpus Christi, the best time is February, March or April. Explain why the best time for planting differs.

   Rule 4: Take plants only from dense groups in areas where erosion will not occur. Plants should not be taken from foredunes. Remove plants in a scattered pattern at intervals of no less than 2 feet. Do not pull them out. Dig them out using a shovel. Explain why this rule is important.

   Rule 5: Plant after rain or water the dune before transplanting. Apply mulch (hay, burlap or mesh made of natural fibers) before or after planting. Pack mulch into the sand. Explain why this is important.

   Rule 6: Do not mow dune grasses. Explain why dune grasses should not be mowed.

2. Select the coastal county in which your Search Our Beach Association (SOBA) is located (see Figure 12.1).

3. Outline the steps that your SOBA plan will follow in rebuilding the dunes and the county beach. List each activity and include the month that it will take place. Make sure that any requests for approval, as well as steps to build up the dunes and the planting of vegetation, etc., are included.

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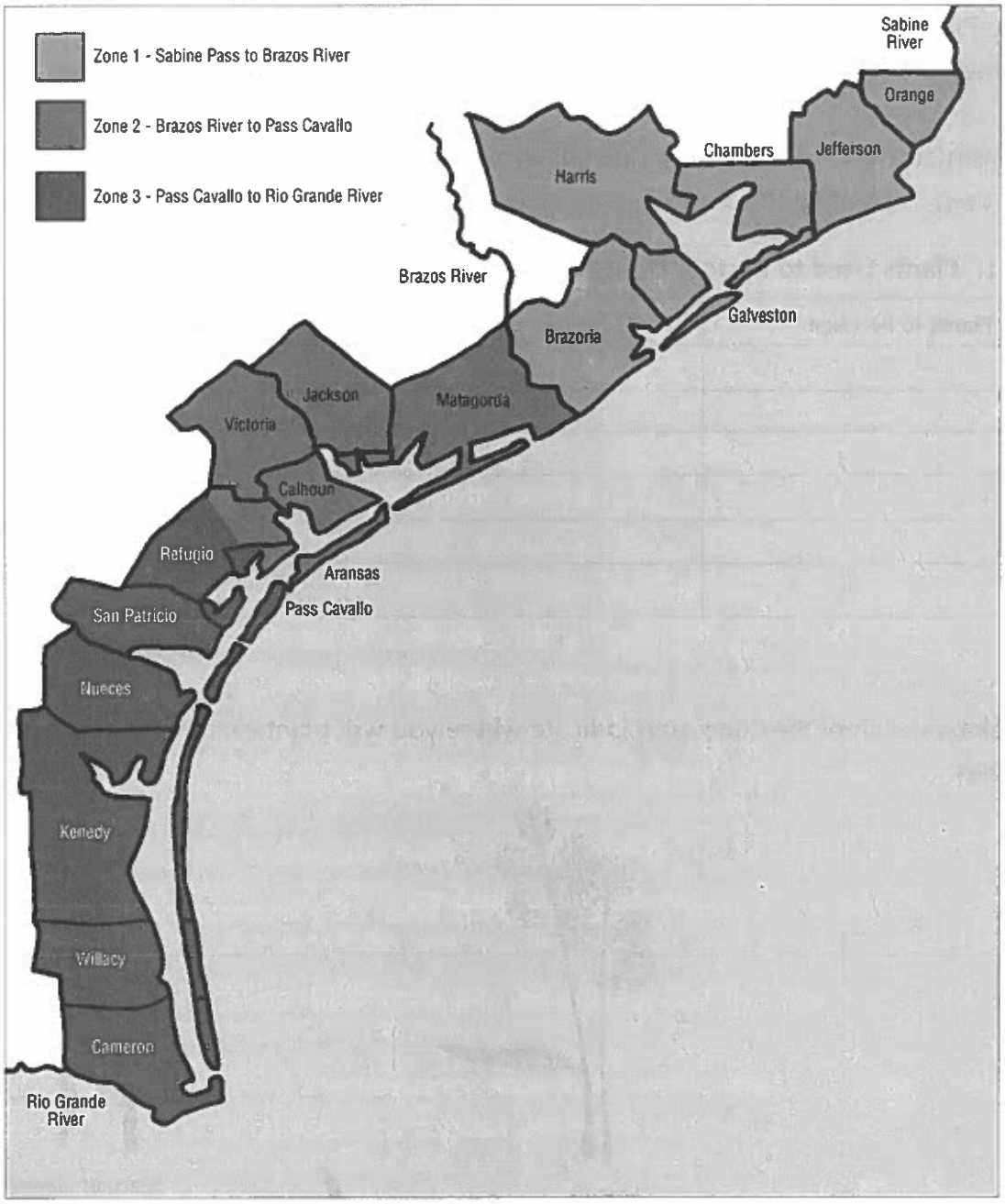


Fig. 12.1. Plant Ranges Along the Texas Coast

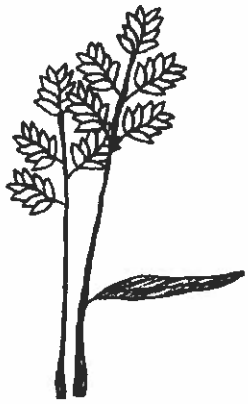
4. Use Plant Ranges along the Texas Coast, Texas Coastal Dunes, Charts of Plants for Coastal Dunes and select the six best plants to use for replanting in your county's dunes.

5. Construct a table similar to the one below. Complete the table by listing the plants that will be used in planting the dunes and an explanation as to why you are using the plant.

Table 1: Plants Used to Restore Dunes

Plants to be Used	Location on Dune	Explanation for Use of Plant
1.		
2.		
3.		
4.		
5.		
6.		

6. Make a sketch of the dunes and indicate where you will plant each of the plants on the dunes.



Seaoats
Uniola paniculata



Seacoast bluestem
'zachyrium scoparium littorale



Seashore dropseed
Sporoboius virginicus



Marshhay cordgrass
Spartina patens

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Plants for Coastal Dunes

Common Name	Scientific Name	Type of Plant	Annual or Perennial	Occurrence	Size	Description	Reproduction	Planting Method	Other Information
Bitter panicum	*Panicum amarum*	Grass	Perennial	Back beach, fore dunes, slopes, dunes, flats	3 to 4 feet tall	Leaves smooth, bluish green; seed heads narrow; extensive below ground rhizome system	Spread by rhizomes, seeds are sterile; grows rapidly	Stems with rhizome or rhizome	A favorite plant of animals; plant favors areas where windblown one growing season to be established to stabilize dunes; highly salt tolerant
Marshhay Cordgrass	*Spa rtina patens*	Grass	Perennial	Dunes-landward side, along bay shores, frontal zone	2 to 3 feel tall	Stems are slender, resemble rushes; seed head of two to several spikes	Network of slender rhizomes, viability of seeds varies greatly	Stems with rhizome attached; mix with Bitter Panicum	Most appropriate to repair stable parts of dunes
Sandbur or grassbur	*Cerichaus species*	Grass	Both annual and perennial species	Dominant in disturbed and heavily used areas; on dunes or back dunes	Under one foot	Low growing, branching with flat leaf blades	Seeds or rhizomes	Seeds or rhizomes	Distinguished by stiff spiny burs; not grown by choice, could be useful to reduce foot traffic
Seacoast bluestem	*Schizachyrium scoparium littoralo*	Grass	Perennial	Windward frontal dunes swales, rare on higher dune slopes	Very low	Prostrate or creeping with grayish loaves	Long rhizomes	Rhizomes	Often forms thick stands; needs more moisture than panicum or sea oats; less salt tolerant
Seaoats	*Uniola paniculata*	Grass	Perennial	Back beach to vegetated flats, on coppice dunes, large dunes, frontal zone, dune crests	3 feet or taller	Narrow pale green leaves, die back in winter, seed heads mature in fall, individual seeds like common oats, relatively few rhizomes	Extensive underground rhizome under natural conditions, seed germination is low and seedling survival is low	Transplant young plants; mix with bitter panicum	Loss salt tolerant than bitter panicum, grows rapidly to avoid being covered by sand, takes two growing seasons to stabilize a dune; tallest dune grass
Seashore dropseed	*Spomboius virginicus*	Grass	Perennial	Low dunes; frontal zone	6 to 18 inches	Low growing, numerous loaves; resembles common bermuda grass; has one seed head	Extensive rhizomes and stolons	Rhizomes	Occurs in wetter areas of dunes, limited to slow dunes with favorable moisture

Common Name	Scientific Name	Type of Plant	Annual or Perennial	Occurrence	Size	Description	Reproduction	Planting Method	Other Information
Gulf dune paspalum	*Paspa/um monostachyum*	Grass	Perennial	Low dunes; frontal zone	Very low	Low creeping grass, wetter areas makes a dense, flat sod	Runners and rhizomes	Runners and rhizomes	Resembles common bermuda grass
Sea purslane	*Sosuvium portulacastrum*	Herba-ceous		Back beach; near dunes	Very low	Creeping plant, forms sprawling mats of growth, succulent leaves, pink flowers with five sepals	Vegetative	Vegetative material roots easily	
Beach morning glory or railroad vine	*Ipornoes pes-capre*	Herba-ceous vine	Perennial	Back beach and fore dunes; windward slopes and leeward dune slopes	Stems may extend 75 feet	Prostrate spreading vine, stems are thick, fleshy and flexible; leaf blade, shape of goat footprint; boll shaped pink/purple flowers, up to 3 inches wide; borne on large stalks, roots emerge at nodes along stem	Seeding	Seeding recommend-ed or runners	Survival is dependent on length of stem; buried leaves die, but somewhere along stem, exposed leaves generate new runners. Literally grows to stay alive.
Fiddle-leaf morning glory	*Ipomoea stolonifera*	Herbac ecus vine	Perennial	Back beach, fore dune slopes, windward and leeward dune slopes	Stems extend 75 feet	Small vine, has narrower leaves, more irregularly lobed, white to yellowish flowers and up to 2 inches wide	Runners	Vegetative runners	Excellent example of creeper
Beach tea	*Croton puricfatus*	Shrub	Perennial	Gulf facing dune slopes especially on South Padre	Low	Low, spreading shrub with a woody base and silvery leaves, leaves, small clusters of light green flowers in late summer	Seeds	Planting seeds, late Fall to April	Seeds are a choice food of birds, ripen in Fall
Partridge Pea	*Cassia fasciculata*	Flower	Annual	Back of dunes; inner dunes	3 feet	Upright plant, yellow flowers with five petals	Seeds	Seeds	

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Topic 8 — Physical Features of the Ocean and the Gulf of Mexico

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Topic Eight: The Physical Features of the Ocean and Gulf of Mexico

Often each ocean or body of saltwater is treated as if it were a self-contained basin of water, separated cleanly from the others. This is not the case. Water flows across the geographic boundaries, both near the sea surface and in the depths, but water molecules in seawater are not confined to the oceans. They are passed through the atmosphere by evaporation; winds and air masses transport the vapor. Some water molecules are transported great distances. Eventually it condenses and falls, often on land, and returns to the ocean as river runoff. The global exchange of water between the ocean, land, and atmosphere is called the hydrologic cycle.

Because of the chemistry of the seawater and the physical nature of the water column, the ocean is a biogeochemical system. The salt content of the ocean comes from the chemical breakdown of rocks on land and from volcanic outpourings along the spreading of oceanic ridges. The driving force underlying the ocean's biogeochemical cycle is the sun. The sun's energy determines the temperature of the water and the stratification of the water column. The energy from the sun and matter (nutrients from rocks) are transferred through the biological systems by organisms. In the oceans, the physical, chemical, geologic, and biological systems are all interacting.

Activity 1: What is the bathymetry of the Gulf of Mexico?

TEKS: Science: 8.10, 8.12

Math: 6.3, 6.8, 7.2, 7.9, 8.2, 8.8

Language Arts: 6.10, 6.13, 6.20, 7.10, 7.13, 7.20, 8.10, 8.13, 8.20

Social Studies: 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- Describe the shape and features of the bathymetry of the Gulf of Mexico.
- Construct a table comparing the features of the Gulf.
- Interpret data on the bathymetry of the Gulf and write a story about a trip along the bottom of the Gulf.

Background:

1. By 1517, the Gulf of Mexico had been recorded by Europeans in their explorations. It was not until 1900 that geological explorations of the coastal areas were well underway. Discuss why the geological knowledge of the Gulf developed very slowly. It was due to a lack of technology for exploration of ocean depths and no interest or attraction for exploration. In 1938, the first offshore well was drilled off shore from Cameron, Louisiana. Geological knowledge about the Gulf grew rapidly after this. Today, advanced seismic technology and visits by submersibles like Alvin are providing even more information. Discuss the impact of the search for oil, gas and other minerals on our knowledge of the geology of the Gulf. Ask why maps of the oceans prior to the 1900s indicated that the oceans were flat and featureless.
2. Have the students work in pairs or teams, using the maps and the reading, to gather data on the bathymetry of the Gulf for completion of a data table. Discuss the data on the geological features of the Gulf. Compare the features of the Gulf to those of land.
3. After the discussion, have the students use the data to write and illustrate a story or develop a multimedia presentation about a trip in the Gulf that communicates the bathymetry of the Gulf.
4. Visit the website www.ecology.com/gulf/gulf_main.asp and click on "view the daily logs" to read the daily logs of *Alvin*, a deep-sea submarine deployed from the *R/V Atlantis*. The log records dives to the different areas of the Gulf of Mexico from October 15-30, 2000; it describes some of the features noted and includes pictures of the organisms seen.

Activity 2: How does the seawater smell and taste?

TEKS: Science: 6.2, 6.3, 6.4, 6.7, 7.2, 7.3, 7.4, 8.2, 8.3, 8.4

Math: none

Language Arts: 6.20, 7.20, 8.20

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- Conduct an experiment to determine the factors that affect the odor and taste of water
- Make inferences about the effect of pollutants on the odor and taste of water.
- Discuss the impact of pollutants on organisms that rely on the senses of smell and taste to locate food or find their way in their environment.

Background:

1. Begin the lesson by asking the students if all water smells and tastes the same. Then ask if all bottled

water tastes and smells the same. Have them share their experiences and make inferences as to why water may taste and smell different.

2. Before beginning Part I, ask if fresh and salt water differ in taste and smell. Ask students to predict how the different types of water will smell and taste.
3. Have the students complete Part I and II to determine if their predictions about the taste and smell of the different types of water are correct. Discuss and summarize their findings.
4. To emphasize the effect of very small amounts of chemicals on the taste of water, provide each student with a 3 oz. cup of water, a toothpick for stirring, and salt or sugar. Have the students add a few crystals of either salt or sugar to the water, then stir and taste the water. Have them repeat the process, adding only a few crystals each time, until they can taste the salt or sugar.
5. Ask the students to design and conduct an experiment to test the effect of very small amounts of a chemical on the smell of water. Have them use a 3 oz. cup and add one drop of vanilla or other flavoring to the water, stir and smell. They should add only one drop at a time until they can smell the flavoring in the water.
6. Many organisms in the ocean rely on their senses of smell and taste for survival. Discuss how organisms might use these senses for determining their location, migrating to different areas, finding food and locating danger.
7. Discuss the impact of pollutants on the smell and taste of water. Ask the students to make inferences about the potential impact of pollution on marine organisms that rely on smell and taste for survival. Discuss how the level of seawater pollutants will vary over time.

Activity 3: What are ppt (parts per thousand) and ppm (parts per million)?

TEKS: Science: 6.2, 6.3, 6.4, 6.14, 7.2, 7.3, 7.4, 8.2, 8.3, 8.4, 8.8, 8.12

Math: 6.3, 6.8, 7.2, 7.9, 8.2, 8.8

Language Arts: 6.10, 7.10, 8.10

Social Studies: none

Learner outcomes: After completing the activities, the students will be able to:

- Explain the meaning of ppt, ppm, and ppb and calculate the concentrations of each.
- Prepare and measure ppt and ppm solutions.
- Discuss salinity and design a graph or chart to illustrate it.
- Evaluate the effect of a ppm or ppb level of pollutant in water.

Background:

1. The concentrations of chemicals in water, whether fresh or salt, are expressed in parts per thousand (ppt), parts per million (ppm) and parts per billion (ppb). Most trace elements, such as manganese, lead, mercury, gold, iodine and iron, occur in concentrations of less than 1 ppm (part per million). Many occur in quantities of less than 1 ppb and even 1 part per trillion. These low concentrations make them difficult to trace, but the presence or absence of these elements can be very important for marine organisms: either they help the organisms to live or they harm or kill the organisms. Therefore, it is important to understand what these expressions mean.
2. For students who are not acquainted with ppt, ppm or ppb measurements, the expressions may seem mysterious and difficult. To help students understand the concept ask them to imagine a jar of M&Ms. If possible, set up a jar of M&Ms to demonstrate the concept. Create additional problems of various concentrations of different colors to help the students understand the concept. Have each group of students create a problem for another group of students to solve.
3. Since oceanographers often convert ppt into a percentage, provide problems to practice these calculations, or have the each student group create problems for another group to solve.
4. Discuss the meaning of seawater that has a salinity of 35 ppt. Emphasize that average ocean water is 3.5 percent sodium chloride, about 96 percent water molecules, and less than 1 percent trace elements. To illustrate this, have the students draw a box around 100 squares on a sheet of graph paper. Ask them to color 3.5 squares to represent sodium chloride and use another color to shade in less than one other square to represent the trace elements in water. The remaining squares represent water.
5. To further expand their understanding of ppt, have the students complete Part II. Discuss the impact of a pollution level in the ppm. Stress that most trace elements, such as manganese, lead, mercury, gold, iodine and iron, occur in concentrations of less than 1 ppm or 1 ppb.
6. If "Activity 2: How does the seawater smell and taste?" was not done previously, use it to reinforce the effect of very small amounts of a chemical in water. Or have the students plan the activity to determine what concentration or ppt of a chemical, such as sugar or salt, must be present in water before it can be tasted or smelled.

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Activity 4: What is the composition of seawater?

TEKS: Science: 6.7, 7.7, 8.8, 8.9, 8.14

Math: 6.3, 6.8, 6.11, 7.2, 7.9, 7.13, 8.2, 8.8, 8.14

Language Arts: 6.10, 6.13, 6.20, 7.10, 7.13, 7.20, 8.10, 8.13, 8.20

Social Studies: 6.2, 6.3, 6.23, 7.20, 7.23, 8.10, 8.32, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- Calculate the percentages of various chemicals found in seawater.
- Graph data from tables to illustrate the composition of seawater.
- Interpret the importance of the principle of constant proportion of seawater.
- Analyze the effect on earth (land and water) of water being a universal solvent.
- Research elements in seawater and appraise their impact on organisms.
- Evaluate the idea of mining the ocean for minerals.

Background:

1. To emphasize the meanings of solvent and solute, make a saltwater solution and ask students to identify the solvent and solute. Using a label from a package of artificial seawater or "Instant Ocean," have students determine what other chemicals (solutes) they might expect to find in seawater.
2. Have the students complete the activity and analyze the data presented in the tables. Ask them to prepare bar graphs of the data to illustrate the composition of seawater.
3. Stress the importance of the principle of constant composition or proportion. During the HMS *Challenger* expedition of the seas between 1872 and 1876, scientists discovered they needed the amount of only one ion in Table 1 to determine the concentrations of the other ions. All of the ions in seawater occur in fixed amounts relative to one type of ion. This was a major breakthrough in determining the salinity of seawater in a rapid, accurate, and economical way. Chemists chose to measure the chloride ion since it is the most abundant.
4. Point out that most plants cannot use elemental nitrogen and phosphorous. Instead, plants absorb phosphate and nitrate to obtain nitrogen and phosphorus. Silicon is used by important groups of plants (diatoms) and animals (radiolaria) to make shells around their cells. Discuss the variations in ocean nutrients due to uptake and release by organisms. Have students infer the impact of the addition of fertilizers.
5. Ask the students to compare Tables 1 and 2 with Table 4 and explain how this information can be used to support the idea that life began in the oceans.
6. Have students explain why marine plants and animals are rich in minerals and trace elements and how eating these plants or animals will provide other organisms (including humans) with the essential nutrients they need.
7. Ask the students to evaluate and provide data for the principle of water as a universal solvent. Challenge the students by asking them to discuss the effect(s) on Earth (land and water) if water were not a universal solvent.
8. Assign elements listed in Table 5 to the students to research and evaluate. As they research their assigned element(s), they should also determine additional uses and the toxicity of the element. If an element is harmful or toxic, ask the students to determine how additional amounts of the element might enter the water and how this might be prevented. For example, the mining of tin or copper can result in these elements entering watersheds and being carried to the gulf or oceans. Some may be released into waterways or the air as by-products of industrial or manufacturing processes.
9. Use the information on each element to determine its value to society. Discuss mining the element from the ocean. Emphasize that tons of seawater would be needed to produce a ton of that element. Also discuss the potential impact of removing elements from seawater on the chemistry of the seawater and organisms.

Activity 5: How does salinity affect the properties of water?

TEKS: Science: 6.2, 6.3, 6.4, 6.7, 6.8, 6.9, 6.14, 7.2, 7.3, 7.4, 7.7, 7.13, 8.2, 8.3, 8.4, 8.8, 8.10, 8.12, 8.14

Math: 6.3, 6.4, 6.8, 6.11, 7.2, 7.3, 7.9, 7.13, 8.2, 8.5, 8.8, 8.14

Language Arts: 6.9, 6.10, 6.13, 6.20, 7.9, 7.10, 7.13, 7.20, 8.9, 8.10, 8.13, 8.20

Social Studies: 6.3, 6.6, 6.22, 8.10, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- Make predictions about the effect of salinity on the properties of water.
- Conduct investigations to determine the effect of salt on the boiling point, freezing point and evaporation of water.

- Evaluate the unique properties of water and how they affect life on Earth (land and water).
- Relate global warming and the salinity of the oceans.

Background:

1. Despite its simple chemical composition, water is a complex substance with remarkable physical properties. The melting and boiling temperatures of water are much higher than expected when compared to chemically related hydrogen compounds (H_2S, H_2Se, H_2Te). Water also has an unusually high heat capacity and a tremendous solvent power. At this point, the physical structure of the water molecule could be examined to determine what accounts for these unusual properties.
2. Each group of students will work as research team to determine if the addition of salt significantly modifies some of the properties of water. Assign each team one of the investigations (Part I, II or III) to conduct. At the end of the investigation, each team will present their findings to the class. This could be a poster presentation.
3. In Part I, the students will observe that water has an unusual high heat capacity and much energy is required to heat water. Discuss the effect of the high heat capacity of water on the temperature of ocean water and life in the oceans.
4. In Part II, the hydrated salt ions "hold on" to individual water molecules, interfering with their rearrangement into an ice crystal. Therefore, adding salt to water lowers its freezing point. However, in freezing, the water crystals separate from the salt so that ice is frozen water instead of frozen salt water. Frozen water is less dense than liquid water; discuss the impact of this property. Ask the students how the Earth and life on Earth would be affected if frozen water were denser than liquid water.
5. When liquid water changes to a solid, heat energy is given off or released from the water. Discuss this property with the students and have them analyze the impact of this on the oceans, lakes, and rivers. Heat energy is released to the surrounding environment so it is warmed as water freezes. This helps to moderate temperatures and the weather. Note that in agriculture this principle is used to keep crops from freezing: Water is sprayed on the crops, and as the water freezes, it releases heat that keeps the air temperature from dropping drastically.
6. In Part III, students will discover that when a liquid such as water is placed in a closed container, some of the molecules will vaporize, thereby decreasing the amount of liquid. As the salinity of water increases, vapor pressure drops. The hydrated ions in saltwater "hold on" to the water molecules making their vaporization more difficult. Because of this, freshwater evaporates faster than seawater.
7. Have the students analyze the patterns in Figure 1. Latitude is a strong influence on the surface temperature of the oceans. Water temperature is highest in the tropics and decreases with distance from the equator. The salinity of the ocean's surface water also varies directly with latitude. The highest salinity occurs between 20 and 30 degrees north and south of the equator. The minimum salinity occurs near the equator and polar regions. The major control of surface salinity is the relative effect of evaporation and precipitation on climate. The high salinity levels in the subtropics are produced because evaporation exceeds precipitation. At the equator, the evaporation rates are high, but rainfall exceeds evaporation so the surface salinity is low. Because global warming is a problem, discuss how higher air temperatures might affect the salinity of the oceans and life in the oceans.

Activity 6: What factors affect the salinity of seawater?

TEKS: Science: 6.5, 6.7, 7.15, 8.8, 8.10, 8.12

Math: 6.4, 6.8, 6.11, 7.3, 7.9, 7.13, 8.8, 8.14

Language Arts: 6.10, 6.11, 6.20, 7.10, 7.11, 7.20, 8.10, 8.11, 8.20

Social Studies: 6.6, 6.22, 6.23, 7.9, 7.21, 7.23, 8.3, 8.32

Learner outcomes: After completing the activities, the students will be able to

- Identify and describe the sources of salts in seawater.
- Compare river and ocean water solute data.
- Analyze the sources of salt input and output to seawater and explain the stability of salts in seawater.
- Explain the differences in salinity along the Texas coast and make predictions about the effect of the salinity differences on marine ecosystems.
- Construct a diagram to illustrate the impact of hurricanes on salinity and life in coastal ecosystems.

Background:

1. There are many dissolved salts in the ocean. Ask the students to make hypotheses to explain where the salts came from and how they got there. (The data analysis they will do provides some answers to this.) Have the students analyze the data in

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Tables 1 and 2 and summarize how the salinity of the oceans has remained constant for at least 3.4 billion years. Discuss the interaction of the geological cycle (weathering, erosion, mountain building, uplifting, volcanic activity, etc.) with the hydrologic and biological cycles to form seawater.

2. Have the students analyze Figure 1 to discover the relationship of latitude, evaporation and precipitation on salinity. Salinity depends on the relative effects of evaporation and rainfall, and therefore varies with latitude.
3. The salinity of saltwater varies even along the Texas coast. Ask the students to construct an explanation for the variation in salinity. The upper half of the Texas coast has a greater rate of precipitation than evaporation. Precipitation is greatest along the Texas/Louisiana border. The lower half of the coast has a greater rate of evaporation than precipitation. Ask the students to make predictions about the effects of salinity differences on organisms and ecosystems in the bays and estuaries.
4. The short-term impact of a hurricane on seawater salinity is often overlooked. Have the students construct a diagram illustrating the impact of a hurricane on salinity and the resulting effects on aquatic and marine organisms in the coastal ecosystem.

Activity 7: What is the temperature of the water?

TEKS: Science: 6.2, 6.3, 6.4, 7.2, 7.3, 7.4, 8.2, 8.3, 8.4, 8.5, 8.8, 8.10

Math: 6.8, 6.10, 7.9, 7.11, 8.8

Language Arts: 6.13, 6.20, 7.13, 7.20, 8.13, 8.20

Social Studies: 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- Predict the pattern of ocean temperatures.
- Analyze data of ocean temperatures.
- Construct a graph of Gulf water temperatures and depth.
- Use data to develop explanations for surface temperature changes with depth.
- Conduct an investigation to determine what happens to seawater in polar regions.

Background:

1. Ask the students to predict how the ocean temperature varies and the pattern of the variations. Then have the students analyze Figure 1 and Table 1 to determine if the data supports or refutes their predictions. Discuss the role of latitudes and the surface temperature of the ocean. Solar energy striking the Earth's surface decreases poleward. Therefore, surface temperatures are highest in the tropics and decrease with distance from the equator. Discuss the effect of the seasons and the resulting variations of solar energy on surface temperatures. Point out that ocean currents flow around the edges of each ocean and affect the distribution of the surface water temperature.
2. After the students have analyzed Table 1 and graphed the data, discuss the pattern. Explain that investigations of water temperature and depth reveal that oceans in the middle and lower latitudes have a layered thermal structure. A layer of warm water floats over the colder, denser water that fills the ocean basin. The two water masses are separated by a sharp, rapid temperature change called a thermocline. Thermoclines are permanent features of temperate and tropical oceans at depths between 200 and 1,000 meters. The surface water temperature will change with the hour, time of day, and the season. However, the water below the thermocline (deep water) is at a low, stable temperature, averaging less that 4°C (near freezing) for most of the ocean, even at the equator. This phenomenon will be analyzed in Activity 8.
3. Before conducting the investigation in Part II, ask the students to develop hypotheses to explain what happens to saltwater that freezes in the polar regions. Have the students analyze their findings to determine if their hypothesis supports the explanation present in Part II, question 4.

Activity 8: What is the temperature structure of the ocean?

TEKS: Science: 6.5, 6.8, 7.8, 8.10, 8.12

Math: 6.8, 7.9, 8.8

Language Arts: 6.10, 6.20, 7.10, 7.20, 8.10, 8.20

Social Studies: 6.3, 6.6, 6.22, 7.8, 7.21, 8.10, 8.3

Learner outcomes: After completing the activities, the students will be able to:

- Compare temperature profiles of the oceans.
- Infer the cause of the variations in the temperature profiles.

Background:

1. Water temperature is regulated by solar heating and varies directly with latitude. Have the students analyze the typical temperature profiles of the ocean water in the low, middle, and high latitudes and summarize their patterns.
2. Ask the students to examine the ocean temperature cross-section and determine the latitude at

which each of the three temperature profiles would be found. Have the students summarize the patterns of ocean temperature and the factors that control these patterns. Discuss the role of the sun as the driving force in the structure of ocean water columns.

Activity 9: What is the link between temperature and environmental problems?

TEKS: Science: 6.2, 6.3, 6.4, 6.9, 7.2, 7.3, 7.4, 8.2, 8.3, 8.4, 8.10

Math: 6.8, 7.9, 8.8

Language Arts: 6.13, 6.20, 7.13, 7.20, 8.13, 8.20

Social Studies: 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- Predict the effect of temperature on environmental problems.
- Conduct an experiment to investigate the effect of temperature on pollution.
- Construct a diagram to apply the data from the experiment to a coastal body of water or the Gulf of Mexico.

Background:

1. Introduce the activity by asking the students to predict the effect of temperature on environmental pollution. Will pollutant movement be the same in the Gulf of Mexico as the Pacific Ocean off the coast of Washington? Have the students conduct the experiment and use their data to support or refute their predictions. They should write a statement that summarizes the relationship of water temperature and the movement of chemicals.
2. Ask the students to use the process of diffusion to explain what happened in their experiments. This could be explained through illustrations.
3. Have the students use the results from their experiment to construct a diagram or illustration to show what happens over time as a chemical enters a bay or the Gulf. The diagram could also include the impact of the climate or season.

Activity 10: What affects the density of seawater?

TEKS: Science: 6.2, 6.3, 6.5, 6.6, 6.7, 6.14, 7.2, 7.3, 8.2, 8.3, 8.5, 8.6, 8.7, 8.8, 8.10, 8.12

Math: none

Language Arts: 6.10, 6.13, 7.10, 7.13, 8.10, 8.13

Social Studies: 6.3, 6.6, 6.7, 7.8, 7.9, 7.10, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- Design and conduct an experiment to compare the density of fresh and salt water.
- Formulate and test a hypothesis describing the relationship between salinity and density.
- Apply the findings on salinity and density to situations in the Gulf of Mexico.
- Formulate and test a hypothesis describing the relationship of temperature and water density.
- Apply the findings on salinity, temperature, and density to the movement of ocean water.

Background:

1. Density is mass per unit volume. The density of seawater depends on temperature, salinity and pressure. The density of seawater increases as temperature decreases and salinity increases. (Pressure affects density only in the deepest parts of the oceans, so it will be ignored for our purposes here.)
2. Have different student teams design a protocol for each investigation. Each team will follow its test design and procedure to investigate density. Upon completion of the experiments, have the students share their findings and then discuss and critique each group's experimental procedures.
3. Fresh water entering the Gulf stays at the top of the Gulf water then eventually mixes with the seawater. Discuss the impact of fresh water entering the Gulf from rivers on the Gulf system. In the Gulf, hurricanes moving inland can push a storm surge of salt water into the bays, estuaries and marshes. Then the hurricane rain adds inches of water, resulting in fresh water floods into the bays, estuaries, marshes and Gulf. Discuss the impact of these changes on organisms in these areas. Explain to the students that organisms living in these areas can die from the changes caused by hurricane floodwaters.
4. Discuss the findings about the relationship of temperature and water density. Relate this to latitude and the findings from Activities 6 and 7. Point out that water density controls the vertical structure of the water column. The denser water will underlie the less dense water. Discuss the role of water density in the horizontal layering of ocean water and the movement of water.
5. Ask the students to explain the interrelationship of the sun, the hydrologic cycle and the geologic system on the density of seawater.

Activity 11: What is the connection between density and ocean currents?

TEKS: Science: 6.2, 6.3, 6.4, 6.5, 6.7, 6.8, 7.2, 7.3, 7.4, 7.5, 7.8, 8.2, 8.3, 8.4, 8.8, 8.12

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Math: 6.8, 7.9, 8.8

Language Arts: 6.9, 6.10, 6.20, 7.9, 7.10, 7.20, 8.9, 8.10, 8.20

Social Studies: 6.6, 6.22, 7.9, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- Formulate and test their predictions about temperature and water movement.
- Construct models to show the role of temperature in the movement of water or water currents.
- Create diagrams of collected data and use them to explain movement of ocean water.

Background:

1. Have each student team list what they know about the temperature, salinity and density of seawater from their previous investigations. Using a model, the students will conduct a series of investigations (A-E) to learn more about the patterns of water movement or currents in the oceans.
2. Prior to each investigation, have each team sketch or write their prediction for the movement of the water. After they have conducted the experiment, students should sketch and summarize what they observed.
3. In Investigation A, where the water temperature is even, the movement of the food coloring will be very slow. This movement is due to simple diffusion of the water molecules. In Investigation B, the water temperature is unevenly heated. The food coloring helps students to discover that warm water rises. When the warm water reaches the surface, it spread to the edges of the container. By the time it has reached the edges of the container, this water will have cooled. It will sink and displace the water over the heat source, and the cycle begins again. This cycle of movement is called a convection cell. Investigation C will also form a convection cell. In the warmer water, the addition of energy causes the molecules to move apart or become less dense, so the warm water rises. As it cools, it becomes denser than the surrounding water and sinks, thereby forming a convection current. In Investigation D no convection currents will occur because the water was cooled. The colder water will remain on the bottom.
4. When the students have completed the investigations, have them prepare a summary of their findings including the effects of temperature, salinity, and density on water movement and the formation of currents. Compare their model with the ocean. The pattern of water movement and convection will be similar. Ask the students to relate their investigations to different areas of the ocean. Which would represent the polar regions? The tropics? What is the role of deep seas vents in the movement of water? Also discuss the role of the currents in moving nutrients from the ocean bottom to the surface and the sinking of organic material from the surface to the ocean bottom. Relate this to the movement and location of organisms.
5. Have the students discuss how the ocean is a system.

Activity 12: How does seawater form layers?

TEKS: Science: 6.5, 6.6, 7.5, 7.12, 8.6, 8.12

Math: 6.3, 6.11, 7.2, 7.9, 7.13, 8.2, 8.8, 8.14

Language Arts: 6.9, 6.10, 6.11, 6.13, 6.20, 7.9, 7.10, 7.11, 7.13, 7.20, 8.9, 8.10, 8.13, 8.20

Social Studies: 6.1, 6.3, 6.6, 6.7, 7.7, 7.8, 7.10, 8.10, 8.12

Learner outcomes: After completing the activities, the students will be able to:

- Construct models to show the movement of different types of seawater in the ocean.
- Use diagrams to explain how seawater forms layers.
- Use diagrams to explain how currents are formed.

Background:

1. The surface layer of the ocean is thin and about 100 meters deep. This represents about 2 percent of the ocean's volume. The water at the surface is the least dense of the water column because of its water temperature. The boundary zone between the surface and deep layers is where a sharp density gradient exists. The water in the boundary zone is in transition between the layers and constitutes 18 percent of the ocean volume. The deep layer of the ocean makes up 80 percent of the ocean volume; it sinks to the bottom because of its high density. Much of this water originates in the upper latitudes.
2. Prior to beginning the activities, ask the students to list what they have learned about density and ocean water. Have them make hypotheses about the formation of currents and layers in water masses.
3. Set up the models and conduct the investigation to determine how the ocean forms layers and how the layers move. Have the students apply this information to what happens when different "rivers" of water (different temperature, salinity, density) flow into the Gulf or an ocean. Summarize the interaction of the different systems.

Activity 13: How do the ocean waters and currents move?

TEKS: Science: 6.5, 6.6, 6.12, 7.5, 7.12, 9.6, 8.12

Math: 6.3, 6.8, 6.11, 7.2, 7.9, 7.13, 8.2, 8.8, 8.14

Language Arts: 6.9, 6.10, 6.11, 6.13, 6.20, 7.9, 7.10, 7.11, 7.13, 7.20, 8.9, 8.10, 8.13, 8.20

Social Studies: 6.1, 6.3, 6.6, 6.7, 7.7, 7.8, 7.9, 7.10, 8.10, 8.12

Learner outcomes: After completing the activities, the students will be able to:

- Compare Ben Franklin's map of the currents with that of NOAA satellite images.
- Compare ocean currents to river currents.
- Analyze figures to determine the relationship of oceanic and atmospheric circulation.
- Use figures of currents to infer how the movement of surface ocean currents has and does affect people and organisms.
- Explain the formation of deep ocean currents.
- Summarize the interaction of ocean currents with Earth's biological system.
- Summarize the impact on Earth if there were no surface or deep ocean currents.

Background:

1. Ocean currents are divided into two types of flow, based on the factors that move them. Most surface currents are driven by the wind; subsurface currents are density driven. Because of gravity, the dense water sinks and displaces less dense water. Although the deep currents are not affected by the wind, the climate does affect them. Climate controls the salinity and temperature of the water and therefore controls the density. The wind-driven surface currents affect only about 10 percent of the ocean's volume. More is known about surface currents than deep ocean currents. As students observe the pattern of the Gulf Stream point out that currents meander like a river.
2. Part I provides students an opportunity to use data on currents to understand how currents were and are used by humans.
3. Use Figures 3 and 4 to help students understand the relationship between the oceanic and atmospheric systems. Explain the role of the Coriolis effect on the ocean and atmosphere. Point out that the large wind-powered circulation gyres in each ocean consist of a system of currents that rotate clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. These wind currents flow around a central mound of water. The ocean currents are a balance between the Coriolis effect and the pressure gradient caused by the wind.
4. In Part II, have the students note the patterns in the currents and how they affect people and organisms (transportation, movement of people and organisms, nutrients available, movement of pollutants, etc.). To further investigate ocean movement, assign each team an ocean area to explore using the maps, pictures, charts, and other information available on the Internet. Visit the National Oceanic and Atmospheric Administration (NOAA) web site at www.@noaa.gov; the U.S, Geological Survey site at www.usgs.gov or search.usgs.gov; and TOPEX/POSEIDON project data sources at http://topex-www.jpl.nasa.gov/science/science.html.
5. To begin Part III, have the students review their results in Activity11: What is the connection between density and ocean currents? and summarize the movement of deep ocean currents. Note that ocean basins exchange water on a regular basis. It is thought that warm water from the Pacific Ocean and Indian Ocean is exported to the Atlantic Ocean along the surface, where it cools and sinks, returning at a depth back to the Pacific and Indian Oceans. Discuss the importance this circulation and the impact of it on pollution.
6. In closure have the students summarize the impact on the Earth and ocean if there were no surface currents and/or no deep ocean currents.

Activity 14: What is the effect of currents in the Gulf of Mexico?

TEKS: Science: 6.5, 6.6, 7.5, 7.11, 7.12, 7.14, 8.11, 8.14

Math: 6.3, 7.2, 8.2

Language Arts: 6.1, 6.9, 6.13, 6.20, 7.1, 7.9, 7.13, 7.20, 8.1, 8.9, 8.13, 8.20

Social Studies: 6.1, 6.3, 6.6, 6.7, 6.20, 6.22, 7.7, 7.8, 7.9, 7.10, 7.20, 7.21, 8.11, 8.29, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- Interpret data concerning currents in the Gulf of Mexico.
- Summarize the interaction of the Gulf of Mexico currents with the biological systems.
- Relate the currents to the movement of nutrients, organisms, sediments, sand and pollutants in the Gulf.

Background:

1. Climate has a strong influence on water circulation in semi-enclosed seas. The water chemistry and marine biology in these basins are influenced

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greatly by their circulation patterns. This activity uses the Gulf of Mexico as an example to help students understand this influence and the effect of surface currents. Have the students use the map of the surface currents to determine how currents affect the movement of nutrients, sand, sediments, organisms and pollutants in the Gulf.

2. Incorporate the information from **Topic Five: Watershed of the Gulf of Mexico,** especially Activities 6, 7 and 9, to expand on the movement of pollutants and nutrients that enter the Gulf. Ask the students to propose ways to use the information about the currents to protect the Gulf.

Activity 15: What causes waves?

TEKS: Science: 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 7.2, 7.3, 7.4, 7.14, 8.2, 8.3, 8.4, 8.5, 8.7, 8.10, 8.12, 8.14

Math: 6.3, 6.8, 7.2, 7.9, 8.2, 8.8

Language Arts: 6.9, 6.13, 7.9, 7.13, 8.13

Social Studies: 6.3, 6.6, 6.23, 7.8, 7.9, 7.23, 8.10, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- Conduct an experiment to investigate the causes and parts of waves.
- Measure wave height, length and period.
- Formulate and test a hypothesis describing the effect of wind speed and the duration of the wind blowing on waves.
- Construct a model to show how water moves in a wave.
- Construct a model to show how the slope of the shoreline affects the type of breakers that are produced.
- Apply experimental findings to explain the relationship of the shoreline to waves and breakers.
- Create an illustration to explain an aspect of waves or rip currents.

Background:

1. One of the most memorable aspects of a beach trip is the surf. The larger the waves the more exciting the trip. When the waves are small, visitors are disappointed. Begin the activity by asking the students to share their experience with waves on the beach, lake, swimming pool or even a bathtub. What do they know about waves? What would they like to know about waves?
2. In Part I, have teams of students explore with waves and list all that they have learned about waves. After the students complete Part II, have each group share their measurements and identify the parts of the wave.
3. Before beginning the investigation of factors that affect waves discuss the safe use of the hair dryer or fan. Have the students record their hypotheses before conducting the experiments. Also discuss the variables and controlling variables. After the investigation, discuss their observations and results about wind and the size of waves.
4. The variety and size of wind-produced waves are controlled by four principal factors: (1) wind velocity, (2) wind duration, (3) fetch, and (4) the original condition of the sea. As wind speed increases, so do wavelength, period, and height of the resulting waves. The wind must blow long enough and the area of water over which the wind blows (the fetch) must be of adequate length for wave formation: the longer the length of the water area, the larger the wave. Therefore, wind blowing 50 mph over a swimming pool will not produce as large a wave as it would over a pond. The waves produced over a lake would be larger than those over a pond, and the ocean would produce the largest waves. If waves are already present on a body of water, the wind will produce larger waves.
5. Part V is important to conduct to help the students understand that water particles and anything floating in water rotate around a vertical circle. An object floating on the water will move back and forth and up and down. This means that with the passage of one wave, all of the water particles and any object floating on the water will be disturbed by the wave but will return to the spot where they began. The larger the wave, the larger the size of the orbit. Ask the students if they have floated on an air mattress or boogie board out beyond the breakers to describe the motion they experienced. Waves that are in water shallower than one-half their length will interact with the ocean floor. The friction caused by the interaction with the ocean floor flattens the orbit of the wave; once waves enter shallow water, the sea bottom affects them. One result is refraction or the bending of the wave crest in response to the drag along the ocean floor. The waves also slow down, increase in height, and increase in steepness. One can see the wave get bigger and steeper just before it collapses as a breaker at the shoreline.
6. In constructing the model of the different shoreline types, the student will learn that the slope of the shoreline determines the type of breaker. The most common breaker is a "spilling" type. Spilling breakers form along shores where the sand is spread out over a gently sloping sea bottom, such as the Gulf coast. On a steep bottom shoreline, the plunging breaker changes into the classic "pipeline" form where the crest curls over the

front of the advancing wave. On shorelines with a very steep bottom, surging breakers form. These do not break because they never reach the critical wave steepness; the waves just decrease in size and lose momentum as they move up the beach. These waves can be found at the steepest beaches, steep seawalls and seal cliffs.

7. After the students conduct the investigation of Part VI, discuss the rip currents and how to avoid getting caught up by them. They are responsible for drownings along the Gulf Coast. Each team can prepare a poster to explain and illustrate some aspect of waves.

Activity 16: What causes catastrophic waves?

TEKS: Science: 6.2, 6.3, 6.4, 6.5, 6.6, 6.14, 7.2, 7.3, 7.4, 7.5, 7.14, 8.2, 8.3, 8.4, 8.5, 8.10, 8.12

Math: 6.3, 6.8, 7.2, 7.9, 8.2, 8.8

Language Arts: 6.9, 6.10, 6.20, 7.9, 7.10, 7.20, 8.9, 8.10, 8.20

Social Studies: 6.1, 6.3, 6.6, 6.7, 7.7, 7.8, 7.9, 7.10, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- Graph and interpret data concerning factors affecting waves in the ocean.
- Explain the cause and destructive potential of storm surges.
- Explain the formation and danger of tsunamis.
- Summarize why little is known about internal waves and why more research is needed.

Background:

1. Graphing the data on waves should indicate to the students that as wind speed increases, so do wave height, wavelength, wave period and significant wave height. Significant wave height is a statistical wave measure which is the average of the highest one-third all the waves present in an area of the sea surface.
2. Storms are an example of the interaction of the oceanic and atmospheric systems. Discuss how the storms affect the shore in a variety of ways. The water surface will rise in response to the low atmospheric pressure of the storm. Strong winds blowing onshore force water landward and cause it to stack up against the shore; this results in unusually high waters levels that cause flooding. These sudden changes in coastal water levels produced by storms are called storm surges. Point out that the most dangerous storm surges are associated with hurricanes and these can and have been deadly. Discuss the impact of a 15- to 20-foot storm surge on the gently sloping Texas coast. Discuss the cautions that should be taken when the possibility of storm surges exist.
3. Tsunamis are a series of sea waves that contain a tremendous amount of energy. These waves have very long periods and wavelengths. They grow in height in shallow water and flood the shoreline. Because of lack of warning, they have been and can be catastrophic. Part II will provide the students with an understanding of the cause of tsunamis. Discuss why tsunamis are so dangerous and why warning systems are needed.
4. Internal waves are submarine disturbances in between the layers in a water column. Discuss why so little is known about internal waves and why more research is needed.

Activity 17: What causes the motion of tides?

TEKS: Science: 6.2, 6.3, 6.4, 6.5, 7.2, 7.3, 7.4, 7.5, 7.14, 8.2, 8.3, 8.4, 8.5, 8.6, 8.10, 8.12, 8.14

Math: 6.8, 7.9, 8.8

Language Arts: 6.10, 6.11, 6.13, 6.20, 7.10, 7.11, 7.13, 7.20, 8.10, 8.11, 8.13, 8.20

Social Studies: 6.3, 6.6, 6.23, 7.8, 7.9, 7.23, 8.10, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- Construct a model to compare the impact of the Moon and Sun on tides.
- Compare data on the three types of tides and their location.
- Interpret diagrams to explain what causes tides.
- Explain the relationship of the activity of organisms and tidal rhythms.
- Evaluate the harnessing of tides for energy.

Background:

1. Explain that models are simplifications of the real world and that the students are going to use magnets to represent the gravitational pull on the Earth. The tidal pulse anywhere on Earth is caused by two principal factors: gravitational attraction and centrifugal force. All masses (the Sun, Moon and Earth) are drawn to each other and exert a gravitational pull. The strength of the gravitational attraction varies directly with the masses of the interacting bodies and the separating distance. Because the Moon is much closer to the Earth than the Sun (the Sun is about 390 times farther away from the Earth), it has more than twice the gravitational pull on the Earth, despite the Sun's immense mass. Therefore, the Moon's gravitational pull is the main force causing tides. Refer to

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the model to help the students understand that the impact of the Sun is less than the Moon.

2. Ask the students to identify the limitations of the model. The models and figures assume the sea bottom does not affect the tides, the ocean basin is uniform and there are no landmasses to distort the tidal bulges.
3. As a point on the Earth enters a water bulge, the tide rises and as it leaves a water bulge, the tide falls. The tides also vary depending on the angle, called declination, between the Earth's axis and the Moon's orbit around the Earth. Different points on the Earth's surface pass through various parts of the tidal bulges. Some pass through the center, others near the edge. The tides differ in areas depending on their location on the globe.
4. The location on the globe determines the period of the tides. Their position determines whether they are diurnal, semidiurnal or mixed tides. Note that the basin's length and water depth affect the tides. In shallow water and near coastlines, tidal currents reverse back and forth.
5. Many coastal organisms are attuned to the rhythms of the tides. Ask the students for ideas as to why organisms are attuned to the tides. Ask the students to make inferences as to how tides would affect the food, shelter, and reproduction of organisms. The students might select organisms that live in the tidal zone and conduct a literature search to determine the relationship. For example, the activity of fiddler crabs is correlated to tides. They remain inactive in their burrows during high tide and emerge to search for food during low tide. This behavior is maintained in the laboratory in the absence of tides. The activity of many organisms that live in the tidal zone is dependent upon the tides. Provide the students with a list of tidal organisms to research and determine if their activity is related to the tides.
6. Ask the students to hypothesize what type of basin is appropriate for producing tides for generating electricity. Explain that a basin like the Bay of Fundy has the appropriate geometry and tidal range. Electrical power can be generated by tidal currents when there is a basin in which there are very high tides. The tide flows over specially designed turbines that are turned by the tides to produce electricity.

Activity 18: Why is the sea blue?

TEKS: Science: 6.2, 6.3, 6.4, 6.12, 7.2, 7.3, 7.4, 7.11, 8.2, 8.3, 8.4, 8.5,

Math: 6.3, 6.8, 7.2, 7.9, 8.2, 8.5, 8.8

Language Arts: 6.11, 6.13, 6.20, 7.11, 7.13, 7.20, 8.11, 8.13, 8.20

Social Studies: 6.3, 6.6, 7.8, 7.9, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- Use diffraction grating or a spectroscope to investigate the wavelengths (colors) of light from various light sources.
- Interpret data concerning the relationship of the absorption of visible light in water and the colors visible at various depths.
- Interpret data concerning the relationship of the absorption of visible light in water and the wavelengths.
- Explain the blue and green colors of the sea and the difference in color of near-shore water.
- Construct a model to show the effect of selective absorption of light and visibility of color.

Background:

1. To introduce the lesson, have the students view a short video segment of undersea environments. Ask the students to describe what they notice about the color of the water. In videos of the ocean, the surrounding area will appear black or bluish in color. The only areas in which there are other colors are those on which the light used in the photography is shining directly on the objects. Discuss the color of water in different coastal and ocean areas. Ask the students to formulate hypotheses to explain the color of the water and differences in the color.
2. In Part I, the students use diffraction grating to discover that white light is composed of the colors of the spectrum. In addition, they will investigate the colors from different sources of light to discover that all white light is not composed of the same amount and type of light waves. They will also discover that light waves from a colored light source include many colors and that there is series of light waves for each color.
3. Part III may be completed next and used to answer the questions in Part II. Stress that as solar radiation (light) strikes the ocean, a large portion of it is reflected from the surface back into the atmosphere. The amount of reflected light depends on the height of the sun above the horizon and the smoothness of the water surface. The light that is not reflected enters the water and is absorbed by water molecules. About 65 percent of the visible light is absorbed within one meter of the ocean surface. Explain that this absorbed energy will heat the water causing the surface temperature of the water to rise.
4. Have the students analyze and look for patterns in the figure of light absorption in water. The longer wavelengths of visible light (reds and yellows) are

absorbed more readily by water than the shorter wavelengths (greens and blues). Ask the students to note the depth at which each color would no longer be seen since wavelengths of that color are absorbed. No more than 1 percent of all sunlight penetrates to a water depth of 100 meters (~330 feet); this light is composed of the blue part of the visible spectrum. Ask the students to make inferences about the impact of high loads of suspended solids, organic and inorganic, in near shore water. Light may not penetrate the turbid water any deeper than 20 meters (~66 feet) and sometimes even less than 1 meter. The color of the near shore water is usually green and yellow because the suspended particles reflect these wavelengths.

5. Ask the students how the diminishing light intensity with depth will affect life in the oceans and how this can be used to divide the water column into vertical zones. In the upper zone in which sunlight penetrates, plants receive adequate levels of sunlight and photosynthesis can occur. This is called the photic zone. Below the photic zone is the dark aphotic zone where plants cannot survive.
6. Explain that water's property of selective absorption of certain wavelengths of light, combined with the scattering of the visible light, accounts for the blue color of the open ocean. Other colors in water are caused by impurities like soil, algae, natural dyes like tannin or pollutants.
7. Water acts like a color filter. It filters out or removes colors as the depth increases. In Part III, the students will create a model to investigate the effect of removing various colors (wavelengths) to determine the color of objects.
8. Have the students revisit their hypotheses and revise or change their explanations about the color of seawater based on what they have learned from the activities.
9. In investigating the light levels in the coral reefs of the Flower Garden Banks, scientists have found that a number of different factors affect how much light reaches the bottom. These include the time of day, cloud-cover, and time of year. Ask the students to formulate hypotheses to describe the relationships of these factors with light penetration. To check their predictions have the students use the Internet to visit http://www-ocean.tamu.edu/NR1/home.html and click on "Light in Water." The Light in Water unit has three parts: (1) The Color of Water, (2) Measuring Light at the Flower Gardens, and (3) How Light Fades in Water. For a graph of the light measurements taken at the Flower Garden Banks or to access graphic data from the Gulf of Mexico for students to analyze, go to http://www-ocean.tamu.edu/NR1/unit_light-water_2.html.

Activity 19: What causes sound and how does it differ in the ocean?

TEKS: Science: 6.2, 6.3, 6.4, 6.7, 6.9, 6.24, 7.2, 7.3, 7.4, 7.6, 7.13, 7.24, 8.2, 8.3, 8.4, 8.5, 8.6, 8.8, 8.10, 8.13, 8.24

Social Studies: 6.3, 7.8, 8.2

Math: 6.8, 7.9, 8.8

Language Arts: 6.10

Learner outcomes: After completing the activities, the students will be able to:

- Define and describe sound and sound waves.
- Demonstrate the properties of sound and sound waves.
- Conduct an experiment to investigate the effect of the medium on sound waves.
- Interpret data concerning sound waves in different mediums and temperature.

Background:

1. Before beginning the lesson, ask each group to develop an explanation of what sound is and the properties of sound. Then have each group complete Part I and revisit their explanation of sound and its properties to revise it if needed. Ask each group to prepare a poster presentation to explain sound and sound waves. Stress that all sounds are associated with vibrations and without vibrations there is no sound.
2. After the students have completed Part II discuss sound in seawater. To summarize their understanding of sound, have each group develop a role-play to illustrate sound waves and the properties of sound.

Activity 20: How can sound be used to study the ocean?

TEKS: Science: 7.6, 8.10, 8.12

Math: 6.3, 6.8, 6.11, 7.2, 7.9, 7.13, 8.2, 8.5, 8.8, 8.14

Language Arts: 6.20, 7.20, 8.20

Social Studies: 6.3, 7.8, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- Use data to calculate the ocean depth and plot the profile of the ocean floor.
- Identify the features of the ocean floor on a profile of the ocean.

  Explain how echo sounding is used to profile the ocean floor, locate objects on the ocean floor or locate schools of fish or submarines.

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Background:

1. Have the students work in pairs or groups to prepare and label a profile of the ocean floor.
2. Explain that the speed of sound in water increases as salinity, temperature and pressure (depth) increase. In the sea, the velocity of sound averages about 1,445 meters per second (m/s). It increases by about 1.3 m/s (~29mph) for every one o/oo increase in salinity and by 4.5 m/s (~10.1 mph) for every 1°C increase in temperature. For every 100 meters (~330 feet) of depth (an increase in pressure), sound velocity increases by 1.7 m/s (~3.8 mph). Salinity varies slightly with water depth; the variations in the speed of sound are due primarily to temperature and pressure. Discuss how these changes affect the profile and why scientists must accurately determine the speed of sound in water when making soundings.
3. Discuss how echo sounding or sonar can be used to profile the ocean floor, as well as locate submarines, whales, or schools of fish, and distinguish between rock layers on the ocean floor.
4. Sound waves are bent or refracted as they travel through water of uneven temperatures. This poses a problem for surface vessels that bounce sound waves off the bottom of the ocean to chart its features because of layers of water at different temperatures (thermal gradients), the refraction of sound leaves gaps or "blind spots" in the water. Submarines use this to hide. If it weren't for refraction, submarines would be easier to detect.
5. Multiple reflections and refractions of ultrasonic waves are used by doctors to "see" inside the body without using x-rays. When high frequency sound enters the body, it is reflected more strongly from the organ surface than the interior, and an outline of the organs is obtained. Bats and dolphins use reflection and refraction of ultrasonic waves for direction.

Activity 21: What is the connection between the ocean depths and force-pressure?

TEKS: Science: 6.2, 6.3, 6.4, 6.6, 6.7, 7.2, 7.3, 7.4, 7.6, 8.2, 8.3, 8.4, 8.5, 8.7

Social Studies: 6.3, 7.8, 8

Math: 6.8, 7.9, 8.8

Language Arts: 6.10

Learner outcomes: After completing the activities, the students will be able to:

- Communicate the relationship of water molecules, pressure, and depth using sketches or diagrams.
- Construct a model showing the relationship of depth and pressure.
- Calculate the water pressure at different depths and on objects at different depths.
- Summarize the impact of pressure on equipment and organisms in the ocean depths.

Background:

1. Have the students place their textbook on the palm of their hand in three different positions: on its back, on its side and standing up or balanced on a corner. Ask the students if they sense a difference. The weight of the book has not changed, but the pressure of the book depends on the area over which the force is distributed. Explain the difference between force and pressure. The upright book or the one standing on its corner exerts the greater pressure. Pressure is defined as the force exerted over a unit of area, such as a square inch, square meter, or square foot.
2. Have the students complete Part I. Discuss the relationship between pressure and depth. Discuss the bottle as a model of the ocean basin and pressure. Explain that water pressure pushes perpendicularly against the sides of a container and increases with depth. The liquid spurts at right angles to the surface before curving downward due to gravity. At greater depths the pressure is greater and the speed of the escaping liquid is greater.
3. Ask the students to think about the feeling of pressure acting on their eardrums when swimming underwater. Ask them what happens when they swim deeper. The deeper they swim, the greater the pressure. Explain that the change in pressure is the change in the weight of the water above pushing against them. Therefore, if they swim twice as deep, the water above is twice as heavy and they will feel twice the water pressure. Point out that pressure does not depend on the amount of liquid; pressure is dependent on depth not volume. They would feel the same amount of pressure a meter deep in a small pool or a meter deep in the middle of the ocean.
4. Have the students examine Table 2: Depth and Pressure. Students should use the information from the table for Part II. The pressure at the surface of the water is 14.7 psi. The pressure then increases 14.7 psi for every 10 meters in depth. Therefore, at a depth of 10 meters, the pressure is 29.4 psi—14.7 psi (surface) plus 14.7 psi (10 meters). At a depth of 60 meters the pressure is 102.9 psi—14.7 psi (surface) plus 14.7 psi multiplied by 6 (60 meters). The pressure at 200 meters would be 308.7 psi; 3,790 meters would be 558.6 psi; and so on.

5. Stress that if submarines, submersibles or instruments used in the depths cannot withstand the pressure or develop a crack, the pressure will destroy them instantaneously. Have the students hypothesize as to how organisms are able to survive in these depths. The liquid pressure in the organism's cells is countering the pressure of the ocean so its body does not collapse.

Activity 22: Can you say it with a dance?

TEKS: Science: none

Math: none

Language Arts: 6.24, 7.24, 8.24

Social Studies: 6.6, 7.11, 8.10

Learner outcomes: After completing the activities, the students will be able to:

- Communicate the motion of water through dance movements or music.

Background:

1. The rhythmical movement of the sea has influenced literature and the arts. In this activity, the students will apply their knowledge of the motion of water to create dances (bodily-kinesthetic activities) and/or to create musical expressions.
2. Students could also locate poetry that illustrates the motion of the water or write poems to illustrate the movement of water.

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1. What Is the Bathymetry of the Gulf of Mexico?

Oceanographer _____ **Team** _____

What is bathymetry? Bathymetry refers to the measurement of the depth of the ocean. It is also the study of the shape of the ocean bottom—its shelves, slopes, plains, peaks, and canyons. You are going to learn about the Gulf's bathymetry.

Materials: colored markers or map pencils

Procedure:

1. As you examine Figure 1.1, note that the Gulf of Mexico is a small ocean basin. The average depth is about 5,000 feet. The Pacific, Indian and Atlantic Oceans each average about 13,000 feet deep. The Caribbean, the Gulf's neighbor, has an average depth of almost 8,700 feet. The Mediterranean Sea averages about 4,700 feet and the Bering Sea about 5,100 feet. Based on depth, then, is the Gulf of Mexico more like an ocean or an enclosed sea? Explain.

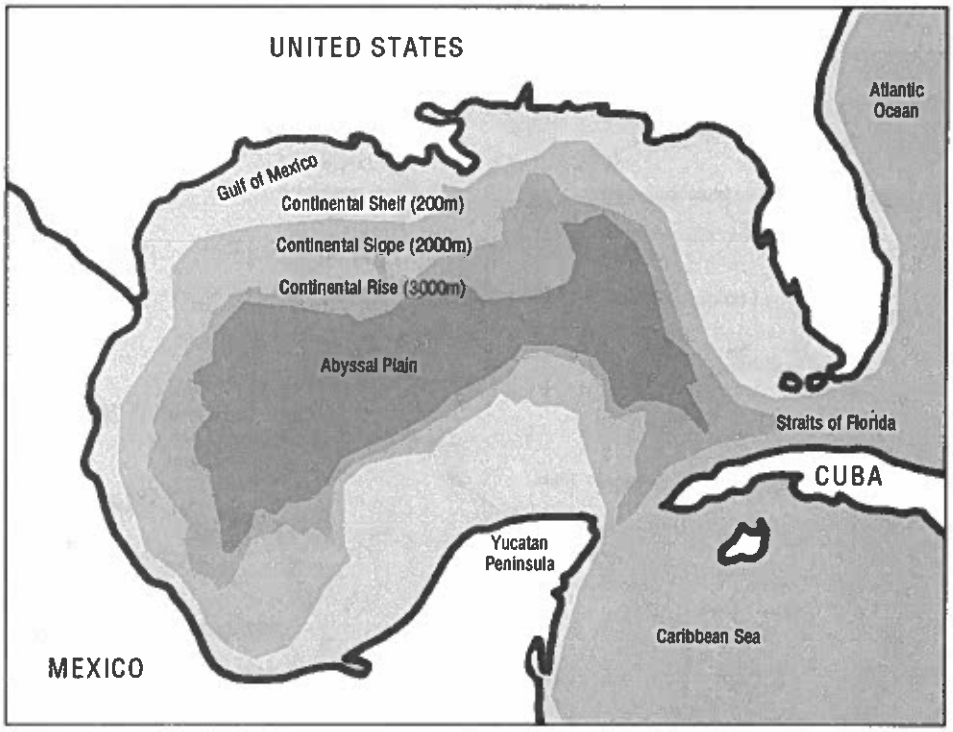


Fig. 1.1. Geologic profile of the Gulf of Mexico (Source: U.S. Department of te Interior Minerals Management Service)

2. On a separate piece of paper create a full page table on the bathymetry of the Gulf of Mexico. Use Table 1 as a model. As you read the description of the bathymetry of the Gulf of Mexico, fill in your table.

Table 1: Bathymetry of the Gulf of Mexico

Area	Location	Description	Depth	Size Width	Surface Appearance

3. The Gulf is divided into four areas: the continental shelf, the continental slope, the continental rise and the abyssal plain.

   The **continental shelf**, as the name suggests, is an underwater shelf that slopes gradually (about 1 degree) from the beaches or shoreline out into the Gulf. It begins to disappear where the water is about 200 m (700 feet) deep. Off Florida and Texas, the shelf is about 200 km (125 miles) wide, but where the Mississippi River has built its delta, the shelf is very narrow. The shelf is actually a part of the continent, so it resembles the Gulf coastal plain both in topography and in mineral content. While it is described as a plain, its surface is irregular. The surface is cut by small canyons and small hills are common. Locate the shelf in Figure 1.1 and color it light brown with a marker or map pencil. Note the location of the shelf in Figures 1.1, 1.2, 1.3 and 1.4.

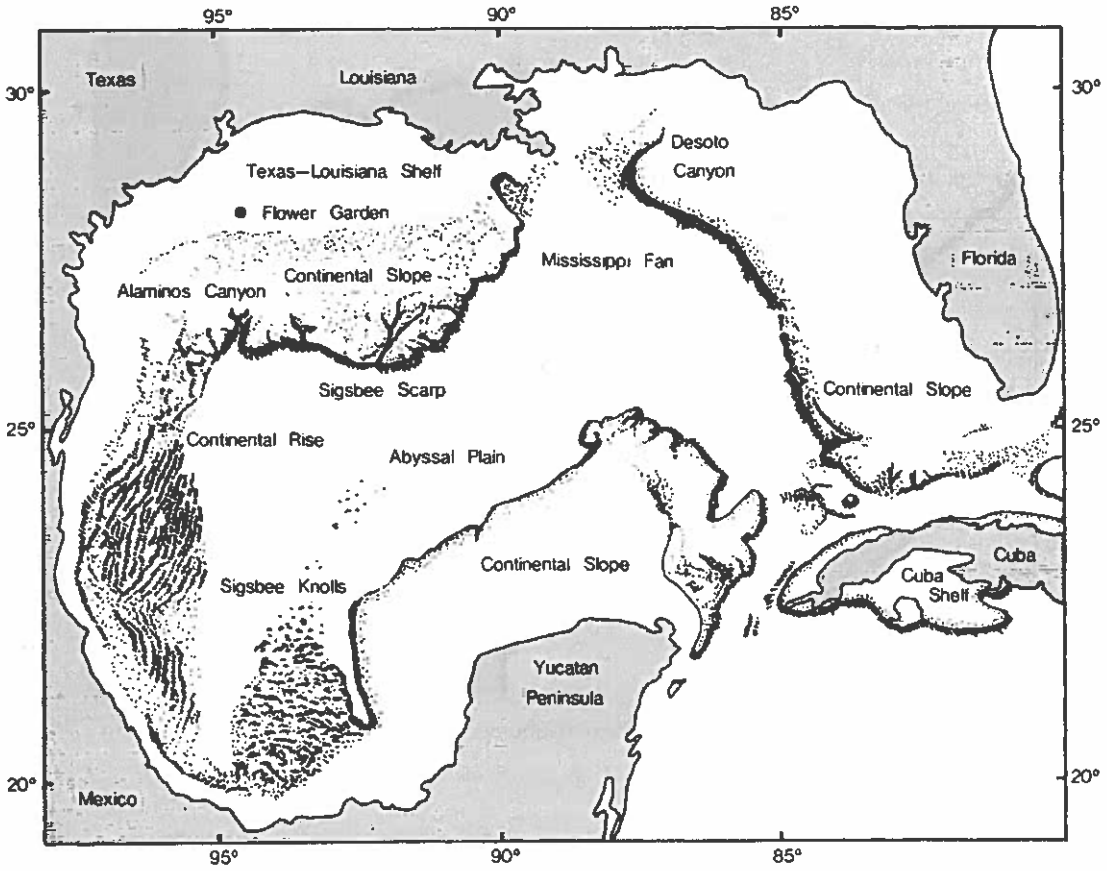


Fig. 1.2. Physiographic provinces of the Gulf of Mexico (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

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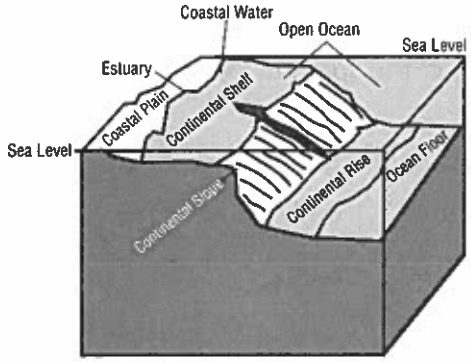


Fig. 1.3. Typica features of a coastal plain (Source: Citizen's Guide to the Gulf of Mexico)

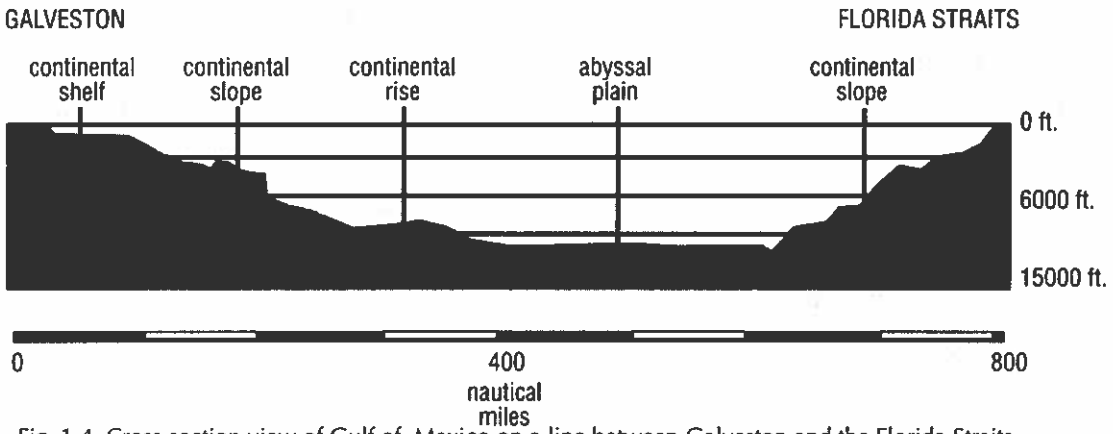


Fig. 1.4. Cross-section view of Gulf of Mexico on a line between Galveston and the Florida Straits south of Key West. (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

The **continental slope** starts at the edge of the continental shelf where the water begins to deepen at a greater rate (see Figures 1.1, 1.2, 1.3 and 1.4). Locate the slope in Figure 1.1 and color it yellow. Note as well the location of the slope in Figure 1.2. The water depth goes from 200 m below sea level to 2,000 m (7,000 feet). In places in the Gulf's slope the water is as much as 3,000 m (10,000 feet) deep.

The slope is divided into two parts. The upper slope is gentle and smooth, sometimes only sloping down 3 to 6 degrees. However, off the coast of southwestern Florida the slope is as steep as 45 degrees since it is formed by old reefs. The DeSoto Canyon cuts into the slope near the Florida panhandle. This is a deep and wide break. Other major submarine canyons include Alaminos Canyon off the Texas coast and Campeche Canyon off Campeche, Mexico. Locate these canyons in Figures 1.2 and 1.3. Many canyons of this type are extensions of rivers on the coastal plain that continue down the continental slope to the sea floor. The slope off the Texas-Louisiana coast consists of a series of shallow banks that have formed on the tops of buried salt domes. The most prominent of these is the Flower Garden Banks, located about 115 miles south of the Texas-Louisiana coast under 350 feet of water.

The lower part of the slope is steeper and is marked by a series of escarpments or cliffs that drop suddenly to the sea floor. The Florida Escarpment, in the eastern part of the Gulf,

is particularly steep. The Sigsbee Escarpment drops down from the salt dome areas off Louisiana and Texas. The Campeche Escarpment is found off the Yucatan Peninsula of Mexico. Locate these features on Figure 1.2.

Another outstanding feature of the continental slope is the Mississippi Fan. Locate the Mississippi Fan in Figures 1.1 and 1.2. Color the fan in Figure 1.1 dark brown. This huge fan or tongue of mud deposited by the Mississippi River spreads out from the Mississippi Delta, covering the features of the shelf and slope in this area.

There are two other important formations in the slope. These are the entrances to the Gulf—the Straits of Florida and the Yucatan Channel. Both are deepwater areas that separate the continental land mass from the island of Cuba. The Straits of Florida are as deep as 6,500 feet. The Yucatan Channel is deeper, dropping as much as 9,800 feet. Locate these features in Figures 1.1 and 1.2.

The slope ends at the **continental rise**, a fan of sediment that has collected at the base of the slope. In the Gulf, the continental rise has a gentle slope of about 1 degree, except where it is cut by underwater canyons. Color the rise in Figure 1.1 green. Locate the rise in Figures 1.3 and 1.4.

At the end of the continental rise is the **abyssal plain**, the flat, deep part of the Gulf. This area has been buried by sediments from the Mississippi and other rivers to form a plain or floor flatter than any plain on land. Note the location of the plain in Figures 1.3 and 1.4. The deepest areas are the Florida Plain and the Sigsbee Plain. The Florida Plain is located in the center of the eastern Gulf between the Florida Peninsula, the Yucatan Peninsula and the Mississippi Delta. It is more than 6,500 feet deep. Locate this area on Figure 1.1 and color it blue. The Sigsbee Plain is located in the middle of the western Gulf and is nearly 10,000 feet deep. Locate this area in Figure 1.1 and color it dark blue. The plains in the ocean basins are generally 2.5 to 3.5 miles deep. These ocean basins make up 30 percent of the earth's surface.

Within the Sigsbee Plain are the Sigsbee Knolls, rising from a few hundred feet up to 1,200 feet above the plain. The deepest part of the Gulf is the Sigsbee Deep at 12,425 feet. The trenches of the oceans are much deeper than the Gulf; the deepest is the Marianas Trench in the Pacific Ocean at 36,000 feet deep.

4. Imagine that, as an oceanographer, you are going to take a trip along the bottom of the Gulf of Mexico in a mini-submarine. You will not need any special clothes since the pressure, air, and temperature are regulated inside the sub. The mini-sub is spherical in shape, the best design that withstands the extreme water pressure of the ocean depths. It is made of a titanium alloy that is only two inches thick but can stand water pressure at depths of up to 23,000 feet. You can see out of thick, round, Plexiglas portholes. The sub is docked at a research ship anchored a couple of miles from Galveston. The mini-sub will enter the

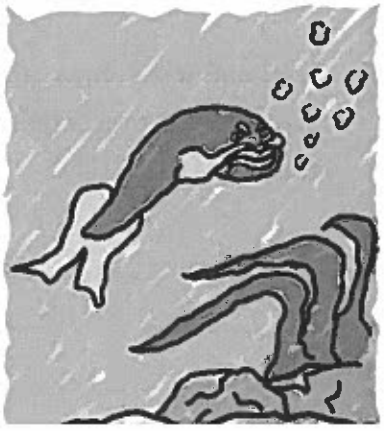
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water over the continental shelf in the Gulf of Mexico. Use the information in the reading on the bathymetry, the information in Table 1, and Figures 1-4 to write a story describing this trip in the mini-sub in the Gulf of Mexico. Your trip may be fictional or realistic. Include the main features of the Gulf in your story. Illustrate your story with drawings.

5. Optional: If you have access to a computer, you can create a multimedia (PowerPoint or Hyperstudio) presentation of a trip into the Gulf of Mexico. Remember to include the main features of the Gulf.

2. How Does the Sea Smell and Taste?

Marine Biologist _____ **Team** _____



The senses of taste and smell, though separate, rely on the same basic principle—the reception of various chemicals. Chemicals dissolved or floating free in the ocean can be detected by the sense of smell. The sense of taste requires that an object be physically touched. By taste a predator knows whether or not its eyes or nostrils were correct in directing it to a definite object. You are going to investigate the smell and taste of the ocean.

Materials: distilled water, salt water (mixture of salt and water), salt water made using Instant Ocean or any type of artificial seawater mixture, pond water or muddy water or aquarium water, plastic cups (3-6 oz.), substances with odors such as vanilla, peppermint oil, lemon, etc. (found in supermarkets), Q-tips

Procedure:

Part I: What does the sea smell like?

1. Obtain several clear plastic cups. Fill the first cup with distilled water, the second with tap water, and the third with salt water. Smell each sample of water by using your hand to move air above the water towards your nose. Record the smell of each sample in Table 1.

Table 1: Smell and Taste of Water Samples

Sample	Description of Smell	Description of Taste
Distilled Water		
Tap Water		
Salt Water		
Instant Ocean Saltwater		

2. Fill another cup with water made from Instant Ocean and smell it. Record the smell in Table 1. How does it smell compared to the salt water in the other cup?

3. If you have been to the ocean or the Gulf and smelled the water, did the salt water in the ocean smell the same as these two saltwater samples? Explain.

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4. Why might water from the ocean have a different odor than your saltwater samples?

5. Fill another cup with pond water or muddy water and describe its odor. Compare this smell to the odors of the distilled water and salt water. Does it differ? What might cause such a difference in odor?

6. Add a drop of each substance with an odor to cups of distilled and salt water. Smell each sample and describe the smell.

7. Summarize what you have learned about the smell of water and what causes its odor.

8. What effects might pollutants in the water have on the water's odor? Explain.

Part II: How does seawater taste?

1. Obtain four clear plastic cups. Add distilled water to the first cup, tap water to the second, salt water to the third, and Instant Ocean water to the fourth. Take a Q-tip and dip the end into the first water sample, and then touch it to the surface of your tongue. Repeat this tasting procedure for each water sample, using the clean end of a Q-tip each time. Record your results in Table 1.

2. Compare the taste of the distilled water to the taste of the tap water. Why might the samples taste alike? Why might they taste different?

3. Compare the taste of the salt water to that of the Instant Ocean water. Are there any differences? Explain.

4. Would a salt water sample from the ocean taste the same as the samples you just tasted in class? Explain.

5. Does all ocean water taste the same? Explain.

6. How might pollutants affect the taste of water? Explain.

3. What Is ppt (parts per thousand) and ppm (parts per million)?

Chemical Oceanographer _____ **Group** _____



One of the most obvious properties of seawater is its salty taste. Seawater is composed of water in which chloride and sodium (salt) have dissolved. Generally, scientists need to be able to determine the amount of material that has dissolved in seawater so that water from different parts of the ocean or different oceans can be compared. They cannot just taste ocean water to find out. Scientists want to know precisely how salty the water is by measuring the amount of dissolved salt in the water. You are going to learn how to do this using ppt and ppm.

Materials: 3 oz plastic bathroom cups, blue, green, or red tempera paint, medicine dropper, toothpicks

Part I: What is ppt?

1. Oceanographers often measure the concentrations of salts in seawater with a ratio — parts per thousand. This is represented by the abbreviation ppt; the symbol o/oo can also be used. Parts per thousand is exactly what it sounds like: out of 1,000 parts of a solution, it is a measurement of how many parts (or units) of an element are found in the total solution

2. To help you understand this concept, imagine you have a jar of M&Ms. The jar holds exactly 1,000 M&Ms. By counting the number of M&Ms of each color in the jar, you get the following results:

red M&M's	264
dark brown M&M's	300
light brown M&M's	144
green M&M's	112
blue M&M's	100
yellow M&M's	80

   Now these results can be reported in parts per thousand. Since there are 264 red M&Ms out of 1,000 total, the concentration of red M&M's is 264 parts per thousand (264 ppt or 264 o/oo). There are 300 dark brown M&M's per 1,000; therefore, the concentration of dark brown M&M's is 300 ppt. What are the ppt concentrations of the blue M&Ms? What about the green? And the yellow?

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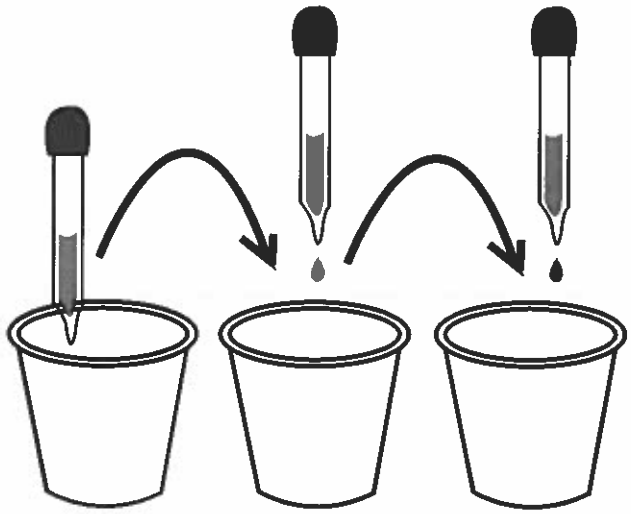
3. For convenience, oceanographers sometimes convert ppt into a percentage. This conversion is a basic math operation. Divide the concentration of each color by 1,000. Then multiply the result by 100, which will give the percentage value. For the red M&Ms, for example:
   red M&Ms (264/1,000) = .264 (100) = 26.4 percent

   Therefore, 264 ppt is equal to 26.4 percent. What are the percentages of each of the other colors of M&Ms? Show any necessary calculations.

4. Average or "normal" seawater has a salinity of 35 ppt (35 o/oo). This means that ocean water consists of 3.5 percent sodium chloride, or salt, and about 96 percent water molecules. Less than 1 percent of seawater is composed of trace elements. Trace elements are the chemical substances that occur in minute or trace amounts in the oceans. Most of these trace elements, such as manganese, lead, mercury, gold, iodine, iron, zinc, aluminum and copper occur in concentrations of less than 1 ppm (parts per million). Many elements occur in quantities of less than 1ppb (parts per billion).

Part II: Can you make a ppt solution?

1. You can dilute tempera paint with water to make a 1 ppt solution. Label seven white bathroom cups 1 through 7. Using a dropper, put nine drops of water in each one of the cups. Add one drop of tempera paint to cup one and stir it with a toothpick. This makes a solution of 1 part paint and 9 parts water, or a 10 percent tempera paint solution. What do you observe?



2. Take one drop of the solution in cup one and add it to cup two. Stir the solution. Cup two now contains 1 part paint and 99 parts water. What do you observe? What is the percentage of tempera paint in the water of cup two?

3. Take one drop of cup two solution and add it to cup three. Cup three now contains 1 part of paint and 999 parts water. Is this ppt? Explain.

4. If the paint was a pollutant, would you be willing to drink water containing 1 ppt of pollution? Why or why not?

5. Continue diluting the tempera paint solution in the cups until you have made a solution of 1 ppm. Sketch a diagram showing the steps along with instructions on how to prepare a solution of 1ppm.

6. Would you drink water with a pollution level in ppm? Why or why not?

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4. What Is the Composition of Seawater?

Chemical oceanographer_____ **Team** _____

Chemical analyses of samples from oceans all over the world indicate that seawater consists of small amounts of salts dissolved in water. These salts exist as charged particles that are spread out among the molecules of liquid water. Thus, seawater is a chemical solution. The dissolving agent, or **solvent**, is the liquid water. The dissolved substances, the salt ions, are the **solutes**. Seawater also contains trace amounts of metals, nutrients, gases, and organic compounds. You are going to examine the chemistry of seawater solutions to determine what substances are found in seawater.

Materials: none

Procedure:

1. Examine the data in Table 1.



Table 1: Major solutes in seawater

Salt ion	Ions in seawater (o/oo)	Ions by weight (percent)
Chloride	18.980	55.04
Sodium	10.556	30.61
Sulfate	2.649	7.68
Magnesium	1.272	3.69
Calcium	0.400	1.16
Potassium	0.380	1.10
Bicarbonate	0.140	0.41
Bromide	0.065	0.19
Boric Acid	0.026	0.07
Strontium	0.013	0.04
Fluoride	0.001	0.00

a. What are the two major solutes in seawater?

b. What is the percentage by weight of the two main solutes?

c. What percentage of seawater is made up of the six most abundant ions?

d. What percentage of seawater does everything else (nutrients and trace elements) make up?

2. Simply defined, **salinity** is the total gram weight of dissolved salts in 1 kilogram of seawater. This is expressed in parts per thousand or o/oo. In examining the salinity of the oceans, chemical oceanographers have found an interesting pattern. Although salinity varies from ocean to ocean due to differences in the total amount of salts dissolved in each ocean, the proportions of the major salts are constant. In fact, the ratio of any two of the six most common solutes dissolved in seawater is the same whether the salinity is 25, 30, or 35 o/oo (see Table 1). Thus, the ratio of sodium to chloride ions in seawater is always the same. This **principle of constant composition** means that chemical oceanographers only need to measure the chloride ions to determine the salinity of water. How might they do this? Explain.

3. Examine the data in Table 2, Trace elements in seawater.

Table 2: Trace elements in seawater

Trace Element	Concentration in parts per billion (ppb)
Lithium	170
Iodine	60
Molybdenum	10
Zinc	10
Iron	10
Aluminum	10
Copper	3
Manganese	2
Cobalt	0.1
Lead	0.03
Mercury	0.03
Gold	0.004

The presence or absence of these elements can be very important for marine organisms: either they help the organisms to live or they can harm or kill organisms. These trace elements make up only 0.01 percent of the dissolved materials in ocean water.

4. Table 3 gives the concentration of nutrients found in seawater.

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Table 3: Representative concentrations of nutrient compounds

Nutrient Element	Concentration in parts per million (ppm)
Phosphorus (P)	0.07
Nitrogen (N)	0.5
Silicon (Si)	3

5. Nutrients in seawater are compounds of nitrogen, phosphorus, and silicon. Plants living in the ocean convert these nutrients into food through photosynthesis. Silicon is used by important groups of microscopic plants (diatoms) and animals (radiolaria) to form shells around their cells. The amounts given in Table 3 are representative amounts because concentrations of these nutrients vary from place to place and over time at any one place. What are some possible reason for this variation?

   Compare Tables 1 and 2 with Table 4.

Table 4: Composition of ions in blood plasma of a typical healthy human adult

Ions in Blood Plasma	Amount (milliequivalents/liter)
Sodium	143
Chloride	103
Bicarbonate	27
Calcium	5
Potassium	5
Phosphates	3
Magnesium	2.5
Sulfates	1
Iron	Trace amounts
Copper	Trace amounts
Iodine	Trace amounts

   a. What do you notice when you compare Tables 1 and 2 of the elements found in seawater with Table 4, the elements found in blood plasma?

   b. How might this information support the theory that life began in the oceans? Explain.

   c. Most marine algae are rich in minerals and contain all the trace elements. Why do you think this is so?

6. Looking at salinity from another perspective, seawater contains an average of 35,000 parts per million of dissolved salts. One cubic mile of seawater weighs about 4.7 billion tons. Thus, there are about 165 million tons of dissolved matter, mostly chlorine and sodium, in one cubic mile of seawater. Examine Table 5. Why might water be referred to as the universal solvent? Explain.

Table 5 Concentrations of 57 elements in one cubic mile of seawater

Element	Tons per cubic mile	Element	Tons per cubic mile
Chlorine	89,500,000	Nickel	9
Sodium	49,500,000	Vanadium	9
Magnesium	6,400,000	Manganese	9
Sulfur	4,200,000	Titanium	5
Calcium	1,900,000	Antimony	2
Potassium	1,800,000	Cobalt	2
Bromine	306,000	Cesium	2
Carbon	132,000	Cerium	2
Strontium	38,000	Yttrium	1
Boron	23,000	Silver	1
Silicon	14,000	Lanthanum	1
Fluorine	6,100	Krypton	1
Argon	2,800	Neon	0.5
Nitrogen	2,400	Cadmium	0.5
Lithium	800	Tungsten	0.5
Rubidium	570	Xenon	0.5
Phosphorus	330	Germanium	0.3
Iodine	280	Chromium	0.2
Barium	140	Thorium	0.2
Indium	94	Scandium	0.2
Zinc	47	Lead	0.1
Iron	47	Mercury	0.1
Aluminum	47	Gallium	0.1
Molybdenum	47	Bismuth	0.1
Selenium	19	Niobium	0.05
Tin	14	Thallium	0.05
Copper	14	Helium	0.03
Arsenic	14	Gold	0.02
Uranium	14		

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7. With your class, research the elements listed in Table 5 to determine the following:
   a. Is the element needed by living organisms?

   b. How is the element used if it is needed by organisms?

   c. Is it harmful or toxic to any organisms?

   d. If it is toxic, what are the effects of the element on organisms?

8. The total volume of the world's oceans is about 350 million cubic miles. Thus, the oceans could be considered a mineral "reserve" of about 60 quadrillion tons. Although the only mineral removed or mined from seawater presently is salt, this could change in the future.
   a. Do you think the ocean could be utilized as a potential source for minerals in the future? Explain.

   b. What would be some problems or issues involved in mining minerals from seawater?

   c. What might be some positive effects of mining minerals from seawater?

5. How Does Salinity Affect the Properties of Water?

Chemical oceanographer_____ **Team** _____

Chemically speaking, the addition of salt changes several properties of water. One of the most obvious is taste. But what other effects do dissolved salts have on the physical properties of water? Your class will divide into research teams and then each team will examine a specific property of water to determine how the water is affected by the addition of solutes. Your team will then present its findings at a class science conference.

Materials: distilled water, tap water, "Instant Ocean" or synthetic seawater mix, hot plates, thermometers that measure from -10° to 110° C, flasks (each with a single hole fitted rubber stopper to hold a thermometer), graph paper, large Pyrex test tubes (each with a two hole fitted stopper), Pyrex beakers, dry ice chunks, gloves, bucket of ice water, graduated cylinder

Procedure:

Each research team in the class will conduct one of the investigations and then share the results with the class.

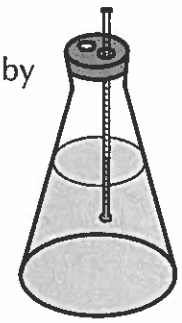
Part I: What is the effect of salt on the boiling point of water?

1. In this investigation, you are going to explore the boiling point of water by observing the differences between distilled, tap (fresh), and salt water. The boiling point of a liquid is the temperature at which it turns to a gas. Which water sample do you think will boil first? Why?

2. Obtain three flasks. Filling each flask *only three-fourths* of the way, fill the first flask with distilled water, the second with tap water, and the third with seawater. Label each flask. Why should each flask have the same amount of water?

3. Make sure that each water sample is at room temperature. If the samples are not at the same temperature, set them aside until they all reach room temperature. Why is it important that all the water samples are at the same temperature when you begin?

4. Moisten the holes in the stoppers. Rub a small amount of soapy water on each thermometer. Carefully insert the thermometers through the stoppers by rotating the thermometer clockwise and counterclockwise as you gently push it into the hole. Do not use force to insert the thermometer into the hole. Using force may break the thermometer. Place a stopper with a thermometer into each flask. Make sure the bulb of the thermometer is in the water. Record the temperature of each water sample.



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5. Place each flask on a hot plate and turn the hot plates on. Each team member will check and record the temperature of one sample as it heats up. Check and record the temperature every 30 seconds (for at least three minutes). When the water bubbles and the temperature no longer changes, the water is boiling. Turn off the hot plates and allow the flasks to cool.

6. In Table 1, record the boiling point and the time it took to reach it for each sample. Plot and graph your time data on graph paper.

Table 1: Boiling and Freezing Point of Water Samples

Water Sample	Time to reach Boiling Point	Boiling point (°C)	Time to reach Freezing point	Freezing Point (°C)
Distilled Water				
Tap water				
Salt water/ seawater				

7. Compare the results of the three water samples. Use your graphs and Table 1. Are there any differences? How could any differences be explained?

8. The amount of energy required to change the phase of a substance from a liquid to a gas is called the **heat of vaporization.** Water, when heated, evaporates and boils slowly compared to other liquids. It must absorb a lot of heat in order to evaporate, so it evaporates slowly. This means that the heat of vaporization is high. In fact, water has the highest heat of vaporization rate of all common liquids. Explain, then, why much of the Earth's water exists in liquid form.

9. Think about the surface temperatures of other planets and moons in our solar system.
   a. Are any other planets or moons able to have liquid water?

   b. How does surface temperature affect each planet or moon's ability to support life as we know it?

Part II: What is the effect of salt on the freezing point of water?

1. In this investigation, you will explore the **freezing point** of water by observing the differences between distilled, tap (fresh), and salt water. The freezing point of a liquid is the temperature at which it turns to a solid. The solid becomes a liquid at its melting point. The freezing point and melting point of all liquids are the same. Which water sample do you think has the lower freezing point? Which do you think will freeze first? Why?

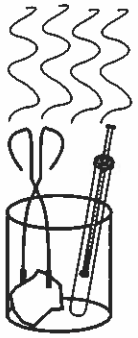
2. Obtain three test tubes. Filling each test tube *only three-fourths* of the way, fill the first test tube with distilled water, the second with tap water, and the third with seawater (salt water). Label each test tube. Why should each test tube have the same amount of water?

3. Make sure that each water sample is at room temperature. If the samples are not at room temperature, set them aside until they all reach room temperature. Why is it important that all the water samples are at the same temperature when you begin?

4. Moisten the holes in the stoppers. Rub a small amount of soapy water on each thermometer. Carefully insert the thermometers through the stoppers by rotating the thermometer clockwise and counterclockwise as you gently push it into the hole. **Do not use force to insert the thermometer into the hole of the stopper. Using force may break the thermometer.** Place a stopper with a thermometer into each test tube. Make sure that the bulb of the thermometer is in the water. Record the temperature of the water in each test tube.



5. Using tongs or heavy gloves, fill the bottom of three Pyrex beakers with chunks of dry ice. **DO NOT TOUCH THE DRY ICE WITH YOUR BARE HANDS!** Place each test tube in a beaker of ice.



6. Each team member can check and record the temperature for one sample. Check and record the temperature every 30 seconds until the temperature no longer changes. What happens to the water? Does the ice float or sink?

7. Record the freezing point of each sample in Table 1. Plot and graph the data on graph paper. How do the three line graphs compare?

8. Does salinity affect the boiling and freezing point of water? How? Specifically, does salinity appear to affect the time it takes to reach the boiling and freezing point of water?

9. What happens to the dissolved salt when seawater freezes? Taste the ice from the salt water. How does it taste?

10. Allow some of the frozen seawater to melt. How does the melted water taste?

11. Based on your observations, would ice from an iceberg be salty or not? Explain.

12. Most liquids increase in density as they cool. Therefore, when liquids are cooled until they

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become solids, the solid phase is even more dense than the liquid phase. However, this is not true of water. Pure water increases in density as it cools until it reaches 4°C - and then further cooling *decreases* the density. Thus, solid, frozen water (0°C) is lighter than liquid water and floats on it. The fact that ice is less dense than liquid water is of great significance to the Earth. Think about the effect this has for ocean life and life in our lakes and rivers in winter. Why is this property so important? Explain.

13. Another interesting property to consider is that when a liquid changes to a solid, heat energy is given off or released.
    a. How does this affect the oceans, lakes, and rivers?

    b. How might this knowledge be used in agriculture to protect crops from freezing air temperatures?

Part III: How does salinity affect the evaporation of water?

1. In this investigation, you will explore the evaporation of water by observing the differences between distilled, tap (fresh), and salt water. Which water sample do you think will evaporate the fastest? Why?

2. Obtain three beakers. Fill the first beaker with 200 ml of distilled water, the second with 200 ml of tap water, and the third with 200 ml of seawater. Label each beaker. Make sure that each water sample is at room temperature. If they are not, set them aside until they all reach room temperature. Why is it important that all the water samples are at the same beginning temperature?

3. Record the temperature of each water sample. Place the beakers on the hot plates. Turn on the hot plates to the medium temperature setting (not high) and heat the water samples for 15 minutes. Turn off the hot plates. Did you notice any differences between the three samples during the heating? Explain.

4. Allow the beakers and the remaining water to cool for 10 minutes. Using a glove, pour the water from the beaker to a graduated cylinder to measure the amount of water remaining in each sample. Record the data. In which water sample was the amount of evaporation the greatest?

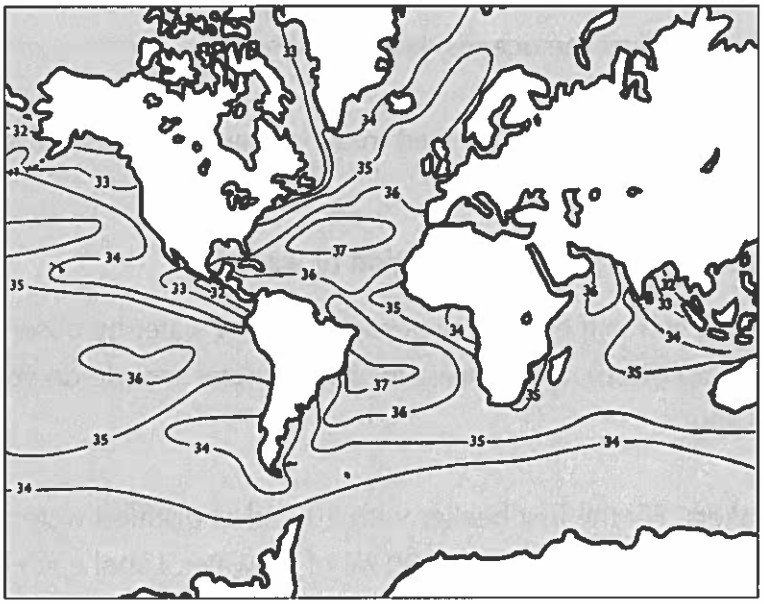
5. In the above investigation, which variables did you control? Which did you change?

6. Think about evaporation from the ocean surface in comparison to evaporation from the

surface of a fresh water lake. How do these processes differ? Which one would evaporate more rapidly?

7. Examine Figure 5.1. Do you see a relationship between the pattern of surface salinity of the oceans and how much sunlight reaches that area of the planet? Explain.

8. Do you see any relationship between the pattern of salinity and sea surface temperature?



Sea-surface salinity (o/oo) in August

Explain.

9. Assume that the Earth will experience global warming in the future. How might higher air temperatures affect the salinity of the oceans?

10. Prepare your team's presentation of findings showing the relationship between salinity and properties of water for your class' science conference.

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6. What Factors Affect the Salinity of Seawater?

Chemical oceanographer_____ **Team** _____

There is a large amount of dissolved salt in the ocean. What supplied all this material to the ocean? What causes variations in salinity? You will analyze data in order to find answers to these two questions.

Materials: none

Procedure:

Table 1: Major solutes in seawater and river water

Salt ion	Ions in seawater (o/oo)	Seawater Ions by weight (%)	Ions in river water (o/oo)	River water ions by Weight (%)
Chloride	18.980	55.04	0.0078	6.5
Sodium	10.556	30.61	0.0063	5.2
Sulfate	2.649	7.68	0.0012	9.3
Magnesium	1.272	3.69	0.0041	3.4
Calcium	0.400	1.16	0.0150	12.4
Potassium	0.380	1.10	0.0023	1.9
Bicarbonate	0.140	0.41	0.0588	48.7
Silica	0.003	0.00	0.0131	10.8

1. Examine Table 1. How does the river water compare to the seawater?

2. Which ions make up the greatest percentage of river water?

3. Generally, river water doesn't taste salty. Why might this be so?

4. Could river water supply the minerals needed to make seawater taste salty? Explain.

5. How much dissolved material is really added to the seawater by the rivers flowing into the oceans? You might think that the amount added is insignificant because the concentrations of solutes in river water is so low. However, the annual amount of material added to the seawater by rivers is between 2.5×10^{15} to 4×10^{15} grams. This roughly equals the amount of mud that is added to the oceans by all the rivers of North America, South America, Africa, and Europe combined. Examine Table 2 to see the sources of the different materials dissolved in seawater.

Table 2: Sources of material inputs and outputs of salts to seawater

Chemical	Input/source of chemical	Output/uptake of chemical
Chloride	Volcanoes; river inflow	Evaporation—deposited as rock salt; diffusion to air;
Sodium	River inflow	Evaporation—deposited as rock salt; diffusion to air; exchange with clays; reaction with basalt rock
Potassium	River inflow; volcanic-seawater reactions (high temperature);	Uptake by clays; volcanic seawater reactions(low temperature)
Calcium	River inflow; volcanic seawater reactions; ion exchange	Secretion of shells; evaporation—deposition as gypsum; precipitation as calcite
Silica	River inflow; basalt-seawater reactions	Secretion of shells
Phosphorus	River inflow; rainfall	Buried; adsorption of volcanic rock; formation of phosphorite rock

6. Sedimentary rocks and the fossil record indicate that oceans have existed on the Earth for at least 3.4 billion years. Data indicates that the salinity of the oceans has not really changed over the last 1.5 billion years. Rivers are constantly adding large amounts of dissolved chemicals each year. What must be happening to keep the amount of dissolved chemicals in the oceans relatively stable from year to year? Use Table 2 to help explain your answer.

7. Variations in salinity are the result of the addition of water molecules to seawater or the removal of water molecules from seawater. Mark the processes that add water molecules to seawater with a check and those that remove water molecules with an X.
   a. Evaporation
   b. Rain
   c. River runoff
   d. Snow
   e. Formation of ice
   f. Sleet
8. Examine Figure 6.1, which shows the salinity of ocean surface waters at different latitudes. In which latitudes (polar, temperate, or tropical) is the salinity the greatest? The lowest?

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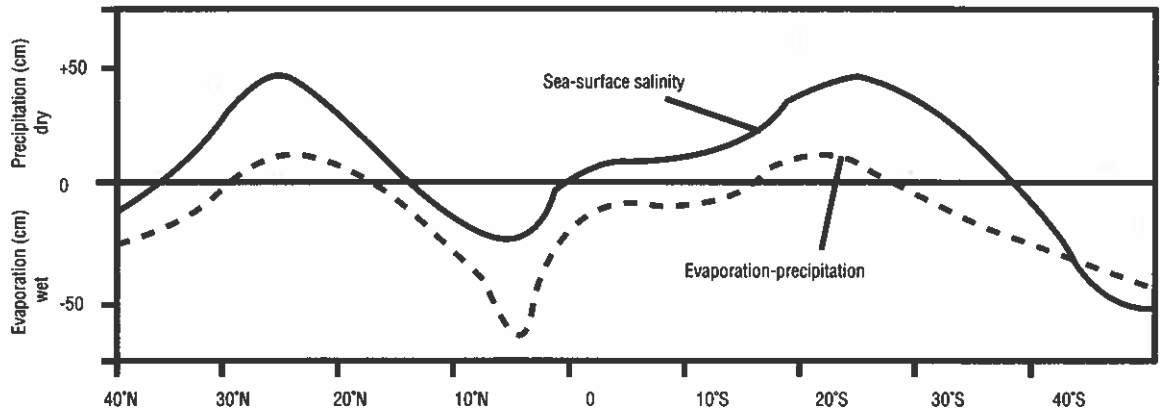


Fig. 6.1. Latitudinal variations in salinity and "dryness." (Source: The Properties of Water)

9. Figure 6.1 also shows ocean evaporation and precipitation rates. If the dashed line is below zero, then precipitation is greater than evaporation; if the dashed line is above zero, then the evaporation is greater than the precipitation. What relationship do you observe between salinity and the evaporation and precipitation rates?

10. Write a statement summarizing the relationship between salinity, the effect of evaporation and precipitation, and latitude.

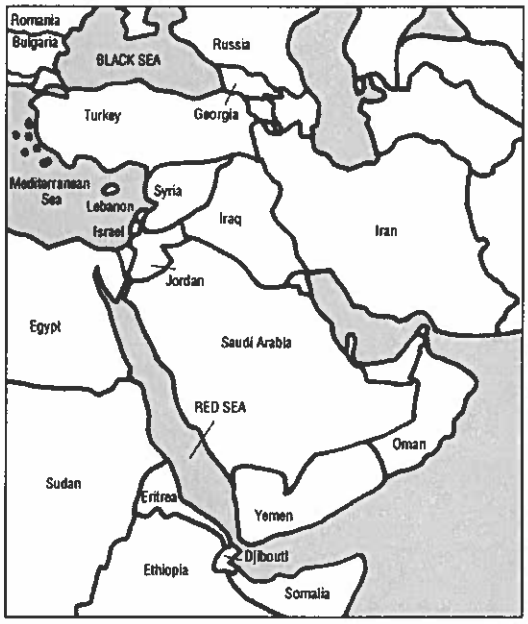


Fig. 6.2. Red Sea and Black Sea

11. Average ocean salinity is 35 ppt (35 o/oo). Use what you have learned about salinity to explain the following statements:
    a. The salinity of the Red Sea can be as high as 40 ppt.
    b. The Black Sea is one of the least salty seas in the world. It can have a surface salinity as low as 18 ppt.
    c. The salinity of the central basin of the Gulf of Mexico is 36 ppt to 36.3 ppt.
    d. The salinity of the Gulf several miles offshore from the mouth of the Mississippi River is less than 25 ppt.
    e. The salinity of Laguna Madre (the bay that extends from Corpus Christi to Brownsville) has reached a high of 130 ppt.

12. What time of the year you would expect the Gulf of Mexico to have its highest salinity? The lowest salinity? Explain.

13. Hurricanes can affect the salinity of bays and estuaries as well as the Gulf itself. When a hurricane approaches the coastline, it can push salt water into bays and estuaries as part of its storm surges with high tide. As it moves inland, large amounts of rain that fall can cause floodwaters to flush into the bays, and eventually into the Gulf of Mexico. Explain how a hurricane might change the salinity of the bays and estuaries along the coast as well as the Gulf of Mexico over the continental shelf.

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7. What Is the Temperature of Ocean Water?

Hydrologist _____ **Team** _____



The temperature of ocean water varies from its surface to its depths. It also varies according to season and location. Water temperature affects the organisms living in the oceans. You are going to analyze the temperature of ocean water.

Materials: salt (kosher salt dissolves more easily), water, plastic cups, ice cube trays, freezer, thermometer (measuring below 0° C)

Procedure:

Part I: How does the water temperature vary?

1. Water from the ocean's surface down to a depth of 300 feet is called surface water. This water is affected by waves, winds, and sunlight. Its temperature varies far more than deeper water, changing throughout the year depending on location. The average surface temperature of the oceans is about 16°C, but it ranges from about –2° C to about 30°C. Sea ice, however, may have a temperature far below –2°C.
   a. Where do you expect ocean surface temperatures be the highest (warmest)? Why?

   b. Where do you expect surface temperatures be the lowest (coldest)? Explain.

2. Ocean temperatures also depend partly on current patterns. Some currents transport warm water to high latitudes and others transport cold water towards the equator. Temperature patterns change with the seasons as well; these changes tend to be greater in the mid-latitudes than at the poles or equator. Why is the temperature of ocean water different in the winter than in the summer? Explain.

3. Why would water temperature changes be greater in the mid-latitudes than at the poles or equator? Explain.

4. Study Table 1. Do you observe a relationship between water temperature and depth? Where do you observe a greater variation in water temperature — in surface water or in the deeper water?

Table 1: Temperature of the Gulf at increasing depths

Temperature Degrees F	Temperature Degrees C	Depth in Feet	Depth in Meters
87°F*	30°C	0 ft.	0 m.
79°F	26°C	300 ft.	91 m.
70°F	21°C	600 ft.	182 m.
60°F	16°C	1,200 ft.	365 m.
50°F	10°C	1,800 ft.	548 m.
41°F	5°C	3,000 ft.	914 m.
40°F	4°C	4,200 ft.	1,280 m.
39°F	3°C	6,000 ft.	1,828 m.
35°F*	1°C	36,000 ft.	10,973 m.

These are summer temperatures. During winter, shallow coastal water temperatures will vary significantly depending on surface weather conditions. Winter temperatures near edge of continental shelf will average between 70° – 75°F (21° – 25°C).
*Temperature for deep ocean.

5. Using graph paper and the data in Table 1, construct a graph that illustrates the relationship between water temperature and water depth. What can you conclude about the water temperature of the Gulf?

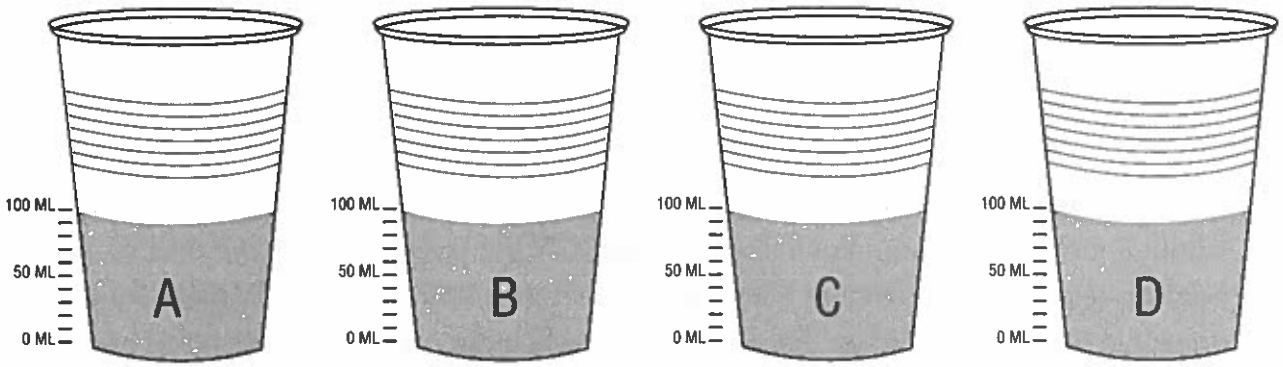
6. The overall average temperature of the oceans is 4°C. This temperature occurs at a depth of 1,600 meters at the equator, but it is the surface temperature at both 55° North and South latitudes. However, water deeper than 3,000 meters is cold at all latitudes. Even at the equator, water near the bottom is very cold, about 2°C at 4,000 meters. There is also very little change in temperature with depth at the poles. Why is deep water cold regardless of latitude?

7. Even though the surface temperature of the sea varies, it varies considerably less than land temperatures. This is due to water's great ability to hold heat. **Heat capacity** is the ability of water to absorb heat energy. Because of its high heat capacity, water tends to heat up slowly and lose heat slowly. Why is this important for marine life?

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Part II: What happens to sea water in polar regions?

1. In this experiment, you will determine the effect of salt on the freezing of water.
   a. Prepare four cups of the following water solutions:
      Cup A: 100 ml of warm water with I tablespoon of kosher salt added
      Cup B: 100 ml of warm water with 2 tablespoons of kosher salt added
      Cup C: 100 ml of warm water with 3 tablespoons of kosher salt added
      Cup D: 100 ml of warm water (no salt added)



   b. Place each cup in a freezer. (If a freezer is not available, mix a salt solution with ice in a plastic pan and place each cup in the pan.) Check the cups periodically and record the temperature of the water each time. Record the temperature at which each sample freezes.
   c. Does adding salt lower or raise the freezing point of water? Explain.

2. In this experiment, you will determine whether saltwater forms salty ice.
   a. In an ice cube tray, place tap water in some cubes and saltwater in the others. Place the tray in a freezer until the samples are frozen.

   b. Remove a tap water ice cube and taste it. (Do not taste a cube that someone else has tasted.) What does it taste like?

   c. Remove a saltwater ice cube and taste it. After tasting it, rinse the cube in tap water and taste it again. What do you observe?

3. What conclusions can you reach about saltwater that freezes? How do you think the water from icebergs might taste?

4. When the ocean's surface is cool enough, microscopic ice crystals begin to form. As freezing continues, a slush forms that covers the surface like a wet blanket of snow. Even-

tually the ice crystals begin to grow downward. These slushy ice crystals contain no salt, but brine (salt and water) fills in the small spaces between them. One kilogram (1000 grams) of newly formed slushy ice consists of about 800 grams of ice (salinity o/oo) and 200 grams of brine (salinity 35 o/oo). Thus, the average salinity of newly formed ice slush is about 7 o/oo, compared to 35 o/oo for liquid seawater. The salinity of newly formed sea ice depends on the temperature at which it formed. At temperatures near freezing, ice forms so slowly that brine can escape. Little seawater is trapped between the ice crystals, so the overall salinity is low. At temperatures lower than freezing, ice forms more rapidly and more brine is trapped, increasing the salinity. However, the salinity of ice is *always* less than that of seawater. Do your observations from the experiments support this statement? Explain.

5. As sea ice ages, brine is dispelled and the ice hardens. A layer of ice up to 20 cm thick (about 8 inches) can form in one freezing season. These layers can build up over many freezing seasons to a maximum thickness of about 2 to 3.5 meters (6 to10 feet). Pools of drinkable fresh water form on the upper surface when old ice melts. These pools of fresh water have saved the lives of several polar explorers who ran out of drinking water. Why is this water fresh and potable? Explain.

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8. What Is the Temperature Structure of the Ocean?

Oceanographer _____ **Team** _____

Oceanographers have gathered a great deal of information about variations in the temperature of the oceans. Much of the ocean has a layered temperature structure. These thermal layers are determined by measuring the temperature of seawater from the surface all the way down to the ocean bottom. The temperature is then graphed versus the depth measurements. This is called a **temperature profile**. You are going to examine some temperature profiles and determine the factors that control the temperature of the ocean water.

Materials: none

Procedure:

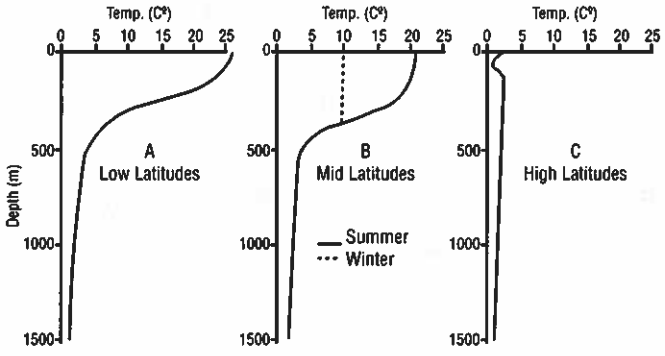


Fig. 8.1. Typical temperature profiles A, B and C

1. Examine the temperature profile of the low latitudes of the tropics and subtropics, labeled "A." Where is the warmer water found? Explain.

2. When warm surface water mixes with cooler, deeper waters as winds, breaking waves, and currents stir the water, the surface layer is then called the **mixed layer**. The temperature in this layer is nearly uniform, a condition known as **isothermal**. To what depth does the mixed layer extend?

3. Examine temperature profile "A." What happens to the temperature of the seawater immediately below the mixed layer?

4. The layer of rapid change in temperature between the warmer mixed layer and the colder deep layer is called the main **thermocline**.
   a. Between what depths is the main thermocline found in profile "A"?
   b. At what depth does the deep colder layer in profile "A" begin?
   c. Is the water of the deep layer isothermal? Explain.

5. Examine the temperature profile for the mid-latitudes labeled "B" or temperate regions.
   a. How does the mid-latitude profile differ from the profile of the low latitudes?
   b. Why does the temperature profile "B" for the mid-latitudes differ between summer and winter? Explain.
   c. Why doesn't the temperature profile "A" of the low-latitudes change with the time of the year? Explain.

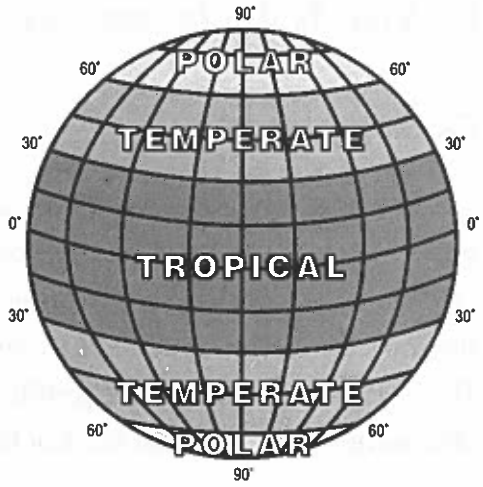


Fig. 8.2. Temperature zones

6. Now examine the temperature profile "C" for the high latitudes, or polar regions. How does it compare to the low and mid-latitudes?

7. Examine Figure 8., an ocean temperature north-south cross-section that extends from about 70° south latitude to 70° north latitude. For each vertical dashed line (A, B, C, D, E) indicate which of the three temperature profiles (tropical, temperate, polar) you would expect to find at that particular latitude.

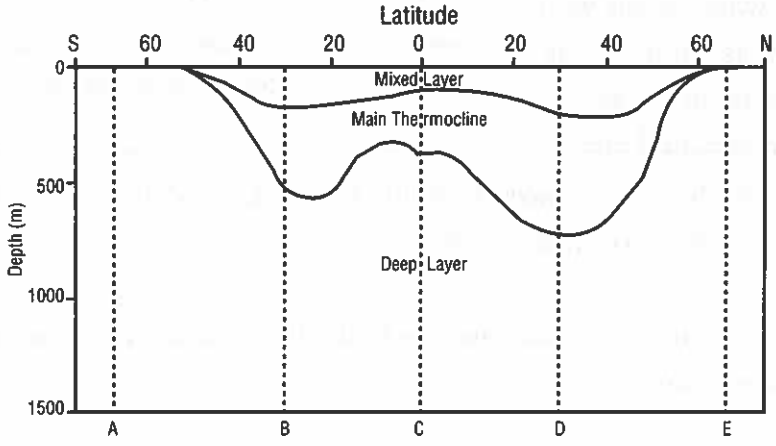


Fig. 8.3. Ocean temperature cross section

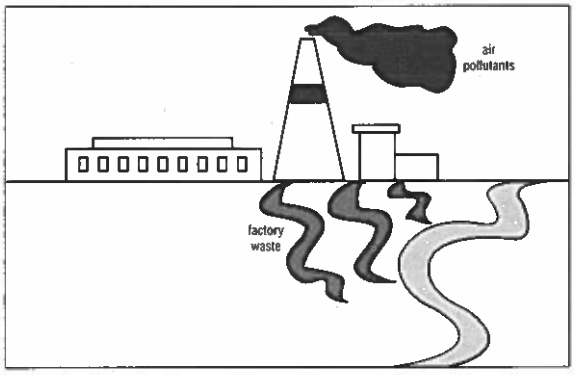
8. Write a statement explaining what factors control the surface temperature of the ocean.

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9. What Is the Link Between Temperature and Environmental Pollution?

Climatologist _____ **Team** _____

Many pollution problems are linked to the location of waste disposal sites, oil and gas fields, and chemical plants. Climatic factors, including precipitation, temperature, wind, and storms can worsen these environmental problems. You are going to analyze the climatic influence of temperature to understand its impact on environmental pollution.



Materials: clear plastic cups (6 oz), food coloring, warm and cold water, thermometer

Procedure:

1. How do you think that air or water temperature can have an effect on environmental problems? Write a statement explaining what you think might occur.

2. Compare the effect of warm and cold temperatures on environmental pollution.
   a. Label one cup "A - cold water" and a second cup "B - warm water."
   b. Fill Cup A with 200 ml of cold (approx. 40° F) water. Let the cup sit for 5 minutes. *Do not move the cup.*
   c. Drop two drops of food coloring into each cup to represent chemical pollutants. *Do not stir the water in the cup.*
   d. Closely observe what happens within the first 30 seconds after the food coloring is added. Look at the cup from the side and the top. Construct a table similar to the example below and record your observations. Continue to observe and record observations for Cup A at the time intervals noted in your table.
   e. Fill Cup B with 200 ml of warm (90° to 100° F) water. Let the cup sit for 5 minutes. Repeat steps c and d above for Cup B. *Do not move or stir the water in the cup.*

Table 1: Observations

Time Elapsed	Cold Water (40° F)	Warm Water (90° F)
30 seconds		
1 minute		
5 minutes		
10 minutes		

3. Why is it important to allow the cup to sit for 5 minutes without disturbing the water? How would moving or stirring affect the water?

4. How did the temperature of the water affect the movement of the food coloring (chemical pollutants)?

5. Compare your results from Table 1 to your prediction in number 1. Do your results support or refute your prediction? Explain.

6. Based on your observations, write a statement that summarizes the relationship between water temperature and the movement of chemicals or pollutants that may be added to shoreline waters or in the Gulf. Does the season or time of year make a difference on how quickly the chemicals will spread? Explain.

7. The driving force behind the movement of the food coloring in the water is called **diffusion**. **Diffusion** is the process by which molecules of a substance move from areas of higher concentration to areas of lower concentration. An increase in the temperature of water increases the diffusion rate because the molecules gain heat energy and spread from areas of higher concentration to lower concentration more quickly. Decreasing water temperature slows the diffusion process, because the low energy of the molecules slows their spread. Based on your experimental observations and this information, explain what happens over time when a chemical pollutant enters a body of water such as a bay or the Gulf. Use sketches and/or diagrams to illustrate your answer.

8. What about pollutants that enter the air? Does the process of diffusion apply to airborne pollution? Explain.

9. Using your observations and the above information, compare and contrast the probable effects of climate on the movement of pollutants from chemical plants and waste disposal sites at the two areas below. Include the environmental impact of pollution at each individual site as well.
   a. The Brazoria/Galveston area, which has an annual mean temperature of approximately 70°F and a mean July temperature of 87°F.

   b. A bay area where the mean annual January temperature is 45°F, and the mean July temperature is 75°F.

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10. What Affects the Density of Seawater?

Oceanographer _____ **Team** _____

Whether it is in the solid, liquid, or gaseous phase, an important property of matter is how much space it takes up or how compact it is. This property is called density. Density is the measurement of how much matter is in a given space. It is the amount of mass per unit volume.

Density = mass/volume

You and your team are going to determine whether fresh water or salt water has a greater density.

Materials: balance, plastic cups, graduated cylinder, tap water and salt water (at cold, hot, and room temperatures), medicine droppers

Procedure:

Part I: Which has the greater density: saltwater or fresh water?

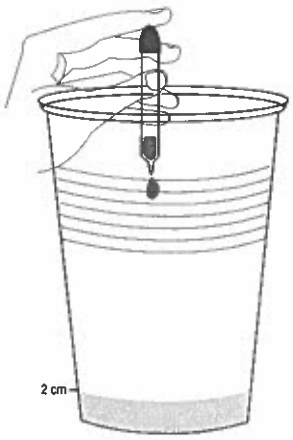
1. You and your team will design a test to determine which has the greater density, fresh or salt water. The only materials you can use in this experiment are a balance, plastic cups, a graduated cylinder and fresh and salt water. Describe your test and its design below.

2. Using your team's design, conduct your test of the density of the two water solutions. Record your results.

3. Based on your team's experiment, is salt water or fresh water more dense? Explain your results.

Part II: What is the effect of salinity on water density?

1. In this investigation, you will explore the effect of salinity on water density. Which water sample do you think will be more dense and thus sink, the fresh or the salt water? Why?



2. Fill a plastic cup with salt water at room temperature to a depth of 2 cm. Add two to three drops of food coloring and stir so that the color is evenly mixed.

3. Fill a second plastic cup with tap water at room temperature. Fill the dropper with the colored salt water from the first cup. Put a drop or

two of the colored salt water into the cup of tap water. What happens to the salt water that is added to the fresh water? Explain.

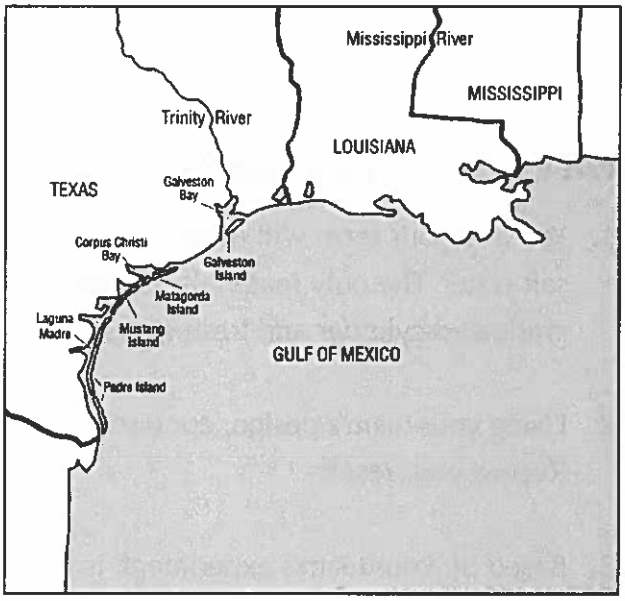
4. Reverse the procedure. Fill a new plastic cup with tap water at room temperature to a depth of 2 cm. Add two to three drops of a new color of food coloring. Stir so that the color is evenly mixed.

5. Fill another plastic cup with salt water at room temperature. Fill the dropper with the colored tap water. Put a drop or two of the colored tap water into the cup of salt water. What happens to the drops of fresh water when they are added to the salt water?

6. Based on your observations, which is more dense — fresh water or salt water? Explain.

7. What do you think happens when fresh water from the Mississippi River flows into the Gulf of Mexico? Does the river water stay on top of the Gulf water or does it sink? Explain.

8. The water in Laguna Madre, the shallow lagoon between Padre Island and the Texas coast, is higher in salinity than the Gulf of Mexico. Does the Laguna Madre water stay on top or sink as it enters the Gulf of Mexico?



9. What would happen if a hurricane pushed a storm surge of salt water into Galveston Bay at the point where the Trinity River enters the Bay? Explain.

Part III: What is the effect of temperature on water density?

1. In this investigation, you will explore the effect of temperature on water density. Which water sample do you think will sink, the warm water or the cold water? Why?

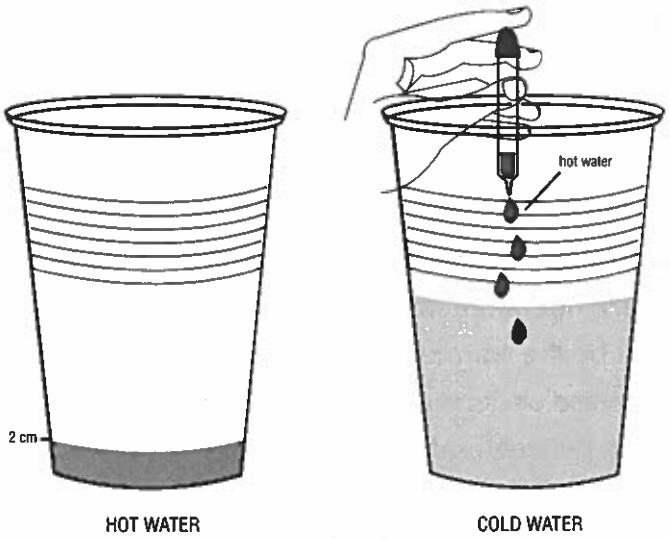
2. Fill a styrofoam cup with hot tap water to a depth of 2 cm. Add two to three drops of red food coloring and stir so that the color is evenly mixed.

3. Fill a second plastic cup with cold tap water. Fill the dropper with the red colored hot

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water from the first cup. Put a drop or two of the red colored hot water into the cup of cold tap water. What happens to the hot water that is added to the cold water? Explain.

4. Reverse the procedure. Fill a new plastic cup with cold tap water to a depth of 2 cm. Add two to three drops of blue food coloring. Stir to mix the color evenly.



5. Fill another plastic cup with warm temperature tap water. Fill the dropper with the cold blue colored tap water. Put a drop or two of the cold blue colored tap water into the cup of warm water. What happens to the drops of cold water when they are added to the warm water?

6. Based on your observations, which is more dense — warm or cold water? Explain.

7. If different temperatures of salt water were used in similar experiments as above, what do you think the results would be? Explain. (If you are not sure, conduct further experiments to find out.)

8. Which water has a greater density — water from the polar region or the water from the equator? Explain.

9. Water density helps determine the horizontal make-up of water into layers. Less dense water is on or near the top while more dense water is below. How could the density of water be increased so that it would sink?

10. What factors determine the salinity of ocean water (Topic 6)? Is this related to latitude? Explain.

11. What factor determines the temperature of the ocean water (Topic 7)? How is this related to latitude?

11. What Is the Connection Between Density and Ocean Currents?

Oceanographer _____ **Team** _____

From your experiments you have learned that seawater increases in density as its salinity increases. You have also learned that seawater, like most substances, becomes less dense as the temperature increases. If the salinity is constant, then, the least dense seawater generally will be the warmest and will be found on the surface. However, no general overall pattern of increase or decrease in salinity with depth has been observed in the oceans. Instead, interactions between salinity, density, and temperature — *not* depth — help in creating the patterns of water movement called currents.

Ocean currents can be divided into two types — currents created by wind and currents caused by density. Winds create the currents in ocean surface waters. These currents influence about 10 percent of the ocean's water. The remaining 90 percent of ocean water currents are caused by increased density from lower temperatures below the surface rather than high salinity. Thus, density drives the ocean currents found below the surface waters. Seawater of different densities may vary only slightly, but these small differences can cause changes in the movement of entire water masses. Therefore, density is of great interest to oceanographers studying currents. You and your team will develop models to study the connection between density and currents.

Materials: one gallon plastic aquarium or clear plastic shoe boxes, red and blue food coloring, saltwater, paper cups, Styrofoam cups, hot water, hot plate and pot (for heating water), ice, medicine dropper, pipettes, masking tape, pint-size zip lock bags, marker

Procedure:

Investigation A

1. You and your team will set up a model to study the currents that are formed when water is unevenly heated.

2. Obtain a one gallon plastic aquarium (or clear plastic shoebox) and five Styrofoam cups. Place four of the Styrofoam cups upside down on the table. Place the plastic container on top of the cups. Move the cups so that there is a cup supporting each corner of the container (see Figure 11.1).

3. Use a pitcher or bottle to fill the container two-thirds full of salt water at room temperature. Allow the water to sit for a few minutes so there is no movement (no currents).

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4. Dip a pipette into red food coloring and draw up a very small amount of the food coloring. Gently put the pipette straight down into the water to avoid stirring up the water. *The tip of the pipette should be touching the center bottom of the container before the drop is released.* Release the drop of food coloring (see Figure 11.1).

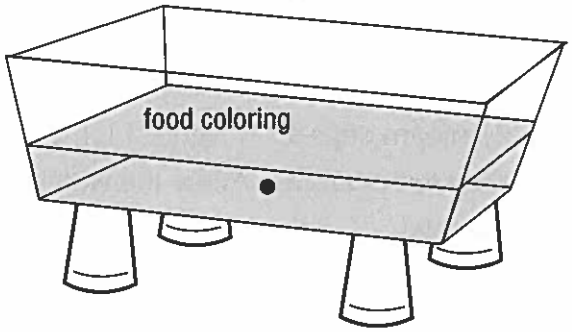


Fig. 11.1.

5. Observe the movement of a drop of food coloring in water at a uniform (same) temperature. On a separate sheet of paper, labeled Data Sheet, sketch four diagrams of the container on the cups from a side view. On the first of the four diagrams, draw what happens to the food coloring as you look at it from the side view. Label this drawing Test A. Write a brief description of what you see below it.

Investigation B

1. Get a styrofoam cup of hot water (nearly full) from the hot plate. Carefully slide the cup under the center and to the middle of the plastic container. Using a pipette, place another drop of food coloring at the center bottom of the container, directly over the cup of hot water (see Figure 11.2). Sketch your observations on the second diagram of the container, using arrows to show any movement. Label this Test B.

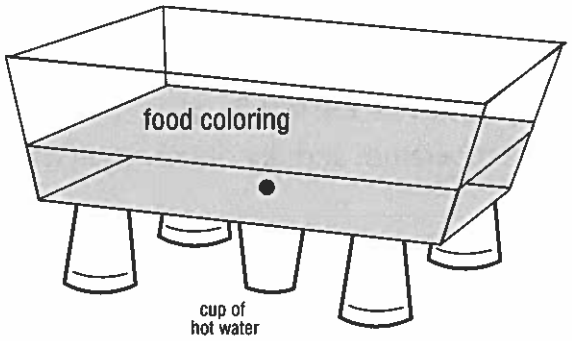


Fig. 11.2.

2. Describe (in your own words) how the water moved. Include answers to the following questions in your description.
   a. Which way did the water move over the heat source?
   b. What happened when the water reached the surface?
   c. What happened when the water reached the edge of the container?
   d. Which way did the water move along the bottom of the container?

3. Summarize your results again, but this time, explain the water's movement in terms of the temperature and density changes that occurred.

4. Why was Investigation A conducted without changing the temperature of the water? What was the purpose of this test? Explain.

Investigation C

1. Empty the water from the plastic container. Again, set up the empty container on the four Styrofoam cups as in Figure 11.1. Fill the container three-fourths full with salt water at room temperature . Allow the water to sit a few minutes until there in no movement (no currents).

2. Get a styrofoam cup of hot water (only three-fourths full) from the hot plate. Carefully slide the cup underneath the container to the center.

3. Using a pipette, place a drop of food coloring at the bottom of the container, about halfway between the center and the side (see Figure 11.3). Sketch your observations on the third diagram of the Data Sheet, using arrows to show movement. Label this Test C.

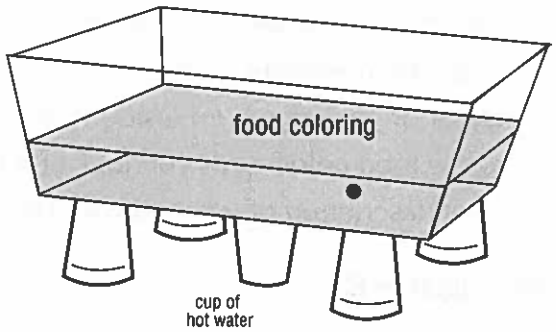


Fig. 11.3.

4. Describe (in your own words) how the water moved.

5. Summarize the results again, this time explaining the water's movement in terms of the temperature and density changes you observed.

6. Your observations should describe one of the ways that heat moves. This movement is called **convection** and the path of motion is called a **convection current**. Examine your sketches. Each circular motion of an arrow is a convection current. Label the convection currents on your sketches.

Investigation D

1. Empty the water from the plastic container. Again, set up the empty container on the four styrofoam cups as in Figure 11.1. Fill the container three-fourths full with salt water at room temperature. Allow the water to sit a few minutes so there is no motion (no currents).

2. Get a styrofoam cup of ice water. Carefully slide the cup underneath the container to the center.

3. With a pipette, place a drop of food coloring at the bottom of the container, directly above the cup of ice water. Sketch your observations on the fourth diagram of your Data Sheet, using arrows to show movement. Label this Test D.

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4. Describe (in your own words) how the water moved.

5. Summarize the results again, this time explaining the water's movement in terms of the temperature and density changes you observed.

Investigation E

1. Your team will conduct additional tests to investigate the following:
   a. Place a drop of food coloring on the surface of the water, directly over the heat source.
   b. Place a drop of food coloring on the surface of the water, halfway between the edge and the center of the container.

2. Sketch your observations on a separate page.

3. Describe in your own words how the water moved.

4. Summarize the results again, this time explaining the water's movement in terms of the temperature and density changes that occurred.

5. Were your models like the ocean? How?

6. Did your models differ from the ocean? How?

12. How Does Seawater Form Layers?

Physical Oceanographer _____ **Team** _____

You will continue investigating the connection between density and ocean currents by studying how layers of water are formed and how they move. First, list what you have learned about density and ocean water in the space below.

Materials: one gallon plastic aquariums or clear plastic shoe boxes, red, yellow, green, and blue food coloring, saltwater, paper cups, Styrofoam cups, hot plate or pot (to heat water),hot water, ice, medicine dropper, pipettes, masking tape, pint-size sandwich bags, colored markers

Procedure:

Part I: How does the ocean form layers?

1. You and your team will set up a model to study the currents that are formed when water is unevenly heated and how layers form in water masses. Your team will need a one gallon plastic aquarium (or clear plastic shoebox), one paper cup, and two Styrofoam cups. Place the plastic container on white paper or a paper towel.

2. Draw a line on the side of the container at the two-thirds full mark. Tape a paper cup to the inside of the container so that the bottom of the cup is approximately 1- 2 cm below the line (and thus will be below the surface of the water). Tape the sandwich bag to the opposite inside of the container so that it is touching the bottom and the opening is 4 or more cm above the marked water level. Use Figure 12.1 for assistance.

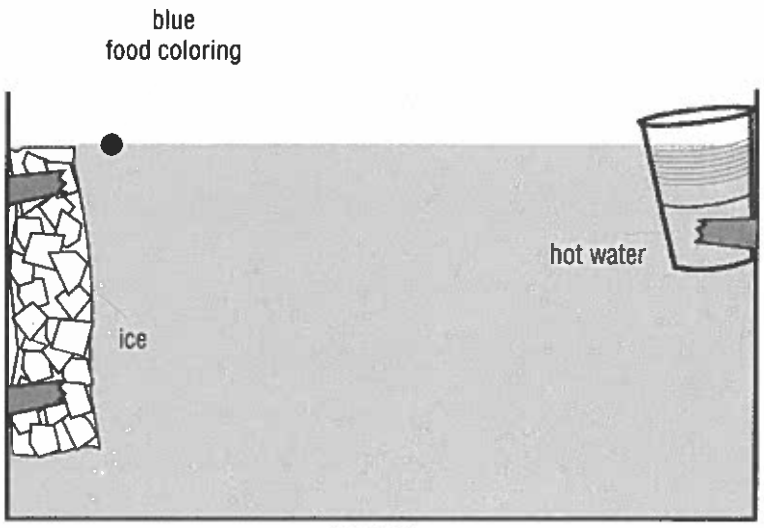


Fig. 12.1.

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3. Sketch an outline of the container below. Label the bag "ice water" and the cup "hot water."

4. Slowly fill the aquarium until it is two-thirds full with saltwater at room temperature. Wait a few minutes for any water movement to stop.

5. Fill a styrofoam cup with heated water. As one team member pours the hot water into the cup attached to the container, another team member should carefully add ice cubes and ice water to the sandwich bag and close it. The bag of ice represents the polar regions and the cup of hot water represents water warmed by the sun at the equator.

6. To the surface of the water *next to* the bag of ice, add several drops of blue food coloring. To the surface of the water *next to* the cup of hot water, add several drops of red food coloring.

7. Hold a white sheet of paper behind the plastic container in order to see the movement of the food coloring. View the container from the side at eye level. Draw the water movement on your sketch, making arrows with colored markers that correspond to the colored water and indicate the direction of movement of each water mass. Label the sketch clearly.

8. Describe in words how the water moved.

9. Which water has a greater density? How do you know?

10. Which water was less dense? Explain.

11. Is your model like the ocean? How?

12. Does your model differ from the ocean? How? Explain.

13. Write a statement that relates the density and temperature of water to the movement of water. Include information on fresh and saltwater.

Part II: What is the impact of river inflow on ocean water?

1. You and your team will set up a model to study the movement of water at the inflow of rivers. Your team will need a one gallon plastic aquarium (or a clear plastic shoebox), two paper cups, and two Styrofoam cups. Place the plastic container on white paper or paper towel.

2. Draw a line on the side of the container at the two-thirds full point. Tape a paper cup to the inside of the container so that the bottom of the cup is approximately 1 cm below the line (below the surface of the water). Tape another paper cup to the opposite inside of the container in the same position as the first cup. Use Figure 12.2.

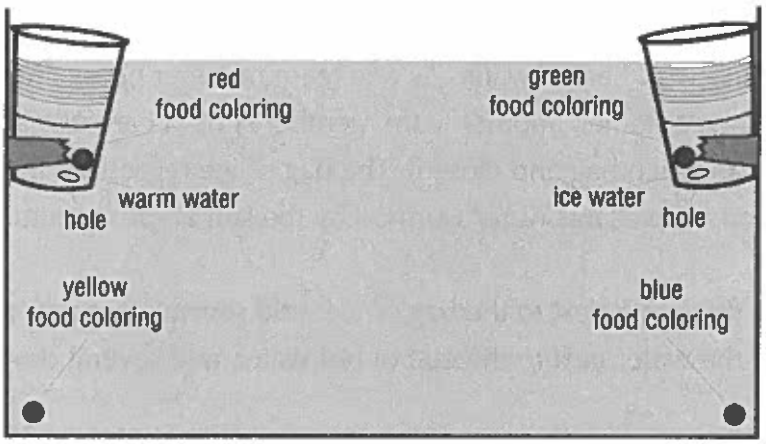


Fig. 12.2.

3. Sketch an outline of the container below. Label one cup "cold water" and the other cup "hot water."

4. Slowly fill the aquarium until it is two-thirds full of saltwater at room temperature. Wait a few minutes for the water movement to stop.

5. Using a pipette, place two drops of yellow food coloring on the bottom of the container below the cup labeled "hot water." Use another pipette and place two drops of blue food coloring on the bottom of the container below the cup labeled "cold water." Move the pipettes straight down into the container of water while doing this to reduce stirring up the water.

6. Fill a styrofoam cup with very warm water and stir in several drops of red food coloring. Pour the hot water into the "hot water" paper cup above the yellow food coloring. This represents river water from a river in the tropical latitudes.

7. Fill another styrofoam cup with ice water and stir in several drops of green food coloring. Pour the ice water into the "cold water" paper cup above the blue food coloring. This represents water from a river in the northern latitudes.

8. With scissors, carefully punch a small hole in the side of each cup, approximately 1 cm

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below the surface of the water. Each hole should be large enough to allow a small stream of water to flow out into the container.

9. Hold a white sheet of paper behind the container in order to see the movement of the food colored water more clearly. View the container from the side at eye level. Fill in your sketch of the container to show how the water moved. Use colored markers that match the color of the water and make arrows to indicate the direction of movement of the different water masses. Label the sketch clearly.

10. Describe in words how the water moved.

11. What happened to the "river" of cold water that flowed into the "ocean" (the "cold water" cup into the container of saltwater)?

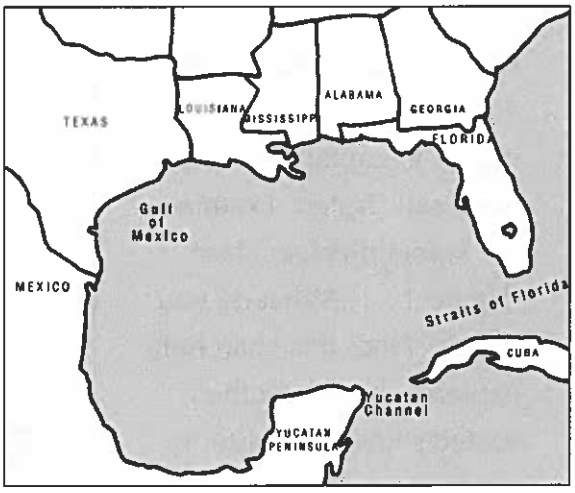
12. What happened to the "river" of warm water that flowed into the "ocean" (the "hot water cup into the container of saltwater)?

13. Based on your observations, which water had the greater density?

14. Summarize your findings and describe how river water flowing into the ocean affects the movement of water.

15. What happens to fresh water from the Mississippi River as it flows into the salt water of the Gulf of Mexico? Explain.

16. The Gulf of Mexico is a basin with only two outlets to the Atlantic Ocean. What do you think will happen to warm water that enters the Gulf through the Yucatan Channel between Mexico and Cuba? Explain.



13. How Do Ocean Waters and Currents Move?

Oceanographer _____ **Team** _____

The ocean's waters are constantly moving. If you swim in the ocean, you are probably familiar with these movements, or currents, of water. Those who sail and navigate the oceans also need to be aware of currents and their direction. Some currents are local, affecting only a small area, such as a beach. These are the ocean's response to shoreline and seasonal conditions. Other currents are more long term and involve larger areas of the ocean. Ocean circulation therefore involves both surface currents and the movement of deep-water masses. You are going to study the movement of the ocean waters.

Materials: colored markers

Procedure:

Part I: How do surface currents move?

1. Early Americans had a large role in explaining the workings of the ocean's surface currents. In 1768, Benjamin Franklin, then Deputy Postmaster General for the American colonies, determined that it took British mail ships about two weeks longer sailing from London to New York than it took merchant ships to sail the same route. Franklin checked with captains coming into port. He deduced that ships coming across the Atlantic from Europe on a more northerly route took two weeks longer to reach the colonies than ships coming from Europe on a more southerly route. Franklin consulted his cousin, Timothy Folger, a Nantucket ship captain, for more information. Folger told Franklin that the British sailors did not know about a certain powerful current the merchants used. To explain, Folger sketched a map. Later, Franklin had Folger's sketch engraved and distributed copies to captains to help them sail "faster." Examine the Franklin-Folger chart (Figure 13.1). What do you notice? Does this chart help explain why the southern routed ships were faster in crossing the Atlantic? Explain.

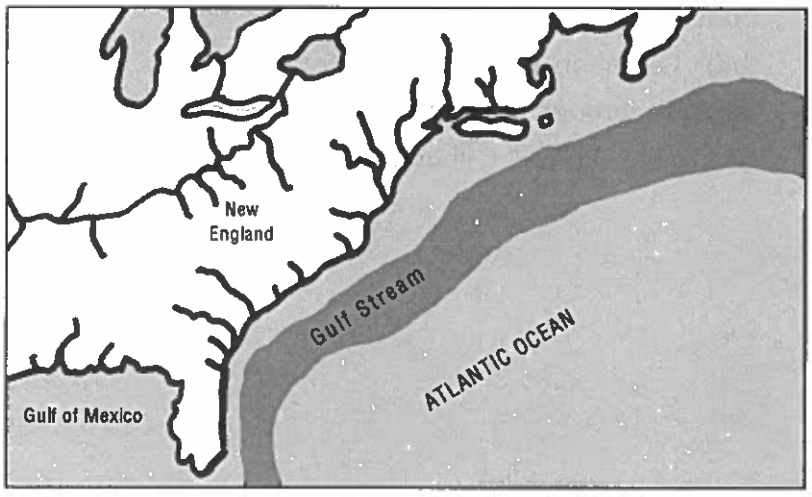


Fig. 13.1. Franklin-Folger Chart (Source: The Restless Ocean)

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2. Examine Figure 13.2, which is based on a National Oceanic and Atmospheric Administration (NOAA) satellite image of the Atlantic. Compare it to the Franklin-Folger chart (Figure 13.1). How are they alike? How do they differ?

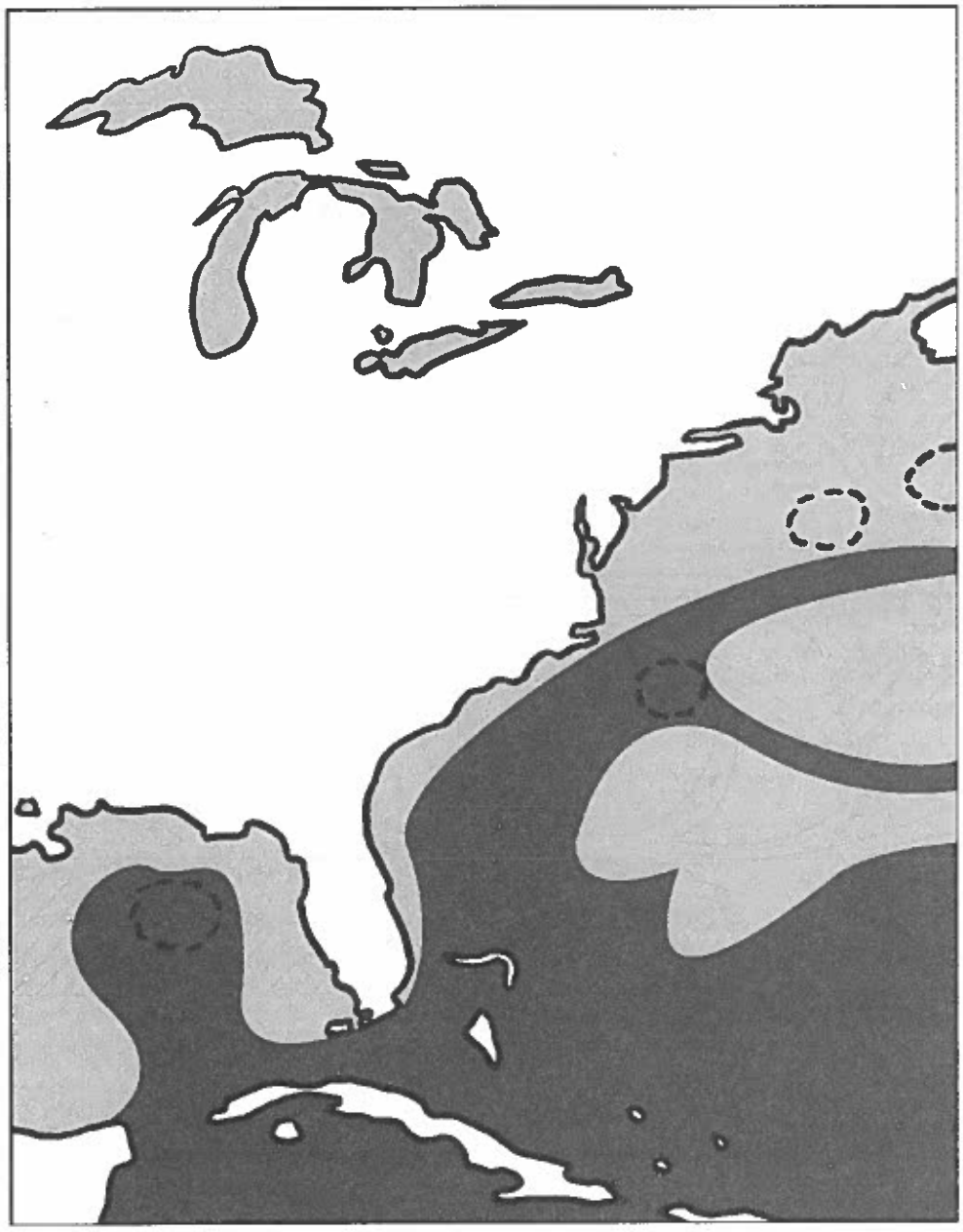


Fig. 13.2. Sea Surface Temperature.

3. "There is a river in the ocean. In the severest droughts it never fails, and in the mightiest floods it never overflows. Its banks and its bottom are of cold water, while its current is of warm. The Gulf of Mexico is its fountain, and its mouth is the Arctic Seas. It is the Gulf Stream."

   This statement was written by Matthew Fontaine Maury in 1855 in his book, **The Physical Geography of the Sea**. What does he mean? Explain, referring to Figures 13.1 and 13.2.

4. The quote by Maury describes the best known and most studied of the ocean surface currents, the Gulf Stream. This current is just a small part of a huge, slow moving circular **whorl or gyre** that flows around the North Atlantic Ocean. Figure 13.3 shows this entire gyre as well as the other major gyres in the oceans. Do you observe any patterns? Explain.

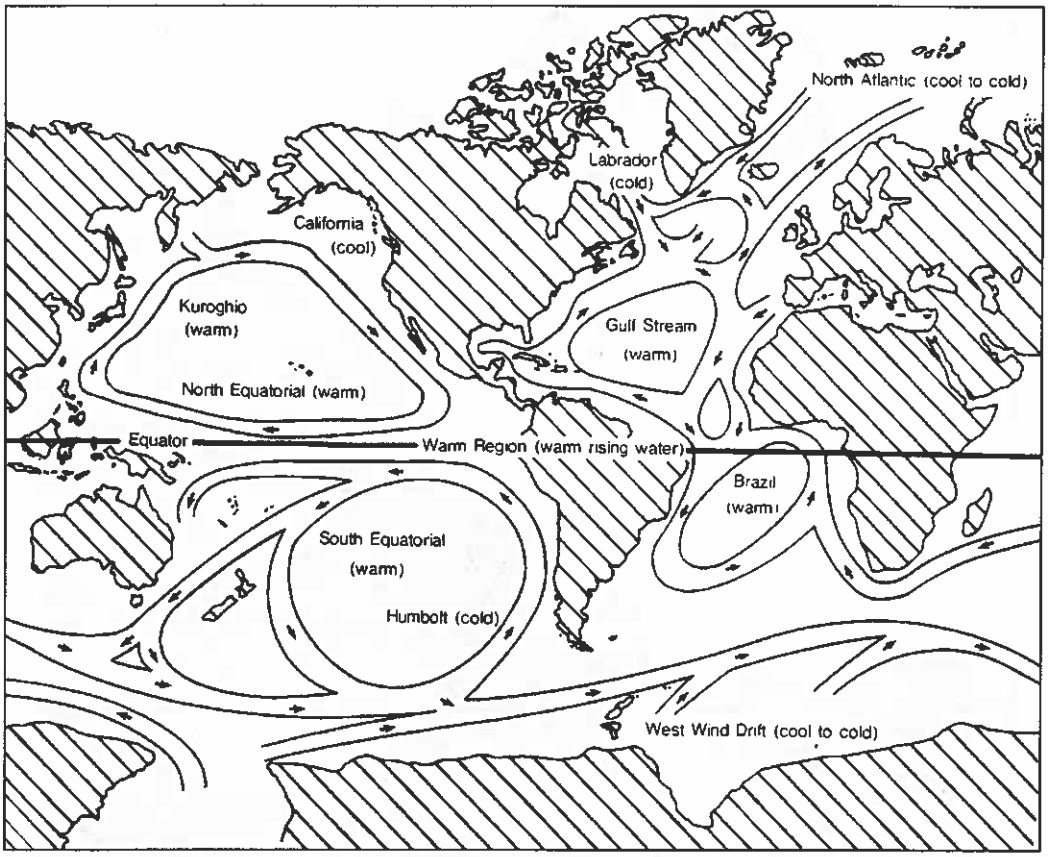


Fig. 13.3. Surface ocean currents. (Source: The Restless Ocean)

5. Compare Figures 13.3 and 13.4. Do you observe a relationship between oceanic circulation and atmospheric circulation? Explain.

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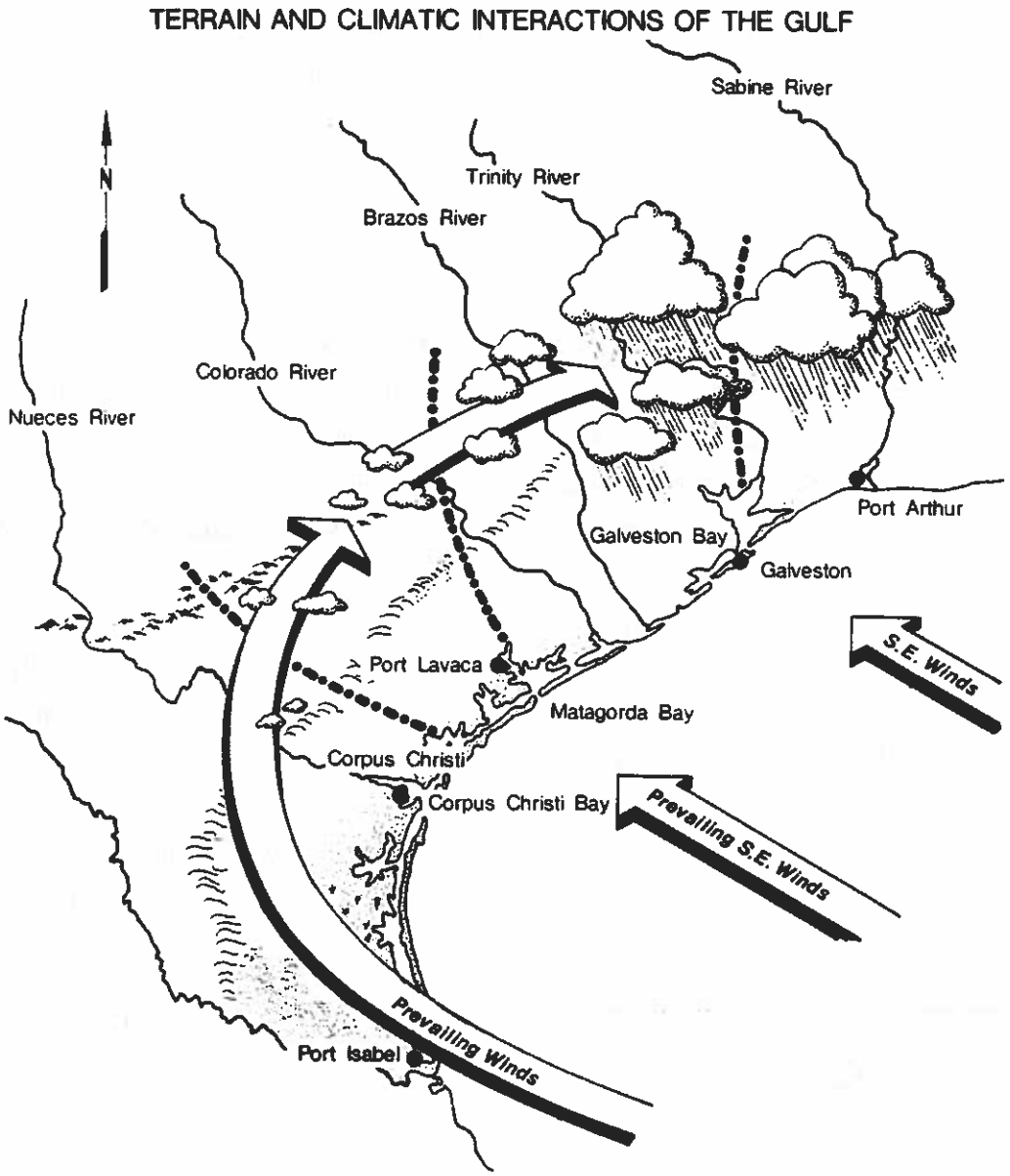


Fig. 13.4. Surface winds from the Gulf of Mexico. (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

6. Although wind is one force that generates surface currents, other factors also influence the movement of ocean waters. Another factor is the friction caused by neighboring water masses or the ocean floor. These tend to slow the current. The most significant factor affecting surface currents, however, is the **Coriolis effect** — a deflecting force caused by the earth's rotation. As the earth rotates, points on the equator travel faster than points near the poles. Therefore an object moving at the equator tends to speed "ahead" of the earth beneath it while an object moving from the poles to the equator gets "left behind." This means that moving materials, such as water, will curve away from the equator. Examine Figure 13.3. In what direction does the water curve in relation to the equator in the Northern hemisphere? In the Southern hemisphere?

7. Major surface currents begin at the equator. What is the temperature of the water where these major currents begin? What happens to the temperature and direction of these currents as they travel to the polar regions?

8. What do you think water movement and weather conditions in the center of gyres might be like? Explain.

9. Use Figure 13.3 to locate the eastern coastlines of the oceans, specifically the coasts of California, South America, and West Africa. Use a marker to highlight these areas. A process known as **upwelling** occurs in these areas. Aided by the Coriolis effect and wind patterns that blow surface currents away from the shore, surface water along the eastern coastlines is moved away from the land. As the surface water is pushed away from the shore, it is replaced by water that wells up from below the surface. This slow upward movement of water from depths of 50 to 300 meters (165 to 1,000 feet) brings up water that is much cooler than the surface waters. What, then, are the differences (with respect to temperature) between swimming in the waters off the coast of California compared to swimming in the Atlantic Ocean off the coast of New Jersey?

10. Coastal upwelling also brings great concentrations of dissolved nutrients to the ocean surface. How might this affect the growth of plankton and the fish populations that depend on them? Explain.

Part II: How do surface currents affect the movement of people and organisms?

1. Ocean currents have played a major role in the movement of people and organisms around the planet over time. Explorers like Ponce de Leon, who used the Gulf Stream to reach the Americas from Spain, relied heavily on ocean currents to navigate their way across an unmapped world. Millions of years ago, ocean currents brought plants and animals to the barren rocky shores of islands now called Galapagos and Hawaii. Use Figures 13.3 and 13.4 to explain how this movement might have occurred.

2. Why was knowledge of the currents and winds so important to early navigators and their sailing ships? Use Figures 13.1-13.3 to explain your answer.

3. Describe the ideal route for ships to take traveling from North America to Europe Why is this a good route? Would your route change on a return voyage? Why or why not?

4. Which areas would you want to avoid on your routes and why?

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5. Young sea turtles from the Gulf of Mexico are often found in the North Atlantic Ocean. How do the turtles travel this great distance? Explain.

6. How might currents affect the movement of pollutants in the ocean?.

7. How could additional knowledge of the ocean currents benefit people in the future?

8. Research Thor Heyerdahl's expeditions (the Kon Tiki and Ra Expeditions) to illustrate how currents played a role in the movement of people around the globe.

9. Use the internet to visit the National Oceanic and Atmospheric Administration (NOAA) web site at www.@noaa.gov. TOPEX/POSEIDON data sources, such as charts, maps, and other information related to ocean movement can be found at: http://topex-www.jpl.nasa.gove/science/science.html.

Part III: How do deep ocean water currents move?

1. Not all ocean circulation is caused by surface currents. Movement also occurs deep in the ocean waters. Deep ocean circulation is controlled by gravity and driven by density differences. As you learned from the activity, "What is the connection between density and ocean currents?" temperature and salinity are the most important factors in forming a dense mass of water. Water that is cold and salty is more dense than warmer, less salty water. With this in mind, the basic principles of deep ocean circulation can be summarized by the following ideas: Surface water cools as heat is lost to the atmosphere, and/or it becomes saltier as water is removed through evaporation or freezing. This denser water sinks towards the ocean bottom and displaces less dense water. The less dense water moves upwards toward the area where the denser water formed.

2. Where on Earth do you think the major dense water masses are created?

3. Use the observations you made in the activity, "What is the connection between density and ocean currents?" and the information above to sketch in the movement of ocean water in the cross section diagram below. Use arrows to show the direction of the currents.

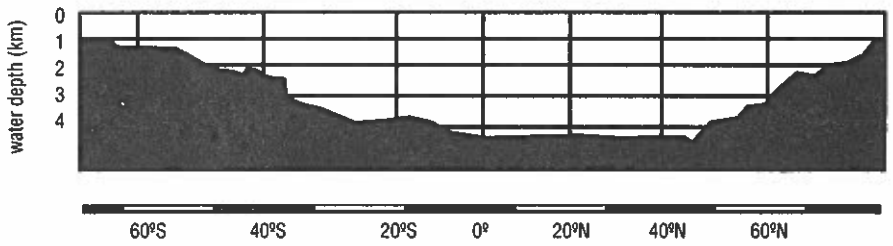


Fig. 13.5. Cross-section view of ocean floor.

4. Surface currents usually have speeds of up to 50 to 100 centimeters per second. However, speeds of 300 centimeters per second have been observed in the Gulf Stream. On the other hand, the deep ocean currents are very slow moving compared with the surface currents, sometimes moving only 2-3 centimeters per second. Measure the length of your classroom in centimeters and then determine how much time it would take the average surface current, the Gulf Stream, and an average deep ocean current to cross the length of your classroom.

5. It has been estimated that it takes about 750 years for ocean water to travel from the Arctic Ocean's surface to the bottom of the North Atlantic Ocean. It takes about 1,500 years for ocean water to travel from the Antarctic to the North Pacific Ocean?. How does this time scale influence our knowledge and research of deep ocean currents?
6. Deep ocean waters can return to the surface after centuries have passed. The return flow is a often slow, upward movement or upwelling. Where do you expect this upwelling to occur?

7. Deep currents carry oxygen into the deepest parts of the oceans. How does this affect life in the ocean depths?

8. Deep currents also bring up nutrients from the sea floor towards the surface. If there were no deep ocean currents, what do you think the depths of the ocean and the surfaces would be like for living organisms?

9. What if the density of ocean water was the same everywhere, regardless of depth or latitude? Describe and explain some of the effects this would have.

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14. What Effects Do Currents Have in the Gulf of Mexico?

Oceanographer _____ **Team** _____

The surface currents of the Gulf of Mexico vary seasonally during the year, with a winter and a summer current pattern. These currents affect the movement of organisms, nutrients, and pollutants throughout the Gulf. You are going to analyze maps of these currents to determine their effects.

Materials: none

Procedure:

1. The Gulf of Mexico can be divided into two parts, east and west, each having a different pattern of water flow. Examine Figure 14.1. Describe the pattern of the surface currents.

2. Where does water enter the Gulf of Mexico? Where does it leave?

3. Notice that the general circulation in the Gulf consists of a large clockwise loop current that flows from the Yucatan to the Florida Strait. Large current rings, or **eddies**, help form this loop. The current in the western half of the Gulf is not as strong

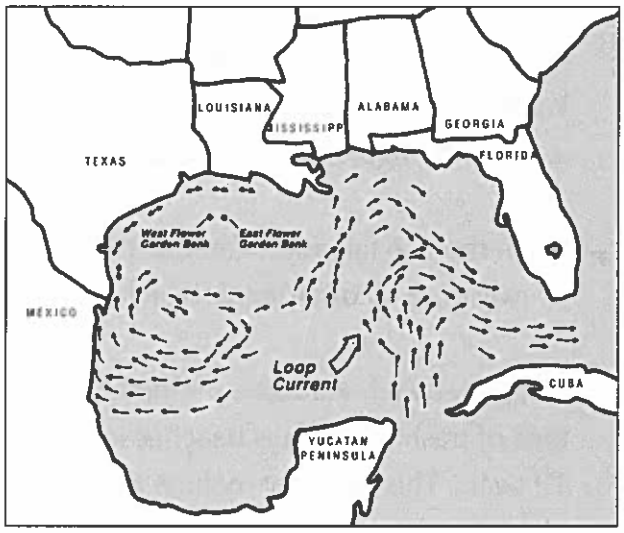


Fig. 14.1. Map of surface current in the Gulf of Mexico. (Source: U.S. Department of Commerce, NOAA, Ocean Assessment Division)

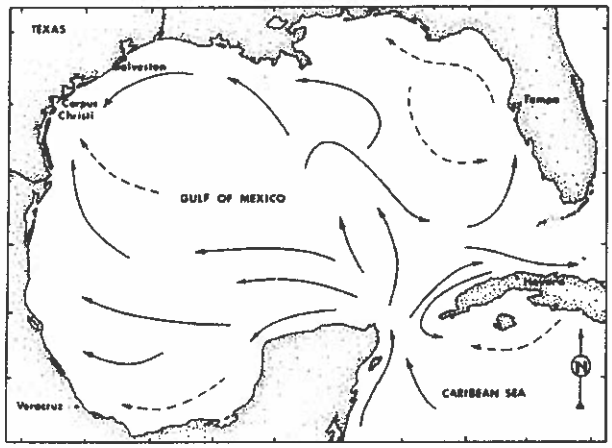


Fig. 14.2. Map of surface current of the Gulf of Mexico in August. (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

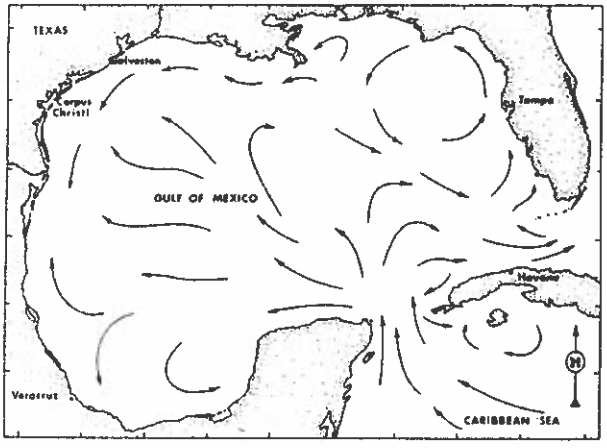


Fig. 14.3. Map of surface currents of the Gulf of Mexico in February. (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

or long term as the eastern half. However, these currents change from winter to summer. Examine Figures 14.2 and 14.3 (page 410). Describe the differences in the summer (August) and winter (January) currents.

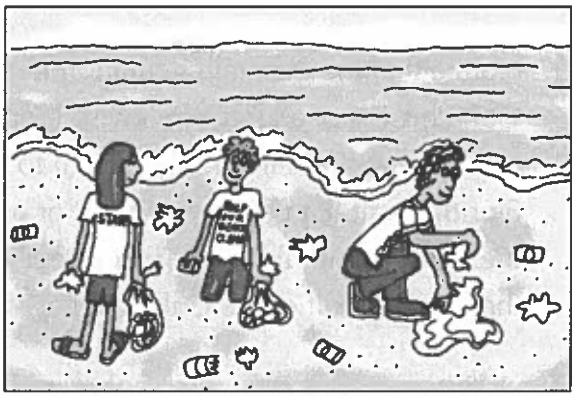
4. Where do the currents carry the nutrients and sediments from the Mississippi River during the winter? In the summer? Why might there be a difference ? Explain.

5. Using Figures 14.2 and 14.3, determine which beaches would be affected by oil spilled from a tanker collision in Galveston Bay in February. Which beaches would be affected in August?

6. On June 4, 1979, the Ixtoc I offshore oil well, located in the Gulf of Campeche, began spewing oil into the Gulf of Mexico. Campeche is located between Veracruz and the Yucatan peninsula of Mexico.
   a. Use the figures to determine onto which Texas beaches the oil washed ashore.

   b. In the late fall and winter of 1979, the well was still spewing oil, but it was no longer washing up onto Texas' beaches. Why?

7. Adopt-A-Beach volunteers removed 3,185 tons of trash from Texas beaches in their first 10 years. This does not include the trash picked up by city and county maintenance crews who clean their local beaches every week. It is estimated that 75 to 90 percent of this beach trash comes from offshore sources. Why does solid waste dumped from throughout the Gulf of Mexico have a good chance of ending up on the Texas coast? Use Figures 14.2 and 14.3 to explain your answer.



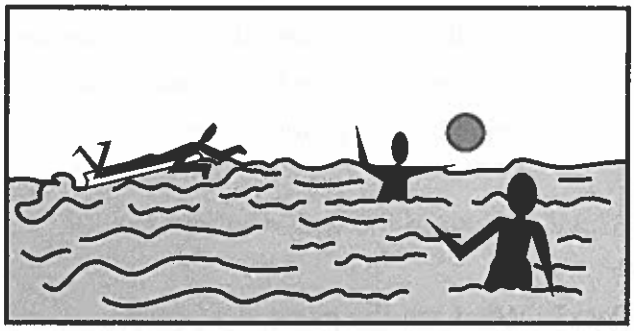
8. Using the figures, determine where solid wastes dumped from oil and gas platforms off the Louisiana coast will end up.

9. There is only a slight exchange of water between the Gulf of Mexico and its neighboring bodies of water (the Atlantic Ocean and the Caribbean Sea). How does this affect the nutrients and pollutants that enter the Gulf? Leaving the Gulf?

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15. What Causes Waves?

Oceanographer _____ **Team** _____



By nature, people are wave watchers. Waves can be relaxing to listen to, mesmerizing to watch — have you ever tried to count 100 waves — and inspiring in their relentless constancy But waves have a tremendous impact as well. They make and reshape ocean coastlines and beaches every year while they entertain millions of sunbathers, surfers, and swimmers. Waves influence the design and operation of boats. They must also be considered in the design and construction of docks, breakwaters, groins and jetties because they can cause the failure or destruction of these structures. Waves from a single storm can even kill hundreds of people and cause billions of dollars in damage to low-lying coastal areas. You and your team are going to investigate waves to learn more about their impacts.

Materials: stream table or large plastic tray or paper ream box top, large white plastic trash bags, duct tape, sand, straws, hair dryer or two speed fan, scissors, ruler, colored pens or pencils

Procedure:

Part I: What causes waves?

1. What are some of the ways you can make waves in water, like in a swimming pool, a bathtub or a sink?

2. If a stream table, wave tank or large plastic tray is not available, then you can construct one from a paper ream box top (see Figure 15.1). Cut the plastic bag along each side and unfold it. Use the plastic bag to cover the bottom and sides of the box lid. Tape the bag to the outside of your new wave tank.

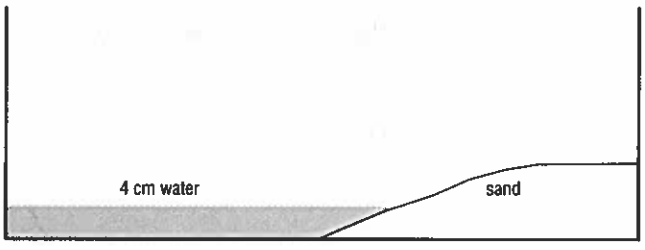


Fig. 15.1. Wave tank

3. Make a "beach" with sand at one end of the tank. Fill the tank with water to a depth of 4 cm. Wait for the water to stop moving.

4. Without touching the wave tank, hold the straw so that it is parallel to the surface of the water and gently blow through it. Observe the patterns that the wind produces.

5. Sketch the pattern you observed in Figure 15.2. With colored pencil or pen, draw arrows to show the direction the air was moving and the direction the water was moving.

6. What caused the waves to form?

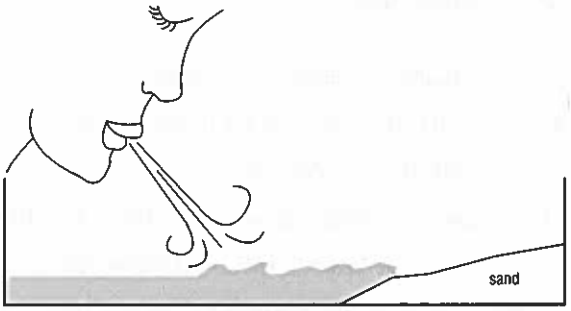


Fig. 15.2. Gently blow through the straw across the water.

Part II: What are the parts of a wave?

1. A wave is the movement across the surface of water, usually created by wind. Again, use a straw to blow across the surface of the water. What is the motion of the water?

2. Observe any patterns in the waves in your tank. The highest point of a wave is called the wave crest, where the water in the wave rises the most. The water then sinks to its lowest point. This is called the wave trough. The wave height is the vertical distance separating the crest from the trough. With the straw, blow across the surface of the water and look for these parts of a wave. How do you think you could you measure the height of the waves?

3. Place a ruler on the side of the wave tank. Use it to estimate the distance between the crest of one wave and the crest of next wave. This distance is known as the wavelength. What is the wavelength of your waves?

4. Put a piece of tape on one side of the wave tank. With the straw, blow across the surface of the water. Watch one wave crest pass by the tape and then a second crest pass by the tape. The time it takes the crest of two successive waves to pass the tape (a fixed point) is the wave period. What is the estimated wave period of your waves?

5. Label the parts of a wave in Figure 15.3.

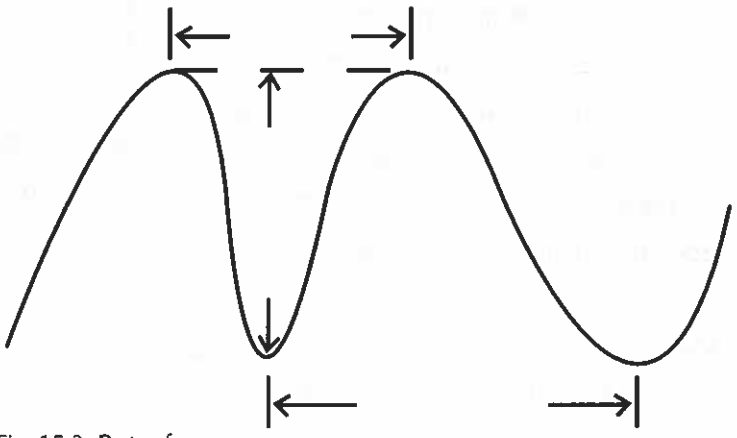


Fig. 15.3. Parts of a wave

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Part III: What is the effect of wind speed on waves?

1. In this activity, you will investigate how the speed of wind affects waves. In Table 1, write a hypothesis that explains how you think the speed of wind (generated by a hair dryer or a fan) will affect the wavelength, wave period and wave height of waves.

2. Place or hold the fan or hair dryer at one end of the wave table. DO NOT allow the fan or hair dryer to touch the water. Turn on the wind source to "low" for two minutes. Turn off the source. Record your observations in Table 1.

3. Let the water become still. Turn on the wind source to "high" for two minutes again. Turn off the source. Construct a table based on the following example and record your observations.

4. Write your conclusion about wind speed and waves in Table 1.

Table 1: Effect of Wind on Waves

Problem	Hypothesis	Observations	Conclusion
What is the effect of wind speed on waves?			
What is the effect of length of time wind blows on waves?			

Part IV: What is the effect of length of time that wind blows on waves?

1. In this activity, you will investigate how the length of time that wind blows can affect waves. In Table 1, write a hypothesis that explains this effect upon the wavelength, wave period, and wave height of waves.

2. Place or hold the fan or hair dryer at one end of the wave table. **DO NOT** allow the fan or hair dryer to touch the water. Turn on the wind source to "high" for 5 minutes. Turn off the wind source. Record your observations in Table 1.

3 Let the water become still. Turn on the wind source on "high" for 10 minutes. Turn off the wind source. Record your observations in Table 1.

4. What conclusion can you make about the waves that are formed and the amount of time the wind blows? Record your answer in Table 1.

5. Did you notice any differences in the waves in the two experiments (Parts III and IV) from one end of the tank to another? Was there a size difference? Did the wavelength differ?

6. Based on your observations, what factors do you think are important in determining the height of a wave?

Part V: How does water move in a wave?

1. Cut three 1 cm pieces from a plastic straw. Place two of the pieces on the bottom of the tank about 5 cm from the end. Place the third piece in the middle of the tank. Let the water still. Turn on the hair dyer or fan to low for two minutes. While the waves move back and forth across the surface of the water, in what direction do you observe the pieces of straw moving?

2. Tie a rope or clothesline to a door and then tie a bright colored ribbon to the middle of the rope. Move the rope up and down to create a wave (see Figure 15.4). As you move the rope up and down, it appears that the waves in the rope move forward — but does the rope move forward with the waves?

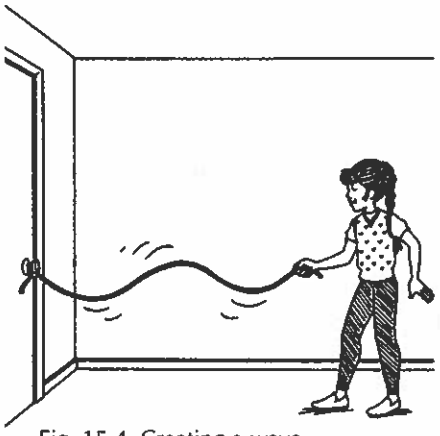


Fig. 15.4. Creating a wave.

3. Water waves behave like the waves you made in the rope. Do you think that the movement of the water (as shown by the movement of the straws) is like the movement of the rope? How?

4. As a wave travels through water, each water molecule moves in a circular motion, moving around until it ends up almost in the same position it began. Examine Figure 15.5. Relate this information to your observations of the movement of the pieces of straw.

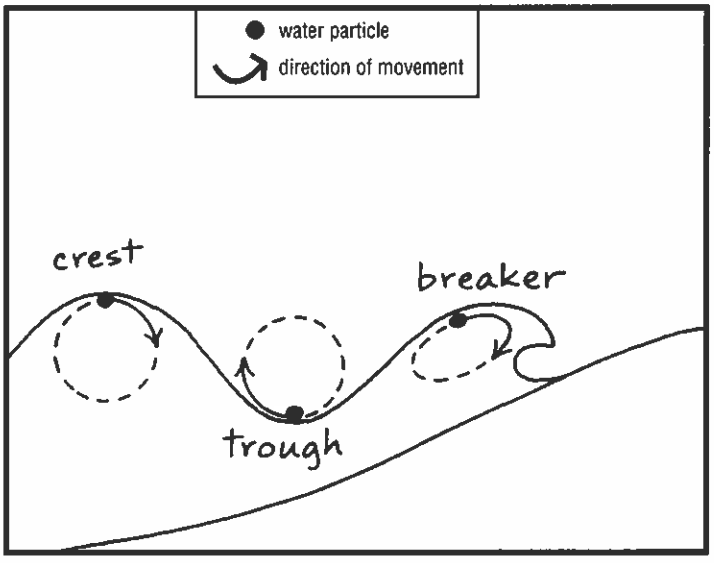


Fig. 15.5. Movement of water molecules.

5. What do you think would happen if the water was too shallow for the water molecules to move in a circular motion? Draw what you think might occur.

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6. Observe what happens to the water when it cannot move in a circular motion by placing a piece of straw about 2 cm from the "beach" in your wave tank. Then, turn on the hair dryer or fan to low. What happens to the waves and the piece of straw?

7. In shallow water near the beach, water molecules can no longer move in a circle. As the water molecules in the trough of the wave hit the bottom surface, friction between the water and the bottom slows their movement. However, water molecules in the wave's crest are not slowed — they move faster. This causes the wave crest to fall forward and collapse into the trough. The result is **breakers**, or waves crashing into the beach. Thinking about it another way, the shore "trips up" the wave and so the wave falls "head over heels".

8. Where does the water go when a wave crashes into the beach?

9. Would there be larger breakers on a steep shoreline or on a shoreline with a gentle slope? Write your hypothesis.

10. Create a shoreline with a gentle slope in your wave tank. Use a hair dryer or fan to create waves. Observe the breakers that form as the waves break along the shoreline. Fill in the sketch below with your observations.

11. Create a steep shoreline in your wave tank. Use a wind source to make waves. Observe the breakers that form as waves break along this shoreline. Complete the sketch with your second round of observations.

12. What is the relationship between the type of shoreline and the type of breakers that form?

13. A shoreline has large waves breaking along the shore. What type of slope would you expect to find along the shoreline? Explain.

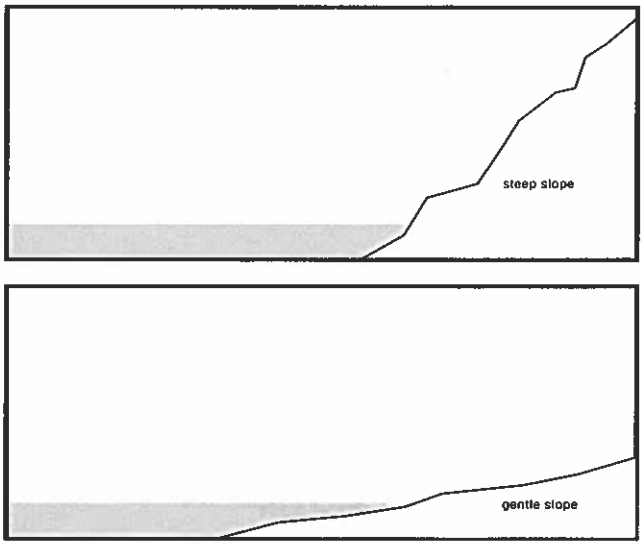


Fig. 15.6. Cross section of a gently sloping shoreline (top). Add waves and breakers to the steeply sloping shoreline (below).

14. Surf (or wave) height depends primarily on the height and steepness of the waves offshore and to a certain extent on the offshore bottom. A good area for surfing not only has big

waves but a bottom that causes the water to leap into a plunging wave and produce a crashing surf. The Texas shoreline has a very gentle slope. Is this shoreline a good surfing area or not? Explain.

15. The Texas shoreline has a wide surf zone with a series of sandbars and troughs along the bottom. If you are looking at Gulf waves from the beach, you will see waves with large breakers on the outer bar furthest offshore, and then smaller breakers on each succeeding bar towards the shore. Why are the waves different?

16. There is almost no surf in the closed bays and lagoons of the Gulf coast. Why?

17. Shell collectors have noted that on some days they find greater numbers of right valves (halves) of clam shells and on other days, greater numbers of left valves. Further investigation has revealed that waves approaching from the right (as you face the Gulf) tend to deposit right valve shells and waves approaching from the left deposit left valve shells. What is a possible explanation for this phenomenon?

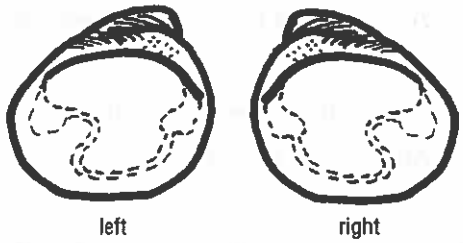


Fig. 15.7. Left and right clam shells.

Part VI: What happens to water in waves?

1. Waves stack up water on the beach. This water does not go back to the ocean as a wave. Write your hypothesis or explanation for where it goes.

2. To investigate, you will use your wave tank again. Place or hold the fan or hair dryer at one end of the wave tank. **DO NOT** allow the fan or hair dryer touch the water. Let the water still. Turn on the wind source to "low" for one minute to create waves. As the waves break on the shoreline, add a drop of food coloring to the water about 1 cm away. Observe what happens to the food coloring. As waves stack the food colored water on the beach, where does it go?

3. As you probably observed, the food colored water did not return as a wave. Instead, it moved as a small stream or current below the surface of the water. These are called **rip currents**, and they extend 300 to 400 feet outward from the shore. Rip currents can travel as fast as 3 to 4 miles per hour. When a swimmer gets caught in a rip current, s/he will usually try to swim toward shore — but the current carries the swimmer out to sea instead. Why? Explain.

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4. Swimmers who try to swim out of the current toward shore often become exhausted fighting the current and may even drown. A swimmer can get out of a rip current by swimming parallel to the shoreline, since rip currents are usually not very wide. Do your observations of the movement of the food coloring support this concept? Explain.

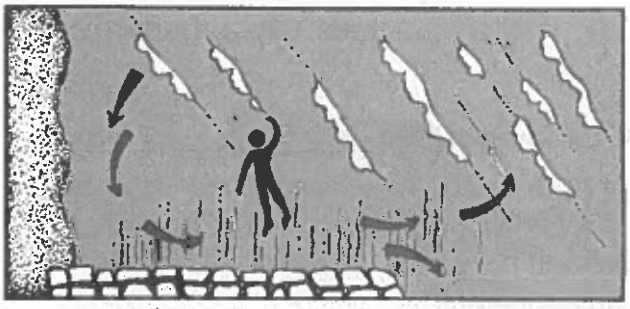
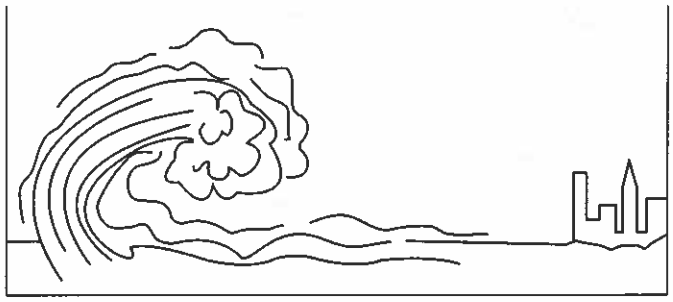


Fig. 15.8. Swimmers can get out of a rip current by swimming parallel to the shoreline.

16. What Causes Catastrophic Waves?

Oceanographer _____ **Team** _____



Sometimes, the most impressive and memorable part of a trip to the beach is the pounding surf. When waves are small or absent, beach lovers can be disappointed. Excitement is high at the beach when the waves are bigger, but when the ocean is at its most spectacular, it is often at its most dangerous as well. You will learn more about this danger by studying catastrophic waves.

Materials: graph paper, plastic shoe box or wave tank, water, stone about the size of a golf ball

Procedure:

Part I: What is a storm surge?

Table 1: Data of waves in the open ocean

Wind Speed (km/hr)	Average Height (m)	Average Length (m)	Average Period (sec)	Significant Wave Height (m)
20	0.33	10.6	3.2	0.5
40	1.8	39.7	6.2	2.5
60	5.1	89.2	9.9	7.1
80	10.3	158.6	12.4	14.3
90	13.9	201.6	13.9	19.3

1. On graph paper, construct a bar graph of the data given in Table 1. Graph each of the four variables (y) in relation to wind speed (x). Next, analyze your graph and Table 1. Do you observe any patterns or relationships among the variables? List your observations.

2. **Significant wave height** is an average of the tallest or highest third of all the waves present in a specific area of the ocean. Big waves carry a lot more energy than small waves do; thus, large waves can have a greater impact and cause more damage. For human safety, the larger waves need to be predicted. Oceanographers use significant wave height for this important task.

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3. **Storm surges**, also known as storm waves or tides, are caused by the powerful and steady winds associated with hurricanes or other severe storms. First, the water surface rises in response to the low atmospheric pressure in the storm area. Then, strong winds blowing towards shore push the water towards land. This causes ocean water to stack up against the beach, bringing deeper water onto land. As a consequence, waves break much further inland than normal. Storm surges can be extremely destructive when they occur with unusually high tides. Why do you think this is so? Explain.

4. The rise in the water's surface level as a storm approaches is greatest in partially enclosed bodies of water like the Gulf of Mexico. First, there is a gradual change in water level, a few hours ahead of the storm's arrival. But when a hurricane arrives, it causes a sharp rise in the water level — this is the surge. The water can rise as much as 13 feet (3.9 m) in as fast as 45 minutes, and even more if it occurs at high tide. The storm surge persists for up to 6 hours after the hurricane has passed, after which the sea returns to normal. Approximately 12 hours later there is another rise in sea level about one-half to one-third as high as the original surge.

5. What is the height of your classroom? Imagine that your school is near the Texas coast and is only about 3 feet (1 m) above sea level. What do you think would happen to your classroom if the coast was hit by a major hurricane with a storm surge of approximately 20 feet (6 m)?

6. How might this affect the neighborhood around your school? Your town?

7. In 1900, a hurricane storm surge hit Galveston, Texas, raising the water level 17 feet (5 m) higher than predicted at high tide. Nearly 6,000 people died as a result. A storm surge 20 feet high (6 meters) struck and covered Bangladesh in 1970 and is estimated to have killed over a half million people. In 1989, Hurricane Hugo struck Charleston, South Carolina with a storm surge approximately 17 feet (5 meters), added to high tide. The damage was over $3 billion. With storm winds over 100 miles an hour, Hurricane Andrew caused widespread flooding across Florida in 1992 and almost $12 billion in damage. Why are storm surges or waves so expensively destructive to coastal areas? Explain.

8. When a hurricane approaches the Texas coast, people asked to leave the area more than a day in advance, before the storm reaches land. Why?

9. With research satellites, it is now possible to measure and study waves from instruments orbiting the Earth. Satellites send out radar pulses that are reflected from the sea surface

and timed. The height of the satellite above the sea surface can be determined to an accuracy of about 10 centimeters (~3.9 inches). Any waves taller than this can be detected and measured. How is this technology important in saving lives from storm surges?

Part II: What are tsunamis?

1. There are other types that are dangerous too. One is the **tsunami**. Once called tidal waves, these waves actually have nothing to do with tides. The Japanese word for "big wave," tsunamis are seismic ocean waves. To see how tsunamis are formed, place a plastic container on your table and fill it with water. Drop a golf ball sized rock into the container of water. Describe what happens. How do the waves move? In what direction?

2. Wait for the water in the container to stop moving. Then, bump the table or the container. What happens? How do the waves move? Describe your observations.

3. A tsunami causes water movement that is similar to the movement in the container. Tsunamis are created from sudden movement. Any shifting of the ocean floor caused by explosive volcanic eruptions, earthquakes, or large masses of sediments moving under water (**submarine slumping**) can cause the water over the area to move in response, forming a tsunami. Actually, a tsunami is not one wave but a series of low, flat waves with long periods and wavelengths. These wavelengths can be greater than 100 kilometers (about 62 mi.). In the open ocean, they can travel at a rate of 760 kilometers per hour (about 483 mph) — this is about the same speed as a modern jet airplane. Tsunamis are not dangerous to ships in the open ocean since they are only a meter or two high. They may not even be noticed, since 10 minutes to an hour can pass between waves. However, the waves of a tsunami can grow to heights of over 10 meters (about 33 feet) as they reach the shoreline. Why do the waves grow larger as they reach the shore?

4. Japan has a long history of tsunamis. Since 684 AD, more than 150 tsunamis have struck Japan. In recent history, a tsunami formed by an earthquake in the sea floor near the Philippine Islands struck Japan, causing 8,000 deaths, 10,000 injuries, and leaving 90,000 people homeless. Why do you think this tsunami was so catastrophic?

5. Tsunamis are most common in the Pacific Ocean, since more earthquakes occur in the sea floor there. Although they cannot be prevented, tsunamis can be predicted. Early warnings of the approach of tsunamis can help prevent the loss of lives. The International Warning System is a network of stations that measure and record the vibrations of the crust to detect earthquakes. Locating and measuring earthquakes in the ocean enables scien-

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tists to predict tsunamis. Coastal areas likely to be struck by the seismic sea waves can then be alerted.

6. Examine Figure 16.1, which shows the position of the first wave of a tsunami that formed off the shore of Colombia, South America, in 1979. How many hours did it take for the wave to reach islands in southeast Asia, including Japan?

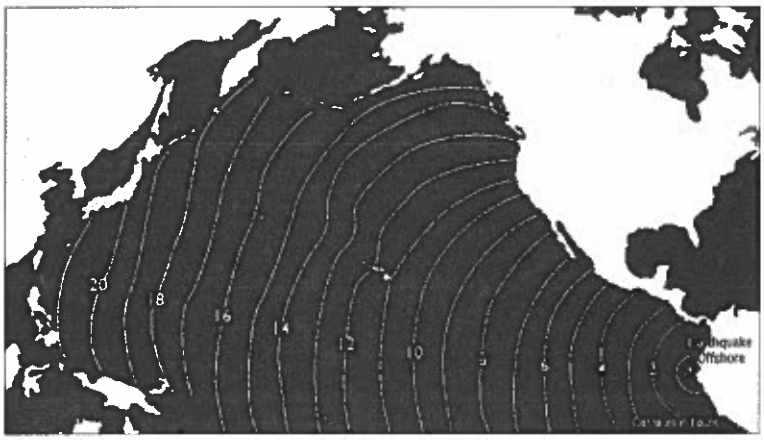


Fig. 16.1. Refraction pattern of 1979 tsunami

Part III: What is an internal wave?

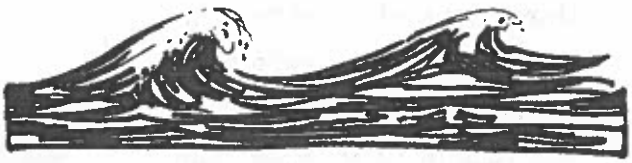
1. **Internal waves** occur underwater only, not at the surface. These waves move along the boundaries that separate water masses of different densities. Why might scientists have discovered and studied internal waves just within the past 30 years?

2. Internal waves can have wavelengths of hundreds of meters. Although they usually have heights of several meters, larger internal waves can reach heights of 100 meters (about 330 ft). This is almost 3 times higher than any large surface waves, and as high as a football field is long. Since these waves only occur underwater, what do they affect? Explain.

3. How internal waves form is still being studied. The U.S. Navy is especially interested in researching the causes and effects of these waves because they suspect internal waves of causing the sinking of several submarines. Submarines cruise along the boundaries of water masses of different densities because water layers of different densities tend to reflect sonar pulses. This enables the submarines to cruise around undetected by sonar. In 1963, the nuclear submarine USS *Thresher* was lost. Navy scientists speculated that the submarine was probably cruising along a water mass boundary when it was hit by a large internal wave traveling along that boundary. The wave may have suddenly dropped the submarine down to a depth where the water pressure was greater than it could withstand. What could happen to the submarine in this case?

17. What Causes the Motion of the Tides?

Physical Oceanographer _____ **Team**_____



One of the most dynamic aspects of the ocean is the ever-changing tide, with its slow up and down movement of sea level every day. If you live inland, you may not be familiar with tides, but those of you who live along the coast or have spent time at the beach have likely observed and experienced tides firsthand. What causes this movement of ocean water? You are going to investigate tidal motion.

Materials: iron filings, large strong magnet, small weaker magnet, baby food jar, computer and Internet capability

Procedure:

1. Tides are waves, but because they are so large their wave-like characteristics are easily overlooked. In their simplest form, tides are huge, shallow water waves that reach across the whole ocean. These waves cause ocean water to move up in a crest on one side of the ocean basin and down into a trough on the opposite side. Tides differ from ordinary ocean waves, however, because of what causes them to occur. Tides are very long, single waves formed by the gravitational attraction of the Moon (and to a lesser extent, the Sun) on the ocean's water. Which do you think has the greater effect on the ocean's water — the Moon or the Sun? Why?

2. You are going to create a model to demonstrate the effect of gravity on the ocean. First, put some iron filings (representing seawater) in ajar. Place the large magnet (representing the Sun) a distance from the jar where it barely moves the iron filings. Place the smaller weaker magnet about 1 cm or less from the jar. Rotate the magnets around the jar.
   a. What do you observe?
   b. What does the pull of the magnets on the filings represent?
   c. Which has the least effect: the larger magnet (the Sun) or the smaller magnet (the Moon)?
   d. Why does the smaller magnet (the Moon) exert a greater attractive force on the iron filings?
   e. What happens when the magnets (Moon and Sun) are in line on the same side of the bottle?
   f. What happens when the magnets (Moon and Sun) are in line but on opposite sides of the jar?

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3. By looking at Figure 17.1, you can see that the area of the ocean closest to the Moon is pulled by the Moon's gravity, creating a "bulge" in the ocean. At the same time, on the opposite side of the Earth, the **centrifugal force** caused by the planet's rotation causes a "bulge" on the opposite side from the moon. To more clearly understand centrifugal force, remember times that you have been a passenger in a car that was driving down a straight highway. When the driver made a quick left turn, you probably felt yourself being "pushed" against the door on the right side of the car, away from the turn. This is centrifugal force acting. The strong "pull" you felt was your body continuing to move in a straight line, even though the car had turned, and gave the feeling of being pushed into the door. This same force causes high tides on the opposite side of the Earth from the Moon. Between these two high tide bulges, water is drawn towards the Earth by the planet's own gravity, causing a flattening of the water, or low tide. The Sun raises two tidal bulges on the Earth, too, for the very same reasons that the Moon does. The Sun's bulges are not as great because the Sun is at a much greater distance from Earth. As the planet rotates, it moves in and out of these tidal bulges. What, then, do you hypothesize is the relationship between the phases of the Moon and the tides?

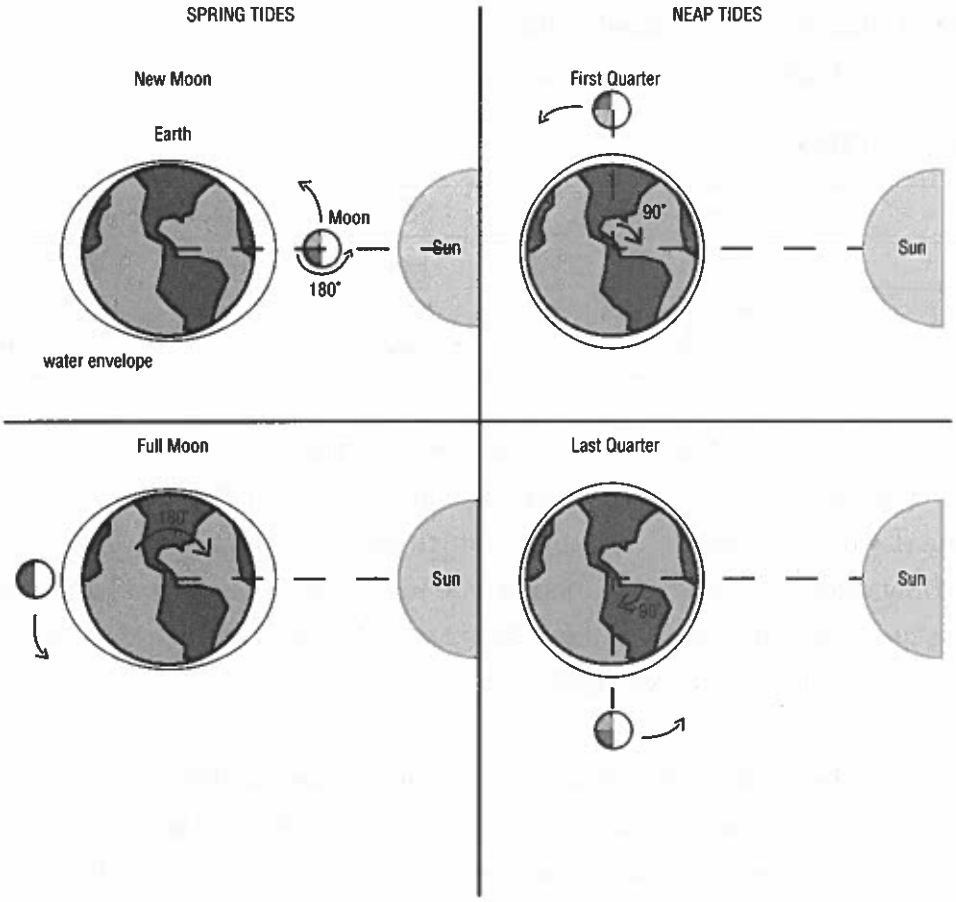


Fig. 17.1 Spring and neap tides.

4. When the Sun and Moon are aligned, their gravitational forces combine to produce the highest tides, called **spring tides**. When do you think spring tides occur?

5. What happens to tides when the Sun and Moon are at right angles to each other? Explain these **neap tides**.

6. Why do spring tides and neap tides occur twice a month, varying directly with the phases of the Moon? Explain.

7. Is it accurate to state that spring and neap tides everywhere on Earth occur at such a regular pattern that the size and time of the tides in a specific location can be predicted with precision far into the future? What is this regular pattern? Use the Internet as your primary resource in answering these questions. (HINT: You might begin by locating tide tables for different locations.)

8. Oceanographers, comparing tidal records for shorelines worldwide, discovered a pattern that is now used to classify tides. Examine Table 1.
   a. What feature is used to classify tides?
   b. How many types of tides are there?

Table 1: Types of Tides

Type	Diurnal Tides	Semidiurnal tides	Mixed tides
Period	Once a day	Twice a day	Twice a day
Pattern/ regularity	one high and low tide	two high and low tides	High and low tides of unequal shape

9. Other factors that affect tides are the shape of the shoreline and the contours of the ocean basin. Winds and atmospheric pressure also affect tides. In the Gulf of Mexico, tides vary. On some days of the month, there are two high and two low tides; other days of the month, only one; still other days, there is one high tide and two lows; and even others, there are two highs and one low tide. Based on this information and Table 1, what types of tides occur in the Gulf of Mexico?

10. The difference between high and low tide, or **tidal range**, of the Gulf of Mexico is relatively small. At most coastal stations, the tidal range is from 30 to 60 cm (1-2 feet) . However, water may move up to 20 feet or more onto shore during a high tide. Why? Explain.

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11. Which tide level do you think would be best for beach combing and shell collecting? Explain.

12. Imagine that you are going fishing just off the Texas coast. Would knowing the times of high and low tide be helpful to you in catching fish? Explain.

13. How might plants and animals in tide pools rely on tidal movements? What would happen to these organisms if there were no tides?

14. What kind of effect do you think tidal flow has on bay and estuary organisms? What effect does tidal flow have on any pollutants that have entered bays, estuaries, or lagoons?

15. Do you think that tides can provide a source of energy for humans? How could tidal energy be "harnessed"? Are any methods being currently used, and if so, where? Use the Internet as your primary resource in answering these questions.

18. Why Is the Sea Blue — or, What Happens to Light in the Ocean?

Oceanographer _____ **Team** _____



Why is the sea blue? Why is the sea sometimes green? If you hold up a glass of seawater, it appears colorless, but stand on the deck of a ship or even on the shoreline and the water appears to be colored. You will investigate what water does to light to understand the ocean's color.

Materials: 3x5 index card, clear tape, paper hole punch, diffraction grating or spectroscopes, clear acetate, clamp on light reflector, different colored light bulbs (white, red, green, blue, yellow), crayons or markers

Procedure:

Part I: What colors make up light?

1. You are going to make a diffraction grating card. (If spectroscopes are available then skip ahead to number 2.)
   a. Obtain an index card and punch a hole in the middle of it with a hole punch.
   b. Obtain two 2 cm x 2 cm pieces of clear acetate and one piece of diffraction grating.
   c. Place the diffraction grating between the two pieces of acetate. Avoid touching the surface of the diffraction grating.
   d. Place the diffraction grating square over the hole in the index card.
   e. Place strips of tape across the top and bottom edges of the diffraction grating square on the card. Be certain the tape does not cover the hole.

2. Look at a light source in the room through the spectroscope or diffraction grating card. Rotate the diffraction grating until you see colors on each side of the light source. Draw the colors you see on both sides of the light source with markers on a separate sheet of paper. Be as accurate as possible! Be sure to make the larger areas of color larger than the smaller areas. Draw the colors in the order you see them.

3. Looking at the colors that are on the right side of the light source *only*, list them in their order of appearance. Begin with the color closest to the light source.

4. The diffraction grating in the spectroscope or card is a special piece of plastic that has thousands of very fine parallel lines etched onto every inch. When light passes through the gaps between these lines, it diffracts, or spreads out, just like water waves. Since the wave-

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lengths of each color are slightly different, the bright regions of each color are slightly offset so you see each color separately. The result is the color spectrum. How many different colors did you see in your observations? Which ones? Did you observe all the colors of the spectrum?

5. If your classroom has windows, look out the window with your diffraction grating card or spectroscope. **Do not look directly at the sun!** Compare the spectrum of sunlight outside to the light inside. Does it differ? How? How is it alike?

6. Based on your observations, what colors make up visible white light?

7. Your instructor will now turn on a light source with a different colored bulb and turn off the class lights. Use your diffraction grating card or spectroscope and look to the side of the colored light bulb. What colors do you see? Construct a table based on the following example and record your observations. Repeat these steps for each light source.

Table 1: Colors Present in Various Light Sources

Light Source	Colors Observed
Sunlight	
Fluorescent Light	
Incandescent Light	
Red Light	
Green Light	
Blue Light	
Yellow Light	

8. The color(s) you see when you look at an object are the color(s) that are reflected to your eyes. When you look at an object and see it as blue, you are seeing the blue light of the spectrum reflected from the object. All other colors of the spectrum are absorbed by the object and therefore cannot be seen. Which wavelengths of light, then, do green plants reflect?

9. Which light wavelengths (colors) are absorbed by green plants and used for energy for photosynthesis?



Part II: What wavelengths of light are visible in the ocean?

1. In ocean water, sunlight can only penetrate to a limited depth before it is scattered and completely absorbed. Red light is absorbed as soon as it penetrates the water's surface, and by a depth of 30 feet, all red light is absorbed. If all the red light is gone at this depth, what would the bright red air tank on a diver look like? Explain.

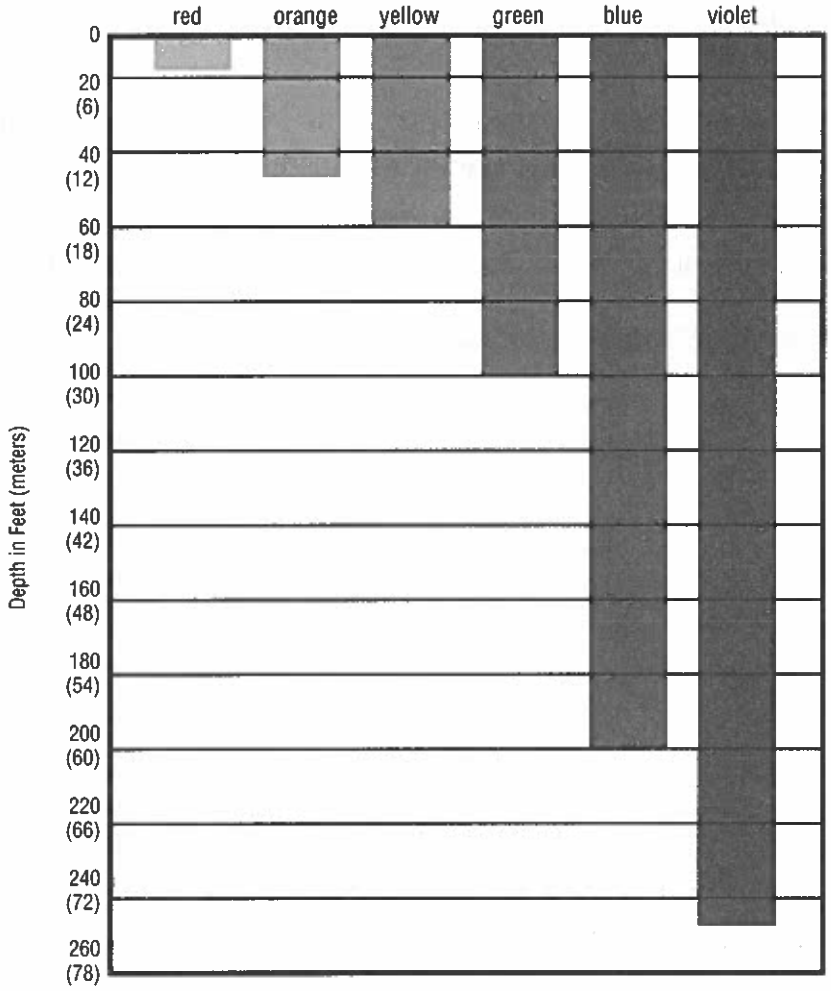


Fig. 18.1. Depth that light waves penetrate

2. Use Figure 18.1 to determine which light waves remain at different depths of water. What colors would a diver see at a depth of 55 feet?

3. A diver's yellow air tank begins to look more bluish-green than yellow at a depth of 75 feet. Use Figure 18.1 to explain why.

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4. A diver is exploring a reef more than 80 feet below the surface. What colors of marine life will the diver *not* be able to see?

5. Pictures the diver takes of this reef more than 80 feet down are developed. The photos show colors as brilliant as if they had been taken out of water. The red colors of a squirrelfish, the yellows of the soft coral, and the brilliant green alga show clearly. How this is possible? Explain your answer.

6. What colors are be visible at a depth of 100 feet?

7. In the clearest ocean water, the light intensity at a depth of about 200 feet is approximately the same as starlight reaching the Earth. Usually, not enough light penetrates beyond 1,600 ft deep to be visible to the human eye. What would a diver see at this depth without any artificial light sources? Explain.

8. Color wavelengths that have the greatest chance of penetrating seawater also have the greatest chance of being back-scattered (Figure 1). The color of the ocean comes from the color of light reflected from the surface and any light that is back-scattered from below the surface. Which colors penetrate the deepest, thereby having the greatest chance of being scattered back to give the water its color? Explain.

9. The sea isn't always blue. Some oceans appear bluish-green, or green, or brown, or even red. These colorations are partly due to the reflection of clouds. If the sky is blue, the water will appear more blue. If the sky is gray, the water will appear as a gray-blue color. Various particles that are in suspension in the water also affect the color. Water tends to look more greenish near the shore from the scattering of light from decomposing plant matter. Muddy water appears brownish because of the light reflected by the brownish suspended sediments. In some areas, blooms of a species of dinoflagellate that is red in color become so numerous that a "red tide" occurs. Why might it be called this? Explain.

Part III: What can a model tell us about light in the ocean?

1. To investigate light and color, you will create a model of light in the ocean. Place the colored light sources with the red, green, and blue light bulbs in front of the room. Turn on the colored lights and turn off the room lights. Observe several colored objects in the room. Compare the appearance of colored objects close to the light sources to those further away, even as far as the back of the room. Describe your observations.

2. To simulate the absorption of red light within the first 25 feet of water, turn off the red

light. Compare the appearance of colored objects close to the light sources and those in the back of the room. Describe your observations.

3. Turn off the red and green light to simulate light that penetrates to a depth of 120 feet. Again, compare the appearances of colored objects. Describe your observations.

4. To simulate a depth of 1000 feet, turn off all the lights. Note the appearances of the objects (if you can!). Describe your observations.

5. Compare your model of light in the ocean with what you have learned about the ocean. Are they similar? How? How do they differ? How might you improve the simulation?

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19. What Causes Sound and Is Sound Different in Water?

Marine Acoustic Engineer _____ **Team** _____

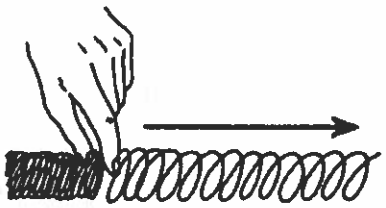
Acoustics is the scientific study of sound. Marine acoustics engineers study the sounds that are heard and transmitted in the sea. In order to study and understand the sounds that are heard, they must understand the properties of sound waves and how sound waves travel in water. You will to investigate the properties of sound waves and how they travel in water.
Materials: Slinky or other coiled spring, aquarium or large plastic container with water, ruler

Procedure:

Part I: What are the properties of sound waves?

1. Clap your hands together near your face (about 4-6 cm in front of your face).
   a. Do you hear a clap?
   b. Do you feel air striking your face?
   c. What causes the air to hit your face?

2. Use a spring as a model to demonstrate the sound wave you created when you clapped your hands. On a smooth floor or table top, have one person hold the spring at each end. Now squeeze together the first 20 cm of the spring as shown in Figure 19.1.



3. The spring represents the air molecules, and compressing air molecules is what you do when you bring your hands together to clap. Release the squeezed section of the spring and observe the resulting wave as it moves through the spring. Sketch and describe the wave you observed.

4. When you clapped your hands, you moved the molecules that form the air away from their resting position and pushed them together. The space in the air in which molecules are pushed or crowded together is called a **compression**. When you clapped your hands you gave the particles energy, and they began to vibrate back and forth. As the molecules moved to the right, they passed their resting positions and bumped into the molecules next to them on the right. These neighbor molecules became compressed. Then the first set of molecules moved to the left while the second set began to vibrate and move to the right. This leaves a space that contains fewer molecules and is less crowded, a space called a **rarefaction**. Each layer of molecules pushes the next layer as the compressions move forward through the medium. Each compression is

followed by a rarefaction. Compressions and rarefactions move in a regular, repeating way to form a wave.

5. A wave of compressions and rarefactions is called a **longitudinal wave**. Energy is transmitted as longitudinal sound waves. In Figure 19.2 below, label the compressions and rarefactions of a sound wave. Why do you think longitudinal waves are also referred to as pressure waves? Explain.

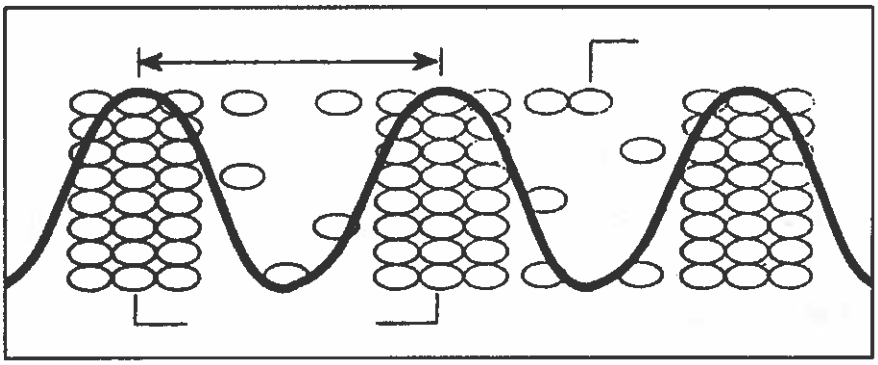


Fig. 19.2. Compressions and rarefactions of a sound wave.

6. If the molecules of a medium move back and forth over and over, a series of waves moving away from their source is created. Each complete movement, from compression to compression, is a complete cycle, and when measured is called the **wavelength**. **Frequency** is the number of compressions or rarefactions that pass a given point per second. The higher the frequency, the shorter the wavelength. How could you increase the frequency of a sound wave?

7. Drop a small stone into the center of a large plastic container of water (aquarium, large bowl, or pan)

a. What happens to the water?

b. Observe the waves. What happens to the waves as they hit the edge of the container?

8. Could the characteristics of waves that you observed in the above activity be applied to using sound waves to locate the bottom of the ocean or large objects in ocean waters?

9. Repeat the activity in number 7 and observe the waves again. The waves are caused by the energy of the stone you dropped in the water. The stone's molecules moved the water molecules, which in turn pushed the neighboring water molecules. As the molecules bump against one another, they transfer energy to all the other molecules around them,

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causing vibrations (energy) to travel in all directions. This forms waves. Notice that the waves become smaller and smaller until they disappear. What is a possible explanation for this phenomenon?

10. What happens when you tap the top edge of the container with a spoon or ruler? In which direction do the waves move?

11. What happens when you tap the side and bottom edge of the container? In what direction do the waves move then? Make a sketch to illustrate what happens.

12. Based on your observations of waves, in what direction will a sound travel if it is made underwater by a marine organism ? Make a sketch to illustrate your explanation.

Part II: Does sound differ in water?

1. Ask a partner to tap the aquarium or other large container with water in it loudly, loud enough for you to hear. Put your ear against the container and have your partner tap again. What happened? Do you observe any differences?

2. What can you hypothesize about sound traveling through air compared to water?

3. The speed of sound depends on several properties. One is the elasticity of the medium. **Elasticity** is the ability of a material to move (stretch) and then return back to its original shape. Sound traveling through materials in which the particles are strongly bound together will travel fastest because the particles return to their positions quickly..

Table 1: Speed of Sound in Different Mediums

Substance	Speed (m/sec)
Air at 0° C	331
Air at 25° C	346
Cork	500
Water at 25° C	1498
Sea water at 25° C	1531
Brick	3650
Wood (oak)	3850
Glass	4540
Aluminum	5000
Steel	5200

4. Look at Table 1. In which substance does sound travel the fastest because it has the greatest

elasticity? List any five substances from Table 1 in order of elasticity, starting with the *most* elastic substance.

5. Using the data in Table 1, draw lines on the table to separate the solids from the liquids, the liquids from the gasses. Does the phase of the medium (solid, liquid, or gas) appear to affect the speed of sound? Explain.

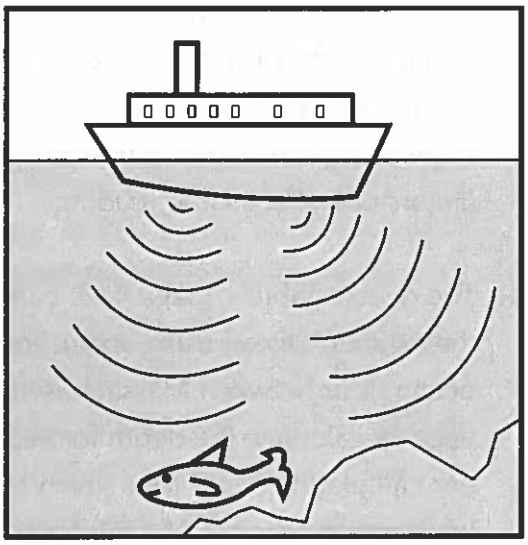
6. Another important property that determines the speed of sound is temperature. How do you think the temperature of a substance affects the speed of sound? What would happen to sound of the temperature was lowered? Use data from Table 1 to support your explanation.

7. Does sound travel faster in surface water (30° C) of the Gulf of Mexico or at the bottom (4° C)? Explain.

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20. How Can Sound Be Used to Study the Ocean?

Oceanographer _____ **Team** _____



There are many ways of using sound underwater to learn more about the oceans. The method for measuring ocean depths by dropping a line to the bottom and hauling it back up began as early as 2000 B.C. with the Egyptians, but this method has now has been replaced by echo sounding. Echo sounding was revolutionary to oceanography. It meant that the time consuming and difficult method of cable sounding (stopping the ship, lowering a cable thousands of feet to the bottom, noting how many feet were used, and then reeling it all in) could be replaced. Today, it is possible to make acoustic soundings with an accuracy of a few inches! It has been claimed that underwater acoustics is the single most useful method that scientists have to study the oceans. You are going to determine how echo sounding has produced maps of the ocean floor.

Materials: graph paper, calculator, tape

Procedure:

1. Echo sounders, or sonar (Sound Navigation And Ranging), the underwater equivalent of radar, are used to study the ocean. They employ sound waves to map the ocean bottom by accurately determining the shape and structure of the sea floor. In using sonar, three basic machines are used: a transducer, hydrophones, and a timer. Look at Figure 1. The transducer is aimed at an area on the ocean floor. It emits electrical impulses converted into sound waves towards the area being mapped. When the sound waves strike the ocean bottom, they are bounced (echoed) back to the hydrophones mounted on the ship's bottom. The hydrophones pick up the echoes and translate them onto a paper recorder or a screen. The timing device indicates the length of time that the sound took to travel from the ship to the ocean floor, and then back to the ship. In this way, the timing device indicates the distance to the ocean floor at the chosen floor location. Oceanographers use the following equation to determine depth:

$$\text{Distance (depth)} = \frac{\text{Speed of sound wave x length of time}}{2}$$

Notice that speed and time are divided by two, since the length of time is the time it takes

the wave to go from the ship to the ocean floor (one) and then back from the ocean floor to the ship (two). Do you think sonar is an accurate method to measure ocean depth! Explain.

2. The speed of sound in seawater is about 4.5 times faster than its speed in air, varying from about 1,450 to 1,550 meters per second. This variation is dependent on the temperature, salinity, and pressure of the water. Why do you think it is so important to accurately determine the speed of sound in water when making soundings? Explain how these other factors can affect sonar readings.

3. The data in Table 1 (page 438) came from soundings made by a ship that traveled across the Atlantic Ocean using sonar. You are going to use this data to plot the profile of the ocean floor between Massachusetts and Spain. Before plotting the data, however, you will need to calculate the depth for each data point. You can work as a team, with each member calculating depth for a given number of points. To determine the depth, use the following formula, using 1,500 m/s for sound wave speed per second:

$$\text{Depth} = \frac{\text{Time (s) } 1{,}500 \text{ m/s}}{2}$$

For example, from Cape Cod to the Mid-Atlantic, Section A, point 3 would be:

$$\text{Depth} = \frac{1.8 \text{ s} \times 1{,}500 \text{ m/s}}{2}$$

$$\text{Depth} = 1{,}350 \text{ meters}$$

4. After calculating all the data points, your team is going to plot the information on a sheet of graph paper. Label the (horizontal x-axis), "depth in meters," and use a scale of 200 meters for every square on the graph paper. Label the (vertical) y-axis, "distance from shore," using a scale of 100 kilometers per square. Half of your team can plot the data for Section A and the other half plot the data in Section B; these two sections can then be taped together. Why do you think it is important that each group use the same vertical and horizontal scales on their graphs? (If available, you can enter the data in a graphing calculator. You might also use a computer to construct your team's graph and then print your profile.)

5. Examine your team's graph. Do you observe any patterns? Explain.

6. Label each of the following areas on your graph:
   a. Continental shelf: an underwater land shelf reaching out from the shoreline to a depth of 200 meters or less

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b. Continental slope: an underwater land slope that plunges from 200 meters to 2,000 meters
c. Continental rise: sediments that collect at the base of the continental slope
d. Abyssal plain: the flat, deep bottom of the ocean
e. Mid-Atlantic ridge: a deep trench bordered by mountains where the ocean plates are dividing

7. Echo sounding is also used by marine geologists to identify types of rocks in the ocean floor. How might this information be used by geologists? Explain.

8. Sonar can locate entire schools of fish at depths of over 500 feet. It provides the exact depth at which the school is traveling, as well as information on the size, density, and shape of the mass . Why might this be helpful? Explain.

9. Underwater acoustics are also being used to map the ocean currents and provide detailed and accurate maps of the ocean floor. Governments and businesses are often willing to invest the large amounts of money needed to produce such maps. Why do you think this is so?

10. Echo sounding can also be used to accurately determine the position of underwater equipment, submersibles and sunken ships. How can oceanographers determine if a reading indicates a feature of the ocean floor or a submarine?

11. Marine organisms can interfere with the operation of sound ranging devices in several ways. Systems listening for the characteristic noises of ships, submarines, or other underwater activities are especially concerned with noises made by marine organisms. These sounds have often been confused with ships' engines, propellers, or other mechanical equipment. Whales occasionally give off signals that sound like a sub because their movement, color, and shape are very similar. Even an octopus dragging shells along the bottom can interfere with sound readings. What are some methods scientists might use to identify exactly what they are hearing?



12. The U.S. Navy is an organization that is probably more interested in marine acoustic research than any one else. Why would the Navy want to be able to identify the sounds it picks up or the features of the ocean floor? Explain.

Table 1: Data for Profile of Atlantic Ocean from Cape Cod, Mass. To Spain

Section A: Cape Cod to Mid-Atlantic

Point	Time for Signal return in seconds (meters/sec.)	Depth in meters	Distance from Cape Cod in kilometers
1	0		0
2	.13		120
3	1.8	1,350 m	200
4	2.4		400
5	2.9		440
6	2.9		480
7	2.4		490
8	2.9		500
9	3.1		560
10	1.1		580
11	3.1		600
12	3.1		640
13	1.2		660
14	1.2		680
15	2.4		690
16	1.8		700
17	3.1		725
18	3.2		1375
19	2.4		1390
20	3.2		1400
21	3.3		1850
22	2.4		1875
23	3.1		1890
24	2.9		2075
25	1.2		2090
26	2.9		2100
27	2.9		2210
28	2.7		2420
29	2.3		2440
30	2.7		2450
31	2.3		2850
32	2.1		2900
33	1.8		2960
34	1.2		2975
35	1.5		3060

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Table 1: Data for Profile of Atlantic Ocean from Cape Cod, Mass. To Spain

Section B: Mid-Atlantic to Spain

Point	Time for Signal return in seconds (meters/sec.)	Depth in meters	Distance from Cape Cod in kilometers
36	2.7		3075
37	2.7		3090
38	1.6		3100
39	1.2		3190
40	1.9		3200
41	2.3		3525
42	1.8		3540
43	2.3		3550
44	2.4		3625
45	1.6		3630
46	2.4		3640
47	2.7		4025
48	.6		4035
49	1.8		4050
50	1.2		4090
51	1.0		4100
52	1.5		4110
53	1.8		4190
54	2.7		4225
55	2.9		4425
56	3.1		4500
57	3.2		4750
58	3.4		4760
59	3.1		4770
60	2.7		4780
61	2.8		4825
62	2.1		5150
63	2.8		5160
64	2.9		5170
65	3.1		5390
66	2.7		5625
67	2.4		5675
68	1.8		5875
69	.13		6050
70	0		6100

21. What Is the Connection Between Ocean Depth and Force-pressure?

Scientist _____ **Team** _____

In the ocean, pressure is the force with which water pushes on an object. Pressure increases with the depth of the water. This increase has some important implications. Instruments used to study the ocean must be able to withstand the pressure changes that come with depth. One of the greatest problems facing engineers of submarines, submersibles, and undersea equipment, is to construct them strong enough to withstand such pressures. You are going to investigate the force of pressure in the sea.

Materials: 2 or 3 liter plastic bottle, ruler, tape, large pan, calculator (optional)

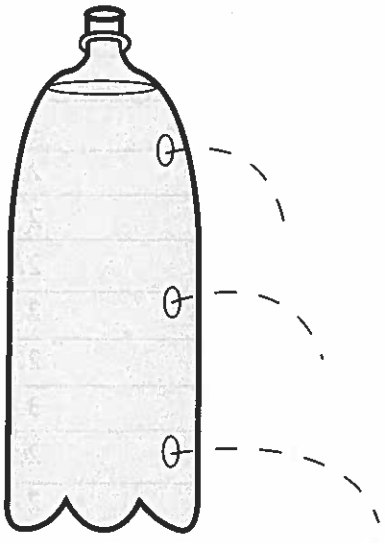
Procedure:

Part I: What is the relationship between pressure and depth?

1. Pressure is the "force" exerted by particles over a certain area. This "force" is created by the particles that make up the material. In liquids and gases, the particles are not packed together tightly. They are able to move freely and constantly in all directions. As each particle moves, it pushes against the other particles with force. This force depends on the mass and motion of particles. Draw a sketch to illustrate this concept.

2. Obtain an empty plastic 2- or 3-liter bottle. Examine the bottle. When the bottle is full of liquid, where do you think the water pressure will be greatest?

3. Tightly secure the lid on the bottle so that air cannot escape or enter. Along the same side of the bottle, punch three small holes: one near the top, one in the middle, and one near the bottom. Measure the distance from the bottom of the bottle to each hole for "depth" and record this in a table similar to the following example. Remove the cap. Put tape or your fingers over the holes while another person fills the bottle with water. Place the bottle at the edge of a sink or in a large pan. Put two rulers lengthwise and end-to-end in the basin. Open the holes one at a time by removing the tape or fingers over each one. Record the distance the pressure pushes the water out into the basin with the ruler. Repeat the activity to compare your findings. What happens to the water? Does it stream out an equal distance from each hole? Why or why not? Explain.



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Table 1: Distance (Pressure) and Depth of Water in Bottle

Hole Location	Depth (distance of hole from top of bottle)	Distance (length) of water stream Trial 1	Trial 2
Top			
Middle			
Bottom			

4. The pressure exerted by a fluid is the same throughout the fluid *only if* there are no other forces acting on the fluid. The other force acting on the water in your bottle was gravity. Gravity pulls downward on all the particles in the fluid.

5. You may have experienced the effects of pressure and depth before. Have you ever swum to the bottom of the deep end of a swimming pool? If you have, then you may remember that your ears began to ache. This happened because your ears felt the difference in pressure as the water increased with depth. What do you predict would happen if you had a taller bottle with more water in it and it had only one hole near the bottom?

6. Write a sentence summarizing the relationship of pressure and depth.

7. Water or liquid pressure is equal to the weight per unit volume times depth. To help understand this equation, imagine a pool of water that has been separated into different layers. Refer to Table 2. At the top of the water, or sea level, the water pressure is zero. However, the air pushes down with a pressure of 14.7 pounds per square inch (psi), or one atmosphere. Because gravity pulls down on the particles in the top layer, the entire layer has a certain weight. Then, the force of the first layer pushes down on the second layer. Thus, at a depth of 10 meters, the pressure doubles to 29.4 psi. The third layer, at a depth of 20 feet, has the effect of gravity on its own particles plus the weight of the first two layers. At this layer, the pressure is 44.1 psi. Pressure increases at a ratio of approximately one atmosphere (14.7 psi) for about every 10 meters of depth. Calculate the missing pressures in Table 2 using this information.

Table 2: Depth and Pressure

Depth	Air	Pressure
0 m (surface)		14.7 psi
10 m	Weight = 1	29.4 psi
20 m	Weight = 1 + 2	44.1 psi
30 m	Weight = 1+2+3	58.8 psi
40 m	Weight = 1+2+3+4	73.5 psi
50 m	Weight = 1+2+3+4+5	88.2 psi
60 m	Weight = 1+2+3+4+5+6	102.9 psi
70 m		
80 m		
90 m		
100 m		

Part II: What is the effect of pressure on submarines, submersibles, and instruments at various ocean depths?

1. At the edge of the Gulf of Mexico's continental shelf, the ocean depth is about 200 meters. What would be the pressure on each square inch of a submersible exploring the edge of the shelf?

2. The Sigsbee Deep is the deepest area of the Gulf of Mexico at 12,425 feet (3,790 m). How much pressure per square inch would a submersible designed to explore this area have to be able to withstand?

3. The deepest spot in the ocean is 36,200 feet (11,041 m). If a bathysphere is lowered to this depth, how much pressure per square inch of window surface area must the windows be designed to handle?

4. The circular window on a bathysphere has one square foot of surface area (144 square inches). What is the total force on the window at 36,200 feet (11,041 m)?

5. If the window is held in place by 10 one inch square bolts, what would be the force on each bolt?

6. What might happen to submarines, submersibles, or instruments for use in the depths of the ocean if they are unable to withstand the pressure as they go deeper into the ocean? Explain.

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22. Can You Say It with a Dance?

Choreographer _____ **Team** _____



It is not surprising that the sea, particularly its rhythmical movement, has inspired choreographers. **Threnody, Pineapple Poll, Lady from the Sea, Sea Shadow, and Water Study** are but a few of the numerous ballets which derive their imagery from the sea. Your team is going to imitate the movement of water and create a dance or dances to reflect that movement.

Materials: tape or CD player, music of student's choice (optional)

Procedure:

1. Sit quietly and think about the motion of the waves and the movement of the surf to and from the shore. Try to feel the sea with your whole body, as a dancer does.

2. As you listen to each team member share their feelings about the motion of the water, put yourself into the experience and try to feel what they are saying.

3. As a group, see if you can illustrate the different types of waves, tides and currents through dance movements. You may use ballet or any type of dance (rock, western, disco styles, modern, jazz, etc.), a combination of dances, or even invent your own.

4. For different types of water movement, think of a specific type of dance or movement. Construct a table similar to the following example to help you plan — either with drawings or descriptions. Include moves to illustrate the cause of the water movement.

5. Select one type of water movement to develop into a complete dance that includes the cause of the water movement. Prepare the dance to present to the class. You may want to integrate different types of music into your dance.

Table 1 Movement of Water in Dances

Type of Water Movement	What feelings does water show	Movement/dance used to express it	Your dance plan for the water movement
Parts of a Wave			
Waves- breaking on shore			
Hurricane-storm surge			
Tsunamis			
Ocean Currents (Gulf Stream, California, Equatorial, etc.)			
Tides			

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Topic 9 — The Interaction of the Land and the Sea

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Topic Nine: The Interaction of the Sea and the Land

The solid Earth, hydrosphere, atmosphere and biosphere are each related to produce a complex and continuously interacting whole Earth system. Earth is a planet dominated by oceans. In fact, 97.25 percent of the water by volume is found in the oceans. The water does not remain indefinitely in one state or place. It is continuously changing back and forth, from gas to liquid to solid and back. It is also shifting from one place or reservoir to another. This exchange of water is the global water cycle or hydrologic cycle that is driven by the sun's energy. The sun's heat evaporates surface water from the ocean and the land. The evaporated water enters the atmosphere and most of it returns directly to the sea as precipitation. The differential heating and heat capacity of land and water cause variations in temperature and precipitation or the weather conditions for a place or region. The Earth's climate system involves the exchanges of energy and moisture that occur among the atmosphere, hydrosphere, solid Earth and biosphere. The oceans store immense amounts of heat that is redistributed across the Earth's surface by atmospheric and oceanic circulation. The ocean atmospheric system is like a giant heat engine that exchanges the cold air and water of the high latitudes for the warm air and water of the low latitudes. In an effort to predict future climate changes, physical oceanographers are examining specifically how the ocean and atmospheric processes are connected. There are numerous questions that are critically important for dealing responsibly and realistically with future climate changes.

The Gulf of Mexico is an example of how the oceans affect our weather. Not only do ocean's affect the coastal states' weather, but most of the United States as well. The overall climate of the Gulf coastal area is subtropical with long, warm to hot summers and short, mild winters. The Gulf of Mexico also affects a large portion of the inland states. Moist air from the Gulf moves inland in the winter and causes record snowfalls in the Midwest (Kansas to Minnesota). In the spring the Gulf's warm moist air moves north, colliding with a cold air mass moving south. There may be thunderstorms with strong winds and even tornadoes where these air masses collide. This often occurs in what is called tornado alley.

The climate of each area of the Gulf coast affects the vegetation and the agricultural products of each region as well as the environment of the estuaries and bays. The climate has impacted the development of ports and cities along the Texas coast. This section will investigate this interaction of water and land including the interaction of storms such as hurricanes.

Activity 1: Which stores the most heat? The ocean or land?

TEKS: Science
6.2,6.3,6.4,7.2,7.3,7.4,8.2,8.3,8.4,8.10,6.14

Math 6.8,7.9,8.8, 6.11,7.13,8.14

Social studies
6.23,8.32,7.8,7.9,6.6,7.23,6.22,7.21,8.30

Language arts
6.9,7.9,8.9,6.10,7.10,8.10,6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

- Conduct an experiment to determine the heat capacity of air, water and soil.
- Relate heat capacity to climate of coastal and inland regions.
- Make inferences about the climate differences on Earth if the amount of water on the earth's surface differed.
- Make inferences about the relationship of water and the climate of other planets and moons in the solar system.

Background:

1. Ask the students if when they have visited the beach, how much the ocean temperatures differ from day to night? Compare this to the land temperatures.
2. Explain that heat is the property that one measures with a thermometer and that results from the physical vibrations of atoms and molecules. The physical vibrations represent energy of motion, kinetic energy. The more heat in a material, the greater the motion of its atoms and molecules. An ice cube appears to be inert, but on an atomic level, the water molecules are vibrating back and forth even though they are locked together in a crystalline framework. If heat is added to the ice, the molecules vibrate faster and move further apart until they break the bonds holding them in place in the crystal. At that temperature, the crystal structure breaks down or melts and the solid ice becomes liquid. The liquid is a loose group of molecules that are in contact, but are free to move. As more heat is added to the liquid water, the temperature rises as the molecules vibrate more energetically. Some molecules contain so much kinetic energy that they escape from the liquid surface and become a gas or evaporate.
3. To create a model to represent this. Mark off a

section of the classroom to represent a container. Ask students to step into one area on the bottom of the marked section (container) and hold hands and move close together (packed together). They are to move in place as they represent the molecules in ice. The teacher can clap slowly to indicate the rate of movement of the molecules (students). Slowly increase the clapping rhythm to represent more heat being added to the ice. The students are to move to the clapping rhythm. Stress that as they move they will bump into other molecules. When they bump into another molecule or wall of the container, they are to move (bounce off) in the opposite direction until they bump into another molecule or container wall. They will bounce or move off in another direction. Some students (molecules) will move enough so that they will need to quit holding the hands to another student to continue moving. At this point there is enough energy of motion that the ice melts. Clap rapidly to indicate the addition of more heat and even more rapid movement. At this point some molecules will break all their bonds and move out of the container. This represents molecules escaping from the liquid surface and becoming a gas. Remind the students that they are molecules and they will not bump or push other molecules with a large force. Discuss the relation of their role-play and kinetic energy being added to ice and water molecules.

4. Explain that heat capacity is the quantity of heat required to raise the temperature of 1 gram of a substance by 1° C and that they are going to conduct an investigation to determine if the heat capacity of different substances is the same or not. Each group may test each substance or each group may test only one substance (distilled water, seawater, soil or sand and air) and their findings will be compiled as part of the class investigation. Stress that they must remove the flask from the heat immediately after recording the temperature.
5. Discuss the results and the implications of water having an unusually high heat capacity. In other words, adding the same amount of heat will raise the temperature of a substance with low heat capacity, air, soil or sand, to a greater degree than water that has a high heat capacity. Have the students discuss the impact of the Earth's oceans covering almost 75% of the Earth's surface instead of a smaller area.
6. Discuss how the differences in the heat capacity of the water and land affect the climate of the adjacent land areas.
7. Encourage the students to gather data from the Internet on the day-night temperatures of inland and coastal areas on the same latitude to determine if this data supports their findings about the heat capacity.

Activity 2: What is the connection between currents and coastal temperatures?

TEKS: science 6.2,6.3,6.4,7.2,7.3,7.4,8.2,8.3,8.4,8.10,6.14,8.5

Math 6.8,7.9,8.8,6.11,7.13,8.14

Social Studies 6.23,8.32,6.3,8.10,6.22,8.30

Language Arts 6.10,7.10,8.10,6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

- Devise an explanation to explain the differences in climates of areas in the same latitudes.
- Explain the effect of oceans on the climate of coastal regions.
- Conduct an investigation to determine the air temperature above warm and cold ocean currents.
- Summarize the role of ocean currents on the climate of coastal regions.

Background:

1. Provide the weather data from the newspaper or Internet and have students compare the temperatures of the east and west coast areas in the same latitude. Or use the data to introduce the students to the problem of the temperatures of cities or countries in the same latitude that differ greatly.
2. In place of having the students complete Part I, it could be used to guide the class discussion of hypothesizing explanations and then using the figure of the ocean currents to evaluate their hypotheses.
3. The students should conclude that the surface flow of the ocean circulation impacts the climate. For example, the Gulf Stream in the North Atlantic moves warm water from the tropics to cooler latitudes where it heats the atmosphere. This results in a mild climate in Norway and Sweden even though they are located in the same latitude as Greenland. Cities of the West coast of the United States are cooler than those in the same latitude on the East coast. The cold water from the north Pacific moves from the Arctic to the tropics cooling the air. Along the East coast, the Gulf Stream moves warm water from the tropics, warming the air.
4. Have the students use figure of the ocean currents to predict the climates of other areas. Once they have made their predictions, they can use the weather page of newspapers, world almanac or the Internet to check their predictions.

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5. In Part II, the students will conduct an investigation using a model to determine if the temperature of the ocean water affects the air temperature. To help the students develop their skill in planning and conducting experimental investigations, ask each group of students to plan and conduct an investigation. Use Part II to guide the students in their planning or have the students compare their investigation to Part II. Discuss the use of their experimental results to explain why areas in the same latitude have different climates.

Activity 3: Why do coastal regions have more moderate climates?

TEKS: Science: 6.2,7.2,8.2,6.3,7.3,8.3,6.4,7.4,8.4,8.5,6.6,8.10,8.12

Math: 6.3,7.2,8.2,6.8,7.9,8.8

Social Studies: 6.3,7.8,8.10,6.6,7.9

Language Arts: 6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

- Formulate a hypothesis to explain the climate of inland and coastal areas.
- Construct a model to investigate the cooling and warming rates of land and water.

Background:

1. Ask the students when do they go to the beach? Do they only go to beach during certain times of the year? If so, explain. Discuss the weather at the beach near the water and inland during the summer.
2. Point out that beginning as early as the classical Greeks and Romans, people would spend time on the beaches. Climate and urban crowding drove both the masses and the wealthy in seasonal migrations to the beach. They even built beach resorts and homes just as people do today. Even in the 1600's in colonial times along our eastern coast, the wealthy had houses along the bays and seashore for their families to spend time. This was true along the Texas coast as families had homes or would visit the beach or coast in Galveston, Port Aransas, Indianola and other coastal towns during the summer. Ask the students to develop an explanation for this migration during the summer to the coast.
3. To help the students plan and implement experimental investigations, ask each group to construct a model of the ocean and land to investigate the cooling rates. Use the questions as a guide to planing their investigation.
4. Have each group share their experiment and findings and evaluate the investigations in terms of does it explain the differences in coastal and inland climates and how could they improve upon their investigation.

Activity 4: How does the Gulf of Mexico influence the coastal area?

TEKS: Science: 6.5,7.5,6.6,8.10,6.14,8.12

Math: 6.3,7.2,8.2,6.4,7.3,8.5,6.10,7.10,6.8,7.9,8.8,6.11,7.13,8.14

Social Studies: 6.3,7.8,8.10,6.6,7.9

Language Arts: 6.10,7.10,8.10,6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

- Make inferences about the climate in the coastal counties.
- Analyze data to determine the factors affecting the coastal weather and climate.

Background:

1. Ask the students if they have visited more than one region of the Texas coast. If they have, ask them to share what differences have they noticed. If possible obtain pictures of each of the coastal regions for the students to observe and compare
2. Provide the students with Figure 1 and Table 1, to analyze to determine the pattern of rainfall, temperature and the growing season along of the coastal counties. Note that the annual rainfall decreases from east to west in the coastal counties. The temperature increases slightly from east to west and the western counties are further south and closer to the equator. The frost-free days increase from east to west. .
3. Ask the students to analyze Figure 2 to develop an explanation for the weather patterns of the counties. Guide the students to note that prevailing winds from the Gulf affect the mean temperatures and precipitation. The wind brings warm moist air from the Gulf and as it passes over the land, the air warms and rises. The water vapor collects and forms clouds bringing moisture and rain inland. Note that due to the Coriolis effect. The Coriolis effect is the apparent force that results from the Earth's spin on its axis. The wind is deflected to the right of its direction of motion so in the latitude of the Texas coastal zone the wind is deflected from west to east. This moves the moisture moving inland from the Gulf toward the eastern portion of the Gulf coastal zone. This results in four distinctively different regions along the coast.
4. Encourage each team to use the Texas Almanac to determine the plants and animals in each region.

5. Ask the students to analyze figure 3 and note differences in the upper and lower coastal regions. The amount of water discharged from the rivers is greatest in the eastern region due to the increased rainfall. The bays, which were formed in submerged rivers valleys, are also larger in the eastern region. Discuss the generalization that more rainfall in a region results in more fresh water entering the bays and estuaries and eventually the Gulf. Therefore the salinity of the bays and estuaries of the eastern coast will have less salinity than those in the western region. This in turn, affects the kinds and types of plants and animals found in a region.
6. Ask each team to present their summarization of the patterns and interaction of the Gulf and inland area of the coastal zone.

Activity 5: How does the Gulf of Mexico influence the Texas climate?

TEKS: Science: 6.5,7.5,6.6,8.10,6.14,8.

Math:
6.3,7.2,8.2,6.4,7.3,8.5,6.10,7.10,6.8,7.9,8.8,6.11,7.13,8.14

Social Studies: 6.3,7.8,8.10,6.6,7.9

Language Arts:
6.10,7.10,8.10,6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

- Analyze data to determine the climate patterns of coastal and inland counties.
- Analyze data to develop a generalization about the relationship of rainfall, temperature, growing season and the distance from the Gulf.
- Explain the effect of the Gulf on Texas weather.

Background:

1. Have each group of students identify the areas of the Texas that they have visited and describe the climate and vegetation in the areas. Ask them to summarize what they know about Texas weather and weather in different regions of the state based on their personal experience.
2. Have each group graph the rainfall, mean temperatures, temperature ranges and growing season. Each student within the group may select one item to graph and then the group can analyze the graphs. They should note the following general patterns: Coastal counties receive more rainfall; have a higher mean January temperature; smaller temperature range and a longer growing season.
3. In Part II, have each group prepare graphs of the data. They should note that the greater distance a county is from the Gulf, the less rainfall, the lower mean January temperature, higher mean July temperature, greater range of temperatures and the shorter the growing season.
4. In preparing graphs of the relationship of distance from the Gulf and the rainfall, mean temperatures and temperature range and the growing season, note that there is not a consistent pattern for the rainfall and distance from the Gulf when the longitude remains the same. The same is true for the mean July temperature. However, the factors indicate a relationship with the distance from the Gulf. The mean January temperature decreases, the range of temperatures increases and growing season decreases the further north away from the coast and further from the warmer, moderating water of the Gulf.
5. As the group, graphs of the distance from the Gulf in a northwest direction and these factors, they should note that the rainfall decreases, mean January temperature decreases, range of temperature increases and the growing season decreases. The reason for the difference between distance from the Gulf and inland areas north, northwest and west of the Gulf is due to the Coriolis effect and the movement of the wind in a west to east direction carrying moisture from the Gulf toward the east instead of west. In all directions, the greater the distance from the Gulf the lower the mean January temperature, the greater the temperature range and the shorter the growing season. These factors affect the vegetation and plants in each region.
6. Encourage the students to conduct additional research about the patterns of climate of other regions and distance from large bodies of water. Do other bodies of water influence the water of the surrounding land areas? For example, the Great Lakes, or does the distance away from the Pacific or Atlantic Ocean affect land areas in the United States. Have the students use a map of the United States to determine from what sites that they will use rainfall, temperature and growing season data to determine if distance from water is related to the climate. The direction of the prevailing winds will have an impact.

Activity 6: What is the relation between climate and agriculture in the Gulf coast?

TEKS: Science 8.10,6.14,8.5, 6.12,7.11

Math 6.8,7.9,8.8,6.11,7.13,8.14

Social Studies 6.23,8.32,6.3,8.10,6.22,8.30

Language Arts
6.10,7.10,8.10,6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

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- Analyze data to determine the relationship of rainfall, temperature, growing season and the agricultural products.
- Interpret data concerning the relationship of agricultural products and climate.

Background:

1. Ask each group to discuss the relationship between climate, agriculture, economy and the Texas coastal zone. At the end of their discussion, they are to formulate hypotheses about the possible relationships.
2. Ask them to use the data in Table 1, to evaluate their hypotheses and edit or add additional hypotheses.
3. At this point the students may need to research the different crops to determine their optimum growing conditions. Assign each pair of students a product (timber, rice, soybeans, grain sorghum, cotton, corn, sugar cane, vegetables, beef cattle, hogs, goats, horses, game animals) to determine its requirements. Timber (wood producing trees) requires regular rainfall. Rice is grown in flooded fields so abundant rainfall is very beneficial. Grain sorghums are grasses that require warm weather and their water requirement is less than other plants. Cotton does not require large amounts of water and does well in hot, dry weather. Vegetables and citrus grow best in warm climates where it does not freeze. There are many different breeds of cattle. Those that do well in the eastern coastal zone require more lush grasses while those that do best in the western counties are better adapted for the heat and drier climate. The Santa Gertrudis cattle were developed for the hot dry climate of Kenedy County. They were able to survive and grow in this climate and use the native grasses. The beef cattle brands that grow very well on the lush grasses of the eastern coastal zone could not survive very well on the grasses and climate of Kenedy County. Deer do not require grasses but are adapted to the shrubs and grasses of South Texas so deer hunting is a major factor in the economy in these areas.
4. Based on what they have learned about the product, have the students use Table 1 and Figure 1 to predict which counties would be the best for the product's growth. Use Table 2 to evaluate their predictions and report to the class on their product.
5. This information should enable the students to explain the relationship of the climate of a county and the agricultural products that are produced. Ask them to summarize the relationship between a plant or animal's climatic adaptation and the agricultural products of the coastal counties.
6. Select an area of the coast and discuss the impact of a tropical storm or hurricane on the agricultural products and its impact on the economy of the area and the state.

Activity 7: Is there a connection between climate and the Gulf ports?

TEKS: Social Studies

6.6,6.9,6.23,7.23,8.32,6.3,7.8,8.10,6.22,7.21,8.30,6.7,7.7,6.20,7.20,8.29

Language Arts

6.13,7.13,8.13,6.20,7.20,8.20,6.24,7.24,8.24

Learner outcomes: After completing the activities, the students will be able to:

- Explain the role of ports and their location.
- Summarize the relationship between the Gulf, climate, ports, agricultural products, industry and population growth.

Background:

1. Discuss the role of a port and their importance to the economy or ask the student's to discuss the impact if a port is closed. Note that most of the ports are located on bays or inland and not directly on the Gulf. This protects the ships and shipping lanes from the full impact of weather and storms.
2. Have each group develop a hypothesis describing the relationship between the Gulf, climate, and the ports.
3. Have the students use the Texas Highway map, **Texas Almanac**, to complete the table. Using this information and data from the lesson "What is the relationship between climate and agriculture in the Gulf coast?" to support or revise their hypothesis.
4. Note that the agricultural products shipped from each port vary. The climate determines the local agricultural products that are shipped. Agricultural products like wheat and corn from the Great Plains states are brought by rail and shipped out. The ports are also developed due to the petrochemical industry. As the ports develop, other industries and services develop around the port. This leads to an increase in the population of the area. Note each port ships a variety of products. The size of the port is related to the population of the area.
5. Have the students locate Baffin Bay on the map; note its size in relation to other bays. Point out that there is no port located on this large bay. Ask the students to formulate a hypothesis to explain the lack of a port and use data to support it.

Remind the students that the depth of a bay is not a problem since all ports have been dredged to create shipping channels for ocean going vessels. Due to the climate, the region around Baffin Bay produces primarily cattle and no other products that are exported. Although oil and gas is produced, it is transported by pipelines. These can easily be transported to nearby Corpus Christi so a port did not develop on Baffin Bay. Ask the students what might have happened if the climate around Baffin Bay had greater rainfall and rice and other products were produced in the area?

6. Summarize the relationship of the climate is determined by the interaction with the Gulf. The climate determines the plants and animals that grow best in the region, which determines the agricultural products that are shipped from the region.

Activity 8: What is the effect of greenhouse gases on climate?

TEKS: Science:
6.2,7.2,8.2,6.3,7.3,8.3,6.4,7.4,8.4,6.5,7.7,8.9,6.14,8.12,8.14

Math: 6.4,7.3,8.5,

Social Studies: 6.22,8.30,6.23,8.32,6.20,8.29

Language Arts:
6.10,7.10,8.10,6.11,7.11,8.11,6.13,7.13,8.13,6.20,7.20,8.20

Learner outcomes: After completing the activities, the students will be able to:

- Conduct an investigation to determine the effect of greenhouse gases on air temperature.
- Predict the impact of greenhouse gases on the earth's temperature.
- Analyze data on global temperature patterns and greenhouse gases.
- Predict the graphs of global temperature and concentrations of greenhouse gases in the future.

Background:

1. Ask the students to list what they know about the greenhouse effect, global warming and greenhouse gases.
2. Explain that the energy from the sun drives the earth's weather and climate and heats the earth's surface. Solar energy passes through the clear atmosphere. Most of the radiation is absorbed by the earth's surface and warms it. Some solar radiation is reflected by the earth and the atmosphere. Some of the radiation passes back through the atmosphere into space. Some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the earth's surface and lower atmosphere. The greenhouse gases have an impact similar to that of the glass in a greenhouse or car. The earth's climate is predicted to change because human activities are changing the chemical composition of the atmosphere through the buildup of greenhouse gases.
3. Each group is going to conduct an investigation so see what happens to the air (atmosphere) if greenhouse gases are added. Temperature probes may be used in place of thermometers. Have the students predict which bottle they think will get hotter, and by how much, when the light is turned on.
4. Have each group conduct the investigation and graph their data. After each group has presented their experimental results, ask the class to summarize the patterns they see when they compare the bottles. In most cases, students will observe that in each bottle the temperature increased, and then leveled off. The open bottle was cooler than the closed bottle. The bottle with the carbon dioxide was warmer than the bottle with air.
5. Use the questions in the activity to guide student discussion. The temperature of the bottles increased because both light and heat from the bulb passed through the plastic and warmed the air and soil in the bottle. The temperature in all the bottles leveled off. Heat from the bulb can get in the bottle and leave the bottle. The point at which the temperature of the bottles leveled off is the equilibrium temperature which means the amount of energy flowing out is equal to that flowing in. The temperature of the open bottle levels off at a lower temperature since the warm air in the bottle mixes with the cooler air outside which cannot occur in the closed bottle. The phenomenon of heat being trapped is called the greenhouse effect. It is called this because greenhouse buildings made of glass, trap warm air the same way.
6. Ask students to relate their model to the real world. The bulb is like the sun, the air represents the atmosphere, the soil is like the earth and the carbon dioxide is a greenhouse gas. This was different from the real thing since the Earth's atmosphere does not have a solid barrier like the plastic.
7. Ask the students what can they conclude about something trapping heat in the earth's atmosphere and the cause of the greenhouse effect in the atmosphere. What are their predictions about the impact of increasing greenhouse gases on the earth's average temperature?
8. For additional information, visit the Environmental Protection Agency (EPA) web site (http://www.epa.gov/globalwarming).
9. Use the questions in Part II to guide the students'

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analysis of the data. The global mean surface temperatures have increased 0.6-1.2°F since the late 19th century. Note that the 20th century's 10 warmest years all occurred in the last 15 years. Ask the students to summarize their conclusions about global temperature, greenhouse gases and global warming. Will the concentration of greenhouse gases remain constant or accelerate. Scientists expect the average global temperature could rise 1.6-6.3°F by 2100 with regional variations.

10. Ask each group to predict the impact of global warming on the sea level.
11. To further investigate the impact of global warming; divide the class into teams or pairs to investigate the impact of global warming using the Internet. The web site: http://www.epa.gov/globalwarming under impacts will provide information on the impact on health, water resources, polar regions, mountains, forests, rangelands, deserts, non-tidal wetlands, coastal zones, agriculture, fisheries, birds and national parks. Each pair of students could be responsible for searching and reporting on one area of impact to the class. Note that the specific projected impact on each state is also included in the web site.

Activity 9: What is the effect of global warming on the sea level of the Gulf of Mexico?

TEKS: Science
6.2,6.3,6.4,7.2,7.3,7.4,8.2,8.3,8.4,8.10,6.14,8.14,8.12,7.14

Math 6.8,7.9,8.8, 6.11,7.13,8.146.10,7.11

Social Studies
6.23,7.23,8.32,6.3,7.8,8.10,6.6,7.9,6.22,7.21,8.30

Language Arts
6.9,7.9,8.9,6.13,7.13,8.13,6.20,7.20,8.20,6.24,7.24.8.24

Learner outcomes: After completing the activities, the students will be able to:

- Conduct an investigation to determine the effect of melting of the earth's ice on sea level.
- Conduct an investigation to determine the impact of an increase in temperature on sea level.
- Explain the role of thermal expansion in sea-level rise.
- Analyze data and explain the impact of sea level rising on the coastal zone.

Background

1. Ask the students to predict the impact of the ice in each aquarium melting on the water level and the impact of an increase in temperature on sea level. Divide the class into groups with some conducting the investigation in Part I and the others, Part II.
2. Sea level is rising, and the impact for future rise has probably caused more concern than any other aspect of the greenhouse effect. Many factors can affect sea level. The Earth's tectonic plates shift and subside. The continents are still "rebounding" from the last ice age. Some forces tend to lower sea level and others cause it to rise. The greenhouse effect may increase sea level because warmer temperatures could lead to some melting of the three bodies of ice that rest on land: glaciers and small ice caps around the world, the Greenland ice cap and Antarctica. The North Pole ice floats on ocean water so any melting there would not affect sea level. Just as melting ice cubes in water does not raise the level of a cold drink in a glass. In addition, because water expands as it warms, a global temperature increase could also contribute to a sea level rise. Over the past century, sea level is estimated to have risen 4 to 8 inches (10-20 centimeters). Questions remain as to how much the sea level will continue to rise.
3. Analyze the map of the Texas coast that indicates the areas that would be subjected to flooding with a rise in sea level. Use the Internet to conduct more research into the impact of the rise. Have each group communicate what they have learned by preparing a brochure or poster to inform others about the impact of a rise in sea level.

Activity 10: What causes hurricanes to form?

TEKS: Science 6.6,6.14, 8.10, 8.12

Mathematics: 6.3, 7.2, 8.2

Social Studies: 6.3, 6.6, 8.10

Language Arts: 6.6, 6.9, 6.10, 6.11, 6.13, 6.20, 6.24, 7.6, 7.9, 7.10, 7.11, 7.13, 7.20, 7.24, 8.9, 8.10, 8.11, 8.13, 8.24

Learner outcomes: After completing the activities, the students will be able to:

- Use a globe or map to locate the areas that hurricanes develop in and their pattern of movement.
- Use a diagram to explain the factors needed for a hurricane to form and the stages in its development.
- Compare the life cycle of a hurricane to the life cycle of humans.

Background

1. Hurricanes are the Earth's most awesome storms. A large hurricane stirs up more than a million

cubic miles of atmosphere every second. They stir up the ocean water hundreds of feet below the surface and created underwater waves that disturbed the ocean hundreds of feet down. They can form waves of 50 feet or higher in the open ocean. When the hurricane hits land, it brings a mound of water that can be more than 20 feet high and flood 100 miles of coast with 10 feet of water. A typical hurricane produces 6 to 12 inches of rain when it comes ashore. Some bring much more and have caused some of the nation's worst floods. Even tropical depressions and lows from the Gulf can produce heavy rainfalls. These may occur in the coastal area or miles inland in central Texas or in the central part of the United States. Hurricanes that reach the United States can form off the western coast of Africa near the Cape Verde Islands, or in the Gulf of Mexico or in the Caribbean Sea. Their formation over water means that there are not scientists in this area to study their formation. The major hurricanes form off the coast of Africa and spend a week crossing the Atlantic and developing into monster storms. With satellites, more is being learned about their formation each year. Warm, moist air is critical for hurricanes. The airflow must enable the warm air to rush toward the center and then upward. Without these factors, hurricanes will not form. If formed, they will break down if the conditions no longer exist. So hurricanes do not form if the water is not warm and the airflow is not right. They will disintegrate over land since warm, moist air is no longer available.

The clockwise winds around the area of high pressure that dominates the Atlantic Ocean—the Bermuda High—establishes the steering current for many hurricanes. A large Bermuda High guides hurricanes into the East Coast of the United States while if the Bermuda High is small; they curve away from the East Coast.

2. Have each group of students analyze the information provided and to demonstrate their understanding by preparing a presentation explaining the formation of hurricanes to inform the public. This might be preparing a videotape or PowerPoint presentation or a brochure.

Activity 11: What is the impact of a hurricane on the coastal zone?

Activity 12: What is the impact a hurricane's storm surge and wind?

Activity 13: What is the impact rain and floods from a hurricane?

TEKS: Science: 6.14, 8.6, 8.10, 8.14

Mathematics: 6.3, 6.11, 7.2, 7.13, 8.14

Social Studies: 6.1, 6.3, 6.6, 6.23, 7.7, 7.8, 7.9, 7.23, 8.10, 8.14, 8.32

Language Arts: 6.6,6.7, 6.10, 6.13, 6.20, 7.6, 7.10, 7.13, 7.20, 8.10, 8.13, 8.20:

Learner outcomes: After completing the activities, the students will be able to:

- Use a map legend and determine the area of impact of various size hurricanes on different regions of the Texas coast.
- Analyze the impact of storm surges on different areas of the Gulf coast.
- Calculate the force of water of different heights of storm surges.
- Summarize the impact of storm surge on people, homes, buildings, roads, crops, livestock and wildlife.
- Calculate the area of impact of hurricane winds.
- Calculate force of hurricane winds.
- Summarize the impact of hurricane winds on the coastal zone.
- Analyze the impact of rain and flooding from hurricanes.
- Interpret data using the Saffir-Simpson Hurricane scale.
- Predict the impact of hurricanes in different areas of the coastal zone.
- Summarize the impact of impact of rain and flooding on the economy, agriculture, transportation, businesses, homes, transportation, animals and wildlife of the area.
- Analyze the impact of population growth on the impact of hurricanes.

Background

1. Use the Jigsaw Cooperative Learning Method for activities 11-13. Divide the class into teams of four. Each student on the team becomes "an expert" on one aspect of the impact of a hurricane by working with members from other teams assigned the corresponding expert topic. The students designated as Expert A from each team will meet together and complete Activity 11. Expert B's will complete Activity 12, Part I; Expert C's will complete Activity 12, Part II; and Expert D's will complete Activity 13. After completing their activity, they will plan how they will share the information with their team members. Upon returning to their teams, each "expert" in turn teaches the group and all students will be assessed on all topics. Or assign each team an activity to complete and prepare a presentation to teach it to the class.

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2. Stress that each hurricane is different and becomes notorious in its own way. There is no pattern to how and where they will reach landfall. Some storms form many tornadoes, others generate incredible wind speeds; others have huge storm surges, and others may produce tremendous amounts of rain in the coastal zone or even hundreds of miles inland. The energy of hurricanes is unbelievable. In 24 hours an average hurricane releases the energy equivalent to 400 twenty-ton megaton hydrogen bombs. Although forecasting the day-to-day situations of a hurricane has improved but there is still a very long way to go in forecasting its path. Also hurricanes involve many factors such as wind, rain, storm surge, flooding or tornadoes and may impact hundreds to thousands of miles, while most other storms have only one or two factors and usually don't damage as large an area.
3. Point out that researchers are using high-resolution data about the contours of the Gulf of Mexico floor and the contours of land to develop a model to predict how storm surge will act when it comes ashore. This model when complete could will give emergency management personnel the ability to tell more quickly how a storm will affect the coast, giving more time to evacuate people. There are areas today that were not affected by storms in the past that are affected now. The newly affected areas are the result of human changes to the topography due to development. Some of the land has lost elevation due to subsidence. In Houston, the Texas Medical Center has subsided approximately two feet in the past 25 years. Causes for the subsidence goes back to the 1950's and 60's when the first skyscrapers were built. Removal of oil and natural gas along with the pumping of water for home and industrial use are factors, which continue today. Building roads and highways lower than the surrounding area creates a natural area for flooding. The flooding is not always in the coastal zone. Tropical depressions and storms may move inland producing over 10 to 40 inches of rain. If the school is located inland, have the students analyze their community to determine the impact of 10 inches of rain or up to 30 inches of rain. The Local Emergency Preparedness office can provide additional information.
4. The following resources will be useful: **Hurricane!** (TAMU-SG-00-503) and the following issues of **Texas Shores, Hurricanes,** Volume 24,Number 2, *In the Flash of a Flood* and Volume 27, Number 1 and *Troubling Waters,* Volume 34, Number 3. In the coastal zone, the local Emergency Management office will have additional information. An Internet search can provide information on each hurricane that reached the coast of the United States.

Activity 14: What affects a hurricane's impact?

TEKS: Science: 6.2, 6.3, 6.4, 6.6, 6.14, 7.2, 7.3, 7.4, 8.2, 8.3, 8.4, 8.10

Mathematics: 6.3, 6.8, 6.11, 7.2, 7.8, 7.13, 8.2, 8.8, 8.14

Social Studies: 6.2, 6.6, 6.23, 7.8, 7.9, 7.23, 8.10, 8.32

Language Arts: 6.13, 6.20, 7.13, 7.20, 8.13, 8.20

Learner outcomes: After completing the activities, the students will be able to:

- Predict the impact of a hurricane on various coastal features.
- Analyze the effect of coastal environment as a hurricane approaches the coast.
- Analyze the impact of a hurricane as it moves inland.
- Summarize the impact of a hurricane on natural features and human-made structures.
- Construct a model of the coast to determine the impact of the hurricanes by experimentation.

Background

1. Have the students locate the coastal features on a Texas highway map and predict the impact of a hurricane on the features.
2. Have each group work together to analyze each of the figures in the general hurricane model and use the questions as a guide for their analysis. As the storm approaches the tides increase and wind velocities increase. Storm tides are higher in narrow funnel-like bays than along the straight barrier islands. The surge deposits sand and shell berms on the beaches. It pushes shelf sand onto the shore face and erodes the fore-island dunes. It may cause breaks in the barrier island through storm or wash over channels. During a hurricane, a barrier island lives up to its name. The island is completely exposed to the full fury of the storm. The storm surge generates huge waves that result in giant breakers that slam into the island and shoreline at nearly 50 miles an hour with uncounted tons of water.
3. As the storm passes over the shoreline, the counterclockwise winds generate currents in the bays. On the left side of the eye, water and sediments are flushed out from the bays through the tidal passes and storm channels. On the right side of the eye, water is pushed into the bay and bay shorelines are eroded. As the eye of the storm moves inland, the currents switch direction along

with low pressure and a violent shift in wind direction.

4. As the storm moves inland, it weakens and diffuses. Tornadoes can develop. Water that stacked up in the bays during the storm approach now drains gulf ward through passes and storm channels. Heavy rains that occur inland cause flooding along streams and the poorly drained coastal prairie. The bay and Gulf circulation closes the storm passes in the barrier islands and waves begin to erode the storm berms.
5. Have the students review their predictions to determine if they were correct. Have them summarize the hurricane model. Discuss the impact of a hurricane on people, buildings, homes, plants and animals.
6. Hurricanes vary in intensity and size, however, several factors affect how severe the impact is. These are: (1) the slope of the floor of the continental shelf; (2) the tide at the time of hurricane's approach; (3) the shape and orientation of the barrier islands, passes, and bay areas; (4) the amount of vegetative cover in the area of impact; and (5) the angle at which the storm strikes the coastline. These determine how much of the storm-tidal surge will be dissipated upon striking land and how much energy will remain to do damage. Encourage each team to design and test a model of the coast to demonstrate the effect of the various factors or one of the five factors on the impact of a hurricane.

Activity 15: What is the history of hurricanes along the Texas coast?

TEKS: Science: 6.14, 7.14, 8.10, 8.14

Mathematics: 6.3, 7.2, 8.2

Social Studies: 6.1, 6.3, 6.6, 6.7, 7.0, 7.7, 7.8, 7.9, 8.10, 8.12

Language Arts: 6.11, 6.13, 6.20, 7.11, 7.13, 7.20, 8.11, 8.13, 8.20

Learner outcomes: After completing the activities, the students will be able to:

- Analyze the historical impact of hurricanes on the Texas coast.
- Use a map to analyze the area impacted by hurricanes in the past and recently.
- Summarize the historical, economic, social, and other changes that hurricanes may cause.

Background

1. Hurricanes, tropical storms, and depressions have affected people since before Columbus first explored the Americas. Storms sunk some of his ships, as well as, those of other early explorers and traders. There were numerous ports along the Texas coast and up the rivers in the 1800's. Have the students use a Texas highway map to locate Indianola and Galveston, use the questions to guide the discussion of why Indianola was referred to as "the mother of western Texas" and the impact of hurricanes on the history of Texas and especially its ports in the past.
2. Use the Texas Highway map and the figures to analyze the impact of recent hurricanes on the Texas coast. Encourage the students to locate additional information on the different hurricanes using National Weather Service Web site or the NOAA web site at www.noaa.gov and use the library to locate books on the history of Indianola, Aransas, Galveston, Houston, Matagorda Island and Corpus Christi. Another research project is to use archival data to trace the path of different hurricanes and their landfall and destruction.
3. Have each team become the news team for a coastal television or newspaper. Use visual and / or audio information from other sources to create a report that will improve community preparedness efforts and personal responses to potential hurricane danger. Include ways in which hurricanes have caused changes in history, economics, agriculture, transportation and society to remind the public of the destruction and loss that hurricanes cause.
4. If your school is located in the Texas coastal zone use a Hurricane Safety Checklist to conduct a survey of the hurricane awareness of you, your family and your community. Each student should develop his or her own hurricane preparedness plans including a checklist.

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1. Which Stores the Most Heat: the Ocean or Land?

Oceanographer _____ **Team** _____

Water covers about 75 percent of the Earth's surface. Its ability to store heat strongly affects the climate and life on Earth. The ability of a substance to store heat energy, or the amount of heat required to raise a substance's temperature, is called its **heat capacity**. You and your team are going to investigate the heat capacities of air, water and soil. You will address such questions as: How much does the ocean change temperature from day to night? How does this change affect the climate of coastal regions? What would happen if the oceans covered only 25 percent of the Earth's surface?

Materials: hot plates, 4 Pyrex flasks (500 ml) of the same size, 4 two-hole stoppers to fit the flasks, 4 thermometers, a bucket of ice water, distilled water, soil or sand, metric ruler, stop watch, plastic shoe box, Internet access

Procedure:

1. Fill one flask with distilled water to a height of 8 cm. Fill a second flask with seawater to a height of 8 cm. Fill a third flask with soil or sand to a height of 8 cm. Leave the fourth flask with air only.

2. Carefully insert the thermometers into the stoppers. (Be careful! Using too much force may cause the thermometers to break). Place a stopper with the thermometer into each flask. Make sure the thermometer is **in** the water or soil sample. See Figure 1. Record the room temperature inside each flask. These temperatures should all be the same. Why is it important that the beginning temperatures in all four flasks is the same?

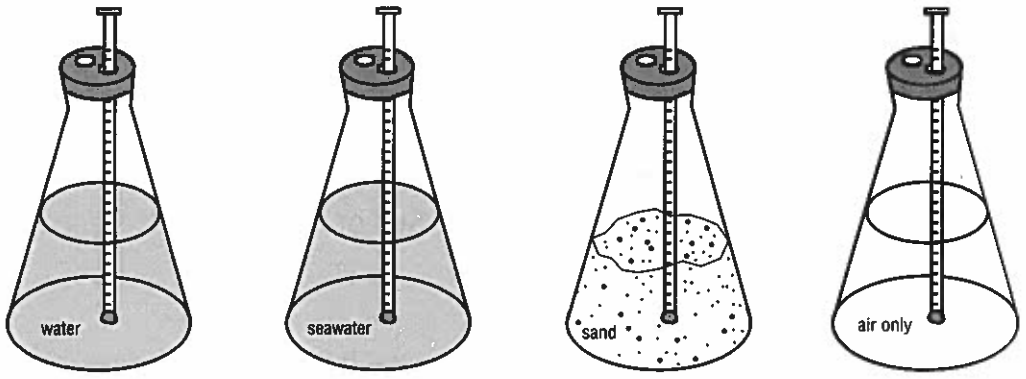


Fig. 1.1

3. Prepare a table for recording your data, using the following as an example.

Table 1: Comparison of Temperature and Time of Soil, Water and Air

Substance	Beginning temperature (°C)	Temperature when distilled water is 50°C	Time to return to original room temperature (°C)
Distilled water		50°C	
Seawater			
Air			
Soil (land)			

4. Place each flask on a hot plate. Turn the hot plate(s) on and start the stopwatch.
   a. Have one member of your team measure the time it takes for the distilled water to reach 50°C. How long did it take? Record your answer in Table 1.
   b. Have other members of the team record in Table 1 the temperature of other three flasks at the very same moment that the distilled water reaches 50°C.

   Remove the flasks from the heat immediately after recording the temperature of each!

5. Compare the temperature of the flask of distilled water to that of the other flasks. Is the temperature of each flask (air, seawater and soil) higher or lower than the temperature of the flask of distilled water?

6. Fill a plastic shoebox with 10 cm of ice and water. Place all of the flasks in the ice water. Record the amount of time it takes for each flask to return to its original room temperature, in Table 1. Which flask takes the longest time to return its original temperature?

7. The **heat capacity** of a substance is the amount of heat energy required to raise its temperature (between the freezing and boiling points). Based on your investigation, which substances must absorb more heat to cause a change in temperature? In other words, which substances have a greater heat capacity?

8. A substance that absorbs more heat before its temperature rises is a stronger buffer against other changes in temperature. Based on your results, do you think the difference between the day to night temperatures will be greater in the Gulf or over the land? Explain your answer.

9. How does heat capacity affect the climate of the coastal land regions? Do you think the day to night temperature differences will be greater along the coast or further inland? Explain.

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10. Suppose the Earth's oceans covered only 25 percent of the Earth's surface instead of almost 75 percent.
    a. Would the day to night temperature differences over landmasses be greater or less? Explain your answer.
    b. How do you think a lack of liquid water (in the form of oceans) affects the day to night temperature differences on other planets and moons in our solar system?

11. Conduct an Internet search to determine if the day and night temperatures of inland and coastal cities of the same latitude supports your results.

2. What Is the Connection Between Ocean Currents and Coastal Temperatures?

Climatologist _____ **Team** _____

Changes in the weather always give people something to talk about. People who live on the west coast often claim that their coast is cooler than the east coast. Can two coastal cities that are at the same latitude but on different sides of a continent really have two different climates? You and your team are going to gather data to test this hypothesis and investigate what may cause such differences.

Materials: map of the United States and map of the world (each showing latitude and longitude), two 2- or 3-liter plastic soda bottles, 2 thermometers that fit into the plastic soda bottles, string, tape, hot water, cold water, World Almanac, Internet access

Procedure:

Part I: Do ocean currents affect the climate of coastal regions?

1. Using a map of the United States, find two coastal cities that are at the same latitude but on different sides of the continent (i.e. San Francisco, California and Norfolk, Virginia, or Eureka, California and New York, New York). Then, use a World Almanac or search the Internet to find the average, or mean, temperatures for each city in January and July. Prepare a table to record your findings.

Table 1: Temperature Comparison of Inland and Coastal Cities

City	Coastal or Inland	Latitude	January Temperature	July Temperature

2. Why might the mean temperatures between the two cities you chose differ? Develop a hypothesis or possible explanation that explains any temperature differences. Record it.

3. Using a map of the world, locate New Foundland and England, then Greenland and Norway. What do you know about the climate of each country?

4. The four countries in the above question are located at the same latitude but their climates clearly differ. Develop a hypothesis or possible explanation that explains the differences in climate between each pair of countries. Record it.

5. Examine Figure 2.1, Ocean Currents. In what direction does the current move along the coastline of California? Is the temperature of this water warm or cold?

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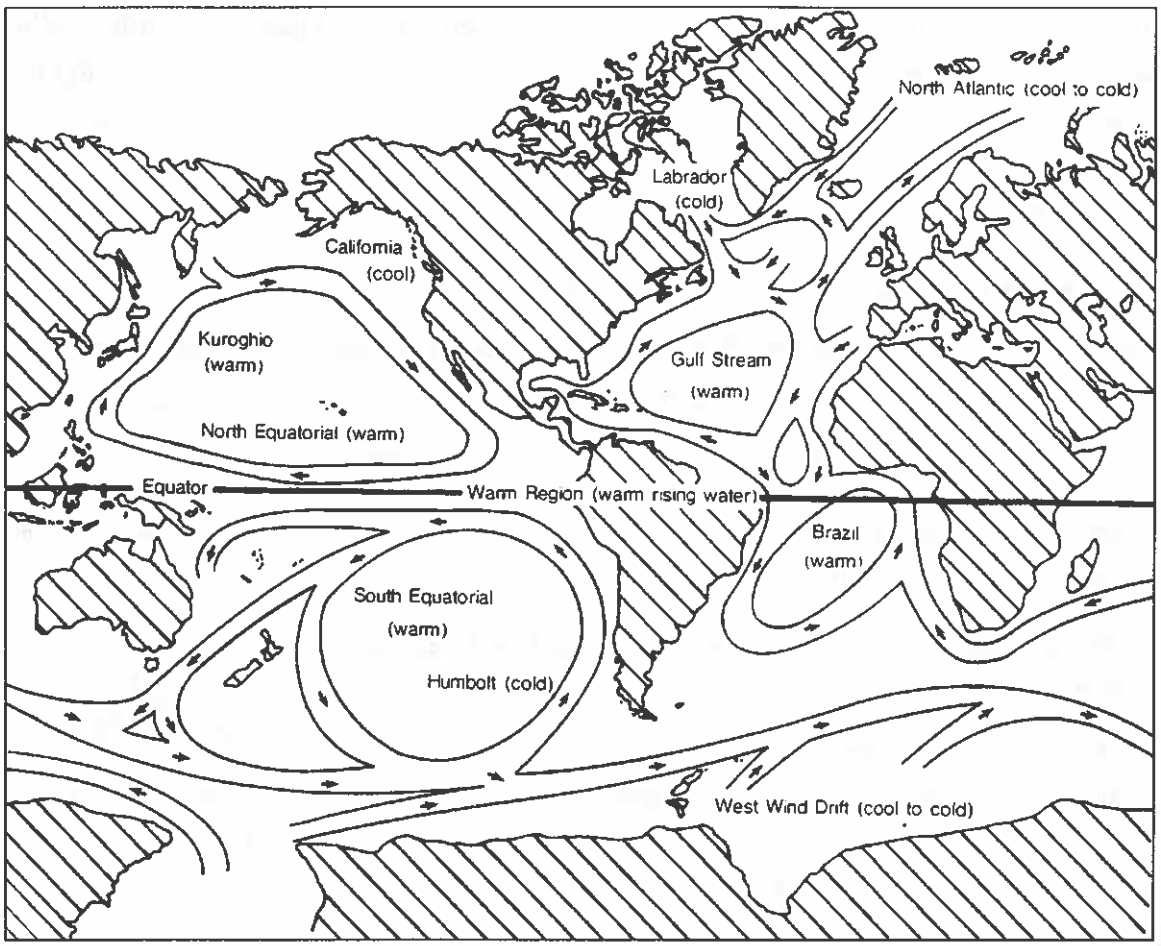


Fig. 2.1. Ocean currents.

6. In what direction does the current move along the eastern side of the United States? Is the temperature of this water warm or cold?

7. Does there appear to be a relationship between the temperature of a current along a coastline and the climate of a coastal region? Explain.

8. Find pairs of cities on opposite sides of the same continent (not including North America). Using weather data from a newspaper, the Internet or an almanac, see if you can determine whether the current off of each coastline is warm or cold.

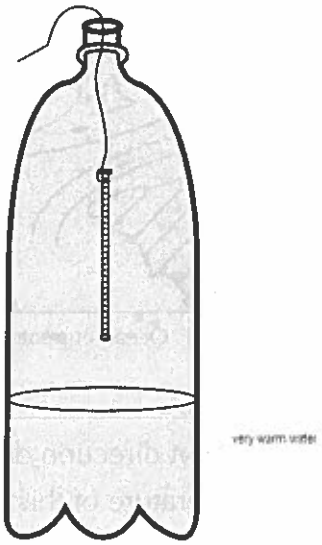
9. Choose five coastal areas in different areas of the world and list them in a table similar to the one below. Then, refer to the world map and use Figure 2.1 to help you predict the climate of the areas you chose. Predict the climate for each area and justify your reasoning. Compare your predictions to actual weather and climate data from the Internet, an almanac or newspapers.

Table 2. Predicted and Actual Climates of Coastal Areas

Coastal Area	Predicted Climate	Basis for Prediction	Actual Climate

10. Based on the information you've gathered, what can you conclude about currents and the climate of a coastal area?

Part II: How do ocean currents cause temperature and climate differences?



1. Begin to conduct an investigation by tying a string around a thermometer so that it can be suspended inside a 2 to 3 liter plastic soda bottle. Lower the thermometer so that its bulb is right above the middle of the bottle and hanging down about halfway. Tape the string holding the thermometer in place to the outside of the bottle. Repeat this procedure for another soda bottle. Next, put the two bottles side by side and measure the air temperature inside of each. Continue taking temperature measurements until the temperature in the two bottles is the same. On a sheet of graph paper, construct a temperature versus time graph for each bottle.

2. Remove the thermometers from each bottle. Fill one bottle half full of very warm water and the second half full of ice-cold water. Lower the thermometers so that each thermometer bulb is about 2-3 cm above the water. Tape the strings holding the thermometers in place to the outside of each bottle. Place a cap on the bottles. Wait five minutes and then measure the temperature of the air in each bottle. *Do not remove the thermometer from the bottle to read the temperature*! Record the temperature on your graph.

3. Read and record the temperatures for each bottle at five-minute intervals. You will do this four times for a total of 20 minutes. Be sure to record the measurements on your graph!

4. Did the temperature of the air in each bottle change? Explain your answer.

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5. Based on this model demonstrating air temperature above a cold-water current and above a warm water current, how do you think warm and cold currents affect the air temperature above oceans?

6. If local winds blow the air from the ocean over the land, how does this affect the temperature of the nearby land?

7. Use the data and results from your experiment to explain why two cities at the same latitude can have different temperatures and climates even though they receive the same amount of solar radiation.

3. Why Do Coastal Regions Have Moderate Climates?

Climatologist_____ **Team**_____

Beginning as early as the classical Greeks and Romans, people would spend time on the beaches. Both the masses and the wealthy participated in seasonal migrations to the beach. They even built beach resorts and homes just as people do today. Even in the 1600's in colonial times along our eastern coast, the wealthy had houses along the bays and seashore for their families to spend time. This was true along the Texas coast as families had homes or would visit the beach or coast in Galveston, Port Aransas, Indianola and other coastal towns during the summer. Even today the summer is when people often head to the seashore to escape the intense heat of inland areas. Some families even own summer homes in coastal regions. Is the climate in coastal regions really more moderate than inland areas or is it just the attraction of the water and the beach? You and your team are going to conduct an investigation to determine if coastal regions have a more moderate climate than the interior.

Materials: 2 containers (1 gallon milk jugs or 5 quart plastic ice cream containers, or large coffee cans), sand, water, thermometers, string, tape, ruler, Texas Highways Map, Texas Almanac, Internet access or national newspaper

Procedure:

1. Do you think the coastal regions are cooler than inland areas during the summer? Why? What is your explanation or hypothesis?

2. Do you think the coastal areas are warmer or colder than the inland areas during the winter? Why? What is your explanation or hypothesis?

3. What sources could you use to find out whether your answers and explanations (hypotheses) to the above two questions were correct?

4. Gather the following materials: two containers, two thermometers, sand, water, string and tape. Use these materials to construct a model of the ocean and land that investigates the cooling and warming rates of each. How will you set up (design) your procedure (inquiry)? Use sketches on a separate piece of paper to illustrate your experiment.

5. How will you display your data — as tables or in graphs? Set up and write out your data display on your design page.

6. What is your explanation of the collected data?

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7. Do your results support your hypotheses in the first two questions? Explain why or why not.
8. Share your findings with other teams in your class. Did each team conduct identical investigations? If not, how did they differ?

9. How could your team improve on your investigation? Better experimental design? A more concise hypothesis?

10. Scientists always repeat experiments to ensure accuracy in both design and in results. Repeat your team's investigation without changing anything. What did you learn the second time?

11. Does the investigation your team designed and carried out help to explain the range in temperature between coastal and inland locations? Why or why not? Explain your reasoning.

12. Review your experiment. How could it be improved?

4. How Does the Gulf of Mexico Influence the Coastal Area of Texas?

Climatologist _____ **Team** _____

Traveling west along the Texas coast from Louisiana to the border of Mexico, it is not difficult to see features in the environment change dramatically. Even the beaches and dunes are not the same! Yet, this entire area is next to the Gulf of Mexico. You and your team will explore the ways in which the Gulf affects the coast of Texas and why each region differs.

Materials: graph paper, map pencils, Texas map, **Texas Almanac**

Procedure

1. Look at Figure 4.1, Texas' Coastal Zone. What do you notice about the location of the coastal counties and the Texas coastal zone on this map?

2. Which county is farthest east (next to Louisiana)? Which county is next to Mexico?

3. What do you think the climate of the county next to Louisiana is like? The climate of the county next to Mexico? Are they similar or different? Explain your answer.

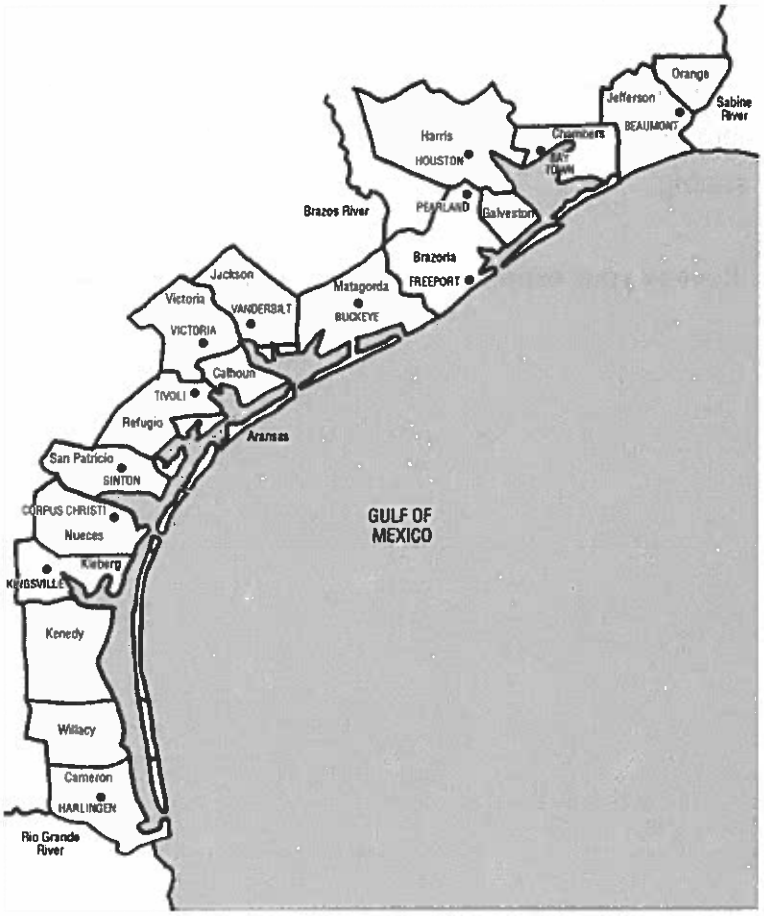


Fig. 4.1. Texas' Coastal Zone

4. Examine the data in Table 1, Annual Rainfall, Mean Temperatures and Growing Season of Coastal Counties. What is the pattern for each set of data as you move from the coastal counties in the east (Port Arthur, Jefferson county) towards the west (Brownsville, Cameron county)? Write a statement that describes the relationships you observe.

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Table 1 - Annual Rainfall, Mean Temperatures, and Growing Season of Coastal Counties

Location (Counties East to West) City	AnnualRainfall Minimum (Inches)	Mean Minimum Temp.	Mean Maximum Temp	Growing Season (Days)
Jefferson(Port Arthur)	52.1	42	93	250
Brazoria(Freeport)	52.3	42	93	268
Calhoun(Port Lavaca)	42.2	44	93	300
Nueces(Corpus Christi)	30.2	46	94	309
Kenedy	29.7	45	95	319
Cameron(Brownsville)	24.5	51	93	341

5. Examine Figure 4.2, Terrain and Climatic Interactions of the Gulf. Using both Figure 2 and Table 1, what patterns in wind and rain do you observe? List your observations.

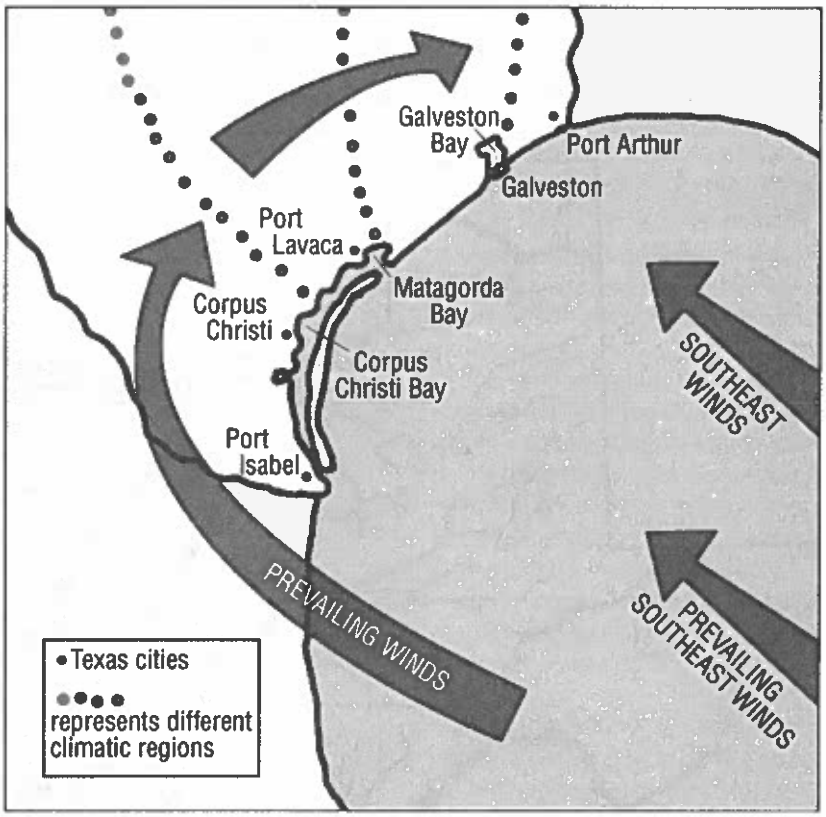


Fig. 4.2. Terrain and Climatic Interactions of the Gulf.

6. Use your observations to explain the effects of the prevailing southeast winds from the Gulf, on the mean annual temperatures, the rainfall and the growing season on the coastal counties. Write a paragraph summarizing the patterns you observe.

7. Look at Figures 4.1 and 4.2. The interaction of climate and terrain along the Texas coast has, over time, created four distinctly different regions. From the Sabine River (Port Arthur)

to Galveston, the climate tends to be extremely humid. Label this area Region A on the map of Figure 4.2. From Galveston to Port Lavaca, there is a wet, sub humid climate in which the moisture loss and supply are in balance. Label this area Region B on the map. There is an important climatic boundary in the Matagorda Bay vicinity. North of Matagorda Bay, the average rainfall is greater than the potential evaporation, and so Regions A and B are more humid. South of Matagorda Bay, however, the potential evaporation rate is greater than the annual rainfall so fresh water (in the form of rain) is in short supply. Thus, the area from Port Lavaca to Corpus Christi is a dry and sub humid belt. Label this Region C. The transition from this dry, sub humid region to one that is semiarid and almost desert-like is gradual from Corpus Christi to Port Isabel. Label this area Region D. What effects do you think these differences in moisture have on the plants and animals that live in each region?

8. Examine Figure 4.3, Discharge of Texas Rivers, and Figure 4.1, Texas Coastal Counties. Do you observe any differences between the bays and the river basins of the upper coast (Regions A and B) and those of the lower coast (Regions C and D)?

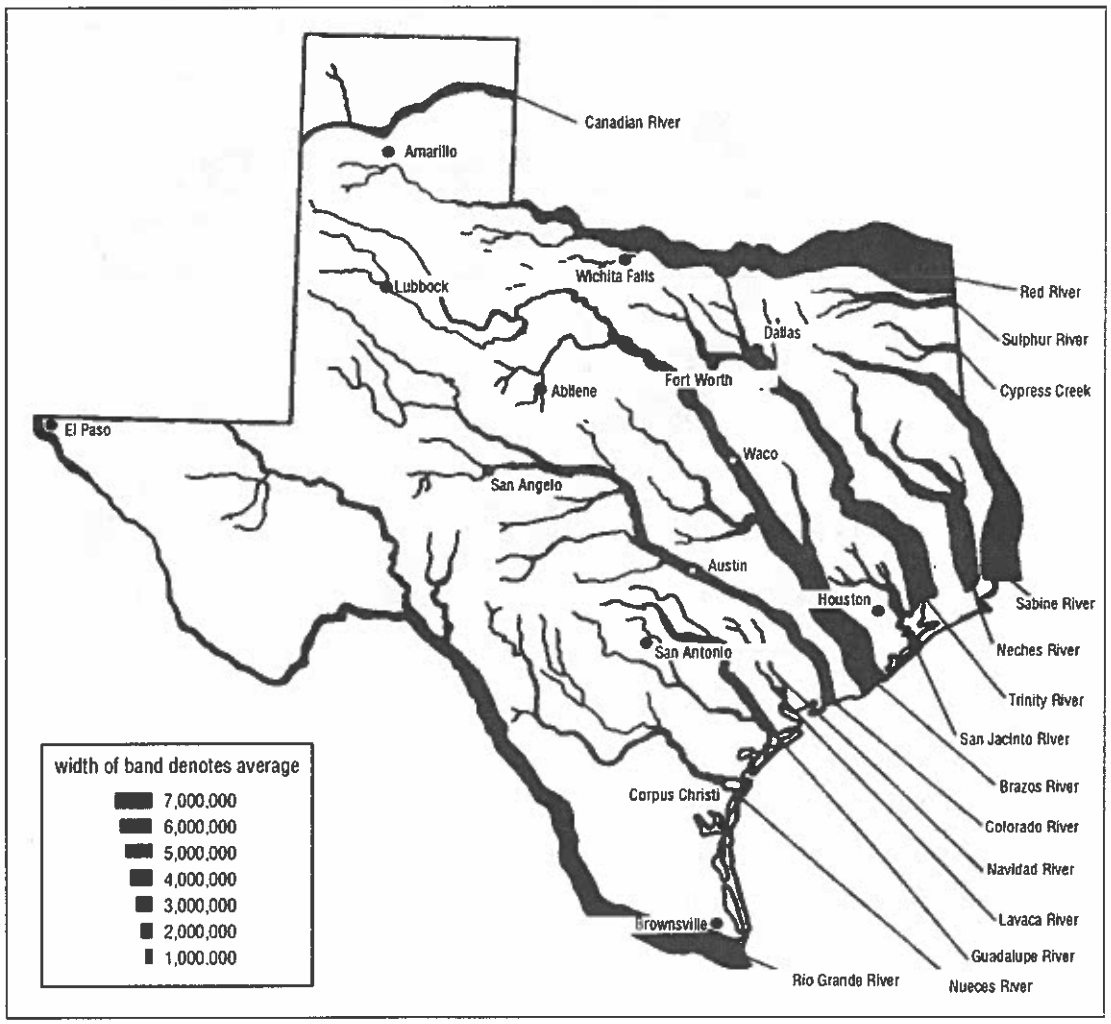


Fig. 4.3. Discharge of Texas Rivers.

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9. What larger patterns in these figures do you notice, if any? Summarize the inferences you've made about the differences in the upper and lower coasts, based on the figures and data provided.

10. How do you think climate affects the salinity of the bays in Region A as compared to Region D? Explain your reasoning.

11. Do you think there is a difference in ocean water salinity between Regions A and D? Which region would be more likely to have greater salinity? Why? Explain your reasoning.

12. Would differences in salinity affect the plants and animals of a region? If so, how?

13. Write a paragraph summarizing the interactions between the Gulf of Mexico (the sea) and Texas (the land).

5. How Does the Gulf of Mexico Influence the Texas Climate?

Climatologist _____ **Team** _____

Texas' weather has been the topic of jokes, praise, and criticism since written history of the state began. What are some of the comments or sayings you have heard about Texas weather? This great variation results from the fact that Texas is divided into 10 climatic zones, each with vast differences in elevation, precipitation, wind velocity, humidity, and other conditions. Your role in this investigation is to analyze data in order to determine how the Gulf of Mexico affects the weather and climate of Texas and other parts of the United States.

Materials: graph paper, map pencils, Texas map, and a copy of the **Texas Almanac**

Procedure

Part I: How does the climate of coastal and inland areas compare?

1. What do you know about the weather in Texas? Write down everything you can think of.

2. What do you know about the weather in different regions of the state? With your group, look at a Texas map and determine who has visited different areas of the state. Discuss what the weather and vegetation was like in areas that your team members have visited. Make a separate table listing each region and what your team knows about each region (the weather/climate and vegetation).

3. Look at Figure 5.1 (page 470). Do you think that the weather differs between inland coastal areas and areas on the coast? Explain.

4. To determine if you were correct about the weather of inland and coastal areas construct a graph to analyze the data. As a team, make a separate bar graph of the data for each pair of counties (A, B, C, & D). Use blue to represent the coastal county data and brown for the inland county data.

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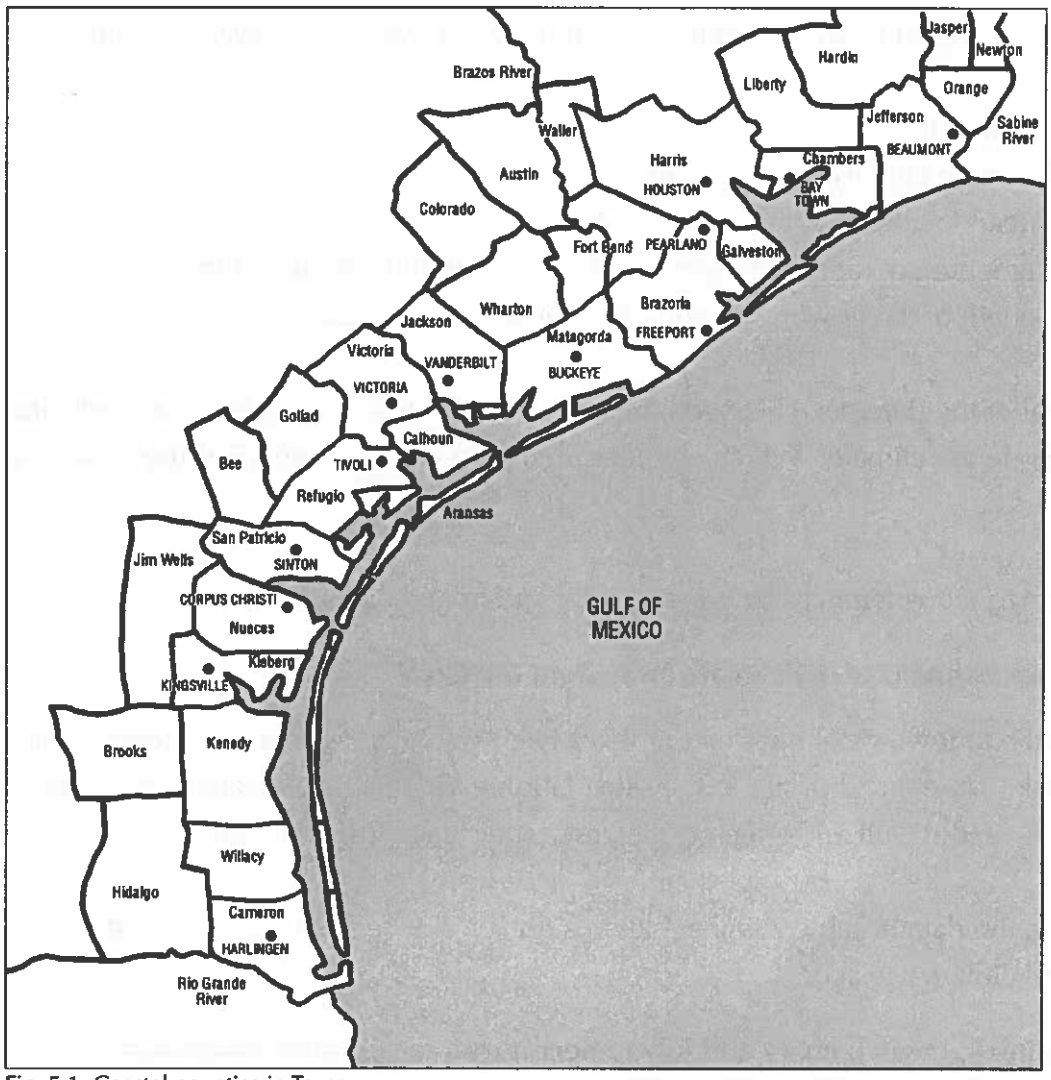


Fig. 5.1. Coastal counties in Texas.

Table 1: Rainfall, Mean Temperatures and Temperature Range, and Growing Season of Paired Coastal and Inland Counties

Paired Counties Coastal/ inland(Group)	Location County	Annual Rainfall (inches)	Mean January Temperature	Mean July Temperature	Range of Temperature (Jan.-July)	Growing Season (days
A -Coastal	Jefferson	57.2	42	92	50	250
A -Inland	Hardin	55.7	37	93	56	246
B - Coastal	Galveston	42.3	47	87	40	335
B - Inland	Liberty	54.1	39	93	54	261
C -Coastal	San Patricio	35	43	94	51	303
C - Inland	Bee	32.1	41	94	53	285
D - Coastal	Nueces	30.1	45	93	48	309
D - Inland	Jim Wells	27.8	43	96	53	289

5. Analyze your graphs, what patterns do you notice between the coastal and inland counties?
   a. In annual rainfall?
   b. In the mean January temperatures?
   c. The mean July temperatures?
   d. The temperature range between mean January and July temperatures?
   e. The length of the growing season (number of frost-free days)?

   The smaller the difference between the mean January and July temperature indicates a more moderate climate. Which counties, inland or coastal have the more moderate climate?

6. Summarize the differences between coastal and inland cities.

Part II: What happens to the climate away from the Gulf?

1. Locate the following counties on the Texas Highway Map: Matagorda, Victoria, Frio and Maverick. Note that they are in the same latitude but different distances from the Gulf. Which is on the Gulf and which is the greatest distance from the Gulf?

2. Examine the data in Table 2. What patterns do you notice as one moves westward away from the Gulf of Mexico?

Table 2: Rainfall, mean January and July temperatures, temperature range, and

County	Annual Rainfall (inches)	Mean January Temperature	Mean July Temperature	Range of Mean Temperature	Growing Seasons (days)
Matagorda	44.7	45	91	46	296
Victoria	37.4	43	94	51	290
Frio	25.4	38	97	59	291
Maverick	21.5	38	98	60	285

3. The data in Table 3 shows the relationship of the distance north of the Gulf and the rainfall, mean temperatures, mean temperature range, and the growing season. What factors do not appear to change a large amount as one moves north?

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Table 3: Relationship of Distance from Gulf and the Rainfall, Mean Temperatures, Temperature Range, and Growing Season

County /City	Approximate distance from Gulf (miles)	Annual Rainfall (Inches)	Mean January Temperature	Mean July Temperature	Range of Mean Temperatures	Growing Season(Days)
Nueces, Corpus Christi	0	30.1	45	93	48	309
Goliad/ Goliad	70	36.5	43	95	52	285
Gonzales/ Gonzales	120	32.4	40	95	52	285
Travis/ Austin	200	31.9	39	95	56	270
Bell / Temple	250	34.9	35	95	60	260
McLennan/ Waco	290	32	34	97	63	253
Tarrant/ /Ft. Worth	380	31.3	35	96	61	230
Cooke/ Gainesville	450	35.8	27	95	68	226

Use the data in Table 3 to prepare two bar graphs on graph paper. One graph will show the relationship of the distance and mean January temperature and the other, distance and the growing season. Summarize the relationships.

4. Explain why changes in temperature, mean temperature range and growing season occur as one moves north.

5. Use the data from Table 4: Relationship of Distance from the Gulf and Rainfall, Mean Temperatures, Temperature Range and Growing Season to prepare three graphs: Graph A of the distance from the Gulf (horizontal axis) and the annual rainfall on the vertical axis. Graph B of the distance from the Gulf (horizontal axis) and the yearly mean temperature range on the vertical axis. Graph C of the distance from the Gulf (horizontal axis) and the length of the growing season on the vertical axis. The length of the growing season is the number of frost-free days. Divide the preparation of the graphs among your team.

Table 4: Relationship of Distance from the Gulf of Mexico and the Rainfall, Mean Temperatures, Temperature Range and Growing Season.

Location County/City	Distance from Gulf (approx. miles)	Annual Rainfall Minimum (inches)	Mean January temperature	Mean July temperature	Range of Temperture (min to max)	Growing Season (days
Jefferson (Port Arthur)	10	52.8	42	93	51	250
Liberty (Liberty)	70	50.7	40	94	54	261
San Jacinto (Cold Spring)	110	48.6	36	94	58	261
Limestone	220	38.3	34	95	61	255
Palo Pinto (Mineral Wells)	340	29.3	34	97	63	221
Baylor (Seymour)	400	25.7	26	98	72	219
Childress (Childress)	500	19.9	26	96	70	217
Potter (Amarillo)	610	19.1	22	91	69	190

6. What patterns do you notice?
   a. In annual rainfall?
   b. In mean January temperature?
   c. In mean July temperature?
   d. In the range of temperature from minimum to maximum?
   e. In the length of the growing season?

7. Write a statement explaining the relationship between the variables of distance from the Gulf and the various climatic factors.

8. Write a statement that summarizes what you were able to infer from the data. Explain the impact of the Gulf of Mexico on Texas weather and climate.

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6. What Is the Relationship Between Climate and Agriculture Along the Gulf Coast of Texas?

Economist _____ **Team** _____

Beginning with its years as an independent republic, Texas has continually attracted economic interest from foreign countries. Today, Texas continues to trade with other countries around the globe. In fact, Texas has a gross state product larger than that of many nations! The Texas Gulf coast plays an important economic role in this investment, ranging from agricultural production, manufacturing, trade, finance, transportation, recreation, to oil and gas production. You and your team are going to explore the relationship between climate and the agricultural economy of coastal Texas.

Materials: Texas Highways map, Texas Almanac, Internet access

Procedure:

1. Agriculture is one of the most important and influential industries in Texas. Measured in cash receipts for farm and ranch products, Texas ranks second in the nation. Cash receipts from agricultural products have even been over $14 billion in some years. Agribusiness, the combined phases of food and fiber production, processing, transporting and marketing is a leading Texas industry. It adds over $44 billion to the Texas economy per year. Texas' share of agricultural exports was over $3.6 billion in previous years.

Table 1 - Annual Rainfall, Mean Temperatures and Growing Season of Coastal Counties

Location(Counties East to West) City	Annual Rainfall Minimum (inches)	Mean Minimum temp.	Mean Maximum temp	Growing Season (days)
Jefferson (Port Arthur)	52.1	42	93	250
Brazoria (Freeport)	52.3	42	93	268
Calhoun (Port Lavaca)	42.2	44	93	300
Nueces (Corpus Christi)	30.2	46	94	309
Kenedy	29.7	45	95	319
Cameron (Brownsville)	24.5	51	93	341

Examine Table 1 and Figure 6.1. In what ways do you think climatic differences such as rainfall, temperature and length of growing season affect the agricultural products of Texas' coastal counties?

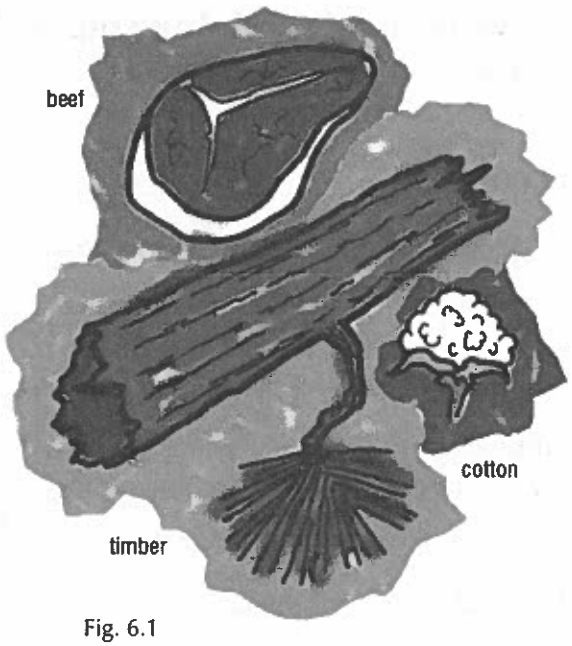


Fig. 6.1

2. Which coastal region(s) are most likely to require irrigation? Explain your answer using data from Table 1.

3. Examine Table 2, Agricultural Products of Texas Coastal Counties. Crops are listed in order of economic importance. Which crops are grown in the counties that have high amounts of rainfall?

Table 2: Agricultural Products of Texas Coastal Counties

County	Agricultural Products
Orange	Timber, Beef cattle, Rice, Horses, Hogs, Hunting leases
Jefferson	Rice, Soybeans, Beef cattle
Chambers	Rice, Soybeans, Beef cattle, Timber
Galveston	Rice, Cattle, Horses, Soybeans, Grain sorghums
Brazoria	Rice, Hay, Greenhouse nurseries, Cotton, Grain sorghum Soybeans, Corn, Beef cattle, Hogs
Matagorda	Rice, Greenhouse nurseries, Cotton, Grain sorghum, Beef cattle
Calhoun	Cotton, Beef cattle, Rice, Grain sorghum
Refugio	Cotton, Sorghums, Corn, Beef cattle, Hunting leases
San Patricio	Beef cattle, Cotton, Grain sorghums, Corn
Nueces	Grain sorghum, Cotton, Corn, Beef cattle, Meat goats, Hogs
Kenedy	Cattle, Horses
Kleberg	Beef cattle, Cotton, Grain sorghum, Hunting leases
Willacy	Cotton, Grain sorghum, Sugar cane, Corn, Vegetables, Cattle, Horses, Goats
Cameron	Cotton, Grain sorghum, Vegetables, Sugar cane, Greenhouse nurseries

4. Which crops are produced in the counties with less rainfall?

5. Cotton has been a major crop in Texas for more than a century. Since 1880, Texas has led all states in cotton production in most years. Today, Texas' cotton harvest equals approxi-

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mately one-fourth of the total cotton production for the United States. Cotton is also grown in the Panhandle and High Plains regions of Texas. Examine Tables 1 and 2. Based on the data, in what type of climate does cotton grow best along the Texas coast?

6. Texas ranks second in the nation in grain sorghum production. Grain sorghum ranks fourth in crops of value in Texas. Much of this grain is exported or used for livestock and poultry feed. Nueces, San Patricio and Cameron counties are state leaders in grain sorghum production. Based on the data in the tables, what type of climate is best for grain sorghum production?

7. Rice is grown in about 20 coastal counties. Texas ranks fourth in rice production in the United States, and rice is third in value among Texas crops. Most of it is exported to other countries. Which climate looks most favorable for rice growing?

8. Wheat used for grain is one of the state's most valuable cash crops. Most of this wheat is produced in the High Plains (Panhandle) and in north central Texas. Why do you think that wheat is not produced in coastal counties?

9. Texas ranks fourth in sugar cane production in the U.S. The sugar cane producing counties are Hidalgo, Cameron and Willacy. Can you infer from the data what type of climate sugarcane requires?

10. A large proportion of the agricultural land in Texas is devoted to forage crop production. The primary forage crops are grasses, hay and some types of corn. These crops provide practically the entire feed requirements for the state's domestic livestock, as well as game animals. What is the role of forage crops in the coastal counties?

11. A few market vegetables are produced in almost all of Texas' counties. In fact, Texas is one of the five leading states in the nation in the production of fresh vegetables. It ranks in the top four in the production of spinach, honeydew melon, cabbage, celery, cucumbers, cantaloupe, watermelon, broccoli and carrots. It ranks in the top ten in the production of cauliflower, onions, bell peppers and Irish potatoes. Hidalgo and Cameron counties are two of the leading producers of vegetables. Why might these coastal counties be leading producers of vegetables? Why do you think this area is referred to as the "winter garden"?

12. Prior to a major freeze in 1989, Texas ranked with Florida, California and Arizona as leading states in the production of citrus (grapefruit and oranges). Most of the Texas citrus production is in Cameron, Hidalgo and Willacy counties. What are some possible explanations for this?

13. Texas ranks first nationally in all cattle, sheep and lamb, wool, goat and mohair production. Discuss importance of livestock production in the coastal counties.

14. The Santa Gertrudis breed of cattle was developed on the King Ranch in Kenedy County. Other breeds of cattle do not do as well in this region. Why might one breed of cattle be better for Jefferson and Chambers counties but not for Kenedy county?

15. The management of wildlife through leasing land for hunting makes a significant contribution to the economy of many counties. In which coastal counties is it most important? What wildlife is hunted and harvested in these counties?

16. Overall, how have climatic differences affected the agricultural products of the coastal counties? Summarize this connection using supportive data from Tables 1 and 2.

17. In what ways might a hurricane or tropical depression affect the agricultural economy of the coastal counties? Do you think the impact would be different for different counties along the coast? Why? Explain your answer.

18. For further investigation, use the **Texas Almanac** to gather agricultural data on other counties in the Gulf coastal region.

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7. Is There a Connection Between Climate and the Ports?

Climatologist _____ **Team** _____

Every year, more than 371 million tons are shipped out from ports along the Texas coast. Thirteen of these shipping centers are considered major deep water ports, all located along the coastline from Beaumont to Brownsville. What determines the location of a port? Is there a relationship between climate and a port's location? Is there a connection between climate and the products shipped from a port? Your investigation will seek to find answers to these questions.

Materials: *Texas Highways* map, **Texas Almanac**

Procedure:

1. What is the role of a port? Why are they important economically?

2. Use a Texas Highway map or the Texas Almanac to locate the major ports. Construct a table similar to the example and complete it by indicating the location of the major ports (bay, river, gulf, etc.) The ports are ranked in order of the total tonnage shipped. Where are all the major ports located?

3. Are more ports located in one region of the coast than another? What might an explanation or hypothesis for the difference in the location of ports?

4. Why are more of the major ports are located along the bays than on the Gulf itself? What is a possible explanation?

5. Use the **Texas Almanac** and/or the Internet to locate information on what is shipped through the ports. When using the Texas Almanac, locate the county in which the port is located, the products produced in the county are given. In searching the Internet search for the web page of Port of _____Authority or the port city by name to locate information about the port. List the products exported in Table 1.

6. Refer to the lesson "What is the relationship between climate and agriculture in the Gulf coast? " to determine what agricultural products would be shipped from each of the ports. List the products shipped in Table 1.

7. Locate Baffin Bay, a large bay in Kleberg and Kenedy County. There is no port located on this large bay. Why? What is your possible hypothesis? What data is needed to support or reject your hypothesis?

8. Write a paragraph that summarizes how the sea interacts with the land. Explain how the Gulf of Mexico influences agriculture, ports, industry and population growth?

9. As a team, discuss why this information is important and who uses this information. Write your teams explanation.

Table 1: Location of Major Ports

Port	Location, County	Products shipped (exported)
Houston		
Corpus Christi		
Texas City		
Port Arthur		
Beaumont		
Freeport		
Galveston		
Brownsville		
Orange		
Sabine Pass		
Port Aransas		
Port Isabel		
Port Mansfield		

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8. What Is the Effect of Greenhouse Gases on the Climate and the Texas Climate?

Climatologist _____ **Team**_____

The climate system is very complex. It is controlled not only by what happens in the atmosphere, but in the oceans, the cryosphere (glaciers, sea ices and continental ice caps), the geosphere (earth's solid surface) and the biosphere (living organisms in the oceans and on land). The interactions of these are difficult to predict and not all the processes are known.

Energy from the sun drives the earth's weather and climate. Gases in the atmosphere trap some of the energy from the sun. This creates a natural "greenhouse effect." Without this effect the Earth's average temperatures would be much lower than they are now. Life as it is known today would not be possible. The greenhouse gases (water vapor, carbon dioxide, methane and other gases) help keep the earth's average temperature around 60°F. However problems arise when human-generated greenhouse gases are released into the atmosphere. As their concentrations rise, the climate must somehow adapt, or change, to keep the energy budget in balance. The earth's climate is predicted to change because human activities are changing the chemical composition of the atmosphere.

You and your team are members of a research institution that is investigating global issues including global warming. First your team is going to conduct an investigation to determine the effect of greenhouse gases on the temperature of the atmosphere. The second part of your assignment is to analyze available data about global temperatures. Working with your team, organize, analyze and prepare to present your data to a major conference.

Materials: Three 2 or 3 liter plastic soda bottles, soil, tape, three thermometers, plastic wrap, rubber bands, one 16 or 20 oz. plastic soda bottle, teaspoon, tablespoon, white vinegar, baking soda, funnel, light bulb (100 watt) or light source (if cannot be put in direct sunlight), clock or timer

Procedure:

Part I: What happens if greenhouse gases are added to the atmosphere?

1. Obtain 3 empty clear plastic 2 or 3 liter soda bottles. Carefully cut and remove the top of the bottles. See figure 8.1. Add 4 to 5 cm of soil to the bottom of each bottle.

2. Because the experiment is going to measure the temperature of the air when exposed to light rays, each bottle

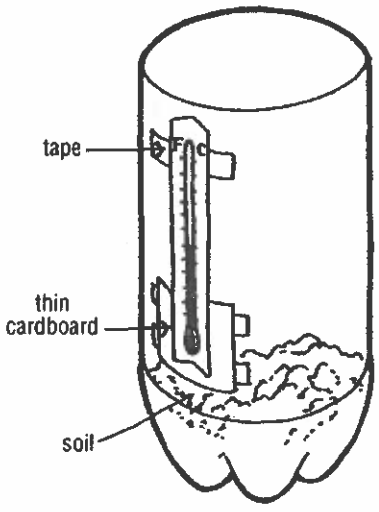


Fig. 8.1.

needs to have a thermometer inside. Tape a thermometer to the inside of the bottle 3 cm above the soil. Tape the thermometer so that the scale can be read through the plastic. Cover the thermometer bulb with paper to protect it from direct rays from the light bulb.

3. Label one bottle as A, this will be the control. It will remain uncovered. B will represent the atmosphere without added greenhouse gases. Put plastic wrap tightly across the top of the bottle. Secure the plastic wrap with a rubber band. C will represent the atmosphere to which human-generated greenhouse gases are added. It will be covered with plastic wrap after the gas is added.

4. To prepare the greenhouse gas, place 1/2 teaspoon of baking soda in the 16 or 20 oz. bottle and add two tablespoons of white vinegar to the baking soda in the bottle to form a gas (carbon dioxide). Roll a piece of paper to form a funnel or use a funnel. Tilt the bottle and hold it at a slant and pour the gas from the bottle into Bottle C. Do not allow any of the baking soda/vinegar mixture to flow out of the bottle. Place plastic wrap tightly across the top of the bottle. Secure the plastic wrap with a rubber band. Carbon dioxide gas is heavier than air and will flow through the funnel into the bottle and stay there until the bottle is sealed.

5. Place all three bottles in direct sunlight or arrange the bottles around a light bulb (with the light off) with the thermometers facing outward so that they can be easily read. See Figure 8.2. Space the bottles equal distance from the light. Predict what will happen to the temperature of the air in all three bottles.

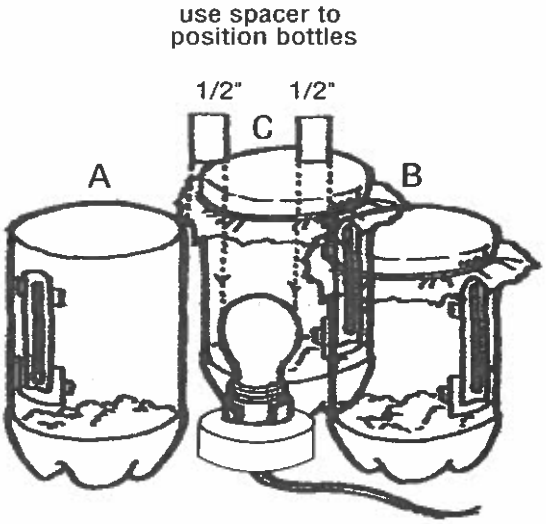


Fig. 8.2

6. Prepare a data sheet. Record the temperature of each bottle (at time=0). Turn on the light. Record the temperature each minute for 20 minutes (longer if the temperature in the bottles has not leveled off.)

7. Use the data to prepare a graph. Did the greenhouse affect the temperature of the air? Compare bottle A to B and explain. The graph should be time vs. temperature with each bottles temperature drawn in a different color and labeled properly.

8. Did the greenhouse gas (carbon dioxide) affect the temperature of the air in the bottle? Compare bottles A, B and C. Explain.

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9. Based on your experiment, what is the effect of atmosphere (bottle B) and greenhouse gases (bottle C) on the temperature?

10. Why did the temperature in each of the bottles go up?

11. Why did the temperature in both bottles level off?

12. Why did the temperature in the closed bottles level off at a higher temperature than the open bottle?

13. What conclusion can you develop from the data of the investigation?

14. Since the beginning of the industrial revolution, human activities have been adding additional greenhouse gases to the atmosphere. The burning of fossil fuels—coal, oil, and natural gas—for energy is the main source of human-generated greenhouse gases. Energy burned to run cars and trucks, heat homes and businesses, and power factories is responsible for about 80 percent of global carbon dioxide emissions, about 25 percent of U.S. methane emissions and about 20 percent of global nitrous oxide emissions. Increased agriculture and deforestation, landfills, and industrial production and mining also contribute to the emissions. In 1994, the United States emitted about 20 percent of the total global greenhouse gases. How do you think this is affecting the earth's average temperature?

Part II: What does the data indicate about global temperatures?

1. Examine Fig. 8.3, the temperature record from 1865-1995. What patterns do you notice?

2. Continue the trend shown in the graph for another 50 years, another 75 years. Make a prediction on how you would expect the graph to look in 50 years; 75 years. What is your prediction?

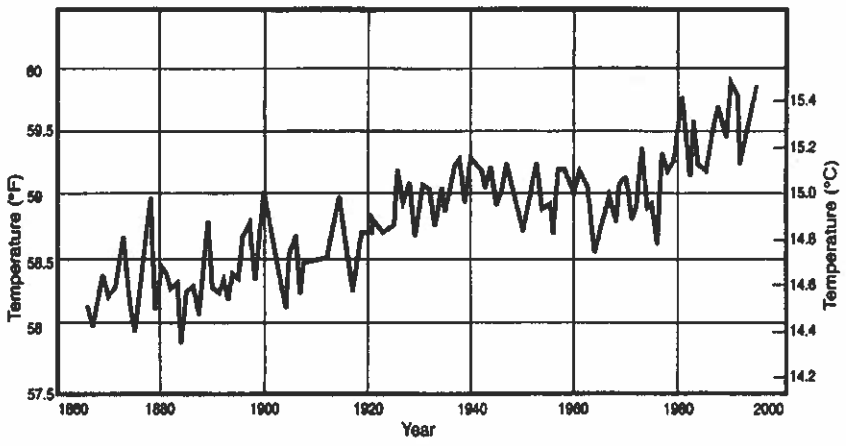


Fig. 8.3. Temperature record from 1865 to 1995.

3. Figure 8.4 shows the deviations from a global mean temperature of

15°C for the period from 1861-1996. Zero represents 15°C. What were the temperature patterns before 1940? What were the temperature patterns from 1980 to 1996?

4. When did the warmest years in the 20th century occur?

5. How much have the mean surface temperatures increased in the last 20 years? Predict what it will be in 50 years?

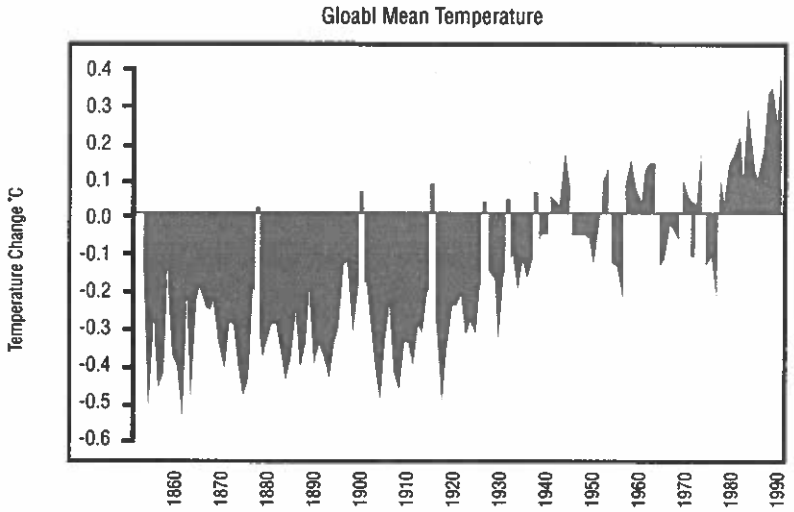


Fig. 8.4. Global Mean Temperature, 1854-1990. (Source: Based on Jones and Wigley, CDIAC 1991, http://www.fsl.noaa.gov/osborn//cg)

6. In September 2000, a team of scientists published the results of their study of lake and river records around the world to find fall freeze dates or spring breakup dates from 1846-1995. Their findings show a steady 150-year warming trend in global temperatures, especially in the Northern Hemisphere. What conclusions can be reached from this study?

7. An article in the September 15, 2000 issue of **Science** reported that ice cores drilled in 1997 through a glacier at 23,500 feet in the Himalayan Mountains have provided scientists with a highly detailed record of the Earth's past climate in the high Tibetan Plateau. These cores reveal that the last decade and the last 50 years were the warmest of any equivalent period in 1,000 years. What conclusion can be reached from this study?

8. Figure 8.5 shows the concentrations of greenhouse gases in the atmosphere. What patterns do you notice?

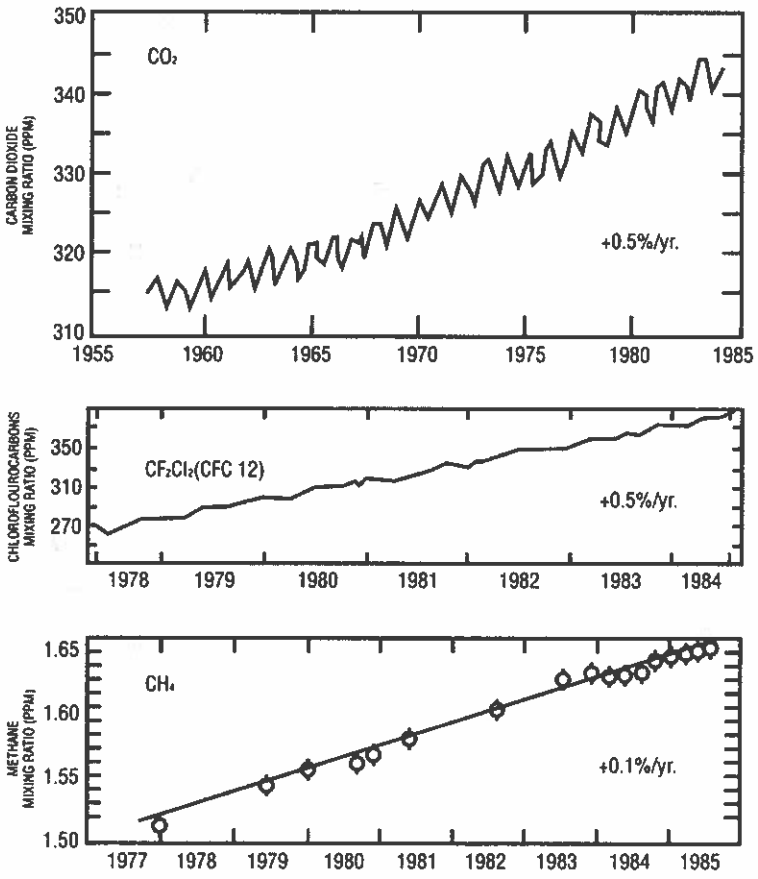


Fig. 8.5. Concentrations of greenhouse gases in the atmosphere.

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9. Make a prediction on how you expect the graphs to look with 50 years more of data.

10. Using figures 8.3, 8.4 and 8.5, what inferences can you make about the global temperature and the concentrations of greenhouse gases.
11. What conclusions can you develop about global warming and temperature changes?

Part III: What is the impact of climate change on Texas and the coastal zone?

1. The earth's climate is predicted to change because of human activities that are altering the chemical composition of the atmosphere through the increase in greenhouse gases. Although scientists do no know exactly how and when the earth's climate will respond, observations indicate changes are occurring. One change is an increase in temperature. As a group list ways that an increase in temperature will affect plants, animals, people, ecosystems and the economy.

2. Construct a table as shown below.

Table 1: Impact of Climate Change

Areas of Impact	Predictions about Impact	Actual Impact	Impact onTexas
Human health			
Coastal areas			
Water resources			
Agriculture			
Forests			
Fisheries			
Birds			
Ecosystems			
Other			

3. List your team's predictions as to how climate change might impact each of the areas.

4. After your team has made its predications, use the Internet to learn what scientists predict the impact will be in each area. The following Internet sites will be helpful: http://www.epa and http://www.epa/globalwarming/impacts/index.html

5. To find out about the impact of climate change on Texas visit http://www.epa.gov/globalwarming/stateimp/texas/index/html. Use the information to complete your table.

6. Summarize what you have learned about climate change.

7. You and your team members can do something about global warming. A few of the simple things that everyone can do are to reduce, reuse and recycle. For example, by recycling all of your home's waste newsprint, cardboard, glass and metal, you can reduce carbon dioxide emissions by 850 pounds a year. How many pounds of emissions could your class alone reduce by recycling? How many pounds could your school reduce if each family in your school recycled?

8. To learn more about global warming and what other things you can do visit the general resources section at: http://www.epa.gov/globalwarming/publications/outreach/index.html. As a team, use the information from this site and the other sites to plan ways to educate your community about global warming and encourage them to take practical steps to save money and protect the environment. Decide whom you want to educate. You may prepare a brochure, posters, a video presentation, short play, an article for the local newspaper or presentation for community groups. Develop an outline of your plan and present it to your instructor.

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9. What Is the Effect of Global Warming on the Sea Level of the Gulf of Mexico?

Climatologist _____ **Team** _____

There is increasing evidence and agreement by scientists that the increase in "greenhouse" gasses will cause a global warming of 1.5-4.5° within the next 50 to 100 years. Sea level rise is considered by many to be one of the most likely effects of global warming. You and your team are going to conduct investigations to determine what happens as snowfields and glaciers melt and what happens as the oceans absorb heat from the atmosphere. In the second part of your assignment, your team will analyze the impact on the sea level of the Gulf of Mexico.

Materials: metric ruler, 2 net bags, ice, water, nonporous rocks, 2 two-gallon aquariums or similar containers, balance and weights, 500 ml flask, two-hole stopper for flask, thermometer and glass tube to fit in stopper, clamp on light with 100 watt bulb, food coloring, internet

Procedure:

Part I: What is the impact of the melting of the Earth's ice on sea level?

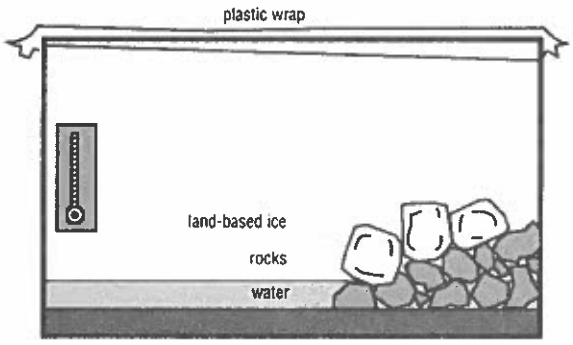
1. Place rocks on one side of the aquariums so that both have the same topography.

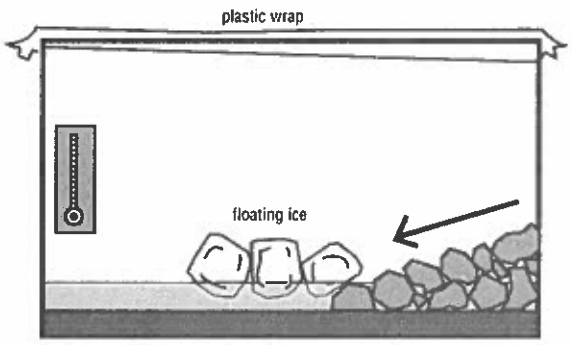
2. Use the balance to divide the ice into two equal sets. Place one bag of ice on the bottom of one aquarium. This will represent the floating ice such as North Polar Ice Pack.

3. Place the other bag of ice on the rock of the second aquarium. This will represent the land based ice and snowfield (i.e. mountain glaciers, ice fields of Antarctica and Greenland).

4. Add water to each aquarium so the levels are the same. Carefully measure and mark the water level in each aquarium. Record your water level measurements.

5. Predict which what will happen to the water level in each aquarium as the ice melts.





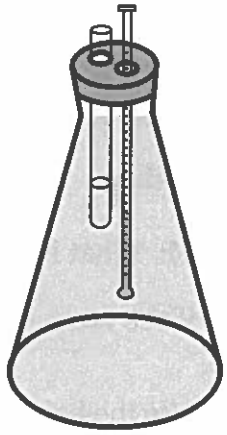
6. After all the ice in each aquarium has melted; carefully measure the water level in each aquarium. What is the water level in each aquarium?
7. What inferences can you make about the melting of the North Polar Ice cap and floating ice caps on sea level?

8. What inferences can you make about the melting of land-based ice and snowfields on sea level?

9. Which would you expect to have a greater affect on sea level—the melting of the North Polar or South Polar ice caps? Would it make a difference? Why?

10. What effect would a rise in sea level have on the Texas Gulf coast?

Part II: What is the impact of an increase in temperature on the sea level?



1. Carefully slide the thermometer and glass tube into the holes in the stopper. USING FORCE TO INSERT THERMOMETER OR GLASS TUBE INTO THE STOPPER WILL CAUSE THEM TO BREAK.

2. Completely fill the flask with very cold water. Add drops of food coloring to the water to improve visibility.

3. Place the stopper into the flask. The water should rise a short distance in the tube.

4. Prepare a data table similar to the one below. Provide space to record data for 20 minutes.

Table 1: Temperature and Level of Water as Heated

Time/Minutes	Temperature, degrees C.	Level of Water, mm
0		
2		
4		
6		
8		

5. Record your predictions as to what will happen to the water level when exposed to heat.

6. Place the flask under the light. Turn on the light.

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7. Record both the temperature of the water and the level of the water every two minutes.

8. Convert your team's data into a graph. Remember the manipulated variable (temperature) is written on the x-axis and the responding variable (level of water) is written on the y-axis.

9. Why did the level of the water in the flask change?
10. What is the relationship of the volume of water and temperature?

11. Thermal expansion occurs when a substance is heated and the volume increases due to increasing movement in their molecules. Explain the role of thermal expansion in sea level rising.

12. What does this experiment suggest might occur to the sea level if the ocean temperature rises sufficiently?

13. Examine Fig. 9.3, the role of thermal expansion in sea-level rise. The global sea-level change due to the melting of small glaciers is shown by the heavy solid line. Above it, in the light line, is an estimated sea level curve for increased greenhouse gases and the resulting rise in ocean temperature. The dotted line reflects the portion due to thermal expansion. What does this graph indicate about the impact of sea level rise due to thermal expansion?

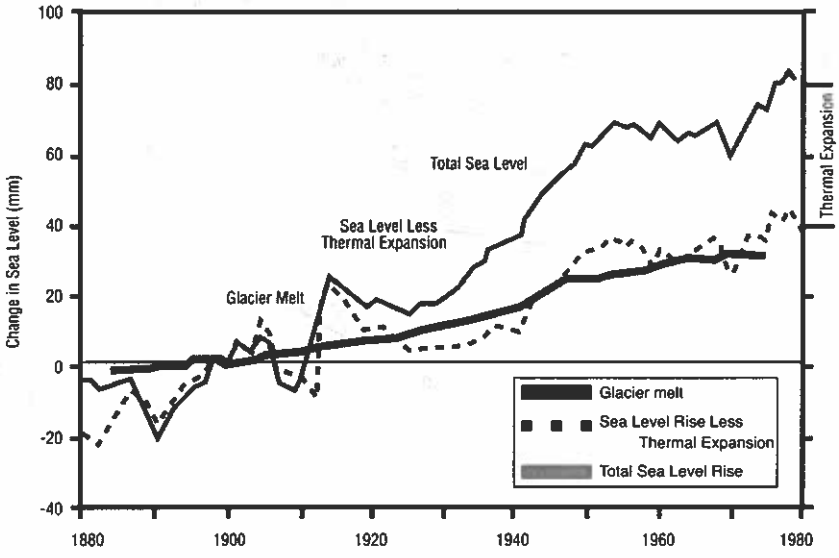


Fig. 9.3. Role of thermal expansion in sea-level rise.

Part III: What would be the impact of the sea level rising on the coastal zone?

1. Studies have estimated that along the Gulf and Atlantic coasts, a one-foot (30 cm) rise in sea level is likely by 2050 and could occur as early as 2025. Examine Figure 4. If there is no more subsidence, areas which are less than 1.5 meters above sea level would be flooded a few times per month with a 70 cm rise in sea level. Which areas of the Texas coast would be subjected to regular flooding due to tides?

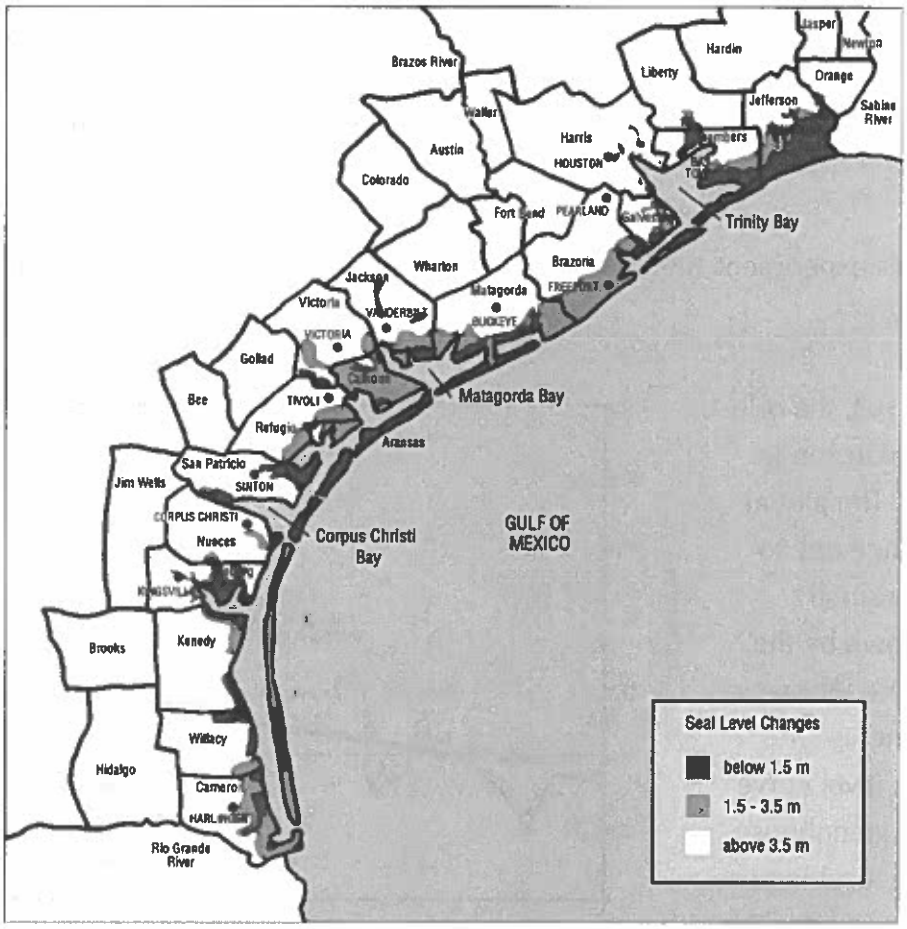


Fig. 9.4. Sea Level Changes

2. Examine the impact of sea level rise on other areas of the Gulf of Mexico by using the following internet site to view maps of potential sea level rises: http://www.epa.gov/globalwarming/publications/impacts/sealevel/maps/gulf.html What will be the impact on Louisiana and Florida?

3. Studies indicated that rising sea level has an impact in many different areas. Use resources including http://www.epa.gov/globalwarming/imapcts/index.html to determine the impact on each of the following: wetlands and other low-lying lands, erosion of beaches, increased flooding and increased salinity of rivers, bays and groundwater tables. Use the information to prepare a brochure providing information on the impact of rising sea level on the Texas coastal zone.

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10. What Causes Hurricanes to Form?

Meteorologist _____ **Team** _____

Most people think of weather in the tropics as calm. Warm breezes, steady temperatures and brief tropical rain showers. Ironically these regions also produce some of the most violent storms on Earth. These storms are tropical cyclones. Cyclones with sustained winds exceeding 73 miles per hour are called hurricanes in the Atlantic, Caribbean Sea, Gulf of Mexico and in the eastern and central Pacific Ocean. In the western Pacific, they are called typhoons and in the Indian Ocean, cyclones. As a team of meteorologists who study and analyze weather patterns, you are going to analyze what we know about hurricane formation.

Materials: Globe or world map

Procedure:

1. As a team, work together to develop your responses to the questions so that your team will become hurricane experts. Hurricanes just don't appear overnight. There are stages in the formation and decay of a hurricane. Most hurricanes form between the latitudes of 5 degrees and 20 degrees over all the tropical oceans except the South Atlantic and eastern South Pacific. The North Pacific has the greatest number of storms, averaging about 20 per year. The formation of the tropical storms that grow into U.S. hurricanes can begin far out in the Atlantic Ocean, in the Gulf of Mexico, in the Caribbean Sea or relatively close to shore off the Atlantic Coast. Fortunately for people living along the Gulf and eastern coastal areas, on the average fewer than five hurricanes develop annually in the warm portion of the North Atlantic. The average Northern Hemisphere tropical storm moves from east to west in the tropical trade winds. Use a globe or a map and locate the tropic latitudes off the western coast of Africa. This is the area were some of the hurricanes form. If conditions are favorable, they grow into very large storms before reaching the United States. Why would some of the strongest hurricanes take more than a week to reach the United States?

2. The first stage of a tropical storm's life cycle is not really known and understood. This is partly due to the complex system of the storm. Another factor is the lack of observations. On a globe or world map, locate the area of the Atlantic off the coast of Africa near the Cape Verde Islands. Explain why little is known about how storms begin that form in this area.

3. Hurricanes begin to develop in a tropical disturbance that is an organized area of showers and thunderstorms that formed. There are heavy rains and gusty winds. In most cases, the

disturbance maintains its identity for 24 hours and then disintegrates. Many of these types of disturbances occur each year, but only a few continue to develop and actually form a hurricane. Why do you think that most do not form hurricanes?

4. Hurricanes form most often in late summer when the ocean-surface temperatures reach 27°C (80°F.) or higher. The warm water is needed to supply the heat and moisture to the air to form the storm. The tropics supply the key ingredients needed for tropical cyclones to form: wide area of warm ocean water, air that is both warm and humid and weak upper-air winds blowing from the same direction as winds near the surface. Hurricanes are one of the ways the atmosphere moves excess heat from the tropics to the middle latitudes. In simple terms, a hurricane is a giant machine in nature, a heat engine that converts the heat energy of warm tropical ocean water and atmosphere into wind and waves. What might happen if tropical depressions, tropical storms and hurricanes did not occur?

5. Fewer than 10 percent of the tropical disturbances grow into a tropical storm because the right conditions are rare. See Figure 10.1. The conditions include ocean water above 80°F because a large amount of warm, moist air is needed. The warm water must be at least 200 feet deep; otherwise the storm would bring up cold water from below. Cold water would stop the formation of the storm. The winds on the surface of the water need to be coming together -converging-near the surface to form a center. As the winds come together, the warm air rises. The air needs to be unstable so it will continue to rise. The air up to about 18,000 feet needs to be humid as it moves into the storm. The extra water vapor is needed to supply energy. As the huge amount of water vapor condenses, it releases heat energy. The heat warms up the air

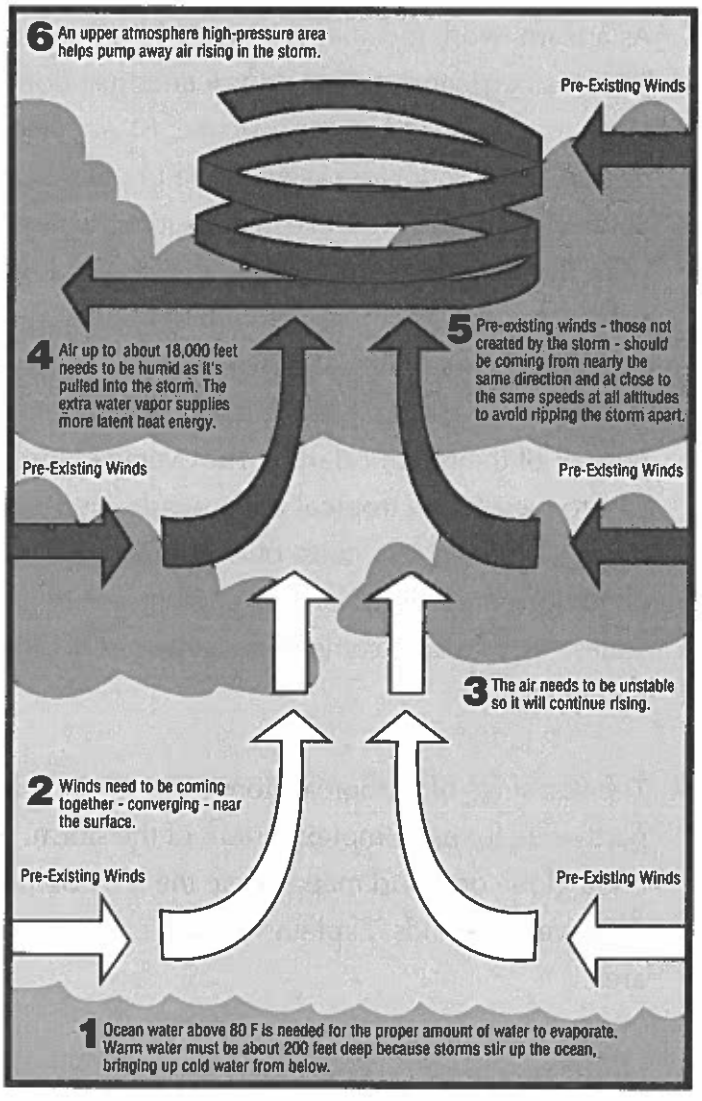


Fig. 10.1. Diagram of hurricane formation

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and it is less dense so it moves upward. This reduces the pressure near the surface. This causes more air to rapidly move into the center and upward. Winds not created by the storm should be coming from nearly the same direction and at close to the same speeds at all altitudes. If the winds are from different directions and different speeds, they will tear apart the storm. The clockwise winds of an upper level high-pressure area are needed to move the rising air away from the storm so that more warm air can rise. If any of the above conditions do not exist then tropical disturbances will not develop into tropical depressions, tropical storms and finally into a hurricane. Imagine that you are an air molecule above the surface of warm ocean water just outside the center, describe what happens as you move to the top and out away from the storm?

6. Based on international agreement, when a storm's winds are less than 38 miles (61 kilometers) per hour, it is called a **tropical depression.** When the winds are between 38 and 74 miles (61 and 119 kilometers), it is called a **tropical storm.** It is during this phase that it is given a name (Alice, Andrew, Hugo, Mitch, etc.). If a tropical storm becomes a hurricane, the name remains the same. Between 80 and 100 tropical storms develop each year. When the winds reach more than 74 miles (119 kilometers) per hour and have a rotary motion, it becomes a **hurricane**. Why do you think that there are so few tropical disturbances that develop into a hurricane?

7. In a hurricane, warm, moist surface air rushes to the core of the storm. There it turns upward and moves up in a ring of cumulonimbus towers.). The rotation of the Earth causes the air to spiral counterclockwise (in the Northern Hemisphere. This forms a doughnut shaped wall of intense activity surrounding the center of the storm. This area is called the **eye wall**. This is the area of the greatest wind speeds and heaviest rainfall. Surrounding the eye wall are curved bands of clouds that trail out from the storm in a spiral. Near the top of the hurricane the air is flowing out which moves the rising air away from the center of the storm. This provides room for more air to move in at the surface. At the very center of the storm is the **eye** of the hurricane. The eye of the hurricane is a feature that

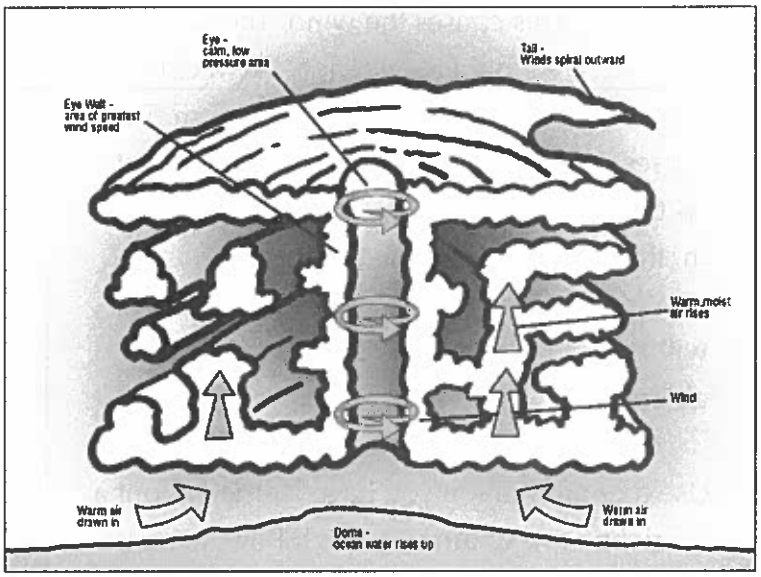


Fig. 10.2. Inside a hurricane.

makes it unique from cyclonic storms of the northern latitudes. The eye is a somewhat circular area of comparatively light winds. It is usually rain free and may vary from 4 to more than 40 miles in diameter. Diameters of 12-20 miles are common. The eye is an area where precipitation stops and the winds subside. It offers a break from the extreme weather in the rest of the hurricane. From the outer edge to the center, the barometric pressure may drop from 1010 millibars to 950 millibars in the center. Use Figure 10.2 to locate the parts of a hurricane and to trace the movement of air.

8. Water powers a hurricane (Figure 10.3). Warm, moist air above the warm ocean water rises. As it rises, the air is cooled and water vapor condenses into drops of water. Heat is released when water vapor condenses into water drops. This heat is called latent heat. It has been estimated that in one day a hurricane can release enough energy to supply all of the nation's electrical needs for about six months months. This latent heat warms the surrounding air making it lighter. The lighter air rises. As warm as rises, more air flows in to replace it. This causes the wind. The low-pressure area in the center acts like a chimney. Warm air is drawn in at the bottom. Then it rises in a column, it cools and spreads out. As the air inside rises and more air is drawn in, the storm grows. Because the Earth is rotating, the air travels in a spiral path. What will happen if warm, moist air is not available?

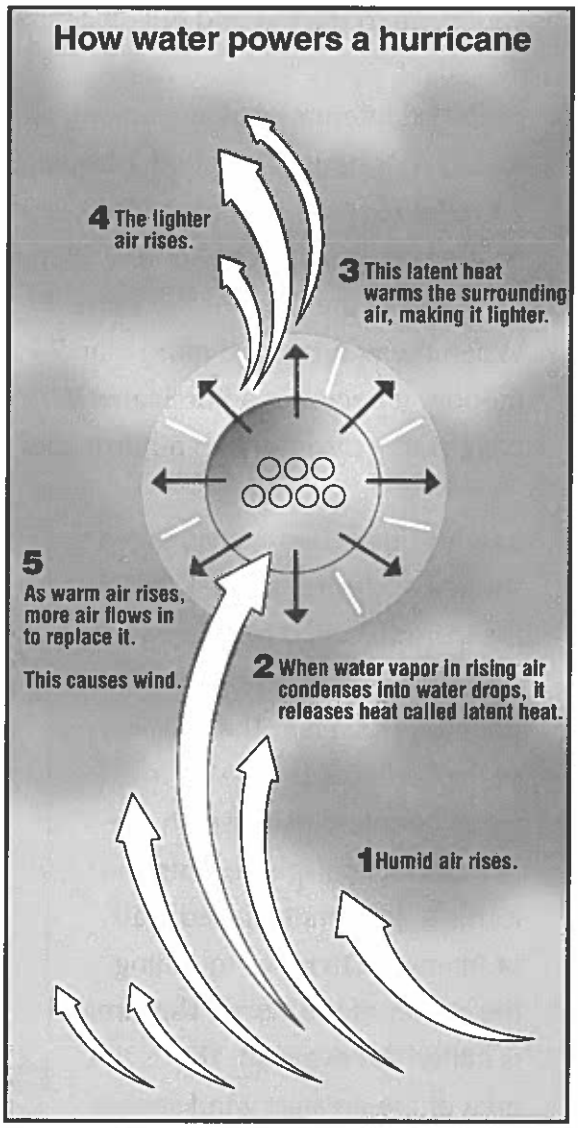


Fig. 10.3. How water powers a hurricane.

9. Use the information you have learned about a hurricane to explain why the following cause a hurricane to weaken in intensity:
   a. moving over ocean waters that cannot supply warm, moist tropical air.
   b. moving over land.
   c. a location where the air flows in the atmosphere above is unfavorable.

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10. The clockwise winds around an area of high pressure (Bermuda High) that dominate the Atlantic Ocean are the steering currents for many of the hurricanes. Locate the Bermuda area on the globe or map. Place a finger on this area and trace a large circular clockwise pattern around the area. (Figure 10.4) Note the direction that the pattern would guide a storm. Explain why large Bermuda High area guides hurricanes to the United States.

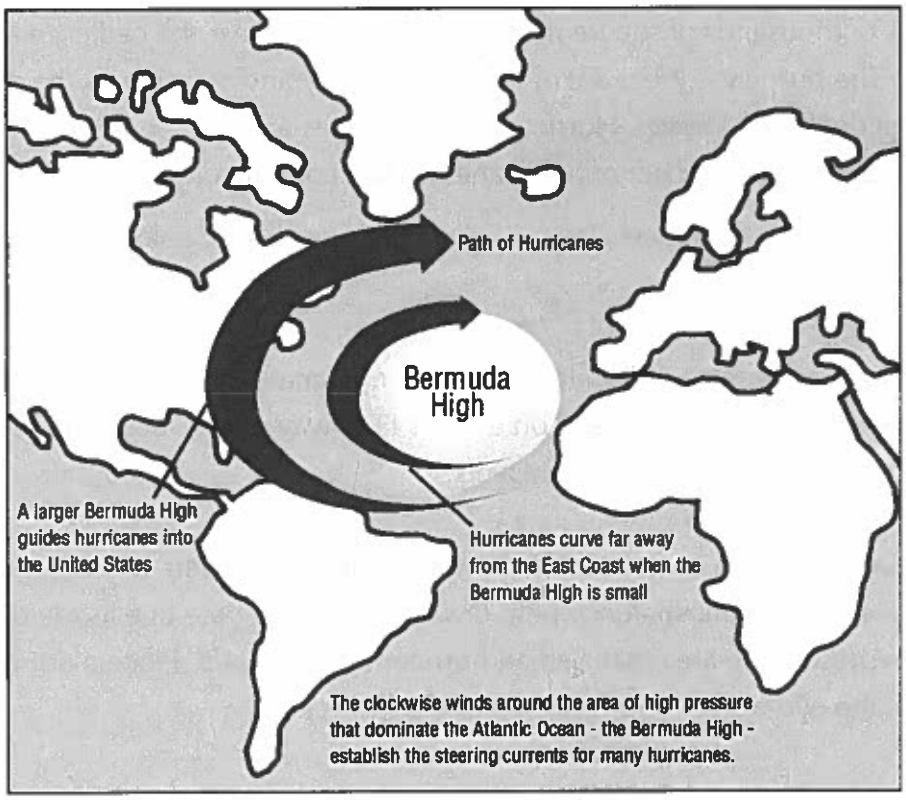


Fig. 10.4. The Bermuda High

11. Now use your finger and make a small circular clockwise pattern around the Bermuda area. (Figure 4) Explain why if the Bermuda High is small the hurricanes curve away from the East Coast into the Atlantic Ocean.

12. The life cycle of a hurricane has been compared to that of humans. It is born over the ocean, spends it teenage years as a tropical storm over the ocean, rages onshore as an adult, and dies miles inland. Analyze the analogy. How is the hurricane life cycle like that of humans? How does the hurricane life cycle differ from that of humans?

13. Research hurricanes on the Internet and other sources. Use what you have learned about hurricanes and prepare a brochure or multimedia presentation to explain hurricanes to the students in the lower grades or the public.

11. What Is the Impact of a Hurricane on the Coastal Zone?

Disaster Analysis Official_____ **Team** _____

Hurricanes called "the greatest storms on earth" are a form of a tropical cyclone. They are an immense storm system that swirls counterclockwise, covering thousands of miles, sometimes hundreds of thousands of square miles. The wind gusts near the center may be over 200 miles per hour. The hurricane, because of its size, intensity and duration, is the most destructive weather phenomenon known. Hurricanes have names and numbers. You and your team are going to investigate the impact of hurricanes on the coastal zone.

Materials: ruler, transparency sheet, Texas Highway map, different colored transparency pens

Procedure:

1. Mature hurricanes average 375 miles in diameter. A small hurricane may be only 100 miles in diameter. Locate the legend on a Texas Highway map. Determine how many miles one centimeter on the map represents.

2. On a transparency sheet, use a ruler to draw a line that represents 100 miles using the map legend. Use a colored transparency pen; draw a circle using the line as the diameter. This circle will represent the area that a small hurricane will impact. Place a dot near the center to represent the eye wall or strongest part of the hurricane.

3. Extend the line to represent 200 miles and use it to draw the diameter of a circle to represent the impact of a hurricane that is 200 miles in diameter. Use another color of transparency pen and draw a circle of 50 miles around the center. This circle represents the area where the hurricane has the greatest impact.

4. Use the transparency to determine the area of the coast that will be affected by different size hurricanes, by placing the center at the point of the coast where the hurricane will reach land. Then determine which is the point (edge of circle) to east and west of the eye that the hurricane will reach. Prepare a table in which to record the data. Remember that the impact of a 200-mile hurricane is approximately 100 miles east and west of the center. Repeat this for a small 100-mile diameter hurricane. A major hurricane may have winds of 200 miles an hour that extend 50 miles from storm center. Storm surges can also extend more than 50 miles. Record the points that would be impacted by these winds and storm surge.

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Table 1: Impact Area of Hurricanes on the Texas Coast

Location hurricane reaches land	200-mile diameter hurricane impact to the east	200-mile diameter hurricane impact to the west	100-mile diameter hurricane impact to the east	100-mile diameter hurricane impact to the west	50-mile impact zone to the east	50-mile impact zone to the west
Port Isabel						
Corpus Christi						
Port Lavaca						
Brazosport						
Galveston						
Port Arthur						

5. What conclusion can you reach about the area of impact of a hurricane on the Texas coast?

12. What Is the Impact of a Hurricane's Storm Surge and Wind?

Disaster Analysis Official_____ Team_____

The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from different size hurricanes. You and your team are going to analyze the impact of the storm surge and wind of hurricanes on the coastal zone.

Materials: Texas Highway Map

Procedure:

Part I: What is the impact of a hurricane's storm surge?

1. The destruction from a hurricane is a result of several factors. These are the wind, storm surge or storm tide, rain and floods and tornadoes. Analyze Table 1: Saffir-Simpson Hurricane Scale (page 498). What is the pattern that you notice from category 1 to category 5 hurricanes?

2. Hurricanes are usually described in terms of their wind speeds, but flooding caused by the high water a storm brings kills more people than the wind. What do you think is the reason for the greater number of deaths due to flooding than wind?

3. Most hurricane deaths come from the sea in the form of a storm surge. The storm surge is responsible for 9 out 10 victims. While over the ocean and away from land the low pressure and water being pushed to the center may combine to create waves of 50 feet or higher. As the storm moves closer to land, the winds continue pushing water inward to the storm's center. But the shallow floor of the Gulf of Mexico blocks water from flowing away. Since the water is unable to flow away, it piles up higher and higher to the right of the eye. The final height of the storm surge or "storm tide" is a combination of the astronomical tide that is approximately 2 feet and the storm surge. So a 2-foot normal high tide plus a 10-foot storm surge will push the water 12 feet above mean sea level. See Figure 12.1. The surge does not arrive as a "wall of water," but more like a quick rise in the tide to extremely high levels. Imagine that a very strong hurricane with a storm surge of 18 feet reaches the coast what will be the height of water above sea level?

4. In addition, waves caused by the high winds could add up to 10 feet to the storm surge. What would be the total height of water of a 10-foot storm surge? A 15-foot storm surge? An 18-foot storm surge?

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Table 1: Saffir-Simpson Hurricane Scale

Factor	Category 1	Category 2	Category 3	Category 4	Category 5
Barometric Pressure (inches)	More than 28.94	28.50 - 28.91	27.91 - 28.47	27.17 - 27.88	Less than27.17
Wind Speed (miles per hour)	74 - 95 mph	96 -110 mph	111 -130 mph	131 -155 mph	Greater than 155 mph
Storm Surge (feet)	4-5	6-8	9-12	13-18	More than 18
Road flooding	Some coastal road flooding	Coastal and low-lying route flood 2-4 hours before center arrives	Low-lying escape routes flooded 3-5 hours before center arrives	Low-lying escape routes flooded 3-5 hours before center arrives	Low-lying escape flooded 3-5 hours before the center arrives
Building Damage	No real damage to building structures; damage primarily to unanchored mobile homes	Roof, window, door damage to buildings; considerable damage to mobile homes	Some structural damage to small residences and utility buildings; mobile homes destroyed	Damage to doors windows; some complete roof failures on small homes; complete destruction of mobile homes; major damage lower floors near shorelines	Complete roof failures on many homes and industrial buidings; complete destruction of mobile homes; major damage to lower floors of all structures located less than 15 feet above sea level
Other Damage	Trees and shrubs	Trees blown down	Leaves blown off trees; large trees blown down	Shrubs, trees and all signs blown down.	All shrubs, trees, and signs blown down.
Coastal Flooding	Minor	Flooding in low-lying areas	Terrain lower than 5 feet above sea level will be flooded inland 8 miles or more	Terrain lower than 10 feet above sea level will be flooded 6 miles inland	Terrain lower than 15 feet above sea level will be flooded; flooding 5-10 miles inland
Examples	Hurricanes Allison (1995) and Danny (1997)	Hurricanes Bonnie (1998) and Georges (1998)	Hurricanes Roxanne 11995) and Fran (1996)	Hurricanes Felix and Opal of 1995	Hurricanes Gilbert (1988) and Mitch (1998)

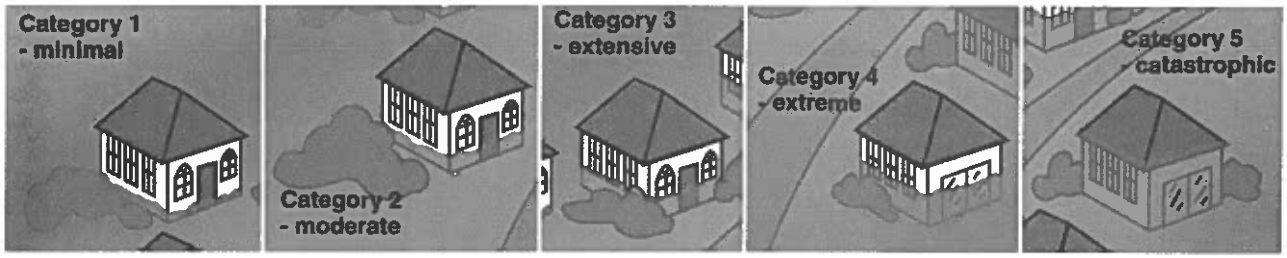


Fig. 12.1. Graphic depiction of Saffir-Simpson Hurricane Scale.

5. This buildup of water level can cause severe flooding in coastal areas. Much of the United States and Texas' densely populated coastline lie less than 15 feet above the mean sea level, what will be the impact of a storm surge of 10 feet or more?

6. The slope of the Texas coast is very gradual so a major storm surge can extend miles inland. It could extend up to 50 miles inland depending on the topography. Use the Texas highway map and note that many cities are located along the bays on the coast. The storm surge will enter the bay and push the water from the bay back up the rivers and streams and on the surrounding land. Use the side of the Texas map that has enlarged maps of the Beaumont-Port Arthur area, Houston-Galveston, Brazosport, Corpus Christi and Rio Grande Valley. Use the legend and a ruler to determine the cities in each area that would be impacted by a 10 -15 foot storm surge that only flooded areas 10-15 miles from the water (bay or gulf). List the cities in each area that will be impacted.

7. A storm surge greater than 8 feet can extend 150 miles along the coastline. Use the Texas highway map and determine where the storms surge would reach if the hurricane eye reached land at Galveston? At Port Lavaca? At Corpus Christi?

8. Wave and current action associated with the storm surge causes extensive damage. This action can erode beaches and erode cuts across barrier islands. Outline an area on the floor or desk that is one foot square. Now stand a ruler up in the square to designate a 1 cubic foot space. One cubic foot of water weighs 64 pounds. This is the force that a cubic foot of moving water could exert on an object in its path. Why is rapidly moving water that is only 1 foot deep able to move cars off the highway? What would be the force pounding of 1 cubic foot of water moving at the rate of 1 foot per second on an object in 1 minute (60 seconds)?

9. The extensive and repeated pounding by the storm surge and waves can demolish structures not designed to withstand such force. Water weighs nearly a ton (2,000 lbs.) per cubic yard. What would be the approximate force in pounds of a storm surge of 9 feet? 12 feet? 18 feet?

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10. More than 6,000 people in the Galveston hurricane of 1900 died from drowning as the storm surge swept across the island destroying buildings. Explain why the death rate was so high? What is the impact of a storm surge on wildlife, crops and livestock?

Part II: What is the impact of the wind in hurricanes?

1. Hurricane winds are not symmetrical about the eye. When facing the direction in which the hurricane is moving, the strongest winds will usually be to the right of the eye. Using Table 1: Saffir-Simpson Hurricane Scale, compare the difference in the impact of the winds of a category 1 storm and a category 4 storm. How does the destruction of trees, shrubs, signs, homes and buildings compare?

2. Explain why people are asked to leave mobile homes and seek shelter elsewhere in all hurricanes.

3. Hurricane winds within 50 miles of the storm center may reach 200 miles an hour or more. The strength of the wind decreases in relation to the distance from the eye. At 200 miles from the eye the winds may be gale force and gusty. Use the transparency you created or use a ruler and the legend on the Texas Highway Map to determine the area of impact of a storm of this size. Determine the impact if the eye of the storm enters the coast in the following locations: Rio Grande Valley, Corpus Christi, Port Lavaca, Brazosport, Galveston and Port Arthur. Record your findings in a table.

4. What will be the impact of these winds on windows in buildings including high rise buildings, power lines, signs, communications towers and roofs of buildings, boats, cars and homes?

5. The wind can also carry debris that can be very dangerous. In winds over 150 miles an hour, what will happen to the shattered glass from buildings especially high rise buildings? What will happen to the metal from signs and roofs? The wood that the winds rips from buildings?

6. The wind is a major threat to life because it can destroy buildings. Most of the damage in southern Florida associated with Hurricane Andrew was wind-related. Most of the damage in the Corpus Christi area during the 1971's Hurricane Celia was caused by high winds. As winds increase, air pressure against an object increases at a much higher rate. The pressure increases with the square of the wind speed. So an increase of 10 times in wind speed results in a 100 times increase in pressure. Consider a house that is 100 feet long and 10 feet high with a 100 mile per hour wind blowing against it. Wind at 100 mph exerts a force of about 40 pounds per square foot. One side of the house would be 100 feet x 10 feet or 1000 square feet. The total force on one side of the house would be 40 lbs per sq.

ft. x 1000 feet. What would be the total force on one side of the house? With a wind of 160 miles per hour, the force would be 100 lbs per sq. ft. x 1000 square feet? What would the force be? Why does this cause a total collapse of buildings?

7. What will happen to people in a building that collapses during a hurricane? What will happen to people if the building collapsed as a result of the wind and a storm surge occurs?

8. What could be done to reduce the impact of the wind in hurricanes?

9. Hurricanes can produce tornadoes. The tornadoes produced are not as strong (about half the size) and nor as long lasting (usually minutes) as the twisters produced by weather systems inland, they do cause destruction and death. Hurricane Beulah produced 115 tornadoes in 1967, including 67 in one day. Hurricane induced tornadoes tend to form just ahead of the storm's reaching land. They can occur between 60 and 240 miles from the storm's center. What kind of damage would a tornado cause?

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13. What Is the Impact of Rain and Floods from a Hurricane?

Disaster Analysis Official_____ **Team** _____

Once a hurricane moves over land, it loses the source of its energy and weakens. However, it's destructive potential is still tremendous. The rainfall can be dangerous and destructive. You and your team are going to analyze the impact of the rain and resulting floods from hurricanes on the coastal zone.

Materials: Texas Highway Map

Procedure:

1. A hurricane can result in 6 to 12 inches of rain over the area it crosses. In some cases the rainfall may be over 30 inches. What would be the effect of 6 to 12 inches of rain in the area where you live? Thirty inches of rain?

2. Use the Saffir-Simpson Hurricane scale; what would be the impact of large amounts of rain with a category 2 hurricane? With a category 4 hurricane?

3. Torrential rains from tropical storms can also result in widespread flooding in the coastal zone. They have provided proof that everyone in the coastal zone may live in a flood plain. Tropical Storm Allison in June 2001 is an example. Allison brought rain on June 5th and then returned again on June 8th to dump more rain as people were cleaning up from the first flood. At least 35 inches of rain fell in the densely populated East Harris County. More than 15 inches fell over 2,180 square miles and 30 inches over 74 square miles. Locate this area on the Texas Highway Map. Locate Katy on the west side of Houston. This area west of Houston received very little rain. Turn to the other side of the map and locate the enlarged map of Houston-Texas City-Galveston Area. Examine the east side of Houston and the downtown; note the streams and bayous that were flooded.

4. Tropical Storm Allison caused an estimated $4.8 billion in property damage. All this was directly a result of the rainfall and flooding. Allison holds the record for causing the greatest level of stream flooding in the San Jacinto River Basin. Tens of thousands of homes and businesses, including downtown office buildings, hospitals, theaters, museums and the Texas Medical Center. How would the impact have differed if Allison had dumped the rain west of Houston in Wharton County instead?

5. Allison's impact continued as the storm moved across the United States. In the end, 28 counties in southeast Texas and counties in Louisiana, Florida and Pennsylvania were

declared disaster areas. Fortunately, Allison's wind speeds were not excessive. What would have been the impact if Allison had actually been a category 1 or 2 hurricane? How would this have affected the flooding and destruction?

6. In October 1994, an unnamed storm brought about by the collision of two weather fronts from the remains of Hurricane Rosa dumped heavy rains over a large portion of southeast Texas. Locate Liberty and Montgomery counties on the Texas Highway map. These counties received between 30 and 35 inches of rain Twenty inches of rain fell from College Station east to Beaumont and from Lufkin south to Houston. Locate this area on the map. Which river basins flooded? What bay did the floodwaters enter? How did the floodwaters reach the Gulf of Mexico?

7. Within a few hours, the rains forced more than 14,000 people from their homes to higher ground. The rivers, bayous, creeks, channels and drainage ditches overflowed their banks flooding roads. Every major highway in and out of Houston and the neighboring cities and towns were closed to travel as flood waters over roads and bridges. The storm caused 23 deaths and 38 counties were declared disaster areas. What would one find in the floodwaters? Imagine that the floodwaters went through your house and garage. What would the water carry downstream? List the items.

8. Of the items found in houses and garages, would there be any hazardous wastes such as paints, thinners, pesticides or household cleaners that could contaminate the ground water? Explain.

9. As the floodwaters slowly subsided, people returned to their homes to find them damaged and the contents destroyed. Trash and mud was also carried into the homes. Think about your home. If it were flooded with 2-4 feet of water, how would you get it cleaned up and what would you need to replace?

10. Another problem after a flood has been carcasses of livestock and dead pets. What problems could these cause? Rattlesnakes, water moccasins, fire ants and mosquitoes are also problems when people return to their homes. Explain why.

11. The impact of the rain and floods is not just in the coastal zone. Tropical storm Amelia in 1978 poured over 4 feet of water in the Hill Country northwest of San Antonio. This resulted in flash floods killing 26 people. Many of these deaths were along the Medina and Guadalupe rivers. Use the Texas Highway map and determine the rivers that would flood if the rains from a hurricane moved inland and dropped 10 to 12 inches or more in the

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following areas: San Antonio, San Marcos, Austin, Waco, Bryan, Dallas and Tyler. Construct a table based on the following example and record the data.

Table 1: Potential Flooding from Rain

Location of Rainfall	Rivers	Downstream Cities and Towns	Coastal Area
San Antonio			
San Marcos			
Waco			
Bryan			
Dallas			
Tyler			

12. As rain falls inland, the water flows downstream towards the Gulf. Use the highway map to determine which towns and cities that are downstream from the rains might also flood. Record the information in the table.

13. Summarize the impact of rain and flooding from tropical storms or hurricanes on the economy, agriculture, transportation, businesses, utilities, homes, animals and wildlife of the area.

14. Imagine being forced to leave your home, your home being damaged or demolished by wind or loosing your possessions to flooding. How would you feel? How would this affect you mentally?

15. The population is increasing not only in the coastal zone but in inland areas as well. How will this affect the impact of future tropical storms and hurricanes?

14. What Affects the Hurricane Impact?

Environmental Geologist _____ **Team** _____

Hurricanes are severe tropical storms that speed up coastal processes. In a few hours hurricanes can change the erosion and deposition that usually take months and years of normal activity. Most hurricanes strike the coast from the southeast, although they may move along the coast, striking it at any angle. Hurricanes become an even more serious problem each year. This is a result of the increasing population, industry and development along the Texas coast. Hurricanes are very high-energy storms that have a very significant impact on the coastal environments that are already stressed by intensive use. As a team of environmental geologists, you are going to investigate the impact of hurricanes.

Materials: Texas Highway Map, Stream table or large plastic container, sand, water

Procedure:

Part I: What are the hurricane effects on the Texas Coastal Zone?

1. Hurricanes display highly variable wind velocities, storm surges and rainfall. However, a general hurricane model is useful in predicting storm effects of the area of Texas coastlines where the hurricane moves ashore. Examine Figure 14.1 to identify the physical features characterizing the Texas coast. As a team, predict the impact of the hurricane on each of the physical features:
   a. Barrier islands
   b. Tidal inlets or passes
   c. Lagoons and bays
   d. Rivers and deltas
   e. Vegetation on the barrier islands
   f. Dunes and beaches

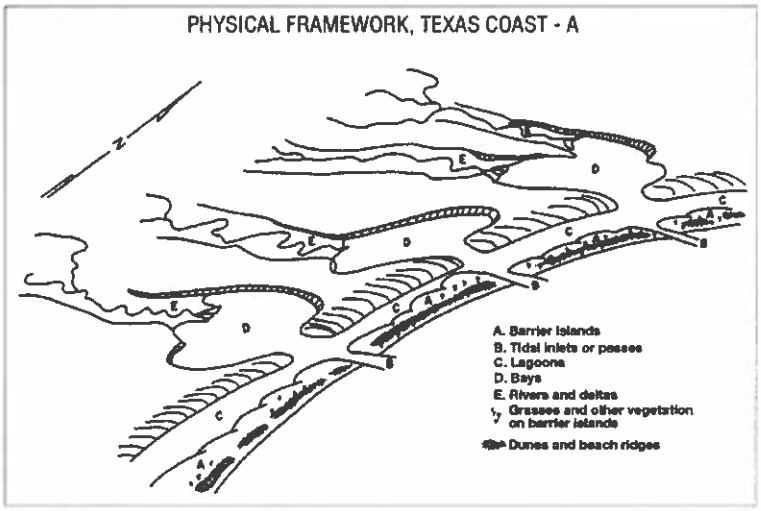


Fig. 14.1. Physical framework of a Texas coastline

2. As the storm approaches, it produces rising tides and wind speeds. The longer the storm remains offshore in the Gulf, the greater will be the storm surge. Storm surges may reach 25 feet. Will the storm tides be higher in the narrow, funnel-like bays or along the straight

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barrier island shoreline? Explain.

3. The storm surge will deposit sand and shells on the beaches and push shelf sand onto the shore. Analyze Figure 14.2 to determine other effects as the hurricane approaches the shore.
   a. Where is wind erosion taking place?
   b. What type of water, fresh or salt, is entering the bays?
   c. What is the direction of the surge currents in the bays?
   d. What will happen to boats that are in the bay?
   e. Where is flooding taking place? What kind of water is the flood water, fresh or salt?
   f. Where is the water cutting across the barrier islands?

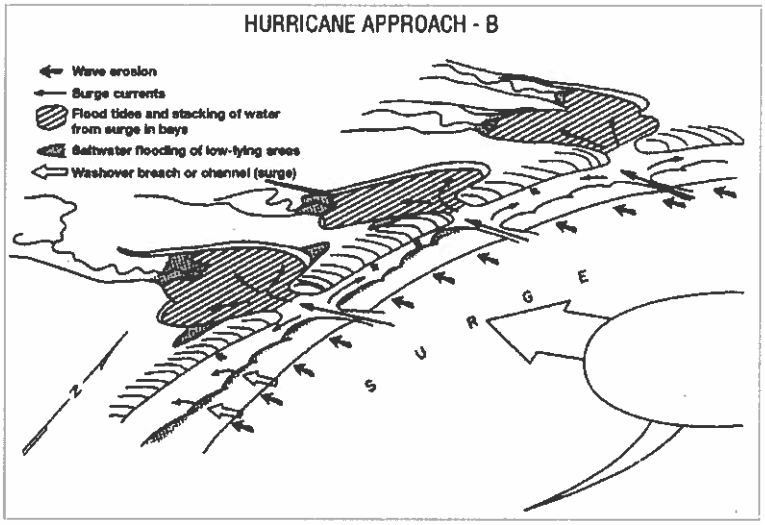


Fig. 14.2. Hurricane approach to coastline.

4. As the storm passes over the shoreline, the counterclockwise winds generate currents in the bays. Examine Figure 14.3 and note the left or south side of the eye, which direction is the water moving? The water is moving toward the Gulf so it is taking sand and sediments out of the bay through tidal passes and storm channels. Why is this referred to as flushing the bays? If the sediments in the bay contain pollutants, what will happen to them?

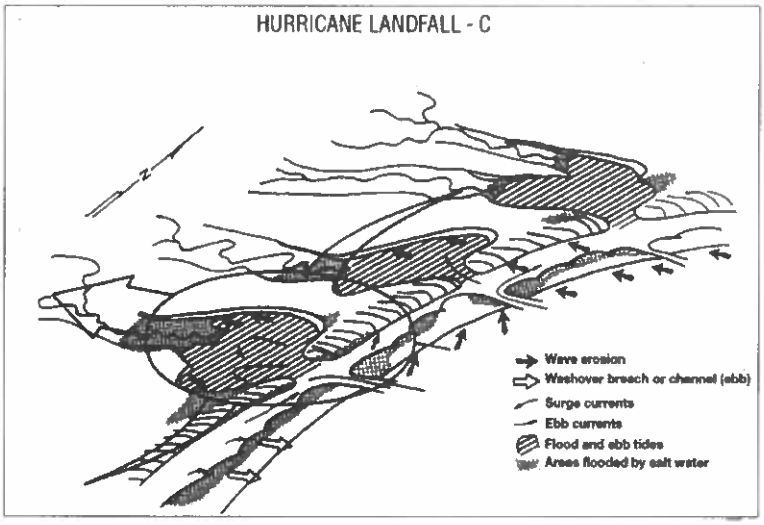


Fig. 14.3. Hurricane makes landfall.

5. On the right side or north side of the eye, what is the direction of the water? When water is stacked in bays, erosion occurs on the bay shorelines. Where is erosion taking place in Figure 14.3?

6. What is happening to the river and delta? Where is flooding by saltwater occurring? What will be the effect of flooding by saltwater on the plants and animals?

7. As the hurricane, moves inland, the currents change direction. Examine Figure 14.3. What is the direction of the currents on the barrier island shoreline?

8. As the storm moves inland, it weakens and becomes more diffused. Examine Figure 14.4. What happens to the water that was stacked up in bays during the storm? In what direction does it flow?

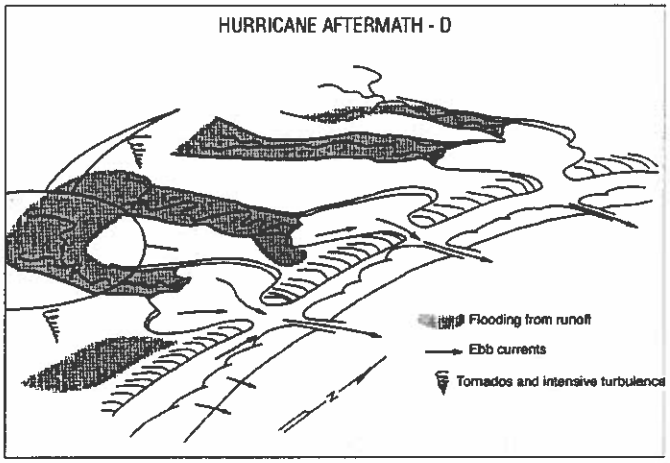


Fig. 14.4. Aftermath of a hurricane.

9. As the storm moves inland, heavy rains occur. This could range from 6 inches to as much as 30 inches are more. Use figure 4 to analyze what will happen to the rivers and their valleys and to the bays. What type of water will be entering the bays, lagoons and the Gulf? How will this impact plants and animals in these areas?

10. Another impact from a hurricane is tornadoes. Examine figures 14.1-14.4. When do they occur and where?

11. Review your predications in number 1. Based on your analysis of figures 1-4, were your predictions correct? Revise your predictions if needed and summarize the impact of a hurricane on each of the following features:
    a. Barrier islands
    b. Tidal inlets or passes
    c. Lagoons and bays
    d. Rivers and deltas
    e. Vegetation on the barrier islands
    f. Dunes and beaches

12. Use your findings to explain the impact of a hurricane to homes, buildings, people, plants, and animals that live on barrier islands? Along the bays? Along the rivers?

Part II: What factors affect the impact of the hurricane on the coastal zone?

1. Hurricanes vary in size and intensity, but several factors affect how severe their impact will be upon the coast. One of these is the bottom slope and profile of the shelf and shoreline. To determine the impact of each of these factors, use a stream table or large plastic container to create a model of a coastal shoreline on one end and add water to represent the Gulf. Change the slope of the model to determine the effect of the slope on the waves and storm surges. Draw a diagram to illustrate how the slope affects the storm surge. Explain

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why the worst storm surges are where the ocean floor slopes gradually such as the Gulf of Mexico.

2. Another factor is the astronomical tidal cycle at the time of the hurricanes approach. Use the stream table to demonstrate the impact of different levels of water (tides) on the height of a storm surge. What was the impact?

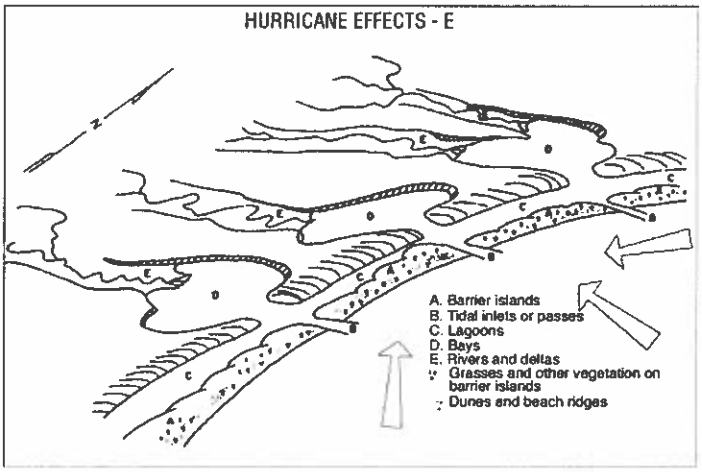


Fig. 14.5. Effects of a hurricane.

3. If the average high tide is two feet above mean sea level, what will be the impact of this on the height of the storm surge?

4. In some areas of the coast the slope is 2 feet per mile. If a storm surge passes on land during high tide what will be the impact on the coast?

5. The shape and orientation of the barrier islands, passes and upper bay areas affects the hurricanes impact. Use the highway map and note the direction of the barrier islands in the Rio Grande Valley, Corpus Christi and Galveston.

6. To determine how the orientation of the barrier island impacts the effect of hurricanes, construct a model in the stream table to test the different orientations. Make sketches of the impact of a hurricane on islands of different orientations.

7. The amount of vegetation cover in the area of impact has an effect. Locate Bolivar Peninsula, Galveston and Follets Island on the Texas Highway Map. The coastal and dune vegetation is much denser and there are few washover channels in this area compared to South Padre where vegetation is limited and washover channels are abundant. Explain how the differences would affect the impact of a hurricane. Use the stream table to create a model to investigate if your explanation was right.

8. The angle at which the storm strikes the coastline also affects its impact. How does the angle affect the impact? Which storm has the greater impact, one approaching the shoreline at an angle or one that hits it head-on? Use the stream table to create a model of the coast and create waves and a surge to hit the shoreline at different angles. What is the relationship between the angle and the impact?

15. What Is the History of Hurricanes Along the Texas Coast?

Historian _____ **Team** _____

As hurricanes can and have changed the physical features of the coastal zone, they have also had a historical impact. You are going to investigate the historical impact of hurricanes.

Materials: Texas Highway Map, map of the United States

Procedure:

Part I: What was the impact of hurricanes along the Texas coast in the past?

1. Use a Texas Highway map to locate the major Texas ports. They are Houston, Corpus Christi, Texas City, Port Arthur, Beaumont, Freeport and Galveston in order by size. Where are they located?

2. Prior to 1875, the largest Texas port was Galveston and the second largest was Indianola. It is located on Lavaca Bay near present day Port Lavaca. Locate Indianola on the Texas Highway map

3. In July1884, Prince Solms-Braunfels, commissioner general for colony of German settlers, landed in Galveston. He did not find land in Galveston so he searched for a more desirable place for receiving the future boatloads of settlers. He selected Indian Point; later named Indianola had water deep enough for permit sailing lessons to anchor. In December 1844 the first group of settlers bound for New Braunfels arrived in Indianola. Locate New Braunfels on the Texas Highway Map. Use the highway to compare the route of settlers from Galveston to New Braunfels and Indianola to New Braunfels. Which port would the better one to reach New Braunfels? Analyze the factors of distance, weather, rivers to cross and type of terrain that the settlers would travel across. Remember that they traveled by wagons.

4. Tens of thousands of immigrants from Germany, Switzerland, France, other parts of Europe and from the southern and eastern United States landed there before heading to the new lands of the west. Use the Texas Highway map and follow the route from Indianola to Victoria to San Antonio and points north and west (follow Interstate Highway 10 and Highway 87). Why did the settlers that settled in the cities and towns west of the Colorado River arrive through Indianola instead of Galveston?

5. Through Indianola's wharves moved the necessities and luxuries for life for the inhabitants of Western Texas. Guns, ammunition and other supplies for the chain of forts that pro-

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tected Texas from Indian tribes came through the port. Supplies from the port continued to nourish the settlements. Indianola played a major role in opening up a supply route through Victoria to San Antonio and on to California. In its streets was the economic interplay of steamships, oxcarts, stagecoaches, roads and railroads. Not only was Indianola, the first Texas port at which U.S. Government supplies were unloaded for Western Texas, as well as the New Mexico and Arizona Territories, there were shipments of silver, lead, copper and other exports flowing into Indianola from Chihuahuan area of Mexico. It was also the beginning of the shortest overland route to California. Indianola was called the "Mother" of western Texas. Its location was on a bay behind the barrier island much like today's largest ports. The port of Indianola no longer exists today. Predict why it no longer exists.

6. Read the article on Indianola (page 514), to learn more about its role in Texas history and what happened to this thriving seaport.

7. Locate Houston and Galveston on the Texas Highway map. How do their locations differ and how might storms affect each?

8. Galveston was once the largest port in Texas and Houston was a swamp. Read the article on Galveston and Houston in 1900 (pages 515-516). How did a hurricane change a region of the coast?

9. Each region of the Texas coast has been affected by a hurricane since the settlement of the state. Many areas have experienced numerous hurricanes. Locate Aransas County, Rockport and Aransas Pass. In 1919, each had around 1,500 residents while Corpus Christi had a population of more than 10,500. Note the location of San Jose Island and Corpus Christi on the Texas map.

10. In 1919 a hurricane washed 10 feet of water over San Jose Island killing hundreds of cattle. One carcass washed into the lobby of a Corpus Christi hotel. Use the Texas Highway map to determine how many miles the carcass was carried by the water and waves.

11. Oil storage tanks on Mustang Island burst coating Aransas County's south beaches with oil. North beach of Corpus Christi is only five feet above sea level. The 229 elegant summer homes on North Beach were swept away. Only the Beach Hotel and one other building remained. Most people living in that area were swept into Nueces Bay. In Corpus Christi itself, huge waves pounded into homes and businesses below the bluff. Two blocks inland,

buildings were crushed under bales of cotton, pilings and timbers. The official death count was 280, but some estimates ranged as high as 600. Use the Corpus Christi area map on the Texas Highway map to determine how far downtown Corpus Christi is from the Gulf of Mexico? Explain what the impact might have been if Corpus Christi was located on the shoreline instead of on a bay?

Part II: What has been the impact of more recent hurricanes along the Texas coast?

1. From the Galveston hurricane up to 2000, there have been 24 major hurricanes that have claimed nearly 3,500 lives. They have cost millions of dollars in damage, and eroded miles of beaches. How often can the coast expect a major hurricane?

2. In recent history of hurricanes along the Texas coast, the landfall areas of the storm and the damage by the storm have varied. Hurricane Carla (1961) was an extreme hurricane. She had all the features (high winds, heavy rain, extensive storm surge and tornadoes) that cause damage. Use of mass evacuation kept the death toll at 34. The wind gusts were more than 175 miles per hour and came ashore near Port Lavaca and caused damage all the way to the Dakotas. Locate Port Lavaca on the Texas Highway map. Carla washed cuts across Matagorda Peninsula and widened Greens Bayou more than a mile. Locate Port O'Connor on the map. The storm surge at Port O'Connor was14 feet and 22 feet at Port Lavaca. Why was the storm surge higher at Port Lavaca that is further inland than Port O'Connor?

3. Locate the Lavaca and Navidad river valleys. Carla's storm surge flooded their river valleys a distance of about 14 miles from the head of Lavaca Bay. Locate the San Antonio and Guadalupe Rivers. The flooding extended about 12 miles inland along these rivers. The vegetation inland is not salt- water tolerant so the storm surge flooding killed a lot of vegetation. Use a ruler and the map legend to determine the area of the flooding. The total area flooded by Carla was about 495 square miles. Use the ruler to measure a 495 square mile area around Port Lavaca.

4. In 1967, Hurricane Beulah struck the coast just north of Brownsville, moved northward to a location near Alice. Locate the area on a Texas Highway map. Beulah then turned to the southwest and moved slowly into Mexico. Beulah caused extensive rainfall from flooding. The total rainfall from Beulah was over 30 inches. Falfurrias reported 36 inches. See Figure 15.1. Approximately 22 percent of the Kingsville area was flooded as a result of the rainfall and 12 percent of the area was flooded by Beulah's storm surge tides. What percentage of the entire Kingsville area was flooded?

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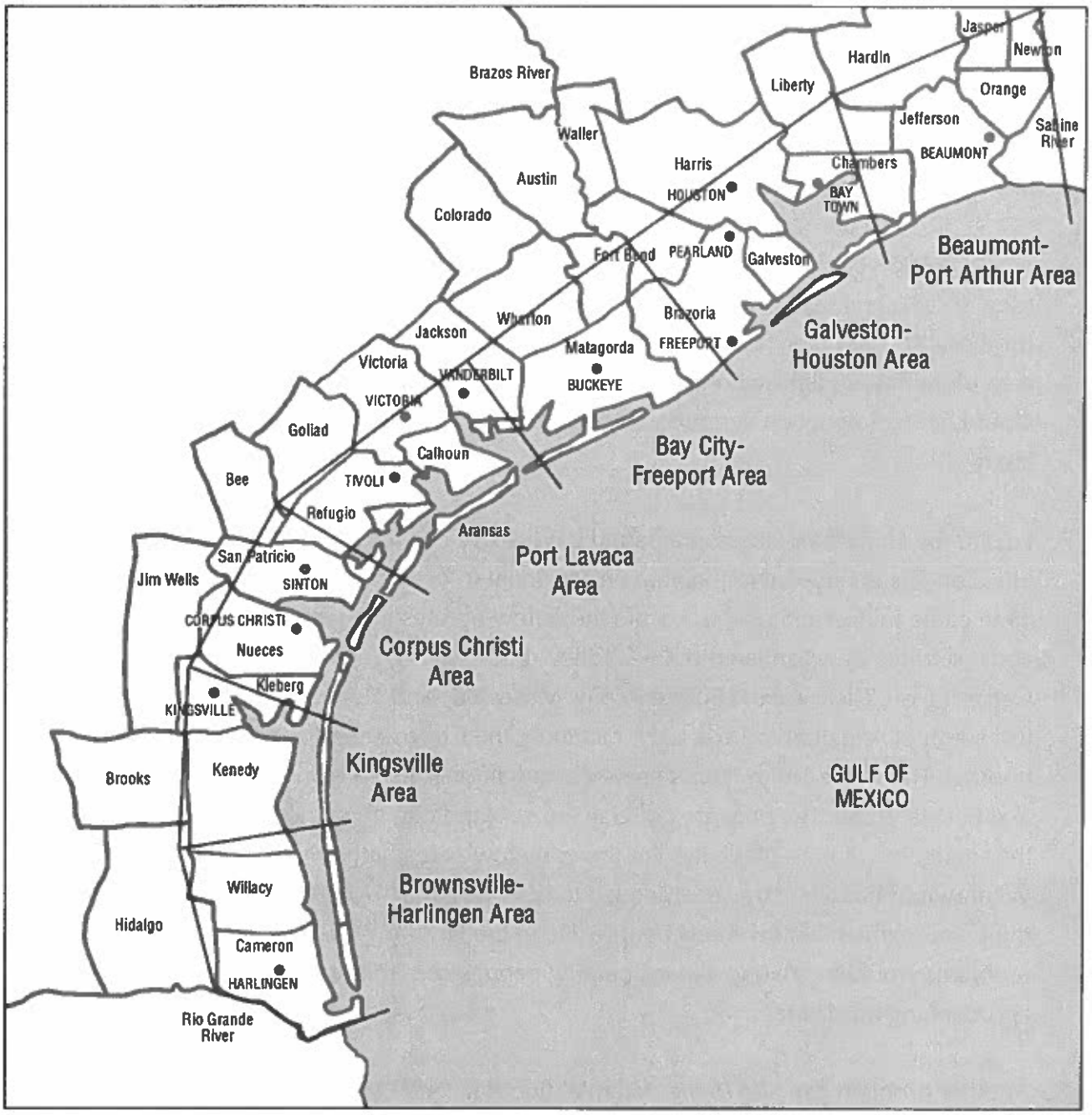


Fig. 15.1. Texas' coastal counties.

5. Note the Brownsville-Harlingen area in Figure 15.1. The area is relatively flat, and has a gentle seaward slope. The soils are impermeable mud so water does runs off very slowly. Approximately 29.7 percent of the Brownsville-Harlingen area was covered by Hurricane Beulah's rainfall flooding and 3.3 percent was flooded by Beulah's storm surge. How much of the entire area was covered by water?

6. A 50- or 100-year hurricane that had maximum winds, flood tides and rainfall could flood from 40 to 60 percent of the Kingsville area. It could also flood more than one-third of the Brownsville-Harlingen area. How would this impact the area? Use the Rio Grand Valley area of the Texas Highway map to determine the cities and towns would be affected. What would be the impact on agriculture, businesses, homes, wildlife and vegetation in the area?

7. Locate the Galveston-Houston area in Figure 15.1. Use the Texas Highway Map and the Houston-Texas City-Galveston area enlargement to determine the impact if a major hurricane came inland in the area. Locate the following sites that would be flooded: Upper ends of Trinity Bay, San Jacinto River Valley upstream from Morgan Point and areas near Cedar Bayou, Clear Lake, Dickinson Bay, Moses Bay and Dollar Bay. The lowlands from just south of Angleton to Texas City, including the Chocolate Bayou valley, would be flooded. The entire Smith Point Peninsula and all of Boliver Peninsula, Galveston Island and Follets Island. The only area of Galveston Island that might not be flooded would be the small area of man-made land in the downtown area, although it, too, might flood. What would happen if the area needed to be evacuated? Use the Texas Almanac to determine approximately how many people live in the Houston-Galveston area. What kind of problems would be involved in evacuating people from this area in a day to avoid an approaching hurricane?

8. Another problem can add to the potential flooding. See Figure 15.2. Areas of land subsidence are even more vulnerable to destruction by a storm surge. During the last 30 years, some areas have sunk as much as seven feet. Subsidence is expected to continue at about the same rate. Examine Figure 15.2 and summarize the impact of subsidence. What areas probably will flood in a future hurricane?

9. In August 1980, Hurricane Allen was called "the storm of the century" because at its strongest, its spiral clouds filled most of the Gulf of Mexico. All indications were that it would come ashore on the upper Texas coast as a powerful, full-blown Category 5 hurricane. A half million people in Texas and Louisiana were evacuated. Allen moved along the coast losing strength and came ashore around Port Mansfield between Brownsville and

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Corpus Christi. Locate Port Mansfield on the Texas map. There were 22 deaths, 12 tornadoes and up to 15 inches of rain. However, the people who had evacuated in the upper coastal did not receive a drop of rain, but the evacuation caused hours of traffic pile-ups in the Galveston area. What will be the impact of evacuating an area only to see the hurricane move into a different area? What might happen if an area is not evaluated?

10. Hurricane Alicia in 1983 was a "medium-sized " hurricane. She left six counties as major disaster areas. These were Galveston, Brazoria, Chambers, Matagorda, Harris and Fort Bend. Locate the counties on the Texas Highway map. Eighteen died in the storm that caused $1 billion in damage. Nearly every house in Alicia's path was damaged. Solid brick walls fell under the weight of wind and water. The glass in the Houston skyscrapers was shattered, creating even more problems.

11. Locate Jamaica Beach in the west part of Galveston Island on the map. Forty percent of its 800 homes were lost as a result of Alicia. The tidal surge eroded the beach and moved the vegetation line inland. This left some homeowners on a public beach. This pointed out that if one builds on the beachfront it might not be there after a 20-foot storm surge comes in.

12. How were all the hurricanes alike and how did they differ?

13. Hurricanes are spectacular and violent ages of natural change. Summarize the ways they also cause historical, economic, social and other changes.

Indianola

Prince Karl zu Solms-Braunfels was named the commissioner general for a project colony of German settlers in 1844. In July 1844, he landed in Galveston. He could not find any land in the Galveston. He went in search of a more desirable place for receiving the future boat-loads of settlers. He decided that Indian Point, later named Indianola had water deep enough to permit sailing vessels to anchor. So in December 1844, the first wave of German settlers bound for New Braunfels arrived at Indianola. Some settlers despaired of ever reaching New Braunfels and bought land and settled there. Indianola was born from a tent camp of immigrants.

Streets in the lower part of town were crowded with wagons and carts waiting their turn at the warehouses and wharves. Wagon trains brought in raw materials from northern Mexico and western Texas for export. They returned with finished lumber, foodstuff, and manufactured goods. Cattle for export came by train. Cattle from the coastal area were shipped to New Orleans as was hay and wool from the Hill country.

Dry goods, grocery, hardware and jewelry stores carried enormous stocks from which selections could be made on a wholesale as well as a retail basis. There were wholesale and retail dealers in liquors, wines, beers and brandies for supplying saloons and liquor merchants in western Texas. One could purchase washing machines, sewing machines, Steinway and Chickering pianos, custom made clothes, boots, shoes, etc. All stores had free delivery for local purchases even ice. Indianola was supplied with ice harvested in New England ponds in the winter and transported south by refrigerator ships and then stored in an icehouse whose thick walls were insulated with saw dust. Ice became a common item for home use, for hotels, restaurants, bars, drug stores and confectionaries where ice cream and chilled drinks were offered to the trade. In its quarter century of existence Indianola saw the arrival of steam-propelled ships, railroads from the interior, gas lighting, packing of fresh meat in tins, mechanical refrigeration and the telegraph. In 1856, Indianola was the beginning point for an extraordinary experiment in the history of the United States War Department. Camels were brought in to transport military supplies from Indianola through west Texas and the New Mexico Territory to California.

Theatrical companies landed in Indianola to begin their tours in western Texas. Each hotel had its own dining room for guests and residents of the city. There were several photographic studies. Hard candies were made in a local factory and a saloon for ice cream lovers that also sold iced "soda water" in several flavors. One could also find billiard rooms, a gymnasium, several theaters and a local baseball team that traveled to play teams in Corpus Christi, Victoria, and other surrounding cities. The city attracted the wealthy from inland areas. They found the fresh sea breezes invigorating and the boundless variety of seafood to be a gourmet's delight. There was crabbing and fishing off the beaches and short piers constructed by hotels for the exclusive use of their guests.

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A few hours before it had been a thriving seaport with costly homes, hotels and beautiful churches. Now warehouses filled with various products of commerce and splendid shops on business streets lay in ruins. Every house was carried away or left in ruins. The cause - a hurricane. The storm surge of the 1875 hurricane carried away three-fourths of the town and killed 176 people. The town was rebuilt but eleven years later the storm surge of the 1886 hurricane carried away or left uninhabitable every house in town. Indianola was never rebuilt after the two "once in a century" hurricanes in eleven years. Today the area is a state park. So widespread and devastating were the effects of the two hurricanes on Matagorda Bay that the entire region sank into a paralyzed economic state. It took more than half a century for it to recover. Hurricanes cause not only natural changes but economic, social, and historical changes as well.

1900 Galveston and Houston

Early Galveston was the largest port in Texas and the third largest in the United States in grain exports. It exported nearly 25 million tons of wheat and corn annually to Liverpool and other European ports. Great coal-burning cargo ships, square-rigged sailing ships and coastal schooners kept the miles of wharves filled. An average of 1,200 ships entered the port. They exported nearly 70 percent of the nation's cotton and grain, flour, breadstuffs, zinc ore, sawed lumber, cottonseed oil, beef, hogs and dairy products brought in by railroads. The ships brought in cane beet sugar, jute butts, sisal, cement, coffee and chemicals.

There were three large storage elevators filled with almost four million bushels of grain by the docks. The sheds along the waterfront were packed with thousands of bales of cotton. Smoke poured from the tall chimneys of the city's manufacturing plants. There was a five-story brewery, cotton mill, rope and twine factory, the Texas Star Flour and Rice Mills, cottonseed oil processing plant, baggage and cordage works and Clarkel Courts, one of the largest printing and stationery firms. The Galveston City Cotton Mill manufactured more textiles than any plant in Texas. There were 60 other industries of varying sizes, ranging from cotton compresses to a hat and shoe factory.

Galveston was neatly laid out with geometric precision. Great mansions were on streets lined with oleander, oak, and palm trees. The city had six public squares, two parks, crushed-shell paved streets, three concert halls, an opera house, 20 hotels and electric streetcars. The economy was good with more than 30 stock companies backed with large capital. Crime was rare in Galveston. At night people could walk down the promenades to take advantage of the Gulf's cooling breezes. Galveston was a beautiful city. Most of the 37,789 people who lived in Galveston claimed they lived in the finest city in the state and even along the entire Gulf coast. On the morning of September 8, 1900, Galveston was a bustling port city. By midnight, winds, storm surge and waves of a gigantic hurricane had destroyed the city and killed over 6,000 people in the worst storm disaster of United States history.

Houston, 50 miles inland from Galveston, was a brawling, hard luck town located between swampy bayous and an unpromising prairie to the north. Houston was unplanned and ugly. Also no sensible person wandered out on Houston's humid streets after dark; its reputation for violence was unmatched anywhere in Texas. There were very few days when a brawl in some saloon did not end a gunfight and death.

Two brothers from New York founded Houston in 1836. They lured immigrants from the East with extravagant newspaper ads. The immigrants came to Houston by wagon train, oxcart, on horseback and aboard flat-bottom canoe-like boats. After traveling through the mosquito infested, root-tangled bayous, they found themselves in an oppressive climate where constant warfare was waged with mud, yellow fever, snakes, and alligators. Many moved on, but others stayed, seeing promise that Houston could one day become a thriving port since Buffalo Bayou led into the bay and then the Gulf.

Promoters envisioned Houston as the state's future "great interior commercial emporium." The main street was to run to the head of the navigable Buffalo Bayou but only shallow-draft paddle wheelers and barges were able to take advantage of pickup and delivery of goods in the heart of town. Attempts to dredge a channel to the sea were a failure. Deep-draft seagoing ships could not approach Houston directly.

Interior trade depended on seven teamed oxen struggling with heavy wagons by dirt roads. These roads turned into bogs whenever it rained, which was frequently, perishables were ruined and schedules were not kept. Railroads were needed and came, but only after a series of financial disasters. Houston also had recurring floods that swamped the town. Casualties were high from a whole series of epidemics, mainly yellow fever carried by millions of mosquitoes swarming in the bayous. Houston as "Port of Houston" at that time was a statewide joke.

Today, the story is different. Houston is the largest Texas city and the largest Texas port. It is the largest United States wheat-exporting port and among the top ports in the value of foreign trade and total tonnage. More than 55 foreign governments maintain offices in Houston. It ranks first in manufacture of petroleum equipment, agricultural chemicals, fertilizers, oil and gas pipeline transmission. It is a leading scientific and research center and a prominent corporate center. Galveston is only the seventh largest Texas port. Houston has almost 14 times the tonnage passing through its port compared to Galveston. The population of Houston today is over 27 times larger than that of Galveston.

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Topic 10—Early Inhabitants of the Texas Coast

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Topic 10: Early Inhabitants of the Texas Coast

Archeology is the study of man's past. When archeologists seek to learn about the prehistoric past, the time before written records were available, they rely on the study of material remains. Archeological evidence indicates that people first came to Texas about 12,000 years ago

Using archeological techniques of studying material remains much has been learned about the cultural traditions of people that lived in the past and did not leave written records. Archeological evidence indicates that the Karankawas or at least people of a similar cultural adaptations, inhabited the central coast of Texas at least 2,000 years ago. Evidence indicates that the Karankawas were in fact a nonagricultural hunter-gather-fisher people. They possessed intimate knowledge of the coastal environment and they fine-tuned adaptive strategies to live in the environment. Archeological data from a range of archeological sites was analyzed. Studies focused on what resources were used and how intensively the sites were occupied. This information was then correlated with the seasonal patterns of resource availability in the coastal environment. This provided an understanding of how the Karankawas used and moved within their environment, as well as, inferences about basic patterns of socioeconomic organization. Karankawan life was organized to successfully respond and interact in the resource-rich coastal environment. Archeological findings dispute the popular folklore that the Karankawas were the most primitive of people who lived from day to day and more or less scavenged a living from a harsh environment.

Even more interesting insights emerged from a study of the archeological and historical documents from the 18th century have yielded a fascinating look at how the Karankawas dealt with Euro-American colonization of their homeland. The Karankawas drew upon their upon their own cultural tradition to develop what was a viable and peaceful interaction with the political, social, and religious dimensions of the Spanish culture. They were able to cope with rapid change once the foreign elements of colonization were integrated within traditional ecological patterns of the coastal environment.

The activities in the unit may be used in several ways: as a unit on Indians that lived on the Texas coast; as an inquiry into how early coastal inhabitants interacted with their environment; or as a series of inquiry investigations to analyze artifacts and other information to learn about a past culture; or as an inquiry into the patterns of change and continuity in the Karankawan world; or as an analysis of the interaction of two cultures over time; or as a problem-solving unit. These activities may be integrated into a social studies unit or used as a thematic unit or incorporated as an ecological study of the interaction of humans and the environment.

Activity 1. What Do Archeologists Know About Prehistoric Texas?

TEKS: Science: 7.14, 8.14

Math: 6.3, 7.3, 8.2, 6.8, 7.9, 8.8

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11

Social Studies: 6.1, 7.7, 6.7, 7.10

Learner outcomes: After completing the activities, the students will be able to:

- construct an archeological timelime of archeological time periods of the Texas coast.
- make inferences about the artifacts found in each time period.
- compare and analyze the archeological time periods.
- predict what artifacts might be found by archeologists in the future.

Background:

1. The concept of prehistoric time periods and artifacts must be understood before students can understand the time periods of the past. Archeology is the study of man's past and when archeologists seek to learn about the prehistoric past, they rely on material remains. Material culture includes any object or structure made or altered by humans. It can include areas that show evidence of human activity. These are clues to past behavior. To introduce the idea of material culture and the important information that it may provide about the ways people live, have each student list 10 items on an index card that would survive a fire. They should not put their names on the card. Collect the cards and redistribute them randomly. Make sure that no student receives their own card. Have the students write a description of the person based on the list of items on the card. Mention things such as likes and dislikes, activities in which the person participates, economic status, and other information. Have some of the students share their descriptions. Discuss how material culture is used to learn about the past.
2. Have the students prepare the time lines and use the reading, " the Archeological Time Periods and the Texas Coast to include the appropriate artifacts in each time period. Use the timelines to discuss the use of archeology to learn about the

past. Discuss what types of artifacts would we leave that archeologists in the future would be using to learn about our lives.

Activity 2. Could You Live on the Texas coast as the Karankawa Indians did?

TEKS: Science: 7.12, 7.14

Math: none

Language Arts: 6.11, 7.11, 8.11, 6.10, 7.10, 8.10

Social Studies: 6.1, 7.7, 6.3, 7.8, 6.7, 7.10, 8.12

Learner outcomes: After completing the activities, the students will be able to:

- identify their conceptual understanding of "Indians" and prior knowledge of the Karankawa.
- identify and evaluate the resources needed to survive in the coastal zone.
- analyze the characteristics of the coastal environment in which the Karankawa lived.
- make inferences about the about the Karankawas knowledge of the coastal environment and their use of the resources.

1. Instead of providing the students with a copy of the activity, you may want to use the questions to guide a class discussion. Begin by discussing their perception of Indians and more specifically the Karankawa Indians. List their perceptions on newsprint to be referred to later.
2. As a class or in groups, ask the students to list all the items that they would need for a weekend camping trip to the coast. Discuss the items that are essential for the trip. After they have completed the list, tell them that they need to adjust their plans to include a group of 50- 100 people including newborns to grandparents and their stay will be for several months. They will be camping but campers and hotels are not part of the resources. Discuss how they would obtain the resources and problems that would need to be addressed.
3. Use a Texas map to identify the area of the Texas coast where the Karankawa lived. Tell the students that they are one of the Indian groups that lived in this coastal zone without any modern conveniences. Discuss how their group (50+) would survive and what coastal zone resources they would use to meet their need for food, clothing and shelter.
4. Discuss how groups of 50 to 100 Karankawa were able to survive in one location for several months using only the natural resources in their environment. Focus on the importance of their environmental knowledge to their survival.

Activity 3. How did the Karankawas Adapt to Their Environment?

TEKS: Science: 7.12, 6.12, 8.11

Math: 8.5

Language Arts: 6.13, 7.13, 8.13

Social Studies: 6.1, 6.3, 7.7, 7.8, 8.10, 6.7, 7.10, 8.12

Learner outcomes: After completing the activities, the students will be able to:

- interpret data about the availability of food resources in the coastal environment.
- make predictions about the relationship of food resources to patterns of gathering, hunting and fishing.
- evaluate a model of inferred patterns of Karankawa activities.

Background:

1. Discuss the importance of analyzing the availability of food resources in the coastal environment to understanding the Karankawa. Use the questions and charts to guide the students' inquiry in analyzing and evaluating data to develop hypotheses about the availability of resources and the Indians use of the resources. Each group of students may develop their own interpretations of the data and the Indians fishing, hunting and gathering. Each group can share their analysis, hypotheses and the class can discuss the information that would be needed to support or refute the hypotheses.
2. This is the same type of analysis that researchers follow in interpreting prehistoric cultures. Research indicates that the Karankawa were very knowledgeable about their environment and the seasonal availability of various resources. Their pattern of fishing, hunting, and gathering followed the availability of the resources. The Karankawa spent time in larger fishing camps along the bays during the winter months when the greatest number of fish were available and plants and animals inland were limited. The large group divided into smaller units and move to the coastal prairie camping along streams during the spring and summer. This was the season when more plants as well as the deer and bison were available in that area.

Activity 4. What Does the Archeological Record Tell Us About the Life of the Karankawa Indians?

TEKS: Science: 6.3, 7.3, 8.3, 6.10, 8.11, 7.12

Math: 6.3, 7.2, 8.2, 6.11, 7.13, 8.14

Language Arts: 6.13, 7.13, 8.13, 6.20, 7.20, 8.20

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Social Studies: 6.1, 7.7, 6.3, 7.8, 8.10, 6.7, 7.10, 8.12, 6.23, 7.23, 8.32, 6.22, 7.21, 8.30

Learner outcomes: After completing the activities, the students will be able to:

- interpret data to determine the pattern and location of Karankawa sites.
- make inferences about Karankawa sites and the resources used at each site.
- analyze data to determine the importance of an animal to the Karankawa.
- evaluate from a site to determine the possible location of the site.
- analyze data and journal reports to determine if is supports or refutes a theory about the lifestyle of the Karankawa.
- summarize the relationship of the season, the location of a Karankawa site, and the resources used.

Background:

Part I

1. Provide the students with the archeological data of the location of the different Karankawa sites. Guide the students to note that the Large shoreline camps were located on the Bays or lagoon and these were fishing camps while the smaller sites were located along inland streams and rivers. The smaller sites were hunting sites on the prairie based on the animal remains found. The larger sites had the larger number of people so would have more artifacts. Discuss the role of the artifacts in providing information about the life at a site (source of food and activities).
2. To determine the importance of an animal to a group, archeologists examine the materials found at the site. The minimum number of individuals of each type of animal used, is determined by the bones found at a site. In the case of fish, it is by the number of otoliths found. The otoliths of each species of fish is different this enables researchers determine the number of each species that were used at each site.
3. Discuss how one would estimate the amount of useable meat that each species would provide. Using the data provided in Table 2: Minimum Number of Individuals and the Meat Weight at a Karankawa site, guide the students in their determination of the estimated meat from each species. Assign each group a number of species to calculate the data and provide it for the class. The fish provided 429,275 grams of meat or 79.7% of the total meat. Mollusks provided 21,720 grams or 4%; and mammals provided 84,550 grams or 15.7% and birds accounted for 28,000 grams or 5%. Discuss the relationship of the percentage of meat provided by a species and the location of the site. Group 1 sites are the bay fishing camps and the majority of the food was provided by fish while the smaller inland camps were hunting camps and the bison provided the greatest amount of meat.

Part II

1. Ask the students to construct hypotheses about the relationship of the seasons and resource usage and the location of sites. Have the students analyze table 4 to determine if the data supports their hypotheses or not. During the fall and espeically during winter, fish were the main source of meat. These sites were located along the bay shoreline. The seasonal use of different environmental areas is revealed through the analyses of the remains of certain kinds of mollusks and fish. Three kinds of materials were highly useful for the seasonal studies in this area. The marine fish otoliths, oysters and freshwater clam shells. Marine fish and oysters were readily available along bay and lagoons shorelines. The freshwater clams live in rivers far enough inland that they were available to coastal people living on the margins of the coastal prairie environment. So seasonal resource use and site occupation can be determined and this allows for determining patterns of mobility. Otoliths and shells have annual, cyclic grow patterns so they can be used to determine the season when the growth pattern was interrupted or when the organisms was used.
2. In the case of the Karankawa, there historical documents, mainly Spanish archival materials that can provide additional information. Have the students analyze the historical data and determine if it supports or refutes the archeological data. Have the students summarize the relationship between the season, the location of a site and the resources used. Also discuss the knowledge that Karankawas had about their environment and their use of the knowledge. Point out that they lived together in groups of 50 -100 people so they had the knowledge with which to procure the rich and abundant resources in the coastal environment. They also had the ability to process the resources and distribute them among members of their society. It appears that the Karankawas possessed intimate knowledge of their environment and had fine tuned adaptive strategies.

Activity 5. Were the Karankawas "Giants"?

TEKS: Science: 6.11, 8.11, 6.12, 7.12

Math: 6.4, 7.3

Language Arts: 6.10, 7.10, 8.10, 6.13, 7.13, 8.13

Social Studies: 6.1, 7.7, 6.3, 7.8, 8.10, 6.7, 7.10, 8.12, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- develop hypotheses to explain the height and health of the Karankawa.
- analyze the diet and nutrient intake of the Karankawa.
- compare their diet to that of the Karankawa.
- analyze journal reports of early explorers and make inferences about the Karankawa diet.

Background:

1. Point out that Karankawas were usually tall for Native Americans and were taller than the Spaniards. Their skeletons were healthier, stronger, more robust. Their bones were stronger, indicated larger muscle attachments, and did not show the effects of disease or dietary deficiencies. Ask the students to discuss this in their groups and develop possible explantations (hypotheses) for this difference.
2. Ask the students to bring in the food labels of the foods that they eat and guide them in determining the nutritional value of their diet. Have the students analyze the nutritional value of the Karankawa diet and compare it to that of their diet.
3. Point out that the Karankawa diet was lacking in carbohydrates and fat and contained almost too much protein. The meat diet provided a caloric intake made up of approximately 85 percent proteins, 14 percent fats, and 1 percent carbohydrates. The actual fat was probably higher since the nutrient data is based on lean meat and does not include subcutaneous or bone marrow fats. Ask them to develop possible sources of food that the Karankawa may have used to obtain carbohydrates in their diet. At the prairie camps, high protein may have been offset to some degree by the abundant supply of bone marrow and subcutaneous facts from bison and deer. Fruits of planst such as mustang grape, prickly pear, Texas persimmon, anacua, and hackberry, as well as, mesquite pods, all available on the prairie floodplains and surrounding area would have provided carbohydrate intake. Then have the students analyze the journal data to determine possible sources of these nutrients.
4. Discuss the role of the Karankawa diet and their size, strength, health and their surviving longer than other Native Americans.
5. Have the students evaluate what they have learned about the Karankawa and these "primitive" peoples knowledge of the environment and its resources. Discuss whether the Karankawa were really primitive or if they were ecologists.

Activity 6. What Was the Material Culture of the Karankawa Indians?

TEKS: Science: 7.6, 6.7, 7.8, 7.12, 8.14

Math: none

Language Arts: 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.20, 7.20, 8.20, 6.24, 7.24, 8.24

Social Studies: 6.1, 7.7, 6.7, 7.10, 8.12, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to

- make inferences about the purpose of the different tools found in the Karankawa sites.
- make inferences about resources were used to make the different tools.
- relate the tools to the lifestyle of the Karankawas.
- describe the activities in a Karankawa camp site based on the artifacts that have been found.

Background:

1. To analyze the artifacts that were found in Karankawa sites, have the students prepare a data table with four columns. First listing the artifact that was found; what it was made from (bone, shell, etc.); its possible uses in column three and in the fourth column indicate at which sites (prairie, coastal or both) the items were found and used.
2. Point out that the most distinctive artifact category is ceramics. Pottery was often quite abundant at some sites. However, very few complete vessels have been found. Most were made directly form the clay, with naturally occurring find sand particles acting as a natural tempering agent. Ceramic smoking pipes were also made and were common. All the pottery was made using a coiling technique. They used shells on the still moist pottery to smooth out the construction coils. The pottery was incised with geometric designs and had painted decorations. Some pottery had tempering agents add so it is assumed that these were used in cooking and tempering acted to reduce the effect of repeated heating on the pottery. Discuss what the distinctive tools and pottery indicate about the lifestyle of the Karankawa.

Activity 7.Were the Karankawa Indians "Savages" and "Cannibals"?

TEKS: Science: 8.11, 7.11, 7.12

Math: 8.5 (using graphs)

Language Arts: 6.10, 7.10, 8.10, 6.11, 7.11, 8.11, 6.13, 7.13, 8.13, 6.24, 7.24, 8.24

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Social Studies: 6.1, 7.7, 6.3, 7.8, 8.10, 6.7, 7.10, 8.12, 6.23, 7.23, 8.32

Learner outcomes: After completing the activities, the students will be able to:

- use journal entries during there time periods: early explorers; Spanish missions; and Anglo-American settlement to analyze their interactions and impact on the Karankawa.
- compare La Salle's and Cabeza de Vaca's interaction with Karankawa.
- analyze the changes and differences in the perception of the Karankawas by early explorers, Spanish mission developers, and Anglo-American settlers.
- analyze the impact of the Spanish mission development on the resources used by the Karankawa.
- analyze the Karankawa's lifestyle of hunting and gathering interaction with the farming and ranching lifestyle of the Spanish.
- evaluate the data to determine how the Karankawa adapted their lifestyle to the Spanish missions.
- evaluate the idea that the Karankawas adapted by treating the Spanish missions as an ecological resource.
- compare the Spanish and Anglo-American policies towards the Karankawa and the impact of each.

Background:

Part I

1. One of the most interesting insights that has emerged from the study of the Karankawa, using the archaeological and ethnohistorical data is how the Karankawa dealt with the Euro-American colonization of their homeland. The Karankawas drew on their own cultural tradition that based on the long-lived adaptive patterns that archaeology indicated. They developed a viable and peaceful interaction with the political, social, and religious aspects of Spanish colonial society. However, the Anglo-American colonization had a different goal and impact. To begin this analysis, have the students create a table that has three periods: Early contact (explorers); Spanish missions; and Anglo-American settlement. For each time period, record the following: action/contact of the Europeans/Americans; action of the Karankawa; interaction of the groups; and the perception of the Karankawa by the outsiders.
2. Have the students analyze each journal entry in terms of each group's action. Then summarize the Karankawas attitudes and social structures based on De Vaca's journals. Analyze La Salle's journals and compare the actions of the Karankawa and explain any differences. Based on these reports were the Karankawa's savages or cannibals? Explain.

Part II and III

1. Have the students analyze the reports during the establishment of the Spanish missions and make inferences about the change in attitude from 1720' to the 1750's. Identify the positive characteristics or interactions and the negative ones. Point out the action of the Europeans often determine the response and action of the Karankawa.
2. Discuss the impact of cattle on the bison and the impact of the decrease in bison on the Karankawa. Prior to the Spanish establishing missions, the bison were plentiful and a source of food for the Indians. However, when the Spaniards, introduced the domesticated animals primarily cattle, the bison disappeared. The Spaniards introduced cattle that utilized the same food source as the bison. The large herds of cattle grazed on the grasses that the bison had used for food. The bison disappeared from the region since their source of food was not available so they were replace by cattle in the prairie habitat. The Karankawa were hunters and gathers. When the cattle replaced the bison, they approached the cattle as they had the bison, animals to be hunted. Discuss the impact of this on the relationship between the Spanish and Karankawa and the impact of people of two different lifestyles, hunters and gathers living in the same area with farmers and ranchers. Discuss the problems that would occur. Relate this to later in the American west interaction of the lifestyle of the rancher and farmer in the same area.
3. Have the students, note the location of the Spanish missions and make inferences as to why the coastal prairie missions were more successful than those in the San Antonio area in attracting the Indians. The pattern of the Karankawas was to enter a mission in the spring and then leave and return in the fall. They would leave the missions for their coastal camps. Note the pattern of their movement to the missions and coastal camps. Is there a relationship between this pattern and the earlier pattern of moving between the bay shoreline camps and the coastal prairies camps. What evidence is there to support the the idea that the missions became an ecological resource for the Indians replacing the bison and deer of the prairie camps. The Karankawas defensive strategy was to lose themselves among the lagoons, islands, and marshes of the coastline. What evidence would support the idea that the Karankawa visited the missions that were situated that a fast retreat to the coast, when required could be accomplished.

The Karankawa did not conform to the Spanish culture but the mission strategically incorporated into their traditional native life at the level of a basic ecological resource. The most immediate attraction of the mission for the Indians was the possibility of receiving food. It appears that they may have turned to the a dependence on the mission for cattle when their traditional source of bison was no longer available. Early records indicate there were two kinds of approaches by the Indians. A leader and accompanied by some warriors would scout the mission to see whether the supplies were sufficiently abundant before bringing the rest of his people or a family group entered the mission and stayed until the provisions became inadequate. It appears that the time of the year they were most interested in the missions matched the time that they moved from the coast to the prairies or from the prairies to the coast.

Part IV

1. Compare the strategy of the Spanish toward the Karankawa of getting them to adapt to the Spanish cultural patterns and converting them to Christianity to that of the Anglo-Americans who wanted to acquire the land to build settlements. Discuss how these difference approaches would impact the hunting and gathering of the Indians. Ask the students if there evidence to support the idea that the Indians were only continuing their hunting and gathering lifestyle when they would steal cattle and produce from settlers.
2. Discuss why the problems, between the Karankawas and settlers continued. Why does the relationship of the settlers and their perception of the Karankawa differ from that of the early explorers and Spanish. Discuss why the Karankawas could not effectively cope with the Anglo-American settlers but they managed to do so with the Spanish. Discuss why the Karankawas suffered catastrophic depopulation during the period of Anglo-American settlement.

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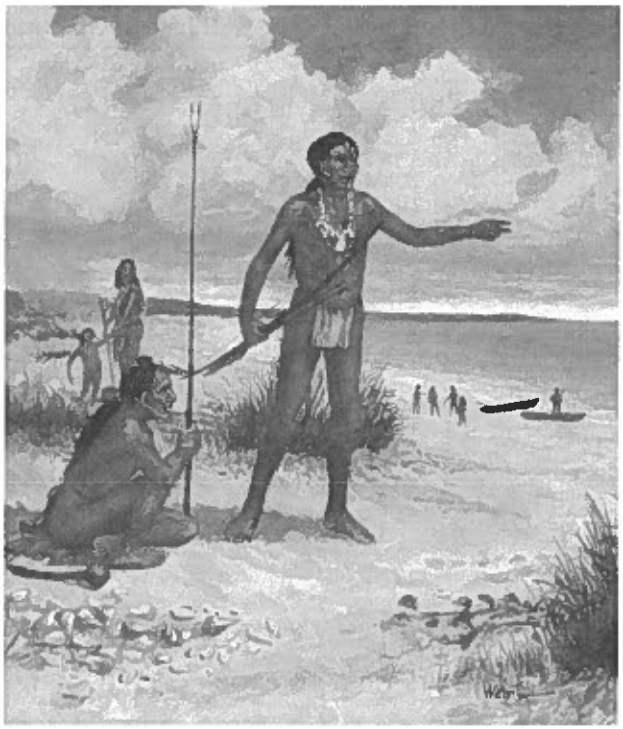
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1. What Do Archeologists Know about Prehistoric Texas?

Archeologist(s) _____ **Team** _____



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Written records of Texas history begin with the accounts of the Spanish explorers, which was less than 500 years ago. However, the first people came to Texas more than 12,000 years ago. Many clues to how past cultures lived have been left behind in many places. The clues to the unwritten story of those thousands of years lie buried in the earth. Archeologists are social scientists who seek information about prehistoric and historic peoples through the study of materials left by peoples of the past. They are detectives using the material remains as clues to learn how past peoples lived. Archeologists use artifacts, features (areas that show evidence of human activity) and other remains as clues to past behavior. They study the material of the culture that includes any object or structure that is made or altered by humans. In an archeological site, material culture includes areas that show evidence of human activity. Some examples are burned rocks surrounding a hearth, mortar holes made in bedrock, concentrations of butchered animal bone, spear or pottery pieces or rock art.

No evidence of humans in the New World or United States is found until very late in the Pleistocene or Ice Age. The most severe period of glaciers was also the latest. It is called the Wisconsin in North America. It lasted from about 80,000 years ago until around 7000 BC, when the earth's glaciers began their final retreat.

Since the last Ice Age about 12,000 years ago or 10,000 BC, the land surface of the Texas coastal zone has undergone deposition. The rivers have deposited soils to form the coastal zone. Since the land surface has been building up because of soil deposits, the older the archeological site, the deeper it will be. If a site has been used during different periods, the material may be deposited in layers or strata. In a site, the older layer will be the deeper one. As an archeologist you are going to prepare a chart of the artifacts for each time period on the Texas coast.

Materials: paper, ruler, copy of "Archeological Time Periods and the Texas Coast"

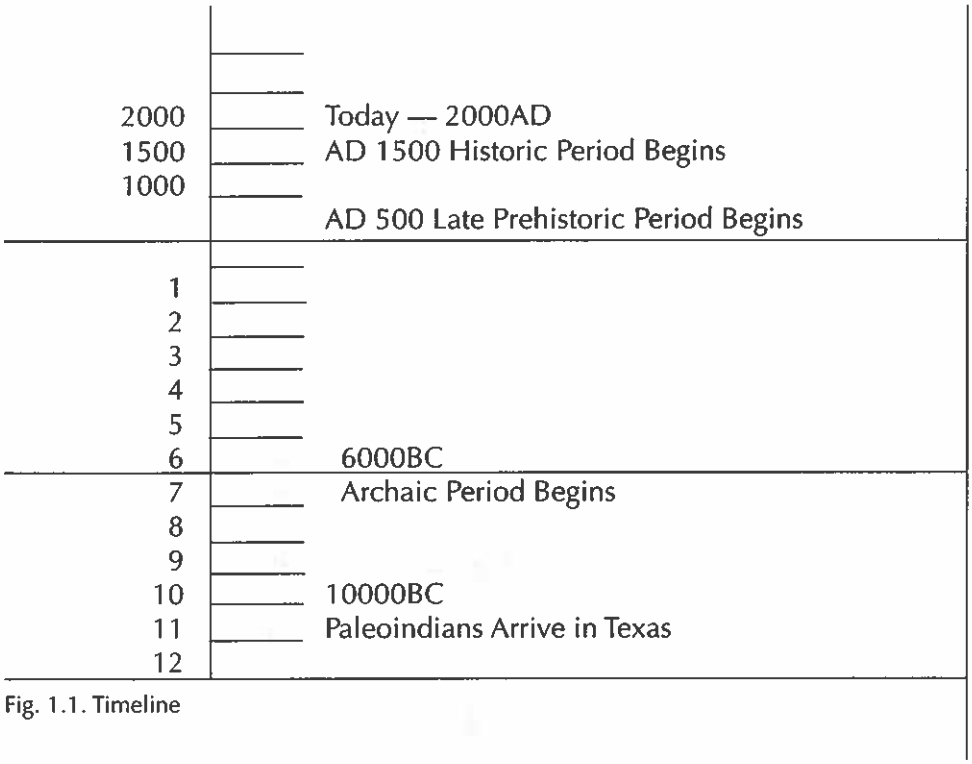


Fig. 1.1. Timeline

Procedure:

1. Place a ruler on a notebook page (lengthwise). Beginning 6 cm from the bottom of the page, mark off 30 cm. The bottom 24 cm will represent years BC and the top 6 cm will represent the years AD. Let each centimeter represent 500 years. See Figure 1.1.

2. Compare the lengths of the time periods. How long were the Indians present along the Texas coast compared to the European explorers and settlers?

3. Use the information from the reading "The Archeological Time Periods and the Texas Coast" and sketch examples of the artifacts associated with that archeological time period in each time period of your timeline. These are the artifacts that an archeologist might find.
   a. As an archeologist, what artifacts would you find in the PaleoIndian Period? Sketch those in that period of your timeline.
   b. What artifacts would you find in the Archaic Period? Sketch those in that period of the timeline.
   c. What are the artifacts common in the Late Prehistoric Period? Sketch these on the timeline.
   d. What artifacts would you find in the Historic Period? Include sketches of these in the timeline.

4. What artifacts would you expect to find in an archeological site along the Texas coast from the 19th century (1800s)?

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5. Think about the early 1900s or 20th century along the Texas coast. What was life like and what tools were used? What artifacts would be left in a site from that time period?

6. What would be the difference between a site from the early 1900s compared to a site that is from the mid 1900s? What differences would you find in artifacts?

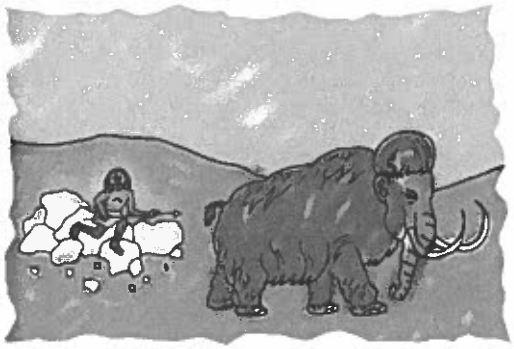
7. What do you think life will be like on the Texas coast in the mid-21st century?

8. What artifacts might a future archeologist find from the 21st century?

The Archeological Time Periods and the Texas Coast

Paleoindian Period (10,000 - 6,000 BC)

Archeological evidence has revealed that the first people came to the Texas coastal region about 12,000 years ago. This was during the time when the glaciers of the last Ice Age were beginning to melt. The beach was some 40 to 50 miles wider and sea level was about 300 feet below where it is now. The shoreline was miles out into the Gulf. The coast did not look like it does today. What are beaches today were part of the inland prairies during this time. The river valleys of 12,000 years ago are the bays today.



The people of that time were nomadic hunters and gatherers. They banded together in small groups, moving from one area to another in search of food. They lived along rivers for water. Animals also were attracted to the water. The humans relied mostly on big game hunting for food but they also hunted smaller game and gathered wild plants. As they moved about the land they left scattered artifacts and a few kill sites that give clues to their culture. Unfortunately many of their remains are under the bay waters and under the waters of the Gulf.

At the McFaddin Beach site near Port Arthur, archeologists have found a large number of Clovis points that have washed ashore. The Clovis point is a projectile point that was very effective in killing the mammoths and other Ice Age animals. Around 9,000 BC, the large spearheads became smaller and more finely formed. These developed into the Folsom points, which were more suitable for hunting the smaller bison.

Archaic Period (6,000 B. C. - A. D. 500)

By 4,000 to 5,000 BC, the melting of the glaciers was causing the Gulf waters to rise to their present level. The river valleys were filling with water to form the bays that exist today.

During these times, people depended more on plants and smaller game animals since most of the large game animals like mammoths were extinct. The primitive tribes of Indians that moved into the coastal zone were hunters and gathers.

Since these people were hunters and gatherers, they depended on the coastal resources in a different way from the earlier big game hunters. They began to develop social systems as evidenced by their artifacts, shell middens and burial grounds. They had fire and pit ovens, which were commonly used to bake plant roots or even animals. Because plants were an important food source in their diet, they had grinding tools. Also the projectile points, which they made for their darts and spears, had a stem at the base. Many different styles were made.

The hunters and gatherers probably did very little to change the environment. The impact was limited to their campsites, and after they left an area, the land reverted to its natural state.

Late Prehistoric Period (AD 500-1500)

Sometime after AD 500, new tools and new ways of producing food changed the life of the coastal Indians. Agriculture and the making of ceramics had been introduced. These practices were probably learned from neighboring groups. Pottery and arrow points are main indicators of the Late Prehistoric Period. Although some groups settled in permanent villages, many Texas Indians including the coastal Indians continued their nomadic lifestyles. They continued to live much like their ancestors had lived in Archaic times.

Historic Period (after 1500 AD)

The Historic Period began in Texas with the arrival of the Spanish. When Cabeza de Vaca landed on the Texas coast in the 1520s most of the coastal tribes were still gatherers and hunters. The introduction of guns, horses, competition for land and the introduction of new diseases altered the lives of the Indians. Also many new Indian groups, including the Comanche and Cherokee, entered the state. Nearly all Indians had been expelled from Texas by the end of the 1800s.



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2. Could You Live on the Texas Coast as the Karankawa Indians Did?

Researcher _____ **Research Team** _____

Thousands of Indians lived along the Texas coast. Their ancestors can be traced back to the Ice Age or 9200 BC. Within 200 years after the arrival of the Europeans, they became extinct. All that remains of the coastal Indians are a few campsites and burial grounds, artifacts made from stone, bone and shell, and mentions in the journals of Spanish and French explorers. You and your research team will be investigating to learn more about the people who could survive the dramatic changes in the New World from the time of the Ice Age of mammoths to a climate with plants and animals similar to today's.

Materials: none

Procedure:

1. What thoughts, ideas or mental pictures does the word "Indians" convey? Discuss this with your team and list your thoughts below (or draw your impressions).

2. What have you heard about the Karankawa Indians who lived on the Texas coast?

3. It was believed that the Karankawas were constantly moving in small groups and barely able to survive. However, archaeologists have found sites with dense deposits of cultural debris. This usually indicates that the area was inhabited by large groups of people (50 to 100) and for a long period of time.
   a. What inferences would you make about the Indians who lived there?
   b. What would be needed if 50 to 100 members of your family, relatives and close friends all camped together in an area on the coast for several months? List below what would be needed to survive for an extended period of time.
   c. How would you go about getting the resources to fill the needs of 50 to 100 people of all ages (newborns to adults)?

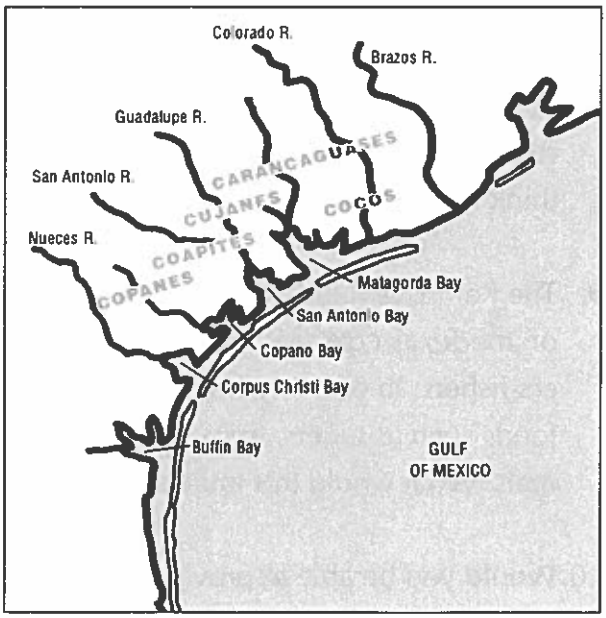


Fig. 2.1. Where the Karankawas lived.

4. The term "Karankawa" can be misleading, it actually refers to several groups of Indians. The names of these groups are repeatedly

found in Spanish documents throughout the 18th century. The documents also indicate that each group lived in a specific region and had specific characteristics. However, they noted that the five groups had a similar language and culture. Although the groups were sometimes referred to individually by the Spanish, the Indians mixed together freely. See Figure 2.1 to determine where the five principal groups lived. Where did they live?

5. Describe characteristics of the environment in which they lived.
   a. How were their environments alike?
   b. What was the topography or terrain of the area probably like?
   c. What was the weather in these areas like?
   d. From what would they need to protect themselves? Climate? Animals?

6. Now imagine that your group was one of the five major Karankawan groups and lived where the Karankawan groups lived during that time period. In other words, there were no modern conveniences (houses, stores, cars, tools, etc.).
   a. How would you and your group of over 50 family members and friends survive?
   b. What resources would you use for food?
   c. What type of clothing would you wear? Explain
   d. What would you use for transportation to move behind the barrier islands? Or how would you move about?

7. How would your group get food, clothing, and shelter? What tools would you use?

8. The Karankawa knew where to find the resources they needed. The Indians were mobile, camping at locations that provided them access to important resources. They needed homes that were simple and easy to set up. The parts needed to be transported. What kind of houses would the Indians use? What kind of house could the Indians make from the resources that would meet their needs? Describe and sketch the kind of house that you think the Indians used.

9. The Karankawa Indians were able to survive in large groups of 50 to 100 in one location on the Texas coast for several months. The Karankawa were non-agricultural hunter-gatherers-fishers. In other words, they fished in the shallow bays and lagoons, gathered plant foods such as tubers, fruits, roots and nuts, and also hunted for deer and other small animals. What would this indicate about their knowledge of the environment? Explain.

10. Would you be able to provide for a group of 50 or more living on the Gulf coast as the Karankawa Indians did? Explain. Why or why not?

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3. How Did the Karankawas Adapt to their Environment?

Researcher _____ **Research Team** _____

To a newcomer, the central coast of Texas can be a confusing maze of islands, lagoons and salt marshes. The topography is low and flat with thick marsh and river floodplain vegetation. The Karankawas had a thorough understanding of this land and the rich resources that it could provide. They adapted to this environment by integrating the use of these resources into their lives. You and your team will investigate how the Karankawas interacted with and adapted to the coastal environment.

Materials: none

Procedure:

1. To understand how the Karankawa used the available food resources found in their environment, you must analyze the food resources that were available to them. Why would all the questions below be important to understanding the Indians and their use of resources?
   a. Where is the resource found?
   b. What amount of the resource was available?
   c. When was the resource available?
   d. Is the availability of the resource predictable or not?
   e. Is the resource concentrated in one area?

2. The fish and shellfish resources of the estuarine bays and lagoons were a major resource for the Indians. The Texas coast has always produced a large supply of shellfish. Oysters, scallops, and quahogs are found in the bays and lagoons. Gastropods are found near the tidal passes between the barrier islands. Clams live in the river influenced areas of the bays and where tides enter the streams. The important fish species of the coastal bays are black drum, redfish, speckled sea trout, Atlantic croaker, sea catfish, southern flounder, sheepshead, silver perch and mullet. While fish can be taken in the bays year-round, there are peak periods for catching the largest amount with the least effort and risk of failure. Examine the data from commercial catches for two major fish species, black drum and redfish, on the central coast of Texas in Figures 3.1, 3.2, and 3.3. Note that different measures are

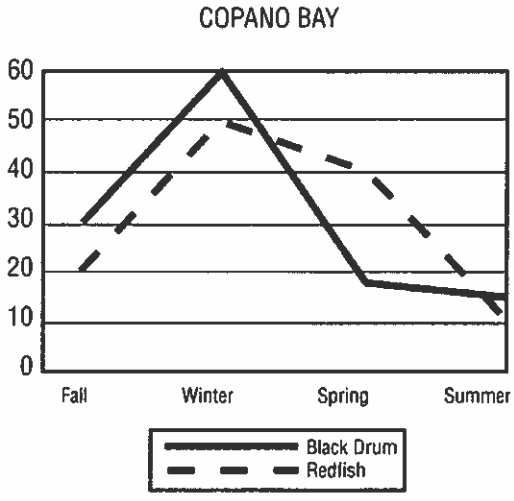


Fig. 3.1. Percent of fish harvested from Copano Bay. (Source: Ricklis: The Karankawa Indians of Texas)

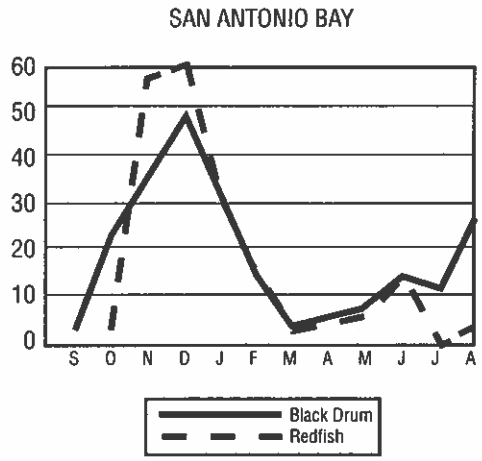


Fig. 3.2. Average number of fish harvested from San Antonio Bay. (Source: Ricklis: The Karankawa Indians)

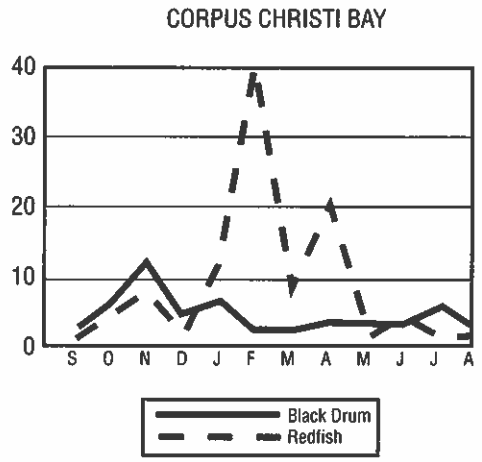


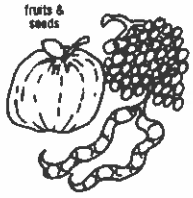
Fig. 3.3. Pounds of fish harvested from Aransqas and Corpus Christi Bays. (Source: Ricklis: The Karankawa Indians)

used to indicate the amount of fish harvested. Also note during what time of the year the greatest peaks (amounts) occur. When would the most fish be caught with least effort?

3. When were black drum and redfish the greatest percent of the catch?

4. When were the most black drum and redfish caught in San Antonio Bay? What was the average of fish in each haul during the peak time?

5. During what time period was the largest amount of redfish caught?



6. The major land resources were white-tailed deer and bison. They were found year round on the coastal prairies, away from the shoreline. Different kinds of plant resources were available at different seasons. Acorns and pecans were available in the fall. The acorns were found along the shorelines in the mottes of oaks. The pecans were found in the river floodplains. The river floodplains provided various edible "greens." These were mainly marsh plants such as cattails. During the fall and winter the cattail roots are edible and were an excellent source of starchy carbohydrate. In the upland prairies, during the spring and summer, there were prickly pear cactus pads (spring) and the fruit or "tunas" in the summer. Berries were also available in the spring and mesquite beans were available in the summer.

   Using the information from Figures 3.1-3.3 and Table 1, how were the food resources that were available for the Karanakawas used during the different times of the year? Winter; Spring; Summer; Fall

7. Based on the times and locations where the food resources were most predictable and concentrated would the Indians have been able to live in one area or would they have moved? Explain.

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Table 1. Availability of Food Resources in the Texas Coastal Environment

Resource Category	Spatial Occurrence	Occurrence During Year
Mollusks	Concentrated (bay/lagoon margins)	Predictable, year-round
Fish	Concentrated (bay shallows, inlet areas)	Predictable, peak in fall-winter
Mammals		
Deer	Dispersed (prairies, wooded areas)	Predictable, year-round
Bison	Concentrated but mobile (prairies)	Predictable, year-round
Plants		
Greens	Variable	Predictable, spring
Fruits, seeds	Variable	Predictable, summer
Nuts	Concentrated (coastal fringe, wooded floodplains)	Predictable, fall
Roots	Variable	Predictable, fall-winter

Source: Ricklis, R. 1996. The Karanakawa Indians of Texas; An Ecological Study of Cultural Tradition and Change. The University of Texas Press.

8. Based on the availability of major categories of food resources, a hypothetical model of the inferred patterns of fishing, hunting, and gathering of the Karankawas by seasons is given in Figure 3.4.

   According to the model, what did the Karankawas probably use for food during each season?
   Winter—
   Spring—
   Summer—
   Fall—

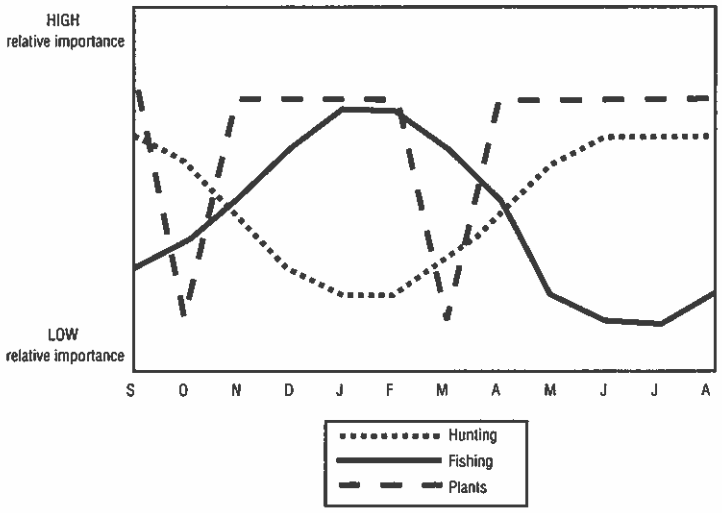


Fig. 3.4. Model of inferred pattern of fishing, hunting and gathering activities of the Karankawas. (Source: Ricklis: The Karankawa Indians)

9. Evaluate the model. Does the data from Figures 3.1-3.3 and Table 1 support the model in Figure 3.4? Explain.

10. The patterns of fishing, hunting and gathering in Figure 3.4 were inferred (concluded from evidence). What information would be needed to prove that the conclusions that were used to create the model in Figure 3.4 are correct?

4. What Does the Archeological Record Tell Us about the Life of the Karankawa Indians?

Archeologist_____ **Archeological Team** _____

To learn about the Karankawan life and culture before the recorded observations of Europeans, our inquiry must look at the archeological record. Although archeological research cannot provide direct evidence and all the details of the culture, it can provide important information. Where the sites are located can provide information on the settlements of the Indians. The kinds of bones, tools, and other materials at each individual site can provide clues about the activities at each site. Growth patterns on shells and fish otoliths indicate when they died. This helps to determine when they were used and the season during which the site was occupied. The size of the site determines the number of people living there. Studies of the animal bones will tell what kind of animals provided food for the group. With this information an archeologist can reconstruct how the Karankawas lived in their environment. You and your archeological team will analyze data from various sites to see what you can learn about the Karankawa Indians.

Materials: calculator (optional)

Procedure:

Part I: Where did the Karankawa live and what resources did they use?

1. Archeologists have examined Karankawa sites in the Corpus Christi Bay and Copano Bay area. Use Figure 4.1 to determine the location of the sites that were examined. Where are all the sites identified as Group 1 located? Where are the sites identified as Group 2 located?

2. Based on the information in Table 1, how does the archeological evidence differ between the Group 1 and Group 2 sites?

3. Study Figure 4.1 and Table 1.

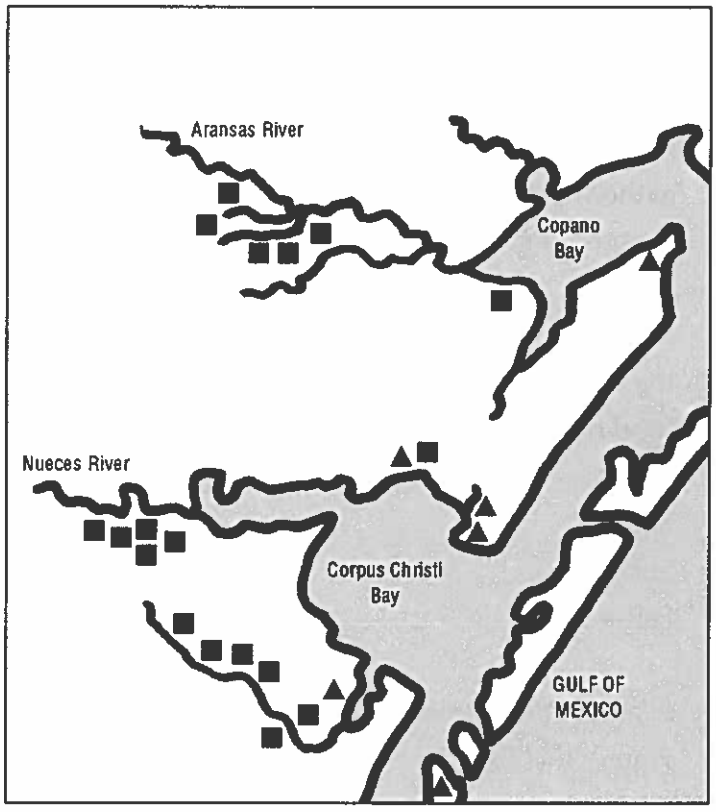


Fig. 4.1. Karankawa camps in the Corpus Christi Bay and Copano Bay area. ((Source: Ricklis: The Karankawa Indians of Texas)

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Table 1: Archeological Evidence of Karankawan Occupation of Texas Coastal Zone

	Group 1 Sites	Group 2 Sites
Deposit Site	Very thick, rich in debris, many layers	Very thin, sparse in debris
Dominant animal remains found	Fish and shellfish	White-tailed deer, Bison
Artifacts	Abundant	Sparse
Types of artifacts	Ceramics, pottery, conch adzes, conch perforators, whelk hammers, clam shell knives and scrapers	Pottery fragments, pots, arrowpoints, adzes, clam shell tools

Source of Data: Ricklis, R.A., "The Karankawa Indians of Texas, An Ecological Study of Cultural Tradition and Change"

What inferences can be made about the sites?

a. Which site had more people? Explain.
b. How did the diet of people from Group 1 differ from the diet of Group 2? Why would Group 1 sites have thicker deposits and more artifacts than the Group 2 sites? What is the relationship between the location of each site and the animal remains found?

4. One way to find out how important an animal was to the Karankawa is by examining the bones found at the site. The minimum number of individuals (MNI) used by the Indians could be estimated by bones found in the site.

   Another method is used for bony fishes. Each bony fish has two otoliths. **Otoliths** are tiny bone-like particles or stony plate-like structures found in the skull of fish. Each fish has a pair. They are different for each species. The otoliths that are found at each site are grouped and counted by species. The number of bony fish that the Indians used is estimated by dividing the number of otoliths (for each species) in half. The estimated usable meat for a given animal species is based on:

   1. The total estimated live weight of the animal
   2. The percentage of the total weight that is usable meat, and
   3. The multiplying of usable meat weight per individual animal by the MNI for that species.

   Use the information provided in Table 2 to determine the estimated total meat from each species that was used by the Karankawa at this site. Multiply the MNI (Minimum Number of Individuals) by the estimated usable meat per individual. Record the amount in the estimated total meat. Complete this for the fish, mollusks, mammals, and birds.

5. Which fish provided the most meat for the camp?

Table 2: Minimum Number of Individuals (MNI) and the Meat Weight at a Karankawa Site

Animal	Minimum number of individuals	Estimated usable meat per individual (grams)	Estimated total meat/species	All meat weight by percentage
Fish				
Blackdrum	103	1,950		
Redfish	52	1,980		
Sheepshead	103	800		
Trout	53	495		
Croaker	69	110		
Marine catfish	22	220		
Gar	1	4,400		
TOTAL FISH				
Mollusks				
Scallop	291	10		
Oyster	262	15		
Lightning Whelk	44	30		
Shark Eye	56	10		
Quahog	21	20		
C-barred Venus	44	5		
Banded Tulip	20	10		
Horse Conch	7	20		
Pear Whelk	6	15		
Ponderous Ark	5	10		
TOTAL MOLLUSKS				
Mammals				
White-tailed deer				
Adult	2	26,500		
Juvenile	1	10,000		
Bison	.05*	295,000		
Bobcat	1	6,000		
Cottontail rabbit	1	800		
TOTAL MAMMALS			-1	
Birds				
Duck	1	700		
Great Horned Owl	1	2,100		
TOTAL BIRDS				
TOTAL AMOUNT				

*Based on percentage of Bison bones in the site area

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6. Did the fish used by the Karankawa provide the most meat? Explain.

7. Which mollusk provided the most meat for the camp?

8. Which animal provided the most meat?

9. Add the total amount of estimated meat provided by each group (fish, mollusks, mammals, birds) of organisms in Table 2 to determine which provided the most meat for the site. Which provided the most meat? List the groups in the order (most to least) that they provided meat.

10. Add together the amount of meat each group provided. What was the total amount of meat used at this site?

11. To determine the percentage of fish, mollusks, mammals and birds used by the Indians at this site, divide the amount of meat for a group by the total amount of meat. Place the percentage for each group in the blank provided in the last column of Table 2. Which group of animals (fish, mollusks, mammals, birds) provided the most meat?

12. Based on this data was this a Group 1 or 2 site? (Refer to Figure 4.1 and Table 1 if needed). Explain.

13. Give reasons (at least two) to support your answer.

14. Examine the data in Table 3. Are sites A and B group one or two sites? Explain.

15. How do Sites A and B differ from the Site in Table 1?

16. Where were sites A and B located, inland along rivers or along a bay shoreline? Explain.

Table 3: Estimated Percentage of Meat Weight for Sites A and B

Percentage of Meat Weight Animal	Site A	Site B
Bison	84.7	90.9
White-tailed deer	12.5	7.6
Rangia Cuneata (freshwater clam)	.5	
Sea trout	.1	0
Catfish	.1	.1
Black drum (fish)		.2

Part II: Was there a pattern to the life of the Karankawas?

1. To determine the season that a resource was used, the fish otoliths and oyster shells are analyzed. The season that the fish or mollusk died is based on the growth patterns of the otoliths or shells. The growth is interrupted or stops during the cold water temperature in the winter. The season of death is determined by comparing the amount of growth since the winter growth interruption. Based on the data in Table 4, during which seasons were fish the main source of meat for the Indians?

Table 4: Seasonal Categories Based on Fish Otoliths

Percentage of Estimated Meat Weight of Fish Season	Site C	Site D	Site E	Site F
Fall	19%	25%	13%	9%
Winter	63%	60%	81%	82%
Spring	5%	5%	0%	9%
Summer	13%	10%	6%	0%

2. During which seasons did the Indians rely on a source other than fish for food? What was the other source of food?

3. Based on Figure 4.1, where would sites C-F (Table 4) have been located? Explain.

4. It has been proposed that the Karankawa spent part of the year in large shoreline fishing camps and the remainder of the year in smaller hunting camps located in the inland prairies along streams or rivers. What data supports this theory?

5. In March 1687, Enrique Barroto, who was sent to explore the coast, met a group of friendly Indians (near Aransas Pass on Corpus Christi Bay) who "came to the beach to play games around the gallery." They also offered the Spaniards gifts of fish. Barroto noted that the Indians left their shoreline camp while his ship was anchored at that spot. He continued to sail north and reached Matagorda Bay in April. He indicated that during the six days of exploring the area, no Indians were sighted. This was the same area where LaSalle had found a camp of more than 400 people in February 1685.

   In 1689, the De Leon expedition was sent from Coahuila in Mexico to locate the site of La Salle's Fort Saint Louis. They arrived in Matagorda Bay in late April and explored the entire southern shoreline of the Bay. No Indians were found along the Bay, however, they found several small camps of Indians inland along Garcitas Creek.

   French navigator Jean Beranger, who sailed from Louisiana in 1720 and reached Aransas Pass in late October described a large shoreline camp. "I was surprised, since I

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least expected to see in a moment a large market town built of these kinds of houses (hide-covered huts) and five hundred persons, at least, well sheltered."

There was a major fish storage facility for fish with this large camp. Beranger stated: "Five leagues north of here, where I was anchored, they have a small permanent village of about a dozen large, quite round huts. That is where they put the supply for the winter that consists of fish that they dry without salt and where worms prevail in large numbers. They took my cook into this village, and after welcoming him and making him eat what they had they brought him back after five days."

Beranger's observations are important in that they indicate a large shoreline camp occupied during the fall and fish and shellfish were the main source of food.

Another source of information was from "Relation of Simars de Bellisle.". Bellisle was marooned on the Texas coast and lived with the Karankawas for more than a year during 1719-1720. He first encountered them in the spring as they were gathering bird eggs along the beach. By summer he noted: "I passed the entire summer in this country with them going everywhere in search of food because they possess no cabins or fields. That is why they travel in this manner the entire summer. The men kill a few deer and a few buffaloes and the women search for wild potatoes." Based on de Bellisle's journal this changed as the season changed. He noted: "When the beginning of the winter came we all left to join a band of their people who were waiting for us at the end of the bay. We arrived there in seven or eight days."

He also noted that hunting was also carried out during the winter. He makes it clear that the hunting expedition used horses and they traveled two to three days inland to hunt buffaloes. Apparently, as early as 1720, coastal people in the Galveston Bay area had at least limited access to horses. These were probably from horses left behind by the De Leon expeditions of 1689-1690. He noted that during the summer season the group moved at a modest rate on foot and on the coast they traveled in the traditional dugout canoe.

From these journal accounts, where were the Indians living in the fall and winter and what did they eat?

6. Where did they live in the late spring and summer and what did they eat?

7. Did the Indians getting horses from the Spaniards change this pattern? Explain.

8. Summarize the relationship between the season, location of the site and the resources used.

5. Were the Karankawas "Giants"?

Researcher _____ **Research Team** _____

By around 8,000 BC, the Pleistocene or Ice Age had ended and the next two thousand years or so are referred to as the Late Paleo-Indian period. The animal life, vegetation and climates became like those of today, and the lifestyle of the Native Americans remained the same. They adapted, increased their populations and covered very diverse environments.



As thousands of years passed, these earliest Americans spread across the North American continent, found their place and became independent. These tribes and bands of hunters and gatherers formed their own unique cultures and spoke their own languages.

In Texas, the Native Americans lived successfully for nine or ten or no one really knows how many thousands of years before the Europeans came. The Native Americans not only survived here but adapted to changes in the climate and increased in numbers. They developed new tools and ways over time. However, they did all this without major damage or changes to the environment.

More seems to be known about the Karankawa than the other groups because they were the ones that Cabeza de Vaca first met. Of the coastal Indians, the Karankawas managed to stay alive longer than the rest.

You and your research team will be investigating to learn more about the people who lived along the coast among the bays, lagoons, marshes, river deltas and prairies of the central coastal zone.

Materials: none

Procedure:

1. The Karankawas shared some of the customs of other Texas coastal Indians, but physically, they were different. This was first recorded by Cabeza de Vaca. On November 6, 1528, he and his crew were slammed onto the Texas coast by a Gulf storm. The exact location of this first meeting of the Karankawa and the Spaniards is not known. It is believed to be somewhere on the far west end of Galveston Island. The Spaniards were soon surrounded by the Karankawa with long bows and sharp arrows wanting to get back the earthen pot, small dog and a few fish they had stolen from a nearby hut. In his journal, Cabeza de Vaca notes that they were surrounded by more than a hundred Indian bowmen, "who if they were not large, our fears made giants of them. . ."

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Table 1: Nutritional Value of Meats in Karankawa Diet at Shoreline Sites

Animal	K calories	Protein (grams)	Fat (grams)	Carbohydrates (grams)
Mammal (deer)	126	26.0	4.0	0
Fish (average)	93	17.8	3.14	0
Mollusks (average)	78	12.8	1.5	2.3
Bird (wild duck)	233	21.1	15.8	0

NOTE: All values are 100 grams of raw meat weight

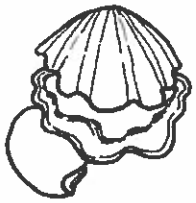
From other sources it is clear that the Karankawas were unusually tall for Native Americans. Men were often near six feet or reached six feet in height. They were also noted for their strong and robust physiques. Measurements of skeletons found in a coastal prehistoric cemetery indicated heights around six feet. The Karankawas were taller than other Native Americans and the Spaniards. It was also noted that the skeletons were healthy, strong, and hardy. The bones indicated that the muscles attached to them were strong. Another observation was that the skeletons from the Karankawas showed less stress than those of the inland Indians. The Karankawas bones were stronger and their bones did not show the effects of any deficiencies in diet (minerals or proteins). Based on these observations, what inferences can you make about their lifestyle?

2. The sources of nutrition and energy in human diets are proteins, fats and carbohydrates. Proteins are the major building blocks of body tissue. Carbohydrates supply most of the body's energy needs. Fats and oils are highly concentrated sources of energy. Using archeological data, the nutritional value of the Karankawa diet at the shoreline sites was determined. The values of the nutrients per 100 grams of raw meat for each of the major meats they ate are given in Table 1.
    a. What percentage of their diet was protein?
    b. What percentage was fat?
    c. What percentage were carbohydrates?

3. What statement could you make about the supply of protein, carbohydrates, and fat in the Karankawan diet?

4. How do the nutrients provided by the Karankawan diet compare to the nutrient intake in your diet?

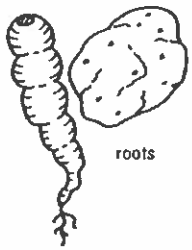
mollusks



5. Generally, various human diets worldwide involve only about 10 to 25 percent protein and most modern diets are made up largely

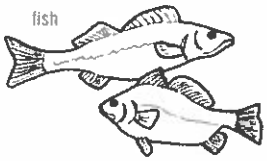
of carbohydrates from which most of the energy is obtained. It is probable that humans cannot survive on a sustained diet consisting of more than 40 to 50 percent protein. This amount of protein would result in "protein poisoning" from the excess nitrogen. What might the Karankawa have eaten that would have provided fat and carbohydrates to balance the high protein diet?

6. Cabeza de Vaca in his journal stated, "From October through February every year, which is the season these Indians live on the Island, they subsist on the roots I have mentioned, which the women get from under the water in November and December. Only in these two months, too, do they fish in cane weirs. When the fish is consumed, the roots furnish the staple. At the end of February, the islanders go to other parts to seek sustenance for the root is beginning to grow and is not edible."



Based on Cabeza de Vaca's journal what may have helped offset the high amount of proteins in the Karankawa's diet?

7. Jean Beranger, a French navigator who sailed from Louisiania in 1720, to the area of Aransas Pass wrote about a large shoreline camp at Aransas Pass, near Corpus Christi Bay that he visited in late October. "I was surprised, since I least expected to see in a moment a large market town build of these kinds of houses (hide-covered huts) and five hundred persons , at least, well sheltered. The descriptions by Beranger leaves no doubt that this was a Karankawan camp. He also reported, "They have a small permanent village of about a dozen large, quite round huts. That is where they put the supply for the winter that consists of fish that they dry without salt." Beranger also made some interesting notes on their diet: "Although they do not cultivate the soil, they eat bread ...they make with acorns, ashes, fibrous plant well crushed and pounded together and cook it over live coals. I ate some of it solely to oblige, but it is nasty eating according to my way of thinking. The rest of their food is fish that they eat half raw, a great deal of roots, and oysters." What does Beranger's report tell us about the diet of the Karankawa?



8. A species of cattail is salt-tolerant and grows in the shallow bays and lagoons along the Texas coast. These roots are high in fiber and are mostly a carbohydrate starch. They are edible until mid- winter. Also acorns from live oak trees have low tannic acid and are available in the fall. The acorns are about 72 percent carbohydrates, 19 percent fats, and 9 percent protein. In the prairie regions, fruits of plants such as mustang grape, prickly pear, persimmon, berries, anacua, hackberry, and mesquite beans were available in the spring and summer.



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These fruits provide carbohydrates in the form of fructose or starch. Based on Cabeza de Vaca's journal, Beranger's report and what is known about plants along the coast, what inferences could be made about the diet of the Karankawas?

9. Why were the Karankawa taller, stronger, and healthier than the other Native Americans and the Spaniards? Based on the descriptions of the Karankawa diet and nutrition, what conclusion could be made about the relationship of diet and size and strength of the Karankawa? Explain.

10. Why did the Karankawas survive longer than many other Indians after the colonists began settlements in coastal Texas?

11. The Karankawas were non-agricultural people who relied on gathering, hunting, and fishing for their food. What does their diet show us about the so-called "primitive" people's knowledge of their environment and survival skills? Were they primitive people? Explain.

12. Summarize your conclusion about the Karankawas below.

6. What Was the Material Culture of the Karankawa Indians?

Archeologist _____ **Archeological Team** _____



To learn more about the Karankawan life and culture, archeologists look at the tools they made and used. The kinds of bones, tools, pottery and other materials at each individual site can provide clues about the activities at each site. Archeologists have found that there are materials that are distinctive or only found in the Karankawan culture. You and your team will analyze information about the materials to determine what you can learn about life of the Karankawa Indians.

Materials: none

Procedure:

1. The stone tools include several arrowpoint types. The main arrowpoint type is the is the Perdiz point. The knives were different shapes and lengths. See Figure 6.1. There was a greater variety in knives at sites where bison were the main source of meat. What are some possible explanations for this?

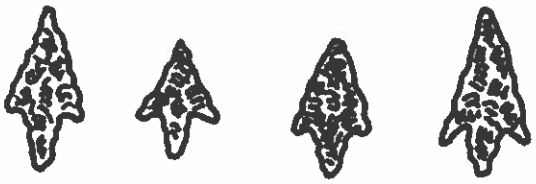


Fig. 6.1. Perdiz arrowpoints commonly found in Karankawa sites. (Source: Ricklis: The Karankawa Indians of Texas)

2. Sandstone metates or grinding stones were also present. For what could these have been used?

3. Shell tools were made from conch and whelk shells. These shells were used to make adzes. Adzes are ax-like tools with an arching blade at right angles to the handle. These were probably used in woodworking. Examine Figure 6.2, which shows a portion of a large lightning whelk shell. Use a marker and shade the part that could be used to make an adze.

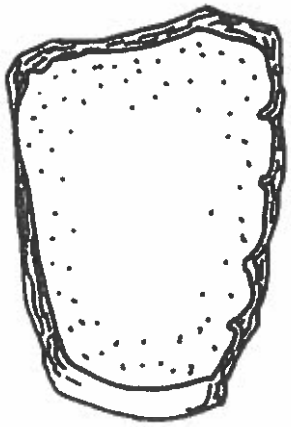


Fig. 6.2. Portion of lightning whelk shell used to make an adze. (Source: Ricklis: The Karankawa Indians)

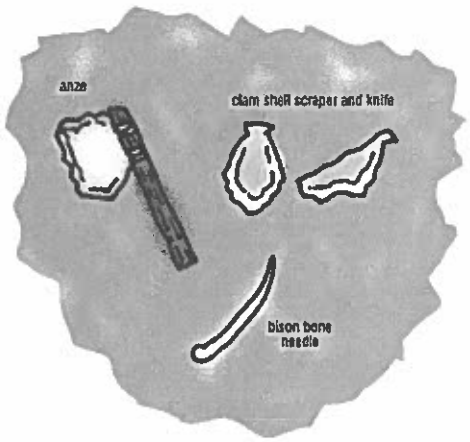
4. Oyster shells were used as weights on fishing nets. Ornaments as well as different kinds of beads were made from shells. Venus clamshells were used to make knives or scrapers. How would the scrapers have been used?

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5. The clamshells were also used to make awls or perforators. These are sharp pointed tools used to pierce holes in materials. How might these have been used by the Indians?

6. What part of the whelk shell could be used to make awls or perforators? What part could be used to make hammers?

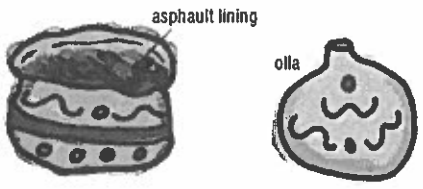
7. Tools and ornaments were also made from bones. They had perforators and flint-making tools from bones. The deer ulnas (small leg bones) were used to make these. Perforators, needles and pins were made from splinters of deer or bison bone. Beads made from cross sections of the long bones of birds and were often highly polished. What inferences can you make about the life and activities of the Indians based on these tools?



8. The most distinctive artifact category found were the ceramics. Ceramic smoking pipes were found and may have been quite common. They had a cylindrical shape and sometimes were decorated with lines or dots. Different types of pottery were quite abundant. However, very few complete ones were found. Why were mostly broken pieces found?



9. Using the curves of the pieces and the few complete and partially complete pieces it has been determined that the pots always had a round bottom. The types of pots were bowls, wide-mouth jars and narrow-mouth ollas. Ollas are shaped like globules and had narrow necks or were neck-less. The openings to the wide-mouth jars and bowls were from 15 to 30 centimeters. These deeper bowls and jars would have held 4 to 6 liters. What inferences can you make about how each type was used? The large wide-mouth jar? The large bowls? The ollas?



Some vessels had material added to harden the clay to prevent them from breaking when they were heated. Some had an inside coating to prevent them from leaking. How would this information help explain the use of the item? Explain.

They were decorated with painted bands, squiggles, and dots that were applied after the vessels had been fired. They used natural asphaltum to decorate the pottery. **Asphaltum** is a naturally occuring tar that washes upon beaches from natural petroleum seepages.

Why is asphaltum painting only found in pottery in the area that the Karankawas lived?

10. Based on the materials found in the Karankawa sites, write a description of or draw the activities you might see in a Karankawa site.

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7. Were the Karankawa Indians "Savages" and "Cannibals"?

Researcher _____ **Research Group** _____

Cabeza de Vaca is credited with one of the most remarkable journeys. His mission had been to find new riches for Spain. Over an eight-year period between 1528 and 1536, he traveled from Florida to Texas. After living with the Karanakawas, he walked across Texas to El Paso, then across northern Mexico to the Gulf of California. He and his companions traveled more than 5,000 miles. During his travels he kept a journal that described the vast wilderness, the people, the plants and animals between Florida and the Gulf of California. Before his expedition, no one imagined such animals as the opossum or the armadillo, or the variety of the tribes of Indians.

Cabeza de Vaca traveled from northern Florida by horsehide boat to the coast of central Texas. Here, his expedition was blown ashore on November 6, 1528. He and his men landed near a Karankawa campsite and took an earthen pot, a small dog and a few fish. A short time later he and his men were surrounded by a group of Karankawas. This is the first time that the Karankawas came in contact with Europeans. Cabeza de Vaca lived with the Karankawas for several years and his journal is considered the most complete account of the coastal Indians found among the 300 years of reports from Spaniards, Frenchmen, priests, pirates, soldiers and settlers. You and your researchers are going to survey the historical record to determine if the Karankawas were indeed the "savages" and "cannibals" as they were often referred to by early explorers and later the settlers.

Materials: none

Procedure:

Part I: What were the Karankawas like when they met the first Europeans?

1. On a separate piece of paper, create a chart using the following format. As you read the journal entries, complete your chart.

Chart 1: Journal Writers and their Attitudes

Date	Journal entries by	Attitude towards Indians

Upon finding his group surrounded by the Karankawa, Cabeza de Vaca used sign language to pledge friendship and gave them gifts of beads. De Vaca recorded in his journal Relacion that the Indians promised to return with food. He stated that they came in the morning and at night for several days laden with fish and roots. These gave his men enough strength that they tried to leave on their makeshift boat. In trying to leave, three of

his men drowned and the rest were half-dead and naked. The Indians arrived with the usual evening meal. This is the reaction recorded by Cabeza de Vaca:

"The Indians, at sight of what had befallen us, and our state of suffering and melancholy destitution, sat down among us, and from the sorrow and pity they felt, they all began to lament so earnestly that they might have been heard at a distance, and continued so doing more than half an hour. It was strange to see these men, wild and untaught, howling like brutes over our misfortunes. It caused in me as in others, an increase of feeling and a livelier sense of our calamity."

Based on this entry in Cabeza de Vaca's journal about this meeting with the Karankawas, how would you describe the Karankawas?

2. In a later entry in his journal, Cabeza de Vaca writes: "...the natives were visited by a disease of the bowels, of which half of their number died. They conceived that we had destroyed them, and believing it firmly, they concerted among themselves to dispatch those of us who survived. When they were about to execute their purpose, an Indian who had charge of me told them not to believe we were the cause of those deaths, since if we had such power we should also have averted the fatality from so many of our people, whom they had seen die without our being able to minister relief, already very few of us remaining, and none doing hurt or wrong, and that it would be better to leave us unharmed." What inferences can you make about the Karankawas from this journal entry?

3. Another incident that Cabeza de Vaca recorded in his journal involved Spanish cannibalism. He stated, "Five Christians, quartered on the coast, came to such extremity that they ate their dead; the body of the last one only was found unconsumed. . . This produced great commotion among the Indians, giving rise to so much censure that had they know it in season to do so, doubtless they would have destroyed any survivor..." Explain this journal entry. Look up the meaning of unfamiliar words.
   a. Who were the cannibals?
   b. What was the reaction of the Indians?

4. De Vaca wrote the following about the Karankawa and their children, "Those people love their offspring the most of any in the world and treat them with the greatest mildness." He went on to note that, "When a child died, particularly a boy or young man, the whole village would weep morning, noon and night for an entire year; the elderly, however, "whose season had passed" were shown no sorrow. Cabeza de Vaca expressed his astonishment at children being nursed until they were 12 years old. He was told that this was necessary if the children were to stay strong in times when little food was available. What do these observations tell us about the Karankawas?

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5. In their daily activities, de Vaca noted that the men hunted the game and the women set up and took down the camps. They also cooked, gathered firewood and cared for the children. He also noted that they were primarily monogamous. Rarely did parents divorce. However, divorce was common among childless couples. Married couples normally became part of the husband's family or band.
   A successful hunting or fishing trip always led to a rousing celebration. He noted that they never failed to observe their festivals and danced and sang around roaring fires despite the white man's diseases that had killed half of them. He also noted that the environment was often hostile with cold northers in the winter and heat in the summer. In spite of these bad situations, Cabeza de Vaca remarked that these coastal Indians were "a merry people." Based on these observations what conclusions could you reach about the Karankawa social structure and attitudes?

6. Based on Cabeza de Vaca's observations, what conclusions could you make about the Karanakawas?

7. After Cabeza de Vaca lived with the Karankawas for several years, it was nearly 200 years before the Karankawas would encounter Europeans again. This time it was the French expedition lead by Rene-Robert Cavelier de La Salle. He landed at Matagorda Bay in 1685 and established Fort Saint Louis on Carcitas Creek. La Salle's party was well received by the Karankawas, who invited them to go on a Buffalo hunt. However, La Salle ordered some of his men to steal several Indian dugout canoes. The Karankawas had worked hard to make the dugouts using shell and stone tools and their lives depended on these boats. The Indians retaliated by killing several Frenchmen. Within a four-year period, La Salle was murdered by his men and his colony was reduced to five. They were the only ones to survive disease and regular attacks by the Karankawas. Jean Baptiste Talon, a boy who was adopted by the Indians after he was captured during an attack on Fort Saint Louis wrote:
   "M. de La Salle would never have had war with the Karankawas if on arrival he had not high-handedly taken their canoes and refused them some little article that they asked him in return for them and for other services that they were ready to render to him. Nothing is easier than to win their friendship (than by giving them presents). But also, as they give voluntarily of what they have, they do not like to be refused. And, while they are never aggressors, neither do they ever forget the pride of honor in their vengeance."
   Compare La Salle's and Cabeza de Vaca's interaction with the Karanakawa by completing the tables in Chart 2.

Chart 2: Comparison of La Salle's and Cabeza de Vaca's Interaction with Indians

Explorer	Similarities	Differences
Cabeza de Vaca		
La Salle		

Explain the differences.

Part II: What were the Indians like during the time of Spanish missions?

1. In the 1750s, a new relationship was established between the Karankawas and the Spaniards. The Spanish began an effort to convert the coastal tribes to Christianity and to the Spanish lifestyle. See Figure 7.1 for a location of the Spanish missions. The Spanish wanted them to live in the missions and to grow crops and raise cattle. The first such effort was the Espiritu Santo mission. In the fall of 1723, disagreements occurred between the Indians and the soldiers at the presidio of La Bahia. This resulted in fighting and the death of two Indians and Captain Domingo Ramon. The cause of the fighting was the attempt of Ramon to kill all the Indians. He had invited them to take part in a feast and instead tried to massacre them. A report by Fray Benito de Santa Ana noted:

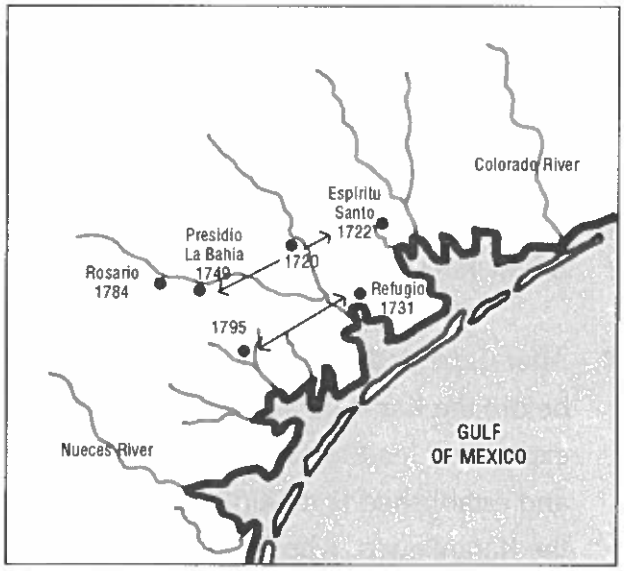


Fig. 7.1. Locations and relocations of Spanish Missions on the central Texas coast. (Source: Ricklis: The Karankawa Indians of Texas)

"For the past twenty years, they have been living in heathendom and with mortal hostilities between the Indians and the soldiers."

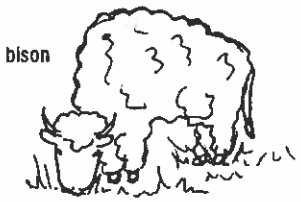
In an inspection visit in 1767-1768, Fray Jose de Solis noted:
"They are all barbarians, given to idleness, lazy, indolent. They are very gluttonous and ravenous and eat meat almost raw, roasted and dripping with blood. . .They are idle and given to all kinds of vices, especially the vices of lasciviousness, robbery, systematic thieving and dancing."

In the 1770s, Fray Augustin Morfi reported, "the Karankawa nation was vile, cowardly, treacherous and very cruel . . Many of them speak Spanish with great fluency, being in many instances, apostates from our missions."

In your own words summarize the perception that the Spaniards held about the Indians.

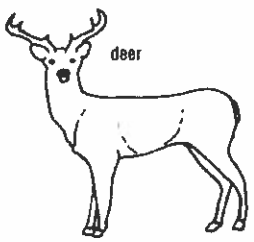
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2. In the first instances of European and Karankawan meetings (de Vaca, La Salle), the Indians appeared to have an open attitude toward visitors to their lands. Barroto's report of a visit with Indians near Aransas Pass stated that the Indians "came to the beach to play games next to the galley" and Captain Yriarte received gifts of fish from the Indian women and he gave them presents of beads. In 1720, Beranger spent several days near a large shoreline camp and reported that the Indians offered his men food. They also helped his men gather enough acorns to fill six casks. Why do you think this early relationship changed?



3. Before domesticated animals were introduced, the reports indicated that bison were plentiful and were a source of food for the Indians. As late as 1768, reports indicate that bison abounded in the region. In his report about the La Bahia mission, Fray Lopez noted that there were more than 15,000 branded cattle on the mission ranches and those unbranded were a much greater number. A 1793 report of the plants and animals of the region makes no mention of the bison when it listed the region's edible animals
   a. What was the effect of the increasing number of cattle herds on the bison? Explain.
   b. How would the decrease in bison affect the Indians?
   c. What could they use to replace the bison as a source of food?

4. As early as 1751, the Spaniards considered the Indians a threat to their herds. Captain Piszina wrote from Mission La Bahia that he sent his lieutenant with a group of men, "...not to trouble them, but only to find out what they wanted and to prevent them from doing damage to the mission cattle, as they are known to have done in the past." As late as 1798, Fray Antonio Garavito wrote from the Refugio mission, "I fear that if the Indians from Rosario do not have enough to eat in their mission, they will wander about doing damage...the cattle will be destroyed, the herds driven off, the tame horses taken."
   a. Why do you think that the Indians took the cattle from the missions? Why would they want the cattle?
   b. Why do you think the Indians replaced game animals such as bison with livestock as their main source of food?
   c. What effect might the introduction of cattle to the coastal prairies have had on the relationship between the Indians and Spaniards?



5. The Karankawa lifestyle was hunting and gathering while the Spanish lifestyle was farming and ranching. How would people of different lifestyles living in the same area affect each other?

6. By the 1780s, fighting between the Karankawas and the Spaniards was frequent. The Indians would take livestock. The Spaniards would send out troops to find the Karankawas to punish them. The Karankawas would flee to the coast. The Spaniards did not have the equipment or knowledge to chase them in the maze of marshes and lagoons. Don Luis Cazorla, commander of La Bahia wrote to Governor Pacheco in 1787 that it was impossible to follow the Indians into marshes and bays to punish them. He proposed gathering them all in the mission and if there were problems, "we could make reprisal and expel them once and for all. With this, without violating our treaties with them (for which I can see no justification in humanity, hospitality or natural law), we would achieve extermination. This is the view which I have developed of the aforesaid coastal Indians—with no other purpose than that of serving God and the King and the public interest." Explain the attitude presented by Carzorla.

7. In 1791, Fray Manuel de Silva who was in charge of all the missions in Texas visited the missions. He also visited with the Karankawas to evaluate the possibility of a new mission for the coastal Indians. See Figure 1 for the location of the missions. The Refugio mission was more successful than the Rosario mission. In de Silva's report to the king, he stated, "Finally, in spite of their crudeness, they heard, without fear or intimidation, the high nature of the venerable mysteries of Our Holy Faith. Nor did the subordination to the civil laws and mercies of Your Majesty appear too hard on them." He also wrote to the King in 1793 that "...attracted by the kindness with which my companion and I treated them, they would later come to establish and keep an inviolable peace with us Spaniards, a peace that so far they have not broken, whereas previously they made hostilities, committing robberies and murders." What was the difference in the attitude towards the Karankawas between Carzorla and de Silva? What are some possible explanations for these differences?

8. Fray Juan Garza who was along with de Silva actually recorded a Karankawan leader's response to the new mission. "Father, don't deceive yourself, for we don't want to go to the Mission (of Rosario). We will do nobody harm, we will go our own way, and let the Spaniards come also to our country, with the assurance that we will receive them as friends, but we do no not want to leave our country. If you want to, put a mission here on the coast for us. We will gather in it, all of us who are Christians, and we will bring with us all the heathens that are on this coast." Explain the significance of this in the Indian and Spanish relations.

9. On the whole, the new mission at Refugio appeared to provide a peaceful connection between the Karankawas and the Spaniards. In 1797, Elquezabel wrote, "From what I have seen of their (the Karankawas') manners and ways of doing things, there does not appear

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to be any bad intention, or anything that one could find suspicious, or any artfulness in their thinking."

Examine the location of the missions (Figure 7.1). It was reported that the Indians would not settle in the missions around San Antonio. The other coastal prairie missions except the short-lived Espirtu Santo were located beyond the inland edge of the Karankawan home territory. The Refugio mission appeared to have the greatest success in converting the Indians to Christianity and getting the Indians to adapt to the Spanish cultural patterns. The Indians would visit the missions for food. The missions used gifts and food to bring the Indians into the missions. Depending on the time of year, the Indians would stay a short time and then leave for the coast or the inland prairies. What might be the explanation for the success of the Refugio mission?

10. The records of the Spanish missions between 1722 and 1798 indicate that the Indians would enter a mission in the spring and then leave and return again in the fall. During the winter they would leave the mission for their coastal camps. Table 1 shows the arrival times of the Karankawas and the number of groups that arrived per month at the coastal missions. Based on the data, what is the pattern of Indians at the missions? What might explain the pattern?

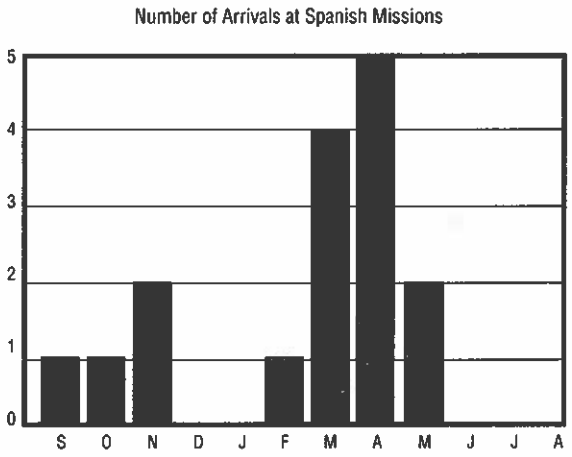


Table 1. Arrival of Karankawas at Coastal Prairie Missions and the Number of Arrivals per Month. (Source: Ricklis: The Karankawa Indians of Texas)

11. Archeological evidence shows that Karankawas had a seasonal adaptive pattern. Examine Figures 7.2 and 7.3.

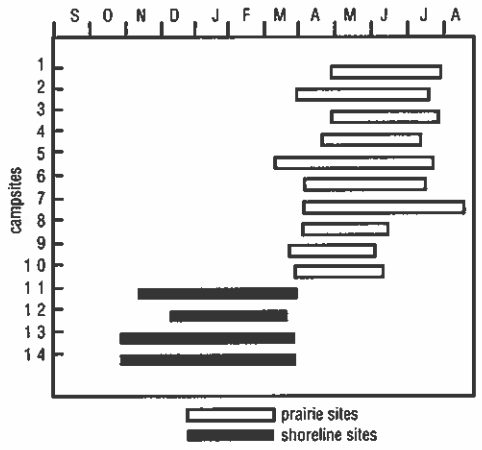


Fig. 7.2. Months Karankawas camped on the Group I shoreline and Group 2 prairie sites.

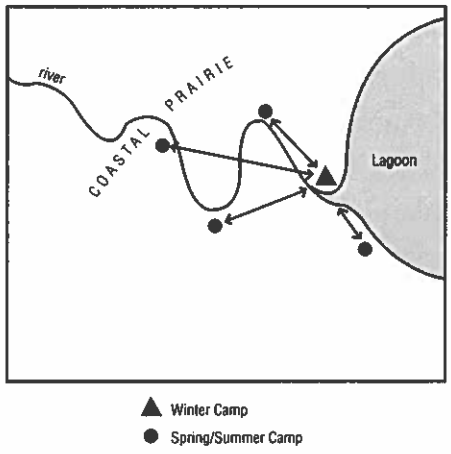


Fig. 7.3. Diagram showing basic patterns of seasonal patterns of Karankawas.

Source for 7.2 and 7.3: Ricklis: The Karankawa Indians of Texas)

a. When did the Indians set up camp along streams in the prairie?
b. When did they camp along the bay shore lines?
c. When did they move between the shore lines of bays and the inland prairie camps?

12. Analyze the data from Table 1 and Figure 7.3. Is there a relationship between the Karankawas seasonal patterns and that of their appearances at the missions?

Part III: What were the Karankawas like after 1830?

1. From 1790 to about 1830, the Karankawas had established an ongoing, peaceful relationship. What was the relationship of the Karankawas adaptive strategy of moving between the coastal and prairie environments and their visits to the missions? Did they change their patterns to visit the missions? Explain.

2. An archeologist has stated that the Karankawas were able to adapt to the Spanish because the Indians treated the mission as an ecological resource. Explain.

Part IV: What were the Karankawas like during the Anglo-American settlement?

1. The Spaniards maintained a policy toward the Indians of getting them to adapt to the Spanish cultural patterns and converting the Indians to Christianity. The Anglo-Americans wanted to permanently acquire land to build settlements. How would the Anglo settlers desires and lifestyle affect the Karankawas?

2. At least five epidemics were recorded in Texas prior to 1751, any of which might have reached the Karankawa. Records indicate that the smallpox or measles epidemic of 1749 did reach the Indians. By 1767, the number of Karankawa were greatly reduced. The numbers then appeared to remain stable until about 1820. Analyze the population curve for the Karankawas in Figure 7.4. What are some possible explanations for the population drops and the level periods?

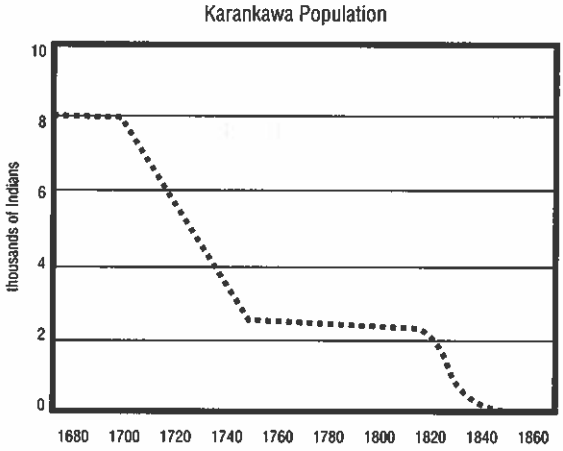


Fig. 7.4. Historical population curve for the Karankawas.

3. Beginning around 1820, Anglo-Americans began to receive land grants for settlement on the coastal prairies just inland from the Karankawa territory. Hypothesize as to the impact of the land grants on the Indians.

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4. From about 1820, hostilities between the Karankawa and Anglo-Americans were ongoing. By 1825, Stephen F. Austin was successful in campaigning against the Karankawas. They signed a peace treaty, but continued to harass the settlers by stealing cattle and produce. Why do you think the Indians continued to take cattle, produce and other items? Could their taking or "stealing" be related to their hunting and gathering lifestyle? Explain.

5. The problems between the Karankawas and the settlers continued. The Mexican government was finally called in and about 50 percent of the Indians were killed. Even more died during the Texas Revolution. The Indians were confused about whose side they were on. They would act as allies of both the Mexicans and the Texans. By the 1850s, the Karankawas had disappeared as a group. Most of the Anglo settlers were glad to see the "man-eaters" gone. The "giant Kronks" driven by their "love of human flesh" had been wiped out. Reports stated these "filthy savages" couldn't ranch or farm and they were lazy. They ate the horses they stole. They reported that the Karankawas smelled very bad and ran around naked. It was also reported that the Karankawa tortured and murdered decent people and showed no mercy toward children. The Karankawa crossed the territorial line that Stephen F. Austin had drawn so he proclaimed there would be no way to subdue the "Kronks, but by extermination." This "disgusting race" was justifiably doomed. These were the feelings and thoughts of the new Texans. How are these descriptions different from those of Cabeza de Vaca and other early Europeans?

   How do these descriptions differ from those of the Spaniards during the mission period and how are they alike?

6. What are some possible explanations for the different relationships and interactions with the Karankawas? (Refer to your completed Chart 1, page 547).

7. Based on what you have learned, how would you describe the Karankawas?

8. Were the Karankawas "savages" and cannibals? Explain.

9. Use Chart 1 (page 547) to create a graphic time line to indicate the Karankawas' interactions from Cabeza de Vaca in November 1528 to the 1850s. Use drawings to illustrate the interactions on your timeline.

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Topic 11—The Interaction of Marine Organisms and the Physical Environment

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Topic 11: The Interaction of Marine Organism and the Physical Environment

The physical factors that characterize ocean environments are many. Examples include temperature, salinity, water pressure, nutrients, dissolved gases, currents, light, suspended sediment, substrate, river inflow, tides, waves and many more. The temperature of the water may be the most important regulator of the distribution and activity of organisms in the ocean. Many species distribution mirrors the shape of the temperature structure of the oceans. Light is a critical factor since it determines the areas of productivity. Water pressure increases by about 1 atm for every 10 meters or 33 feet of water so organisms must adapt to pressure. In the sea without light or limited light, organisms must depend on other means of communication other than vision. These include smell and echolocation.

The activities in this unit may be integrated with the related physical features in Topic Eight: The Physical Features of the Ocean and Gulf of Mexico. For example after completing the three temperature activities in Topic Eight, the students could complete Activity1 in this unit. If you are focusing on the biological aspects then the students may begin Activity 1 and the temperature activities from Topic Eight can be integrated on a need to know basis.

Activity 1. How does the water temperature affect marine animals?

TEKS: Science: 6.5, 6.12, 7.5, 7.11, 8.11

Math: 6.8, 7.9, 8.8

Language Arts: 6.9, 6.10,7.9, 7.10, 8.9, 8.10

Social Studies: 6.6, 7.9

Learner outcomes: After completing the activities, the students will be able to:

- interpret data about the relationship temperature and the location of fish.
- make inferences about the impact or location of fish based on temperature.
- summarize the relationship between temperature and productivity.
- conduct an investigation to determine how animals are adapted for living in extreme temperatures.
- design and conduct an experiment to use information about animal's adaptions to extreme temperatures to design "survival suits" for people.

Background:

Part I

1. Ask the students to make a chart in one column listing the different marine environments. Then next to each marine environment, list the temperature of the environment. Instead of actual temperatures, they may use polar, tropical, etc., and then list animals found in each environment. Include the deep sea hydrothermal vents as an environment. Than have the students analyze their chart, are there any patterns?
2. Discuss that temperature is considered the single most important factor in the distribution and activity of organisms in the ocean. Refer to the temperature graphs in Activity 8, Topic 8. The distribution of many marine species fits the shape of the temperature isotherms. Temperature is a strong controlling factor in the rates of chemical reactions. This affects the synthesis of enzymes in the cells which affects the growth rates, reproductive success and the general activity of the organisms. This is true for many of the marine organisms since their body temperature is the same as the water around them. It has been found that the biological activity of marine organisms tends to double for every 10 degree rise in water temperature. So organisms living in polar seas grow more slowly, reproduce less frequently and live longer than do organisms in tropical oceans. However, the cold water has more nutrients than warm water so more marine plants grow in colder water than in warm equatorial waters. Tolerance to changes in water temperatures varies with each species. However, usually eggs, larvae and juveniles are more sensitive to temperature fluctuations than are the mature adults of the same species. Since the majority of invertebrates and fishes hatch in water, the water temperature that surrounds the eggs strongly influences their embryonic development and survival rate. Even after hatching, larvae and juveniles generally have little tolerance for temperature changes. Ocean temperatures range from 2°C and 40°C but more that 90 percent of the ocean's water is colder than 5°C. Plants and animals thrive in this water provided they receive adequate food. There is a much greater supply of nutrients in the colder waters than in the tropical waters. So there is more life in the colder waters than the warmer waters. Increasing water temperatures may lead to

a decrease in organisms.

3. After discussing the relationship of temperature and marine organisms, use the questions for discussion and application.

Activity 2. How do smells in the seawater affect animals?

TEKS: Science: 6.2, 6.3, 6.4, 6.5, 6.7, 6.12, 7.2, 7.3, 7.4, 7.5, 7.11, 7.12, 8.2, 8.3, 8.4, 8.5

Language Arts: 6.10, 6.20, 7.10, 7.20, 8.10, 8.20

Learner outcomes: After completing the activities, the students will be able to:

- construct a model to investigate how particles move through water.
- compare the model of particle movement to that of scenarios.
- participate in role plays to investigate how marine organisms locate food.
- design and conduct an experiment to investigate the effect of pollutants.
- design and conduct an experiment to determine how divers may protect themselves from shark attacks.

Background:

1. Before beginning this lesson and without the students observing, place an object that gives off a pleasant odor where it can't be seen. Using wintergreen, peppermint, or spearmint oil or an air freshener. Point out that a living organism has the ability to use materials from the environment to supply itself with energy and reproduce. A nonliving object is unable to do this. Locating food or a meal in the ocean is more difficult partly due to the differences between water and air. In the ocean pressure and darkness are a factor. Many organisms find food through an acute sense of smell. Identify the odor that you hide in the room. Ask the students to locate the source of the odor. If some students do not smell the odor suggest that they move around to see if they can locate it. Discuss what they observed.
2. To explain how odor molecules travel, either demonstrate number 1 or have each team complete the activity. Use the information to explain scenario number one and two. Note that sharks can zero in on a wounded fish from a quarter mile or more away. Night feeding fish can find food without light. All use an acute sense of smell.
3. Number four can be set up in the classroom or outside. It should be set up ahead of time so the students do not see the source of the odor. Assign students to move in circles and others to move randomly. Assign some students to be observers and record the movement of the student sharks. Discuss their observations.
4. Use plastic 35mm film canisters. Place the odor producing item in the bottom of the canister and then place a cotton ball over it and replace the cap. If you use a liquid, place several drops of the liquid on a cotton ball in the bottom of the canister. Place another cotton ball above it. Use spices (cloves, cinnamon, nutmeg, allspice, sage, etc., or flavor extracts like vanilla, strawberry, maple, peppermint, etc.). Several students (fish) can be given the same food source. Discuss how an organism in the ocean might find a mate or its spawning area or detect enemies.
5. Discuss the impact of unwanted chemicals (pollutants) in the water. Ask the student how they might design an experiment to investigate the impact. This can be demonstrated by repeating number 4, but this time also spray the room with another odor. Discuss the possible impact on organisms that rely on their sense of smell.
6. Challenge each team to think of ways a diver may prevent a shark from smelling him. Encourage each team to design their "suit " to protect their diver, they can bring materials to make their "suit" or the materials may be provided. Designate one team to act as judges. The judging team will need to develop guidelines on the "diving suit" such as size and weight, as well as other criteria. Each group is provided with a slice of onion to represent their diver that they will put in a protective suit. The judges will decide which team's "suit" is the best based upon their criteria.

Activity3. What are the sounds in the ocean?

Activity 4. How do marine animals produce sounds?

TEKS: Science: 6.2, 6.6, 7.2, 7.11, 8.2

Language Arts: 6.9, 6.10, 6.13, 6.20, 7.9, 7.10, 7.13, 7.20, 8.9, 8.10, 8.13, 8.20

Social Studies: 6.1

Learner outcomes: After completing the activities, the students will be able to:

- describe sounds at the beach and discuss what the sounds indicate.
- make inferences about the source of the underwater sounds on a tape.
- infer that unknown sounds may have resulted in the tales of ghosts and spirits told by sailors on sailing ships.
- interpret information to construct explanations

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about legends about the sea and how marine organisms make sounds.

- formulate hypotheses about research on the sounds in the ocean, their importance and the impact of sonar on marine organisms.

Background:

1. Sound is a key medium for many marine organisms seeing without eyes, especially sea mammals. Use the activities as a guide for class discussions. Activity 3 can be used as an introduction to discuss the legends and tales of the sea from the days of sailing ships. Note that people do not have an explanation for an event like the sounds that the sailors at sea heard, other nonscientific explanations (myths, legends, etc.) are developed to explain the unknown. As technology has developed tools to investigate the unknown, then scientific explanations replace the nonscientific ones.
2. Continue with activity two, if possible obtain pictures of the organisms mentioned in the Voice of the Noisy Deep to show the students as it is discussed. As each method of sound that a marine organism makes is discussed, ask the students which musical instrument uses a similar method. Or how they make sounds using similar methods.
3. Discuss the importance of learning to understand the communication of the animals and how we might use this information to protect people and animals.

Activity 5. How do animals detect sound in the ocean?

Activity 6. What is echolocation and how does it work?

Activity 7. How do marine animals produce and receive the echolocation sounds?

TEKS: Science: 6.2, 6.3, 6.4, 6.6, 6.7, 6.10,6.10, 7.2, 7.3, 7.4, 7.6, 7.11, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.10,8.11,

Math: 6.9, 7.9, 8.8

Language Arts: 6.9, 6.8, 6.10, 6.11, 6.13, 6.20, 6.24, 7.9, 7.10, 7.11, 7.13, 7.20, 7.24, 8.9, 8.10, 8.11, 8.13, 8.20, 8.24

Social Studies: 6.1

Learner outcomes: After completing the activities, the students will be able to:

- communicate how fish use the lateral line to detect sound.
- intrepret a diagram to explain how the lateral line functions.
- construct a table to compare the ears of fish and people.
- gather data to explain how human ears work underwater.
- Construct and analyze a graph to determine the range of hearing of animals.

Background

1. Divide the class into 6 teams and each team becomes an expert on a part of the lesson and teaches the class or use Jigsaw II. To use Jigsaw II each team will need 6 members and each individual student becomes an expert on a subsection of the activities and teaches that subsection to the team. The subsections would be: Activity 5, Part I; Activity 5, Part II; Activity 5, Part III; Activity 6, Part I; Activity 6, Part II and Activity 7. The experts for each subsection would meet together to learn about their topic and develop their presentation for teaching the team or class. Encourage them to conduct additional research on their subsection and to include demonstrations or role plays in teaching their section. They should provide the information to answer the questions in their section.
2. When a solid object moves through air or water, it causes molecules around it to move. The molecules in front of it are pushed together, or compressed. This is a pressure wave. The molecules behind the object spread out to fill in the space left by the moving object. Water molecules are much harder to compress than molecules of air. This means less energy is lost in the wave motion in water than air. This energy travels about 5 times faster in water than in air. If the object moves back and forth, it creates a series of pressure waves, which travel away from the object. Each complete movement is called a cycle. The number of cycles that occur in a period of time is the frequency of the movement. The frequency is timed in seconds. If the frequency is between 20 cycles per second (hertz) and 20,000 hertz (Hz) then humans can hear them and they are called sonic. If the frequency is less than 20Hz, it is called infrasonic and if it is over 20,000 Hz, it is ultrasonic. Whales and dolphins have highly developed hearing and are particularly sensitive to ultrasonic sounds. Although the sea may seem silent to human divers, to animals it is noisy. Swimming animals produce unintentional noises as they move, feed, and bend their bodies. Others make intentional grunts, groans, chirps, and other noises. Added to these are sounds of surface waves, the ocean is filled with sound within, below and above the range of

human ears.

The lateral line system is especially sensitive to low-frequency vibrations caused by movement underwater. It gives fish a long distance sense of touch and keeps it aware of nearby animals and objects.This is vital to fish schooling in dark water. It also enables them to detect predators or prey. Pressure waves also play an important role in the social behavior of fish. In the rituals before mating, some fish fan their mates as part of the courtship procedure and some fish fan their opponents to establish dominance. The vibrations set up by the fanning probably convey appropriate messages to the animals involved.

The lateral line sense organs of fish are similar in design to those of its ear. They are contained in canals and stretched out along the side of the fish's body and branches which encircle the head. The canals are located just beneath the skin. Pores through the skin or scales open them to water.

3. For almost every invention of humans a similar system exists in nature that is better. This is true for animal sonar or echolocation. The dolphin and other members of the toothed whales can determine the range and location, but also the size, shape, texture and density of objects. The characteristics of the clicks sent by the animal are changed into an echo by the target. This echo informs the animal of the object's makeup. There is no way of knowing what a dolphin or whale "hears." The system is amazingly accurate and gives the animal many more times the information than obtained by human developed sonar. This sophisticated system of echolocation for target detection and orientation enables toothed whales to compensate for reduced visibility and their inability to smell underwater.

   To hear recordings (for properly equipped computers) of the "clicks" and along with a discussion, visit http://www.unmassed.edu/Public/People/kamaral/thesis/marinemammalacoustics.html#echolocation

4. The speed of sound in water increases with salinity, temperature and pressure increase. Temperature and pressure changes have a more marked effect on sound speed than salinity does. As a result sonar can determine the boundaries of the different water masses.

5. Discuss the possible implication of the increased use of radar and sonar by boats and ships and the detonation of underwater explosions on the echolocation system of animals. Point out that currently we do not know enough about the echolocation of animals to know if human activity is creating problems.

Activity 8. What is the relationship between light and organisms in the ocean?

TEKS: Science: 6.2, 6.3, 6.4, 6.5, 6.8, 6.12, 7.2, 7.3, 7.4, 7.9, 7.11, 8.2, 8.3, 8.4, 8.6,

Math: 6.10, 7.11,8.5

Language Arts: 6.10, 6.11, 6.13, 7.10, 7.11, 7.13, 8.10, 8.11, 8.13

Social Studies: 6.20, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- formulate hypotheses to explain factors that affect light intensity
- use the internet to gather data to determine if hypotheses was correct or not.
- formulate hypotheses to explain the movement of zooplankton.
- relate light intensity to productivity.
- use internet data to note patterns in productivity.
- infer the reason for the unusual eyes of marine organisms.
- explain the role of luninescence.

Background:

Part I

1. Review Activity 18 in Topic 8. If this activity has not been completed then combine the two activities. Begin this activity, ask each team to formulate their explanation of why the requirement for light is the main limiting factor of the distribution of all marine photosynthetic organisms. No more than 1 percent of all sunlight penetrates to a water depth of 100 meters. This level separates the photic zone where plants primarily photoplankton can photosynthesize from the aphotic zone where plants cannot photosynthesize. Nearshore water contains a high sediment load, which limits light penetration to a depth of no more than 20 meters below the sea surface. The color of the nearshore water typically is green and yellow because of the suspended particles that reflect these wavelengths. If plants cannot survive in an area then zooplankton and other animals will not survive since they depend on the plants for their energy. There is less light energy in the early morning and late evening due to the angle of the sun's rays striking water. This is also the case in winter when the angle of the sun's rays is at a greater angle than during the summer. Cloud cover also reduces the light intensity which in turn reduces the photosynthetic activity and productivity. High latitudes, shallow waters and zones of updwelling generally support large populations of phytoplankton and algae. Most of this production is

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accomplished during the warm summer months when light is not a growth limiting factor.

2. Note that any factor necessary for growth or health of an organism that limits growth if it is not in sufficient supply is a limiting factor. Phytoplankton populations are limited by a combination of factors. Important limiting factors for phytoplankton are light and nutrient availability and herbivore grazing. In the ocean each major group of phytoplankton responds differently to combinations of these factors. One group may thrive in lower light intensities and colder water while a group does not thrive under those conditions. As a result, conditions that promote the growth of one group will tend to exclude another group. This reduces competition among the phytoplankton.
3. Many animals feed directly or indirectly on the phytoplankton. This results in the Deep Scattering Layer (DLS) which is a sound reflecting layer of zooplankton and nekton that move up at night and down each day. This vertical migration is a response to changing light levels. The layers of the ocean are not fixed to a single level, but the organisms tend to remain in groups. As the waters darken with the coming of night, these animals respond. They begin a vertical migration toward the surface. Animals at the upper side of the DSL may move up a few hundred feet to reach the surface. Those that spend their daylight hours at the lower limit may climb thousands of feet up to the surface. During the day, they remain in dark waters where they are relatively safe from predators. At night when they are safe from visual detection, they move upward to feed on the phytoplankton and algae. If the photosynthetic organisms produce any toxins during photosynthesis, they are able to avoid them.

Part II

1. Ask why on land animals rely primarily on sight to obtain their food and in the ocean sight is not a primary sense. Although lobsters, crabs and many other crustaceans have compound eyes, as a rule, animals that live in the sea have spherical lenses that provide them with sharp vision underwater. Among the fish there are a wide variety of eyes. Each is adapted to the special circumstances of that species. Some fish that live in lightless caves have no eyes. Some cave-dwelling and deep sea fishes have vestigial eyes that may only be able to sense light. Others in the deep ocean have large eyes with the capacity for opening pupils to a great size, enabling them to gather the small amount of light available. Many eyes have special adaptations to increase vision in limited light. Some fishes have good binocular vision. Some can move their eyes independently and adjust the portions of the vision field independently.
2. Point out that bioluminescence refers to cold light emitted by organisms. It is known to be produced in many marine species of bacteria, dinoflagellates and invertebrates. Among vertebrates, fish are known to produce bioluminescence and it becomes increasingly important in the deep seas. It may have a communication function but for many species the reasons for its use are not certain. The chemicals may act as a decoy to distract predators, serve as a type of camouflage, lure their food, warn against attack, communication for feeding and reproduction. Different types of luminescence are observed.

Activity 9. What is the effect of pressure on marine organisms?

Activity 10. What is the effect of pressure on divers?

TEKS: Science: 6.2, 6.3, 6.5, 6.10, 6.12, 7.2, 7.3, 7.9, 7.11, 7.12, 8.2, 8.3, 8.6

Math: 6.3, 7.2, 8.2

Language Arts: 6.10, 6,11, 7.10, 7.11, 8.10, 8.11

Social Studies: 6.20, 8.29

Learner outcomes: After completing the activities, the students will be able to:

- use a model to formulate an explanation of the impact of pressure on gases in body cavities.
- explain how organisms are able to survive the pressure of the ocean depths.
- construct an explanation of what happens to fish with air bladders that are brought to the surface from 200-1000 meters deep.
- observe the cartesian diver and explain the effect of pressure on body cavities.
- explain the problems that can develop during diving.
- explain the importance of decompressing properly and the use of dive tables.
- interpret the data of dive tables.
- use the Cartesian diver model to explain how submersibles diver.
- analyze the impact of manned submersibles, ROV's and AUV's on exploration and knowledge about the ocean.

Background:

1. If Activity21 in Topic 8, has not been completed use it to provide background information and then integrate Activity 9 and 10 as applications.

Hydrostatic or water pressure is another limiting factor that marine organisms must adapt to and it greatly impacts people entering the ocean and exploring its depths. Ask for hypotheses as to how deep sea organisms withstand the pressure.

2. Show the students a styrofoam cup on which you have written or drawn on with a marker. If the cup is taken to ocean depths. It will be greatly reduced in size and it is will be hard. The air has been forced out. Land organisms have air in their organs and body cavities. Gases are compressible(in car tires). The same will happen to people if they dive to the depths without any protection from the pressure. Fish that have air bladders to help them remain neutrally buoyant. These are usually those fish living in depths between 200 and 1,000 meters. They can not move to areas of greater or less pressure without physiological stress or even death.
3. Ask for hypotheses as to why this is not a problem for marine organisms living in the ocean depths. Marine organisms living in the ocean depths do not have air in their organs and body cavities nor do they have swim bladders. Their body cavities are filled with water and water does not compress very easily. As a result pressure changes will not produce stress or death. Discuss the implications for this in diving.
4. Humans have been diving before there was a written history. The eastern Mediterranean, warm waters of the Persian Gulf and Indian Ocean, islands in the Pacific, and even in the icy waters of Tierra del Fuego, humans have been diving. These primitive divers brought back food and treasure, as well as, fantastic tales that kept mythology alive—pearls, coral, sponges, monster stories, and legends of mermaids. They perfected naked diving to depths of 150 to 200 feet. These dives listed around two minutes. Their techniques were passed on from generation to generation. It was not until the end of the 19th century that technology and science was able to improve on these methods. Since then progress in diving has been explosive. This has coincided with the population and the industrial explosions. Areas for additional research might include: Japanese Pearl divers, Leonardo da Vinci's designs, Henry Fleuss, Roberto Galeazzi, Willam Beebe, David Bushnell, George Comheines, Elihu Thomson, Conself I and II, Sealab I and II, Jaques Cousteau, Robert Ballard and Sylvia Earle. These are only a few.
5. Diving consists of air breathing diving from surface to approximately 200 feet. Diving is for recreation, geological, biological and behavioral research, salvage, rescue, coral and pearl collecting, oyster farming and undersea archaeology; and all have demonstrated the efficiency of human presence under water. Deeper diving, however, involved gas mixtures, elaborate habitats and decompression chambers, voice unscramblers, power lines, power tools, communication devices, and each hour on the bottom is extremely expensive and often dangerous. For this reason, the main customers were offshore oil exploration companies. The time spent decompressing made this very expensive. This lead to the development of robots, close circuit television and submersibles that are lowered from a ship.
6. Invite a scuba diver to demonstrate and explain how the diving gear works and problems that can occur. Or have a group of students do a video tape interview with a scuba diver or scuba instructor to share with the class.
7. Discuss why people having the following problems should not dive:
   a. acute or chronic sinus trouble
   b. chronic gastrointestinal disease, including ulcers.
   c. Endocrine disturbances such as Addison's disease
   d. Cardiovascular diseases
   e. Chronic lung disease
   f. Epileptic episodes or diabetic problems
   g. Emotional stability
   h. Ear problems
   i. Women who are pregnant
8. Discuss how submersibles and ROV's have enabled people to overcome the pressure and other problems associated with ocean depths. Discuss the advantages and disadvantages of human divers exploring the depths versus submersibles and ROV's. Discuss the role of technology in increasing about knowledge of the ocean depths.

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1. How Does the Water Temperature Affect Animals?

Ichthyologist _____ **Team** _____

Fish live nearly everywhere there is water. This ranges from warm tropical seas to the icy polar oceans. In the Persian Gulf, water temperature readings of 96 °F have been taken. In the Polar Regions the temperature can reach a below freezing temperature of 28°F. The distribution of various forms of marine life is closely associated with geographical differences in seawater temperatures. Surface ocean temperatures are highest near the equator and decrease toward both poles. These differences are important to animals. Fish are believed to sense water temperature through nerve endings in their skin. These sensors can detect changes in water temperatures of less than 0.1°F. You are going to analyze the effect of water temperature on animals and how this information can be used.

Materials: For each group, 4 quart freezer bags, 1-1 1/2 pounds of lard, 2 large bowls or coffee cans, access to hot water, cooler filled with ice, 2 thermometers, materials that could act as insulation (leather, wool, cotton, fur, down feathers, blanket, saw dust, bubble wrap, etc.), duct tape

Procedure:

Part I: What is the effect of water temperature differences on marine animals?

1. Some marine organisms live in coastal tropical lagoons where the temperature can be as high as 104°F. Some of the bacteria associated with the deep-sea hydrothermal vents experience water temperatures from 400°F to over 500°F. Other deep-sea animals spend their lives in water 1-2° below freezing. Penguins and a few other birds and mammals are well adapted to extreme cold and can tolerate air temperatures far below freezing. Some animals (stenotherms) are more dependent on a given temperature. Other animals (eurytherms) can adapt to a greater variation in water temperature. Look at Table 1 from "What is the temperature of ocean water?" (page 382). In what depths of the Gulf would be the best for the stenotherms that fish that require a constant temperature? Explain.

2. What depths or areas would be best suited for fish that are eurytherms that adapt to temperature variations? Explain.

3. What might stenothermal animals do to survive as the water temperature changes during the day or with the seasons?

4. How do people that fish use the information about water temperature to improve their catch?

5. Fish cannot maintain a constant body temperature and their life processes speed up in warm water and slow down in cold water. Water temperature regulates the spawning habits and is a controlling factor in the hatching of eggs and growth rates of animals. How can the knowledge of the temperatures that particular fish prefer help predict where they will be at given times of the year? Explain.

6. In 1983 and 1989, there were several days of freezing temperatures along the Texas coast. This resulted in a decline in the number of many kinds of fish. Explain what happened.

7. A friend of yours has a large saltwater aquarium stocked with reef fish from the Caribbean. He travels and is often gone for several days. He has asked your advice about what he can do to make sure that the fish are able to survive while he is gone. What advice particularly about water temperature would you give? Explain.

8. Marine aqua culturists have asked for your assistance. They want to know how to speed up both the reproductive and growth rates of the fish they are raising on their fish farm. What would you recommend? Explain.

9. Water temperature also influences the photosynthetic activity of plants. Generally there is little production in water with temperatures of less than 32°F and more than 100°F. How will this affect the animal population in the area? Explain.

10. In temperatures between 32° F and 100°F ranges, the rate of chemical reactions in the plant cell increases as the water temperature increases. The amount of sunlight that reaches the sea surface decreases toward the poles. Therefore, one would expect production to be higher at the equator and decrease toward the poles. However, this is not the case. Why would this indicate that other factors are also involved in determining productivity?

11. Satellite surveys have detected a sharp decline in plankton in several oceans. In the northern Pacific Ocean, the summer levels of plankton have dropped by more than 30 percent since the 1980's. The researchers don't know whether the decline is part of a natural cycle in the oceans. However, they found a close link between the drop in plankton and the increasing ocean surface temperatures. Researchers think that the warmer ocean surface temperatures may interfere with the cold, nutrient -rich water that moves up from the depths. This water provides the nutrients that the plankton need. In what other ways might the rise in ocean temperature affect organisms?

Part II: How are animals adapted for survival in extreme temperatures?

1. How might you keep from freezing if the temperature is below freezing?

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2. What does "insulate" or "insulation" mean? Check your definition in the dictionary.

3. Blubber is a type of fat that acts as an insulator for some animals. To create a model to determine its insulating properties, conduct the following investigation. Fill one Ziploc bag with lard. Turn the second bag inside out. Put it into the first bag. "Zip" the two bags together so that the fat is in between them. Tape the opening on either side to make it airtight. Put your hand in the "mitt" and spread the lard in an even layer. Repeat the procedure to the control "mitt", leaving out the lard.

4. Fill a bowl or coffee can with warm water and record its temperature. Each team member should take turns placing their hands in both mitts and putting them in the water. What did you notice?

5. Fill a bowl or coffee can with ice and water. Record the temperature. Each team member should take turns placing their hands in both mitts and putting them in the ice water. What did you notice?

6. Next, place one cube in the blubber (lard) mitt and another in the control mitt. Use duct tape to seal each mitt and make it watertight. Place both in the container of hot water and wait five minutes. Remove the mitt and observe how much each cube has melted.

7. Summarize your findings.

8. Explain how fat or blubber enables animals to survive in regions of extreme temperatures.

9. Animals fluff their fur or feathers to allow in air. Is air an effective insulator in extreme temperatures? What is your hypothesis?

10. How would you design an experiment to find out? Conduct your experiment. Summarize your findings.

11. Your team may want to address the challenge of designing your "survival suits" for extreme temperatures. Use the mitt designs and substitute different materials to determine which work best. Describe your design and experiment.

12. What did your team learn? Summarize your findings and include the supporting data.

2. How Do the Smells in the Water Affect Animals?

Marine Biologist_____ **Team**_____

Sharks can zero in on a wounded fish from a quarter mile or more away. Night-feeding fishes can find food without light. Eyeless cavefish's can too. How? They do this through a particularly acute sense of smell. The sense of smell is highly developed in some fish. They use it to learn about the water's chemistry in their area, to communicate with others, or to locate a meal. Many marine organisms to become dependent upon their ability to smell. You are going to investigate how animals might use the sense of smell.

Materials: water, 2 or 3 liter plastic soda bottles, fish flakes or oatmeal, plastic cups (2-6 oz.), dropper, food coloring, flavorings (substances with odors) that dissolve in water, cotton balls and film canisters. (See teacher's instructions for instructions for setting up the search area.), plastic sandwich bags

Procedure:

1. To investigate how molecules move through water, fill a two or three liter plastic bottle with water, 5 cm from the top. Add a few particles of fish food or oatmeal to the water. Observe what happens to the particles of food. Add a drop of food coloring to another bottle of water. Observe what happens to the colored fluid. On a separate page prepare a table as shown below. In the first column, describe the sequence of events that occurred to the food particle after you placed it in the water. In the second column, sketch an illustration for each sequence that you described.

Table : Comparisn of Sequence of Events

Description of sequence of events	Sketch of each event	Description of corresponding event in No. 2	Sketch of corresponding event in No. 2

2. Matter is made of molecules, which are bound together chemically. When the molecules enter the water, they may separate from each other because of the chemical action of water. The solvent properties of water allow molecules to be dissolved, scattered, and easily moved. The molecules are carried on currents or simply diffused through the water. Animals in the area can smell these molecules and can identify the source of the molecules from their smell. Example One: A fish attacks another animal, the victim's blood and other fluids move with the currents and even countercurrents. Other fish in the area may pick up the scent when the individual molecules or groups of molecules come to

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them and stimulate the olfactory sense. The fish follow the scent pathway until they reach its source. Example Two: The same situation occurs when a diver cuts apart a sea urchin. Liquid and solid parts of the sea urchin are set adrift. The particles reach the fish. They follow the scent to the source. Soon the whole area is filled with small reef fish feasting on the remains of the sea urchin. To complete table one, select example one or two. In column three, describe the sequence of events from the example that match those you observed in number 1. Then in column four, sketch the sequence of events that you described in column three.

3. Based on your descriptions and sketches in Table 1, is the sequence of events similar or different? Explain.

4. Role play number one. You are going to role-play a shark searching for food. You will use your sense of smell to locate the food. Plastic cups with a particular odor have been placed around an area that represents a part of the ocean. Sharks swim in circles or random patterns, picking up odor gradients to pinpoint the source of an attractive smell. Decide how you will move around the area (in a circular or a random pattern). As you move around the room, use your nose to pinpoint where the odor is the strongest. This is the source of the food. Where you able to find the food source? Describe your experience and the problems you had?

5. Role play number two. You are going to participate in another role-play. In this situation, each of you will be a different fish. Each fish searches for a particular odor that represents food to them. Obtain you film canister which has the odor of the food source you will be trying to locate. Open the cap of your film canister and smell the odor in the can. This is the odor of your food. Move around the room, smell the film canisters to determine which contains your food source. Did you find your food source? Describe your experience.

6. Compare your experiences in number one and two. Was one more difficult than the other? Explain.

7. How does your sense of smell compare to that of fish? Explain.

8. How would unwanted chemicals in the water (pollution) affect the ability of fish to find their food source?

9. Use either role-play number one or two, what would you do to simulate the effect of pollutants in the water. Conduct the role-play incorporating the effect of pollution. Describe the results.

10. Based on the results of your role-play, what effect might pollutants have on the marine organisms finding food, locating their spawning area, and moving around their environment?

11. Since the sharks have a very well developed sense of smell, how could divers in the water keep sharks from smelling them? What are some possible ways?

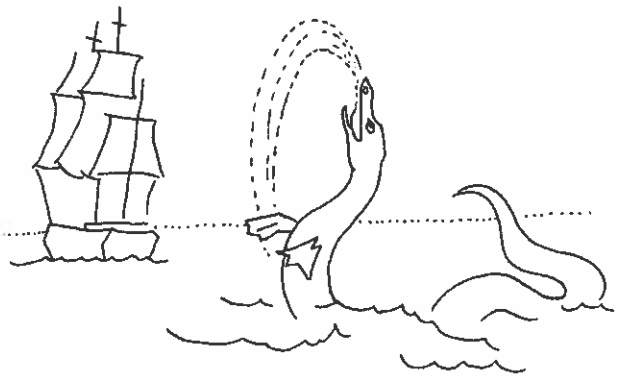
12. It has been suggested that if a diver were wrapped in a plastic suit, the shark would not smell the diver. Design an experiment to test this hypothesis in your classroom. Describe your experiment below. Use a sliced onion to represent the diver.

13. Would a plastic suit work? Does your experiment support this or not? Explain.

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3. What Are the Sounds in the Ocean?

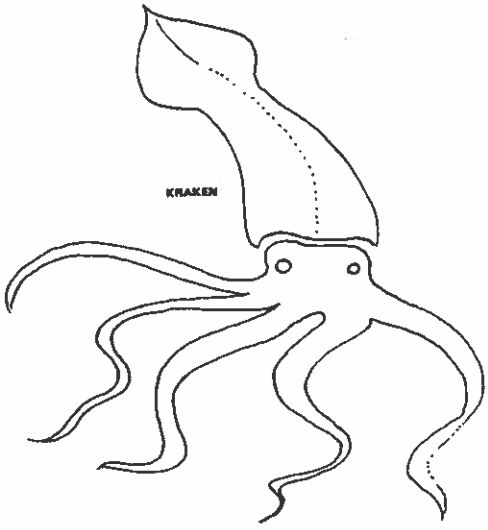
Marine Biologist _____ **Team** _____



The sea was thought to be a silent world. However, sailors reported hearing sounds, some which were strange. During World War II with the development of submarines, scientists began to listen to the ocean. Were there sounds? Were the sounds made by submarines and ships, or did animals make the sounds? What are the sounds in the sea? You are going to investigate sound in the ocean.

Materials: Tape of the Noisy Deep, Tape player

Procedure:



1. You are going to investigate the sounds of the sea. First close your eyes. Imagine that you are standing on the beach with the water in front of you and sand dunes behind you. Listen in your imagination. Describe what you might hear. List all the different sounds that you might hear.

2. Which animal sounds did or would you hear? Why are the animals making the sounds?



3. What sounds are made by humans?

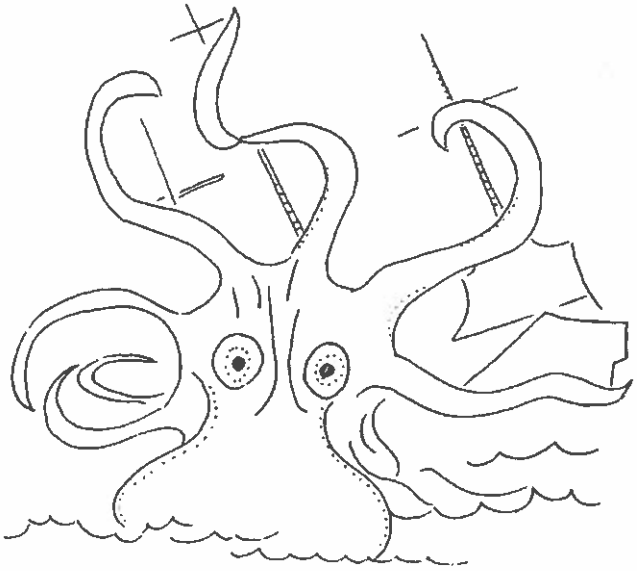
4. Will the sounds always be the same or will they differ? Explain.

5. Now we will continue our investigation with undersea sounds. Imagine you are on a research vessel in the Gulf and these are the sounds that you hear. Listen to the sounds on part one of the audiotape, The Noisy Deep. On a separate paper, as you listen describe each sound you hear and list your inference as to what is making the sound.

6. How would you describe the sounds in the sea?

7. If you were a sailor lying in your bunk on a sailing ship in the 1700's, how would you feel if you heard these sounds?

8. What would you think caused the sounds? What stories might you tell about the sounds?
9. Could these sounds be those of the ghosts and spirits about which sailors of the past talked? Why or why not?



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4. How Do Marine Animals Produce Sounds?

Marine Biologist _____ **Team** _____

The ocean has been called the silent world, but the sea is filled with sound. If you were to listen below the oceans surface you would probably hear grunting, clicking, squeaking, booming, buzzing, scratching, rumbling, drumming, and other noises. These sounds come from natural and human sources. Fishermen and sailors reported hearing noises coming from the ocean for a long time, but the importance of these sounds was not recognized. However, in World War II, listening to the underwater sounds became very important. Hydrophones were designed to listen to underwater sounds. Naval scientists were the leaders in underwater sound research or the acoustics of the ocean. This research was a result of listening for the characteristic noises of ships, submarines, or other activities. They were trying to determine if a sound was an enemy submarine or ship. The scientists found that the ocean was noisy and that the sounds of marine organisms could be confused with the ships' engines, propellers and other equipment. You are going to investigate the sounds of marine organisms and how they are produced.

Materials: Tape of The Noisy Deep, Tape player,

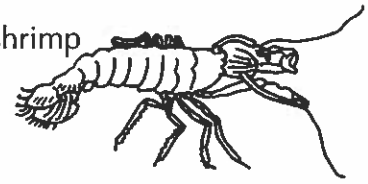
Procedure:

1. Scientists have found that no fish, crustacean, or other invertebrate animal has vocal cords to help it produce sounds in the same way that you do. What are some ways that you can produce sounds without using your vocal cords? You can only use your fingers, hands, arms, legs, feet, etc. You can not use any other objects. Discuss the sounds you produced.

2. Could you use the above sounds to develop a means of communicating? Explain.

3. Discuss ways in which marine organisms that do not have vocal cords might produce sounds.

4. Read "Voices of the Noisy Deep". Listen to Part two of the audiotape, The Noisy Deep. The sounds and the animals that produce the sound are listed below in the order that they are heard on the tape. For each animal, describe its sound and explain how it produces the sounds you heard.

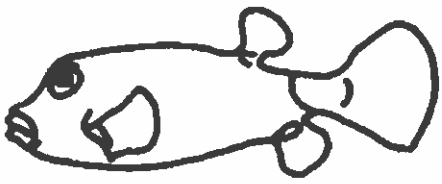
   a. snapping shrimp 

   b. toadfish 

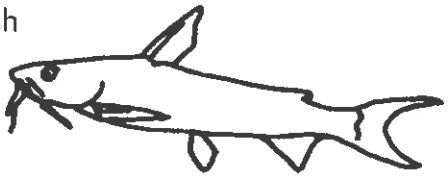
c. trigger parrotfish



h. cowfish



d. sea catfish

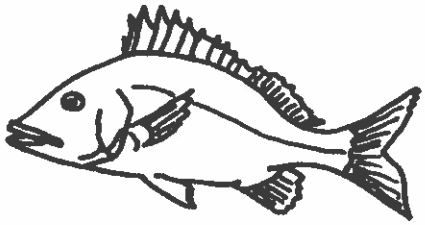


e. single catfish



i. manatee

f. white grunt

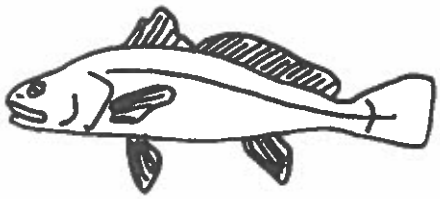


j. one porpoise



k. school of porpoises

g. drum fish



l. whales



5. Discuss why conducting research to learn about the sounds of the ocean is important to the navy.

6. Hypothesize as to the possible impact that sonar or radar from submarines or ships might have on marine organisms and their communication.

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Voices of the Noisy Deep

A variety of sounds are broadcast in the sea by a multitude of organisms. The most frequent and prolific sound-producers are three groups of animals: fish, crustaceans and mammals. Besides the variation in the types of sounds fish producer, the sounds may vary in length. The sounds also may be produced at different intervals. Scientist are studying how, when and why organisms produce various sounds, but so far, only a small part of the story is known.

The sounds of each organism are a voiceprint, or fingerprint. Once a spectrogram is made of the sounds of an organism, it can be used to determine if an unidentified sound was made by the same organism. For example, a sonar-listening device picked up a sound similar to that of a submarine distress signal. Further investigations failed to locate a submarine in the area. Spectrogram analysis of the sound tapes indicated the sounds were not from a submarine, but had been made by a drum fish.

No fish, crustacean or other invertebrate animals have vocal cord to help produce sounds, so they use various other methods. Some produce sounds by rubbing or grinding together hard parts of their bodies. This is called stridulation.

Fish of the grunt family produce grunt-like sounds by grinding their upper and lower pharyngeal teeth in their throat. Their swim bladders resonate and amplify these sounds. These sounds can be heard when the fish are caught and removed from the water. Croakers produce croaks, or thumps, by vibrating the strong muscles on the sides of their swim bladders much the way a guitar string vibrates when plucked. Drums and croakers are the best known of the sound-producing fish; they also produce sounds by vibrating the muscles attached to the swim bladders. Drums give off noises of varying pitch, from deep, drum-like thumps to higher pitched sounds. The snappers, sea robins, damselfish, angelfish and squirrelfish also use the swim bladder and associated muscles to produce sound. The resulting sounds have been described as weak knocks, thumps, bumps, booms, staccatos, grunts and growls. The toadfish produces two sounds: grunts and boat whistles (foghorn). Filefish grind their teeth to produce sounds variously described as tearing canvas, grinding, grating, rasping and scratchy clicks. Puffers, porcupine fish and burr fish produce scraping and thumping sounds primarily when they are inflated by grinding their mouth plates together.

Mussels and clams secrete threads to anchor themselves to rocks and to each other. They must break these lines to move, producing the primary background crackling sound heard outside the tropical waters. Pistol shrimp clap the two parts of their large claw together to make popping sounds. This produces a sharp report that can stun a small animal with the wave concussion it creates. Pistol shrimp use their "guns" to stun their prey and protect their burrows. Spiny lobsters have noise-making devices at the base of their antennas. Vibrations are produced by their stridulatory or noise-making apparatus. The antennas pick up sounds as they vibrate in the water. Fiddler crabs are able to hear vibrations through the ground they are

standing on. They use the ground to communicate. The males produce rapping sounds by drumming on the ground with the large claw. Movement of their legs produces other sounds. The females are able to hear the low-frequency sounds produced by the males from more than ten meters away. Seals, seal lions, and walruses have vocal cords. They use them to bark or growl. They make clicking sounds underwater, which begin in the larynx or behind it.

Marine mammals produce several types of sounds – clicks, grunts, whistles, ticks, sighs, wheezes, clucks or rumbles. Dolphins and humpback whales may emit sounds and repeat them a varying number of times. They even produce a series of phrases in different sequences.

Sea creatures often make sounds in response to hunger, fear, light, anger or aggression. Noises may be used to species or sex identification, navigations, for schooling, as a threat or to express danger.

Research has found hundreds of different types of sounds in the sea and, undoubtedly, will find more. What is the behavior associated with each sound? Are these animals actually "talking"? Can this communication begin to be classified as language? Will we talk to the marine animals one day?

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5. How Do Animals Detect Sound in the Ocean?

Marine Acoustical Scientist_____ **Team** _____

In the animal world, on land and sea, it is the nervous system that acts like a high-speed computer, receiving and interpreting information. It indicates the approach of enemies or of food or of a mate and directs the muscles to respond appropriately. The use of senses is not the same on land and in the sea. In the sea the land sense of sight is not the most important. Sight is useful only to a depth of a 100 feet even in the clearest water. Sound is the key source of information for the sea mammals and other organisms. The sound producing and sensing organs of the whales and dolphins are as vital to them as eyes are to an eagle. You are going to investigate how organisms in the ocean detect sound

Materials: cotton balls

Procedure:

Part I: How does the lateral line detect sound?

1. Hold you left arm in front of you. Hold your right hand, 1-3 cm above your left arm. Close your eyes. Move your right hand slowly back and forth above your left arm. What do you observe?

2. Can you detect the motion of your hand in the air? Explain how you detected the motion?

3. Would you be able to detect the same movement underwater? Explain.

4. A swimming fish produces a low frequency wave in the water. These are often referred to as pressure waves. How do you think another fish might detect these waves?

5. As fish swim through the three-dimensional space of water in search of their meals, they use what is called their "sixth sense": the lateral line organ. The lateral line sense organs are located in canals, which are stretched out along each side of the fish's body and branches encircle the fish's head. (See Figure 5.1)

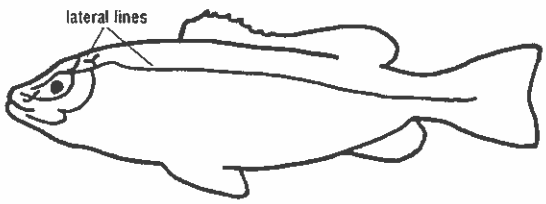


Fig. 5.1. The lateral line serves as a "sixth sense" for a fish.

The canals are located just beneath the skin; pores through the skin or scales open them to the water. Inside the canals are neuromasts or sensory cells; each has tiny hairs projecting from it. When a disturbance near the fish sets up a pressure wave, the moving water

hits the fish and disturbs the mucus in the pores and canals. The mucus then moves the hair of the neuromasts. The hairs stimulate the nerves. The nerves send nerve impulses to the brain. (See figure 5.2) The brain then interprets the messages. How does this compare to your detection of movement in number 5.1?

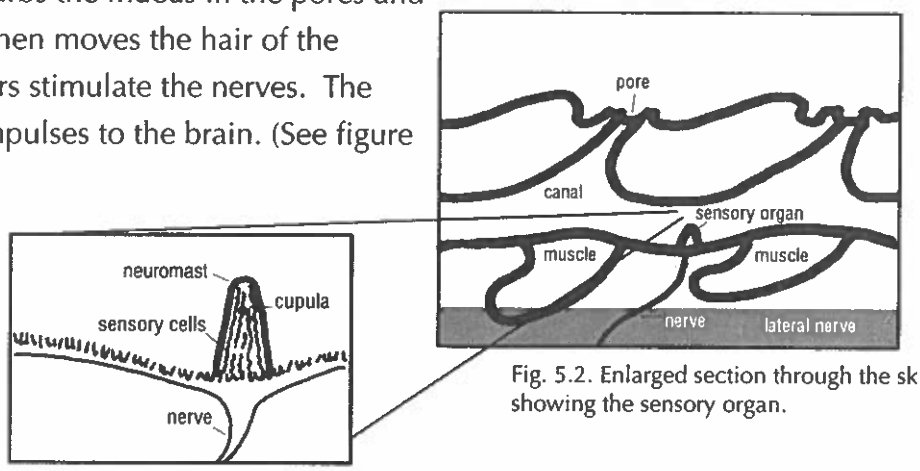


Fig. 5.2. Enlarged section through the skin showing the sensory organ.

6. Use figure 5.2 to trace the pathway of a low frequency wave from the water toward the fish's brain.

7. The lateral line can detect pressure waves that have traveled long distances as well as those next to the fish. How could this help the fish locate its meal or warn the fish that a predator is coming?

Part II: How do the ears of fish compare to humans?

1. Think about how you hear. How does the sound travel to your ears?

2. Read "The Ears of Fish and People" (page 541-542). Use the information in the reading to compare the ears of fish and people by completing Table 1 on a separate sheet of paper.

Table 1: Comparison of Hearing in Fish and People

	Fish Ears	Human Ears
Function of Ears		
Location of Ears		
Number of Parts		
Pathway of sound wave to brain		
Organs of ear receptors of sound		
Organ of balance		
Medium sound travels through		
Other information		

3. To hear underwater sounds, a diver must hold his breath, or the sound of the exhaust

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bubbles from the diving tanks will drown out the other sounds. Explain why this happens. Does sound travel to your ears through your body? (Think about the sounds as you eat chips.)

4. Although noises do exist underwater and travel clear, fast and far, to the ear of the diver they sound muffled, like cotton in one's ears. Place a cotton ball in your ears. Describe the effect on your hearing.

5. To help explain why sounds to humans are muffled underwater, review the structure of the human ear. Note the canal of the outer ear and middle ear air space. Explain why the air in these areas block out many of the sounds underwater.

6. A fish's body, like that of all animals contains a lot of water. Sound can travel straight through the fish's body to its ears. Explain why this works.

7. What can you conclude about the hearing in fish and people? Explain.

Part III. Do all animals hear the same sounds?

1. Animals with sensory organs adapted to water must find the ocean as a noisy place. Swimming animals make unintentional noises as they move, feed, and bend their bodies. Others make intentional sounds such as grunts, groans, chirps, clicks and other sounds. Add these to the surface wave noises and to the sounds of boats, ships and submarines and the ocean becomes a noisy place. Some are within the range of human hearing and others are below and well above the human range. Each animal detects sounds differently. The frequency of a wave is measured in hertz (Hz). Humans can hear the sound wave when the frequency falls between 20 and 20,000 Hz. Frequencies in this range are called sonic. If the frequency is less than 20 Hz, it is called infrasonic. If it is greater than 20,000 Hz, it is called ultrasonic. Whales and dolphins have highly developed hearing, particularly to ultrasonic sounds. Porpoises can hear frequencies that fall between 150 and 150,000 Hz. Fish appear to hear sounds that are in the 200 to 600 Hz range. Some fish are sensitive to sounds with frequencies as low as 10 Hz and other fish may hear frequencies over 10,000 Hz. Animals appear to have different ranges in which they can hear. For example, dogs can hear sounds from 15 to 50,000 Hz; cats can hear from 60 to 65,000 Hz; bats can detect sounds from 1,000 to 120,000 Hz; frogs can hear from 50 to 10,000 Hz; and a bird (Robin) can hear from 250 to 21,000 Hz. On a separate sheet of paper use the information above to prepare a bar graph of the frequencies of sounds heard by people and animals.

2. Analyze your bar graph. Explain why all animals including people do not hear the same sounds or what would happen if all animals made and heard sounds in the same range?

The Ears of Fish and People

The ears of both fish and people have two functions, to maintain equilibrium and to detect sounds. The human ear has three parts, an outer, middle and inner ear. Fish ears are simpler and are made of only an inner ear. The inner ear in both fish and humans is where sounds are actually sensed. It is made up of a fluid-filled chamber designed to detect sound vibrations, gravity, and motion.

Follow the sound through the human ear (figure 5.3). The sound reaches the cone-shaped part of the outer ear. It is directed into the auditory canal, the tube leading to the eardrum. The sound waves hit the eardrum (tympanic membrane) and cause it to vibrate. The vibrating eardrum causes a series of three tiny bones to vibrate. These bones relay the vibrations across the middle ear. These bones reduce the amplitude (loudness) while increasing the force 22 times more than the force that caused the eardrum to vibrate. This amplifies the faint sounds so that they can be heard. The vibration is relayed to the inner ear or cochlea. The vibrations cause the fluid in the canals of the spiral-shaped cochlea to move. The movement of the fluid bends the tiny sensory hairs. This triggers the sending of nerve impulses to the brain. The brain interprets the nerve impulses into sounds.

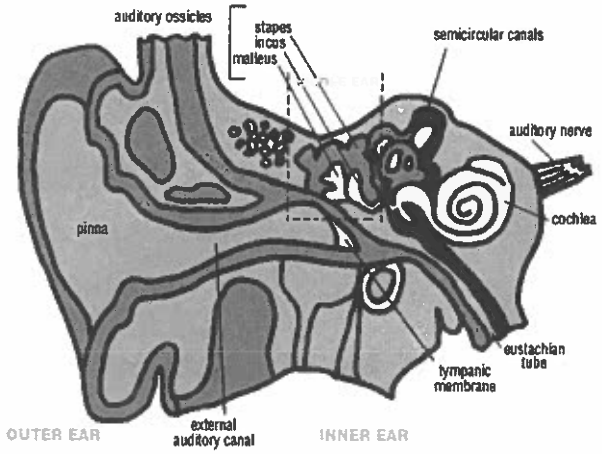


Fig. 5.3. Human ear

Fish, like people, have two ears, called labyrinths. The ears of most fish don't have openings to the outside. Sharks and rays are an exception. A small tube leads from their ears to the water. Fish also do not have eardrums. A fish's ears are covered and located inside capsules on both sides of the head, just behind the eyes. Sound vibrations pass the fish's body to its ears just as the sound waves pass through water.

The organs of hearing and balance are very similar. They are fluid-filled chambers in which sensitive hair like cells respond to the movement of the fluid in the chamber. In both people and fish, the three semicircular canals detect any turning motion through a movement of fluid within the canals. Each canal matches one of the

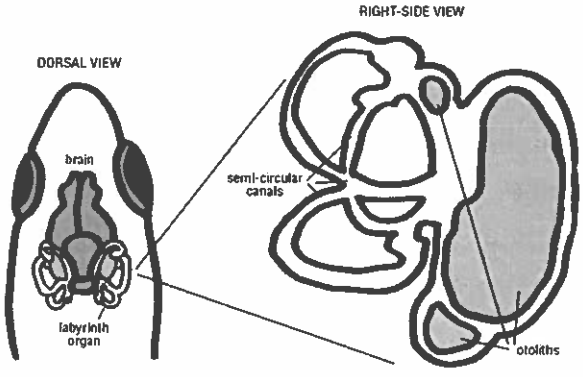


Fig. 5.4. Dorsal view of fish showing labyrinth organ (left) and enlarged vew of labyrinth organ (right).

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three dimensions. When the head is tilted, the fluid within the canals moves. This stimulates the sensory hair cells, which send nerve impulses to the brain.

The organs for hearing in fish and people differ but have the same basic parts as seen in the semicircular canals. In the fish, the organs associated with sound are the otoliths. (Figure 5.4). Otoliths are small calcareous stones embedded in fluid filled sacs. On each side of the head, two or three otoliths are suspended in liquid filled sacs, which have tiny sensory hairs. When sound waves reach the fish, they move the fish very slightly. As the fish moves, the dense otoliths lag behind and bend the hairs. This stimulates nerve cells that send impulses to the brain.

6. What Is Echolocation and How Does It Work?

Marine Acoustic Engineer_____ **Team**_____

To understand how sound can be used by people and animals, we must remember that sound waves can be absorbed, bent, reflected and scattered. The higher the frequency of the sound, the greater the effect. Sound also travels through different materials at different speeds. These are all factors in understanding and using sound in the ocean. Another factor to remember is that for almost every invention of people a similar system exists in nature. The system in nature is always better than the human designed one in efficiency and capabilities. One of these is animal sonar or echolocation. You are going to learn about living sonar.

Materials: two sturdy cardboard tubes without ends (poster or art tubes) large smooth piece of sturdy board about 40 cm x 40 cm, blindfold, slinky or spring

Procedure:

Part I: What happens when sound waves hit a surface?

1. First you must find out if sound will bounce off a hard surface. Have a team member hold a piece of board upright on a large table. Place the tubes on the surface of the table at an angle to the cardboard and to each other. Leave a space of about 5 cm between the cardboard and the ends of the tubes (Figure 6.1). Cover the outer end of one tube with a book. Listen through the end of the uncovered tube. Cover your outer ear with your hand so that the only sounds you hear are coming through the tube. What do you hear?

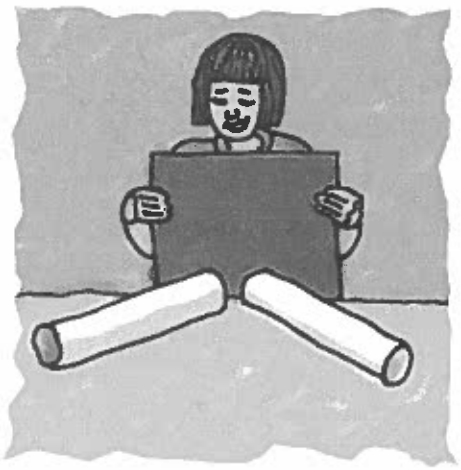


Fig. 6.1

2. Place a ticking clock or timer or windup toy just inside the end of one tube and cover it again. Listen in the other tube. Take turns listening. What do you hear? Explain your observations.

3. Explain why a sound in one tube can be heard in the other.

4. Change the angle that the tubes are placed. Does the angle make a difference? Explain.

5. If a tube is placed at a 90° angle to the surface, what happens to the sound?

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6. Repeat the activity several times, but each time cover the board with a different material, such as a variety of fabrics or foam. Determine how these materials affect what you hear. Explain why.

7. Summarize what you have learned about sound waves from above activities.
8. Stand about three meters in front of a large brick wall outdoors (the side of the school or a garage). Put on a blindfold. Clap your hands as you slowly walk towards the wall. The sound from your clapping hands bounces off or echoes from the walls around or in front of you. Listen carefully for differences in sound as you approach the wall. What are the differences in the echoes as you get closer to the wall?

9. Can you use those differences to stop yourself from bumping into the wall? Explain.

Part II: What is sonar or echolocation and how does it work?

1. In 1938 it was discovered that bats emit high-pitched sounds that cannot be detected by the human ear. The bats emitted the sounds and received the echoes to catch mosquitoes for food and learn about their surroundings. About 10 years later observations of dolphins by scientists in Florida led to the discovery of echolocation in dolphins. Dolphins emit clicking sounds ranging from less than 2,000 to more than 100,000 hertz. Each click lasts only a fraction of a millisecond and is repeated as often as 800 times a second. The animals adjust the click rate to allow the click echo to return to the animal during the very short space between outgoing clicks. What would happen if the animals did not adjust the click rate with the click echo?

2. As each click strikes a target, a part of it is reflected back to the animal. What would the time required for a click to travel from an animal to the reflecting target and back again tell the animal?

3. Use a Slinky or spring to represent a sound wave to determine what can be learned from an echo. On a smooth floor or table top, have one person hold the spring at each end. Now compress (squeeze together) the first 20 cm of the spring and release it. The end being compressed will represent the animal sending the click and the other end will represent the target. What happens to the compressed area as it is released? Could you use this to tell you the direction from which the echo returns? Explain.

4. The frequency of the wave can be determined by measuring how many times a second a specific coil moves from its normal position, through a complete back and forth cycle. Can you change the frequency? Repeat the activity in number 5 by changing the distance

between the two people holding the spring or the length the spring is stretched. What happens to the frequency if the spring is shorter or the two people are closer together? What happens to the frequency if the distance between the two people holding the spring is increased?

5. The animal can use the changes in the frequency of the echo to determine if the target is moving toward or away from it. If the target is moving away what will happen to the frequency of the sound? If the target is moving toward it? Explain.

6. You have experienced the change in the frequency of sound from an object quiet often without realizing it. Have you ever stood and listened as a police car or emergency vehicle with a siren on has gone past? If so, then you should have noticed that the siren was higher as it came towards you and lower as it moved away from you. This change in pitch is the Doppler effect. This occurs whenever there is motion between the source of a sound and its receiver. When there is no movement between the source of a sound and its receiver, the sound waves will be sent out equally in all directions. When there is motion, however the waves pile up or spread out. On a separate page sketch figures to illustrate the sound waves between a dolphin and its target, a fish in each of the following:
   a. The fish is moving away from the dolphin
   b. The fish is not moving.
   c. The fish is moving toward the dolphin.

7. Explain what the time elapsed for the echo to return will tell a dolphin.

8. A vibration with more energy produces sound waves with more energy. The more energy a sound wave has, the greater its amplitude or size. The louder the greater the amplitude of the sound wave. What information can the amplitude of the sound wave tell the dolphin about its target? Explain.

9. Dolphins and members of the toothed whales, can determine not only the speed and direction, but also the size, shape, texture and density of the target. Explain how they can use echolocation to determine this.

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7. How Do Marine Animals Produce and Receive the Echolocation Sounds?

Marine Biologist _____ **Team** _____

The living sonar or echolocation in animals is much better than any human designed one. Using only echolocation abilities, blindfolded dolphins have repeatedly shown that they can determine the difference between objects that are similar such as: two fish of the same general size and shape, plates of different metals and pieces of metal differing only slightly in thickness. The dolphin's system is amazingly accurate. It also gives the animal many more times the information than humans can get from sonar. A navy trained dolphin is able to retrieve three pennies thrown in the water at the same time in three different directions. The first penny is picked up while it is still sinking in the water and the other two pennies are found in the sediment in a few seconds. You are going to analyze what is known about echolocation.

Procedure:

1. Based on the types of sounds produced, it suspected echolocation is used in all toothed whales (sperm whales, beaked whales, porpoises, narwhals, orcas, belugas, etc.), few baleen whales (gray, mink and blue), river dolphins, true dolphins and some pinnipeds (the Weddell seal, California sea lion and possibly the walrus). Echolocation is not used all of the time by all species. For example, Orcas echolocate to hunt fish, but don't use it when hunting other cretaceans (whale, dolphins, porpoises) or seals. What do you think is the reason for this?

2. Scientists are beginning to understand how the dolphin's clicks are produced and sent and how the dolphin detects the echoes. The clicking sounds are produced inside the dolphin's head. The sounds are made even when the dolphin is underwater without loss of air. Therefore, the air it uses to make sounds must be recycled in the dolphin's respiratory tract. Why would it be important that sounds could be produced without air escaping?

3. The larynx of the toothed whales is well muscled and complex, but it lacks vocal cords. The tip of the larynx extends into a tube leading to the blowhole at the top of the head (Figure 7.1). This completely

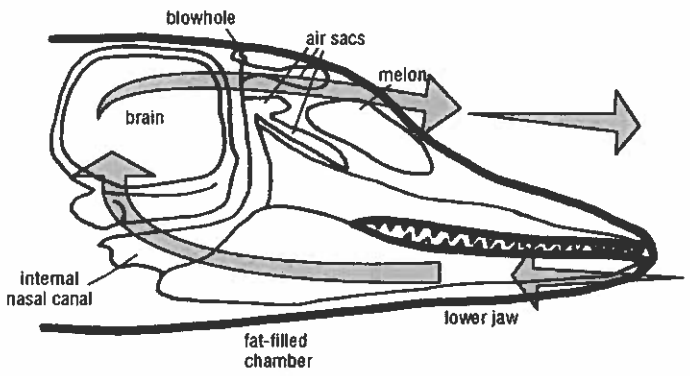


Fig. 7.1. Dolphin's head (Source: Sumich: An introduction to the Biology of Marine Life)

separates the pathways for food and air. This enables the animals to feed underwater and produce sounds at the same time. Can people swallow food and talk at the same time? Explain.

4. Why would eating and producing sounds at the same time be important to underwater animals?

5. At the blowhole is a pair of strong valves called the nasal plugs. These plugs, and air sacs branching from the nasal passage, are the sites of the click production in the smaller toothed whales (figure 1). The clicks produced here are directed forward by the concave front of the skull and then focused by the melon. The fatty lens-shaped melon (the rounded forehead structure characteristic of toothed whales) concentrates the clicks into a narrow beam. Some studies indicate that some toothed whales may also stun fish prey with intense blasts of sound energy. What would happen if the animals were not able to focus the clicks into a narrow beam? (Think about the directions that sound travels.)

6. Studies suggest that all marine mammals have good hearing. Humans are sensitive to sound frequencies ranging from 16 to 20,000 vibrations per second. Marine animals respond to frequencies in excess of 150,000 Hz. Can you hear someone who is across the room from you speaking in a whisper while you are yelling loudly? Try it. Explain what happens.

7. Marine animals can detect faint sounds while they are producing powerful blasts of outgoing clicks. They are able to do this because their sound-processing structures of the middle ear are enclosed in a bony case (figure 1). The bony case is separated from adjacent bones of the skull by sinuses filled with an insulating emulsion of mucus, oil and air. Your middle ear does not have insulating materials separating it from the bones of your skull. Listen as you chew some food. What happens to sound produced in your head by chewing?

8. Why is the insulating material between the middle ear and the head of marine animals important? What would happen if they did not have the insulating material?

9. As scientists mapped the acoustically sensitive areas of dolphins' heads, they found that the lower jaw was six times more sensitive to sound. How does this support the hypothesis that the lower jaw is used for receiving sound?

10. The bones of the lower jaw are flared toward the rear and are very thin. In each half of the

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lower jaw is a fat or oil filled chamber that connects directly to the wall of the middle ear. The fat or oil acts as a sound channel to transfer sounds from the flared part of the lower jaw directly to the middle ear. On either side of the forehead is another area nearly as sensitive to sound as the lower jaw. This would provide for four very sensitive centers for sound reception. Why would this be beneficial?

11. When a dolphin is traveling, it usually moves its head slowly from side to side and up and down. It is also sending out low frequency sounds which long range. If it gets interested in a small target, such as a fish, its scanning motions become fast and jerky. It also uses high-pitched clicks that are for short-range, high definition detection. What is the meaning of the different scanning movement of the dolphin? Why is echolocation so important to these marine mammals?

12. Examination of the fossil skulls and ear bones of toothed whales and dolphins indicate that they were able to echolocate from their earliest beginnings, about 30 million years ago. How might this ability explain why they are more diversified in structure and lifestyle than any other group of marine mammals?

8. What Is the Relationship Between Light and Organisms in the Ocean?

Marine Biologist _____ **Team** _____

The requirement for light imposes a limit on where all marine photosynthetic organisms can live. To live these organisms must stay in the **photic** zone, the zone in the ocean where light intensity is sufficient for plants to grow. On land, animals rely primarily on sight to obtain their food. In the ocean, an animal relying mainly on sight would be limited to a depth of only 100 feet in the clearest water and a distance of only a few dozen feet. You and your team are going to investigate the relationship between light and organisms in the ocean.

Materials: None

Procedure:

Part I: What is the relationship between light, organisms and ocean productivity?

1. Review what you learned about light in Topic 8, Lesson 18, Why is the sea blue? As you learned in that investigation, water causes light in seawater to decrease from the sea surface downward. At some depth the light intensity is so faint that no photosynthesis will occur. This critical depth is approximately the depth at which the available light is reduced to 1% of its surface intensity. This depth is the bottom of the photic zone. It varies from a few meters deep in coastal waters to more than 200 meters in clear tropical seas. Why does this depth vary in different areas? What are some possible factors?

2. Plants can only obtain energy from the wavelengths of light they absorb in the lighted zone. In which areas of the ocean can photosynthetic organisms live? (See fig. 8.1)

3. How do you think the time of the year, time of day and cloud-cover would affect the photic zone? Formulate a hypothesis to explain the relationships to light intensity.

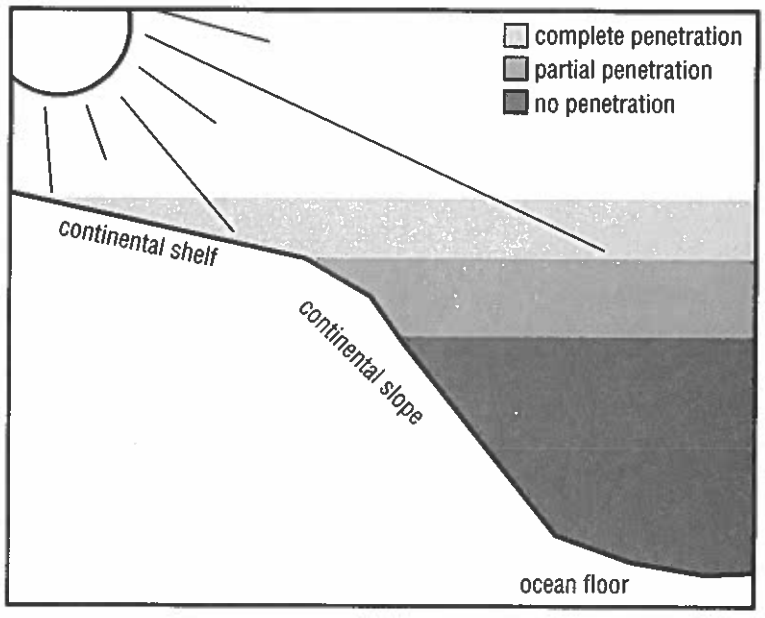


Fig. 8.1. Light Penetration (Source: Lien, 1979: Investigating the Marine Environment and Its Resources)

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4. In moderate and low light intensities, photosynthesis is directly related to the light intensity. The greater the light intensity the greater the productivity and the closer to the surface the greater the productivity. At higher light intensities, photosynthesis may remain the same or actually decrease near the surface. What might be a possible explanation for this?

5. Use the internet sites: http://www-ocean.tamu.edu/NR1/unit_light-water_2.html and http://www-ocean.tamu.edu/NR1/unit_light-water_chall_b.html to learn more about measuring light in the Flower Garden Banks in the Gulf of Mexico. Use the graph of light measurements to determine if your hypothesis was correct.

6. The amount of plankton in an area determines the productivity of the area. Do you think that some regions are more productive than others? Explain.

7. When a great number of phytoplankton float in the lighted surface waters of an area, they may change the color of the water. From space, variations in ocean color can be measured with sensitive instruments. Satellite instruments measure the amount of reflected light of different wavelengths. This allows scientists to estimate the productivity of the Earth's landmasses and oceans. Visit the Internet site: http//athena.webnet.edu/curric/oceans/color/index.html to compare the productivity of the different oceans and in different latitudes. Which regions are the most productive and which are the least productive? What patterns do you notice? Summarize what you have learned.

8. Different plankton groups respond differently to the light intensity. For example, dinophytes seem better adapted to intense light than diatoms. How would this affect their location in the oceans?

9. Small marine animals, zooplankton, migrate up and down depending on the light penetration from day to night. These layers of animals swim toward the surface as night approaches and descend in the morning as sunlight begins to enter the water. This migration of animals produces the phenomena of the Deep Scattering Layer (DSL) or "false bottom" recorded on echo sounders. What is your hypothesis for explaining this movement of this zooplankton?

10. How might humans affect the photic zone?

11. What might be the effect of less light in the photic zone or a shallower photic zone on an ocean ecosystem? What is your hypothesis for explaining this?

Part II: How do the animals detect light?

1. On land, animals rely primarily on sight to obtain their food. In the ocean, an animal relying mainly on sight would be limited to a depth of only a 100 feet in the clearest water and a bubble of sight only 200 feet across. Sight is not the primary sense in the ocean. However, sight takes over where other senses leave off. Lobsters, crabs and many other crustaceans have compound eyes like insects. These compound eyes consist of many individual light sensors that work independently. What each sensor detects is relayed on to the brain. Each of the sensors points in a slightly different direction. The brain integrates all the signals to produce a mosaic image. Why does this make compound eyes well adapted for detecting movement?

2. In deep-sea crustaceans, the eyes have large amounts of reflective pigments that enable them to utilize the tiny amounts of light more efficiently. Why is this important to these animals?

3. We have no way of knowing what a fish sees. Experiments show that fish are more far-sighted when seeing towards the side. They also appear to have sharper vision looking forward. How would this adaptation help them survive?

4. Most fish have no muscles to change the shape of their eye lenses; they move the entire lens backward to see things at a distance or forward to view near objects. How does this compare to focusing a camera?

5. As most fish swim along, they move their bodies from side to side, scanning as they swim. To see how this affects their field of vision, keep your head focused straight ahead and see how much you can see on each side without turning your head. Now turn your head from side to side and determine how much you can see by moving your head. How is the effect on a fish's field of vision by moving their bodies from side to side?

6. Most of us have seen a cat's eyes glow when they are caught in the beam of a car's head-lights at night. Many fish have reflecting eyes. These eyes have an iridescent layer that is a series of precisely placed mirrors behind the retina of the animal's eye. When light ray enters the retina of the eye, the mirror behind the rod cells picks up the light and sends it back to the retina so that it stimulates another rod cell. How does this help fish and sharks see in very dim light?

7. The animals in the depths of the ocean have unique eyes. Most have very large eyes. The orbit of the eye may occupy more than half the length of the animal's skill. The pupil is

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also enlarged. They will also have large retinas with many more receptor cells. How do all of these adaptations enable the animals to see where there is only very dim light?

8. Animals that live in the depths have adapted in many ways to the darkness of the deep ocean. Many are luminescent, bringing their own light to the depths. Luminescent animals are found in nearly all the oceans, from the shallow coastal areas to the deepest waters. In the deep waters, they provide the only visible light. It is estimated that perhaps 80 percent of the total deep-sea organisms are luminescent. The luminescence differs from animal to animal. Some have lights on their heads, others near their tails, others have light organs along their sides or on their fins and some even have them in their mouth. These light organs probably do not help the animal's see. They are primarily used as signaling devices. Why might they use their lights to signal?

9. What Is the Effect of Pressure on Marine Organisms?

Marine Biologist _____ **Team** _____

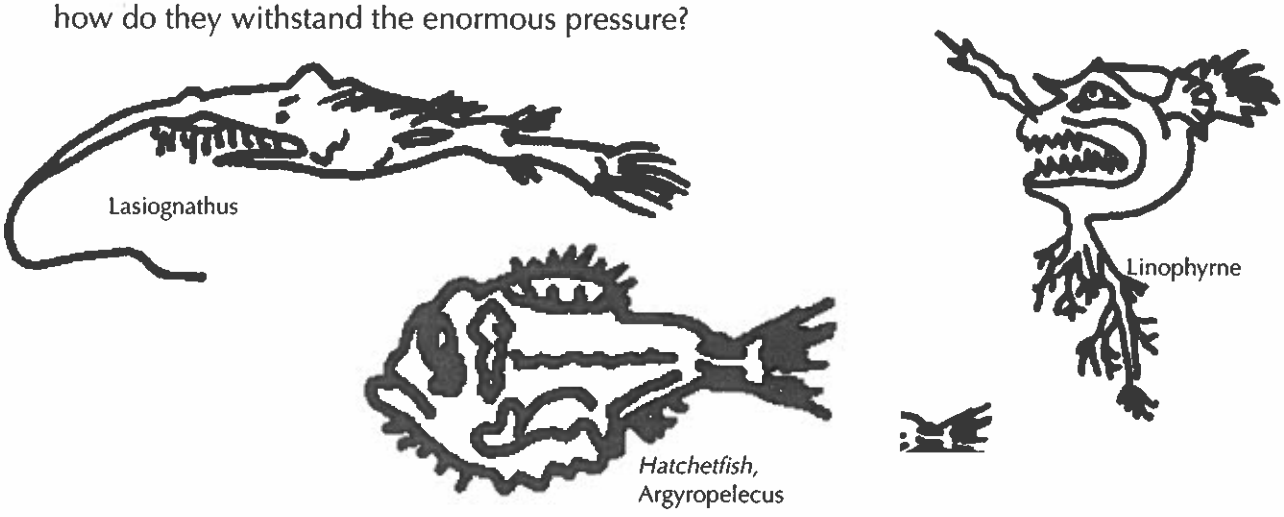
We are not really aware of the pressure exerted by the enormous column of air above us. This is because we are adapted to living in this gaseous environment. In water, it is very different. If you dive down just a few meters below the surface of water, you notice the pressure. Water is 800 times denser than air. So if a person or animal descends below the water surface, pressure increases rapidly. At the surface of water, the water pressure is zero. However, at 33 feet below the surface, the pressure is 14.7 psi (pounds per square inch) and the air above it is also exerting a forced of 14.7 psi. This means that pressure of water on a fish, diver or rock at 33 feet is 29.4 psi. At 66 feet below the surface, the pressure is 44 psi. You and your team are going to investigate the impact of hydrostatic or water pressure on organisms.

Materials: balloon, empty plastic water or soft drink bottle and medicine dropper

Procedure:

1. In the 1800s scientists hypothesized that life could not exist in the great depths of the ocean. In 1972, H. M. S Challenger sailed from England on a four-year investigation of the world's oceans. The Challenger expedition found many different kinds of creatures at great depths in the ocean. Today we know that the deep ocean including deep-sea trenches have a rich and diverse population of animals. What do animals from the depths of the ocean look like? Tall and thin to avoid the pressure? Spherical to withstand the pressure? Make sketches of what you think creatures from the depths of the ocean would look like to withstand the pressure.

2. Look at Figure 9.1. Is there a definite pattern or shape to deep see organisms to help them withstand the pressure? If deep-sea marine organisms do not have a definite shape, then how do they withstand the enormous pressure?



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3. Take an empty plastic bottle fill it with air, close it and tighten the cap so that air cannot escape. Increase the pressure on the bottle by squeezing the bottle. What happens to the volume of the gas (air) in the bottle?

4. Stop squeezing the bottle. What happens to the volume as you decrease the pressure?

5. If people or land animals, with all the air cavities inside their bodies, want to enter the depths of the sea, what will the pressure do to the body cavities?

6. So how do animals that live in the depths of the ocean cope with such high pressure? The answer lies in the fact that gases, which are highly compressible, are absent in the bodies of most organisms found in the deep ocean. They are composed mainly of water. Completely fill your plastic bottle with water so that there is little or no air in it. Put the cap on and tighten it so water will not escape. Squeeze the bottle. What happens when a force is applied to the bottle of water?

7. Summarize how bottom dwelling organisms are able to survive the extreme pressure that exists at depths of the ocean.

8. Many fishes that live between 200 and 1,000 meters (- 660 to 3,300 feet) have gas filled swim bladders to help them maintain buoyancy at different depths. When these fish are caught and brought to the surface, the drop in pressure will cause the gas bladder to expand. This will force internal organs out of their mouth and cause their death. Explain why this happens.

10. What Is the Effect of Pressure on Divers?

Marine Physiologist _____ **Team** _____

With the help of technology, people are entering the sea. Although people lack blubber, this problem is solved by developing better diving suits. There is a struggle to develop the perfect breathing devices and understand the physiology of diving. At the same time, submersibles, manned and unmanned, are being developed to explore the ocean. People cannot fly. People cannot dive very well. Yet humans have conquered the air, the moon, space and the deepest ocean trench. You and your team are going to study the impact of pressure on diving and how technology has helped overcome the extremes of the ocean.

Materials: plastic water or drink bottle, medicine dropper, water

Procedure:

1. The underwater environment, with its rapidly changing pressures, presents problems to divers. Yet, using technology humans have devised ways to supplement their limited ability to dive and their total lack of being able to breathe underwater. Scuba (self-contained underwater breathing apparatus) equipment has enabled people to breathe underwater. The scuba diving limit is 133 meters or 436 feet. Scuba diving has a limited depth due to pressure. To determine what happens to air in the lungs, stomach and body cavities; fill a plastic soft drink bottle with water up to 2-3 cm from the top. Drop a medicine dropper into the bottle so that it floats. Cap the bottle. Tighten the cap so no air or water can escape. Slowly squeeze the bottle. What happens to the air in the dropper? What will happen to the air in a diver's organs and body cavities as he descends into the ocean?

2. Stop squeezing the bottle and release the pressure on it. What happens to the air in the dropper? What will happen to the air in the diver's organs and body cavities?

3. At sea level the body is saturated by the air that surrounds it. Approximately a quart of nitrogen is dissolved in the blood and tissues at sea level. When a diver descends, the amount of dissolved nitrogen in his body increases proportionally to the increase in pressure. This is similar to making carbonated drinks. Gas is added by increasing the pressure. When you open a can or bottle of a carbonated drink, did you decrease or increase the pressure inside the bottle? What happens to the gas that was dissolved in the drink?

4. When a diver has been breathing compressed air for some time and rises, enough nitrogen has dissolved in his system to form bubbles in his blood and body as the pressure decreases in moving up to the surface. If the gas bubbles are released into the blood as a

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diver ascends, it could block blood flow to the lungs or cut off oxygen to the brain that can result in death. This could happen in ascents of only several feet. Less severe effects could be damage to the sinuses or middle ear or pain in the joints (the bends). How can a diver prevent the gas being released from the blood like the gases from a carbonated drink? Think about what you do to slow the release of gases from carbonated drinks.

5. The treatment for all these diving accidents is immediate recompression. Why is this needed?

6. What effect would poor circulation, varicose veins, lung problems, asthma, epilepsy, diabetes or drug addiction have on a diver's developing problems diving? Explain.

7. Another danger to the diver breathing compressed air is nitrogen narcosis. At 100 feet down his efficiency begins to decrease. At 150 feet down, the diver's nervous system is impaired. Below 200 feet there is the feeling of being drunk. Below this level, the intoxicating sensation may become violent enough to bring on an epileptic seizure, followed by loss of consciousness. To escape these effects, the diver must ascend to 30 or 40 feet. Why do divers fear this condition? Why is it recommended that one never dive alone?

8. Although technology has greatly improved diving equipment over the centuries, there are severe restrictions on the depth and length of time divers can spend beneath the sea because of the pressure and the gases one breathes. Use the table below to determine how long a diver could work at 50 feet without having to decompress. At 100 feet? At 150 feet? At 200 feet?

Table: Depth of Dive and Time at a Depth without Decompression

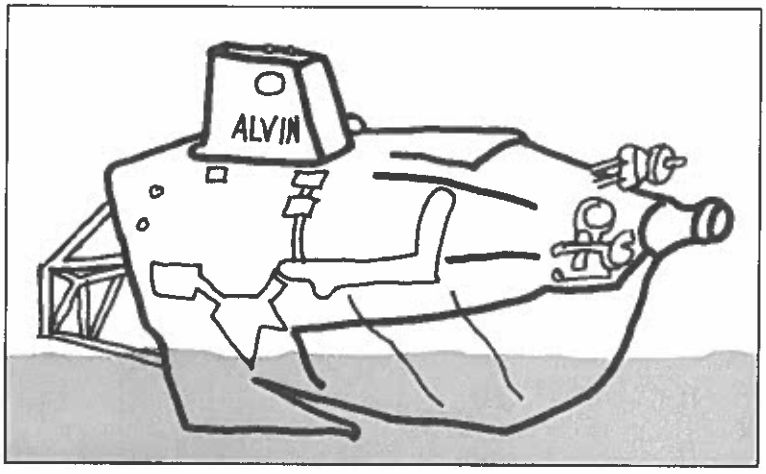
Depth (feet)	Number of Minutes without Decompression Time	Depth (feet)	Number of Minutes without Decompression Time
10	no limit	90	30
20	no limit	100	25
30	no limit	110	20
40	200	120	15
50	100	130	10
60	60	140	10
70	50	150	5
80	40		

9. Diving at greater depths requires breathing a special mixture of gases. Due to the pressure, if divers return to the surface too quickly they can suffer decompression sicknesses that result from the formation of air bubbles in the blood and tissues as a result of the sudden lowering of the pressure. Use the Internet to locate the U.S. Navy Standard Air Depression or Dive Tables to determine decompression times that is required for different depths. Bottom time refers to the time from the moment the diver leaves the surface to the moment the diver leaves the bottom to return to the surface. The bottom time determines the rate at which a diver can ascend. It determines how many and how long the diver must stop at different depths to decompress slowly to avoid problems. If a diver goes to a depth of 300 feet and his diver had gone to 300 feet. For example if a diver has 20 minutes in bottom time, he first decompression stop will be at 4 minutes and at 60 feet for 2 minutes. The second stop will be at 50 feet for 3 minutes; then at 40 feet for 7 minutes, 30 feet for 10 minutes, at 20 feet for 23 minutes, and then at 10 feet for 47 minutes for a total of 97 minutes spent ascending. If the diver spent 30 minutes of bottom time at 300 feet, it would require 7 decompression stops and ascent time would be 172 minutes. If the diver spent, 60 minutes of bottom time in the dive at 300 feet, it would require 12 stops and a total of 460 minutes or 7 hours and 40 minutes of ascent time. What is the relationship of bottom time, number of stops and total ascent time?

10. Why is diving to explore the ocean bottom or to repair cables and pipelines on the ocean floor a problem?

11. Large submarines and deep-sea submersibles with pressurized cabins have been developed for diving below 400 feet. Why?

12. Large submarines dive to about 1,500 meters (5,000 feet). Half of the Earth's surface lays 3,000 or more meters (about 9,800 feet) under water. Alvin, the submersible that was used to explore the sunken ocean liner *Titanic,* can dive to 4,000 meters or 13,000 feet. The cabin in Alvin is a tight fit for 3 people. The walls are two inches thick and round like a ball. Why is the cabin sphere-shaped?



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13. The walls of Alvin are made of titanium, a metal as strong as steel, but lighter. Why does the cabin have to be so strong?

14. Use the bottle and dropper (Cartesian diver) again. What causes the dropper to descend? What causes the dropper to rise? Explain this in terms of density.

15. To get to the bottom, Alvin carries a 1,000 pounds of steel. Then the pilot tosses half of it away so that Alvin is light enough to move around. When it is time to surface the pilot drops the rest of the steel and Alvin floats upward. How is this like the Cartesian diver? If steel makes Alvin sink, what makes Alvin float?

16. How many miles can you walk in an hour? Most people can walk three to five miles an hour. This is twice as fast as Alvin goes. The average dive takes a little over 6 hours. The descent to 4,000 meters takes two and a half hours. Yet submersibles like Alvin have enabled man to explore the ocean depths. This has led to a tremendous increase in our knowledge of the marine environment. In 2000, Alvin was used in exploring the bottom of the Gulf of Mexico. Use the Internet and read the daily logs and pictures of this exploration of the Gulf at http://www.ecology.com/gulf/gulf_log

17. Today ROV's (remotely-operated vehicles) are used on regular basis in exploring the ocean along with submersibles like Alvin. The size of the ROV's range from that of a small toaster to massive work vehicles that weight several tons. Both manned submersibles and ROV's require the presence of a surface support vessel. Now engineers and scientists are working on developing Autonomous underwater vehicles (AUV's). This type of vehicle could involve a vessel putting the vehicle in the water at one location and another vessel recovering it several thousands of kilometers away and weeks later. Discuss how the ROV's have changed our exploration of the ocean depths and predict the potential impact of AUVs.

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