

Fundamentals of Threats and Hazards

ELK0102

Student Guide

October 2025
Version 1.0

FEMA

NATIONAL DISASTER & EMERGENCY MANAGEMENT UNIVERSITY

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Course Introduction

Course Goal

The goal of this course is to understand how scientific principles can be used before, during, and after a disaster, including a basic understanding of scientific terminology as it applies to Emergency Management.

Course Objectives

Upon completion of this course, participants will be able to:

- Indicate the relationship between science and our understanding of disasters.
- Describe how scientific understanding can help with managing disaster-related risks.
- Indicate how climatological principles and processes influence natural hazards, including convective storms, hurricanes, nor'easters, winter storms, and extreme cold temperatures.
- Indicate how earth science principles and processes influence surface hazards such as floods and mass wasting.
- Indicate how earth science principles and processes influence geological hazards such as earthquakes, tsunamis, and volcanoes.
- Indicate how climatological principles and processes influence extreme heat, drought, and wildfires.
- Indicate the scientific basis for chemical, biological, radiological, and nuclear hazards, explosives (CBRNE), and their impact on society.

Course Design/Methodology

This training uses a combination of training methods to facilitate learning. These methods include:

- Instructor presentation
- Video presentations
- Group discussion
- Small-group activities

Course Time Plan

Course Schedule (Classroom)

Module	Time	Suggested Day
Module 1: Course Welcome	1 hour	1
Module 2: Science and Emergency Management	1 hour	1
Module 3: Weather Trends	1 hour, 25 minutes	1
Module 4: Severe Storms, Thunderstorms, and Lightning	1 hour, 30 minutes	1
Module 5: Tornadoes	50 minutes	1
Module 6: Hurricanes	1 hour, 45 minutes	1
Module 7: Nor'easters and Bomb Cyclones	30 minutes	1
Module 8: Winter	30 minutes	2
Module 9: Heat and Drought	30 minutes	2
Module 10: Wildfires	30 minutes	2
Module 11: Floods	1 hour	2
Module 12: Mass Wasting	1 hour, 10 minutes	2
Module 13: Earthquakes	30 minutes	2
Module 14: Tsunamis	1 hour	2
Module 15: Volcanoes	1 hour, 20 minutes	2
Module 16: Chemical, Biological, Radiological, Nuclear, and Energetic Materials (CBRNE) Concepts	30 minutes	2
Module 17: Biological Hazards	1 hour, 50 minutes	2
Module 18: Fundamentals of Matter	1 hour	2, 3
Module 19: Chemical Hazards	1 hour, 30 minutes	3
Module 20: Radiation Hazards	1 hour, 40 minutes	3
Module 21: Explosive Hazards	1 hour, 30 minutes	3
Module 22: Emerging Hazards	40 minutes	3
Module 23: Course Summary	40 minutes	3

Course Schedule (Virtual)

Module	Time	Suggested Day
Module 1: Course Welcome	1 hour	1
Module 2: Science and Emergency Management	30 minutes	1
Module 3: Weather Trends	55 minutes	1
Module 4: Severe Storms, Hail, Thunderstorms, Lightning	1 hour, 30 minutes	1
Module 5: Tornadoes	50 minutes	1, 2
Module 6: Hurricanes	1 hour, 45 minutes	2
Module 7: Nor'easters and Bomb Cyclones	30 minutes	2
Module 8: Winter	30 minutes	2
Module 9: Heat and Drought	30 minutes	2
Module 10: Wildfires	30 minutes	2
Module 11: Floods	1 hour, 10 minutes	2
Module 12: Mass Wasting	1 hour, 15 minutes	2
Module 13: Earthquakes	30 minutes	2
Module 14: Tsunamis	1 hour	2
Module 15: Volcanoes	1 hour, 20 minutes	2
Module 16: Chemical, Biological, Radiological, Nuclear, and Energetic Materials (CBRNE) Concepts	30 minutes	2
Module 17: Biological Hazards	30 minutes	2
Module 18: Fundamentals of Matter	1 hour, 50 minutes	2, 3
Module 19: Chemical Hazards	30 minutes	3
Module 20: Radiation Hazards	1 hour, 30 minutes	3
Module 21: Explosive Hazards	1 hour, 40 minutes	3
Module 22: Emerging Hazards	1 hour, 30 minutes	3
Module 23: Course Summary	40 minutes	3

Evaluation Plan

This course uses Kirkpatrick's Level I, II, and III evaluation tools.

Level I: The NDEMU Course Evaluation will be used to document student feedback at the end of the course on the overall quality of content, instruction, and facilities. The evaluation form uses a 1—5 rating system, with 5 being the highest value. The feedback shall be used to identify strengths and weaknesses in the delivery, course content, learning setting, and facility.

Level II: This evaluation involves measuring and assessing learning that has taken place. Participants will demonstrate their proficiency in applying knowledge and/or skills learned. Participants will demonstrate their proficiency in applying knowledge through a multiple-choice test for this course. Minimum passing grade for this course is 75%. Complete the Knowledge Gained template and turn it in to the course manager within three business days.

Level III: The NDEMU Follow-up Evaluation Survey OMB No. 1660-0130 will be used to document participant feedback after the course has been completed and the participant has returned to their normal work duties. NDEMU will send out this survey to students 3 months after the completion of the course and collect the responses from the survey. The evaluation uses a 1–4 rating system, with 1 being the highest value.

Student Prerequisites

None.

Icon Map



Definition: Key term that is often field-specific and may be unfamiliar



Handout: Additional information provided to facilitate the scenario-based activity



Key Point: Essential learning concept and discussion



Break: Built in break time.



Activity: A student activity

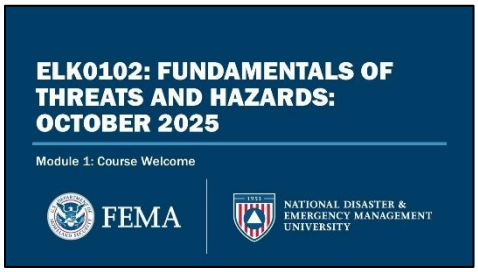


Workbook: An indication to open the referenced page in the Student Workbook to complete an activity

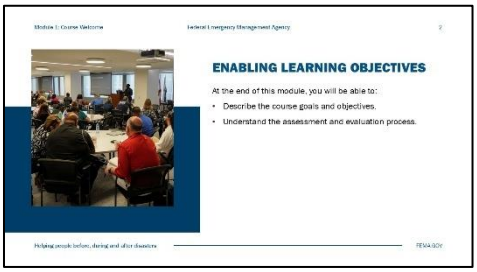
Module 1

Course Welcome

Administration



Slide 1-1, Module 1: Course Welcome



Slide 1-2, Enabling Learning Objectives

Duration

1 hour

Terminal Learning Objective (TLO)

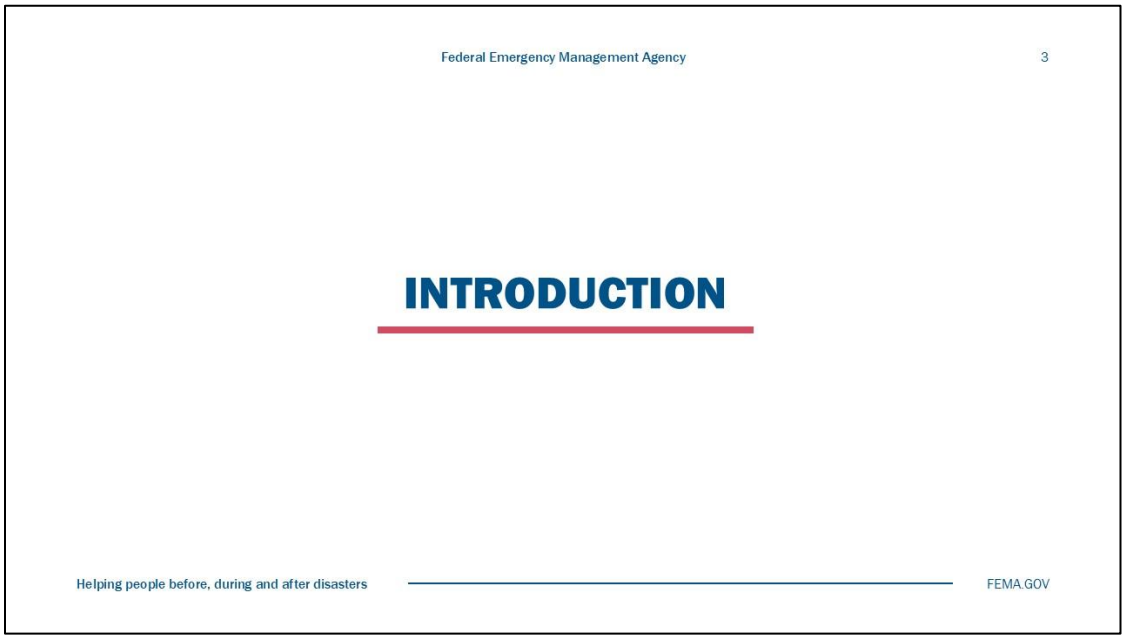
By the end of this module, participants will be able to demonstrate a comprehensive understanding of the key concepts, core principles, and relevant fundamental terminology, allowing them to confidently engage with subsequent course materials.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Describe the course goals and objectives.
- Understand the assessment and evaluation process.

Introduction (1 of 5)



Slide 1-3, Introduction

Not Applicable.

Introduction (2 of 5)

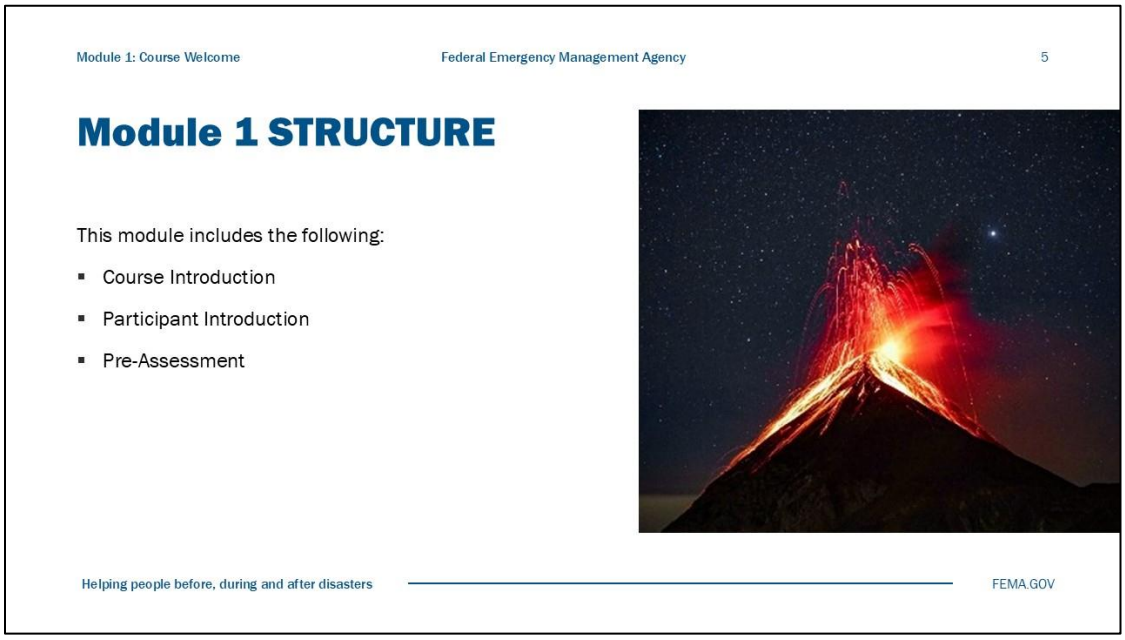


Slide 1-4, Module 1: Welcome

Welcome to **ELK102 Fundamentals of Threats and Hazards**.

This course, offered at the National Emergency Management Basic Academy, is designed to provide participants with an overview of scientific principles and concepts that shape our increasingly complex and ever-changing world.

Introduction (3 of 5)



Slide 1-5, Module 1 Structure

This module includes the following:

- Course Introduction
- Participant Introduction
- Pre-Assessment

Introduction (4 of 5)



Slide 1-6, Instructor Introductions

- Instructors
- Course Manager(s)
- Other Course Personnel (e.g., state training officer)

Introduction (5 of 5)

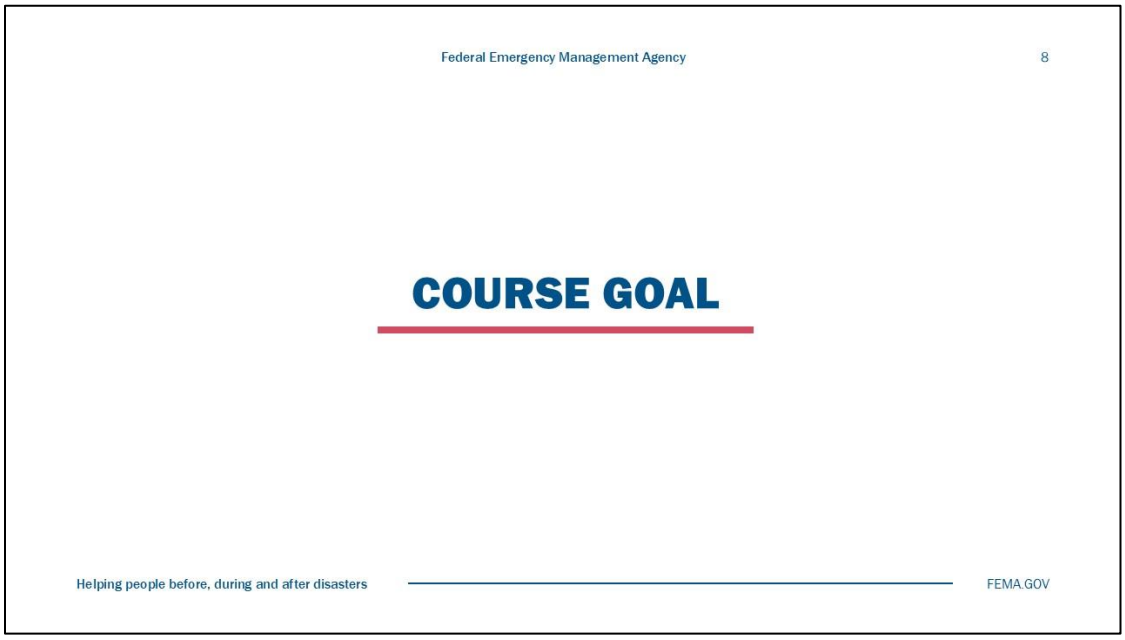


Slide 1-7, Administrative Information

- Emergency Exits
- Restrooms
- Cell phones
- Other logistics

Please remember to silence your mobile devices.

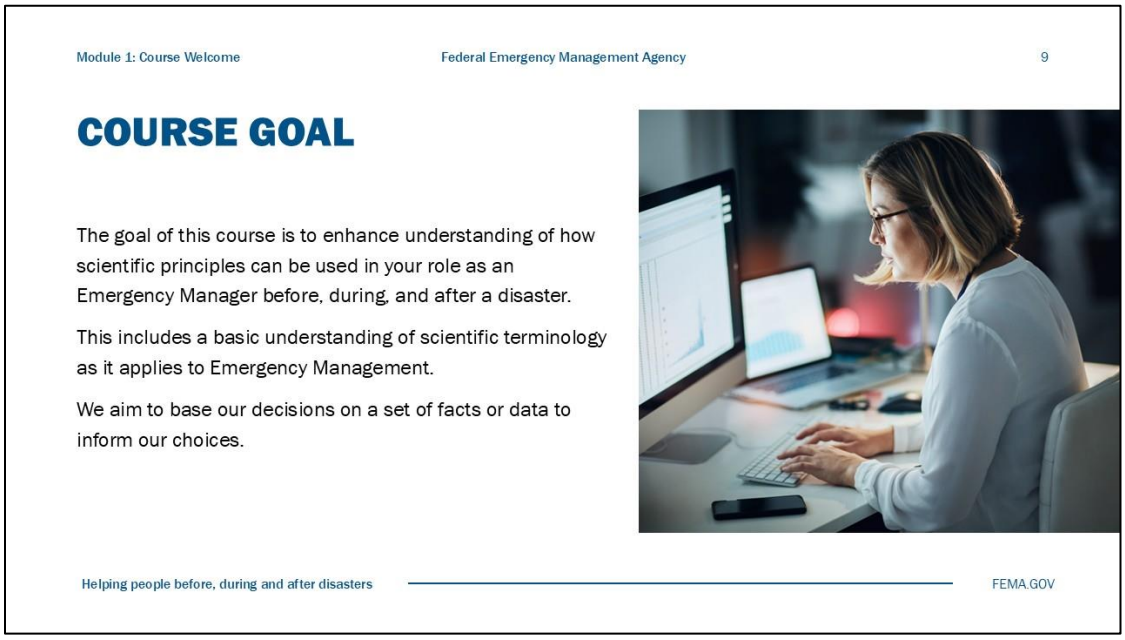
Course Goal (1 of 4)



Slide 1-8, Course Goal (1 of 2)

Not Applicable.

Course Goal (2 of 4)



Slide 1-9, Course Goal (2 of 2)

The goal of this course is to enhance understanding of how scientific principles can be used in your role as an Emergency Manager before, during, and after a disaster. This includes a basic understanding of scientific terminology as it applies to Emergency Management. We aim to base our decisions on a set of facts or data to inform our choices.

We will explore various types of natural, technological, and human-caused threats and hazards, and consider the science behind:

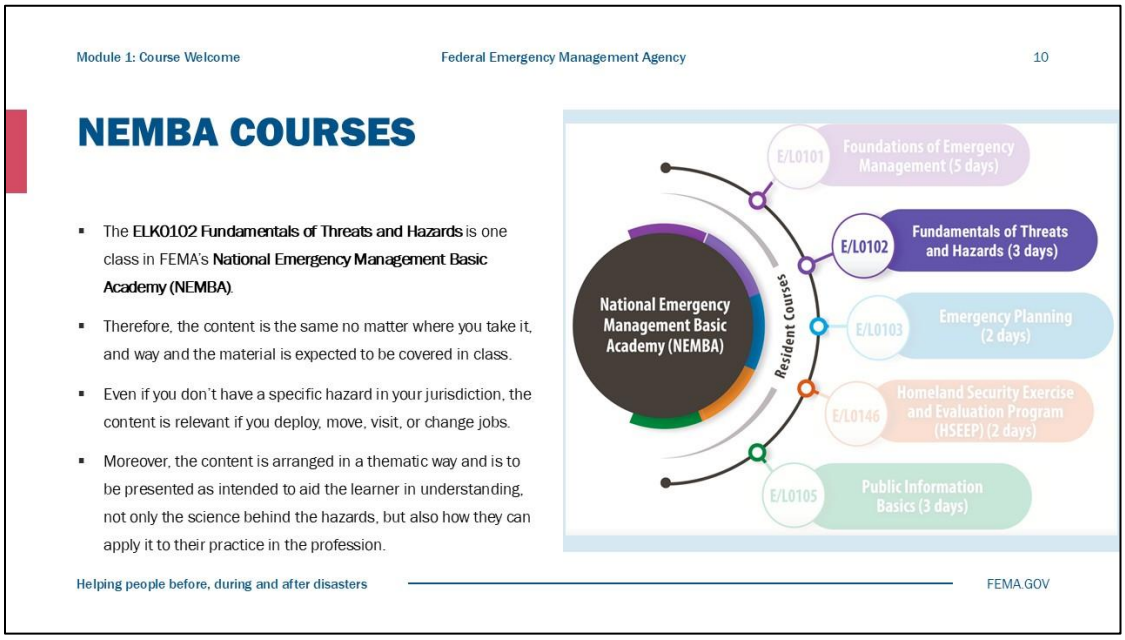
- How they occur;
- Why they occur;
- Where they occur; and
- What we can predict about their occurrence.

We will also consider what Emergency Managers can do with the types of warnings and predictions provided by scientists.

Scientific information and methods can play a crucial role in emergency management. Being informed and taking full advantage of scientific analysis and prediction helps communities build and sustain core capabilities that enable us to:

- Prevent;
- Protect against;
- Mitigate the effects of;
- Respond to, and
- Recover from disasters.

Course Goal (3 of 4)



Slide 1-10, NEMBA Courses

National Emergency Management Basic Academy (NEMBA) courses include:

- ELK0101 Foundations of Emergency Management covers the basic principles and terminology of Emergency Management; what it is we do, and how we do it.
- ELK0102 Fundamentals of Threats and Hazards connects the emergency manager with the information on disasters with the people who study the hazards (SMEs), and that understanding is the foundation of all our EM programs. It helps inform our practice by understanding the threats and hazards our jurisdictions face. Understanding the underlying mechanisms of the hazards helps emergency managers determine what information is needed to effectively address them.
- ELK0103 Planning: Emergency Operations uses information on the threats and hazards to do risk assessments and write the plans that help us prepare for, respond to, recover from, and mitigate the threats and hazards. These planning documents serve as the training standards we use in whole-community preparedness, as well as in engaging with all stakeholders during planning activities.
- ELK0146 HSEEP gives us the structure to test and validate our planning and training through exercises based on the threats and hazards identified.

- **ELK0105 Public Information Basics** is how we communicate roles and responsibilities throughout the emergency management process to our whole community.

Additional information can be found on the National Emergency Management Basic Academy webpage (https://training.fema.gov/empp/basic.aspx)

Every NEMBA class leads you to further study and the next step in your career progression.

- ELK0101 is about working in a team and leads to the Advanced Academy, where you will also learn to lead teams.
- ELK0102 leads to Intermediate Fundamentals of Threats and Hazards (in development).
- ELK0103 leads to the Planning Practitioner Program.
- ELK0146 leads to the Homeland Security Exercise and Evaluation Program (HSEEP) Training Course.
- ELK0105 leads to the Advanced Public Information Officer Program.

Emergency Management Professional Program (EMPP)

The vision of the Federal Emergency Management Agency's (FEMA's) National Disaster & Emergency Management University (NDEMU) is to strengthen the field of emergency management by establishing an Emergency Management Professional Program (EMPP). The EMPP provides a framework for acquiring the knowledge, skills, and abilities necessary to enter and progress through the field, as well as to meet the challenges of a dynamic and complex environment.

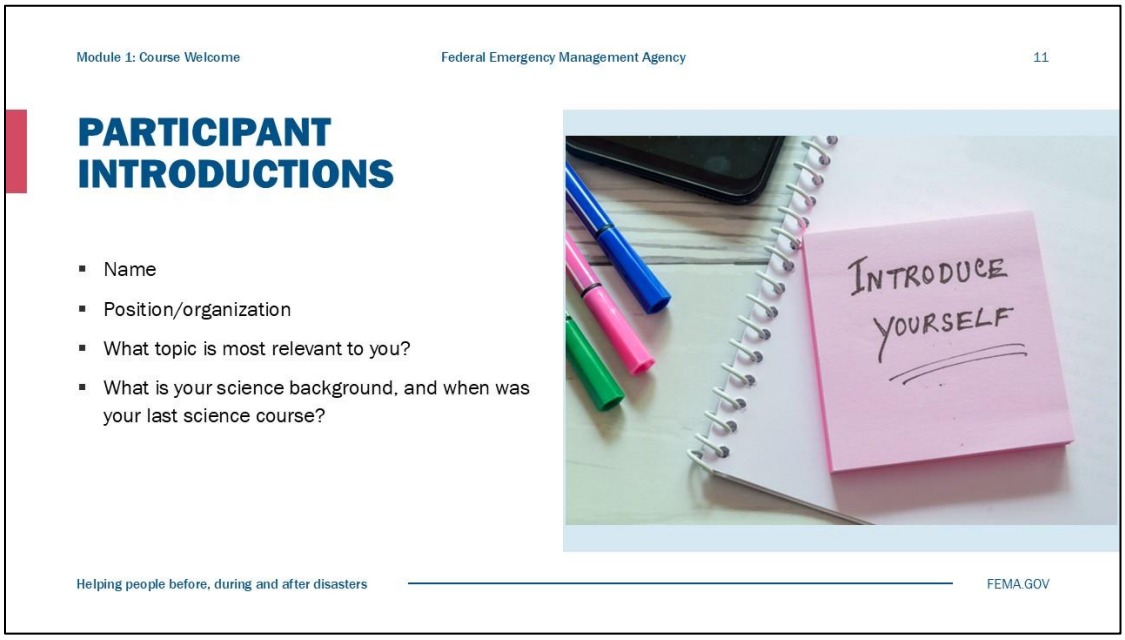
The EMPP includes five distinct competency-based academies shown below:

Academy	Focus	Courses
National Emergency Management Basic Academy (NEMBA)	Foundational knowledge and skills in Emergency Management (outlined above)	
National Emergency Management Advanced Academy (NEMAA)	Executive Level Leadership Theories, Strategic and Critical Thinking, Decision Making, and Complex Systems	• Four courses held over one year as a cohort • Applications in Spring • At NDEMU and in the States

Academy	Focus	Courses
National Emergency Management Executive Academy (NEMEA)	Advancing strategic and policy-level executive leadership in emergency management by fostering collaboration, critical thinking, and innovation to address contemporary and emerging challenges.	• Four courses held over one year as a cohort • Applications in spring • At NDEMU and in the States
Public Information Officer Program	Designed to provide PIOs with the essential knowledge, skills, and abilities to support proper decision-making by delivering the right message to the right people at the right time.	• E/L0387 – Joint Information System/Joint Information Center Planning for Tribal, State, and Local PIOs • E/L0388 – Advance Public Information Officer
Executive Public Information Officer Program		• Three courses over one year • One cohort annually • Applications in Spring

Additional information can be located on the EMPP Webpage (https://training.fema.gov/programs/emergency-management-professional/)

Course Goal (4 of 4)

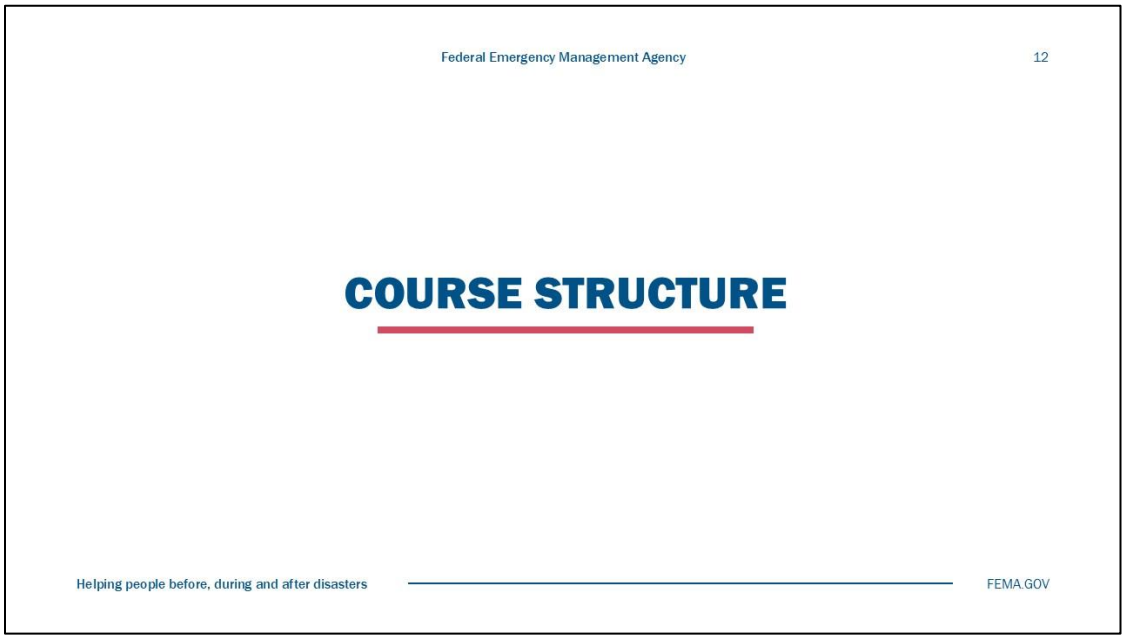


Slide 1-11, Participant Introductions

You will have the opportunity to introduce yourself. Please include the information:

- Name
- Position/organization
- What topic is most relevant to you?
- What is your science background, and what was your last science course?

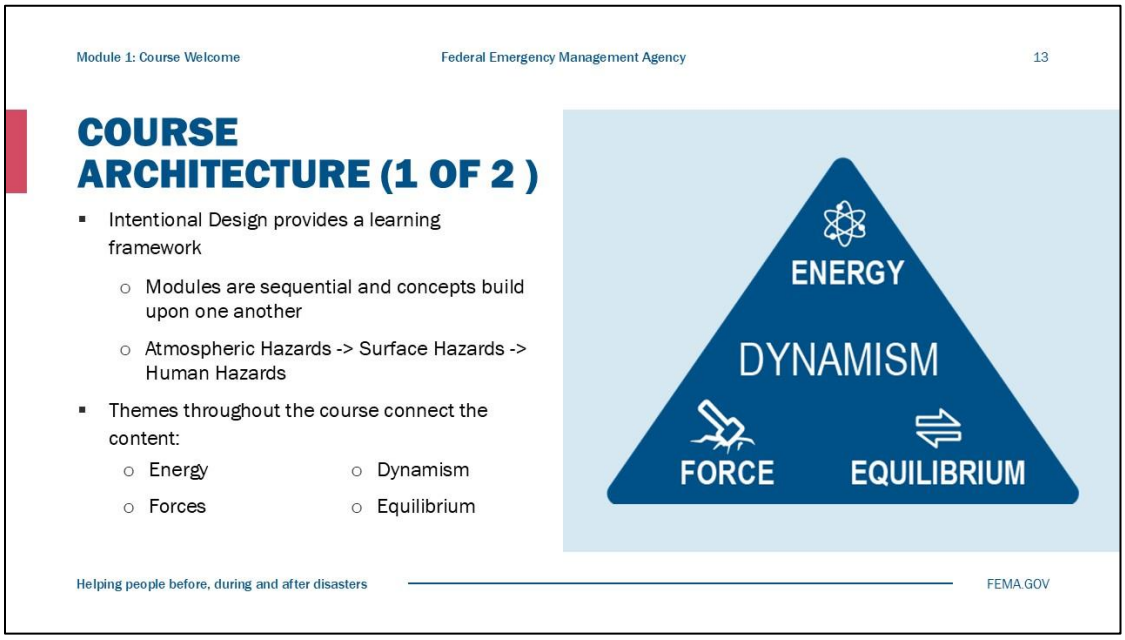
Course Structure (1 of 11)



Slide 1-12, Course Structure

Not applicable.

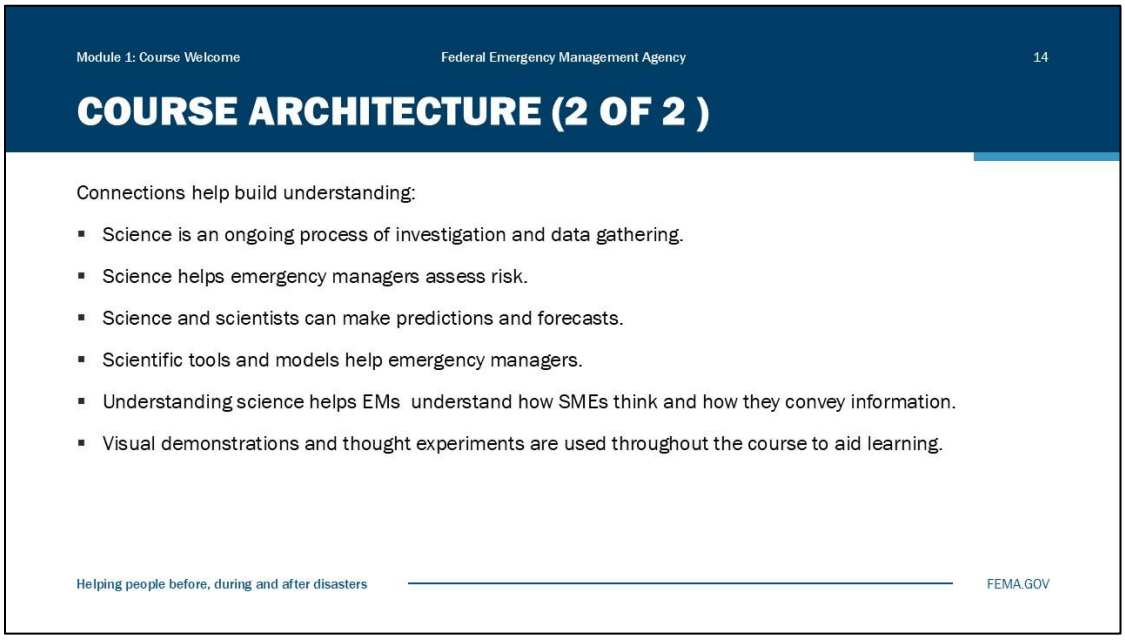
Course Structure (2 of 11)



Slide 1-13, Course Architecture (1 of 2)

- Intentional Design provides a learning framework:
  - Modules are sequential and concepts build upon one another.
  - Atmospheric Hazards -> Surface Hazards -> Human Hazards
- Themes throughout the course connect the content:
  - Energy
  - Forces
  - Dynamism
  - Equilibrium

Course Structure (3 of 11)

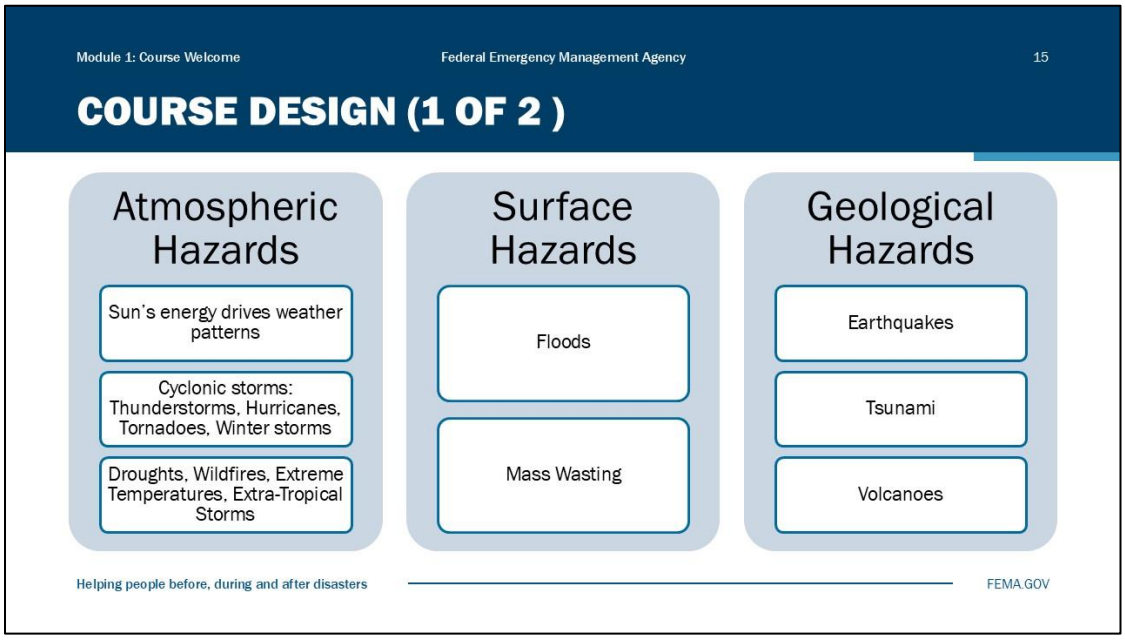


Slide 1-14, Course Architecture (2 of 2)

Connections help build understanding:

- Science is an ongoing process of investigation and data gathering.
- Science helps emergency managers assess risk.
- Science and scientists can make predictions and forecasts.
- Scientific tools and models help emergency managers.
- Understanding science helps EMs understand how SMEs think and how they convey information.
- Visual demonstrations and thought experiments are used throughout the course to aid learning.

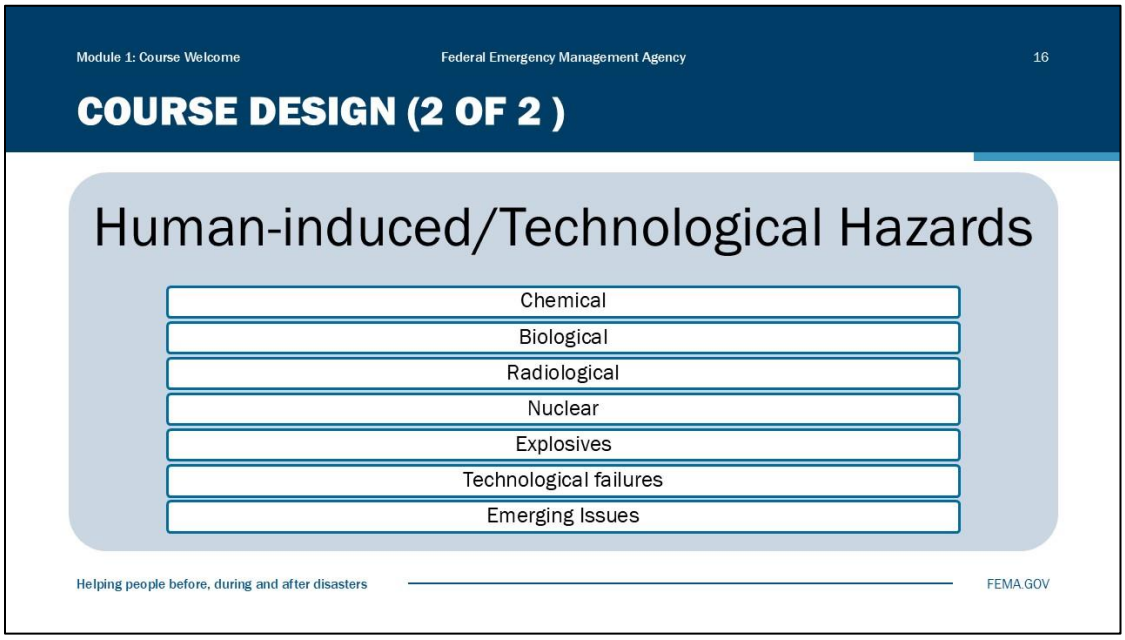
Course Structure (4 of 11)



Slide 1-15, Course Design (1 of 2)

- Atmospheric Hazards
  - Sun's energy drives weather patterns
  - Cyclonic storms: Thunderstorms, Hurricanes, Tornadoes, Winter storms
  - Droughts, Wildfires, Extreme Temperatures, Extra-Tropical Storms
- Surface Hazards
  - Floods
  - Mass Wasting
- Geological Hazards
  - Earthquakes
  - Tsunami
  - Volcanoes

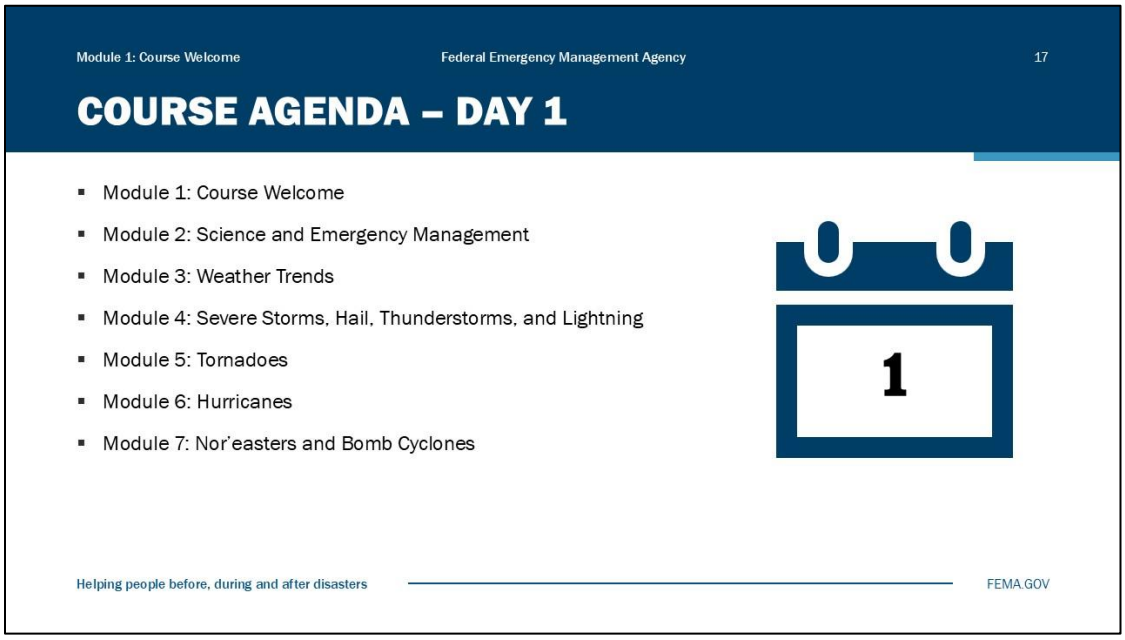
Course Structure (5 of 11)



Slide 1-16, Course Design (2 of 2)

- Human-induced/Technological Hazards
  - Chemical
  - Biological
  - Radiological
  - Nuclear
  - Explosives
  - Technological failures
  - Emerging Issues

Course Structure (6 of 11)



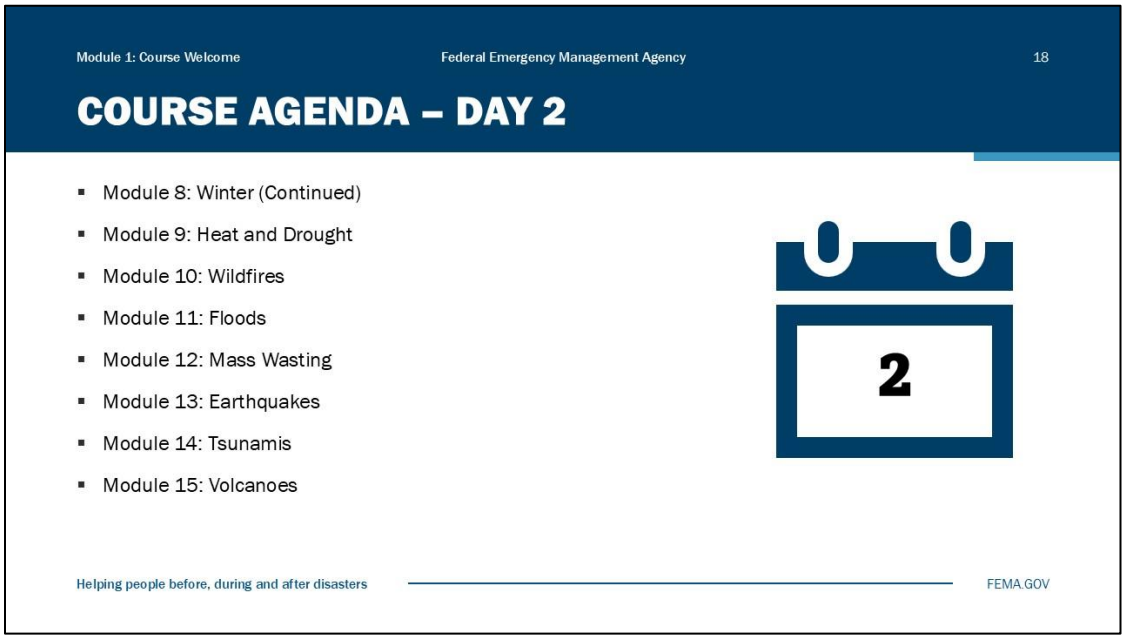
Slide 1-17, Course Agenda – Day 1

This course will introduce you to scientific concepts and principles related to natural and human-caused disasters in several key areas. It is not possible to cover each and every hazard that might occur. Instead, the course will focus on common and emerging threats that provide a basis for understanding the science of disaster. The course is organized as follows:

Day 1

- Module 1: Course Welcome
- Module 2: Science and Emergency Management
- Module 3: Weather Trends
- Module 4: Severe Storms, Thunderstorms, and Lightning
- Module 5: Tornadoes
- Module 6: Hurricanes
- Module 7: Nor'easters and Bomb Cyclones

Course Structure (7 of 11)

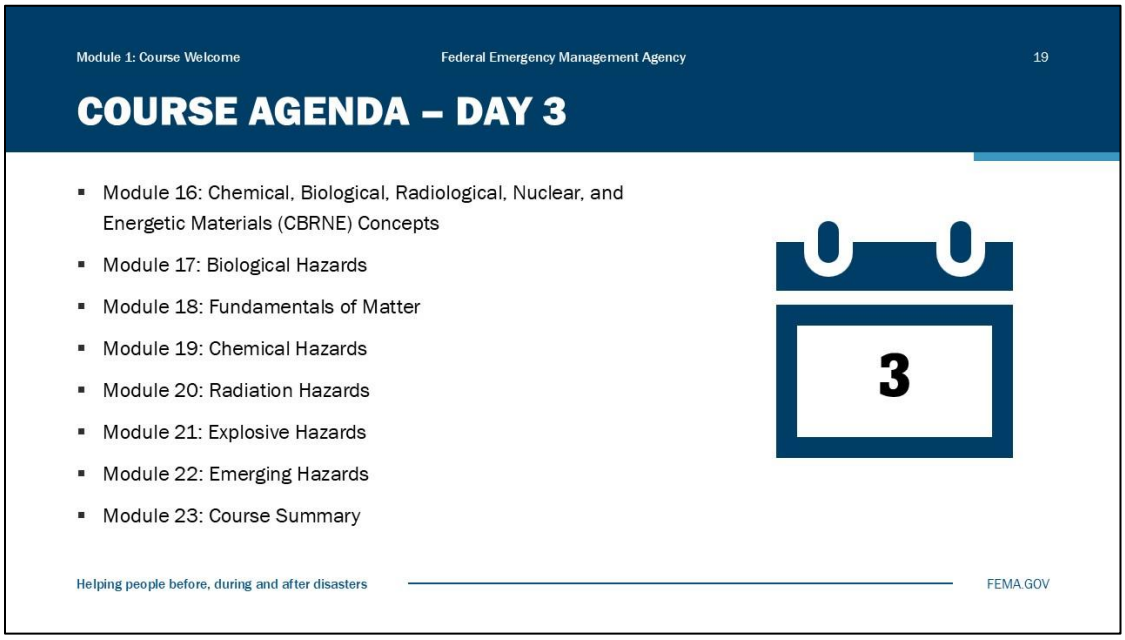


Slide 1-18, Course Agenda – Day 2

Day 2

- Module 8: Winter (continued)
- Module 9: Heat and Drought
- Module 10: Wildfires
- Module 11: Floods
- Module 12: Mass Wasting
- Module 13: Earthquakes
- Module 14: Tsunamis
- Module 15: Volcanoes

Course Structure (8 of 11)



Slide 1-19, Course Agenda – Day 3

Day 3

- Module 16: Chemical, Biological, Radiological, Nuclear, and Energetic Materials (CBRNE) Concepts
- Module 17: Biological Hazards
- Module 18: Fundamentals of Matter
- Module 19: Chemical Hazards
- Module 20: Radiation Hazards
- Module 21: Explosive Hazards
- Module 22: Emerging Hazards
- Module 23: Course Summary

Course Structure (9 of 11)

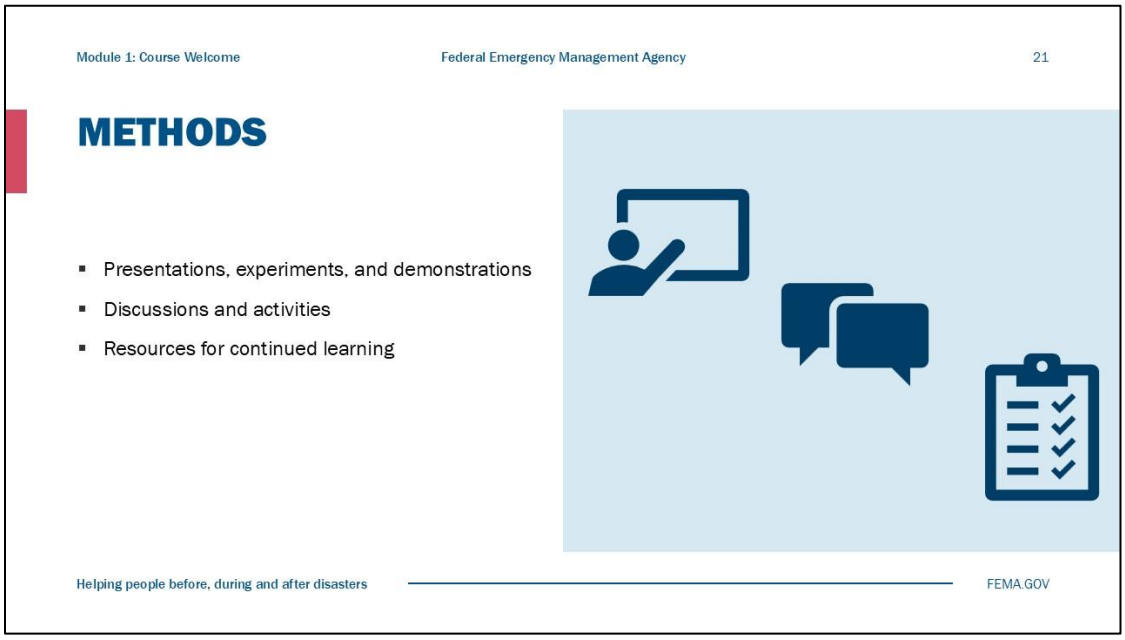


Slide 1-20, Course Expectations

The instructors' expectations for you include:

- **Punctuality:** We expect you to be prompt in arriving for the beginning of the training day and returning from breaks.
- **Participation**: This course is most successful if everyone participates in the discussions and activities.
- **Positive attitude**: Being open-minded will help you maintain a positive attitude toward learning.
- **Professionalism**: We expect you to be courteous, conscientious, and considerate of others. Listening skills and accepting constructive criticism are also important.
- **Flexibility:** Emergency management requires flexibility. During the training, you can practice being flexible by being open to change and new information. Additionally, we require that everyone be able to adapt to new information, changing conditions, and unexpected obstacles.
- **Commitment**: You are expected to make a commitment to continued learning following the classroom training portions. You will complete an individual action plan at the end of each module. We ask that you make a commitment to complete the action form and follow through when you return to your work setting.

Course Structure (10 of 11)

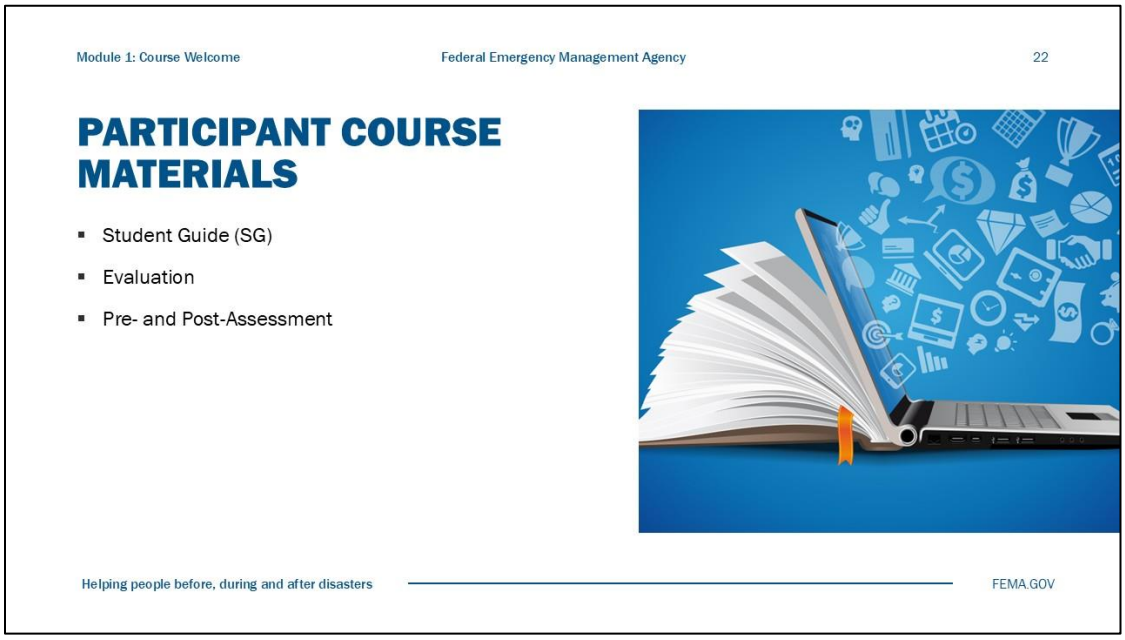


Slide 1-21, Methods

The presentations in this course will provide basic scientific information related to natural and human-caused disasters. There will be opportunities to apply these concepts in large-group discussions and table-group activities.

Finally, each module will identify resources from which you can continue learning about the topic. A wide array of resources is available to help you learn more about the scientific principles underlying disaster hazards and threats, including web-based resources, training, and local experts.

Course Structure (11 of 11)

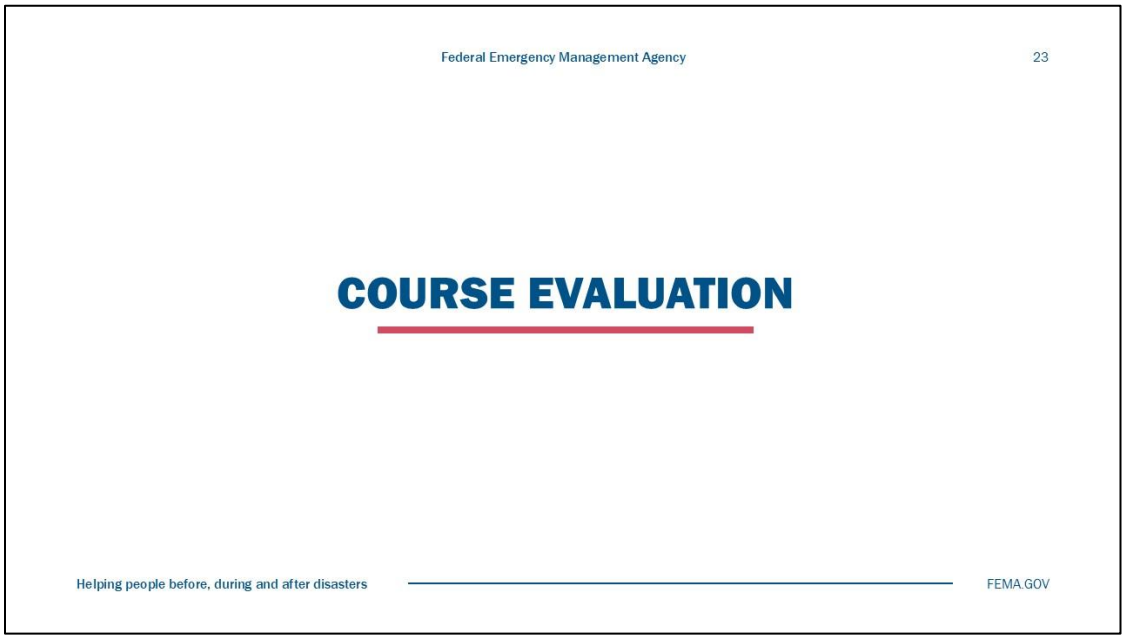


Slide 1-22, Participant Course Materials

Course Materials include:

- **Student Guide (SG):** Here you will find the course slides and course information.
- **Evaluation:** Please complete the evaluation. This information on the evaluation is relevant in how we review, update, revise and develop curriculum.
- **Pre- and Post-assessment**: They gauge your current knowledge before attending the course or your pre-existing knowledge.
  - The post-assessment gauges what you have learned throughout the course or the knowledge gained.

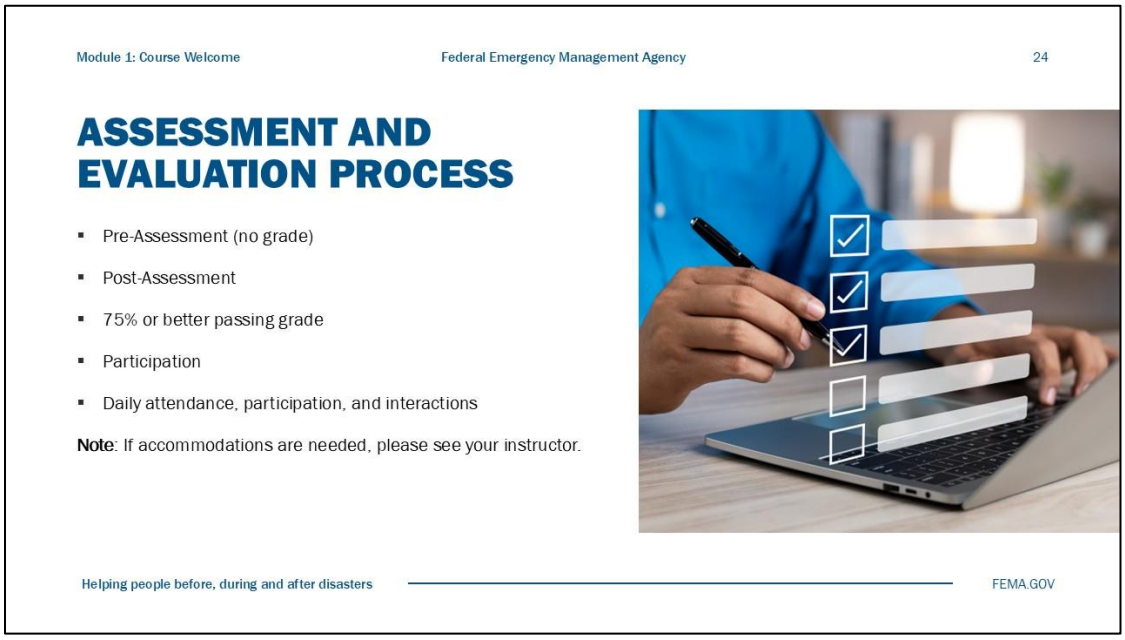
Course Evaluation (1 of 4)



Slide 1-23, Course Evaluation

Not Applicable.

Course Evaluation (2 of 4)



Slide 1-24, Assessment and Evaluation Process

The course will contain several graded and ungraded assessments and evaluation opportunities.

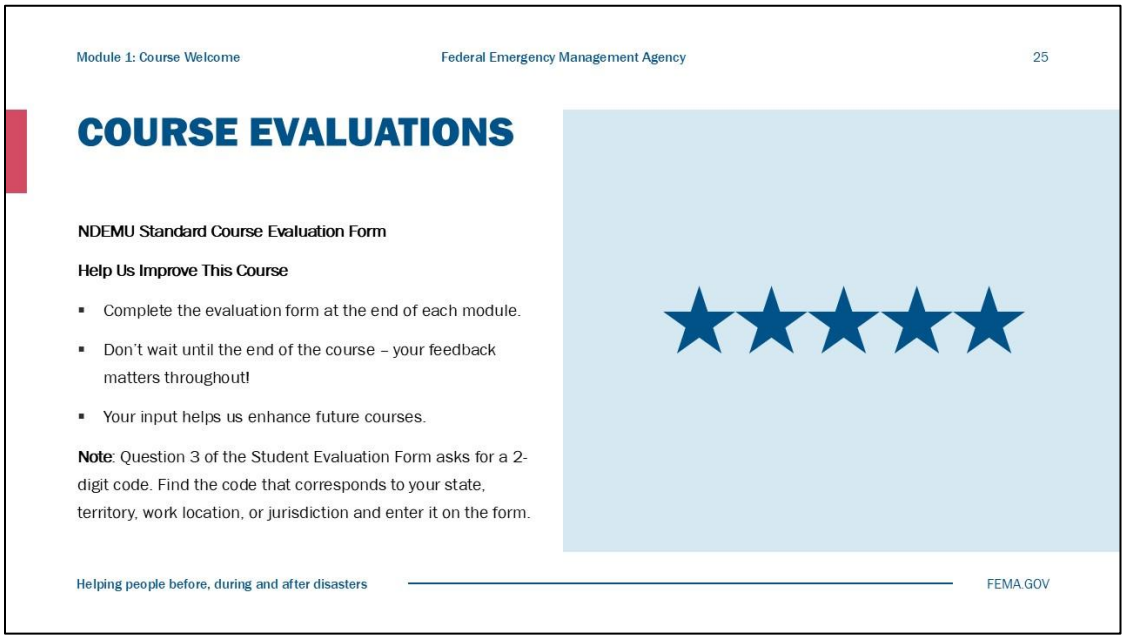
There will be two assessments—a pre-assessment and a post-assessment. The pre-assessment will not count towards the score to pass the class.

You are required to score a minimum of 75% on the post-assessment.

In addition to the required minimum scores on the post-assessment, you will also be required to be an active participant in the class.

Note: If accommodations are needed, please see your instructor.

Course Evaluation (3 of 4)



Slide 1-25, Course Evaluations

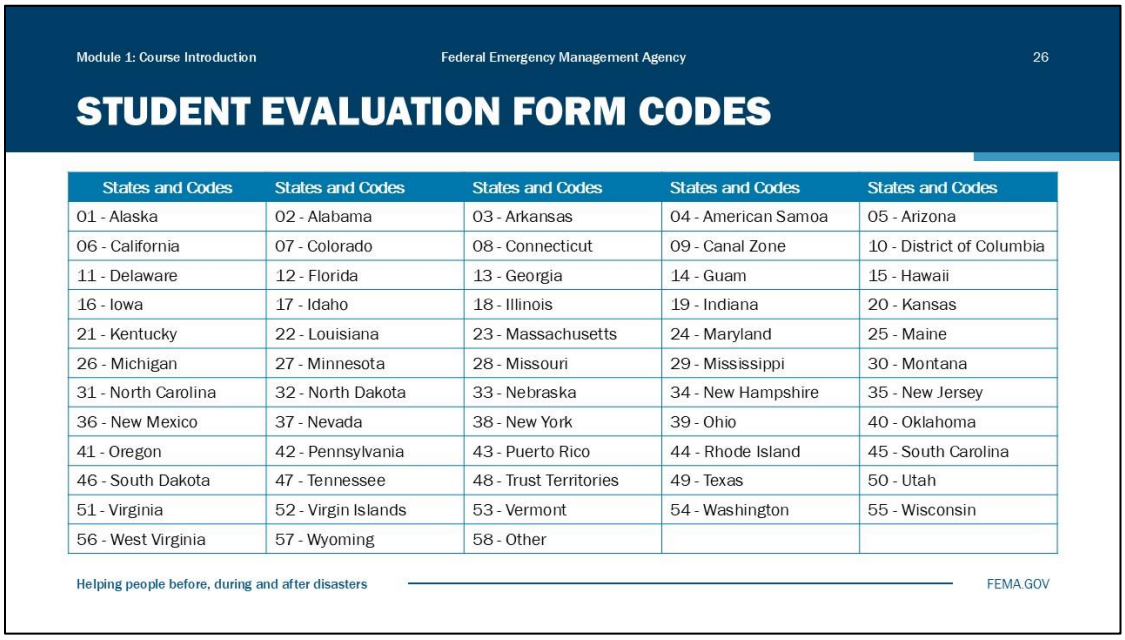
NDEMU Standard Course Evaluation Form

Help Us Improve This Course

- Complete the evaluation form at the end of each module.
- Don't wait until the end of the course – your feedback matters throughout!
- Your input helps us enhance future courses.

Question 3 of the Student Evaluation Form asks for a 2-digit code. Find the code that corresponds to your state, territory, work location, or jurisdiction and enter it on the form.

Course Evaluation (4 of 4)



States and Codes	States and Codes	States and Codes	States and Codes	States and Codes
01 - Alaska	02 - Alabama	03 - Arkansas	04 - American Samoa	05 - Arizona
06 - California	07 - Colorado	08 - Connecticut	09 - Canal Zone	10 - District of Columbia
11 - Delaware	12 - Florida	13 - Georgia	14 - Guam	15 - Hawaii
16 - Iowa	17 - Idaho	18 - Illinois	19 - Indiana	20 - Kansas
21 - Kentucky	22 - Louisiana	23 - Massachusetts	24 - Maryland	25 - Maine
26 - Michigan	27 - Minnesota	28 - Missouri	29 - Mississippi	30 - Montana
31 - North Carolina	32 - North Dakota	33 - Nebraska	34 - New Hampshire	35 - New Jersey
36 - New Mexico	37 - Nevada	38 - New York	39 - Ohio	40 - Oklahoma
41 - Oregon	42 - Pennsylvania	43 - Puerto Rico	44 - Rhode Island	45 - South Carolina
46 - South Dakota	47 - Tennessee	48 - Trust Territories	49 - Texas	50 - Utah
51 - Virginia	52 - Virgin Islands	53 - Vermont	54 - Washington	55 - Wisconsin
56 - West Virginia	57 - Wyoming	58 - Other		

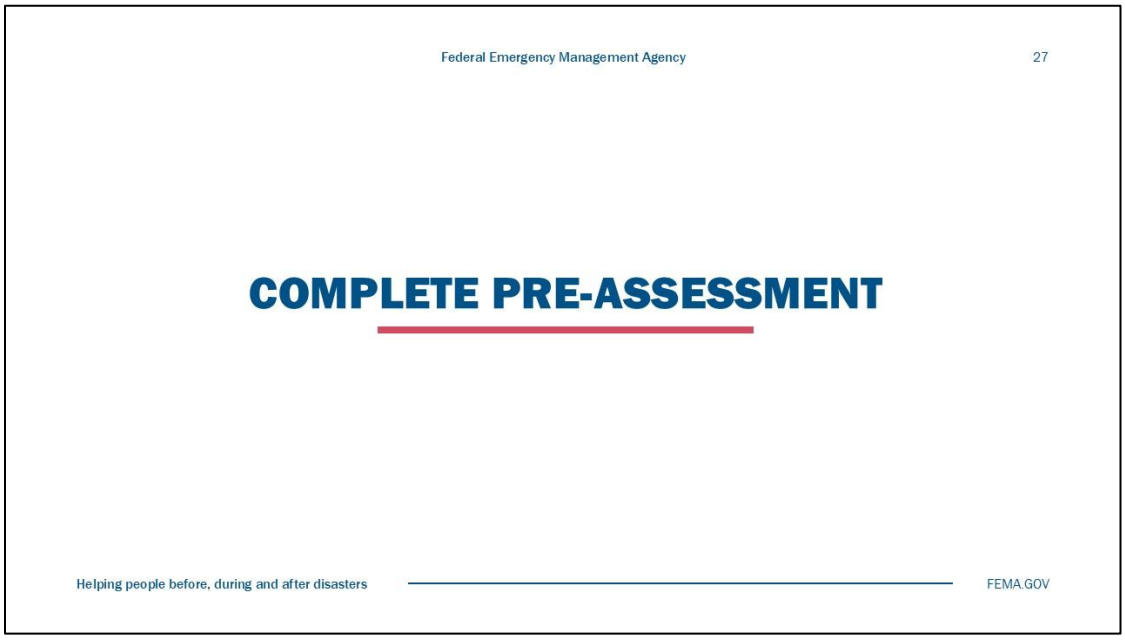
Slide 1-26, Student Evaluation Form Codes

Two-Digit Numerical Codes for States and Territories

States and Codes	States and Codes	States and Codes	States and Codes	States and Codes
01 – Alaska	02 – Alabama	03 – Arkansas	04 – American Samoa	05 – Arizona
06 – California	07 – Colorado	08 – Connecticut	09 – Canal Zone	10 – District of Columbia
11 – Delaware	12 – Florida	13 – Georgia	14 – Guam	15 – Hawaii
16 – Iowa	17 – Idaho	18 – Illinois	19 – Indiana	20 – Kansas
21 – Kentucky	22 – Louisiana	23 – Massachusetts	24 – Maryland	25 – Maine
26 – Michigan	27 – Minnesota	28 – Missouri	29 – Mississippi	30 – Montana
31 – North Carolina	32 – North Dakota	33 – Nebraska	34 – New Hampshire	35 – New Jersey
36 – New Mexico	37 – Nevada	38 – New York	39 – Ohio	40 – Oklahoma

States and Codes	States and Codes	States and Codes	States and Codes	States and Codes
41 – Oregon	42 – Pennsylvania	43 – Puerto Rico	44 – Rhode Island	45 – South Carolina
46 – South Dakota	47 – Tennessee	48 – Trust Territories	49 – Texas	50 – Utah
51 – Virginia	52 – Virgin Islands	53 – Vermont	54 – Washington	55 – Wisconsin
56 – West Virginia	57 – Wyoming	58 – Other		

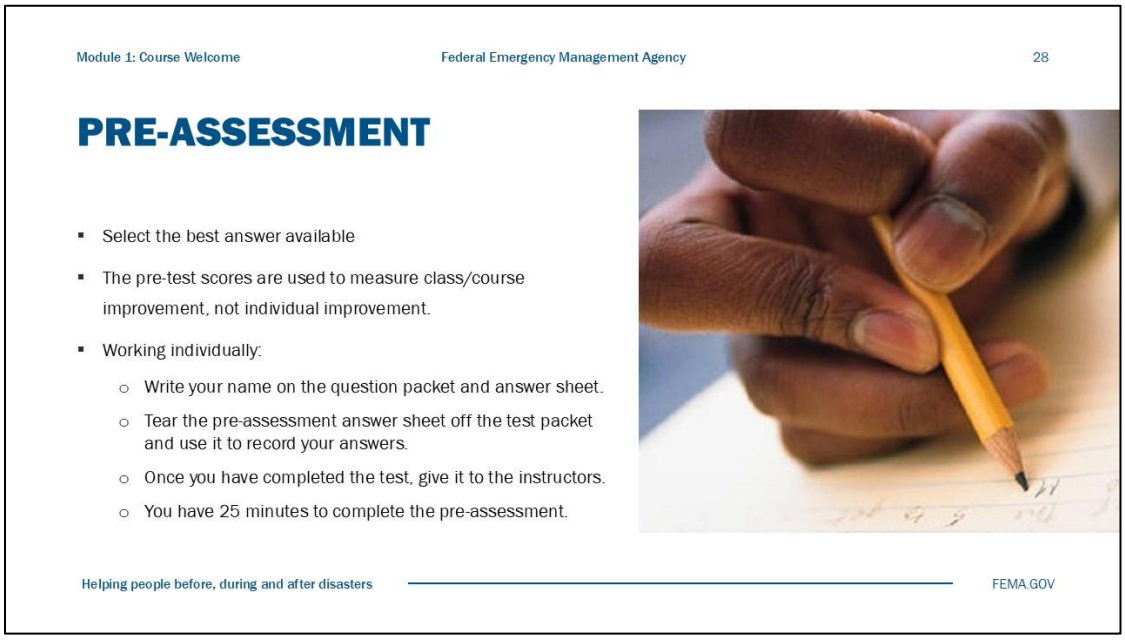
Complete Pre-Assessment (1 of 2)



Slide 1-27, Complete Pre-Assessment

Not Applicable.

Complete Pre-Assessment (2 of 2)



Slide 1-28, Pre-Assessment

Instructions: Working individually:

1. Write your name on the question packet and answer sheet.
2. Tear the pre-assessment answer sheet off the assessment packet and use it to record your answers.
3. Once you have completed the assessment, give it to the instructors.
4. You have 25 minutes to complete the pre-assessment.

Instructions: Working individually:

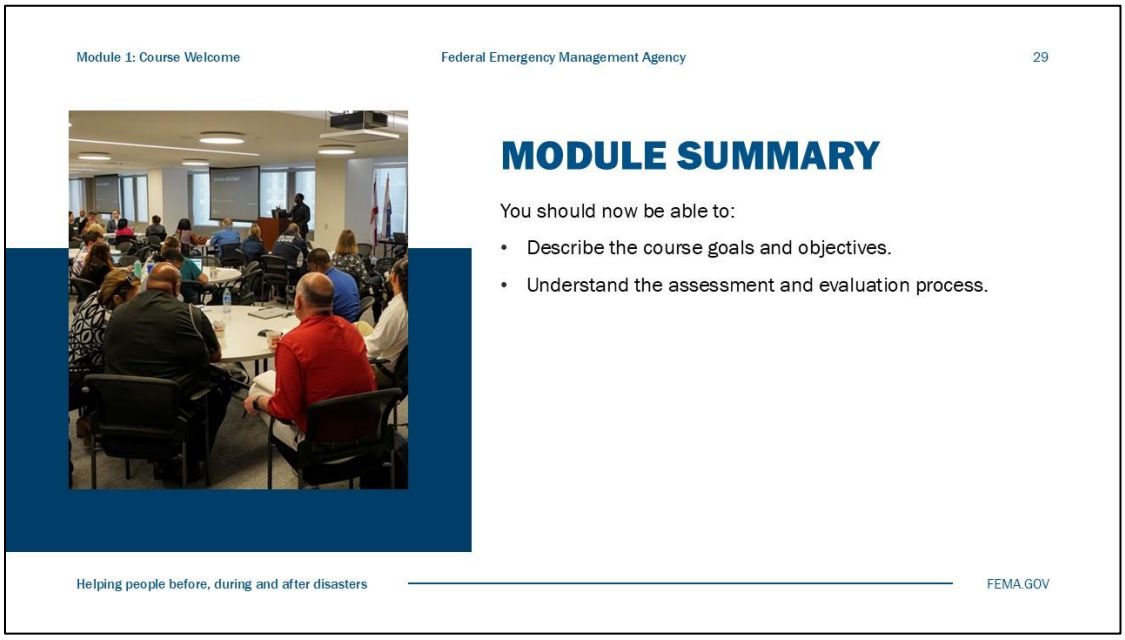
1. Write your name on the question packet and answer sheet.
2. Tear the pre-assessment answer sheet off the assessment packet and use it to record your answers.
3. Once you have completed the assessment, turn it in to the instructors.
4. You have 25 minutes to complete the pre-assessment.

Pre-and Post-Assessment:

The pre-assessment gauges your current knowledge before attending the course or your pre-existing knowledge. If you know the correct answer, please put it down. If you don't know, it's better to leave that question blank to give us data for our quality improvement program. Test-taking strategies like eliminating one answer and guessing will not allow us to get an accurate measure of the knowledge gained at the end of the course.

The post-assessment gauges what you have learned throughout the course or knowledge gained. Please answer all questions to the best of your ability.

End of Module (1 of 2)

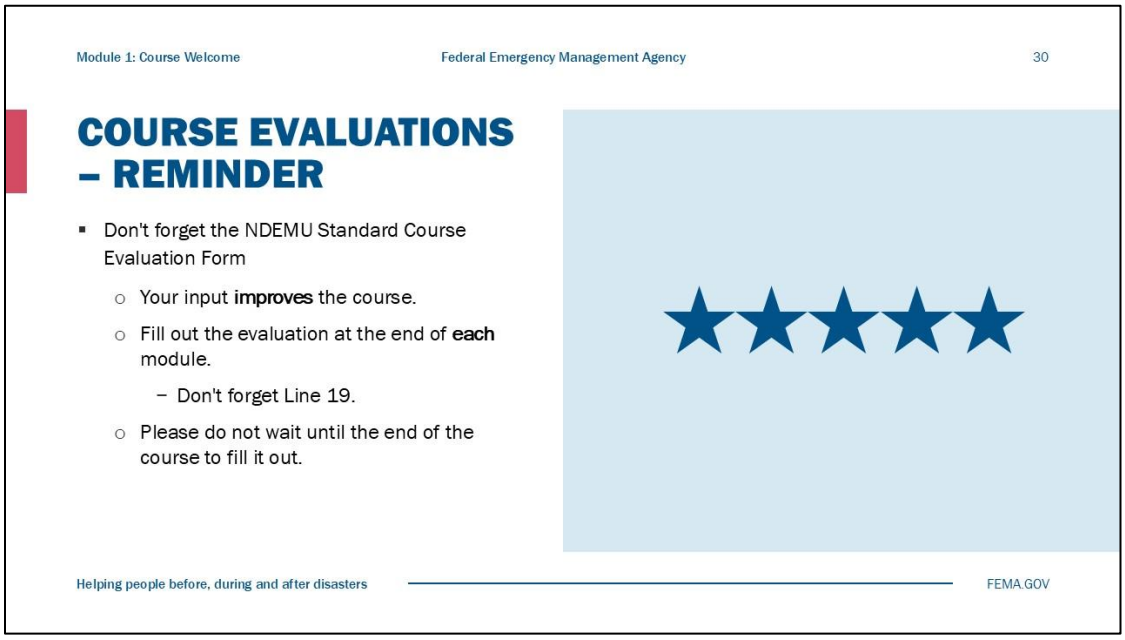


Slide 1-29, Module Summary

You should now be able to:

- Describe the course goals and objectives
- Understand the assessment and evaluation process

End of Module (2 of 2)



Slide 1-30, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

First Responder Training System. (n.d.). E0101: Foundations of Emergency Management. Retrieved May 15, 2025, from https://www.firstrespondertraining.gov/frts/npccatalog?id=2024

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NDEMU | EMPP | National Emergency Management Basic Academy. (n.d.). Retrieved May 15, 2025, from https://training.fema.gov/programs/emergency-management-professional/basic/

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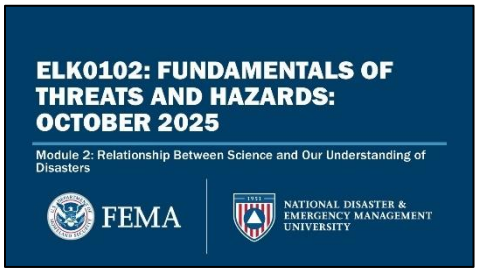
NTED | National Preparedness Course Catalog. (n.d.-e). E0102: Science for Disasters. Retrieved May 15, 2025, from https://www.firstrespondertraining.gov/frts/npccatalog?id=2025

Module

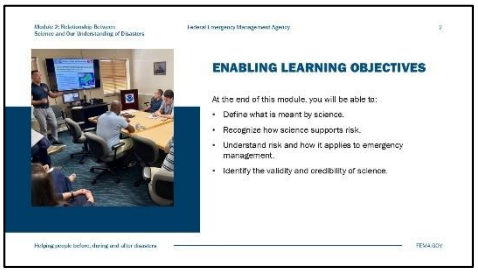
2

Relationship Between Science and Our Understanding of Disasters

Administration



Slide 2-1, Administration



Slide 2-2, Enabling Learning Objectives

Duration

1 hour

Terminal Learning Objective (TLO)

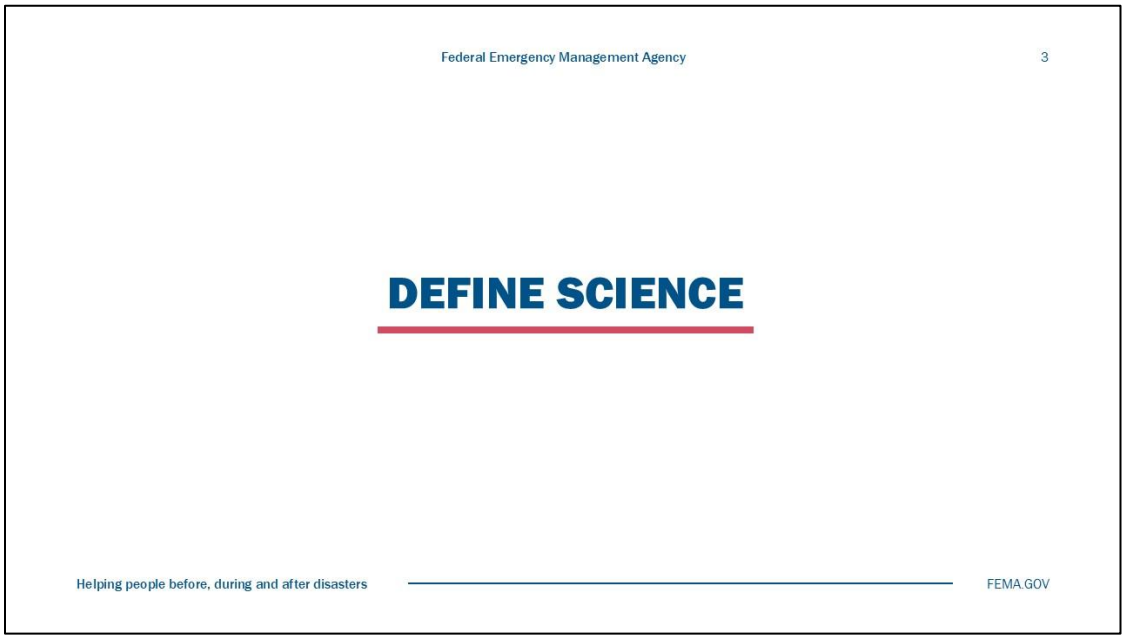
By the end of this module, participants will be able to analyze the role of science in understanding, predicting, and mitigating disasters, and apply scientific principles to enhance emergency management practices.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Define what is meant by science.
- Recognize how science supports risk.
- Understand risk and how it applies to emergency management.
- Identify the validity and credibility of science.

Define Science (1 of 10)



Slide 2-3, Define Science

Not Applicable.

Define Science (2 of 10)

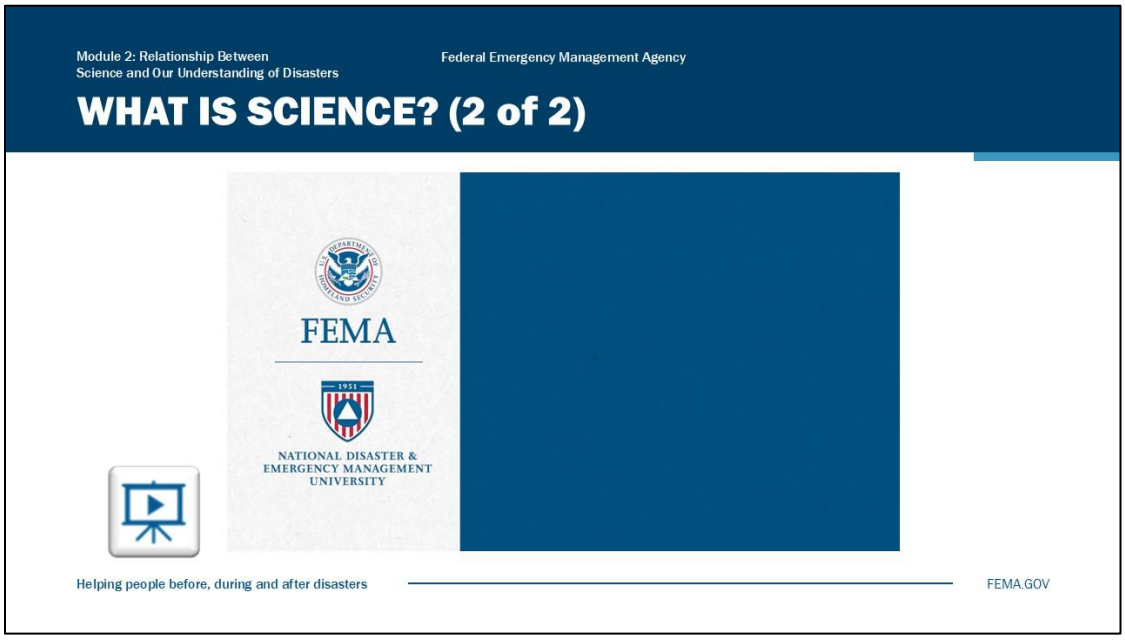


Slide 2-4, How do you define science?

How do you define science?

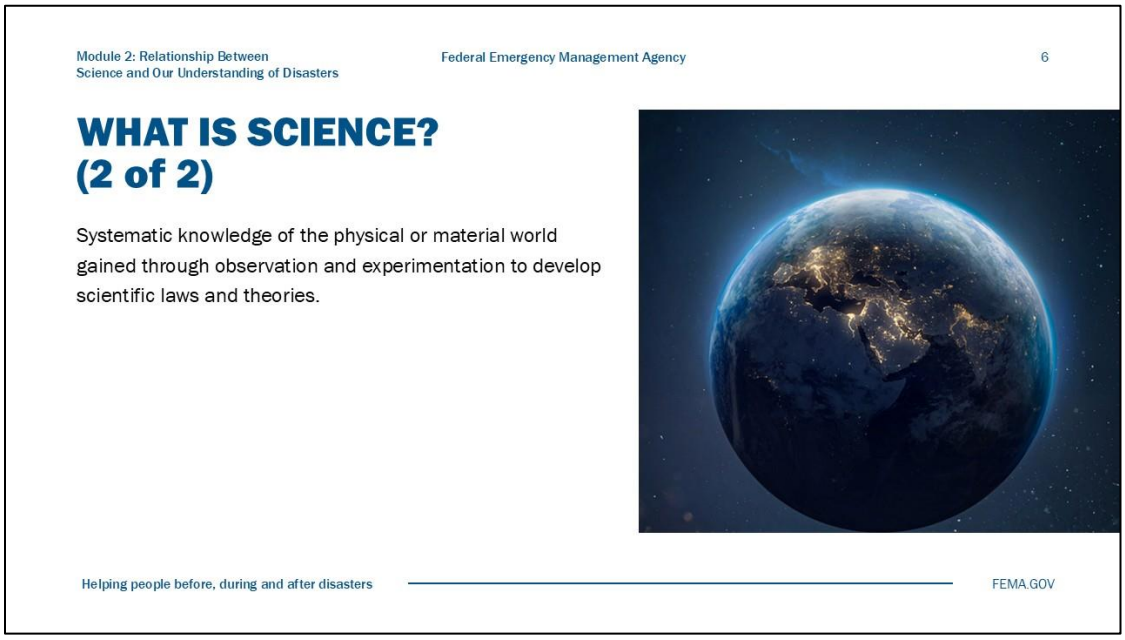
Science can be defined as the systematic knowledge of the physical or material world gained through observation and experimentation to develop scientific laws and theories.

Define Science (3 of 10)



Slide 2-5, What is Science? (1 of 2)

Define Science (4 of 10)



Slide 2-6, What Is Science? (2 of 2)

- Systematic knowledge of the physical or material world gained through observation and experimentation to develop scientific laws and theories.

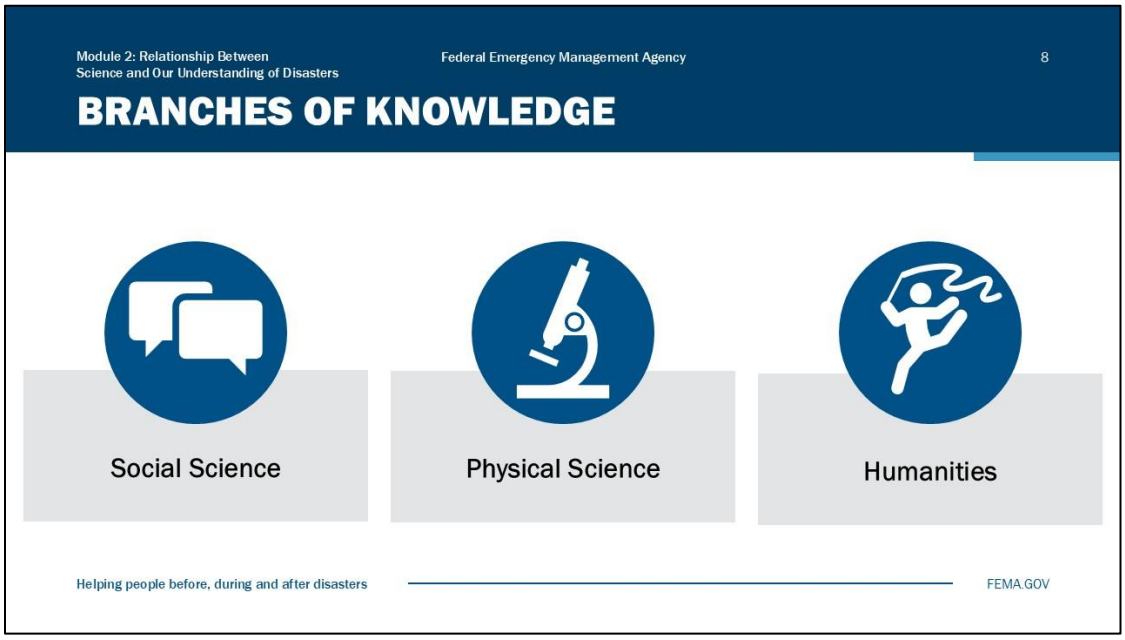
Define Science (5 of 10)



Slide 2-7, Definitions of Science

- A branch of knowledge or study dealing with a body of facts systematically arranged and showing the operation of general laws.
- Systematic knowledge of the physical or material world gained through observation and experimentation.

Define Science (6 of 10)



Slide 2-8, Branches of Knowledge

Social Science

They study human behavior and interaction.

- Economist
- Political Scientist
- Sociologist
- Psychologist
- Emergency Manager

Physical Science

They do the science we talked about in the previous slide.

- Meteorologist
- Geologist
- Chemist
- Physicist

Humanities

Express individual perspectives on the world (beliefs, thoughts, and feelings.)

- Musician
- Dancer
- Poet
- Graphic Artist
- Faith-based practitioner

Social sciences, like economics and sociology, deal with human behavior and interaction. Social sciences are a way to study our society. Social sciences also use a scientific method, but the content and context are more subjective, and responses can vary because of that.

The humanities, like history, art, and music, all deal with the individual perspective or how an individual or group views an event, literary work, or performance.

The CDC defines a hypothesis as "a supposition, arrived at from observation or reflection, that leads to refutable predictions; any conjecture cast in a form that will allow it to be tested and refuted.

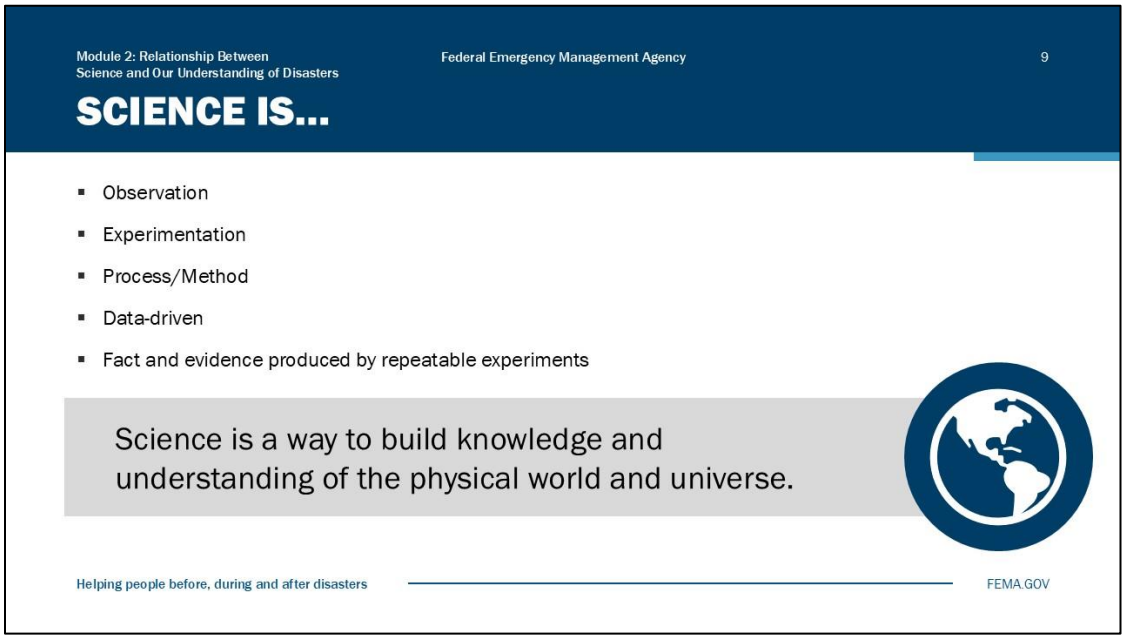
It is important that people recognize that theories DO NOT become law once they are “proven true.” Laws and theories are two entirely different concepts.

Laws describe **how** an object behaves in a given circumstance and under specific conditions. Laws do not explain **why** something happens. For example, Kepler’s Laws of Planetary Motion describe how the planets revolve around the Sun but give absolutely no explanation of why they revolve around the Sun the way they do. Laws are specific and can often be described with a mathematical equation. They describe one type of thing rather than a broad range of observations.

Also highlight those responses that mention the words “truth” and “proof.” Scientists do not seek truth! Nor are scientists’ intent on proving things true! Proof exists in mathematics and logic because these are self-contained systems. Science deals with the world/universe/nature as it exists. Scientists seek to describe and explain the physical world using empirical evidence. The evidence may support or refute a claim; both results are equally acceptable. This empirical evidence must be substantiated through reproducible experiments or additional evidence. This testing increases the validity of the claim.

Conversely, theories try to explain why something occurs as it does. Plate tectonics explains why mountains form where they do, why volcanoes occur where they do, and why earthquakes occur along localized zones. Theories involve a mechanism or process that explains a wide range of observations. Theories NEVER become laws. Theories, like laws, are the best that we have.

Define Science (7 of 10)



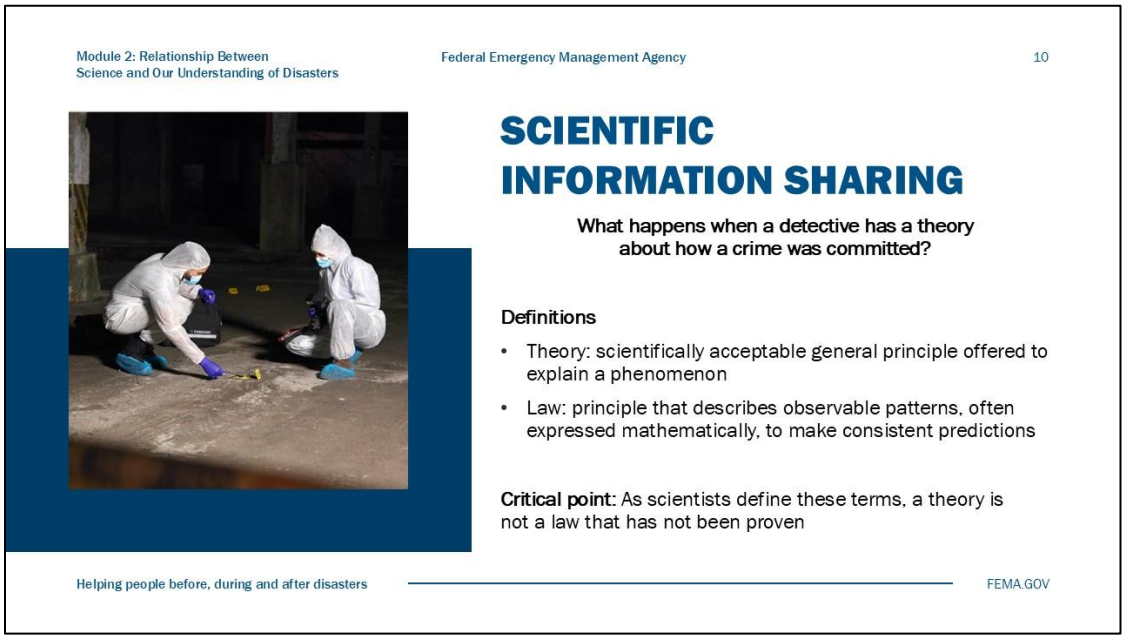
Slide 2-9, Science is...

Science is:

- Observation;
- Experimentation;
- Process/Method;
- Data-driven; and
- Fact and evidence produced by repeatable experiments.

Science is a way to build knowledge and understanding of the physical world and the universe.

Define Science (8 of 10)



Slide 2-10, Scientific Information Sharing

The detective has made an educated guess, likely based on past history and a brief examination of the scene. Then he collects evidence to prove or disprove his theory.

In society, a theory is conjecture; it is a guess that has not been proven. Scientists use these terms differently. In science, a law describes how something works (often expressed as a mathematical equation). A theory describes why it works the way it does. A theory never becomes a law through being "proven" because it is not "provable." Nothing is ever 100% provable. We are always using observations to adjust our statistical models.

- **Theory**: scientifically acceptable general principle offered to explain a phenomenon
- **Law**: principle that describes observable patterns, often expressed mathematically, to make consistent predictions

It is important that people recognize that theories DO NOT become law once they are "proven true." Laws and theories are two entirely different concepts.

Laws describe **how** an object behaves under specific circumstances and conditions. Laws do not explain **why** something happens. Theories explain why something happens. For example, Kepler's Laws of Planetary Motion describe how the planets revolve around the Sun but give absolutely no explanation of why they revolve around the Sun the way they do. Laws are specific and can often be

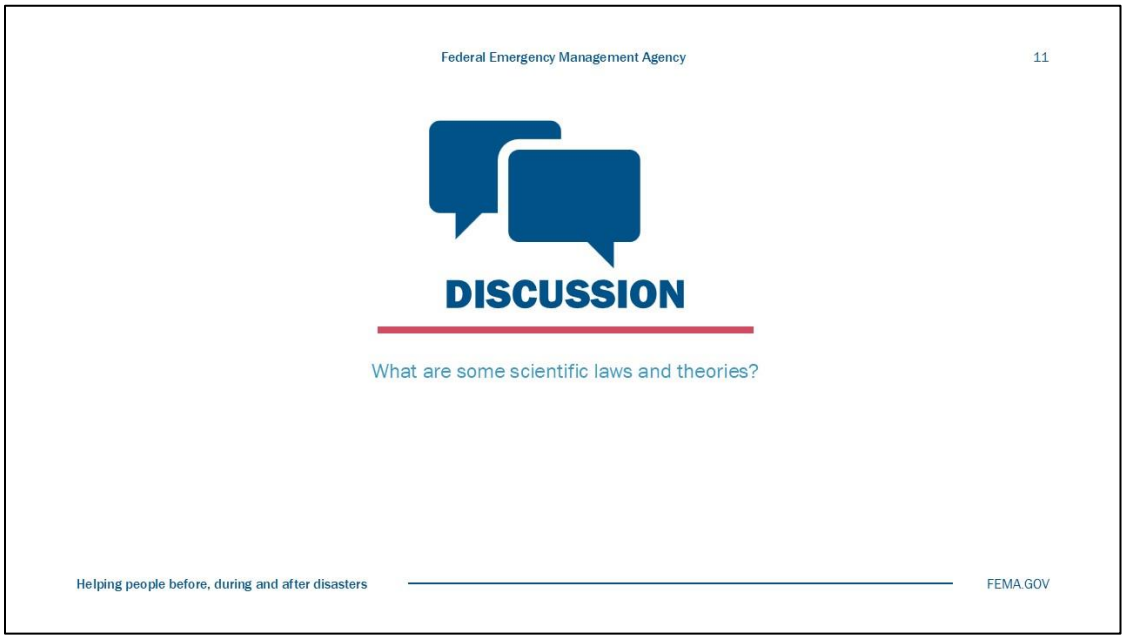
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Theories that last are well-documented with a wide range of confirming evidence that supports the process or mechanism. For example, the process of evolution was recognized in various ways long before Darwin hypothesized the mechanism by which it occurred. Darwin’s ideas of natural selection explained the observations in the fossil record, and the observations in animal husbandry, and the observations of biodiversity. DNA studies provide further confirming evidence in support of evolutionary theory.

Define Science (9 of 10)



Slide 2-11, Discussion Question

What are some scientific laws and theories?

It is important that people recognize that theories DO NOT become law once they are "proven true." Laws and theories are two entirely different concepts.

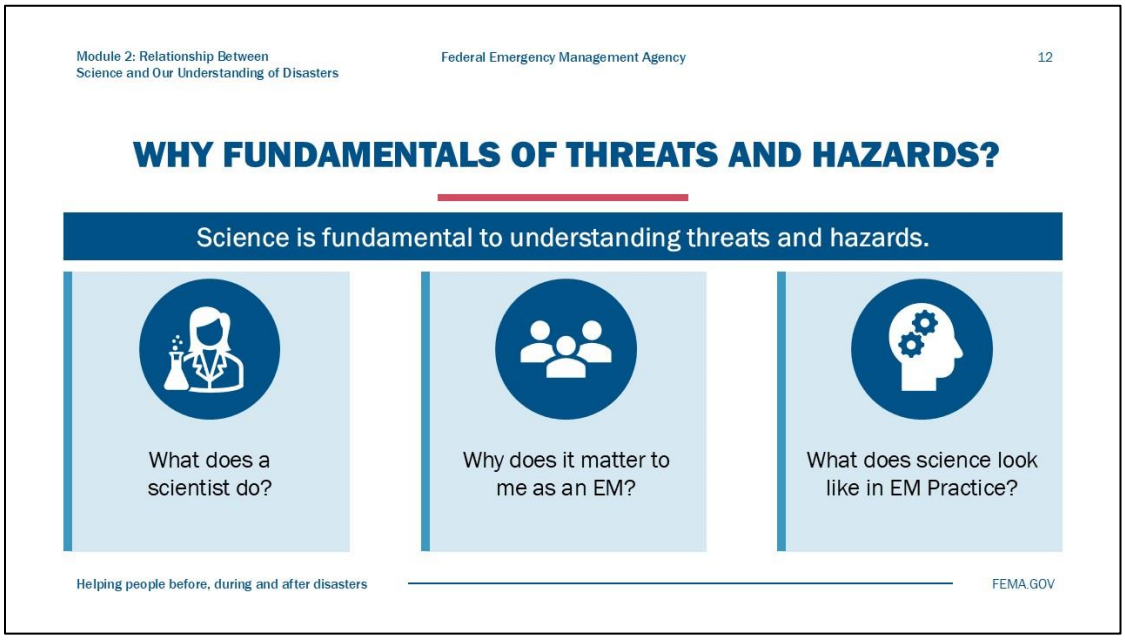
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Be wary of words like "truth" and "proof." Scientists do not seek truth! Nor are scientists' intent on proving things true! Proof exists in mathematics and logic because these are self-contained systems. Science deals with the world/universe/nature as it exists. Scientists seek to describe and explain the physical world using empirical evidence. The evidence may support or refute a claim; both results are equally acceptable. This empirical evidence must be substantiated through reproducible experiments or additional evidence. This testing increases the validity of the claim.

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Define Science (10 of 10)

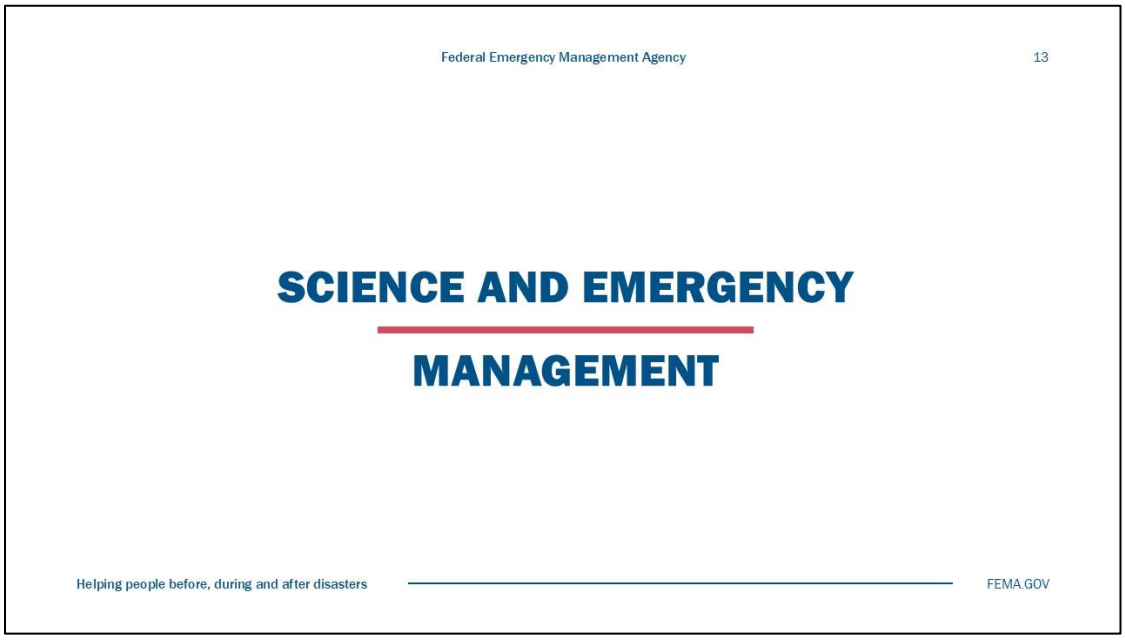


Slide 2-12, Why Fundamentals of Threats and Hazards?

Science is fundamental to understanding threats and hazards.

- What does a scientist do?
- Why does it matter to me as an EM?
- What does science look like in EM practice?

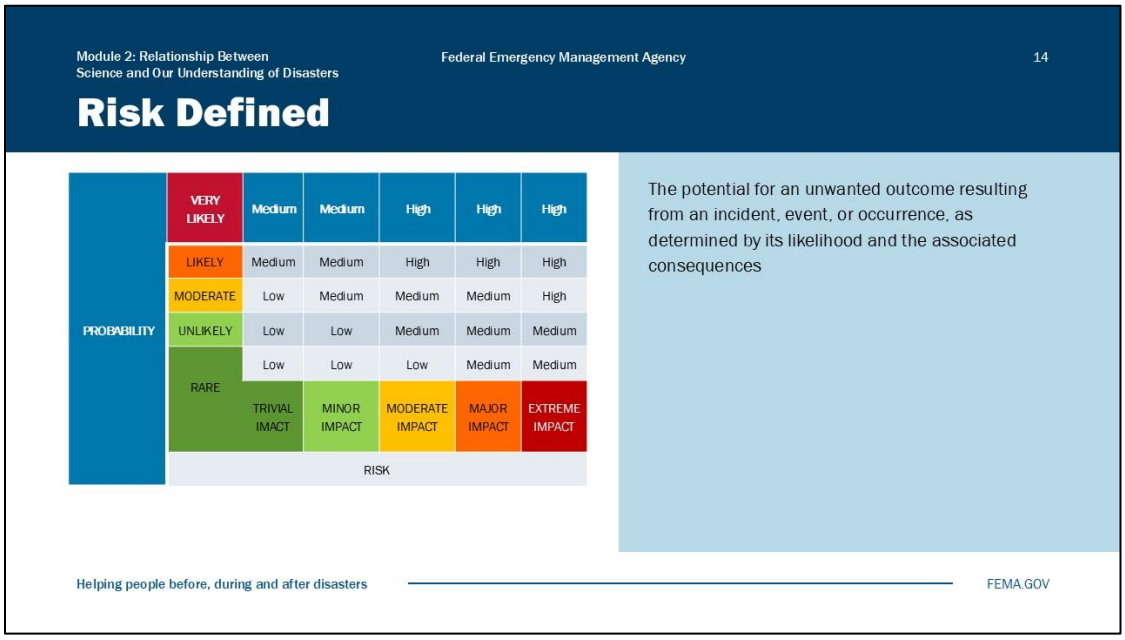
Science and Emergency Management (1 of 5)



Slide 2-13, Science and Emergency Management

Not applicable.

Science and Emergency Management (2 of 5)

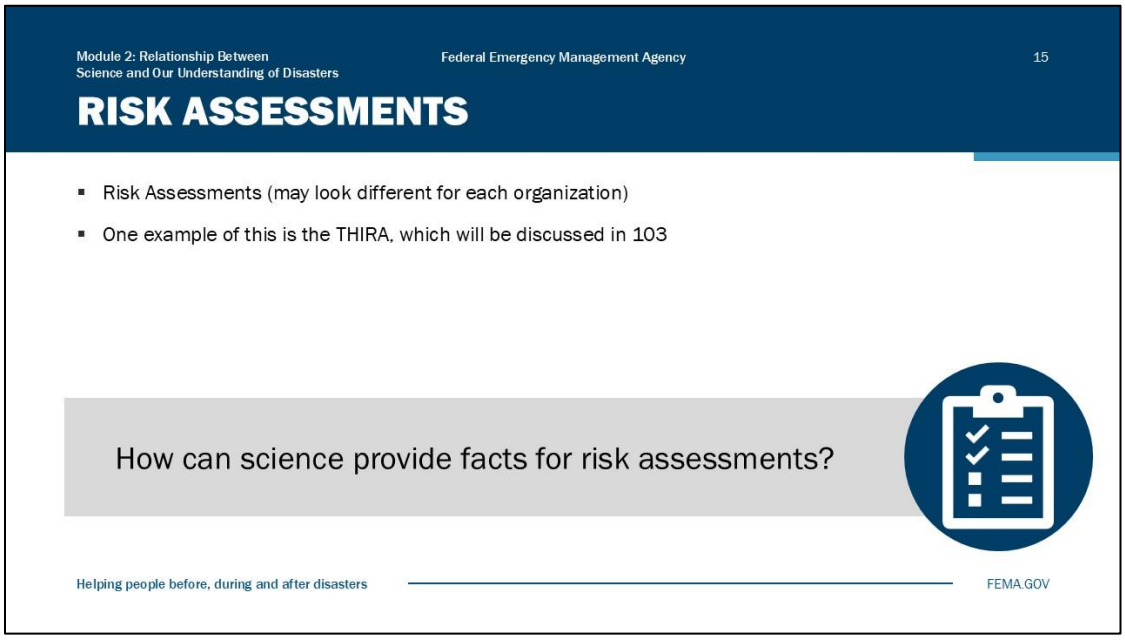


Slide 2-14, Risk Defined

- Definition of risk: The potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated consequences.
- Risk = Threats x Vulnerabilities x Impact
- Note: The probability that a risk will happen (low-med-high) is reflected within the evaluation of the threat and vulnerabilities to a community.

PROBABILITY	VERY LIKELY	Medium	Medium	High	High	High
	LIKELY	Medium	Medium	High	High	High
	MODERATE	Low	Medium	Medium	Medium	High
	UNLIKELY	Low	Low	Medium	Medium	Medium
	RARE	Low	Low	Low	Medium	Medium
		TRIVIAL IMACT	MINOR IMPACT	MODERATE IMPACT	MAJOR IMPACT	EXTREME IMPACT
	RISK					

Science and Emergency Management (3 of 5)

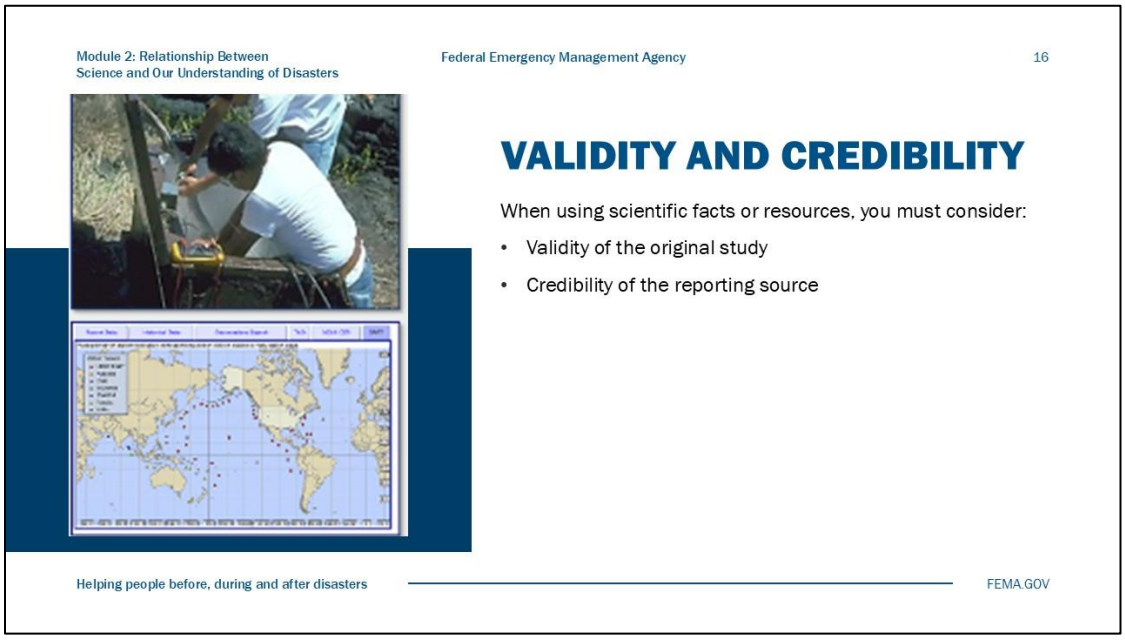


Slide 2-15, Risk Assessments

- Risk Assessments (may look different for each organization)
- One example of this is the THIRA, which will be discussed in 103

How can science provide facts for risk assessments?

Science and Emergency Management (4 of 5)



Slide 2-16, Validity and Credibility

Not all sources (models, maps, etc.) are equal, so as Emergency Managers, you must be mindful of the validity and credibility of a source/resource when gathering scientific information. The popular press and public view may contain bias. Not all sources of information are accurate or credible. Scientific writing only passes on facts that meet a statistical level of validity. It is important to realize that, in fact-based reporting, not both sides are always valid.

Validity:

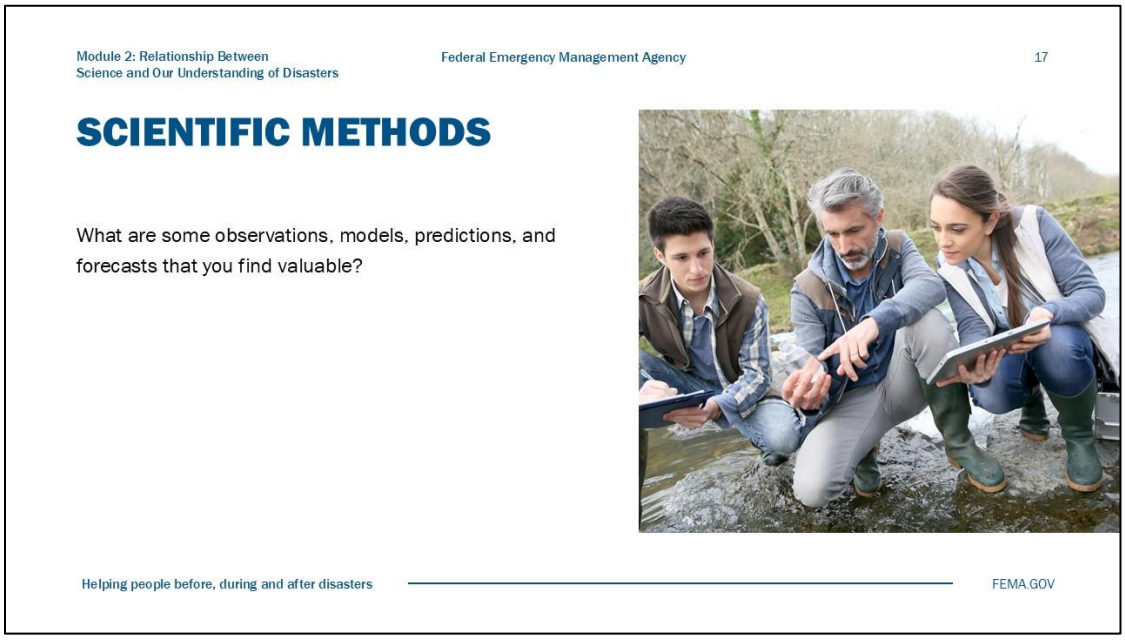
- Who paid for/sponsored the study?
- Was the study large enough to pass statistical muster?
- Was it designed well?
- Did it last long enough?
- Were there any other possible explanations for the study's conclusions, or reasons to doubt the findings?
- Do the conclusions fit with other scientific evidence? If not, why?
- Do you have the full picture?
- Have the findings been checked by other experts (i.e., peer-reviewed)?

- What are the implications of the research? Any potential problems or applications?

Credibility:

- Type: What kind of content is this?
- Source: Who and what are the sources cited and why should I believe them?
- Evidence: What is the evidence and how was it vetted?
- Interpretation: Is the main point of the piece proven by the evidence?
- Completeness: What is missing?
- Knowledge: Am I learning every day what I need?

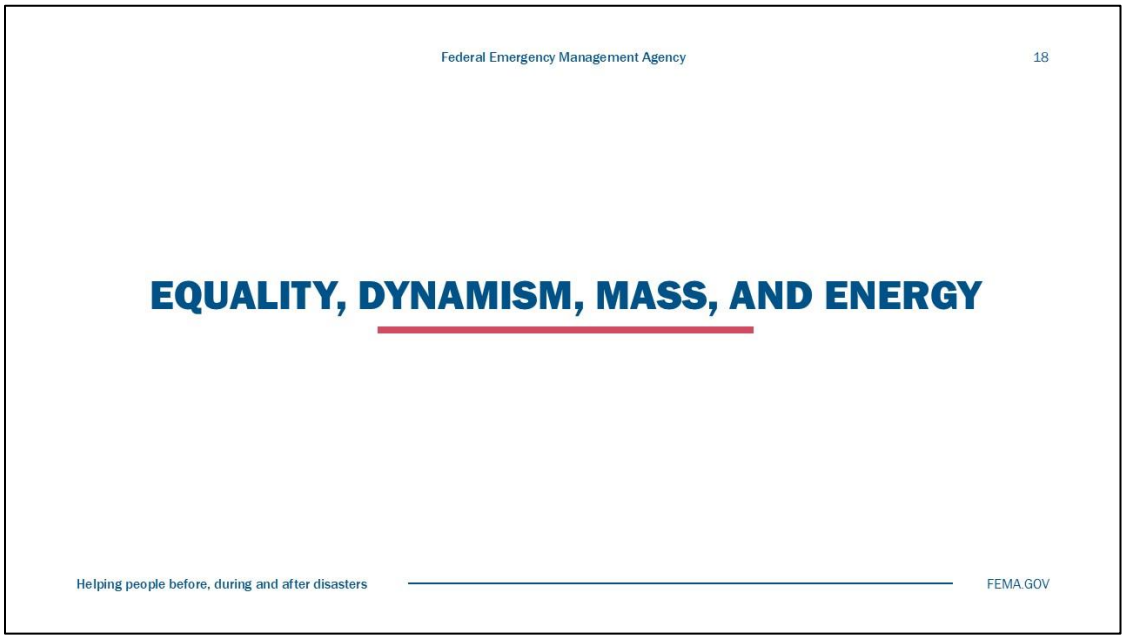
Science and Emergency Management (5 of 5)



Slide 2-17, Scientific Methods

- What are some observations, models, predictions, and forecasts that you find valuable?

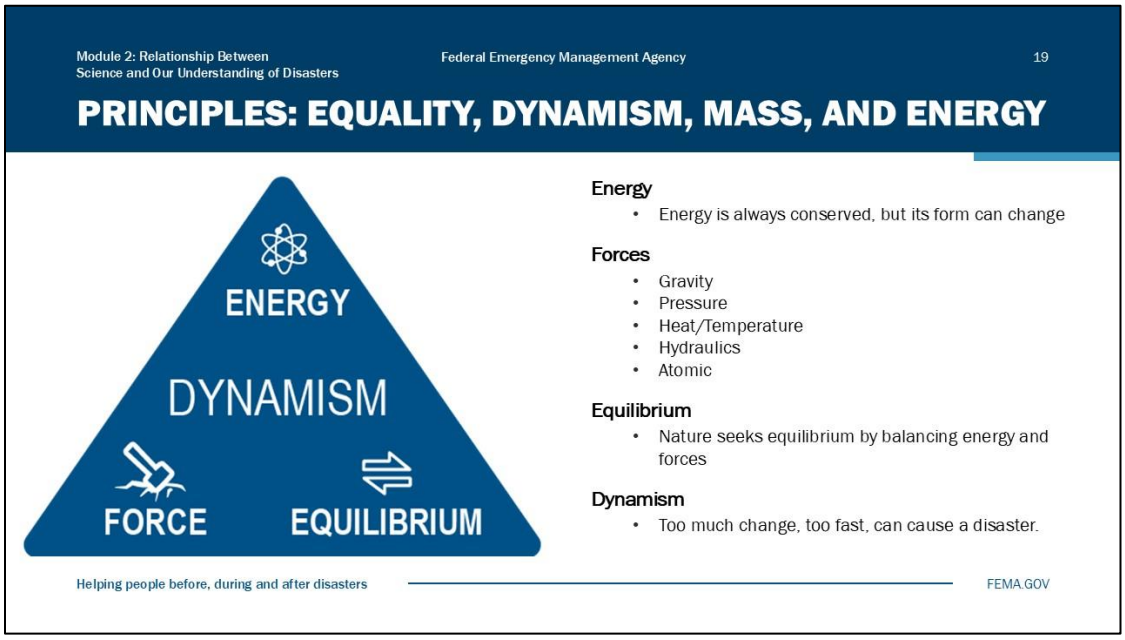
Equality, Dynamism, Mass, and Energy (1 of 4)



Slide 2-18, Equality, Dynamism, Mass, and Energy

Not applicable.

Equality, Dynamism, Mass, and Energy (2 of 4)



Slide 2-19, Principles: Equality, Dynamism, Mass, and Energy

Energy: Energy is always conserved, but its form can change

Dynamism: Too much change, too fast, can cause a disaster.

Force: Forces cause change:

- Gravity
- Pressure
- Heat/Temperature
- Hydraulics
- Atomic

Equilibrium: Nature seeks equilibrium by balancing energy and forces.

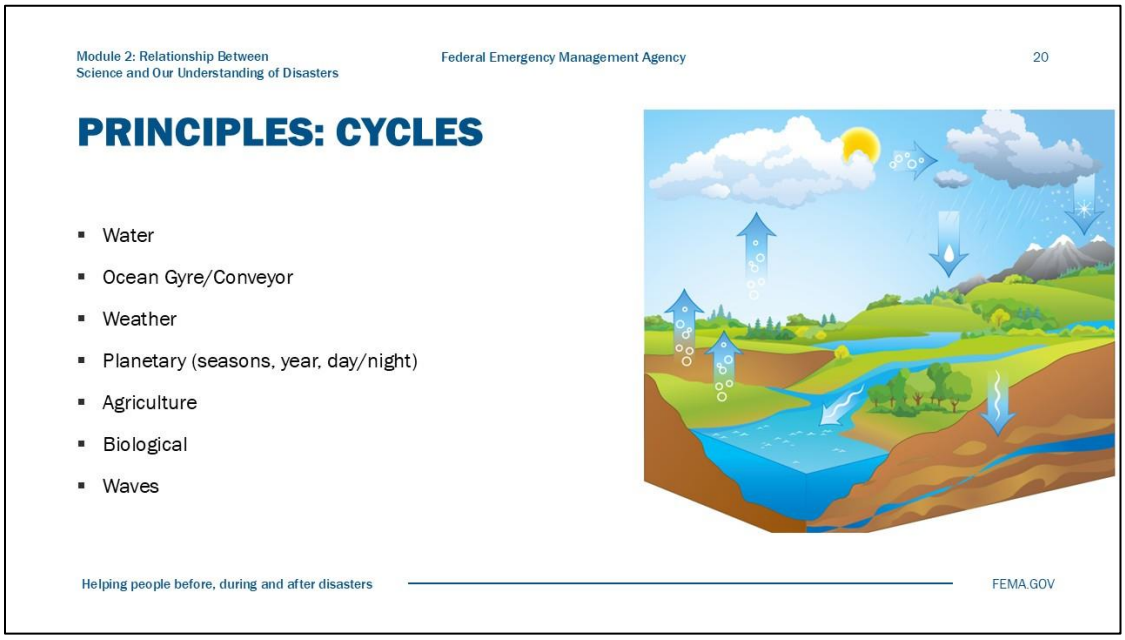
Throughout this course, you will notice images with a combination of the icons in the triangle. They are shown to quickly identify topics that relate to that principle. Here is what they mean:

- **Equilibrium** – Everything in nature wants to be equal. Pressures, temperatures, densities – all aspects of our natural world will mix to equalize as they come into contact with each other.
- **Dynamism** – We live in a dynamic (or changing) world. We have adapted to thrive in change within certain parameters, but change outside of those parameters can be the definition of a disaster.
- **Force and Mass** – All objects have mass. Gravity is the force of attraction between two objects due to their mass. Other forces discussed in this course include friction, pressure, electric, and nuclear forces.
- **Energy** – The transfer of energy through our environmental systems is a fundamental aspect of the environmental and physical sciences.

Terms:

- **Force** – A push or a pull on an object due to an interaction.
- **Gravity** is a force that causes smaller objects to be attracted to larger ones, such as the Earth attracting everything from people to rocks to water.
- **Mass** – A property of all matter determined by the type of matter (what it is made of) and the size of the object (physical dimensions). A mass will be the same for a certain object everywhere in the universe (gold is gold, iron is iron, etc.). Mass and weight are related through the force of gravity. The Earth's gravitational pull on a mass is referred to as the object's weight. The more mass (matter) an object has, the more it will weigh. Thus, 100 kilograms of mass (a rock, a person, a refrigerator, etc.) will weigh 220 pounds on Earth, but 100 kilograms of mass (the same object) will weigh 33 pounds on the Moon since it has less gravity. (This is mixing units, but the concept is correct.)
- **Energy** – The amount of work a force can do. Energy can be stored in a system, like faults in tectonic plates. This energy is stored as potential energy, ready to be harnessed and do work. Once the fault ruptures, the energy is released and becomes kinetic (energy of motion).

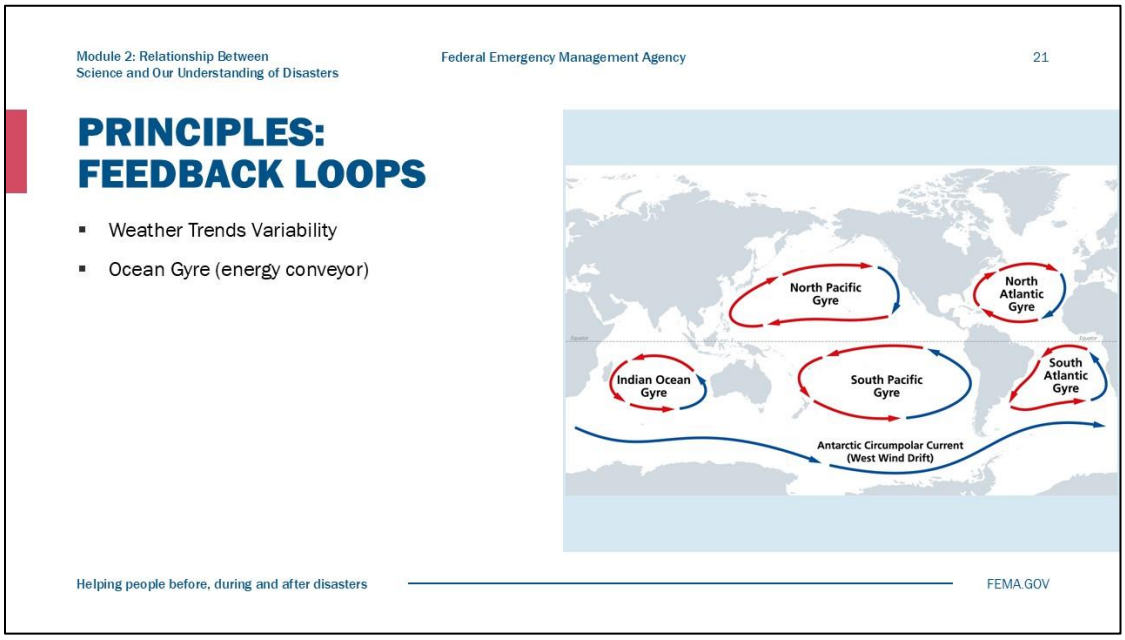
Equality, Dynamism, Mass, and Energy (3 of 4)



Slide 2-20, Principles: Cycles

- Water
- Ocean Gyre/Conveyor
- Weather
- Planetary (seasons, year, day/night)
- Agriculture
- Biological
- Waves

Equality, Dynamism, Mass, and Energy (4 of 4)



Slide 2-21, Principles: Feedback Loops

- Weather Trends Variability
- Ocean Gyre (energy conveyor)

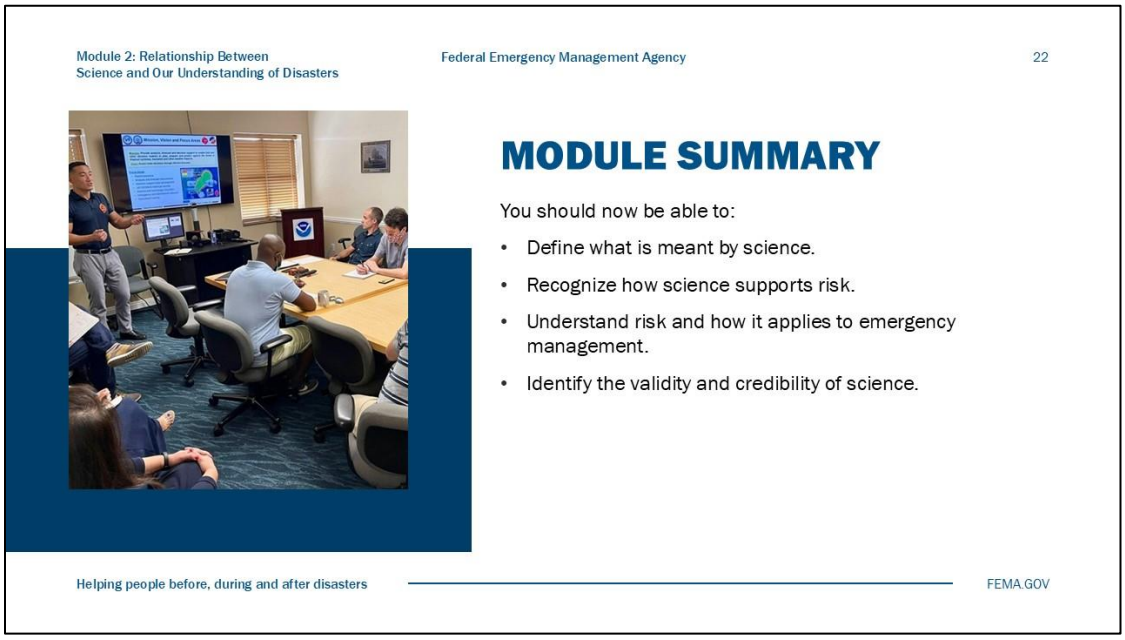
Feedback loops can either enhance (reinforce) or diminish (reduce) a change in a system. You may be familiar with the feedback sometimes heard when a band is rehearsing. The sound from the singer is fed into the microphone, which then passes it to the speaker. The speaker's sound is reintroduced into the microphone. This feedback is amplified rapidly, causing the screeching sound you hear. Feedback loops can be positive (reinforcing), as in the example above, or negative (reducing), causing a decrease over time. Feedback loops are prevalent in Nature, although these systems can be complex in some cases. Positive and negative feedback loops cause disequilibrium, driving systems to become less stable and to change dramatically.

Other examples include:

- When a predator eats too much of its prey, less available prey causes the predator population to dwindle over time due to a lack of food. Once the predator population drops, the prey population can rise, and so on.
- In a chemical reaction, the energy released can cause the reaction to speed up, releasing more energy. More energy released causes the reaction to speed up more, and so on. This can result in an explosion.

- When the climatic system warms, more polar ice melts and colder water is introduced into the oceans. This can disrupt the large system of rotating ocean currents. The Gulf Stream is part of one such gyre that moves warm ocean waters up along the East coast of the U.S. and out across the Atlantic Ocean toward Europe. Disrupting this current can cause changes to weather patterns across Europe.
- A warming climatic system reintroduces more carbon dioxide (CO_2) into the atmosphere. More carbon dioxide in the atmosphere traps heat, causing the atmosphere to warm further, much like car windows trap heat inside a car in the summer. If left unchecked, this feedback loop continues to increase.

End of Module (1 of 2)



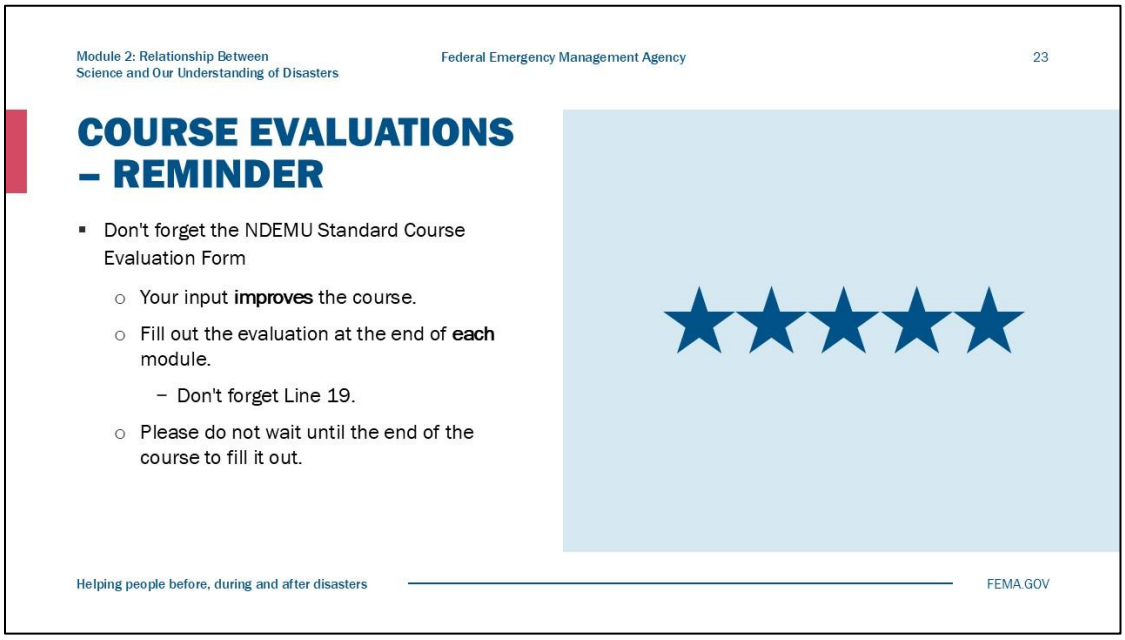
Slide 2-21, Module Summary

You should now be able to:

- Define what is meant by science;
- Recognize how science supports risk;
- Understand risk and how it applies to emergency management
- Identify the validity and credibility of science.

Do you have any questions about the material covered in this module?

End of Module (2 of 2)



Slide 2-22, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

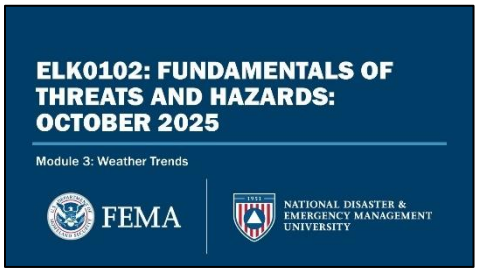
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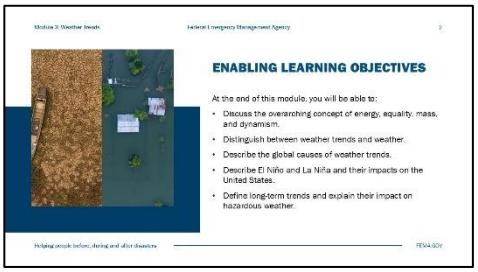
Module 3

Weather Trends

Administration



Slide 3-1, Module 3: Weather Trends



Slide 3-2, Enabling Learning Objectives

Duration

1 hour, 25 minutes

Terminal Learning Objective (TLO)

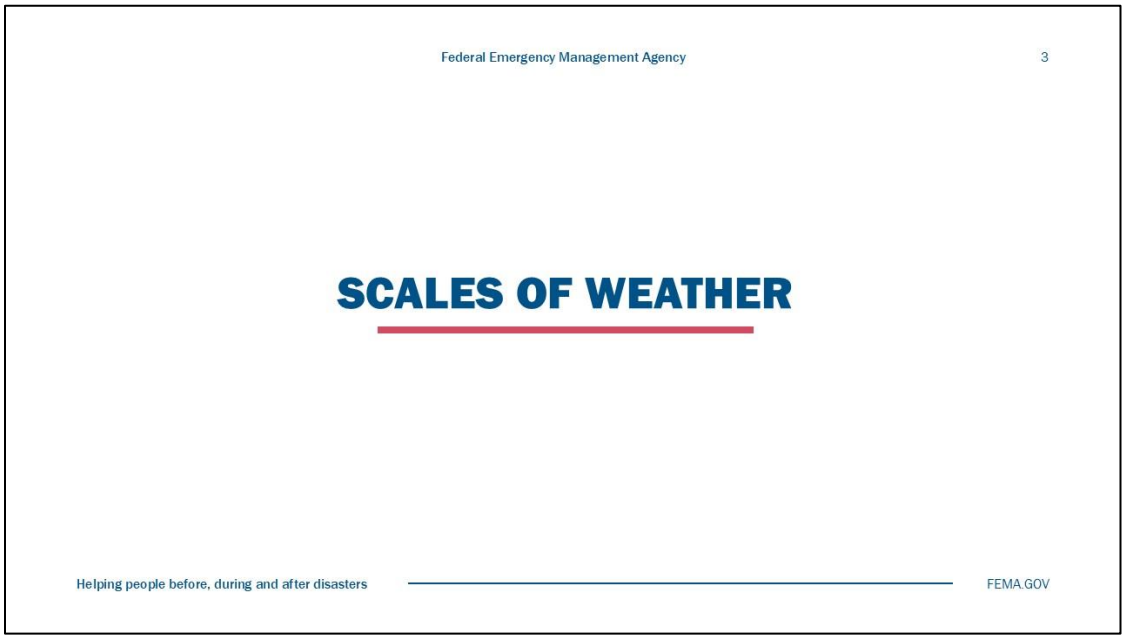
By the end of this module, participants will be able to explain the fundamental atmospheric processes that drive weather and weather trends, including the roles of energy transfer, convection, and global circulation patterns.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Discuss the overarching concept of energy, equality, mass, and dynamism.
- Distinguish between weather trends and weather.
- Describe the global causes of weather trends.
- Describe El Niño and La Niña and their impacts on the United States.
- Define long-term trends and explain their impact on hazardous weather.

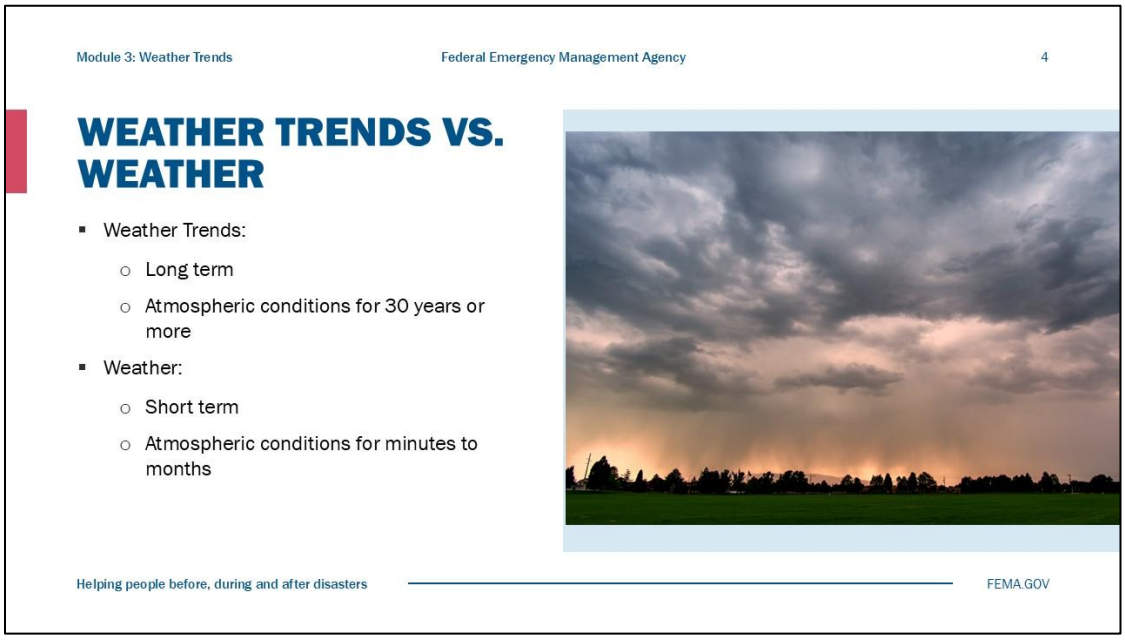
Scales of Weather (1 of 2)



Slide 3-3, Scales of Weather

Not applicable.

Scales of Weather (2 of 2)



Slide 3-4, Weather Trends vs. Weather

The difference between weather trends and weather is essentially one of time.

Weather Trends: Weather trends describe long-term (i.e., 30 years or more) trends and patterns of weather.

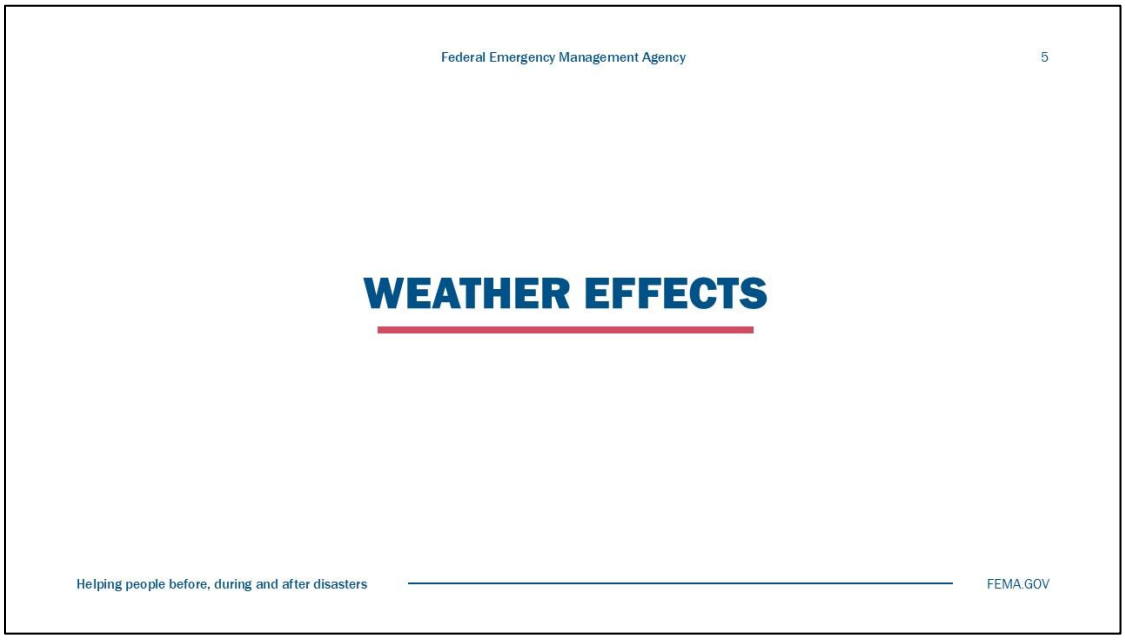
Climatology is the study of the sum total of the meteorological elements that characterize the average and extreme condition of the atmosphere over a long period of time at any one place or region of the Earth's surface, or the collective state of the atmosphere at a given place or over a given area within a specified period of time.

Understanding climatology provides the basis for future weather trends expectations and enables planning by assisting in long-term prediction.

Weather: Weather, on the other hand, describes the conditions of the atmosphere over a much shorter period of time (i.e., minutes to months).

Meteorology is a science dealing with the atmosphere and its phenomena, which sounds quite similar to climatology. The distinction is that climatology is primarily concerned with average, not actual, weather conditions.

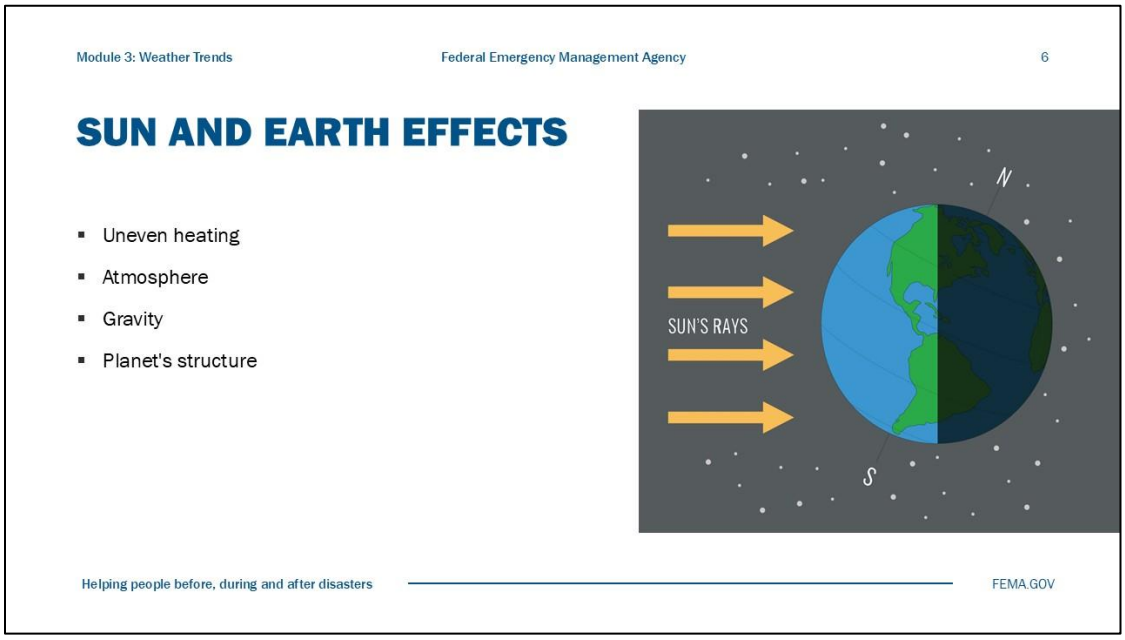
Weather Effects (1 of 3)



Slide 3-5, Weather Effects

Not applicable.

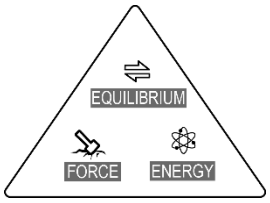
Weather Effects (2 of 3)



Slide 3-6, Sun and Earth Effects

- Uneven heating
- Atmosphere
- Gravity
- Planet's structure

This is equilibrium, force, and energy.

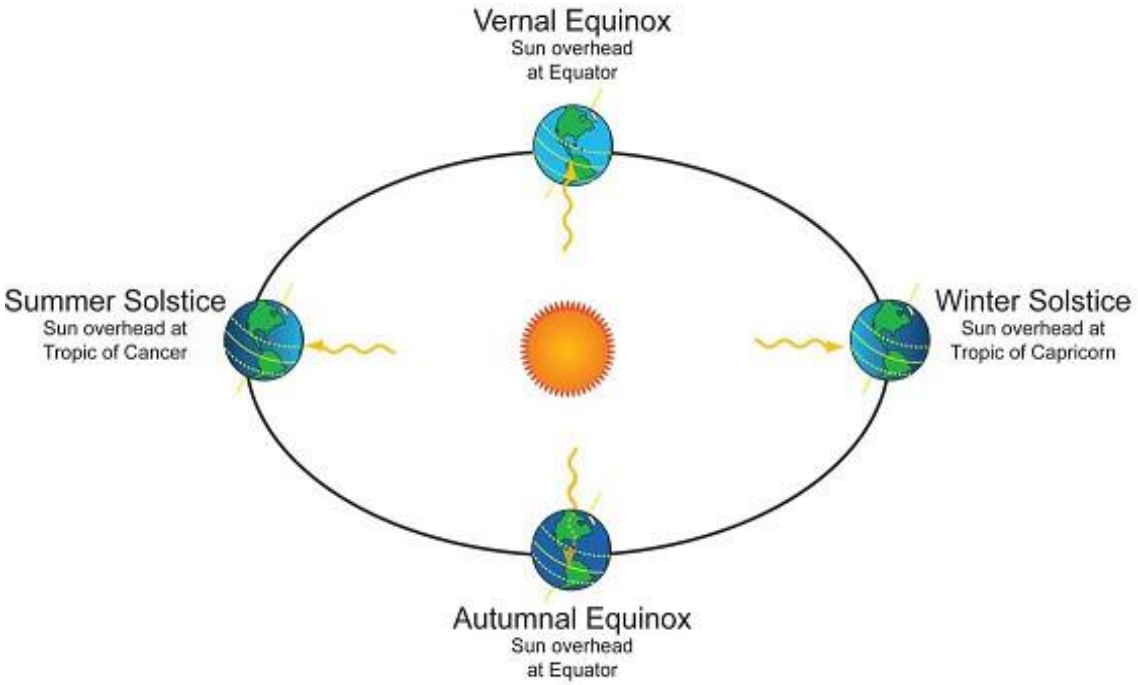


On a global scale, weather is influenced by the effects of the sun and Earth.

Uneven heating: The weather on our planet largely results from the sun heating areas of the planet unequally. This unequal distribution occurs because of:

- **Tilt, rotation, and orbit:** Earth's axis is tilted 23.5 degrees. Earth rotates on its axis every 24 hours, creating day and night. It revolves around the sun on an elliptical path, creating our seasons as it completes its yearly journey.

  As Earth moves around the sun, the concentration of sunlight shifts to be either more or less concentrated in the northern hemisphere depending on where Earth is relative to the sun.



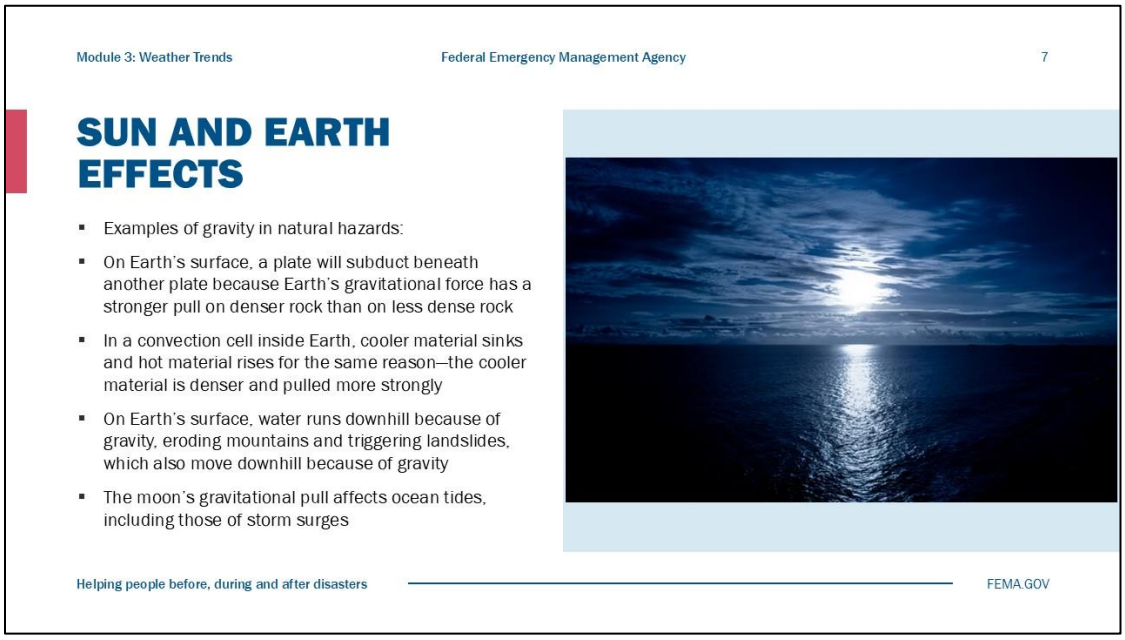
  - **Day/night temperature differences:** The sun's radiation reaches only half the planet (the "daylight" side) at any one time. Half of Earth is heating up during the day while the other half, the night side, is cooling down. Sunlight that is striking the planet during the day heats up Earth's surface-both land and water.
  - **Spherical shape:** The amount of radiation reaching the surface varies at different places. Because Earth is almost a perfect sphere, the sunlight is more concentrated in some areas (e.g., at the equator) and less concentrated in others (the polar regions). This differential heating, along with the rotation of Earth, creates moving weather.

- **The planet's atmosphere:** Earth's atmosphere is the layer of gas that surrounds Earth and is held to Earth by gravity. The atmosphere is a fluid that moves and circulates because of differences in temperature and pressure.

- **The structure of the planet:** The basic structure of the planet-landforms, oceans and other bodies of water, mountains, deserts, vegetation, and even urban areas—is also important in determining weather.

The oceans are particularly important because they provide much of the water that evaporates into the atmosphere.

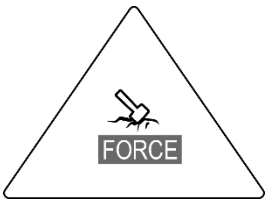
Weather Effects (3 of 3)



Slide 3-7, Effects of Gravity

How do you think gravity impacts natural hazards?

This is force.

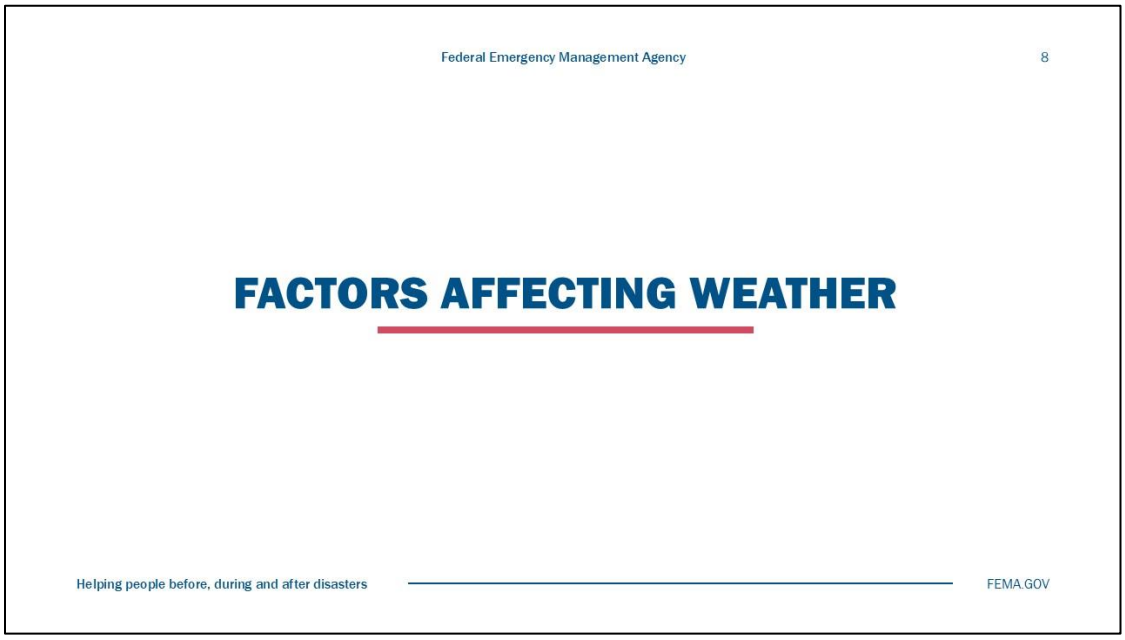


We all have gravitational pull, but ours are trivial compared to those of Earth, the sun, and the moon.

Examples of gravity in natural hazards:

- On Earth's surface, a plate will subduct beneath another plate because Earth's gravitational force has a stronger pull on denser rock than on less dense rock.
- In a convection cell inside Earth, cooler material sinks and hot material rises for the same reason—the cooler material is denser and pulled more strongly.
- On Earth's surface, water runs downhill because of gravity, eroding mountains and triggering landslides, which also move downhill because of gravity.
- The moon's gravitational pull affects ocean tides, including those of storm tides.

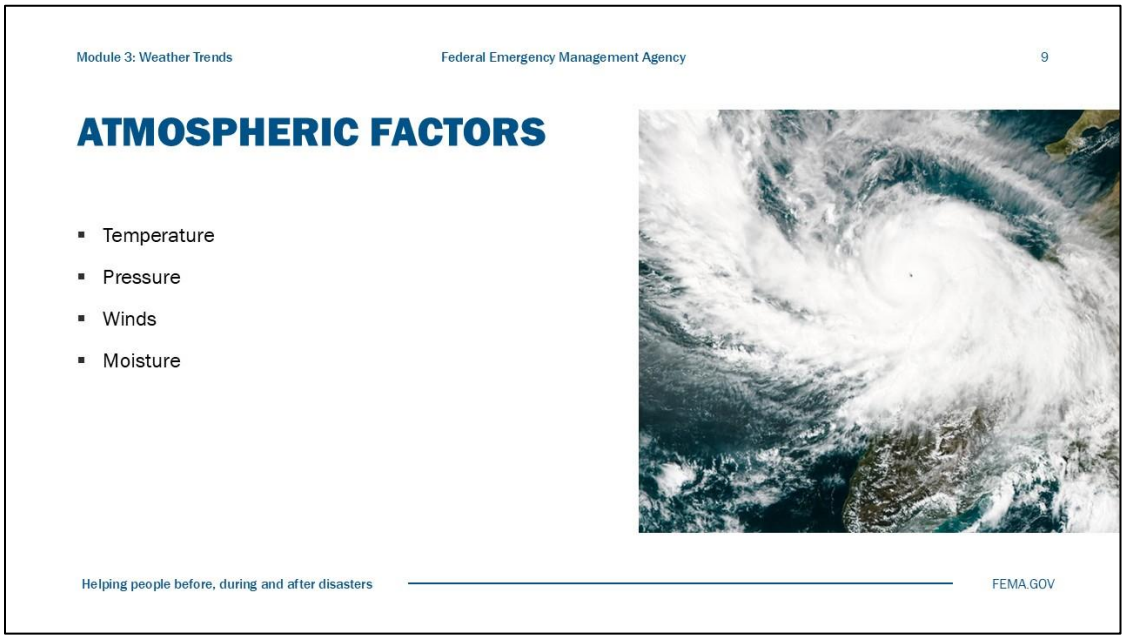
Factors Affecting Weather (1 of 19)



Slide 3-8, Factors Affecting Weather

Not applicable.

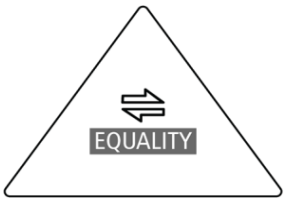
Factors Affecting Weather (2 of 19)



Slide 3-9, Atmospheric Factors

- Temperature
- Pressure
- Winds
- Moisture

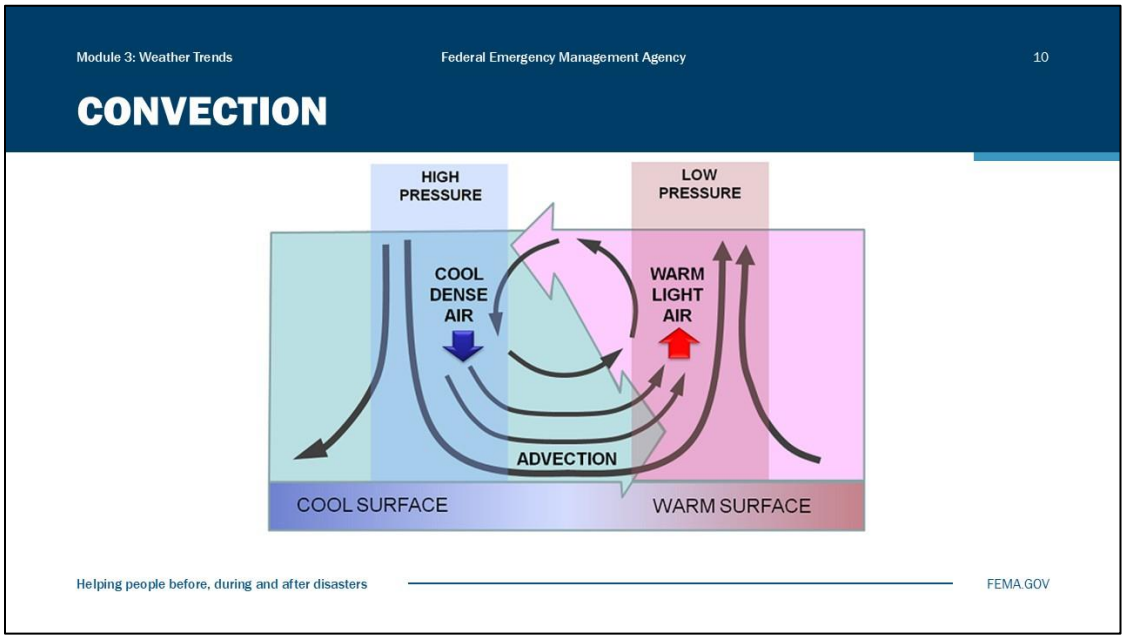
This is equality.



Atmospheric factors that affect weather include:

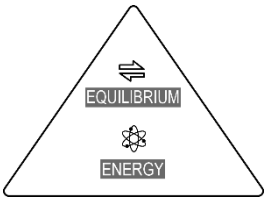
- **Temperature:** Temperature is a measure of heat describing the molecular energy of an object. As the atmosphere heats up or cools down, its density changes. Warm air expands and rises, cool air contracts and sinks. Variations in temperature, both on a daily and seasonal basis, cause the circulation of the atmosphere as the molecules move to equalize the planet's temperature. Of course, temperatures never actually equalize due to the planet's shape and its continual rotation and revolution.
- **Pressure:** Air pressure is the weight of the atmosphere pushing down at a given location. Because air is a gas composed of particles (e.g., water vapor), it is affected by Earth's gravity. Cold air weighs more, indicating high pressure, while hot air indicates low pressure.
- **Winds:** The same processes that try to equalize temperature differences over the globe also try to balance the pressure differences between denser and lighter air. These processes create winds that blow from areas with higher pressure to those with lower pressure.
- **Moisture:** While water vapor is not the most abundant gas in the atmosphere, it is very important in terms of weather. In addition to forming liquid and solid particles in clouds that fall as rain or snow, the process of changing from the gaseous state into liquid water or ice releases large amounts of heat that serve as an energy source for weather systems, particularly thunderstorms and hurricanes

Factors Affecting Weather (3 of 19)



Slide 3-10, Convection

This is equilibrium and energy.



Temperature differences cause pressure differences in the atmosphere. The air that is warmer and moister relative to its surroundings becomes buoyant and rises. Air that is colder and drier is heavier and descends.

Since surface pressure is a measure of the weight of the column of air above, a column of warm, moist air has lower surface pressure. Likewise, a column of cold, dry air results in higher surface pressure.

These differences in temperature and pressure cause the atmosphere to circulate:

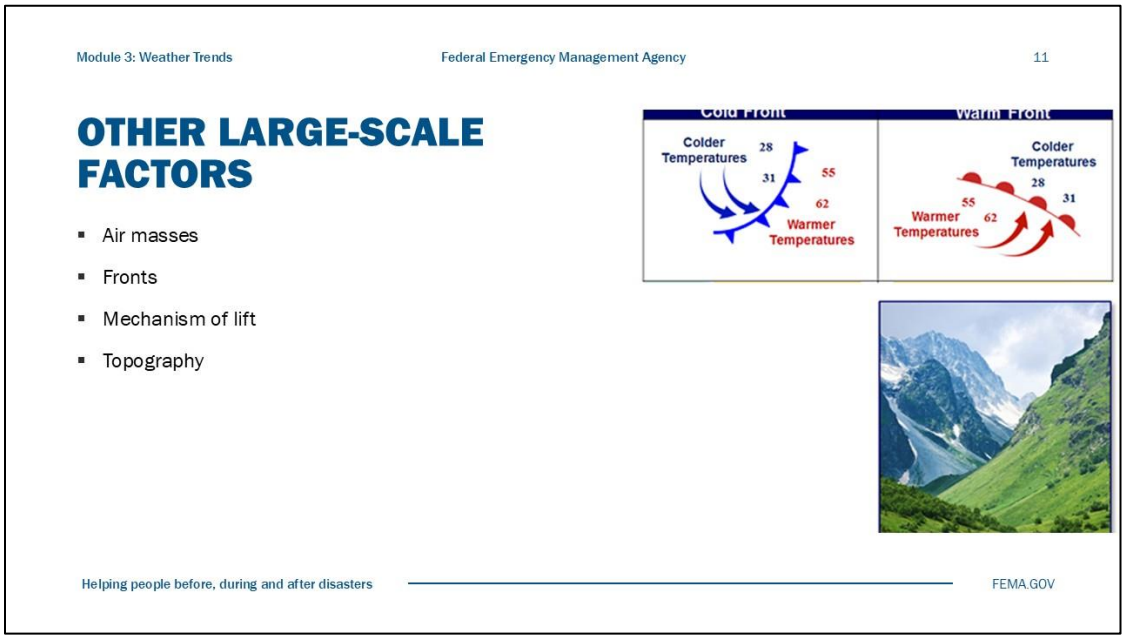
- When descending air encounters Earth's surface, it spreads out, away from the center of high pressure. The air moves across the Earth's surface through advection, heating up

and collecting moisture. (**Advection** is the transport of an atmospheric property by the wind.)

- As the air becomes warm and moist, it ascends toward the upper atmosphere.
- As the warm, moist air rises, it becomes unsettled as it cools and condenses, producing clouds and rain.

It is important to realize that on Earth's surface, air moves away from regions of high pressure and toward regions of low pressure.

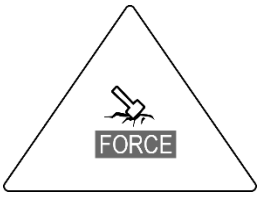
Factors Affecting Weather (4 of 19)



Slide 3-11, Other Large-Scale Factors

- Air masses
- Fronts
- Mechanism of lift
- Topography

This is force.



On a global scale, temperature, pressure, and moisture are crucial in determining weather patterns. In addition, the following factors are important:

- **Air masses:** If a body of homogeneous air moves slowly or stays over an extensive area that has fairly uniform temperature and moisture characteristics, the air takes on those characteristics and is called an air mass.

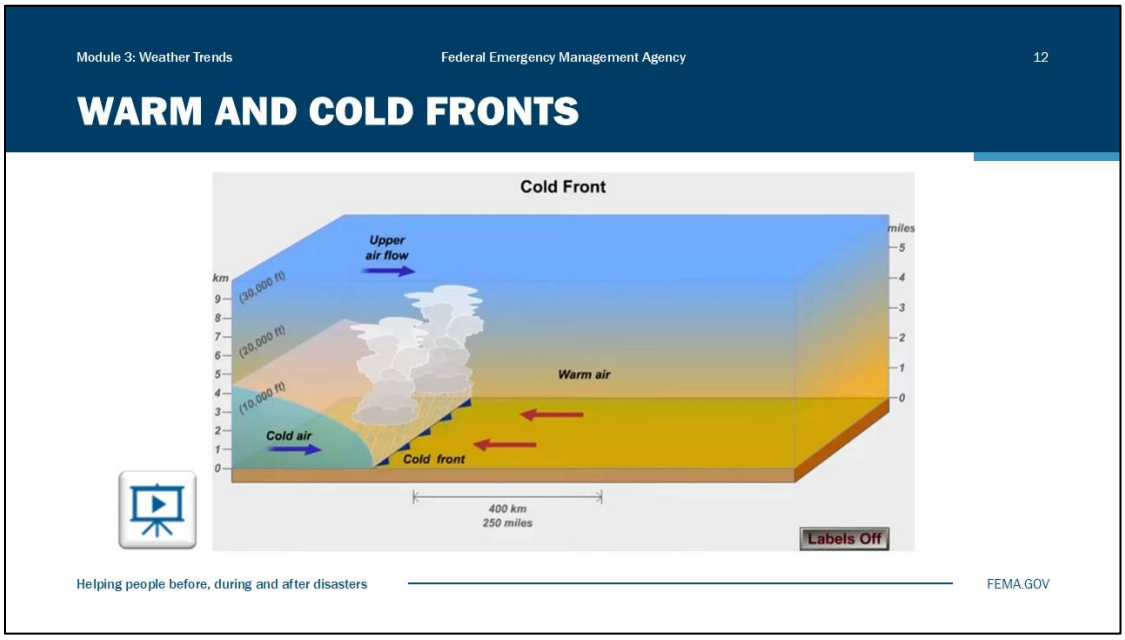
- **Fronts:** As air masses move out of the area in which they form, they come in contact with other air masses with different characteristics. The boundaries between different air masses are called fronts. Cold and Warm fronts are the result of the relationship between two masses of air and can occur in a season-agnostic manner.

A cold front is the leading edge of an advancing cold air mass. The edge of an advancing warm air mass is a warm front.

Stationary fronts occur when a front stops moving and neither of the air masses replaces the other.

- **Mechanism of lift:** Most hazardous weather conditions require some sort of mechanism for lifting air. These mechanisms include:
  - Air rising in areas of low pressure. Fronts acting like a wedge to lift air.
  - Air encountering upslopes of mountains, which forces the air upward, resulting in lift.
- **Topography:** In addition to creating lift, topography can also affect temperatures. For example, large, paved surfaces in urban areas heat and cool at different rates than vegetated areas—a temperature change that translates to local changes in pressure.

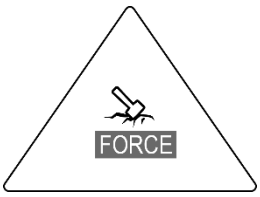
Factors Affecting Weather (5 of 19)



Slide 3-12, Warm and Cold Fronts

Cold Fronts **Video description**—*The clouds form above the front edge of the front. (https://youtu.be/IR4dBS4Ly0c?si=A75ZG4cISADPeTEl)*

This is Force.



At the surface, the front marks where cold air overtakes and replaces warmer air. As the cold air moves in, it creates lift as the retreating warm air rises. Notice how the cold front creates lift and changes in the weather

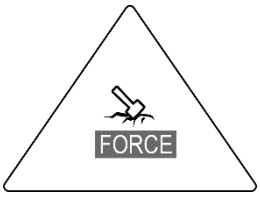
Concerns with cold fronts include:

- When the warm, moist air is pushed rapidly into the upper atmosphere, the conditions become very unstable.
- During summer, cold fronts typically create a squall line of thunderstorms just in front of the advancing front.
- Cold fronts can easily produce large thunderstorms with lightning, hail, and tornadoes.

- A large amount of rainfall could occur in a short period of time, leading to flooding.
- The temperature will change to colder conditions as the front passes.
- In cold weather, cold fronts produce hazardous winter conditions.
- Because the slope of the cold air mass is steep, temperature, pressure, and weather tend to change dramatically near the front.

Warm Fronts **Video description—***The clouds form ahead of the surface front.* (https://youtu.be/lR4dBS4Ly0c?si=KqkmPowjlY1l8Uey&t=14)

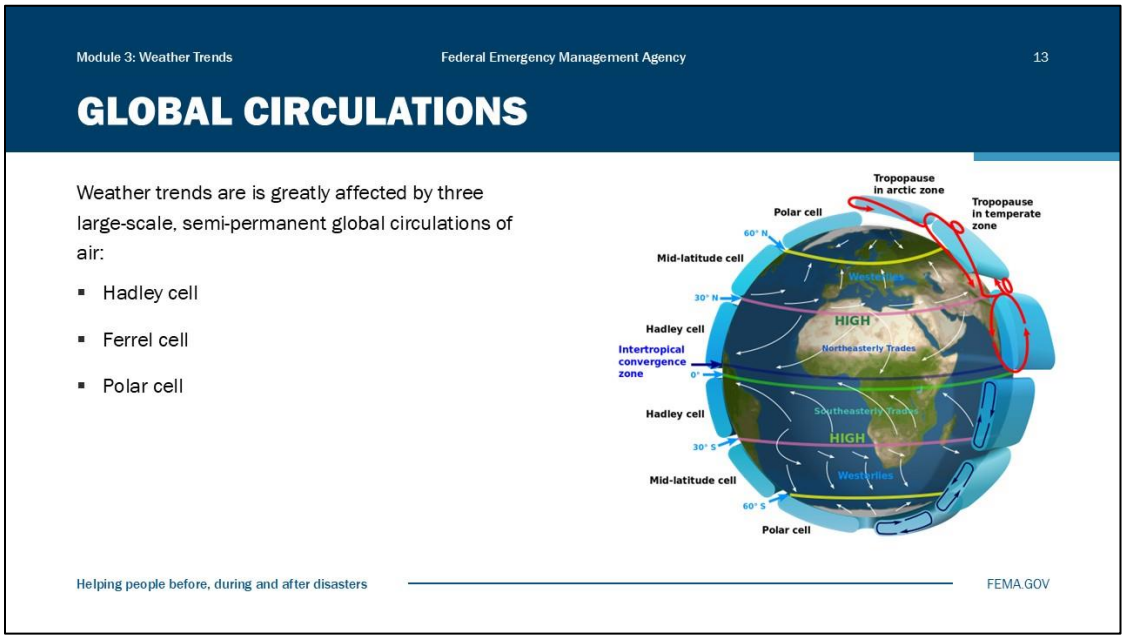
This is force.



At the frontal boundary, warmer air overtakes and replaces colder air. As the warm air moves in, it lifts over the wedge of cold air. Warm fronts occur when warm, moist air is slowly pushed up over a cooler air mass.

The results are rain or snow showers ahead of the warm front. Large amounts of heavy rain or snow could fall during this time.

Factors Affecting Weather (7 of 19)



Slide 3-13 Global Circulations

Your location on the planet, topography, proximity to water bodies, and other factors influence the weather trends in your area. However, weather trends can also be influenced by long-term global patterns, such as jet streams, trade winds, and El Niño or La Niña. Take a closer look at the atmospheric patterns that influence weather trends, particularly on a global scale.

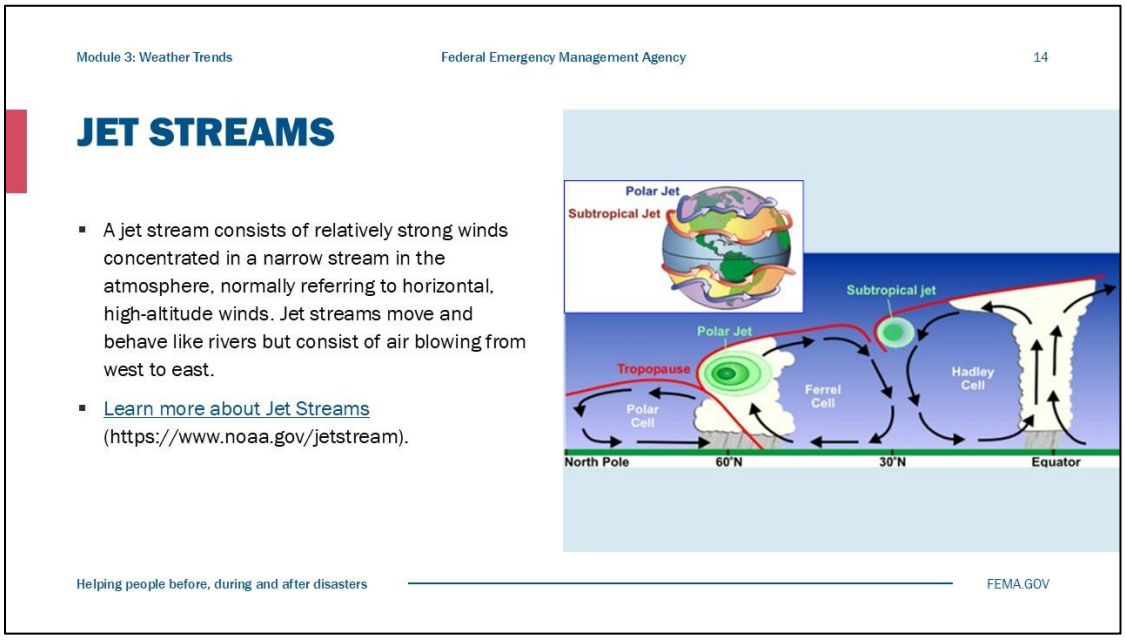
Weather trends are greatly affected by three large-scale, semi-permanent **global circulations** of air (convective cells) that result from the rotation of Earth, its axis, and the distribution of land mass in the two hemispheres.

1. **Hadley cell**: In this low-latitude circulation, the movement of air toward the equator rises vertically with heating, resulting in a convection cell that dominates tropical and subtropical natural systems.
2. **Ferrel cell**: In this mid-latitude atmospheric circulation cell, the air flows poleward and eastward near the surface, and equatorward and westward at higher levels.
3. **Polar cell**: Here, the air rises, diverges, and travels toward the poles, resulting in easterly surface winds (polar easterlies).

High-pressure bands exist between these cells at approximately 30°N/S latitude and at each pole. This high pressure often results in fair and dry/hot weather (e.g., desert conditions around 30°N/S).

Low-pressure bands exist around the equator and 50-60°N/S. In contrast, the low-pressure bands tend to result in higher precipitation rates due to increased storm formation (especially on the west coasts of continents).

Factors Affecting Weather (8 of 19)



Slide 3-14, Jet Streams

The Earth's rotation is also responsible for the jet stream, another key factor in weather trends.

Jet stream definition: A jet stream consists of relatively strong winds concentrated in a narrow stream in the atmosphere, normally referring to horizontal, high-altitude winds. Jet streams move and behave like rivers, but consist of air blowing from west to east.

Temperature and pressure differences: At the same latitudes mentioned on the previous page (30° N/S and 50-60° N/S), significant temperature and pressure differences exist, resulting in increased wind strength in the upper atmosphere.

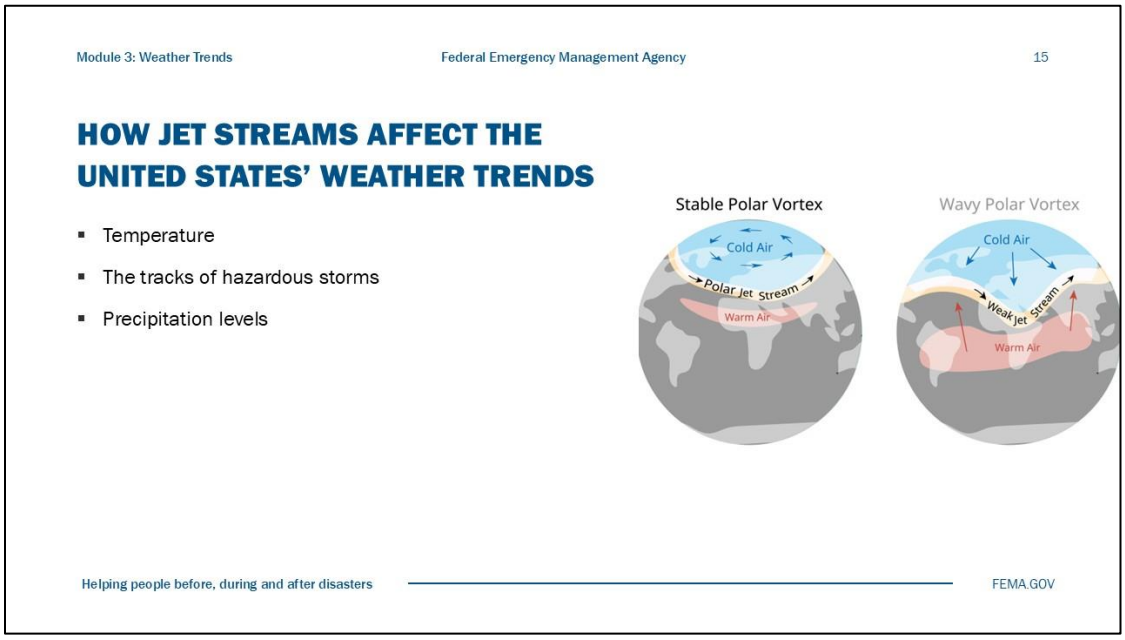
At latitudes of 50-60° N/S, a jet stream known as the polar jet is present. At 30° N/S, there is a jet stream known as the subtropical jet. These jet streams can be as high as 4 to 8 miles and reach speeds of over 200 miles per hour.

Jet stream movement: The position and orientation of jet streams vary from day to day. General weather patterns (hot/cold, wet/dry) are closely related to the position, strength, and orientation of the jet stream(s).

As seasons change and the atmosphere fluctuates, the jet streams dip and rise, move and meander, and even briefly disappear and reappear; however, they always have a significant impact on weather trends.

Learn more about Jet Streams (https://www.noaa.gov/jetstream).

Factors Affecting Weather (9 of 19)

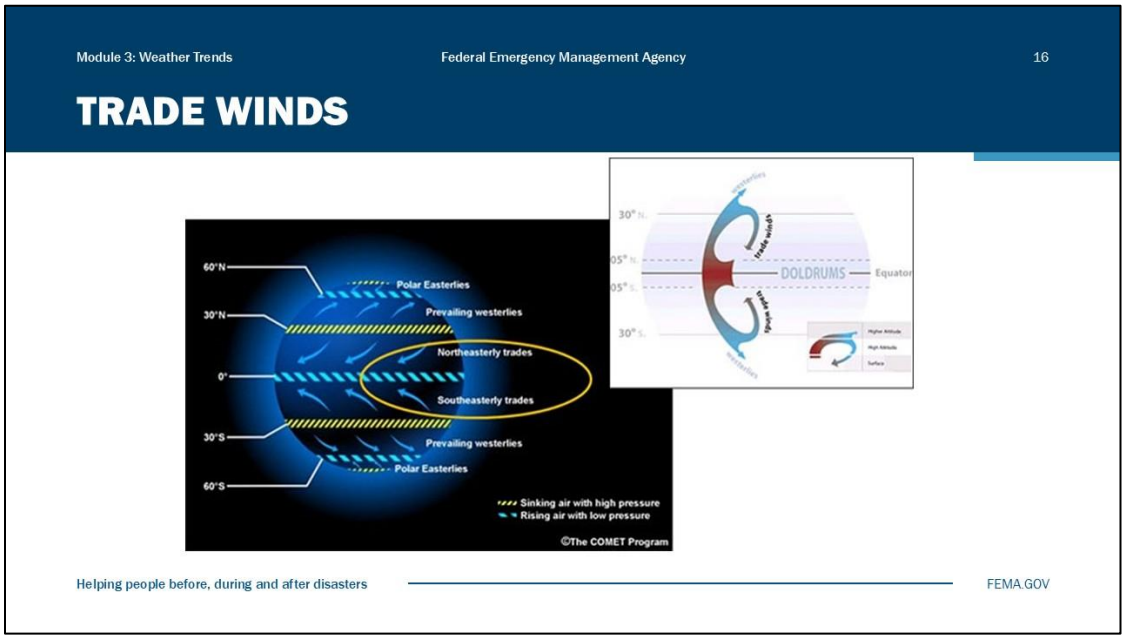


Slide 3-15, How Jet Streams Affect the United States' Weather Trends

Here are some of the things jet streams can affect:

- **Temperature:** Jet streams "follow the sun." As the sun's elevation increases in the spring, the jet stream shifts north, moving into Canada by summer. In the autumn, when the sun's elevation decreases, the jet stream helps to bring cooler air into the country by moving south into the United States.
- **The tracks of hazardous storms:** During El Niño years (which we will learn about later in this module), the jet stream dips in the eastern Pacific (a "trough"), shifting the storm track and sending huge amounts of moisture and precipitation as far south as Southern California, potentially resulting in flash floods and debris flows.
- **Precipitation levels:** If the jet stream shifts south, sending huge amounts of moisture and precipitation further south, this also means that the areas north of the jet stream (the Pacific Northwest) become drier than usual. These types of decreases in precipitation levels can contribute to a drought, which we will cover in a later module.

Factors Affecting Weather (10 of 19)



Slide 3-16 Trade Winds

The area where the trade winds converge and force air up into the atmosphere was originally labeled "the doldrums" by early sailors, who were well aware of the weak winds and heavy precipitation to be found there. This area, known now as the Intertropical Convergence Zone (ITCZ), is essentially a steady band of clouds encircling the globe between the northeast and southeast trade winds near the equator, resulting in frequent showers and thunderstorms. Like the jet streams, the ITCZ follows the sun and has a position that varies seasonally; in the northern summer, it moves north, and in the northern winter, it moves south.

Another key factor in understanding weather trends is the movement of the trade winds. The trade winds are:

- The wind systems, occupying most of the Tropics, which blow from the subtropical ridges of high pressure toward the equator;
- Major components of the general circulation of the atmosphere;
- Northeasterly in the Northern Hemisphere and southeasterly in the Southern Hemisphere; hence they are known as the **northeast trades** and **southeast trades**, respectively, and
  - The remaining air in both hemispheres (i.e., westerly winds or westerlies) travels toward the poles.

Trade winds have a significant impact on moisture, temperature, and precipitation patterns, and consequently on weather trends.

Trade winds affect weather trends in some notable ways:

- They can steer hurricanes and other storm systems in the Tropics;
  - If the trade winds are weakened, storm movement is less predictable.
- If there is an increase in the strength of trade winds, they can move surface ocean waters, prompting the rising of deep, colder waters below ("cold upwelling");
  - This affects ocean temperatures and, therefore, global weather patterns.

Factors Affecting Weather (11 of 19)

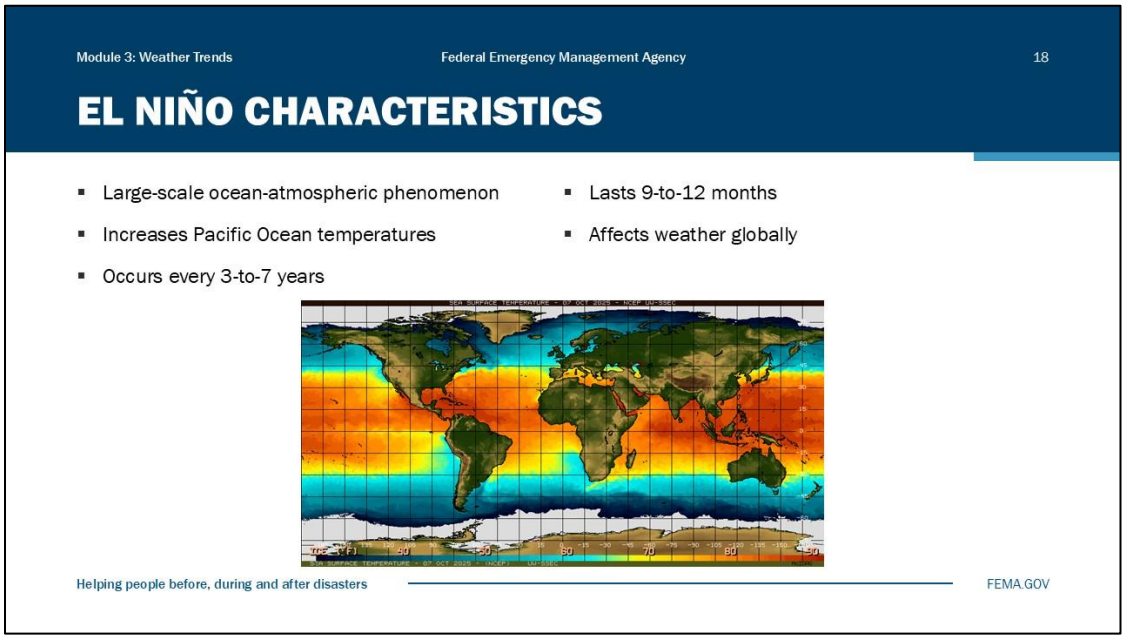


Slide 3-17, Video: El Niño, July 2009

El Niño Video description—*This animation, made using data from NOAA satellites, illustrates the onset of an El Niño event in July of 2009.* (https://www.youtube.com/watch?v=Vd0Y8aQvmII)

The next part of the module will focus on El Niño and La Niña. This animation, made using data from NOAA satellites, illustrates the onset of an El Niño event in July of 2009.

Factors Affecting Weather (12 of 19)



Slide 3-18, El Niño Characteristics

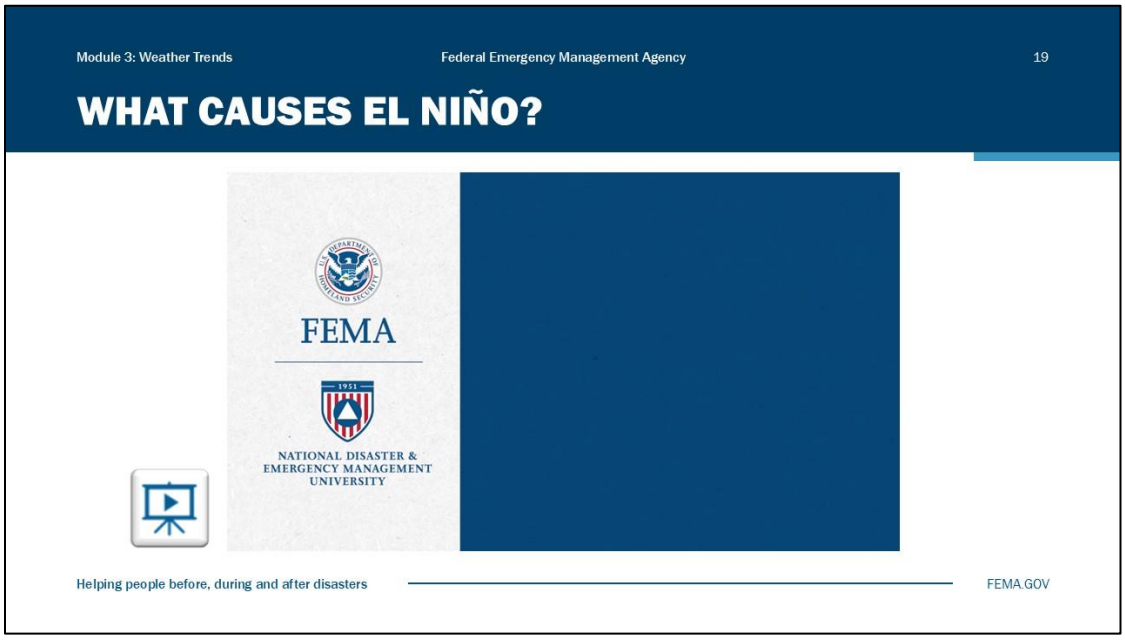
Definition: El Niño constitutes the warm phase of what is called the El Niño/Southern Oscillation (ENSO) cycle. (La Niña is the cool phase of the same cycle.) The ENSO cycle consists of yearly variations in the equatorial Pacific Ocean in:

- Sea-surface temperatures
- Convective rainfall
- Surface air pressure
- Atmospheric circulation

Seasonal outlooks are based on El Niño and La Niña. El Niño:

- Is associated with a warming of the ocean current along the coasts of Peru and Ecuador;
- Is generally associated with dramatic changes in the weather patterns of the region and with changes in weather patterns worldwide;
- Generally occurs every 3 to 7 years;
- Tends to develop between March and June and is typically much stronger during the winter months; and
- Tends to last for 9 to 12 months.

Factors Affecting Weather (13 of 19)



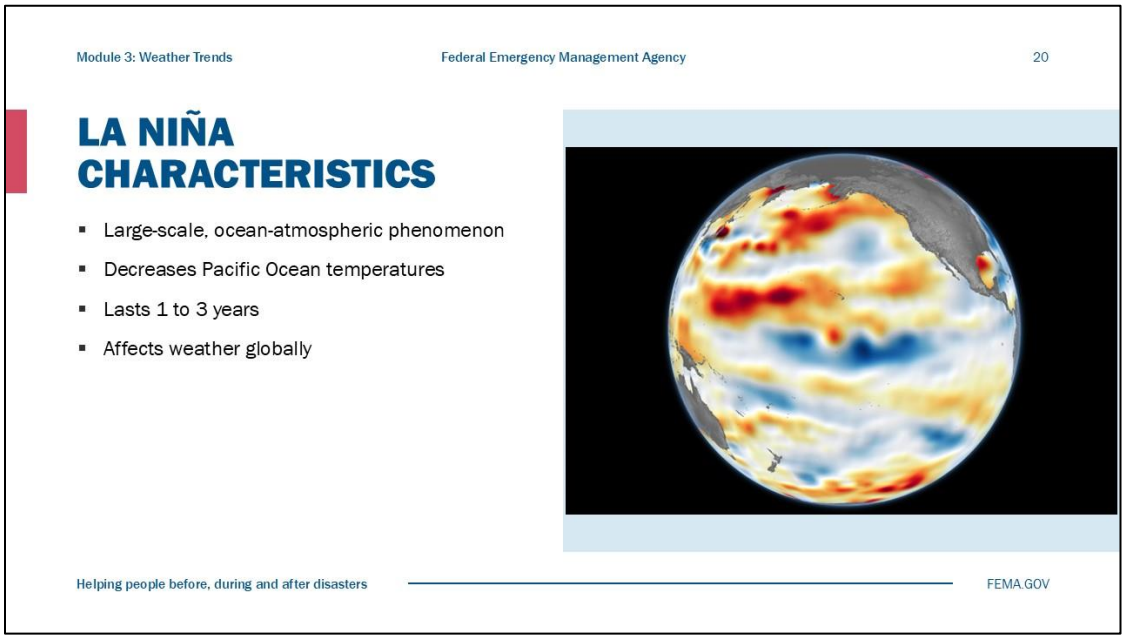
Slide 3-19, What Causes El Niño?

El Niño naturally results from the interactions between the ocean surface and the atmosphere in the tropical Pacific Ocean. The process that leads to El Niño is illustrated in this diagram. In short:

- The trade winds calm and weaken, affecting ocean circulation across the Pacific;
- This results in weak upwelling (i.e., less upward movement of deeper, colder ocean water to replace surface waters) and an increase in sea-surface temperatures; and
- This impacts precipitation, wind patterns, and eventually global weather.

Although the immediate cause of El Niño (weakening trade winds) is known, and scientists have made great progress in studying El Niño, the precise nature and origin of its repetitive cycle remains somewhat of a mystery.

Factors Affecting Weather (14 of 19)



Slide 3-20, La Niña Characteristics

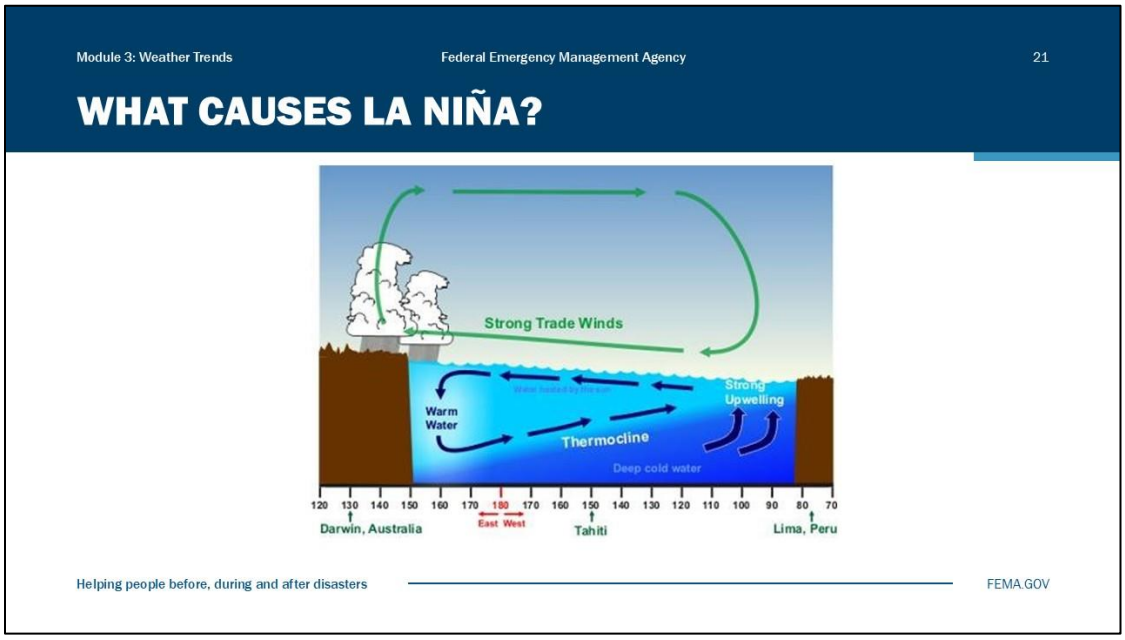
La Niña is another large-scale, ocean-atmospheric weather trends phenomenon (the cool phase of the ENSO cycle), sometimes referred to as a Pacific cold episode.

Definition: The preliminary Climate Prediction Center (CPC) definition of La Niña is a phenomenon in the equatorial Pacific Ocean characterized by a negative sea surface thermal anomaly departure from normal.

La Niña:

- Is a periodic cooling of surface ocean waters in the eastern tropical Pacific, along with a shift in convection in the western Pacific, further west than the climatological average;
- Affects weather patterns around the world;
- May last 1 to 3 years;
- Tends to develop between March and June; and
- Is typically much stronger during the winter months.

Factors Affecting Weather (15 of 19)



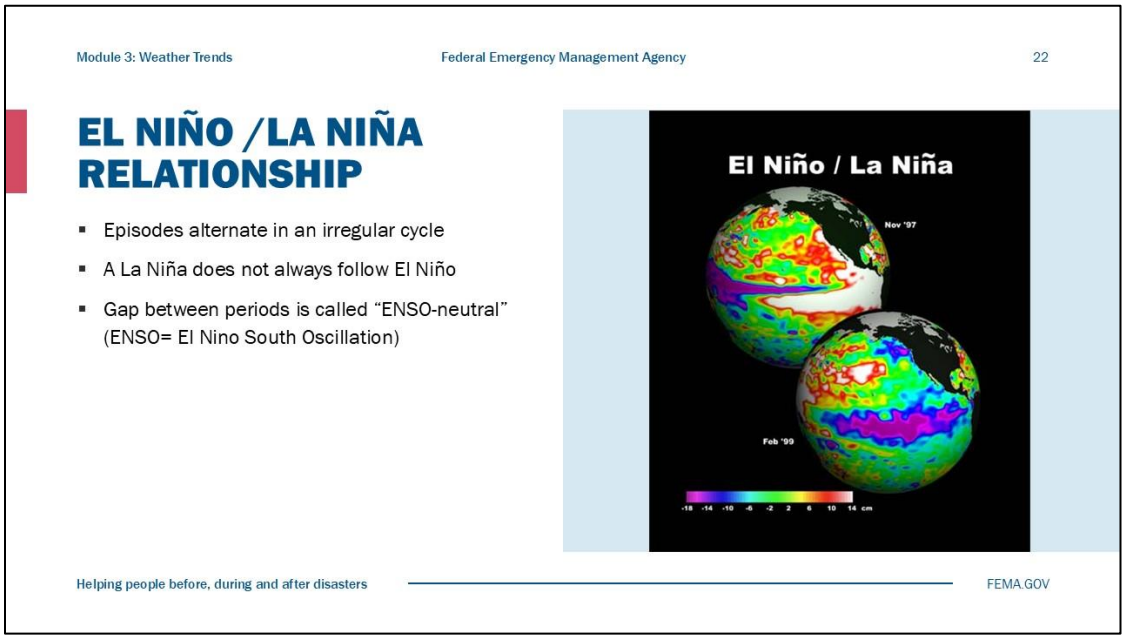
Slide 3-21, What Causes La Niña?

What Causes La Niña?

Like El Niño, La Niña naturally results from the interactions between the ocean surface and the atmosphere in the tropical Pacific Ocean. The difference is that it begins with the trade winds strengthening, rather than weakening. In short:

- The trade winds strengthen, affecting ocean circulation across the Pacific;
- This results in strong upwelling (i.e., more upward movement of deeper, colder ocean water to replace surface waters) and a decrease in sea-surface temperatures; and
- This affects precipitation, wind patterns, and, eventually, global weather.

Factors Affecting Weather (16 of 19)



Slide 3-22, El Niño /La Niña Relationship

Image description—*The image portrays ocean temperature levels during two more moderate El Niño (1997) and La Niña (1999) events.*

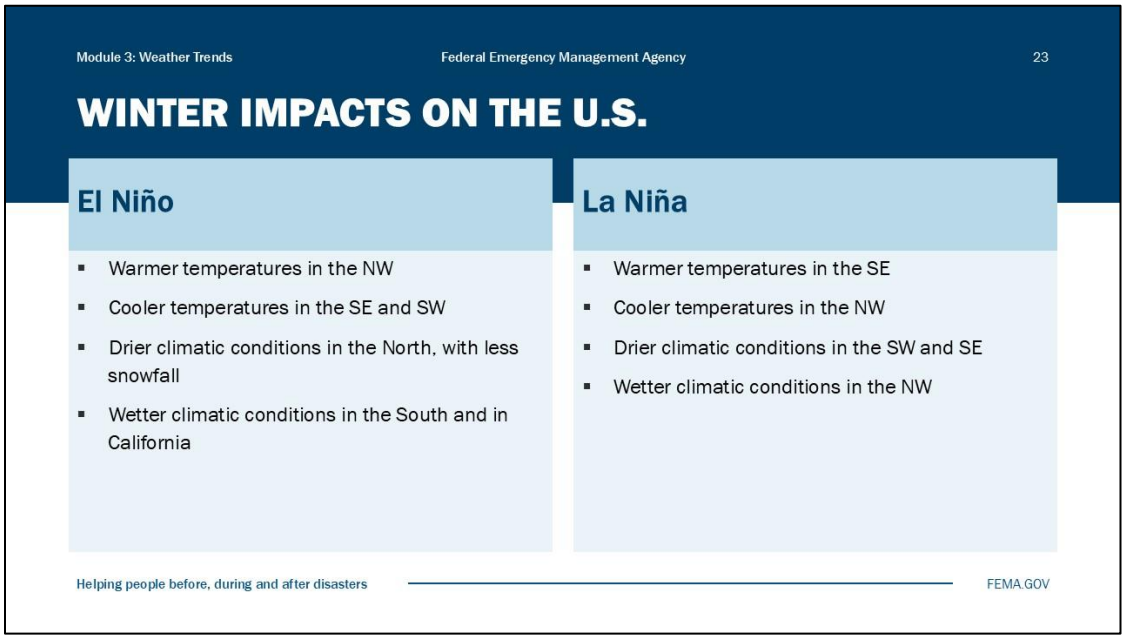
These two phenomena—which are the main sources of weather trends variability in many areas of the world—tend to alternate in an irregular cycle. For example, a La Niña episode does not always follow an El Niño episode.

There is also a gap between El Niño periods and La Niña periods called "neutral" or "ENSO- neutral." In these periods, neither El Niño nor La Niña is present, and ocean temperatures, precipitation patterns, and atmospheric circulation around the equatorial Pacific are close to the long-term averages.

El Niño and La Niña events:

- 2020–2021: A La Niña event
- 2021–2022: A La Niña event
- 2022–2023: A La Niña event
- 2023–2024: An El Niño event

Factors Affecting Weather (17 of 19)



Slide 3-23, Winter Impacts on the U.S.

El Niño has several notable climatological impacts on the United States. During El Niño years, the winter season is characterized by warmer-than-normal temperatures in the Northwest and North Central States, and cooler-than-normal temperatures in the Southeast and Southwest. The climatic conditions are drier in the North and wetter and stormier in the South and in California. These changes can result in the following weather hazards:

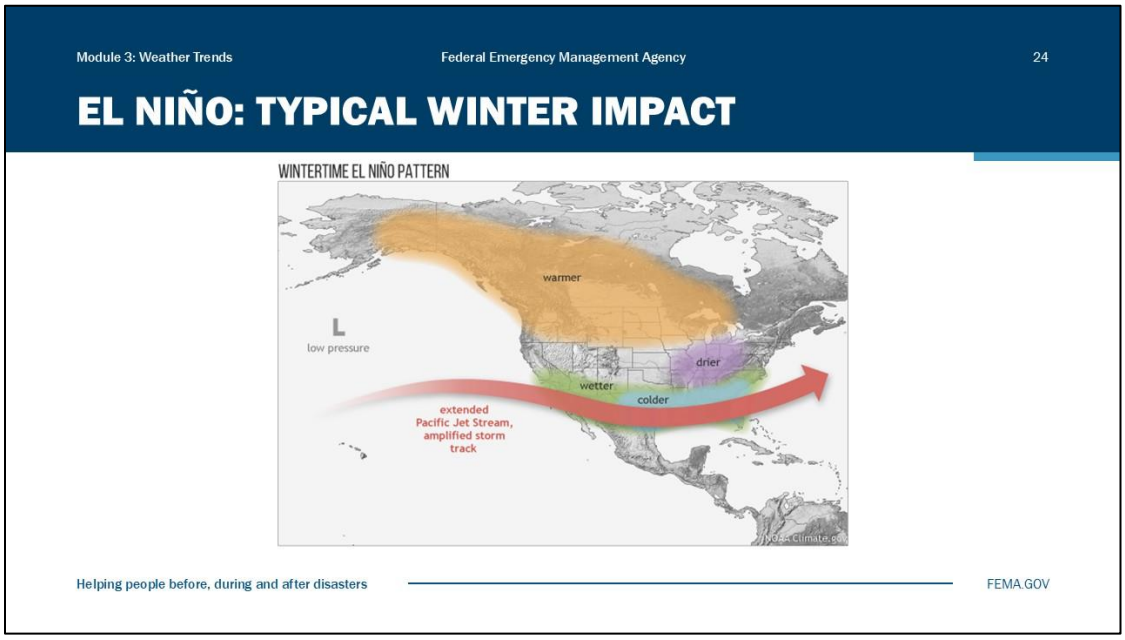
- Droughts in the Northwest;
- Severe flooding or coastal flooding in the South;
- Ice storms in the South;
- Severe weather in the Great Lakes area; and
- Severe weather over the northern Gulf of Mexico and northern Florida
  - This is due to the shift of the Pacific jet stream, as a strong jet stream is a key ingredient in producing severe weather like tornadoes

It is important to note, however, that **it would be inaccurate to label a hurricane, tropical storm, winter storm, drought, or flood strictly as an El Niño event**. El Niño simply alters or enhances certain weather patterns (e.g., the jet streams) and affects the track of storms and their intensity.

La Niña also has climatological impacts on the United States. During the late fall and winter seasons of La Niña years, there are generally:

- Warmer than normal temperatures in the Southeast;
- Cooler than normal temperatures in the Northwest;
- Drier weather patterns in the Southwest and the Southeast; and
- Wetter and stormier climatic conditions in the Northwest.

Factors Affecting Weather (18 of 19)



Slide 3-24, El Niño: Typical Winter Impact

El Niño: Typical Winter Impact

This graph illustrates the typical January - March impacts on the United States during a moderate to strong El Niño. Note that:

- There is a strong, persistent jet stream and storm track across the South.
- The North has warmer, milder conditions.

These impacts result from four major changes:

- An extension of the East Asian jet stream eastward into the Southwestern United States.
- Above-average west-to-east flow of jet stream winds across the country.
- A shift of the storm track southward, moving from the northern to the southern part of the United States.
- A shift of the main region of cyclone formation to the Southeast, just west of the coast of California.

For more about how El Niño and La Niña affect precipitation and temperature during the winter, visit How El Niño and La Niña affect the winter jet stream and U.S. climate. (This link can also be

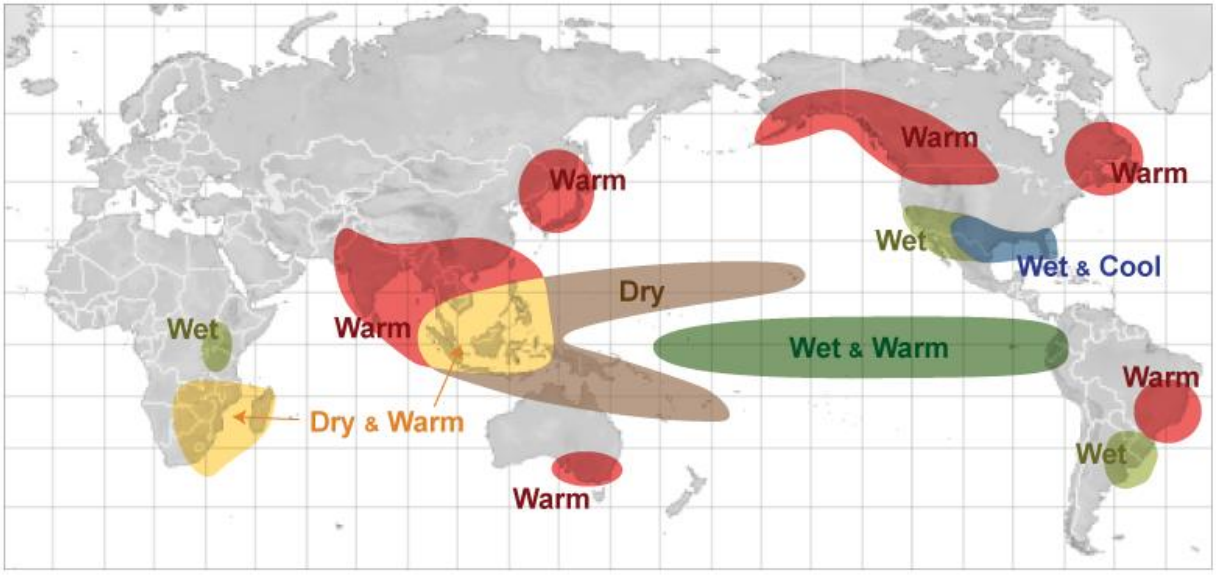
accessed at the following URL: https://www.climate.gov/news-features/featured-images/how-el-ni%C3%B1o-and-la-ni%C3%B1a-affect-winter-jet-stream-and-us-climate).

El Niño—Winter vs. Summer: Notice how differently El Niño affects the globe in winter months (December to February) and summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

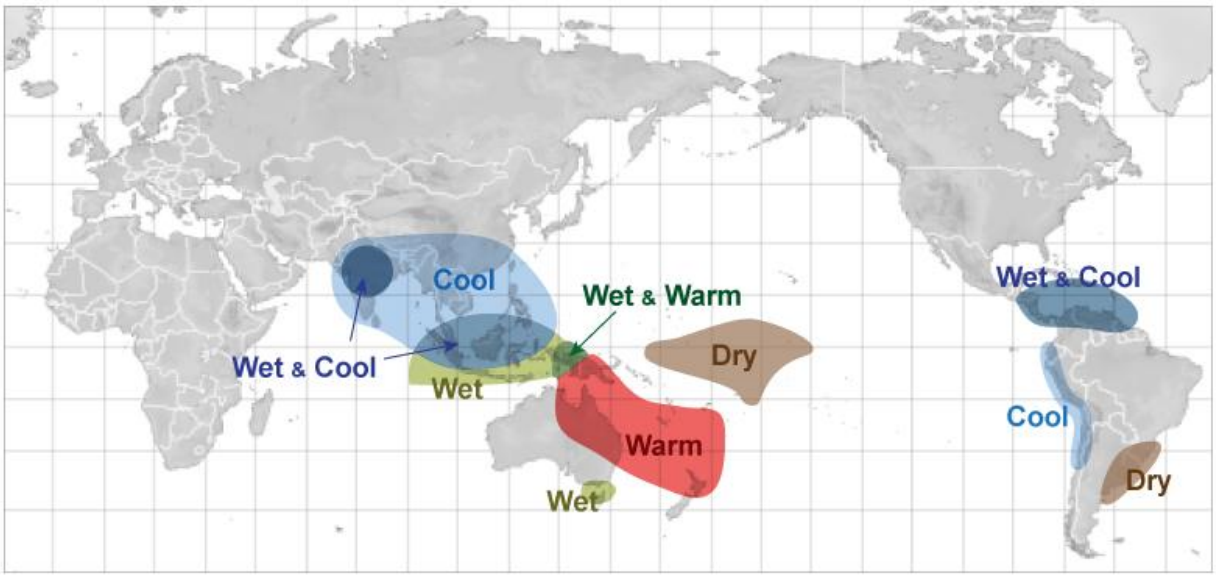
In the summer months, only one small area in the Northwest tends to experience unusually high precipitation. Other than this increase (and the typical heightened tendency for hurricanes to hit), most of the United States is unlikely to suffer any drastic impacts of El Niño during the summer months.

Remember, **El Niño tends to develop between March and June, and it is typically much stronger during the winter months.** This is because the equatorial Pacific sea-surface temperatures are usually at their warmest this time of the year.

El Niño effects from December through February.

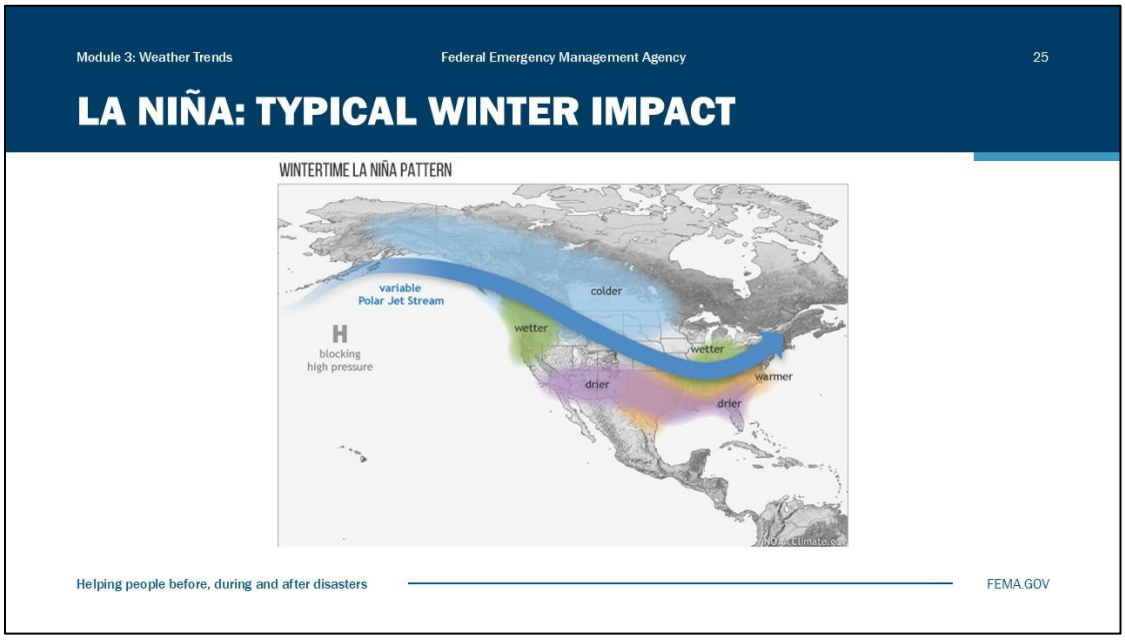


El Niño effects from June through August.



Source: Weather impacts of ENSO. (n.d.). National Oceanic and Atmospheric Administration. https://www.noaa.gov/jetstream/enso_impacts

Factors Affecting Weather (19 of 19)



Slide 3-25, La Niña: Typical Winter Impact

This graph illustrates the typical January - March impacts on the United States during a moderate to strong La Niña. Note that there is a very wavy jet stream flowing over the United States as well as Canada. This generally results in stormier than average conditions in the northern part of the country, and warmer and less stormy conditions in the southern part.

This impact results from three major changes in atmospheric flow:

- An amplification of the mean wave pattern and increased meridional flow across the continent and the eastern North Pacific.
- Increased blocking activity (Black H - "Blocking High Pressure") over the high latitudes of the eastern North Pacific. (High pressure systems are a bit like the "bullies" of weather—they are big, and push everything else around, including weather systems and even jet streams.)
- The variability of the Pacific jet stream (orange line), with an average jet position that enters North America in the northwestern United States or southwestern Canada.

Notice how differently La Niña affects the globe in the winter months (December to February) and the summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

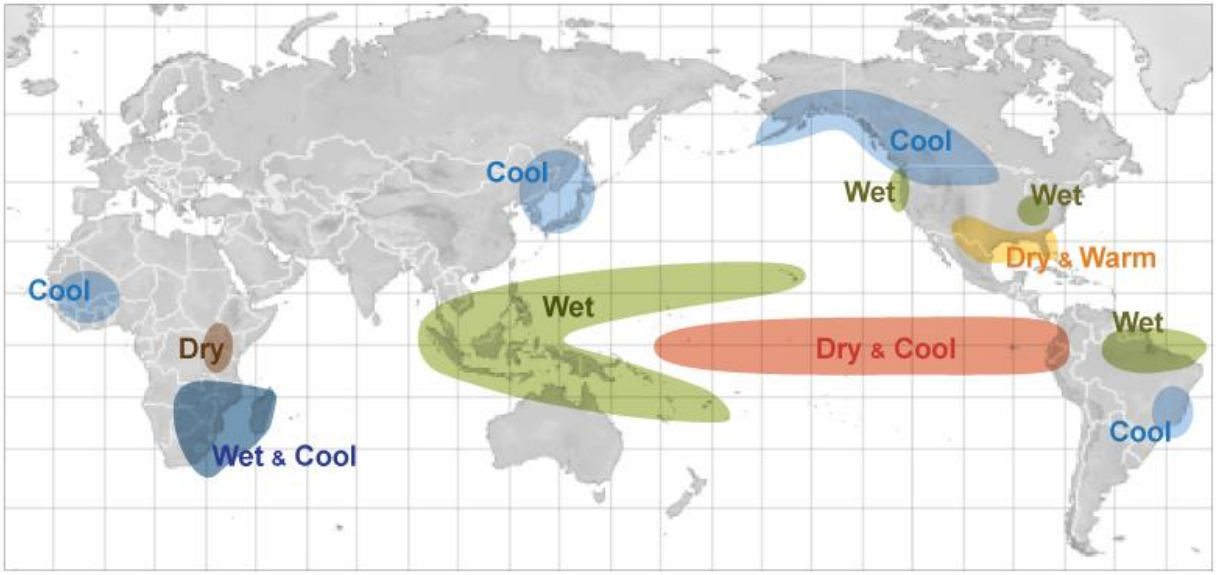
Like El Niño, most of the United States is unlikely to experience any drastic impacts of La Niña during the summer months (again, except for the typical heightened tendency for hurricanes to occur).

La Niña—Winter vs. Summer

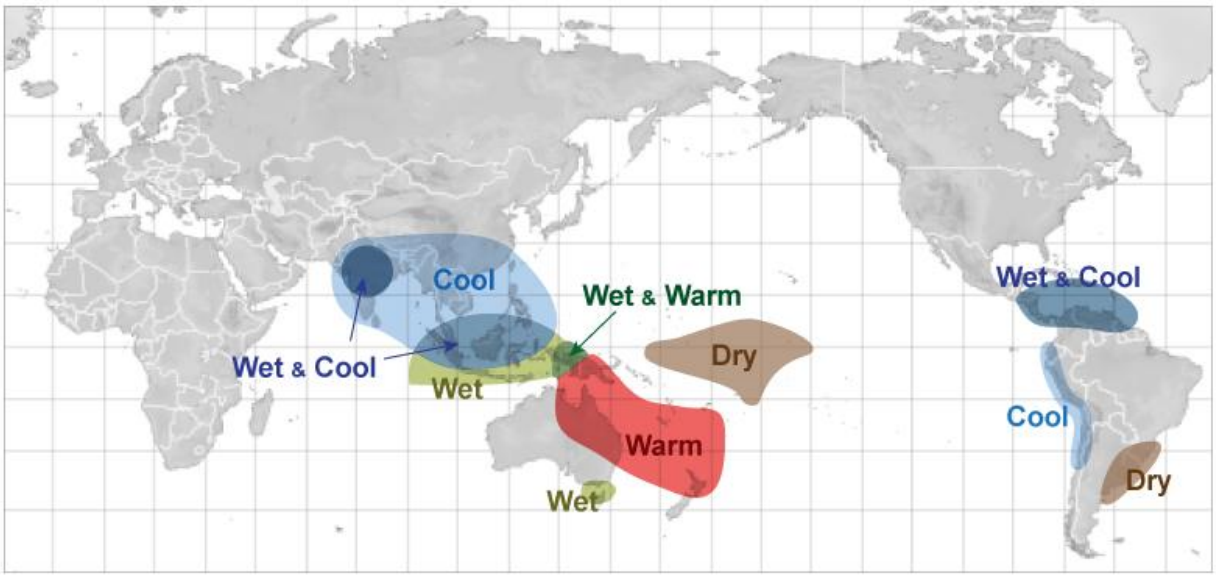
The maps below illustrate how La Niña affects the globe differently in the winter months (December to February) and the summer months (June to August). The regions with the greatest precipitation and temperature impacts due to shifts in the jet stream are highlighted with color.

Like El Niño, most of the United States is unlikely to experience any drastic impacts of La Niña during the summer months (again, except for the typical heightened tendency for hurricanes to occur).

La Niña effects from December through February.

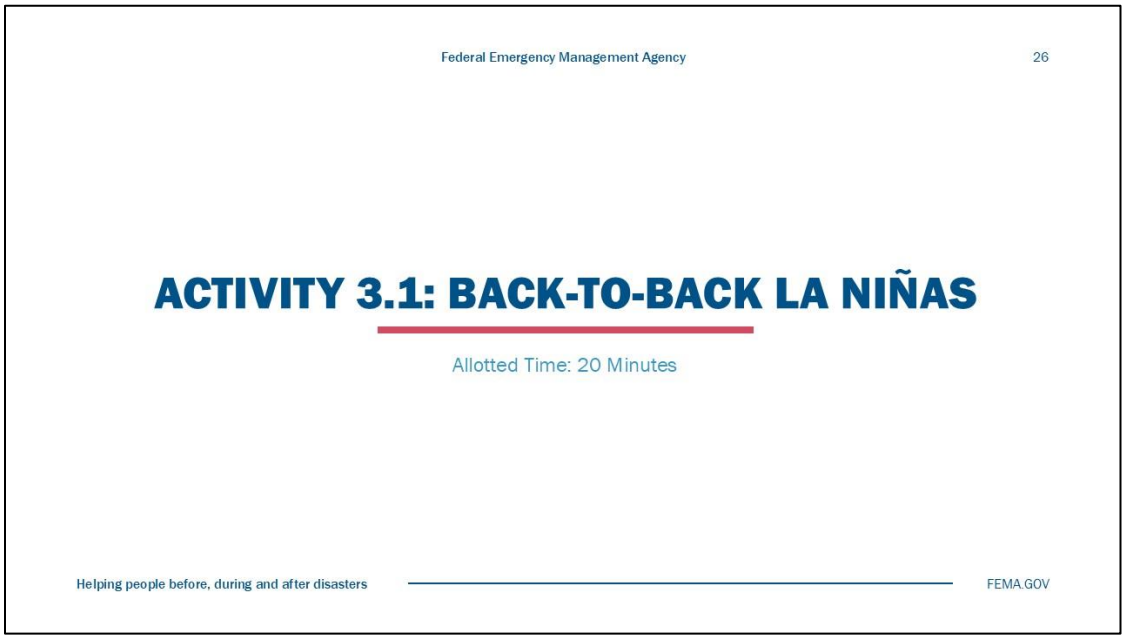


La Niña effects from June through August.



Source: Weather impacts of ENSO. (n.d.). National Oceanic and Atmospheric Administration. https://www.noaa.gov/jetstream/enso_impacts

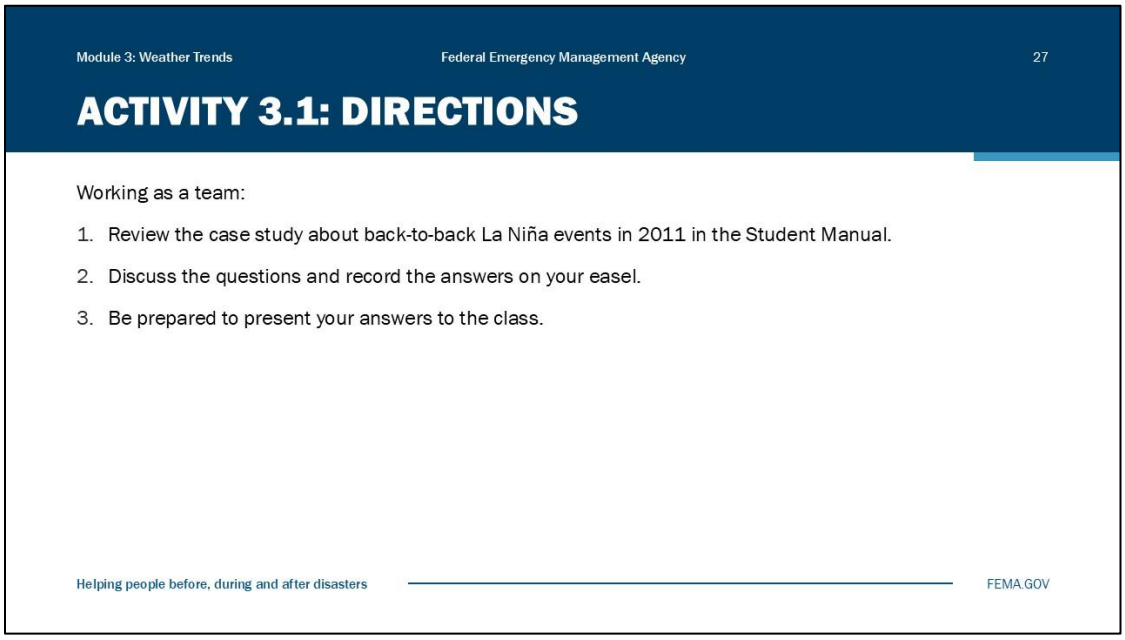
Activity 3.1: Back-to-Back La Niñas (1 of 2)



Slide 3-26, Activity 3.1: Back-to-Back La Niñas

Not applicable.

Activity 3.1: Directions (2 of 2)



Slide 3-27, Activity 3.1: Directions

Activity 3.1: Back-to-Back La Niñas—Directions to Students

Working as a team:

1. Review the case study about back-to-back La Niña events in 2011.
2. Discuss the questions and record your answers on your easel.
    a. What do you think are some of the *expected side effects* of La Niña-associated weather events in your region?

    b. How would you manage the implications?

3. Choose a spokesperson to present your group's recommendations.
4. Be ready to share your group's findings and action steps with the class during the debrief.

Case Study: Back-to-Back La Niñas

El Niño and La Niña don't always follow each other; occasionally, there are back-to-back El Niño episodes or back-to-back La Niña episodes. It is July, and you have received a briefing from your regional National Weather Service meteorologist. You are aware that last year there was a La Niña episode and now current models predict that there will be another episode beginning this fall.

In the U.S. during this time, there were 12 disasters exceeding $1 billion each for a total of more than $200 billion in damages:

- **Texas, New Mexico, Arizona Wildfires, spring–fall:** 1 million acres in Texas were burned during this year's record wildfire season. The Bastrop Fire in Texas was the most destructive fire in the State's history, destroying over 1,500 homes. The Wallow Fire consumed more than 500,000 acres in Arizona, making it, at the time, the largest wildfire on record in the state. The Las Conchas Fire in New Mexico was, at the time, the state's largest wildfire on record, scorching more than 150,000 acres while threatening the Los Alamos National Laboratory. More than 3 million acres burned across Texas during that wildfire season. Total damage in Texas alone, due to the loss of property, timber, and agriculture, exceeded $750 million. Losses for wildfire activity across all three states exceeded $1 billion.
- **Midwest/Southeast Tornadoes and Severe Weather, June 18–22:** An estimated 81 tornadoes struck across Oklahoma, Texas, Kansas, Nebraska, Missouri, Iowa, and Illinois. Additional wind and hail damage occurred across Tennessee, Georgia, North Carolina, and South Carolina. The storms resulted in more than $1 billion in insured losses, with total losses exceeding $1.3 billion.
- **Hurricane Irene, August 20–29:** Irene first struck the United States as a Category 1 hurricane in eastern North Carolina, then moved northward along the Mid-Atlantic coast. Wind damage in coastal North Carolina, Virginia, and Maryland was moderate, with considerable damage resulting from falling trees and power lines. Irene made its final landfall as a tropical storm in the New York City area, dropping torrential rainfall in the Northeast that caused widespread flooding. More than 7 million homes and businesses lost power during the storm, and Irene caused at least 45 deaths and more than $7.3 billion in damages.

- **Upper-Midwest flooding, summer:** Melting of an above-average snowpack across the northern Rocky Mountains, combined with above-average precipitation, caused the Missouri River and the Souris River to swell beyond their banks across the Upper Midwest. An estimated 11,000 people were forced to evacuate Minot, North Dakota, because of the record-high level of the Souris River. Numerous levees were breached along the Missouri River, resulting in the flooding of thousands of acres of farmland. The flooding, which is ongoing, has caused more than $2 billion in damage.
- **Mississippi River flooding, spring-summer:** Persistent rainfall nearly tripled the normal precipitation amounts in the Ohio Valley, and combined with melting snowpack, caused historical flooding along the Mississippi River and its tributaries. The region suffered losses of $2 to $4 billion.
- **Southern Plains/Southwest drought, heat wave, and wildfires, spring-summer: Drought, heat waves,** and wildfires scorched through Texas, Oklahoma, New Mexico, Arizona, Southern Kansas, Western Arkansas, and Louisiana this year. In Texas and Oklahoma, respectively, 75% and 63% of range and pasture conditions were classified as "very poor" as of mid-August. Wildfire-fighting costs for the region are about $1 million per day. Well over $5 billion in damage has occurred so far, with more than 2,000 homes and structures lost.
- **Midwest/Southeast tornadoes**, May 22–27: Central and southern states saw approximately 180 twisters and 177 deaths within a week. A tornado rated EF-5 on the tornado-damage scale struck Joplin, Missouri, resulting in at least 141 deaths, making it the deadliest single tornado to strike the United States since modern tornado record keeping began in 1950. The total losses exceeded $7 billion, and an estimated $3 billion was required to rebuild Joplin, making it the single-costliest tornado in United States history.
- **Southeast/Ohio Valley/Midwest tornadoes, April 25–30:** This outbreak of tornadoes over central and southern states led to 327 deaths. Of those fatalities, 240 occurred in Alabama. The deadliest of the estimated 305 tornadoes in the outbreak was an EF-5 that hit northern Alabama, killing 78 people. Several major metropolitan areas were directly affected by strong tornadoes, including Tuscaloosa, Birmingham, and Huntsville in Alabama, as well as Chattanooga, Tennessee. Total losses exceeded $9 billion.
- **Midwest/Southeast tornadoes, April 14–16:** An outbreak over central and southern states produced an estimated 160 tornadoes. Despite the large overall number of tornadoes, few were classified as intense, with only 14 EF-3 tornadoes identified, and no EF-4 or EF-5 tornadoes. Total losses exceeded $2 billion. Thirty-eight people died, 22 of them in North Carolina.

- **Southeast/Midwest tornadoes, April 8–11:** An outbreak of tornadoes over central and southern states saw an estimated 59 tornadoes. Total losses exceeded $2.2 billion.
- **Midwest/Southeast tornadoes, April 4–5:** An outbreak of tornadoes over central and southern states saw an estimated 46 tornadoes. Total losses exceeded $2.3 billion. Nine people died.
- **Groundhog Day blizzard, Jan. 29–Feb. 3:** A large winter storm hit many central, eastern, and northeastern states. Chicago was brought to a virtual standstill when 1 to 2 feet of snow fell across the city. Total losses were greater than $2 billion, and the storm killed 36 people.

Additionally:

- 3 million residents lost power during an unseasonably early nor'easter storm from October 29–31.
- 19 tropical storms formed in the Atlantic during this year, the third-busiest season on record.

Some events in other countries that resulted from back-to-back La Niñas included:

- Historic droughts in East Africa and Northern Mexico;
- The wettest 2-year period (2010–2011) in Australia's history, relieving a decade-long dry spell; and
- The coolest year on record for the globe (2011) since 2008. (However, temperatures remained above the 30-year average because of weather trends.)

Long-Term Trends (1 of 4)



Slide 3-28, Long -Term Trends (1 of 4)

Not applicable.

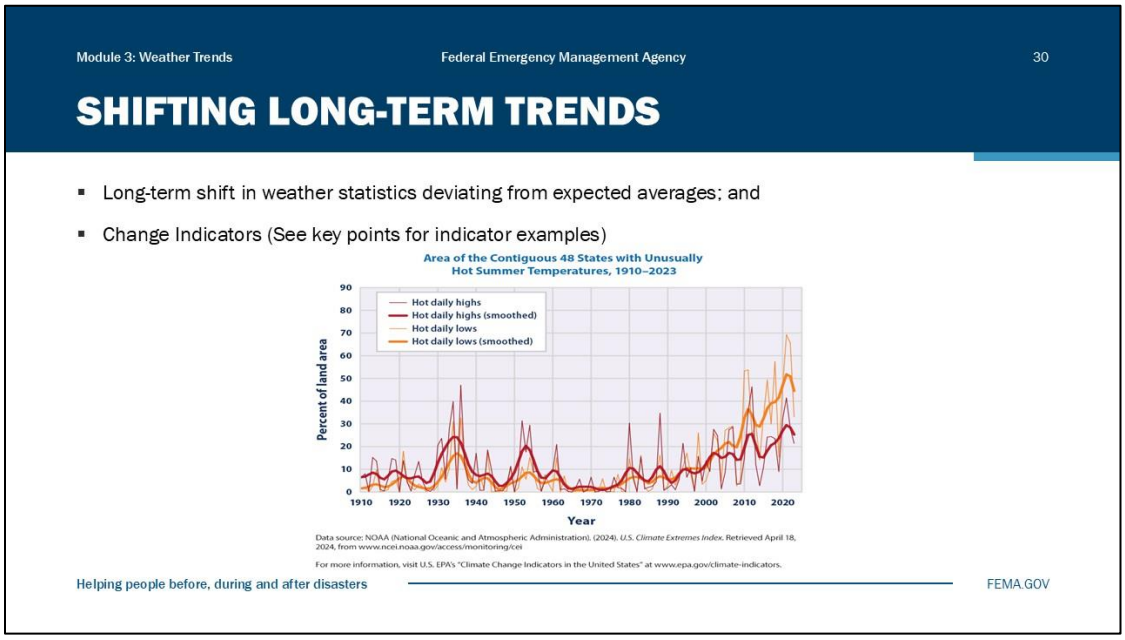
Long-Term Trends (2 of 4)



Slide 3-29, Weather Trends (2 of 4)

Not applicable.

Long-Term Trends (3 of 4)



Slide 3-30, Shifting Long-Term Trends

Long-Term Trends

- Long-term shift in weather statistics deviating from expected averages; and
- Change Indicators (See key points for indicator examples).

Data source: NOAA, 2015 (https://19january2021snapshot.epa.gov/climate-indicators/climate-change-indicators-high-and-low-temperatures_.html)

Change Indicators include:

- Weather and Weather trends
- U.S. and Global Temperature Drought
- Oceans
- Sea Surface Temperature
- Sea Level
- Ocean Acidity
- Snow and Ice

- Sea Ice Glaciers

Society and Ecosystems: Flora and Fauna Movement, Heat-Related Deaths

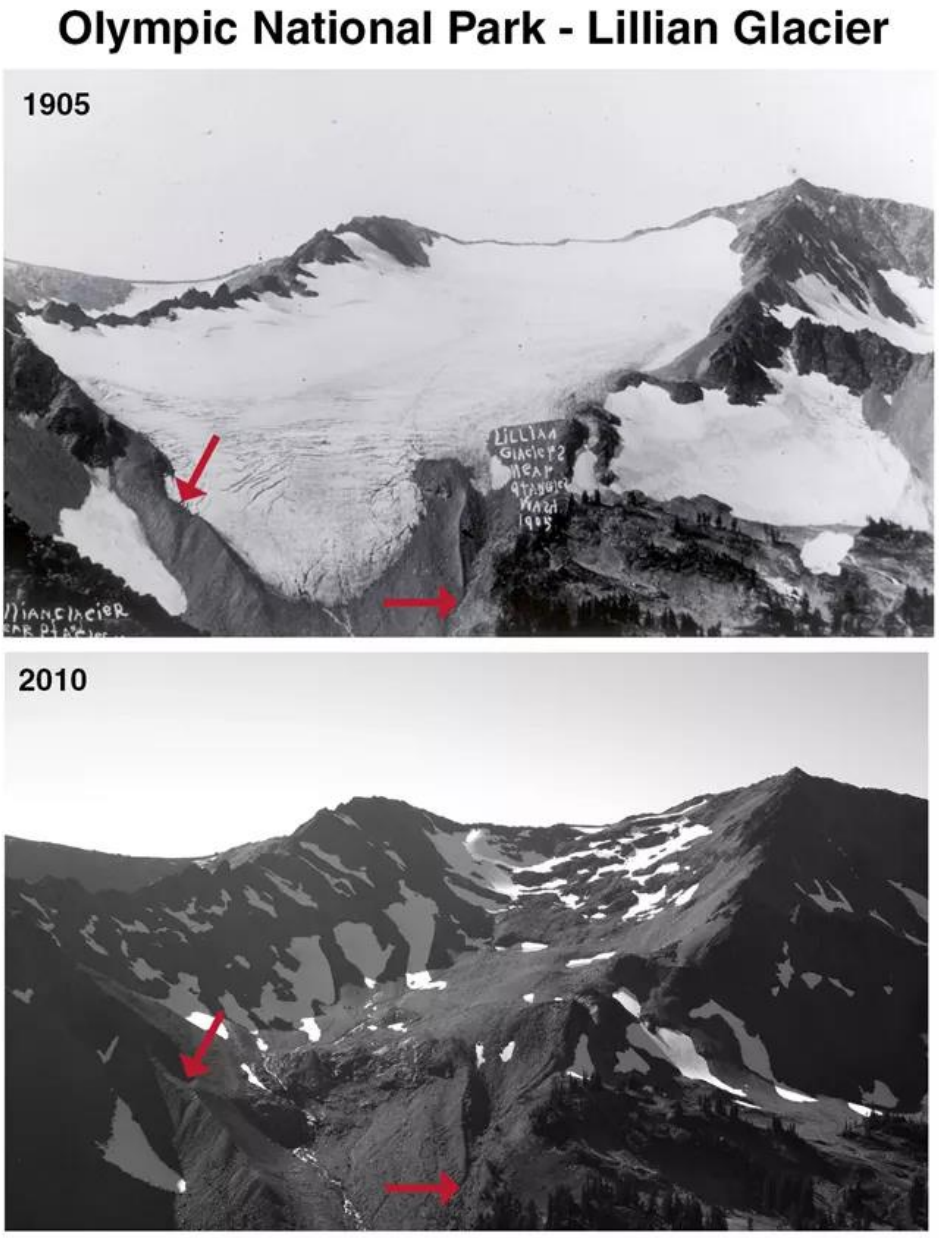
Another major factor in weather pattern variability is the trend in weather patterns. Weather trends are broadly defined as a long-term shift in weather statistics that deviates from expected averages. Scientists have determined that we are, in fact, in a period of weather trend changes; the last few decades have been the warmest period on record (i.e., since the mid-19th century).

These change indicators signal these weather trends ("global warming"):

- **Natural variability:** Weather trends are a naturally occurring phenomenon that is related to complex interactions between the oceans, the atmosphere, and land masses, as well as changes in the amount of solar radiation.
- **Greenhouse Gases:** The greenhouse effect was first identified and studied in the early 1800s. Scientists observed that certain gases in the atmosphere, such as water vapor, carbon dioxide, and methane, absorbed natural long-wavelength radiation emitted from the Earth. This process effectively warms the Earth above the temperature we would expect simply from our distance from the sun.
- **Sea Level is Rising:** Global mean sea level has been rising at an average rate of approximately 1.7 mm/year over the past 100 years. Since 1993, global mean sea level has risen at an accelerating rate of around 3.5 mm/year. (This link can also be accessed at the following https://www.climate.gov/climatedashboard) Sea level rises for two reasons:
- **Water expands as it heats up**. As the oceans warm, their volume will increase, allowing them to take up more space. More than half of the sea level rise is a result of the oceans' warming. (2) Sea level rises because ice caps on continents melt. As more continental ice sheets melt, more water goes into the oceans. Melting sea ice does not cause the sea level to rise.

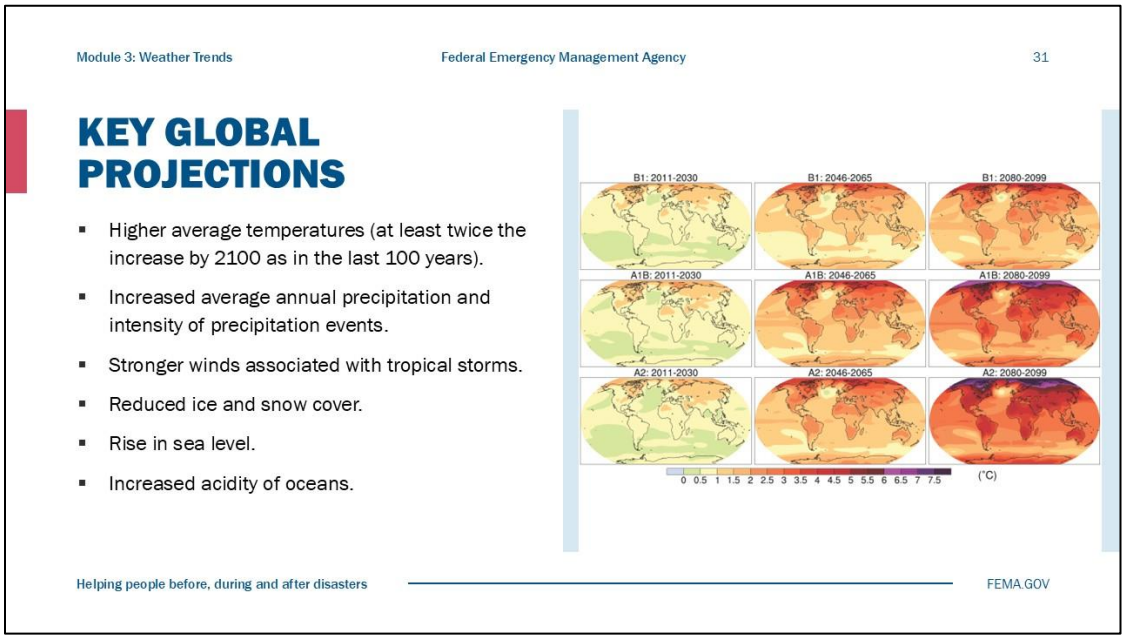
Note: The record of global average temperatures was compiled by NASA's Goddard Institute for Space Studies. The "zero" on this graph corresponds to the mean temperature from 1961 to 1990, as directed by the Intergovernmental Panel of Climate Change (IPCC).

An example of a long-term trend: Lillian Glacier, 1905 - 2010



Source: National Park Service. (n.d.). *Glaciers – Olympic National Park*. U.S. Department of the Interior. https://www.nps.gov/olym/learn/nature/glaciers.htm

Long-Term Trends (4 of 4)



Slide 3-31, Key Global Projections

Based on their study of the 26 indicators, scientists project higher average temperatures, increased amount and intensity of precipitation, and other changes. Below are some key projections for the United States:

Temperature

- By 2100, the average U.S. temperature is projected to increase by about 4°F to 11°F, depending on the model.
- An increase in average temperatures worldwide implies more frequent and intense extreme heat events, or heat waves. The number of days with high temperatures above 90°F is expected to increase throughout the United States, particularly in regions that already experience heatwaves.

Precipitation

- Northern areas are projected to become wetter, especially in the winter and spring. Southern areas, especially in the West, are projected to become drier.
- Heavy precipitation events will likely be more frequent. Heavy downpours, which currently occur about once every 20 years, are projected to occur about every 4 to 15 years by 2100, depending on the location.

- More precipitation is expected to fall as rain rather than snow, particularly in some northern areas.
- The intensity of Atlantic hurricanes is likely to increase as the ocean warms. Weather trends models project that for each 1.8°F increase in tropical sea surface temperatures, the rainfall rates of hurricanes could increase by 6-18% and the wind speeds of the strongest hurricanes could increase by about 1-8%.
- Cold-season storm tracks are expected to continue to shift northward. The strongest cold-season storms are projected to intensify and become more frequent.

Sea Level Change

Regional and local factors will influence future relative sea level rise for specific coastlines worldwide. For example, relative sea level rise depends on land elevation changes that occur as a result of subsidence (sinking) or uplift (rising). Assuming that these historical geological forces continue, a 2-foot rise in global sea level by 2100 would result in the following relative sea level rise:

- 2.3 feet in New York City
- 2.9 feet at Hampton Roads, Virginia
- 3.5 feet at Galveston, Texas
- 1 foot at Neah Bay in Washington State

Relative sea level rise also depends on local changes in currents, winds, salinity, and water temperatures, as well as proximity to thinning ice sheets.

Weather Trends (1 of 3)



Slide 3-32, Weather Trends

Not applicable.

Weather Trends (2 of 3)



Slide 3-33, How Weather Trends Affect Natural Disasters

How Are Weather Trends Affecting the Risk of Natural Disasters?

Weather trends affect disaster risks in several ways. High temperatures and persistent droughts increase the risk of wildfires by creating conditions that make it easier for fires to ignite and to spread. Oceans have also reached historically high temperatures, which makes hurricanes more severe by increasing the amount of moisture they carry and unleash on communities in their path. That, in turn, increases the risk of coastal flooding, particularly in places where sea levels have risen. Understanding those risks and how they are evolving is the first step in preparing for them, both to mitigate their potential for causing damage and to provide resources for those who suffer property losses to recover from them.

At a Glance

Weather trends heighten the risks of wildfires and other natural disasters. As insurance payouts for losses sustained in those disasters increase and uncertainty about future losses grows, people in many high-risk areas have faced difficulty obtaining or affording property insurance. As risk and costs increase, premiums will also rise, potentially making insurance less affordable for homeowners. If state regulators do not allow higher premiums, insurers may exit high-risk areas, reducing the availability of insurance.

In this report, the Congressional Budget Office analyzes recent changes in property insurance markets and considers alternative insurance products as well as policy approaches to increase the

availability and affordability of insurance for homeowners and renters. The highlights of that analysis include the following:

Higher land and ocean temperatures, drought, sea level rise, and excessive precipitation are all features of weather trends that contribute to increasing the risks of natural disasters, including wildfires, hurricanes, and floods. With increased uncertainty attributable to weather trends, insurers may limit coverage for risks that are difficult to quantify or where regulators constrain their ability to set prices reflecting risk.

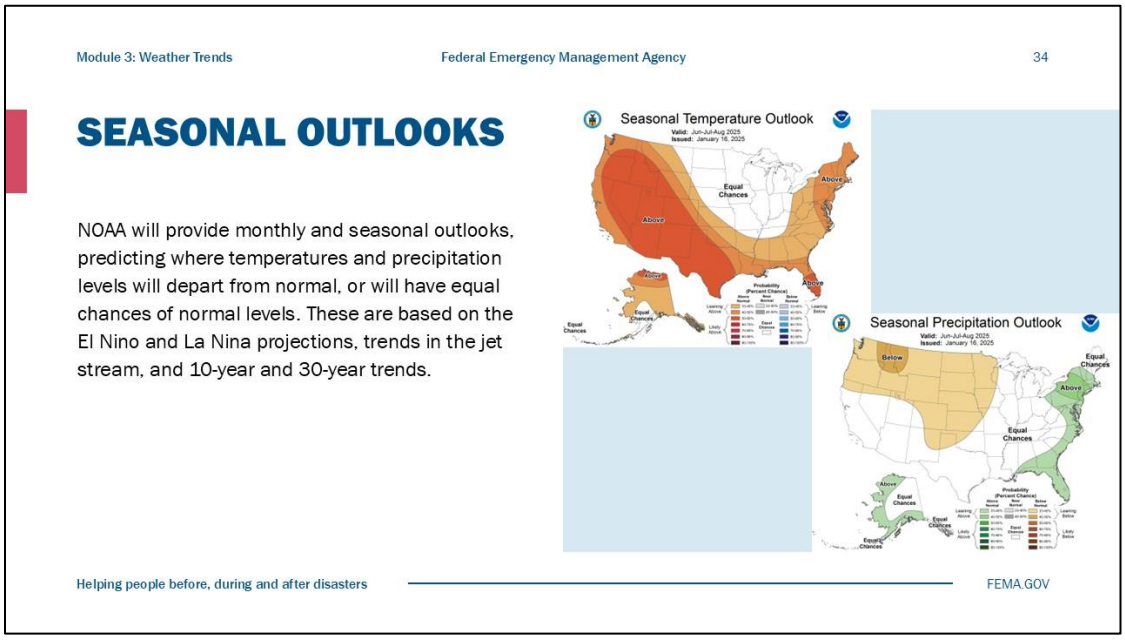
Households may underinsure for natural disasters for a variety of reasons, including a lack of information about the risks and the extent of any post-disaster government assistance.

Means-tested subsidies would make coverage more affordable for low- and moderate-income households. That approach has the advantage of targeting assistance and preserving incentives for other policyholders to mitigate losses, but controlling costs and implementing the program could be difficult.

Other approaches would expand the availability of insurance. States could lessen regulatory constraints on insurers' risk-based prices. The federal government could act as a catastrophic risk reinsurer or insurer, as it does for flood insurance, and bear a greater share of the cost of disasters.

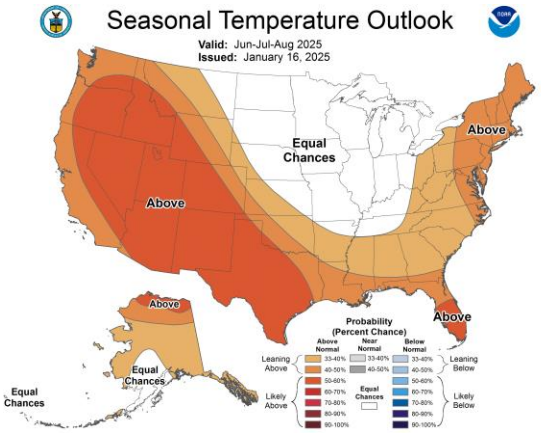
Source: Congressional Budget Office. (2020). *The effects of climate change on the U.S. economy*. https://www.cbo.gov/publication/60674

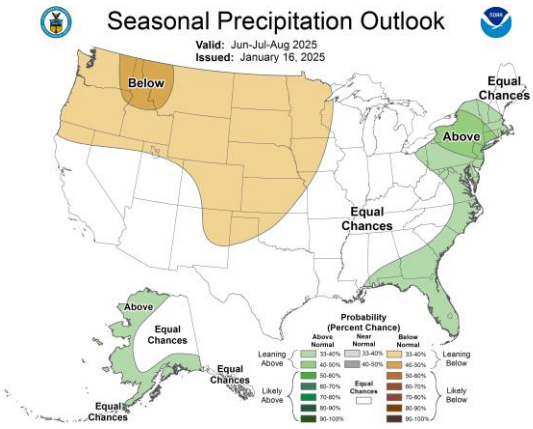
Weather Trends (3 of 3)



Slide 3-34, Seasonal Outlooks

NOAA will provide monthly and seasonal outlooks, predicting where temperatures and precipitation levels will depart from normal, or will have equal chances of normal levels. These are based on the El Nino and La Nina projections, trends in the jet stream, and 10-year and 30-year trends. In the images below you can see areas predicting deviations from normal temperatures and precipitation for areas across the country.





The Climate Prediction Center (CPC) issues maps that show the probability of exceeding thresholds for above- and below-normal conditions in terms of temperature and precipitation. These outlooks are issued from 2 weeks to 13 months in advance for the lower 48 states, Hawaii, and other Pacific

Islands. The CPC also makes available versions of these outlooks giving temperature (degrees Fahrenheit) and precipitation (inches) for the lower 48 states by climatic conditions regions (Probability of Exceedance), analysis and outlooks of tropical Pacific sea surface thermal anomalies which indicate El Niño or La Niña episodes, and skill scores of the CPC outlooks.

Monthly

- United States Outlook Maps - The CPC produces an outlook map of the probability of 30-day total precipitation and temperature departing from normal, accompanied by a technical discussion.
- United States Color Graphics Map - Maps show areas of the country that are expected to experience departures from normal for temperature and precipitation during the next 30 days.
- Hawaii Outlook - The Hawaii 30-day outlook (text only) discusses departures from normal for temperature and precipitation.
- Monthly U.S. Temperature and Precipitation GIS Data - GIS shape and raster files for the United States monthly temperature and precipitation outlooks.
- Monthly Drought Outlook - The CPC issues the Monthly United States Drought Outlook on the last day of each month.

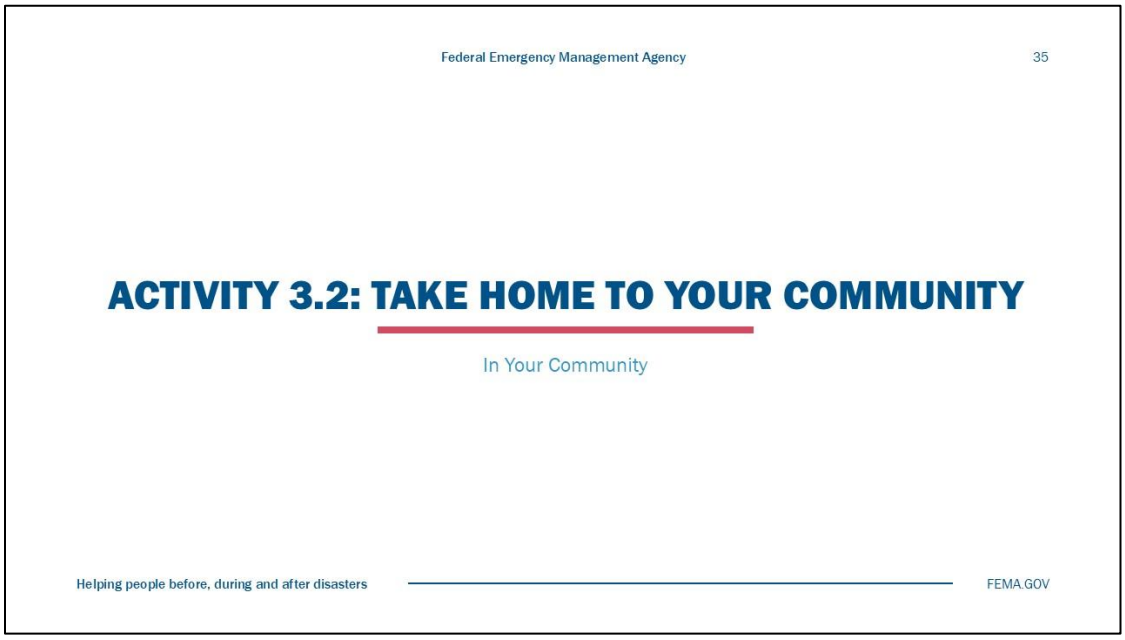
Seasonal

- United States Seasonal Outlook Maps and Graphs: The CPC issues seasonal outlooks of the probability of deviations from normal temperature and precipitation, for the lower 48 states, for a total of 13 seasons, each of which covers a period of 3 adjacent calendar months; technical discussion of the long-range outlook; and skill levels for each season's outlook; normals; and probability that a temperature or precipitation quantity will be exceeded for a region for the given season at the given lead time of two weeks to a year. These outlooks are issued approximately midway through the month on Thursdays.
- Hawaii Outlook Maps and Graphs: The Hawaii 30–90-day outlook is text only, while a bar graph shows the 13-month seasonal outlook.
- Seasonal U.S. Temperature and Precipitation GIS Data: GIS shape and raster files for the United States seasonal temperature and precipitation outlooks.
- Tropical Pacific Islands Graphs: The CPC provides various rainfall outlooks for the United States and non-United States-affiliated Pacific islands based on the Correlation Analysis (CCA) model. Seasonal outlooks of rainfall deviations from normal are provided for selected tropical Pacific stations, covering overlapping 3-month periods up to a year.
- Tropical Pacific Sea Surface Temperatures (SST) Graphs - The CPC issues the NWS official SST Forecast (including region Niño 3.4, an important region of the tropical Pacific

for monitoring for El Niño and La Niñas) and a 3-season El Niño-Southern Oscillation (ENSO) outlook.

- Seasonal Drought Outlook - The CPC issues the Seasonal United States Drought Outlook each month in conjunction with the Thursday release of the long-lead temperature and precipitation outlooks near the middle of the month.

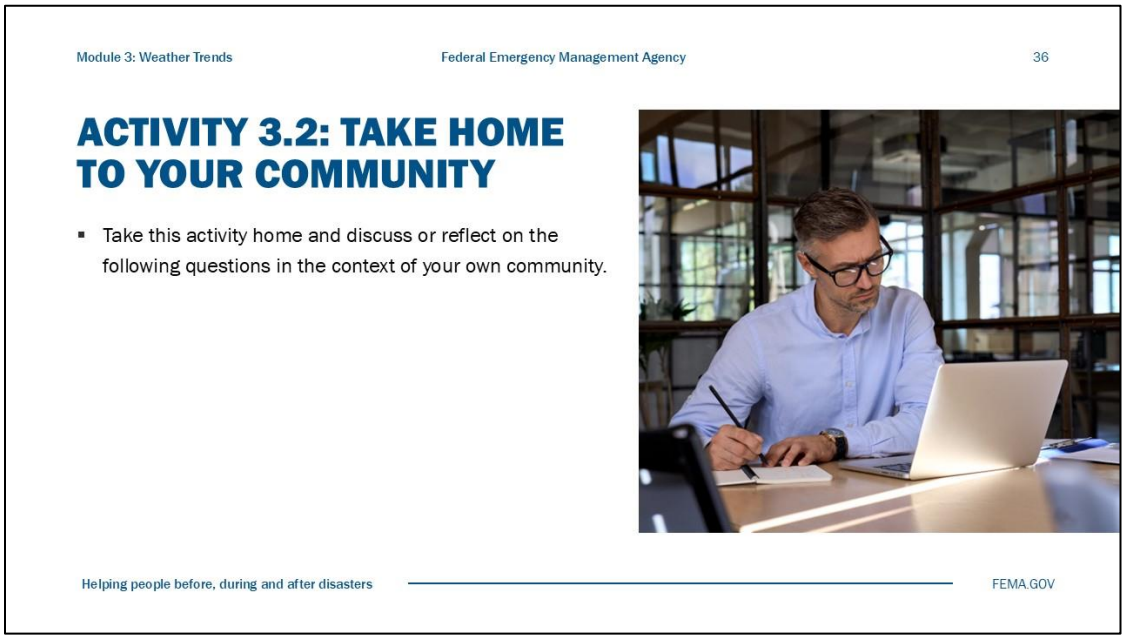
Take Home Activity 3.2: In Your Community (1 of 2)



Slide 3-35, Activity 3.2: Take Home to Your Community

Not applicable.

Take Home Activity 3.2: In Your Community (2 of 2)



Slide 3-36, Activity 3.2: Take Home to Your Community

Activity 3.2: In Your Community—Directions to Students

1. Take this activity home and discuss or reflect on the following questions in the context of your own community:

    a. What are some short- or long-term trends you are seeing with weather hazards in your community?

    b. Have certain hazards become more or less frequent, more or less severe?

c. How has your community dealt with those changes?

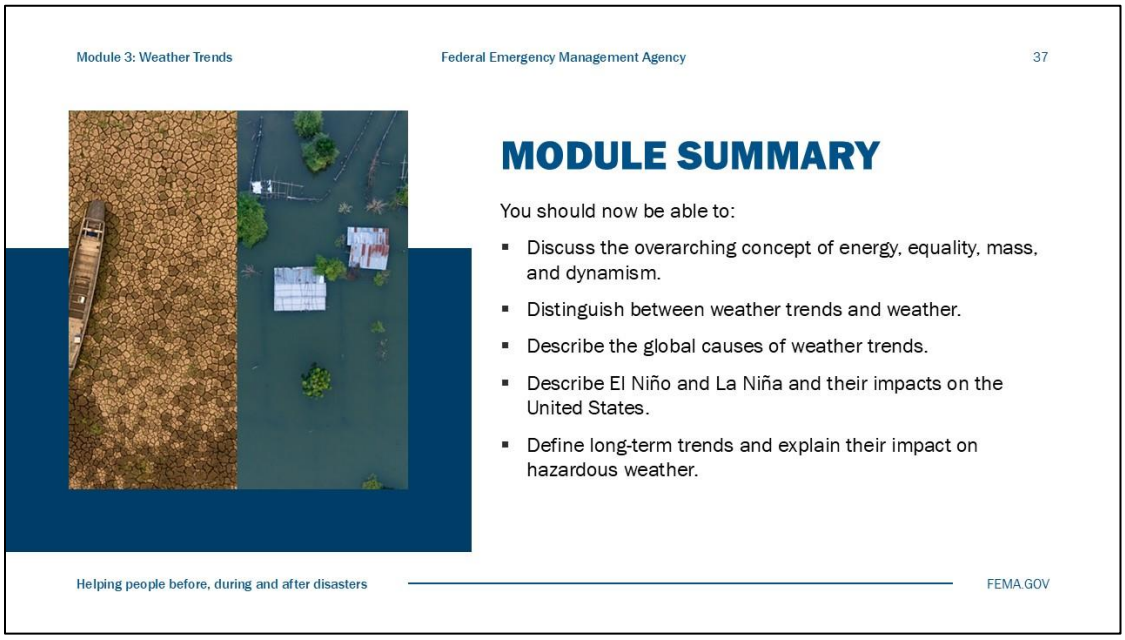
d. What core capabilities are needed to continue addressing these hazards?

e. Was your capacity to respond to and recover from them a challenge?

f. What mitigation measures have you taken, or would you suggest taking, if these trends continue?

2. Be prepared to share your insights in a future classroom discussion. You may wish to consult local resources or speak with individuals who are involved in emergency management or community planning.

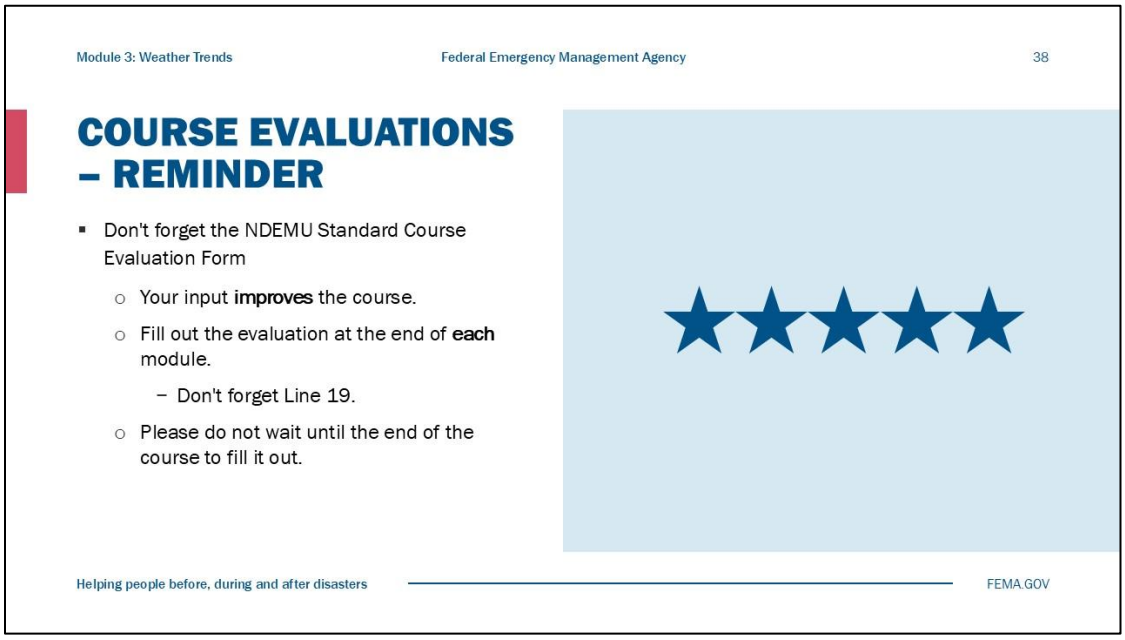
End of Module (1 of 2)



Slide 3-37, Module Summary (1 of 2)

- Discuss the overarching concept of energy, equality, mass, and dynamism
- Distinguish between weather trends and weather
- Describe the global causes of weather trends
- Describe El Niño and La Niña and their impacts on the United States
- Define long-term trends and explain their impact on hazardous weather

End of Module (2 of 2)



Slide 3-38, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

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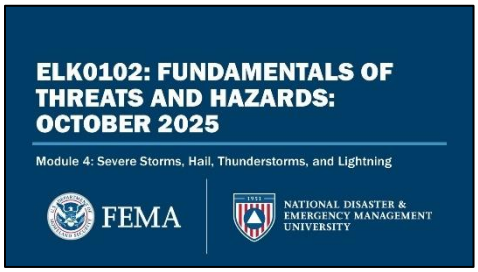
Weather Impacts of ENSO | National Oceanic and Atmospheric Administration. (n.d.). Retrieved May 15, 2025, from https://www.noaa.gov/jetstream/enso_impacts

Module

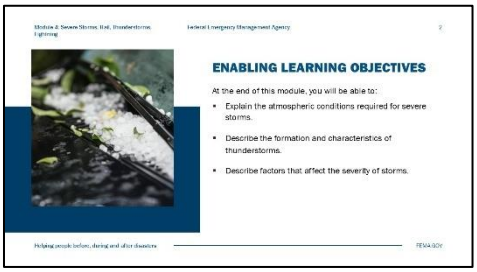
4

Severe Storms, Hail, Thunderstorms, Lightning

Administration



Slide 4-1, Module 4: Severe Storms, Thunderstorm, Lightning



Slide 4-2, Enabling Learning Objectives

Duration

1 hour 30 minutes

Terminal Learning Objective (TLO)

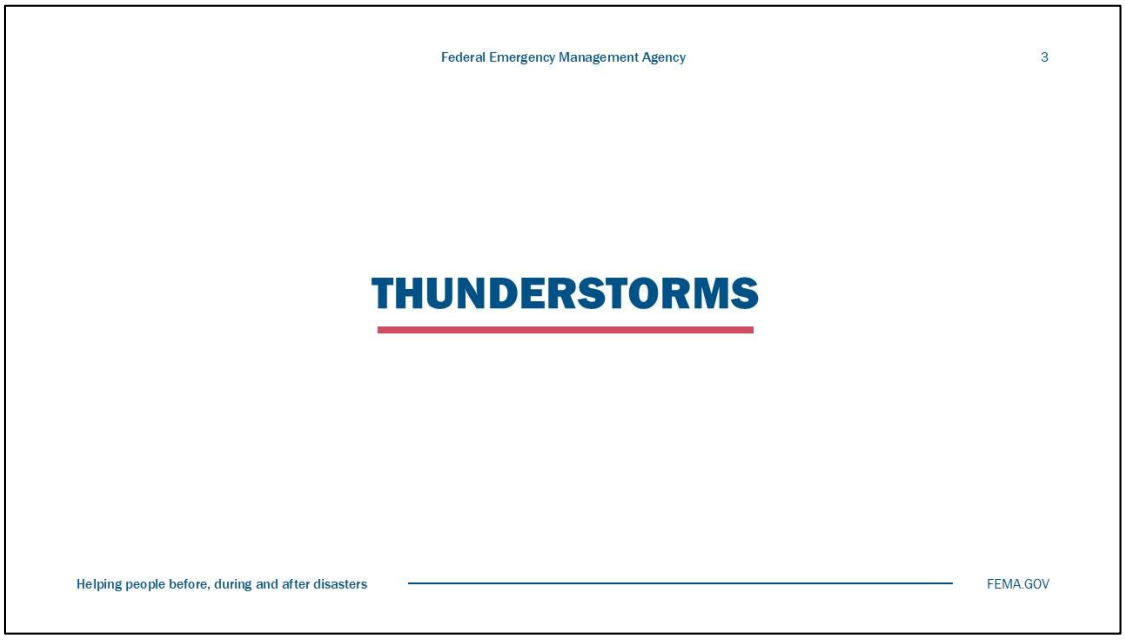
By the end of this module, participants will be able to describe the formation, characteristics, and impacts of severe storms, including thunderstorms and lightning.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Explain the atmospheric conditions required for severe storms.
- Describe the formation and characteristics of thunderstorms.
- Describe factors that affect the severity of storms.

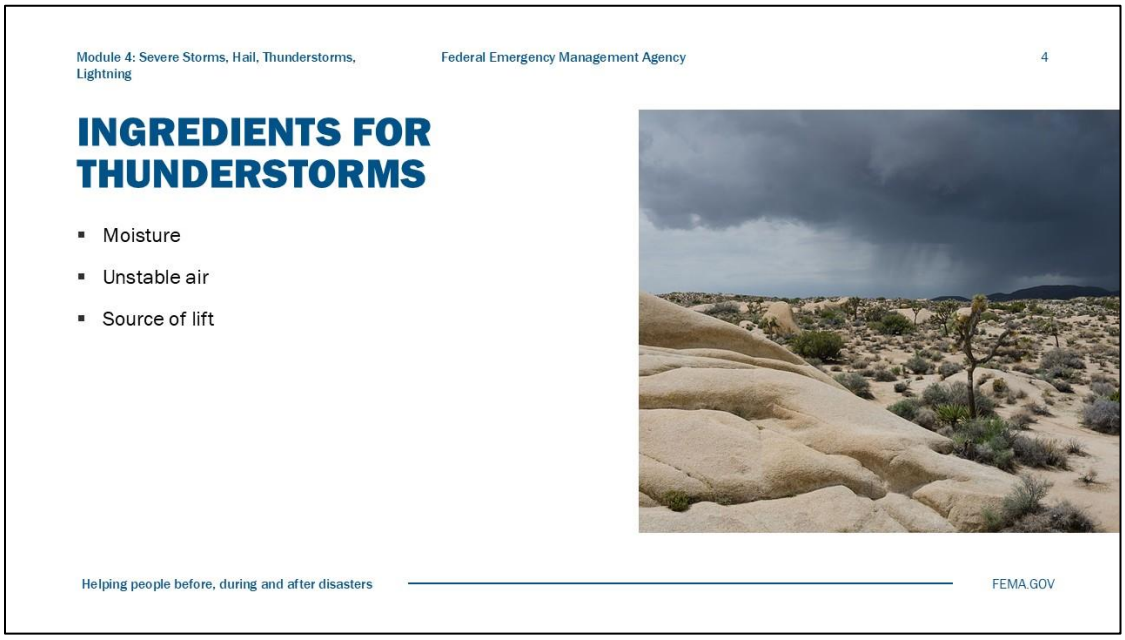
Thunderstorms (1 of 3)



Slide 4-3, Thunderstorms

Not applicable.

Thunderstorms (2 of 3)



Slide 4-4, Ingredients for Thunderstorms

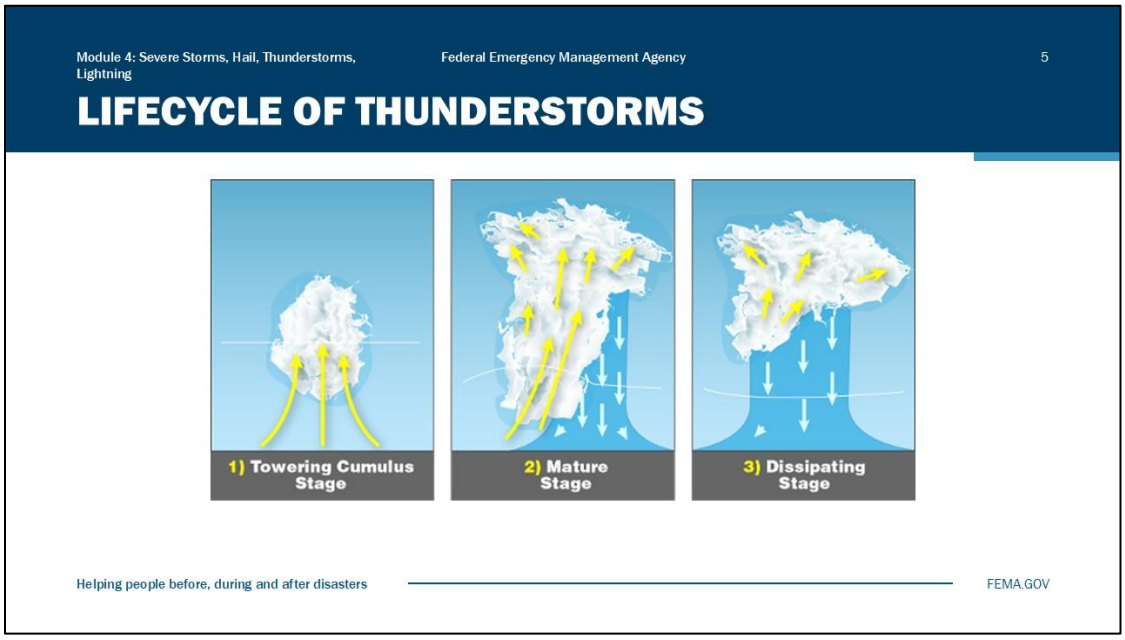
The three ingredients necessary for thunderstorm formation are:

- Moisture (e.g., water vapor from the Atlantic, Pacific, Gulf of Mexico, or Great Lakes);
- Unstable air (i.e., climatic conditions in which warm, rising air can maintain upward motion);
- A source of lift (e.g., cold fronts, warm fronts, gust fronts, sea breezes, or lake breezes). In short, thunderstorms require warm, humid air rising in unstable climatic conditions.

As discussed in the previous module, a cold front is the leading edge of an advancing cold air mass. At the surface, these fronts mark where cold air overtakes and replaces warmer air.

During the summer, cold fronts often initiate thunderstorms. (In cold weather, they produce hazardous winter conditions.)

Thunderstorms (3 of 3)

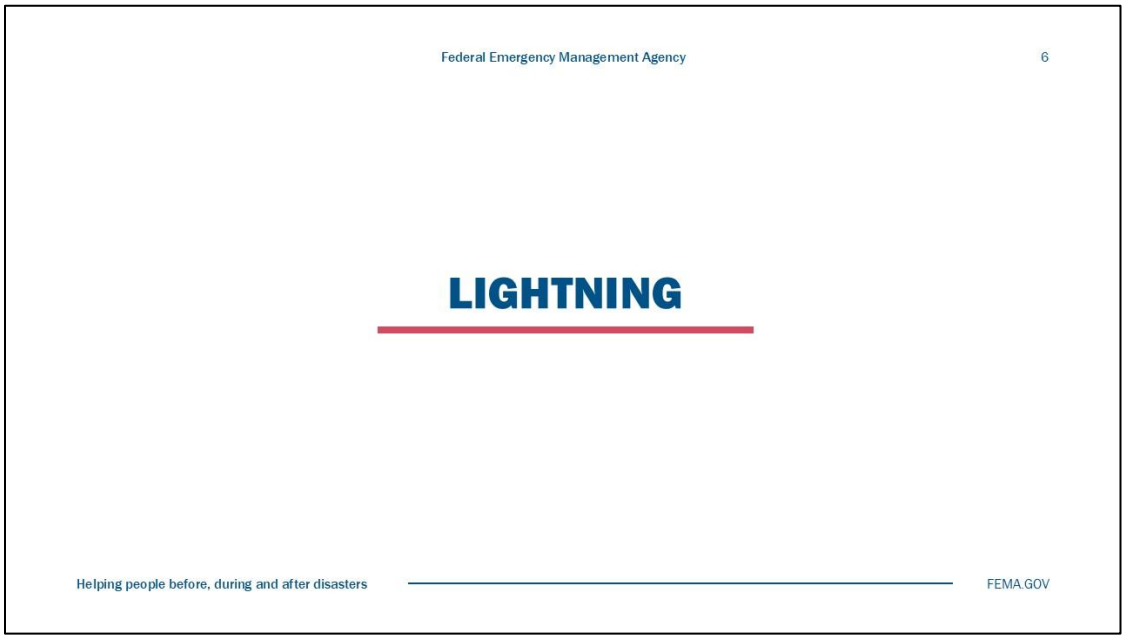


Slide 4-5, Lifecycle of Thunderstorms

This diagram illustrates the three stages of thunderstorm development:

- **Stage 1: Towering Cumulus Stage or Developing Stage.** Stage 1 consists entirely of an updraft, a small-scale current of rising air. In this stage, clouds have a puffy, cauliflower appearance. There is no rain yet.
- **Stage 2: Mature Stage.** Stage 2 consists of both updraft and downdraft. In this stage, a flat cloud formation, resembling an anvil, forms at the top of the storm, but parts of the cloud are still distinct. The characteristic anvil shape results from warm air being unable to rise any further and spreading out laterally. Severe weather occurs in this stage. Strong downdrafts may result in downbursts (outward bursts of damaging winds on or near the ground) or microbursts (strong, concentrated downbursts). Downburst winds can produce damage similar to a strong tornado. Although usually associated with thunderstorms, downbursts can occur with showers too weak to produce thunder.
- **Stage 3: Dissipating Stage.** Stage 3 consists entirely of a downdraft, a small-scale column of air that rapidly sinks toward the ground. In this stage, the whole cloud begins to dissipate and appears "fuzzy." This stage occurs when the storm no longer has enough warm air rising to sustain it and begins to die out.

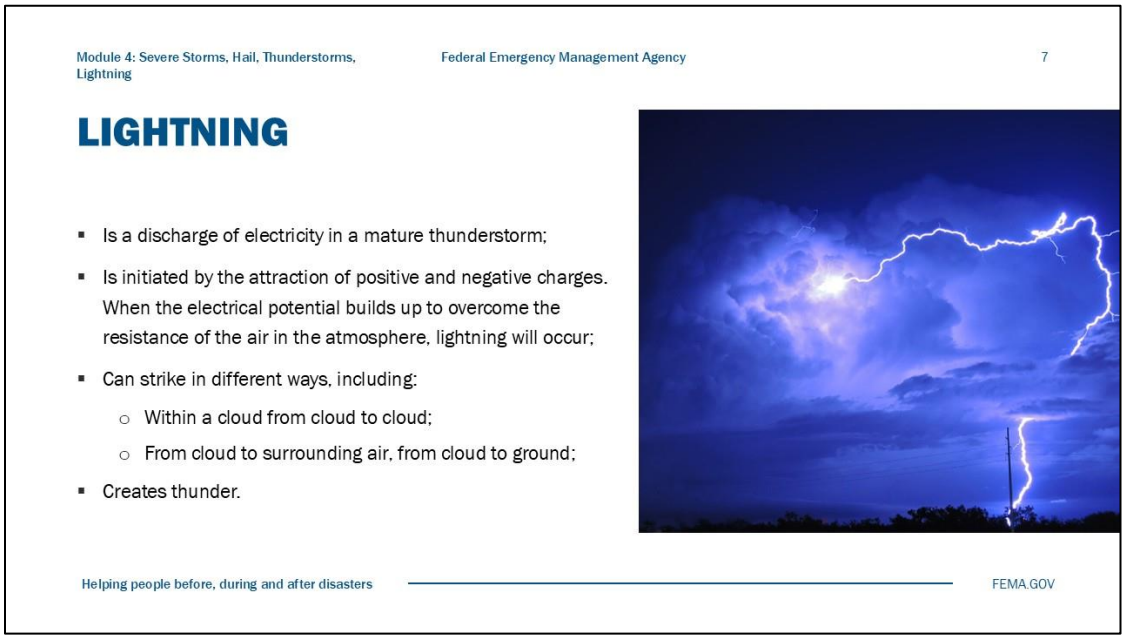
Lightning (1 of 2)



Slide 4-6, Lightning

Not applicable.

Lightning (2 of 2)



Slide 4-7, Lightning (2 of 2)

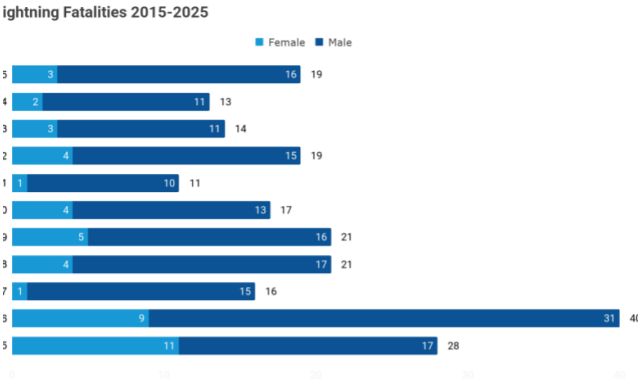
Lightning characteristics:

- Is a discharge of electricity in a mature thunderstorm;
- Is initiated by the attraction of positive and negative charges. When the electrical potential builds up to overcome the resistance of the air in the atmosphere, lightning will occur;
- Can strike in different ways, including:
  - Within a cloud from cloud to cloud;
  - From cloud to surrounding air, from cloud to ground;
- Creates thunder.

Lightning dangers: Lightning is a serious danger, striking the United States an estimated 20 million times a year. You can be struck by lightning even if you are away from the thunderstorm; if you are close enough to hear the thunder, you are close enough to be struck by lightning.

Lightning can strike up to 10 miles from a storm.

- In the United States, lightning kills an average of 54 people every year.
- In 2024, there were 11 fatalities due to lightning.
- Hundreds more are permanently injured every year.



Source: US Department of Commerce, N. (n.d.). *National Weather Service Lightning Fatalities in 2025: 19*. NOAA's National Weather Service. Retrieved October 9, 2025, from https://www.weather.gov/safety/lightning-fatalities

People struck by lightning suffer from a variety of long-term, debilitating symptoms, including:

- Memory loss
- Attention deficits
- Sleep disorders
- Chronic pain
- Dizziness
- Stiffness in joints
- Irritability
- Fatigue
- Muscle spasms
- Depression

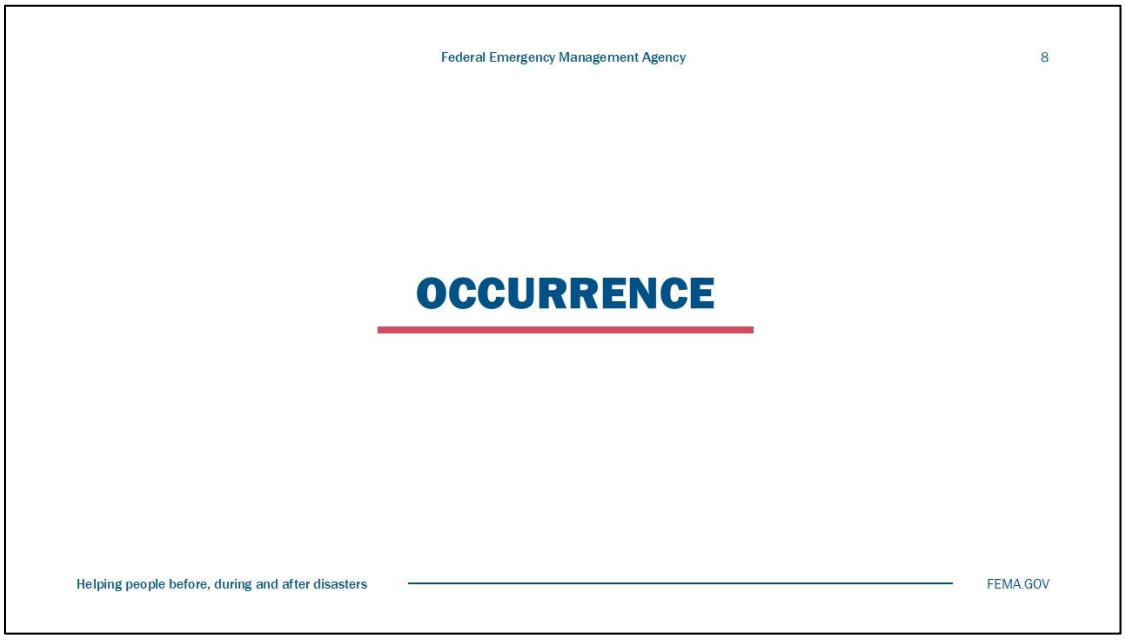
Thunder: Even though lightning only has a diameter of 1-2 inches (2-5 cm), it can heat air up to 70,000 degrees F (39,000 degrees C) in just a few milliseconds. This sudden and drastic increase in temperature causes the surrounding air to expand violently at a rate faster than the speed of sound. This results in a shock wave that, after extending 30 feet, becomes an ordinary sound wave, or thunder.

How close is the storm? Light from lightning travels at the speed of 186,000 miles per second. Sound travels at a much slower rate–only about 1 mile every 5 seconds. This explains why the light from lightning reaches us before the sound of thunder.

Knowing this information, you can estimate how close a storm is to you.

1. Count the number of seconds it takes between the time you see a lightning flash and before you hear the thunder.
2. Each 5 seconds counted equals 1 mile. For example, if you count 15 seconds, the flash was 3 miles away. Anything under 6 miles is still in the high danger zone.

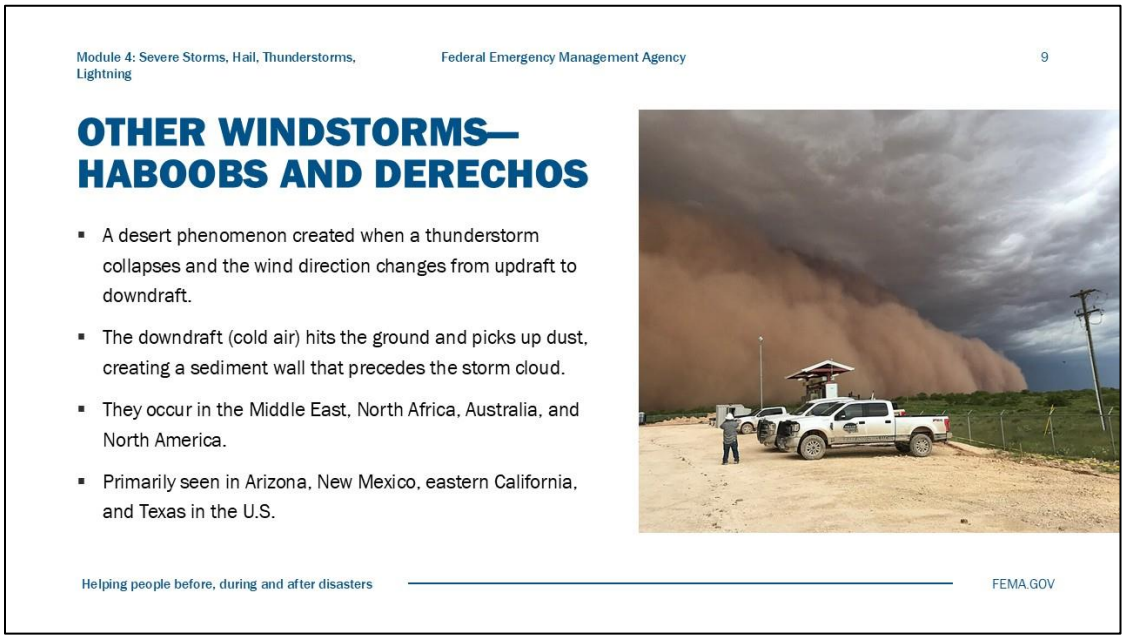
Occurrence (1 of 4)



Slide 4-8, Occurrence

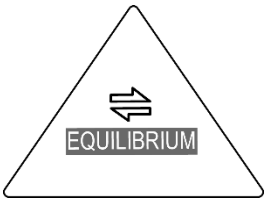
Not applicable.

Occurrence (2 of 4)



Slide 4-9, Other Windstorms—Haboobs and Derechos

This is equilibrium.



Other Windstorms—Haboobs and Derechos

- Haboobs and Derechos are created when a thunderstorm collapses and the wind direction changes from updraft to downdraft.
- The downdraft (cold air) hits the ground and picks up dust, creating a sediment wall that precedes the storm cloud.
- They occur in the Middle East, North Africa, Australia, and North America.
- Primarily seen in Arizona, New Mexico, Eastern California, and Texas in the U.S.
- Occasionally seen in Eastern Washington and Northern Idaho

- May also be seen in agricultural areas experiencing extreme drought, such as during the Dust Bowl
- Also known as “sandstorms” or “dust storms.”
- The dust wall can exceed 50 miles wide and 10,000 feet high. The winds can reach speeds of up to 60 mph.
- They can approach with little to no warning.
- Rain may or may not appear at ground level.

“Dry” windstorms are called “virgas”

Severe wet ones may be called “mud storms”

- Moving to a shelter is highly recommended.

If you must go outside, eye and respiratory protection are advisable.

- NWS may issue a Dust Storm Warning or a Blowing Dust Advisory.

Since 2018, the National Weather Service has issued Polygon-based (i.e., on a map) dust storm advisories and warnings. A WEA Cellphone alert is issued whenever a Dust Storm Warning is issued, but it is not issued with a Dust Storm advisory. The criteria are:

- **Blowing Dust Advisory**: This is a long-duration event of widespread or localized blowing dust, reducing visibilities to one mile or less but greater than 1/4 mile.
- **Dust Storm Warning:** A sudden drop in visibility to 1/4 mile or less, resulting in widespread or localized blowing dust.

Derechos

A derecho (pronounced like "deh-REY-cho") is a widespread, long-lived windstorm. Derechos are associated with bands of rapidly moving showers or thunderstorms, variously known as bow echoes, squall lines, or quasi-linear convective systems.

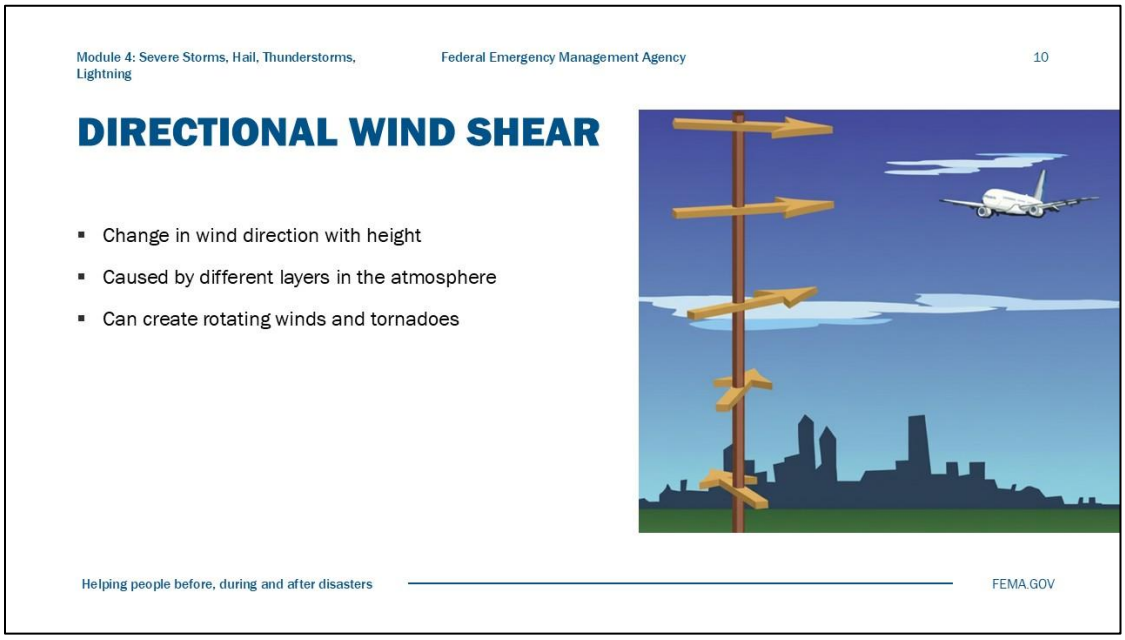
Although a derecho can produce destruction like that of a tornado, the damage typically occurs in one direction along a relatively straight path. As a result, the term "straight-line wind damage" is sometimes used to describe derecho damage.

If the swath of wind damage extends for more than 250 miles (about 400 kilometers) and includes wind gusts of at least 58 mph (93 km/h) along most of its length, and also includes several, well-separated 75 mph (121 km/h) or greater gusts, the event may be classified as a derecho.

Source: *Facts about derechos - Very damaging windstorms*. (n.d.) and https://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

More information: 2020 Midwest derecho. (2025). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=2020_Midwest_derecho&oldid=1315671669

Occurrence (3 of 4)



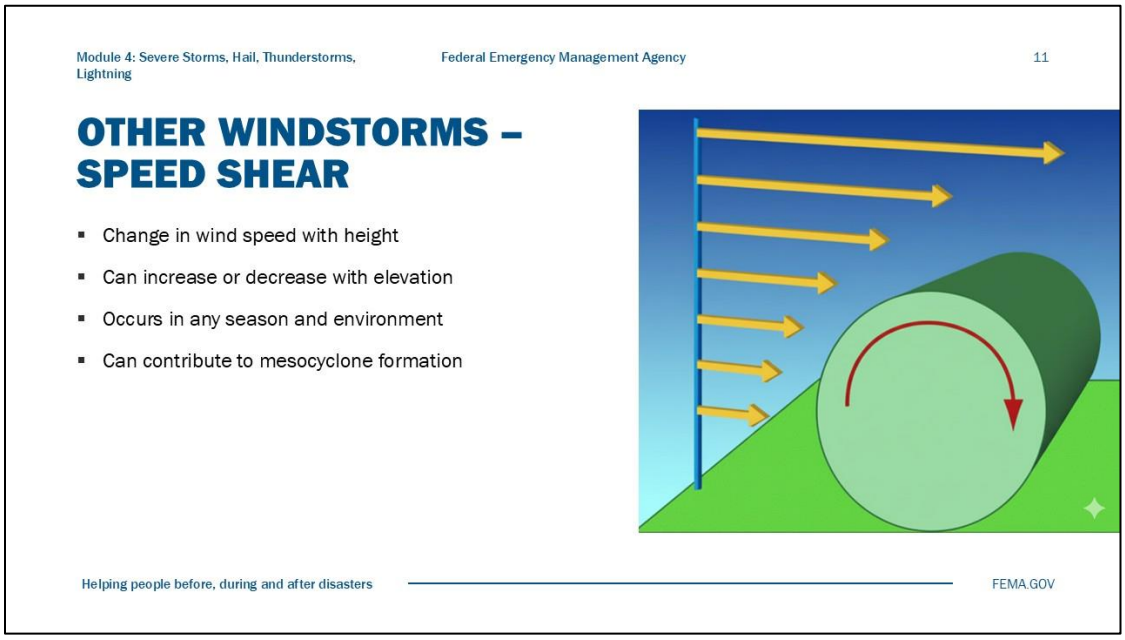
Slide 4-10, Directional Wind Shear

Next, we will look at some key components of thunderstorms: wind shear, speed shear, lightning, and thunder.

- **Wind shear** is the rate at which wind velocity changes from point to point in a given direction. It can include:
  - **Speed shear**, where the wind speed changes between two points, but the direction remains the same.
  - **Directional shear**, where the direction changes between two points, but the speed remains constant.
  - A combination of both speed and directional shear.
- **Directional wind shear** is the change in wind direction with height, caused by the layered structure of the atmosphere. For example, imagine the accompanying image shows a view looking north. Near the surface, the wind is blowing toward the northwest. As elevation increases, the wind veers clockwise—first to the south, then southwest, and finally west. This change illustrates the hazard directional wind shear poses to aircraft, especially during landing and takeoff.

- **Vertical directional wind shear** creates a rising, twisting motion. This motion can lead to wind rotation and may even form a tornado. Wind shear can produce a roaring sound that is sometimes mistaken for a tornado.

Occurrence (4 of 4)



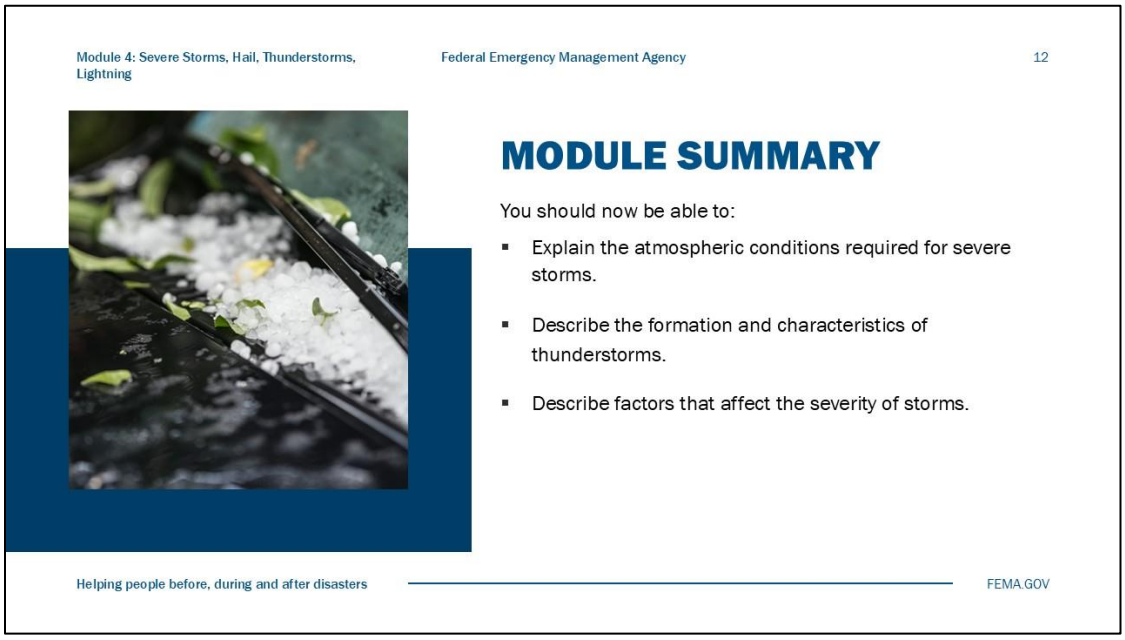
Slide 4-11, Other Windstorms – Speed Shear

Speed shear is the change in wind speed with height. Wind speed can either increase or decrease with height. When it decreases, stronger winds may occur at the surface. Speed shear can develop in any season and in a variety of environments.

The image in the visual shows how wind speed typically increases with height, which can create a rolling motion in the atmosphere. This rolling effect is believed to be a key factor in the formation of **mesocyclones**.

- A **mesocyclone** is a rotating column of air, approximately 2 to 50 miles in diameter, that forms within a convective storm. Mesocyclones are most often linked to localized low-pressure regions inside severe thunderstorms. These storms may include strong surface winds and large hail. Mesocyclones commonly occur alongside strong updrafts in supercells and are associated with tornado formation.
- Mesocyclones are believed to form when strong changes in wind speed and/or direction cause sections of the lower atmosphere to spin in invisible, tube-like rolls. The storm's convective updraft pulls this spinning air upward, turning the rolls from a horizontal to a vertical position. This causes the entire updraft to rotate as a vertical column.

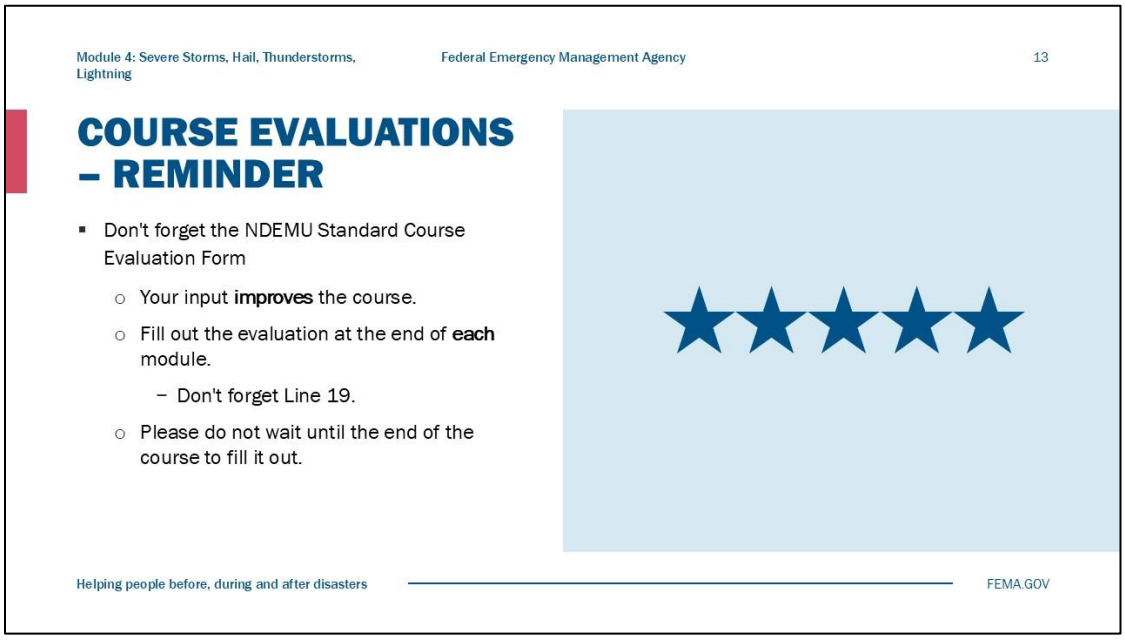
End of Module (1 of 2)



Slide 4-12, Module Summary

- Explain the atmospheric conditions required for severe storms.
- Describe the formation and characteristics of thunderstorms.
- Describe factors that affect the severity of storms.

End of Module (2 of 2)



Slide 4-13, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

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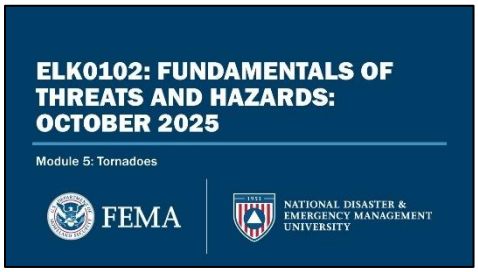
Facts About Derechos—Very Damaging Windstorms. (n.d.). Retrieved May 15, 2025, from https://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

US Department of Commerce, N. (n.d.-a). *National Weather Service Lightning Fatalities in 2025: 19*. NOAA's National Weather Service. Retrieved October 9, 2025, from https://www.weather.gov/safety/lightning-fatalities

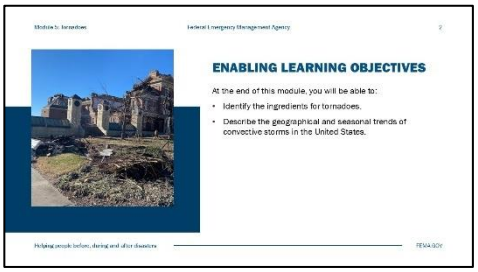
US Department of Commerce, N. (n.d.-b). *Severe Weather Topics*. NOAA's National Weather Service. Retrieved October 9, 2025, from https://www.weather.gov/ilx/swop-springtopics

Module 5
Tornadoes

Administration



Slide 5-1, Tornadoes



Slide 5-2, Enabling Learning Objectives

Duration

50 minutes

Terminal Learning Objective (TLO)

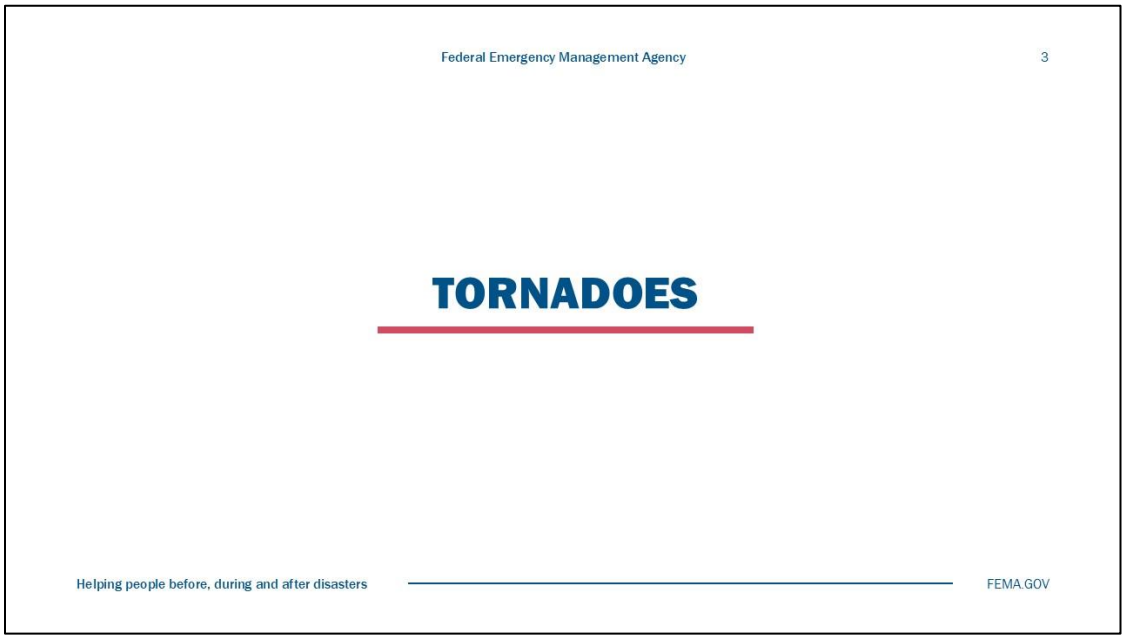
By the end of this module, participants will be able to describe the formation, characteristics, and impacts of tornadoes, identify methods for predicting tornado events, and discuss strategies for preparedness and mitigation.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Identify the ingredients for tornadoes.
- Describe the geographical and seasonal trends of convective storms in the United States.

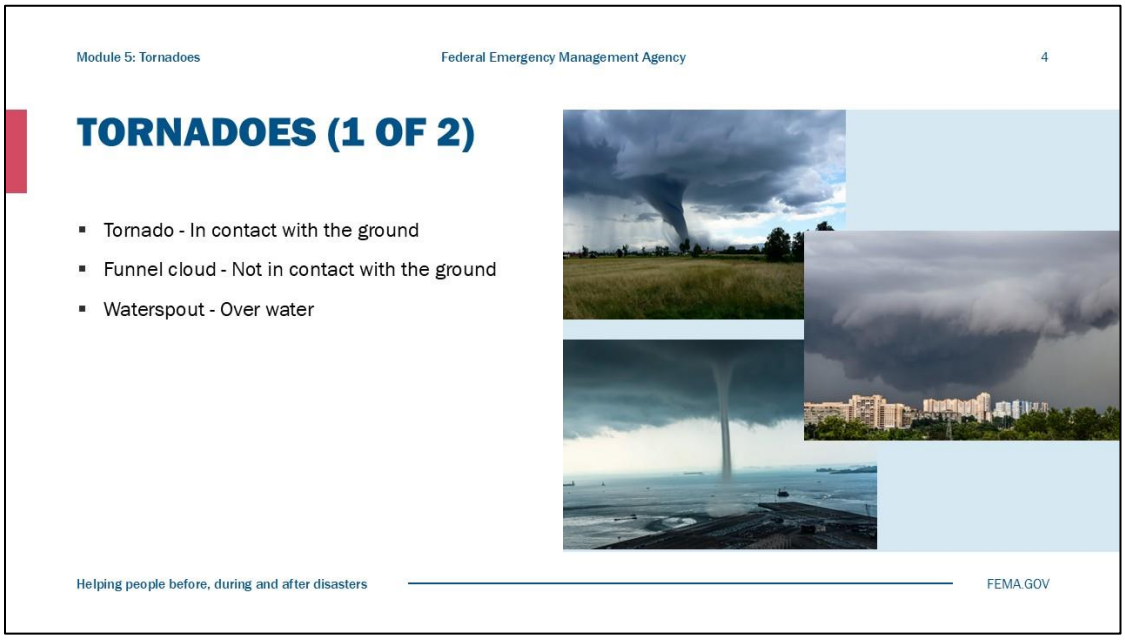
Tornadoes (1 of 5)



Slide 5-3, Tornadoes

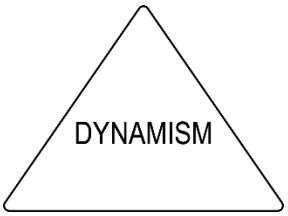
Not applicable.

Tornadoes (2 of 5)



Slide 5-4, Tornadoes (1 of 2)

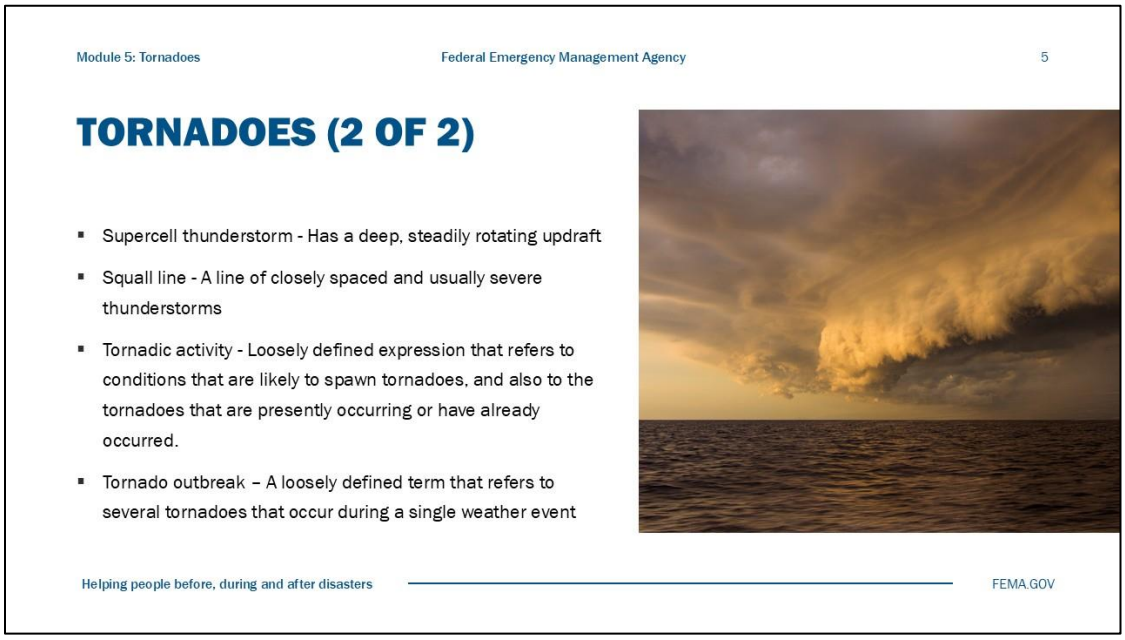
This is dynamism.



A rotating updraft, the result of wind shear, is the key to the development of a tornado. This rotation or spinning creates the well-known funnel shape. Rotating winds include tornadoes, funnel clouds, and waterspouts.

- A **tornado** is a rapidly rotating column of air that comes in contact with the ground. These columns of air are by-products or side effects of severe thunderstorms.
- A **funnel cloud** is slightly different than a tornado, in that it is a rapidly rotating column of air that is not in contact with the ground.
- **Waterspouts** are tornadoes that form over water.

Tornadoes (3 of 5)

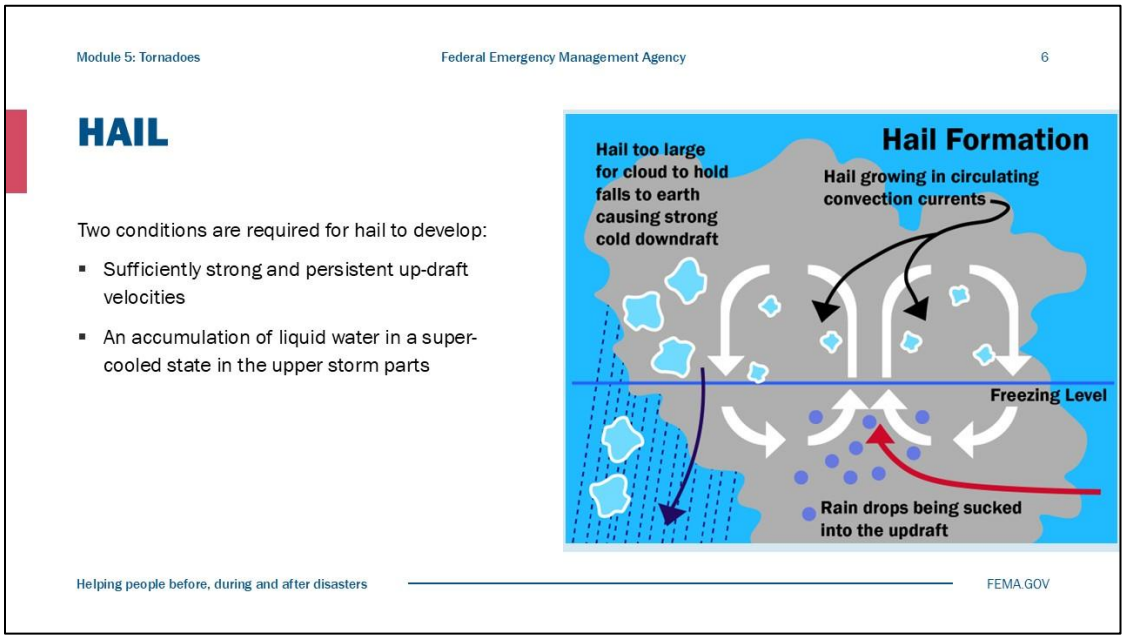


Slide 5-5, Tornadoes (2 of 2)

- Other terms you will hear associated with the severe thunderstorms that cause tornadoes include the following:
- **Supercell thunderstorm** has a deep, steadily rotating updraft, or a "mesocyclone," which can reach speeds of over 100 miles per hour. These thunderstorms can produce extremely large hail, extreme winds, flash flooding, and violent tornadoes; in fact, almost all major tornadoes in the United States result from supercell thunderstorms.
- **Squall line** is a line of closely spaced and usually severe thunderstorms. Squall lines often occur along or ahead of a cold front and can spawn tornadoes. Squall lines usually advance rapidly into a warm, moist air mass, which then feeds into the updrafts of the oncoming thunderstorms and maintains them. If a squall line slows or stalls, it usually weakens because it does not have a new supply of warm, moist air.
- **Tornadic activity** is a loosely defined expression that refers to conditions that are likely to spawn tornadoes and also to the tornadoes that are presently occurring or have already occurred. Note that in some cases, tornadoes are not visible because they have not picked up debris.

- **Tornado outbreak** is another loosely defined term that refers to several tornadoes that occur during a single weather event. A single supercell thunderstorm can produce more than one tornado, but most of the tornadoes in an outbreak occur from separate thunderstorms, often from a line of such storms that constitute a squall line.

Tornadoes (4 of 5)



Slide 5-6, Hail

Two conditions are required for hail to develop:

- Sufficiently strong and persistent updraft velocities
- An accumulation of liquid water in a super-cooled state in the upper storm parts

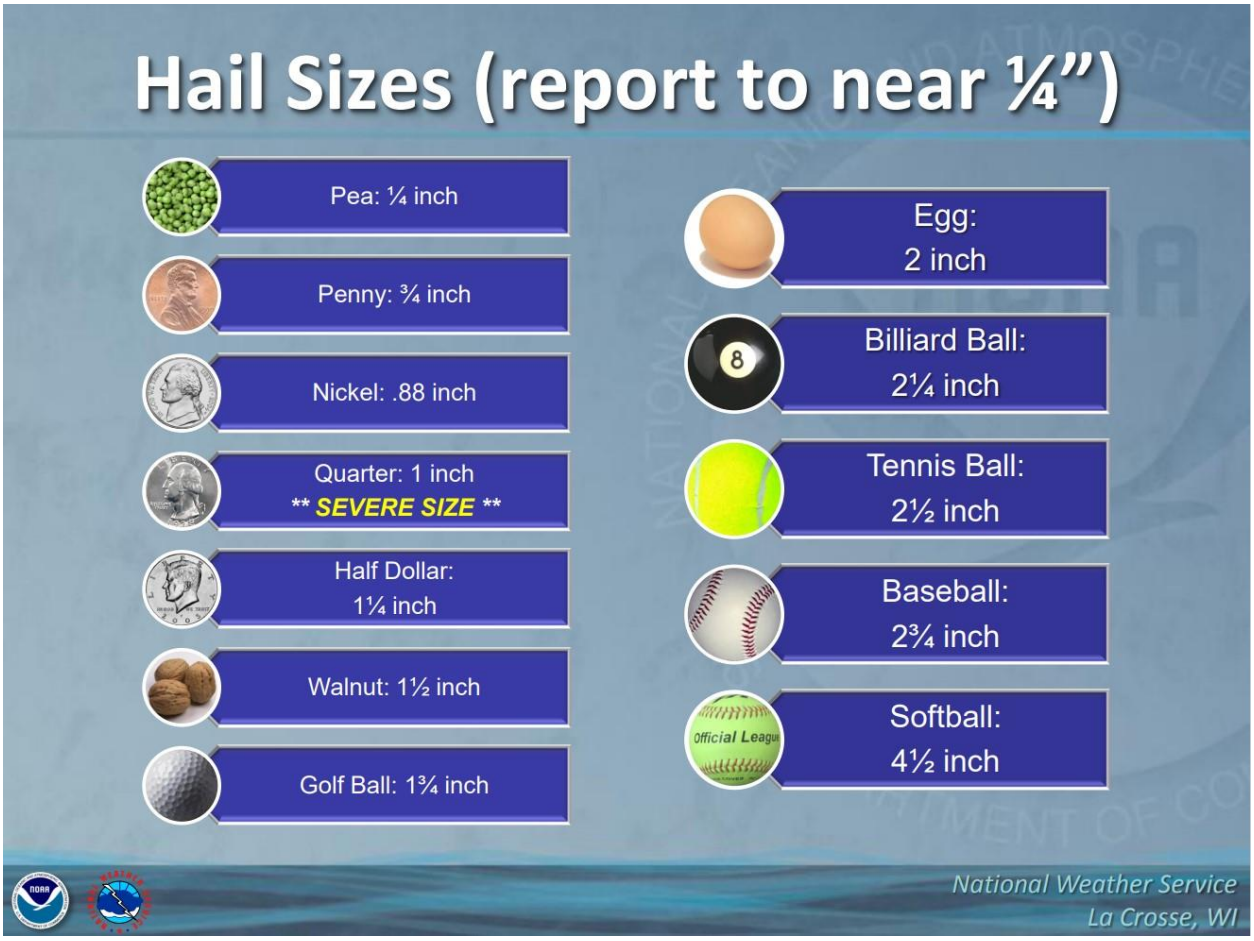
In a thunderstorm, convective currents create updrafts that bring water droplets up higher into the atmosphere. Studies of thunderstorms indicate that two conditions are required for hail to develop: sufficiently strong and persistent updraft velocities and an accumulation of liquid water in a super-cooled state in the upper parts of the storm. Hailstones are formed as water vapor in the warm surface layer accumulates on dust, microscopic particles, and biological particles in a process called nucleation. These small droplets rise quickly into the cold upper atmosphere due to convection. The water vapor is frozen at higher altitudes and begins to fall; as the water falls, it accumulates more water vapor. This cycle continues until there is too much weight for the updraft to support, and the frozen water falls too quickly to the ground to melt along the way.

Hail may be spherical, conical, or irregular in shape and can range in size from barely visible to grapefruit-sized. Hailstones equal to or larger than a quarter are considered severe.

NWS Hail Size Estimates

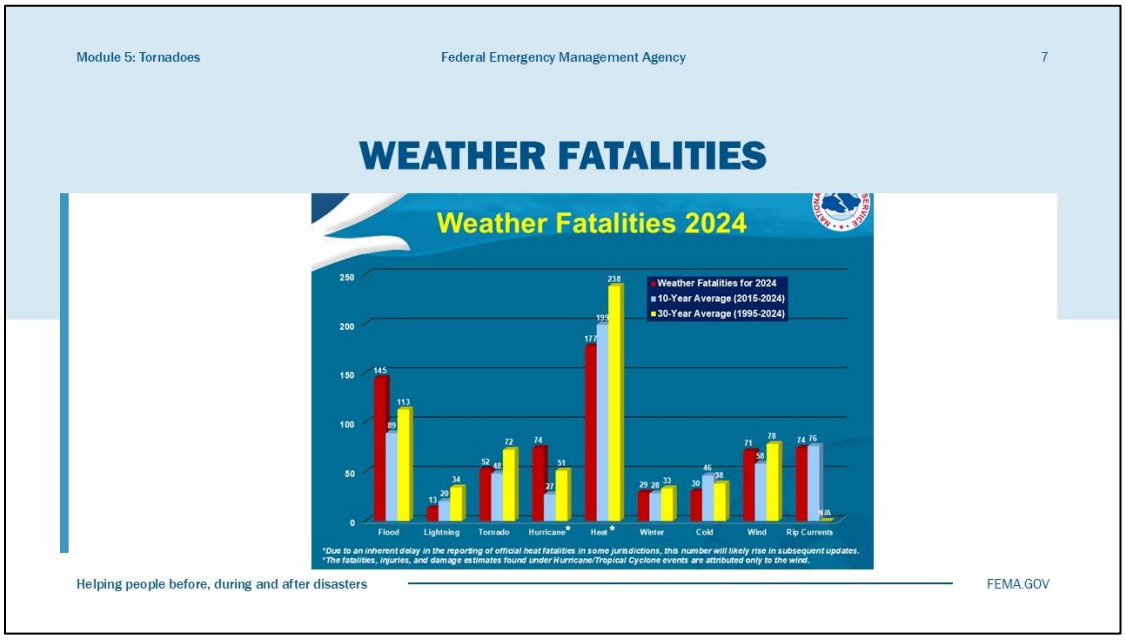
Size	Inches in Diameter
Pea	1/4 inch
Marble/mothball	1/2 inch
Dime/Penny	3/4 inch
Nickel	7/8 inch
Quarter	1 inch
Ping-Pong Ball	1 1/2 inch
Golf Ball	1 3/4 inches
Tennis Ball	2 1/2 inches
Baseball	2 3/4 inches
Tea cup	3 inches
Grapefruit	4 inches
Softball	4 1/2 inches

Hail falls in swaths that can be from 20 to 100 miles long and from 5 to 30 miles wide. A hail swath is not a large continuous path of hail but generally consists of a series of hail cells that are produced by individual thunderstorm clouds traveling in the same area.



https://www.weather.gov/images/ind/hail_size_ref.jpg

Tornadoes (5 of 5)



Slide 5-7, Weather Fatalities

As of February 2025, as reported in https://www.weather.gov/hazstat/

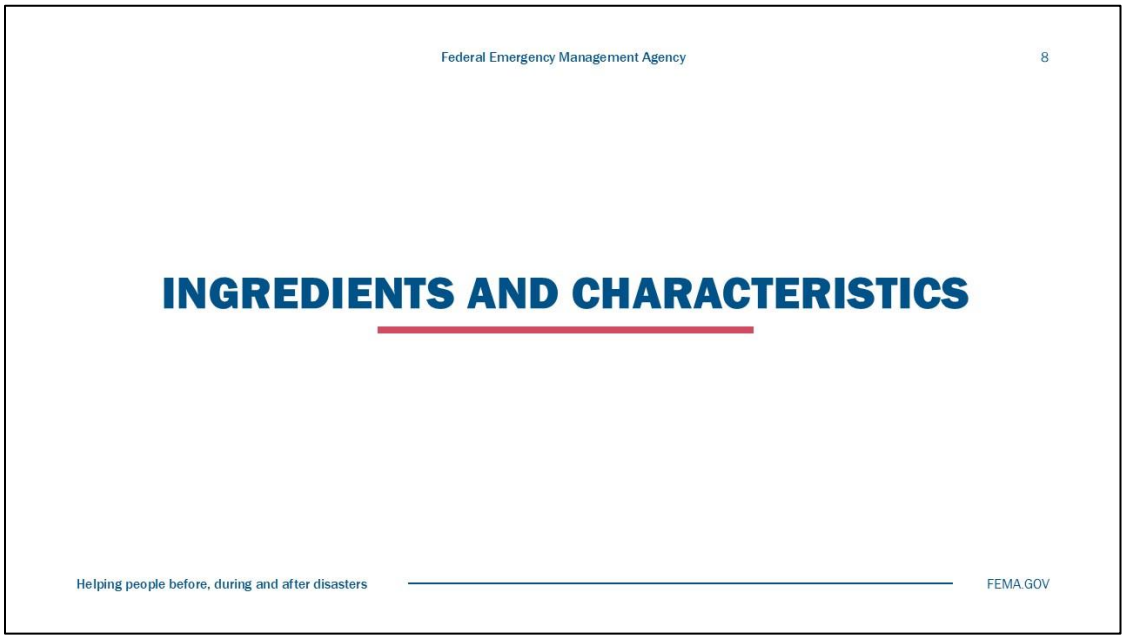
** Due to an inherent delay in the reporting of official heat fatalities in some jurisdictions, this number will likely rise in subsequent updates.*

** The fatalities, injuries, and damage estimates found under Hurricane/Tropical Cyclone events are attributed only to the wind.*

We are below the 10- and 30-year averages in 2023.

Source: NOAA's National Weather Service. (n.d.). *Weather related fatality and injury statistics*. https://www.weather.gov/hazstat/

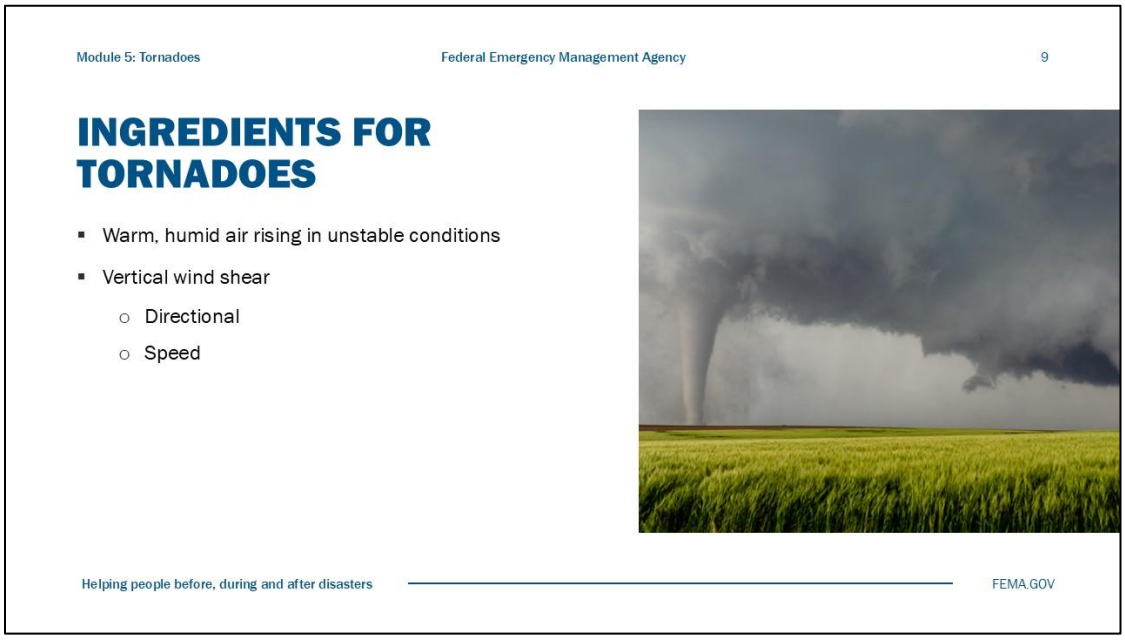
Ingredients and Characteristics (1 of 2)



Slide 5-8, Ingredients and Characteristics

Not applicable.

Ingredients and Characteristics (2 of 2)



Slide 5-9, Ingredients for Tornadoes

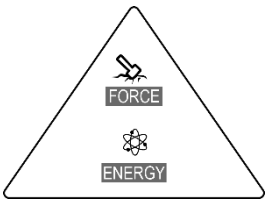
Because tornadoes are a by-product of thunderstorms, the ingredients for tornadoes are the same as the ingredients for thunderstorms. In order for a tornado to form, there must be:

- Moisture;
- Unstable air;
- A source of lift (same as for thunderstorms); plus the addition of
- Vertical wind shear (directional and/or speed).

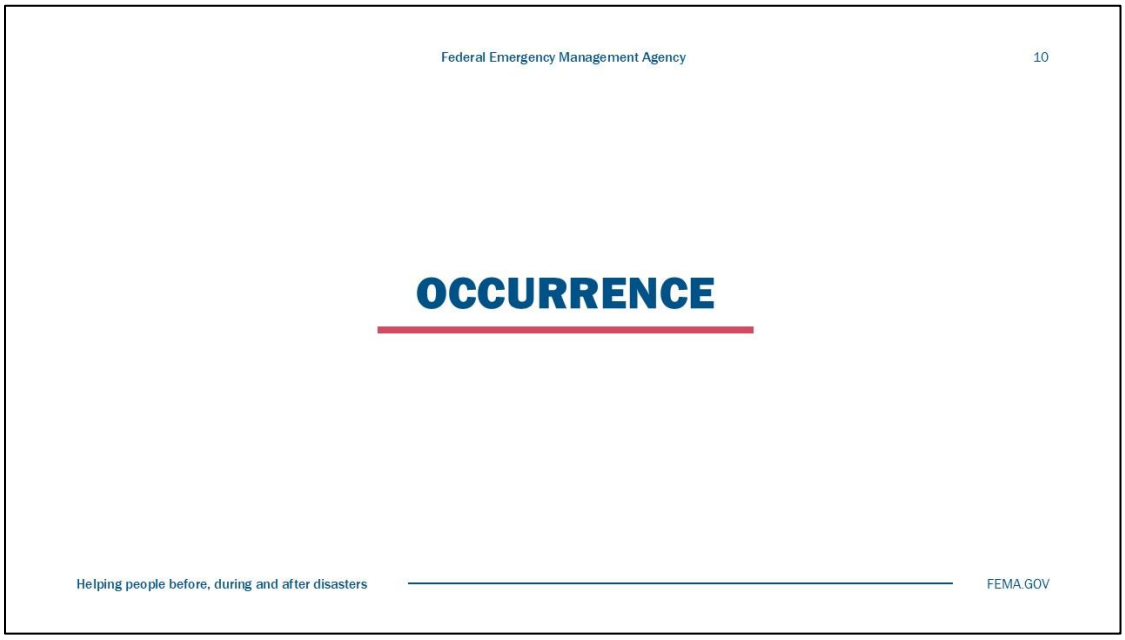
The visible column of a tornado is composed of water droplets formed by condensation in the funnel. The vortex (or multiple vortices) pulls in air from near the ground, along with dirt and debris. The dirt and debris block light, giving the tornado a dark color.

The fast-moving winds of a tornado (either flowing into the tornado or in the main tornadic circulation) are what cause most of the damage.

This is force and energy.



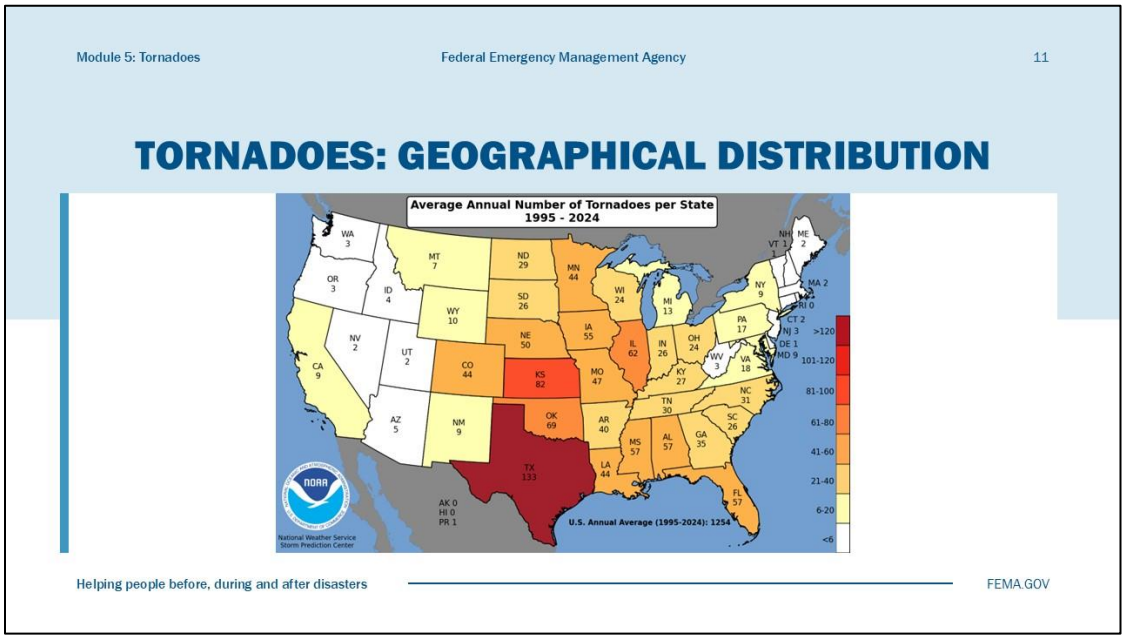
Occurrence (1 of 7)



Slide 5-10, Occurrence

Not applicable.

Occurrence (2 of 7)



Slide 5-11, Tornadoes: Geographical Distribution

https://www.spc.noaa.gov/wcm/permonth_by_state/

Tornadoes: Geographical Distribution

State	Average Annual Number of Tornadoes (1994 2023)
AL	55
AK	<1
AZ	4
AR	39
CA	9
CO	45
CT	2
DE	1
FL	56
GA	36
HI	<1
ID	4
IL	58
IN	25
IA	52

State	Average Annual Number of Tornadoes (1994 2023)
KS	81
KY	26
LA	41
ME	2
MD	9
MA	2
MI	13
MN	44
MS	55
MO	45
MT	7
NE	48
NV	2
NH	1
NJ	3
NM	9
NY	9
NC	31
ND	29
OH	22
OK	66
OR	3
PA	17
RI	<1
SC	26
SD	27
TN	30
TX	135
UT	2
VT	1
VA	18
WA	3
WV	2
WI	24
WY	10

Source: NOAA's National Weather Service. (n.d.). *Storm Prediction Center Maps, Graphics, and data page*. https://www.spc.noaa.gov/wcm/

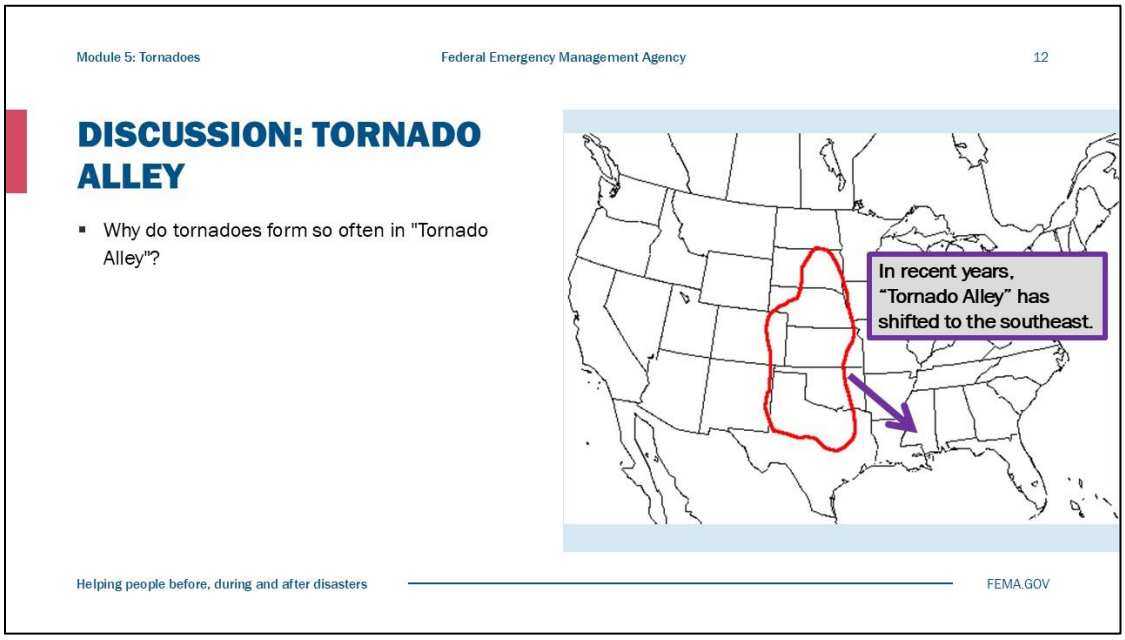
Like thunderstorms, tornadoes are not limited to any particular part of the country. In fact, tornadoes have occurred in every single state in the United States.

However, some areas are more susceptible to tornadoes due to their unique climatic conditions and landscape.

This map shows the geographic distribution of tornadoes across the United States from 1985 to 2014. The two areas with the highest frequency of tornadoes are:

- Florida, because of the high frequency of thunderstorms, as well as the influence of tropical storms and hurricanes, and
- The section of the country referred to as "Tornado Alley."

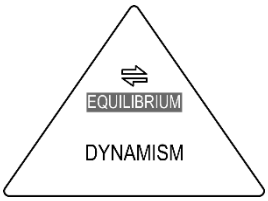
Occurrence (3 of 7)



Slide 5-12, Discussion: Tornado Alley

Why do tornadoes form so often in "Tornado Alley"?

This is equilibrium and dynamism.

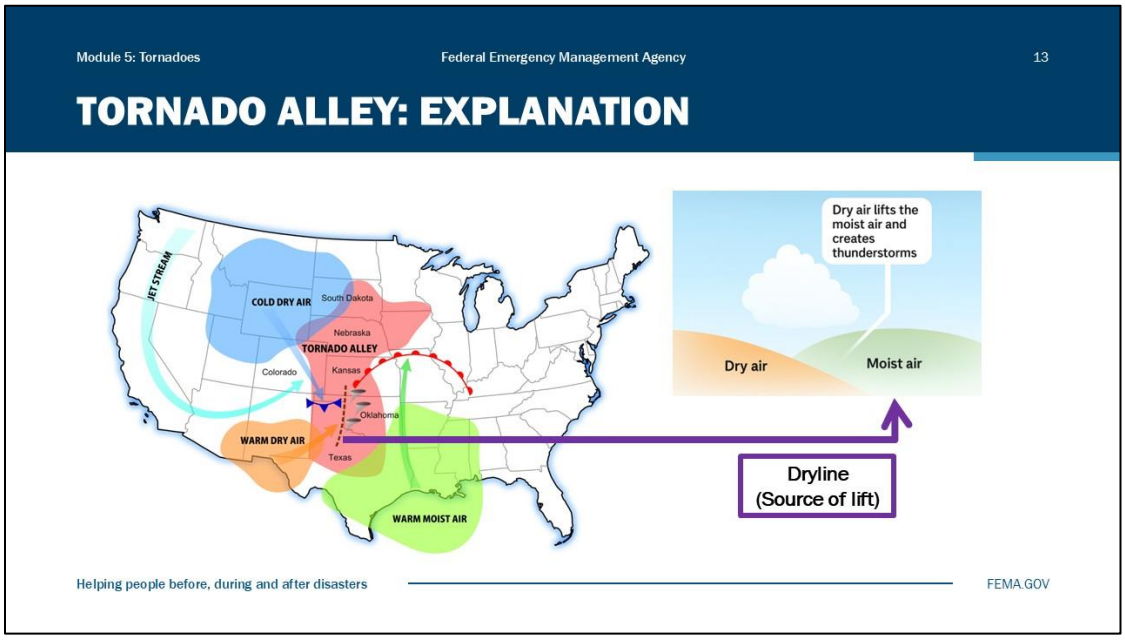


"Tornado Alley" is a nickname given to a region of the central United States that experiences a disproportionately high frequency of tornadoes every year. This area stretches from central Texas to northern Iowa. The thunderstorm that brought down Flight 191 mentioned in the case study occurred in the afternoon, in the summer, in "Tornado Alley."

In recent years, "Tornado Alley" has shifted to the southeast.

The explanation visual is shown on the next slide. Also, notice that the diagram below shows that tornadoes are more likely to occur at certain times of the year, and in somewhat different areas throughout the season as we go from Spring to Fall.

Occurrence (4 of 7)



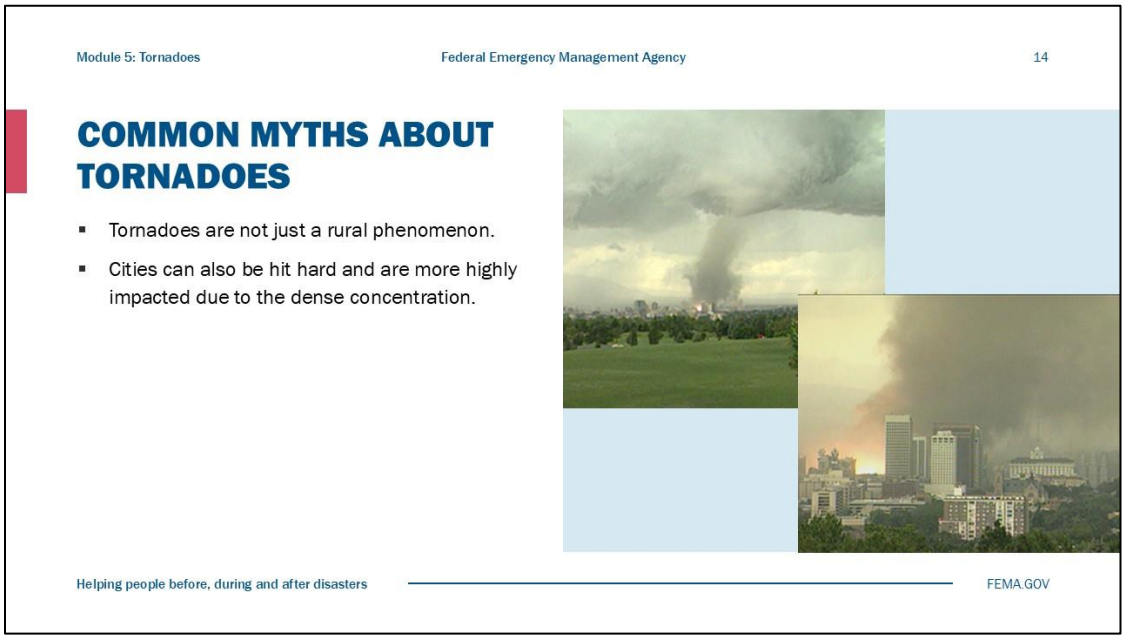
Slide 5-13, Tornado Alley: Explanation

This graphic illustrates the weather patterns that make **Tornado Alley** especially prone to severe storms and tornadoes.

- **Tornado Alley** spans parts of Texas, Oklahoma, Kansas, Nebraska, and surrounding states.
- The region is where **cold, dry air** from the north and west meets **warm, moist air** from the Gulf of Mexico.
- A key feature shown is the **dryline**, which acts as a boundary between dry and moist air. It creates **lift**, helping trigger thunderstorms.
- The **jet stream** also contributes by increasing wind shear, a critical factor in tornado formation.

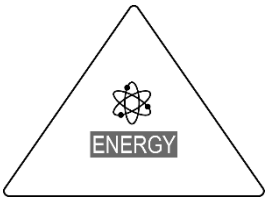
Together, these elements create ideal conditions for supercells and tornadoes in the central U.S.

Occurrence (5 of 7)



Slide 5-14, Common Myths about Tornadoes

This is energy.

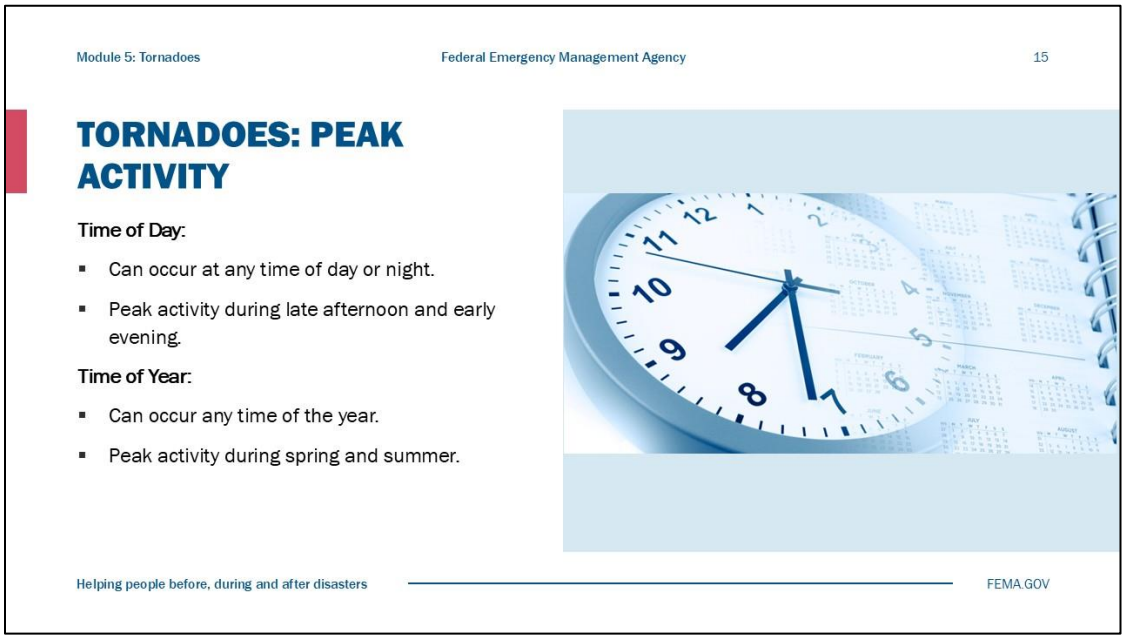


It is a common myth that tornadoes do not strike urban areas or cities. Tornadoes have, in fact, hit many urban areas and cities, for example:

- Miami, Florida
- Nashville, Tennessee
- Dallas, Texas
- Salt Lake City, Utah
- Cincinnati, Ohio
- Detroit, Michigan
- Atlanta, Georgia
- New York, New York
- St. Louis, Missouri

The next several pages will present key information about the geographical and seasonal trends of convective storms in the United States.

Occurrence (6 of 7)



Slide 5-15, Tornadoes: Peak Activity

Time of Day: Tornadoes can occur at any time of day or night. Peak activity occurs during late afternoon and early evening. In the southeast, many tornadoes occur at night and in the morning.

Time of Year: Tornadoes can occur at any time of the year, but peak activity occurs during spring and summer.

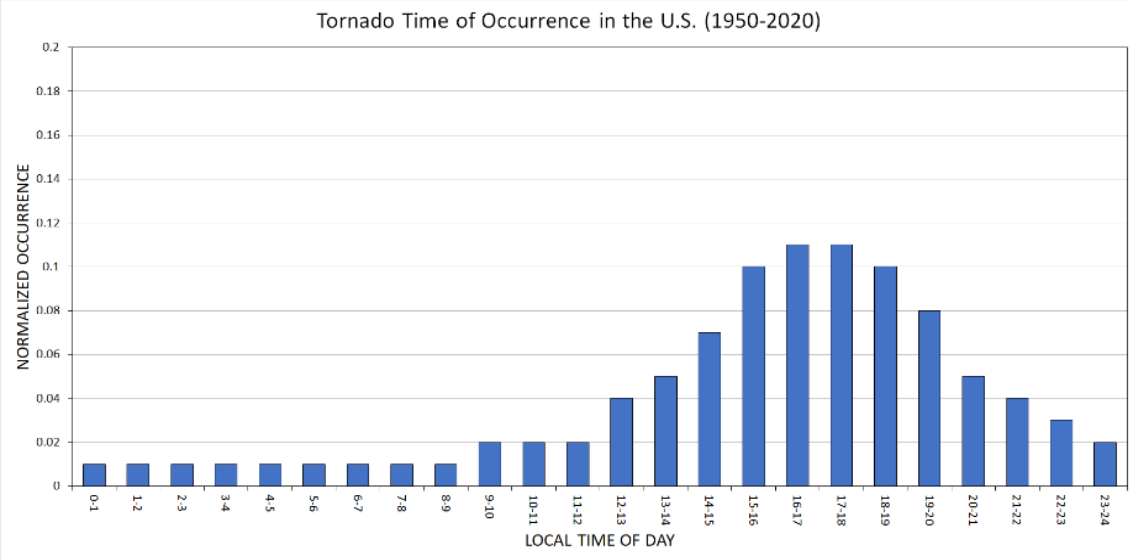
The frequency of tornado formation is closely related to the clash of warm and cold air masses in the progression of the warm season. As a result:

- Early spring tornadoes tend to occur in the southeast and south-central regions.
- Late spring tornadoes generally occur farther north, in and around Kansas and Nebraska.
- In mid-summer, most of Tornado Alley is susceptible to tornadoes.
- In late summer, the upper Midwest and Ohio valleys tend to have stronger tornadoes.
- In late autumn, the pattern shifts back southward.

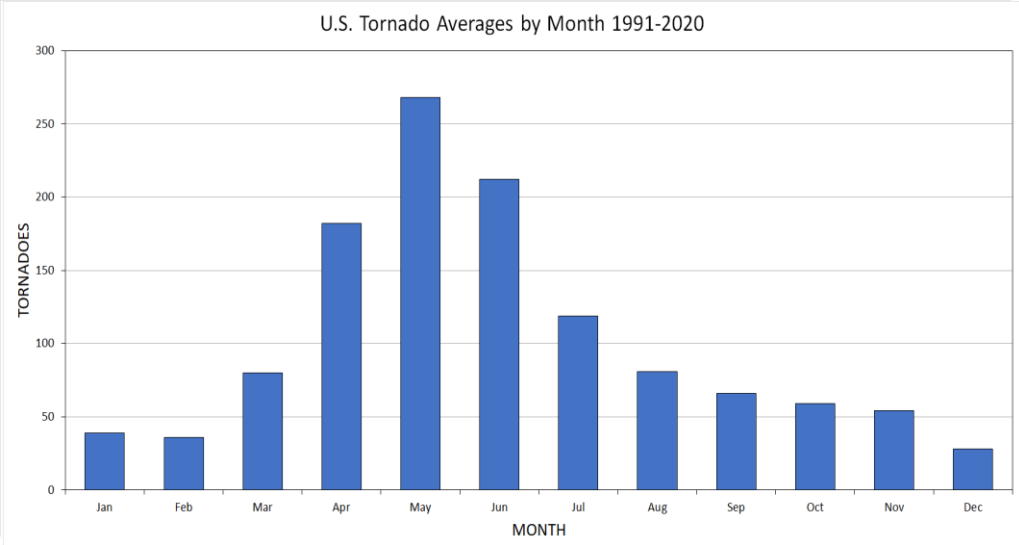
Although the winter months have historically yielded the fewest tornadoes, deadly winter outbreaks can and do occur.

More detail is provided in the following graphs.

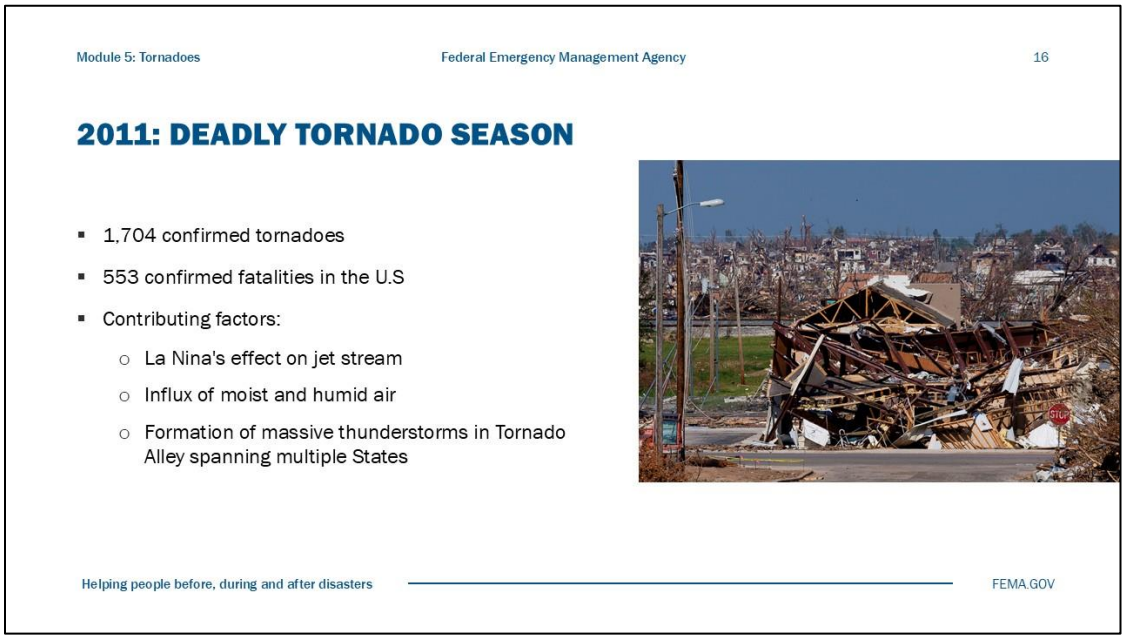
This graph shows the average time of day at which tornadoes occurred across the United States from 1980 to 2010, with peak activity in late afternoon and early evening.



This graph shows the average monthly number of tornadoes from 1991 to 2010 in the United States. Although the peak month is May, tornado activity is not limited to any particular time of year. However, tornadoes, like thunderstorms, happen most frequently in the spring and summer months.



Occurrence (7 of 7)

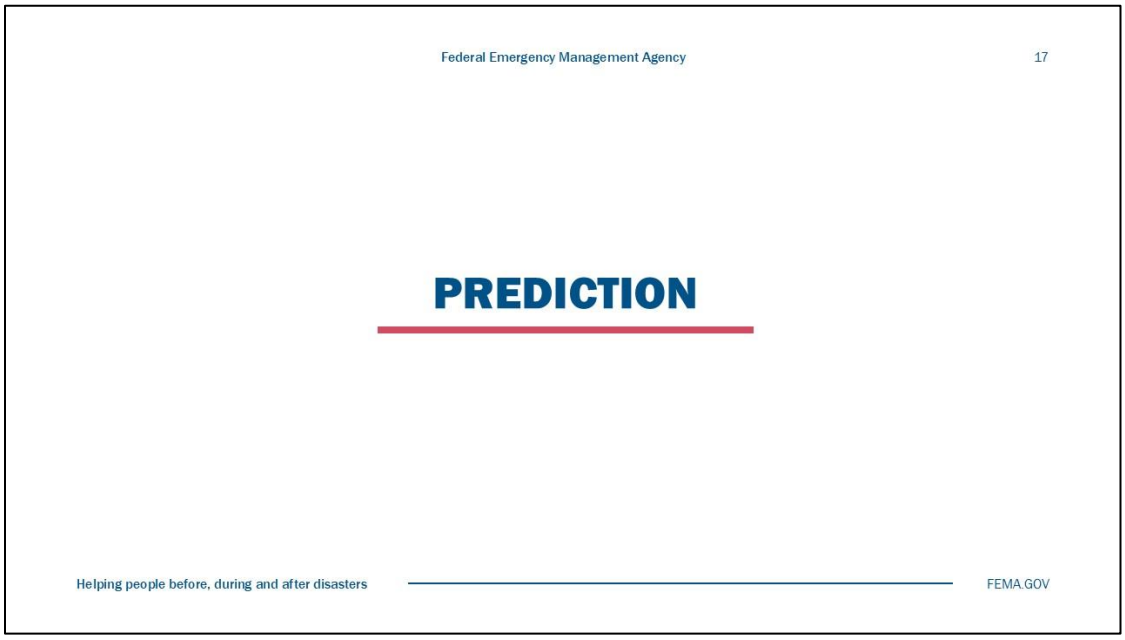


Slide 5-16, 2011: Deadly Tornado Season

The 2011 outbreak of tornadoes across the southern United States (which included the massively destructive tornado in Joplin, Missouri) was devastating and record-breaking.

- The 2011 tornado outbreak resulted from the formation of massive thunderstorms in Tornado Alley, fed from an influx of moist and humid air. The thunderstorms stretched across multiple states, spawning tornadoes that lasted as long as 10 minutes.
- Researchers have concluded that La Niña played a factor in the 2011 tornado outbreak. As you learned in the previous module, La Niña affects the position of the jet stream, intensifying and shifting weather patterns on a national scale. The position of the jet stream during the 2011 outbreak was similar to its position during two other massive tornado outbreaks in 2002 and 1974.

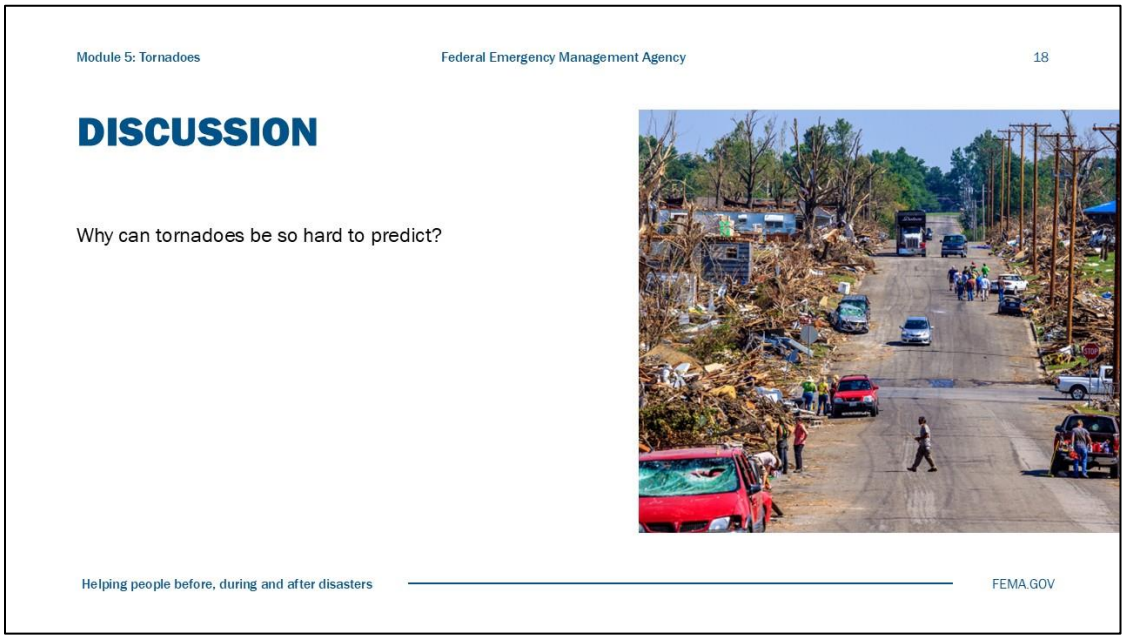
Prediction (1 of 3)



Slide 5-17, Prediction

Not applicable.

Prediction (2 of 3)



Slide 5-18, Discussion

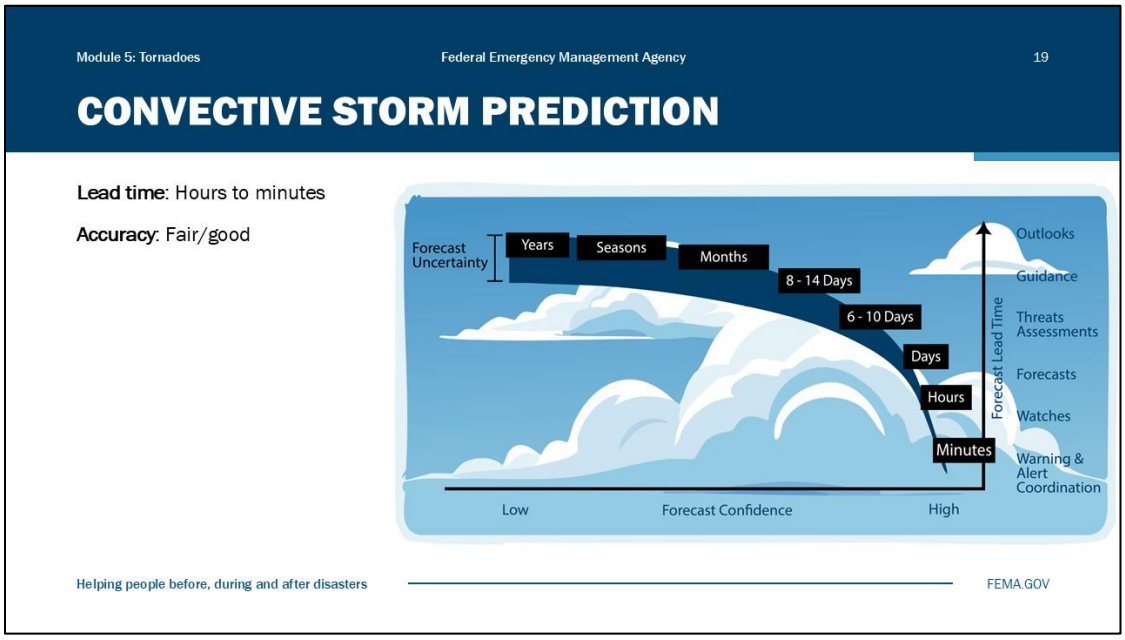
Why can tornadoes be so hard to predict?

Forecasters generally use the following sources of information to predict these tornado outbreaks:

- Radar technology, including Doppler radar;
- Satellite imagery;
- Computer models;
- Weather balloons and
- People on the ground (i.e., storm chasers, reporters, emergency managers, victims, etc.)

Discussion Question: Why are tornadoes so hard to predict?

Prediction (3 of 3)



Slide 5-19, Convective Storm Prediction

Convective Storm Prediction

- Lead time: Hours to minutes
- Accuracy: Fair/good

Forecasts of severe convective weather are based on a combination of:

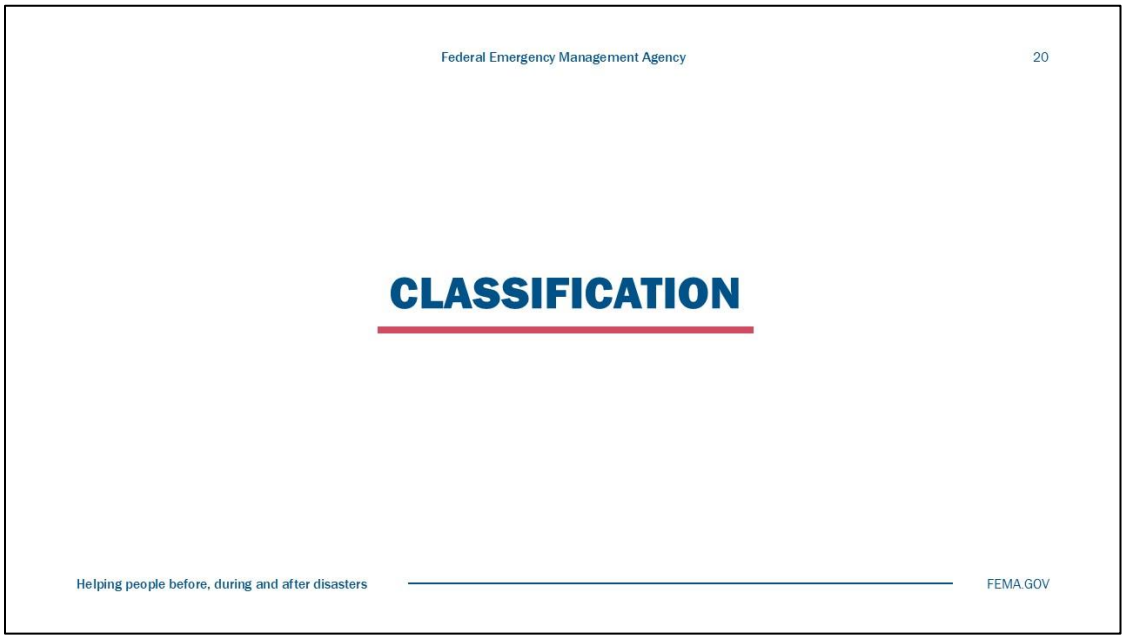
- Extrapolation of current conditions;
- Climatology;
- Application of conceptual models (experience); and
- Guidance from numerical forecast models.

Although the lead time for predicting convective storms can be low (hours to minutes), the accuracy is generally fair to good.

In general, forecasts are best expressed probabilistically because:

- The current state of the atmosphere is never completely known.
- Atmospheric flow can vary in time and space from smooth and uniform to turbulent and chaotic.

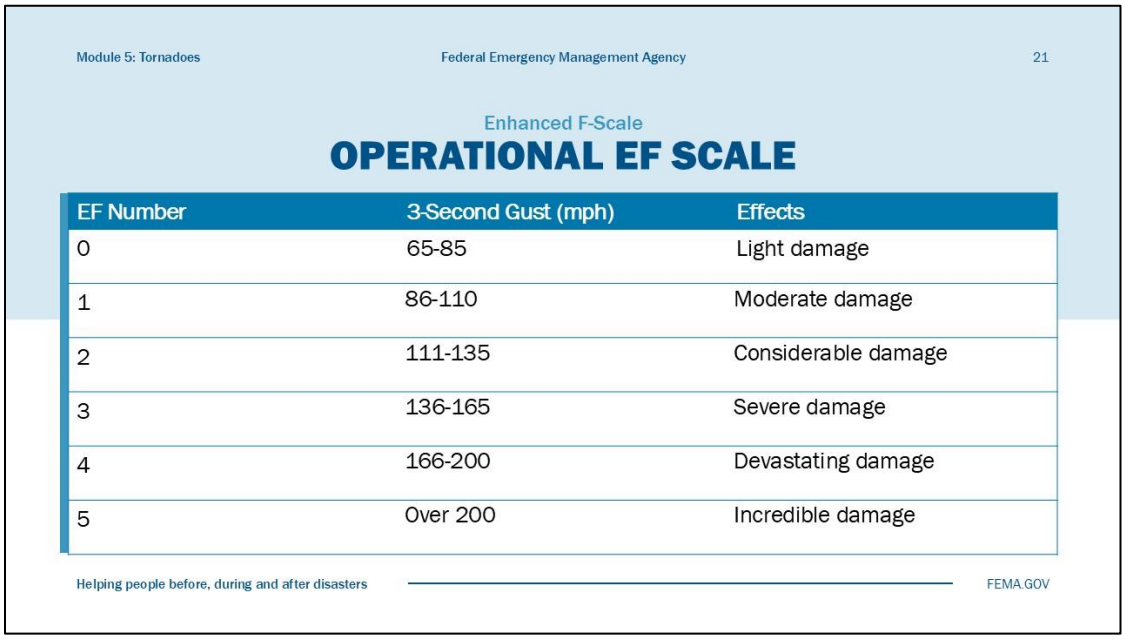
Classification (1 of 2)



Slide 5-20, Classification

Not applicable.

Classification (2 of 2)



Slide 5-21, Enhanced EF Scale

Operational EF Scale

EF Number	3 Second Gust (mph)	Effects
0	65-85	Light damage
1	86-110	Moderate damage
2	111-135	Considerable damage
3	136-165	Severe damage
4	166-200	Devastating damage
5	Over 200	Incredible damage

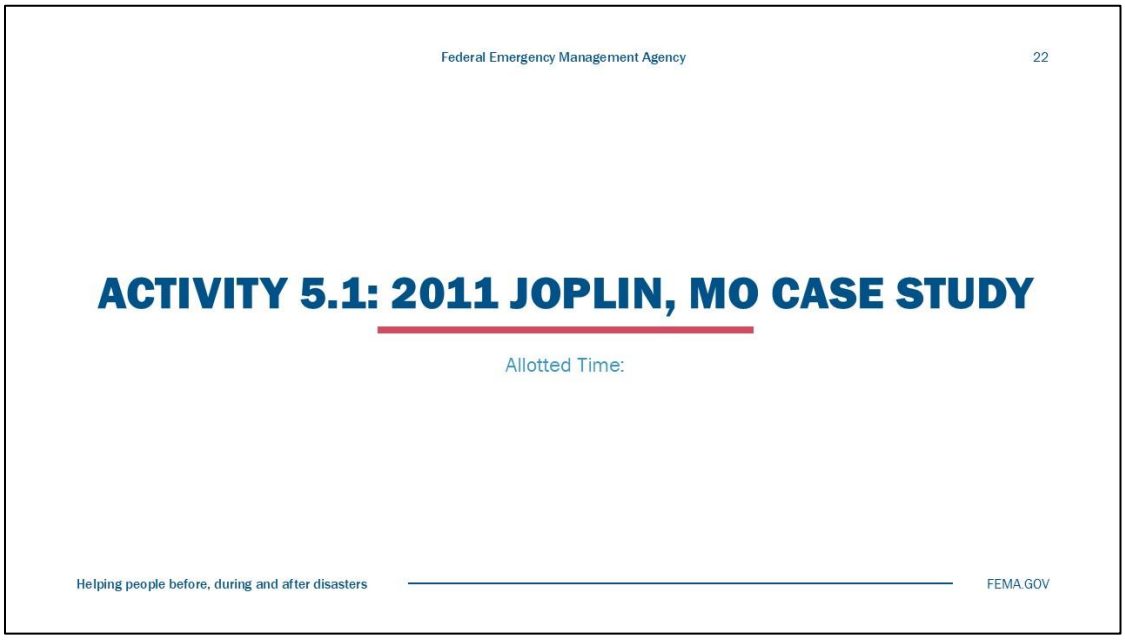
Note that this scale is logarithmic, meaning that the damage intensity increases exponentially with each category on the scale, with higher categories representing significantly greater destructive power compared to the previous one; essentially, the damage jump between an EF1 and EF2 is much larger than the jump between an EF0 and EF1, etc.

The F-Scale: In 1971, severe storms researcher Ted Fujita introduced a scale for characterizing tornadoes by area and intensity and extrapolating wind speed from tornado-caused damage. The F-Scale became the heart of the tornado database, which contains a record of all tornadoes in the United States from 1950 to the present day.

The EF-Scale: In 2007, an enhanced version of the scale came into use. This Enhanced F-Scale has the same basic structure as the original scale, and it supports and maintains the original tornado database. However, it more accurately estimates wind speeds as they correlate to the damage that has been caused (primarily to buildings).

It is important to understand that this scale is used to classify a tornado **after** the tornado occurs. (For example, if a tornado moves through a neighborhood, the type, area, and extent of damage will be assessed to determine a wind speed range, and finally an EF number, e.g., EF-2.)

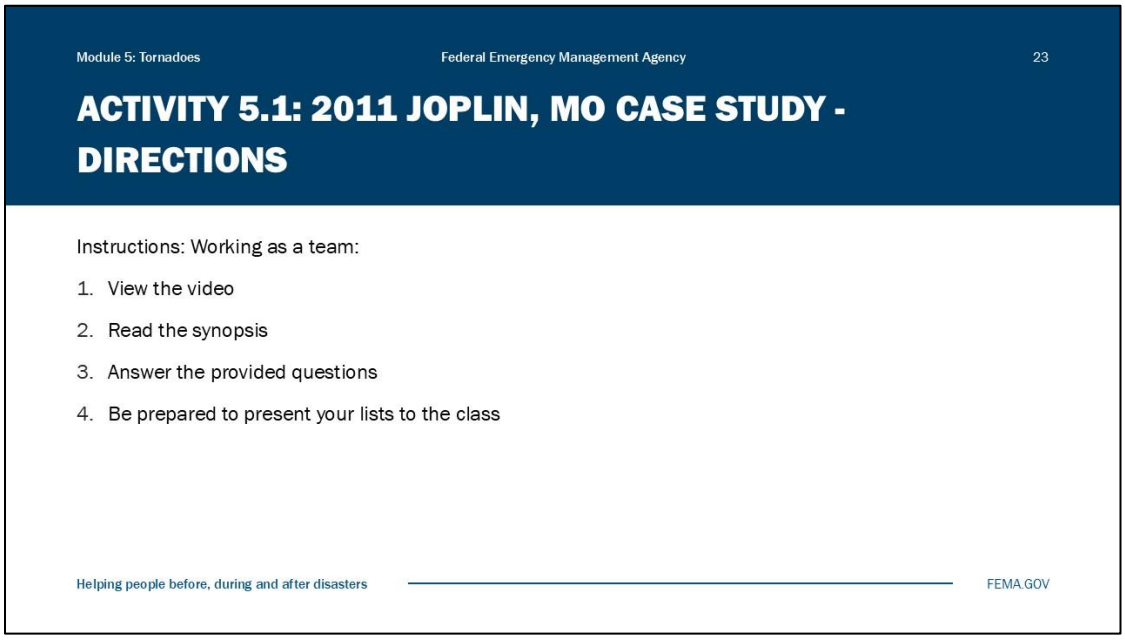
Activity 5.1: 2011 Joplin, MO Case Study (1 of 2)



Slide 5-22, Activity 5.1: 2011 Joplin, MO Case Study

Not applicable.

Activity 5.1: 2011 Joplin, MO Case Study (2 of 2)



Slide 5-23, Activity 5.1: 2011 Joplin, MO Case Study – Directions

Activity 5.1: 2011 Joplin, MO Case Study – Directions for the Students:

Working as a team:

1. View the video
2. Read the synopsis
3. Answer the following questions and be prepared to present your lists to the class:
    a. What conditions made this storm so devastating?

    b. What were the complicating factors during this tornado incident?

c. What are some ideas to mitigate against repeats of the problems?

Meteorologist

Video Meteorologist (URL: https://www.youtube.com/watch?v=t8aWzAuWOmo)

In this video, meteorologist Jeff Penner breaks down the Joplin weather system that created the deadliest, single tornado since modern record keeping began in 1950.

Video Transcript:

May 22nd 2011, 5 years ago, was a very, very bad day in Joplin and we're gonna look a little bit at the meteorology: how did the weather set up? Well with a low pressure area in South Dakota, there is a cold front right through Omaha and near Kansas City and Oklahoma. Warm front off to the north, and then a dry line down to the south.

Here's Joplin down here, so we had a warm, humid air mass from the Gulf of Mexico, we had a hot dry air mass coming in out of Oklahoma, and a cooler, drier air mass coming in out of Kansas. All intersecting in southeast Kansas and southwest Missouri, and also you had a jet- stream moving from west to east above all of this.

So you had convergence at the surface of all these air masses, and the winds are coming in from the southeast of the low levels while the upper levels are going in from the west and southwest. There was shear turning of the winds with height, and everything was there for thunderstorm development. That's where we had some of these super cells form. When they formed, it was so humid that they became very big thunderstorms and began to rotate and, unfortunately, one of those produced a very large tornado right over Joplin. But now it wasn't just Joplin on that day they got hit it was a whole severe weather outbreak from eastern Oklahoma all the way up into the great lakes. There were 75 tornado reports, 359 reports of hail, and 409 reports of wind for a total of 843 reports of severe weather.

There is even some severe weather in our area and Lafayette County; there are a couple smaller tornadoes on the eastern part of our viewing area, and then it moved off to the east. So, quite an active day 5 years ago

Here's a look at the satellite picture from that day. Here's Kansas City; Joplin's here; see these bumps in the cause? These are anvil, this whole white area, the anvil of the thunderstorms that the bumps the overshooting top— that's where the top of the thunderstorm shoots above the anvil into the lower part of the stratosphere. That means there's some intense rising motion you can see in southeast Kansas--there were some and even in Central Missouri and then these move right in to the Joplin area. The radar is very impressive when you see a radar image like this and a very dangerous signature, the hook, see the red here. This is Joplin and there's a hook and the reason why there's a hook, the rain is wrapping around the thunderstorm and the tornadoes usually are right in there. Unfortunately, it's right over the city of Joplin, as things continue to move, there are very impressive signatures on radar. The track at this is where it was at five--right through the middle part of the city north of 32nd Street and south of Duquesne there--right through the city. It was in the evening;

people were out--just absolutely horrific, Let's hope nothing like this ever happens again in a city because that is just horrible. The Joplin tornado facts: one-mile wide, 200 miles-per-hour winds as strong as it was on the ground for 38th minutes; 7,000 homes destroyed. And there is a picture of the tornado--a very violent day in Joplin and in southwest Missouri. This is tornado season, so just keep in mind the peak for our area is April and May, It's been quiet so far but in the next week to 10 days and early June, it's gonna be active a lot, so keep an eye to the sky. On average of sixty-eight tornadoes in Kansas and Missouri, that's one tornado per day on average, so have a plan in place; know how to get warnings when they're issued; stay safe, Stay with 41 Action News, and we will keep you advised.

Activity 5.1 – Job Aid 1

The **2011 Joplin tornado** was a catastrophic EF5-rated multiple-vortex tornado that struck Joplin, Missouri, late in the afternoon of Sunday, May 22, 2011. It was part of a larger late-May tornado outbreak and reached a maximum width of nearly 1 mile (1.6 km) during its path through the southern part of the city.[6] It rapidly intensified and tracked eastward across the city, and then continued eastward across Interstate 44 into rural portions of Jasper County and Newton County.[7] It was the third tornado to strike Joplin since May 1971.[8]

Overall, the tornado killed 158 people (with an additional four indirect deaths), injured some 1,150 others, and caused damages amounting to a total of $2.8 billion. It was the deadliest tornado to strike the United States since the 1947 Glazier–Higgins–Woodward tornadoes, and the seventh-deadliest overall. It also ranks as the costliest single tornado in United States history.

In a preliminary estimate, the insurance payout was expected to be $2.2 billion; the highest insurance payout in Missouri history, higher than the previous record of $2 billion in the April 10, 2001 hail storm, which is considered the costliest hail storm in history as it swept along the I-70 corridor from Kansas to Illinois.[9] Estimates earlier stated Joplin damage could be $3 billion. By July 15, 2011, there had been 16,656 insurance claims.[10]

Meteorological synopsis

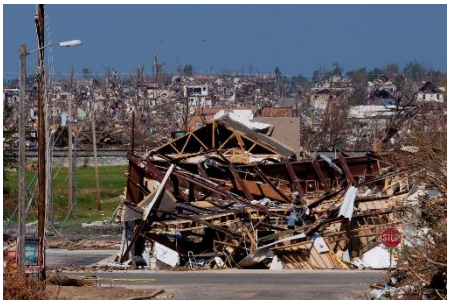
The tornado initially touched down just east of the Kansas state line near the end of 32nd Street at 5:34 pm CDT (22:34 UTC) and tracked due east, downing a few trees at EF0 intensity. Eyewitnesses and storm chasers reported multiple vortices rotating around the parent circulation in this area.[11][12] Civil defense sirens sounded in Joplin 20 minutes before the tornado struck in response to tornado warnings issued by the National Weather Service, but many Joplin residents did not hear them.[13] The tornado rapidly strengthened to EF1 intensity as it continued through rural areas towards Joplin, snapping trees and power poles and damaging outbuildings. The widening tornado then tracked into the more densely populated southwest corner of Joplin, near the Twin Hills Country Club. Several homes were heavily damaged at EF1 to EF2 strength at a subdivision in this area. The tornado continued to strengthen as it ripped through another subdivision just east of Iron

Gates Rd. Numerous homes were destroyed at EF2 to EF3 strength at that location, and multiple vehicles were tossed around, some of which were thrown or rolled into homes.[11]



EF5 damage to the St. John's Regional Medical Center, which later had to be torn down due to deformation of its foundation and underpinning system.

The destroyed area in the tornado's damage path.





Several 300-pound concrete parking stops anchored with rebar were torn from a parking lot in this area and were thrown up to 60 yards away. Iowa State University wind engineer Parka Sarkar was able to calculate the force needed to remove the parking stops, and he found that winds exceeding 200 mph were needed to tear them from the parking lot.[14] Damage became remarkably widespread and catastrophic at and around the nearby St. John's Regional Medical Center. The hospital lost many windows, interior walls, ceilings, and part of its roof, and its life flight helicopter was also blown away and destroyed. Six fatalities were reported there, and the nine-story building was so severely damaged that it was deemed structurally compromised and was later torn down. An engineering survey of the building revealed that the foundation and underpinning system were damaged beyond repair. According to the NWS office in Springfield, Missouri, such extreme structural damage to such a large and well-built structure was likely indicative of winds at or exceeding 200 mph.

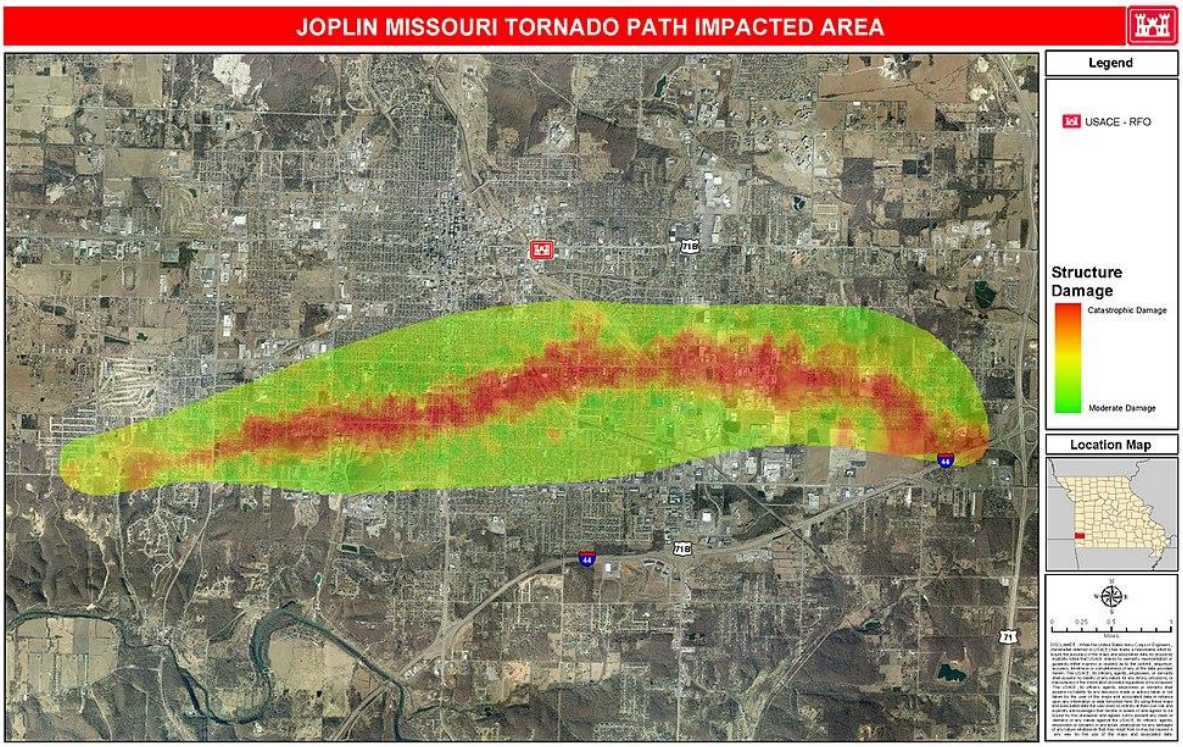
A large church, Greenbriar Nursing Home, Franklin Technology Center, St. Mary's Catholic Church and School, and Joplin High School were all destroyed along this corridor. No one was in the high school at the time; the high school graduation ceremonies held about 3 miles (4.8 km) to the north at Missouri Southern State University had concluded shortly before the storm. Pieces of cardboard were found embedded sideways into stucco walls that remained standing at Joplin High School.

Steel beams and pieces of fencing were deeply embedded into the ground in fields near the high school as well, and steel fence posts were bent to the ground in opposite directions. A school bus was thrown into a nearby bus garage. The Greenbriar nursing home was completely leveled, with 21 fatalities occurring there alone. As the tornado crossed Connecticut Avenue further to the east, it destroyed several large apartment buildings, Dillon's grocery, and a bank.

Only the concrete vault remained at the bank, and a wooden 2x4 board was found speared completely through a concrete curb at one location as well. The tornado then approached Range Line Road, the main commercial strip in the eastern part of Joplin, flattening additional neighborhoods along 20th Street.

The tornado lifted east of Diamond at 6:12 pm CDT (23:12 UTC) according to aerial surveys. The tornado's total track length was at least 22.1 miles (35.6 km) long. Overall, 6,954 homes were destroyed, 359 homes had major damage, and 516 homes had minor damage. A total of 158 people were killed, and 1,150 others were injured along the path. A separate EF2 tornado touched down near Wentworth from the same supercell about 25 miles (40 km) east-southeast of Joplin.

Aftermath and impact



East of Joplin, a Risk Management Plan facility released 3,000 to 5,000 pounds (1,400 to 2,300 kg) of anhydrous ammonia; it was contained within 2 days.

The $2.8 billion in damage is the largest amount for a tornado since 1950.

The Joplin Globe reported that 54 percent of the people died in their residences, 32 percent died in non-residential areas and 14 percent died in vehicles or outdoors. After the tornado, Joplin officials announced plans to require hurricane ties or other fasteners between the houses and their foundations (devices add about $600 US to the construction costs). Officials rejected a proposal to require concrete basements in new houses. Officials noted that only 28 percent of Joplin's new homes had basements as of 2009, compared with 38 percent two decades before.

Officials said they rescued 944 pets and reunited 292 with owners.

On June 10, 2011, it was announced that a rare fungal infection, zygomycosis, had been noted to cause at least eight serious cases of wound infection among the injured survivors, confirmed by reports to the Missouri Department of Health and Senior Services.

Response

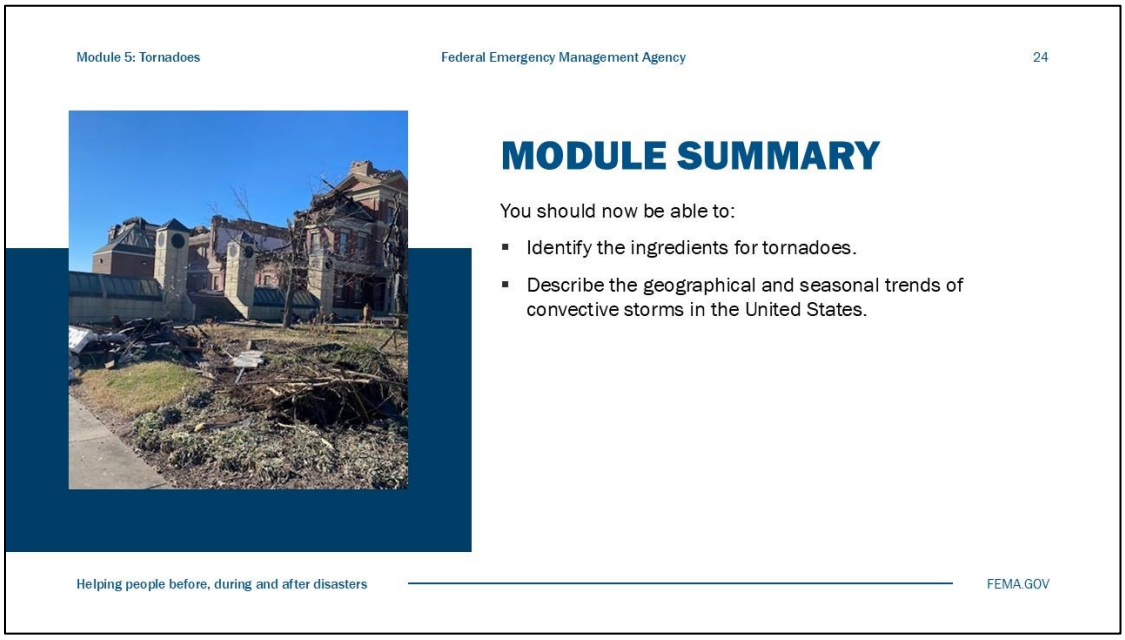
Social Media Response: The tornado also highlighted a new form of disaster response, using social media. This type of disaster response is now known as Social Media Emergency Management. News

outlets began aggregating images and video from eyewitnesses shared through social media. Public, citizen-led Facebook groups as well as websites, such as Joplin Tornado Info coordinated information, needs, and offers. The results were so effective that the project became a finalist in the 2011 Mashable Awards for Best Social Good Cause Campaign.



Media handling: President Barack Obama toured the community on May 29, flying into Joplin Regional Airport and speaking at a memorial at the Taylor Performing Arts Center at Missouri Southern State University about 2 miles (3 km) north of the worst of the devastation. Obama had been on a State visit to Europe at the time of the storm. Members of the controversial Westboro Baptist Church were also scheduled to protest the same day in Joplin, but they did not show up. There was a massive counter protest that was organized in response to the Westboro protest, in which thousands of protesters showed up holding signs saying, "God Loves Joplin" and "We Support You Joplin."

End of Module (1 of 2)

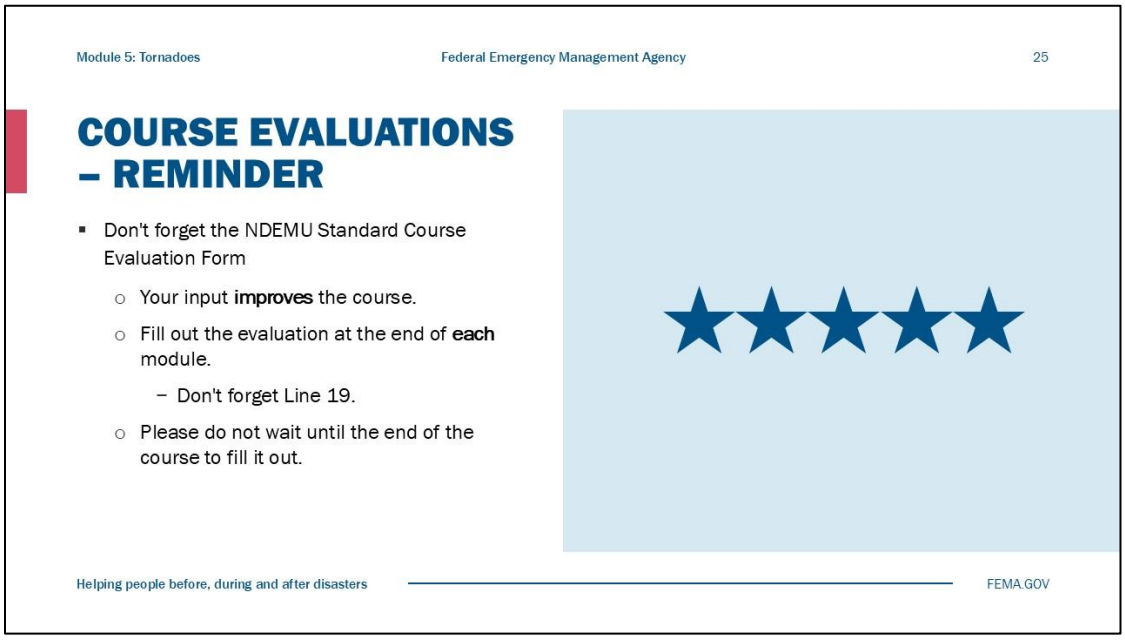


Slide 5-24, Module Summary

You should now be able to:

- Identify the ingredients for tornadoes.
- Describe the geographical and seasonal trends of convective storms in the United States.

End of Module (2 of 2)



Slide 5-25, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

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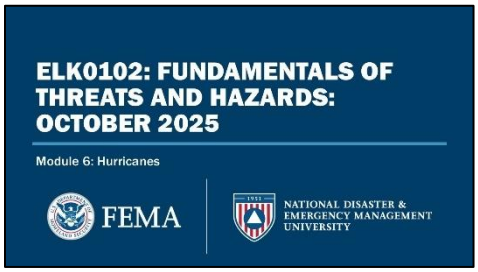
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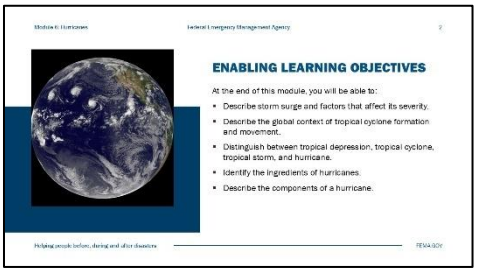
Module 6

Hurricanes

Administration



Slide 6-1, Module 6: Hurricanes



Slide 6-2, Enabling Learning Objectives

Duration

1 hour 45 minutes

Terminal Learning Objective (TLO)

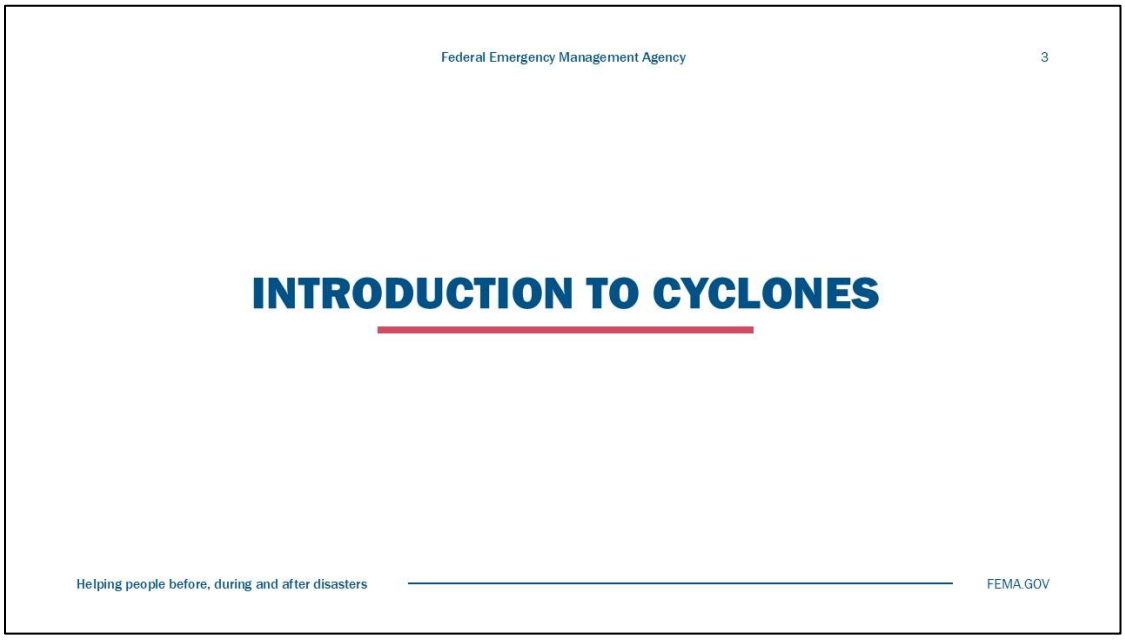
By the end of this module, participants will be able to demonstrate comprehensive knowledge of hurricane dynamics, including their formation, classification, movement, and impact, to support effective disaster risk management and response planning.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Describe storm surge and factors that affect its severity.
- Describe the global context of tropical cyclone formation and movement.
- Distinguish between tropical depression, tropical cyclone, tropical storm, and hurricane.
- Identify the ingredients of hurricanes.
- Describe the components of a hurricane.

Introduction to Cyclones (1 of 2)



Slide 6-3, Introduction to Cyclones

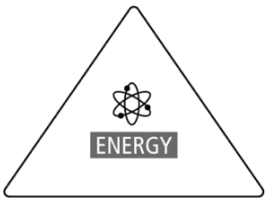
Not applicable.

Introduction to Cyclones (2 of 2)



Slide 6-4, Cyclone Terminology

This is energy.



What are cyclones? Begin with some important cyclone-related definitions:

- **Cyclone:** An atmospheric closed-circulation, low-pressure system rotating counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.
- **Tropical cyclone:** A cyclone with a warm core originating over tropical or subtropical waters, with surface wind circulation about a well-defined center. Once formed, a tropical cyclone is maintained by the extraction of heat energy from the ocean and heat export aloft. Types of tropical cyclones include:
  - **Tropical depression:** A tropical cyclone with winds of 38 mph or less.
  - **Tropical storm:** A tropical cyclone with winds of 39 - 73 mph.
  - **Hurricane:** A tropical cyclone with winds of 74 mph or more.

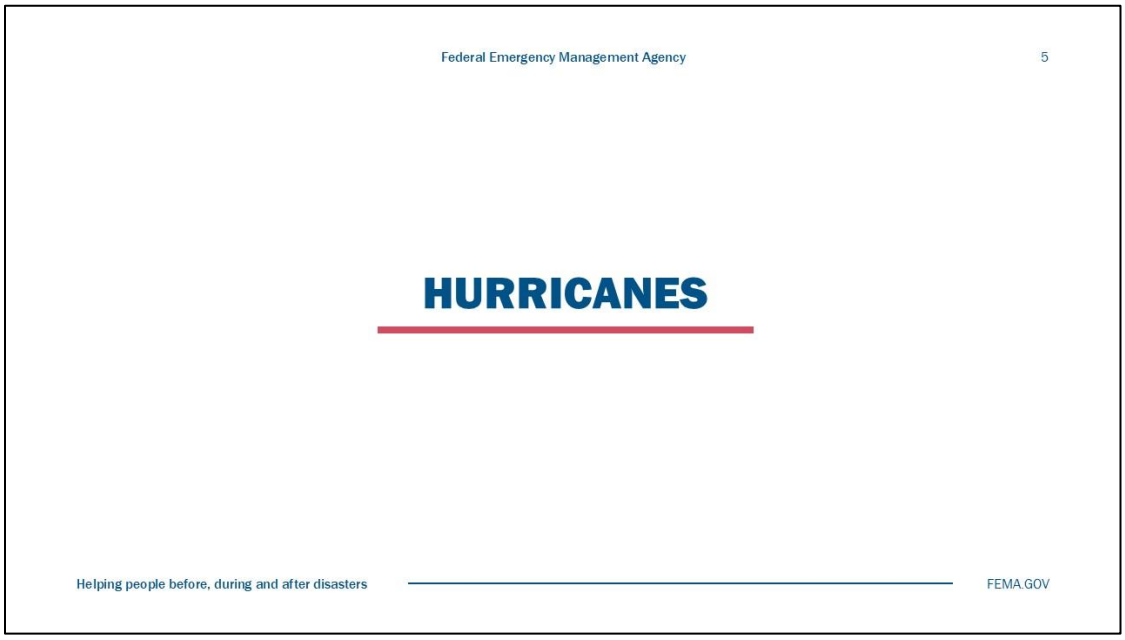
As you can see, the hierarchy of tropical depression, tropical storm, and hurricane is based on wind speeds. Although tropical depressions and tropical storms do not produce winds and storm surge as severe as those of hurricanes, they can still result in damaging winds and high rainfall amounts that cause freshwater flooding and tornadoes.

Tropical Cyclone Categories

Category	Wind Speed (mph)	Damage at Landfall	Storm Surge (feet)
1	74-95	**Minimal** While wind speeds are quicker than the speed a cheetah can run, there is not much damage to property.	4-5
2	96-110	**Moderate** Wind speeds are as fast or faster than a baseball pitcher's fastball. This category cyclone may break windows and destroy trees.	6-8
3	111-129	**Extensive** This wind speed is similar, or close, to the serving speed of many professional tennis players. This category cyclone can break windows and doors.	9-12
4	130-156	**Extreme** With winds quicker than the world's fastest rollercoaster, there is much damage to property in this category cyclone.	13-18
5	157 or higher	**Catastrophic** This category cyclone causes the most damage. With wind speeds similar to the speed of some high-speed trains, it destroys buildings.	19+

https://mynasadata.larc.nasa.gov/basic-page/hurricane-dynamics

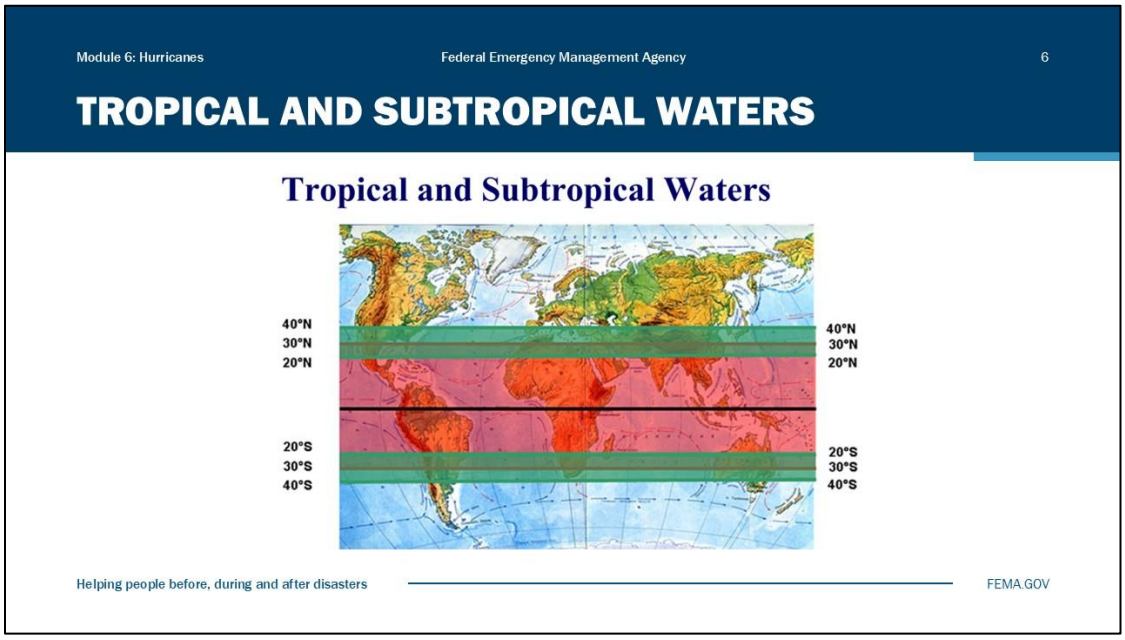
Hurricanes (1 of 3)



Slide 6-5, Hurricanes

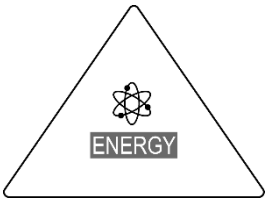
Not applicable.

Hurricanes (2 of 3)



Slide 6-6, Tropical and Subtropical Waters

This is energy.



A tropical cyclone can originate over tropical or subtropical waters.

The area in the middle on this visual shows the region of tropical waters that is accepted by major experts. This region:

- Stretches from 30° N to 30° S
- Has sea surface temperatures (SSTs) of 80 °F or higher
- Is where the greatest potential for cyclones to develop exists

Unlike extratropical cyclones, which derive energy from the horizontal temperature contrasts in the atmosphere, a tropical cyclone is maintained by extracting heat energy from the ocean at high temperatures and exporting heat aloft.

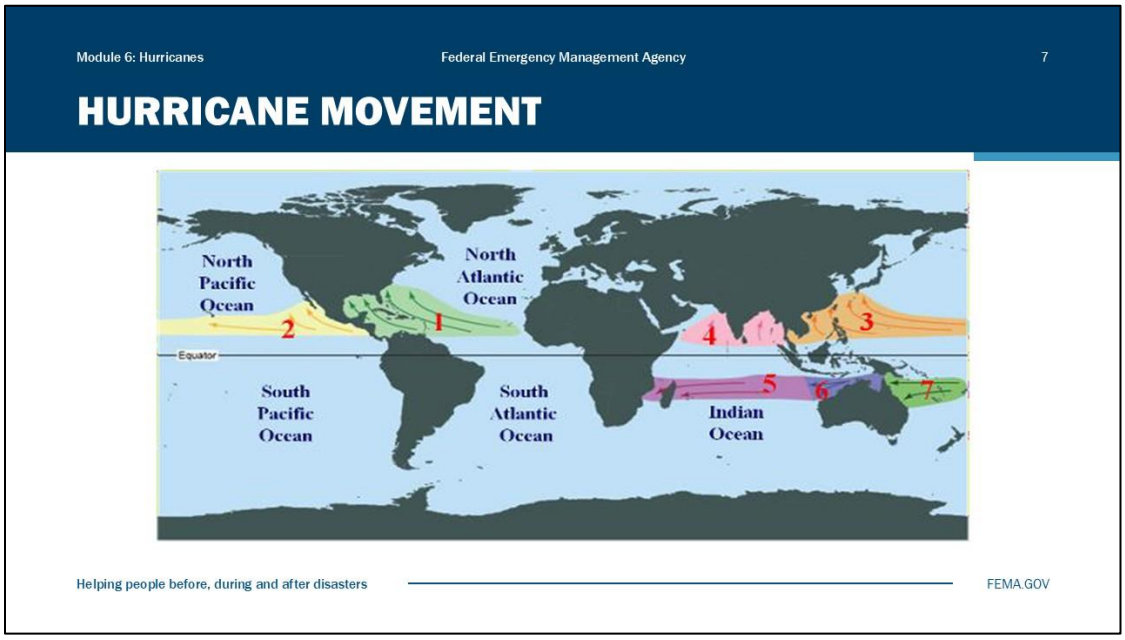
The areas above and below the tropical waters on the map indicate **subtropical waters**, the two regions that make up the border between tropical waters and more temperate regions.

Like tropical cyclones, subtropical cyclones are not frontal, synoptic-scale cyclones. However, unlike tropical cyclones, they:

- Have characteristics of extratropical cyclones—namely, existing in a weak to moderate horizontal temperature gradient region;
- Have a radius of maximum winds which is farther out (60 - 125 miles from the center) than what is observed for purely "tropical" systems;
- Have a less symmetric wind field and distribution of convection; and
- Have maximum sustained winds not stronger than about 33 m/s (74 mph).

Often, subtropical cyclones transform into true tropical cyclones. For example, Hurricane Otto (October 2010) began as a subtropical cyclone before becoming fully tropical.

Hurricanes (3 of 3)



Slide 6-7, Hurricane Movement

Hurricane Movement

This map illustrates the seven "basins" where tropical cyclones form on a regular basis.

The same type of storm (tropical cyclone) is called by different names in different regions of the world.

- **Hurricanes** occur in Regions 1 and 2. The term hurricane is generally used for tropical cyclones east of the International Dateline to the Prime (Greenwich) Meridian.
- **Typhoons** occur in the Western Pacific, in Region 3. The term typhoon is generally used for Pacific tropical cyclones north of the Equator and west of the International Dateline.
- **Tropical cyclones** occur in Regions 4, 5, 6, and 7. This area includes the Indian Ocean and the southwestern Pacific Ocean.

For the rest of this module, we will focus primarily on hurricanes. Most U.S. hurricanes are formed off the coast of Africa and move to the United States, sometimes lasting over 2 weeks over the ocean. But how do hurricanes travel from one continent to the other?

Most Northern Hemisphere hurricanes forming between 5° and 30° N typically move from east to west in the trade winds.

As hurricanes are pushed westward, they sometimes turn north or northwest out in the Atlantic, then curve toward the northeast, as a result of shifting winds in the middle and upper levels of the atmosphere.

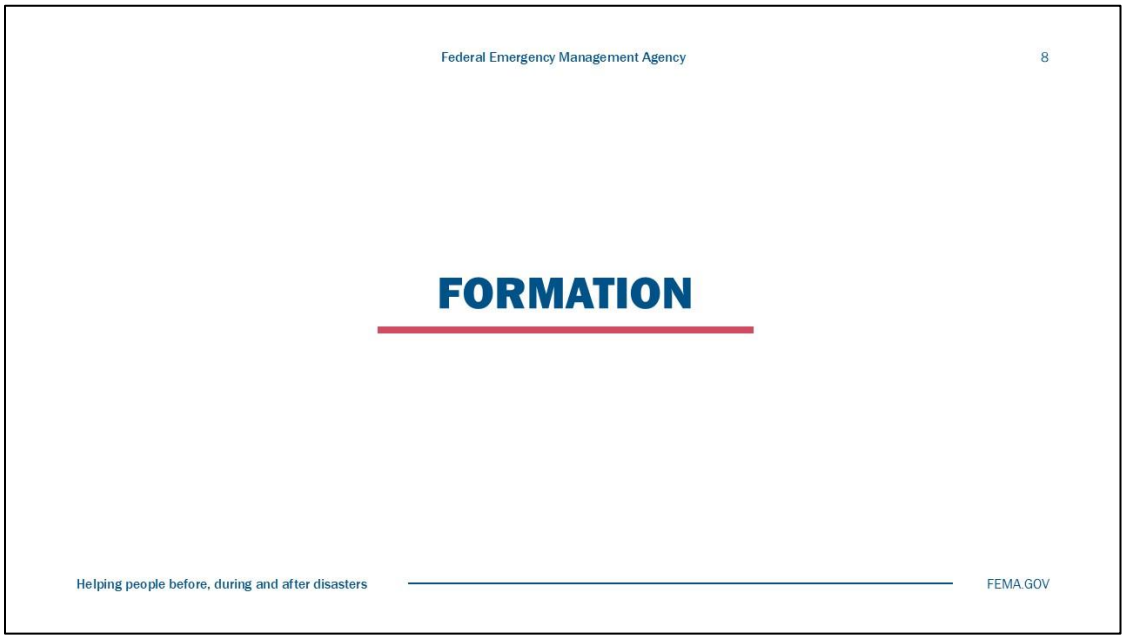
Storms that move up the East Coast usually pick up speed around North Carolina and may travel at speeds up to 70 mph.

THE SEVEN TROPICAL CYCLONE BASINS

Basin	Location	Beginning	Peak	Ending
Atlantic basin	North Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea	"Officially" June 1st	Early to mid-September	"Officially" November 30th
Northeast Pacific basin	Mexico to about the dateline	Late May or early June	Late August/early September	Late October or early November
Northwest Pacific basin	From the dateline to Asia, including the South China Sea	All year round; main season begins in July	All year round; main season peaks in late August/early September	All year round; main season ends in November
North Indian basin	Including the Bay of Bengal and the Arabian Sea	April	Double peak of activity in May and November	December
Southwest Indian basin	From Africa to about 100° E	Late October/early November	Double peak of activity – one in mid-January and one in mid-February to early March	May
Southeast Indian/Australian basin	100° E to 142° E	Late October/early November	Double peak in activity – one in mid-January and one in mid-February to early March	May

Basin	Location	Beginning	Peak	Ending
Australian/ Southwest Pacific basin	142° E to about 120° W	Late October/early November	Late February/early March	Early May

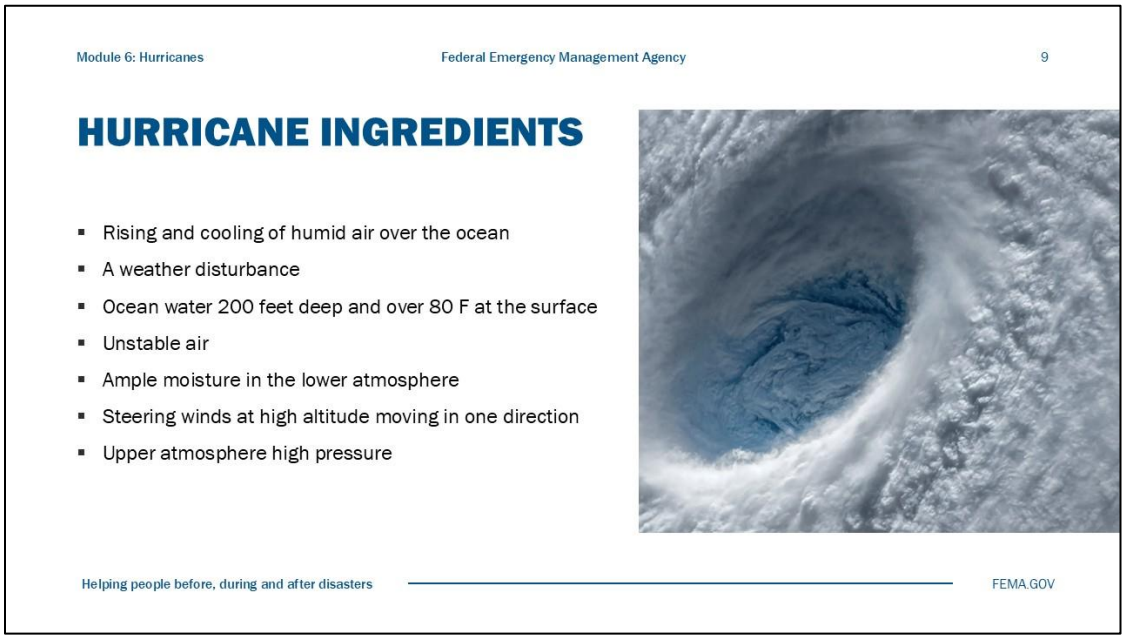
Formation (1 of 8)



Slide 6-8, Formation

Not applicable.

Formation (2 of 8)



Slide 6-9, Hurricane Ingredients

The ingredients for a hurricane include:

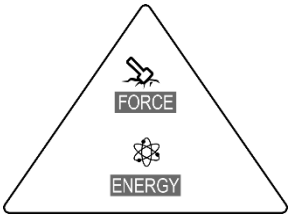
- Rising and cooling of humid air over the ocean;
- A weather disturbance;
- Ocean water 200 feet deep and over 80°F at the surface;
- Unstable air;
- Ample moisture in the lower atmosphere;
- Steering winds at high altitude moving in one direction; and
- Upper atmosphere high pressure.

Hurricanes are generated by the rising and cooling of humid air over the ocean, in combination with the following ingredients:

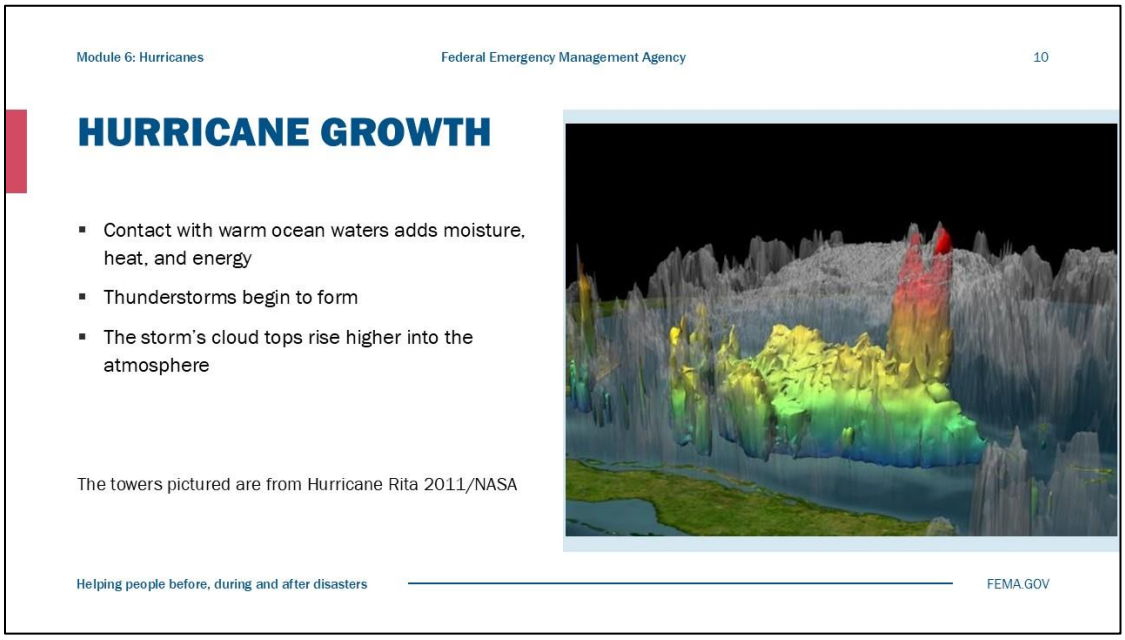
- A weather disturbance;
- Warm ocean water about 200 feet deep (60 m) and over 80°F (27°C;
- Unstable air (so the warm, moist air will continue rising);
- Ample moisture in the lower atmosphere (to supply heat energy);

- Steering winds at high altitude moving in one direction (to move the storm along without breaking it up); and
- Upper atmosphere high pressure (to help move out the rising air of the storm).

This is force and energy.



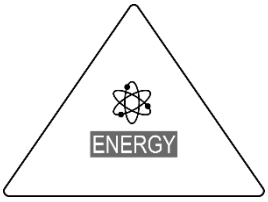
Formation (3 of 8)



Slide 6-10, Hurricane Growth

- Contact with warm ocean waters adds moisture, heat, and energy;
- Thunderstorms begin to form; and
- The storm's cloud tops rise higher into the atmosphere.

This is energy.

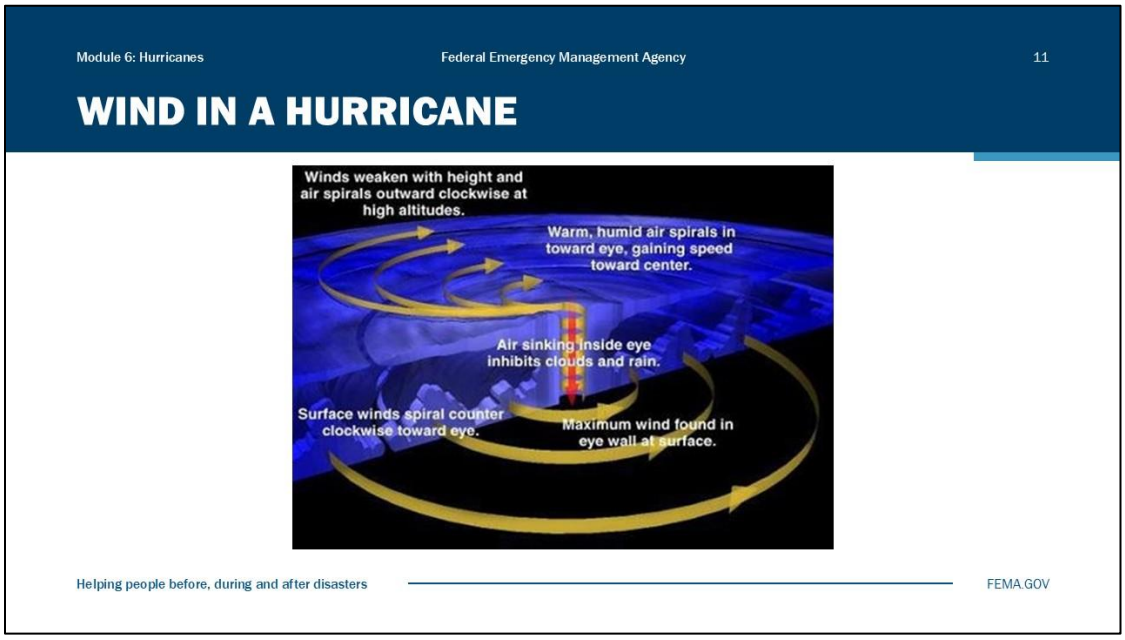


As the storm grows:

- Contact with warm ocean waters adds moisture, heat, and energy.
- Thunderstorms begin to form. In fact, on satellite imagery, the early stages of a tropical cyclone appear as a somewhat unorganized cluster of thunderstorms.
- The storm's cloud tops rise higher into the atmosphere.
- The storm remains intact and gains strength if the winds at these high levels of the atmosphere remain relatively light (meaning little to no wind shear).

With the right ocean and weather conditions, the storm can continue to strengthen until it becomes a tropical depression (winds less than 38 mph). It is at this point that the storm will take on its characteristic spiral appearance, resulting from both Earth's rotation and wind flow.

Formation (4 of 8)

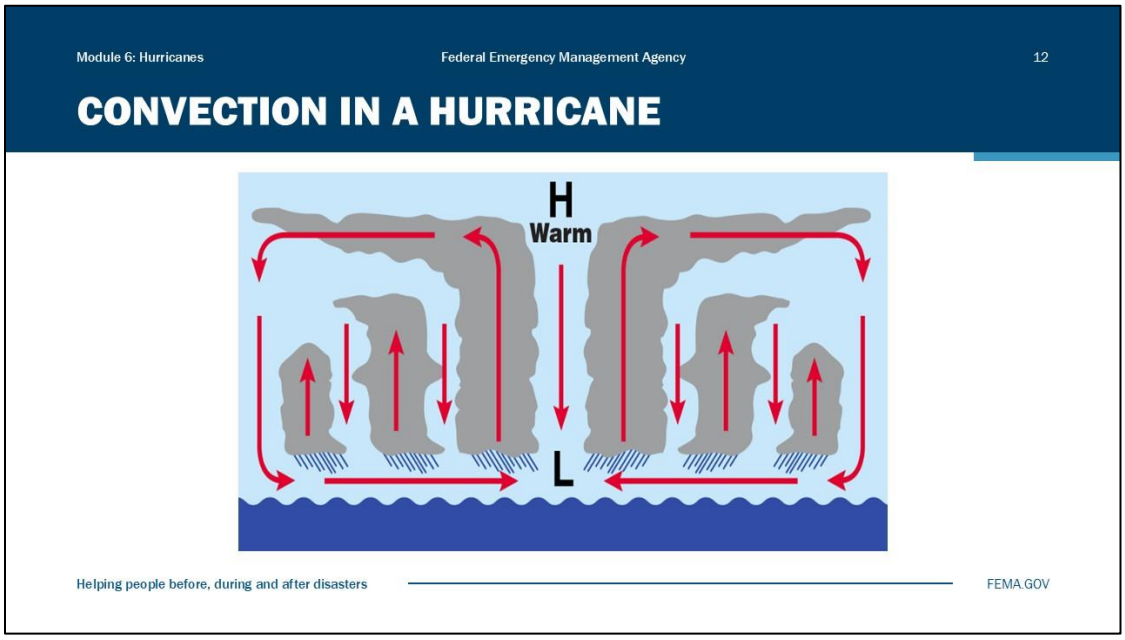


Slide 6-11, Wind in a Hurricane

The main structural components of a hurricane are:

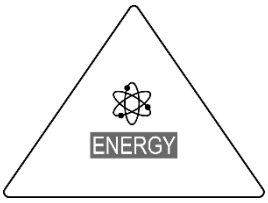
- Rain bands on the outer edges;
- The eye; and
- The eyewall.

Formation (5 of 8)



Slide 6-12, Convection in a Hurricane

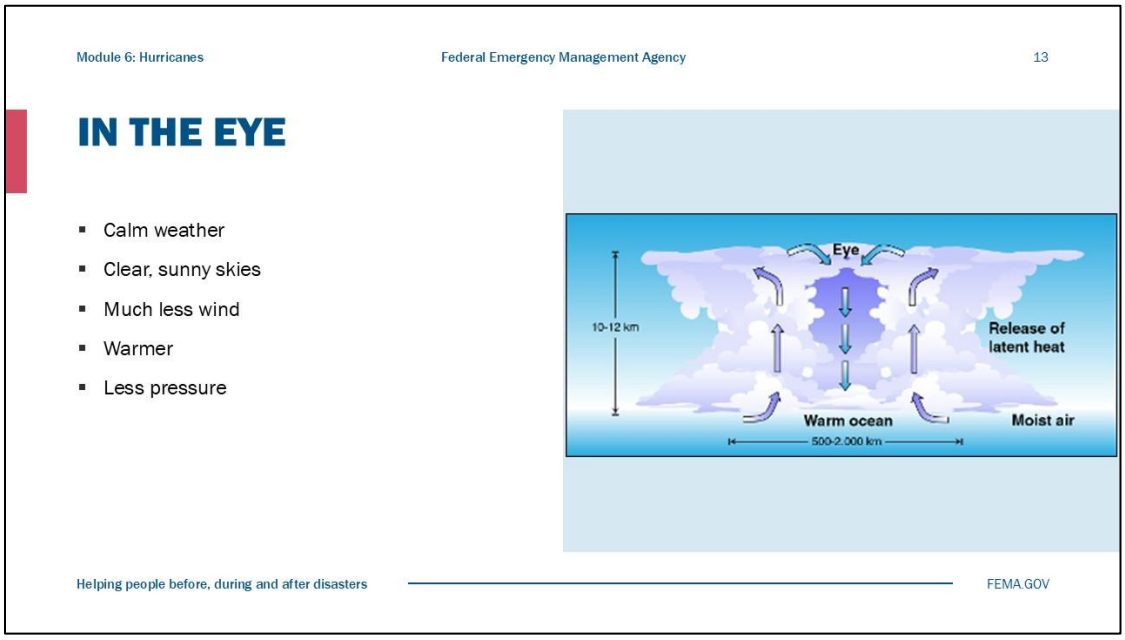
This is energy.



Recall that convection is a key element in all storms. Convection in a hurricane:

- Occurs in the eyewall and forms and maintains the eye;
- Is organized into long, narrow rain bands. These bands are oriented in the same direction as the horizontal wind, and because they seem to spiral toward the center of a hurricane, are sometimes called spiral bands; and
- Is fueled by the warm ocean surface water that supplies heat and moisture to the surface air spiraling in toward the center of the hurricane.

Formation (6 of 8)



Slide 6-13, In the Eye

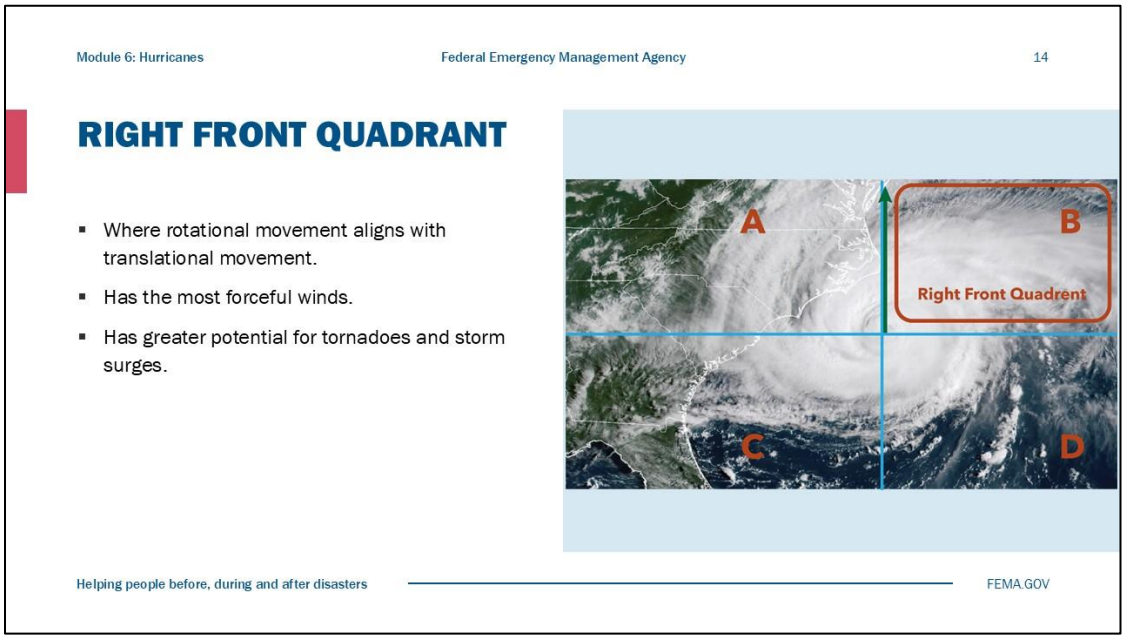
The eye of a hurricane:

- Is the roughly circular area of comparatively light winds that encompasses the center of a severe hurricane; and
- Is either completely or partially surrounded by the eyewall cloud, an organized band or ring of cumulonimbus clouds.

In the eye of the hurricane:

- The weather is calm, with clear, sunny skies. Dry, calm air is descending, and wind velocity dramatically decreases.
- It is much warmer.
- The pressure drops significantly. (Remember, a hurricane has closed wind circulation around a well-defined low-pressure center that is warmer than the surrounding air.)

Formation (7 of 8)



Slide 6-14, Right Front Quadrant

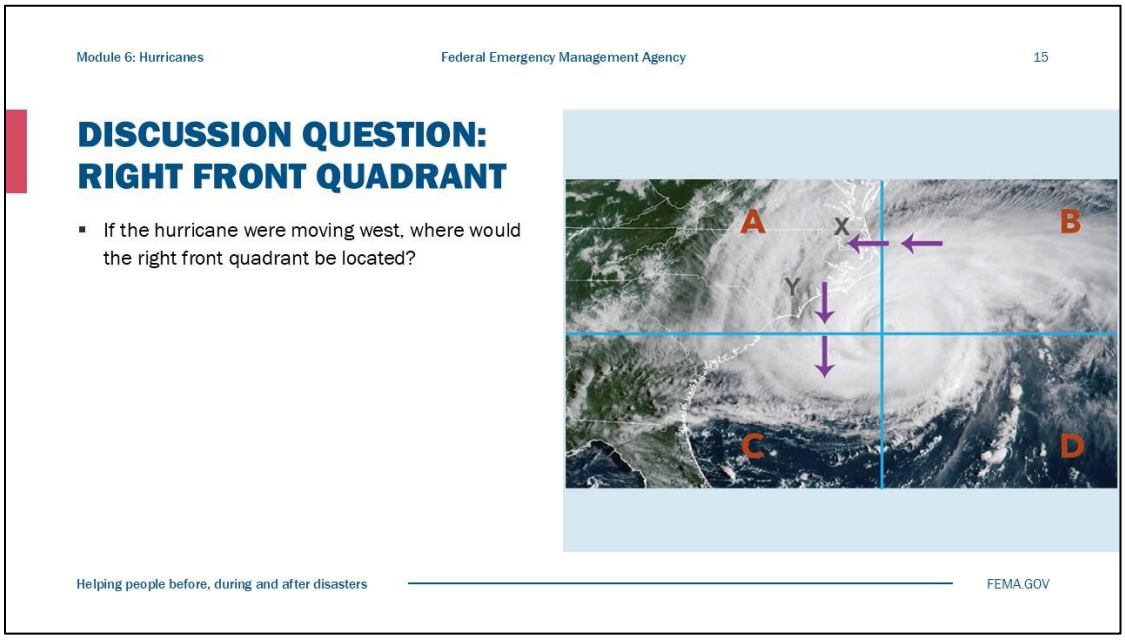
Unlike the eye, which is calm, the right front quadrant of a storm has the most forceful and damaging winds, as well as a heightened potential for tornadoes and storm surges. This is why regions projected to be hit by this quadrant are often of the greatest concern.

The intensity of the right front quadrant results from two types of movement:

- The rotational movement of the circulation (red arrows).
- The translational movement of the storm is actually traveling in its path (blue arrow).

In the right front quadrant, the rotational movement most closely aligns (points in the same direction) as the translational movement. The two movements are essentially added together for a compounded effect, resulting in the most forceful winds (i.e., the greatest power).

Formation (8 of 8)



Slide 6-15, Discussion Question: Right Front Quadrant

If the hurricane were moving west, where would the right front quadrant be located?

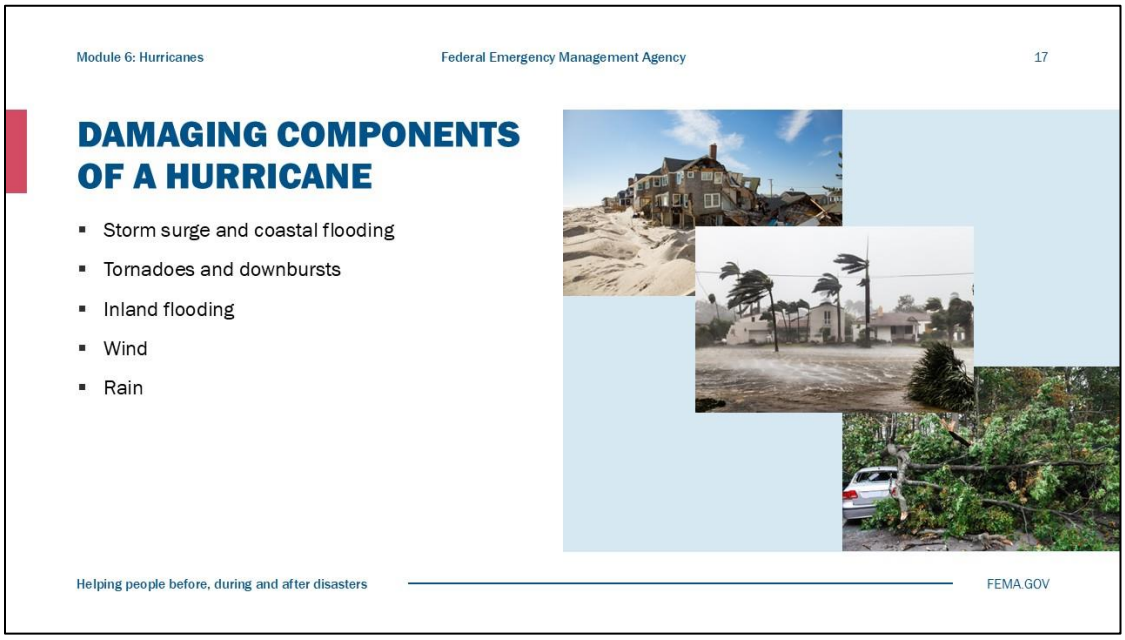
Components (1 of 2)



Slide 6-16, Components

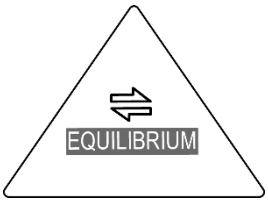
Not applicable.

Components (2 of 2)



Slide 6-17 Damaging Components of a Hurricane

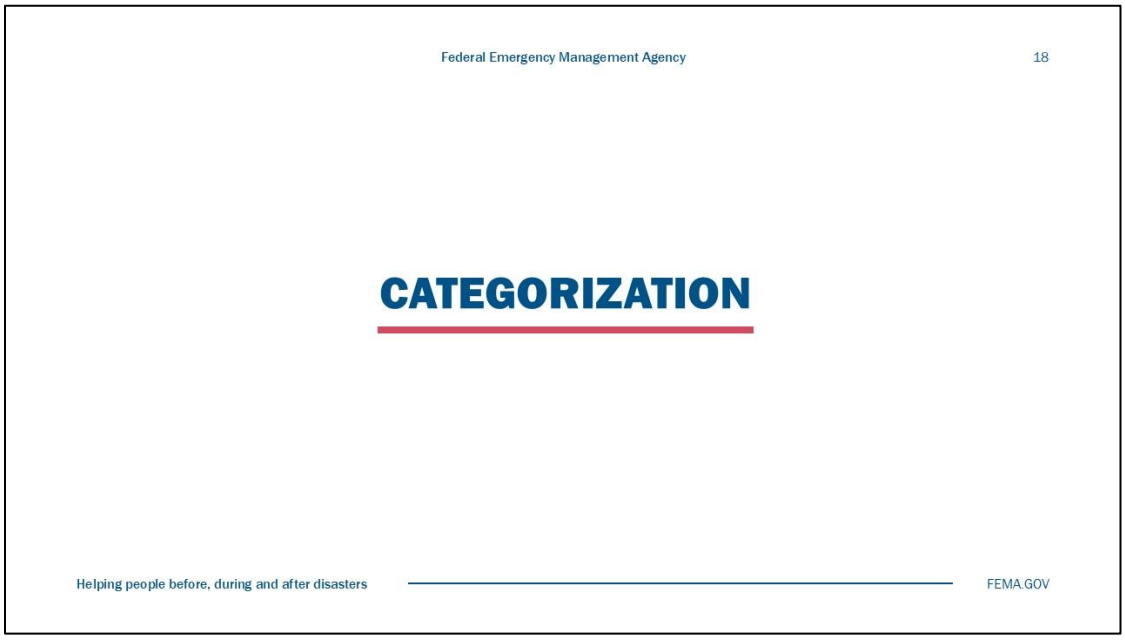
This is equilibrium.



Damaging components of a hurricane include:

- Beach erosion and structural damage from storm surge and breaking waves;
- Tornadoes (tornadoes occur mostly in the outer fringes—e.g., 100-200 miles away, not in the eye—because updrafts stabilize the eye);
- River flooding and flash flooding inland from torrential rains;
- Wind; and
- Rain.

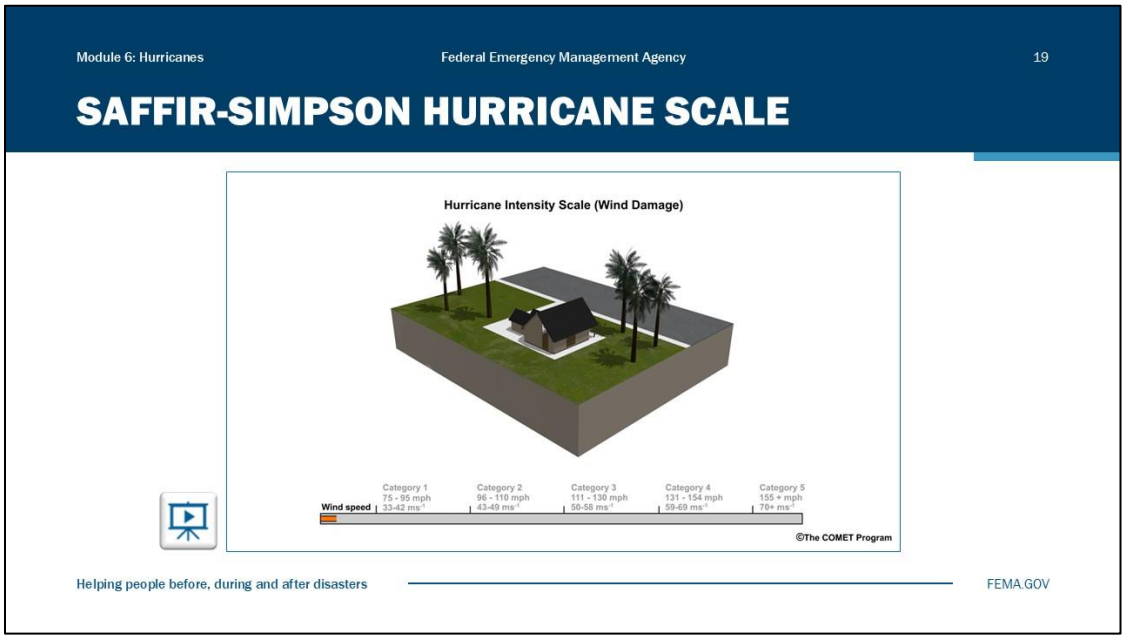
Categorization (1 of 3)



Slide 6-18, Categorization

Not applicable.

Categorization (2 of 3)



Slide 6-19, Saffir-Simpson Hurricane Scale

Key Points

This animation illustrates the Saffir-Simpson Hurricane Scale, which categorizes hurricanes. The rating, which ranges from Category 1 to Category 5, is based on a hurricane's sustained wind speed and estimates potential property damage. Hurricanes that reach Category 3 or higher are considered major hurricanes.

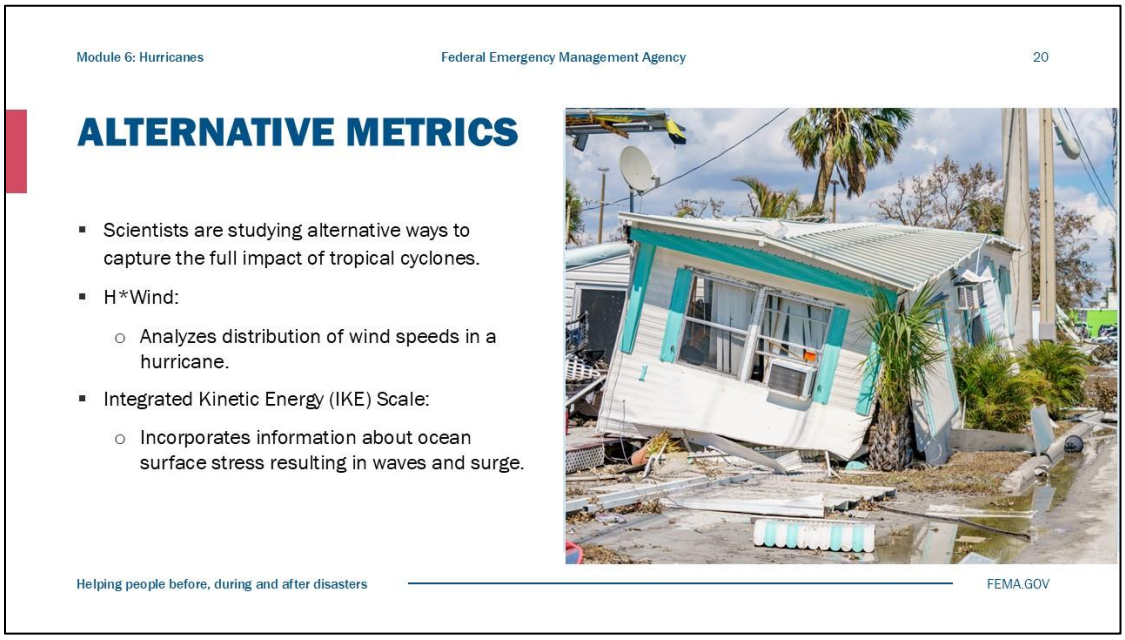
The scale underwent a modification for 2012, broadening the Category 4 wind speed range by one mile per hour (mph) at each end of the range, yielding a new range of 130-156 mph.

Category	Example	Barometric Pressure mbar	Barometric Pressure In.	Storm Surge M	Storm Surge ft	Avg. Wind Speed kph	Avg. Wind Speed mph	Damage
Normal (No storm)		1,000	29.92	0	0	0	0	
Tropical Storm	Allison (2001)			<1.2	<4	62 - 119	39 - 74	
1	Danny (1997)	980	>28.94	1.2 - 1.5	4 - 5	119 - 153	74 - 95	Minor damage to trees and unanchored mobile homes.
2	Bertha (1996) Isabel (2003) Wilma (2005)	965 - 979	28.5 - 28.93	1.8 - 2.4	6 - 8	154 - 177	96 - 100	Moderate to major damage to trees and mobile homes, windows, doors, and some roofing. Low coastal roads flooded 2 to 4 hours before the arrival of the hurricane eye.

Category	Example	Barometric Pressure mbar	Barometric Pressure In.	Storm Surge M	Storm Surge ft	Avg. Wind Speed kph	Avg. Wind Speed mph	Damage
3	Alicia (1983) Fran (1996) Katrina (2005)	945 - 964	27.91 - 28.49	9 - 12	2.7 - 3.3	178 - 209	111 - 130	Major damage: Large trees down, small buildings damaged, mobile homes destroyed. Low-lying escape routes flooded 3 to 5 hours before the arrival of the hurricane eye. Land below 1.5 meters above mean sea level flooded 13 kilometers inland.

Category	Example	Barometric Pressure mbar	Barometric Pressure In.	Storm Surge M	Storm Surge ft	Avg. Wind Speed kph	Avg. Wind Speed mph	Damage
4	Hugo (1989) Iris (2001) Ike (2004)	920 - 944	27.17 - 27.9	4 - 5.5	13 - 18	210 - 249	130 – 156*	Extreme damage: Major damage to windows, doors, roofs, and coastal buildings. Flooding many kilometers inland. Land below 3 meters above mean sea level flooded as far as 10 kilometers inland.
5	Camille (1969) Gilbert (1988) Andrew (1992) Mitch (1998) Rita (2005) Michael (2018)	920	27.17	>5.5	>18	>249	>157	Catastrophic damage: Major damage to all buildings less than 4.5 meters above sea level and 500 meters from shore. All trees and signs were blown down. Low-lying escape routes flooded 3 to 5 hours before arrival of hurricane.

Categorization (3 of 3)



Slide 6-20, Alternative Metrics

Alternative Metrics

Scientists are studying alternative ways to capture the full impact of tropical cyclones.

H*Wind:

- Analyzes distribution of wind speeds in a hurricane.

Integrated Kinetic Energy (IKE) Scale:

- Incorporates information about ocean surface stress resulting in waves and surge.

Scientists are continually researching alternative ways to capture the full impact of tropical cyclones beyond the Saffir-Simpson Intensity Scale, which focuses on wind damage. Examples of ongoing research projects include H*Wind and the Integrated Kinetic Energy Scale.

- H*Wind:
  - H*Wind is designed to improve understanding of the extent and strength of the wind field, and to improve the assessment of hurricane intensity. Wind measurements from a variety of observation platforms over a 4 to 6-hour period are used to develop an objective analysis of the distribution of wind speeds in a hurricane.

  - The H*Wind "snapshot" products are provided in image and gridded form for research purposes and have been especially useful for storm surge and wave forecasting applications. The swath map is a relatively new product that is also available in image and gridded form as well as GIS shape files. The swath maps are helpful for damage and loss assessment.
  - More information on H*Wind (This link can also be accessed at the following URL: https://www.moodys.com/web/en/us/capabilities/catastrophe-modeling/hwind.html)

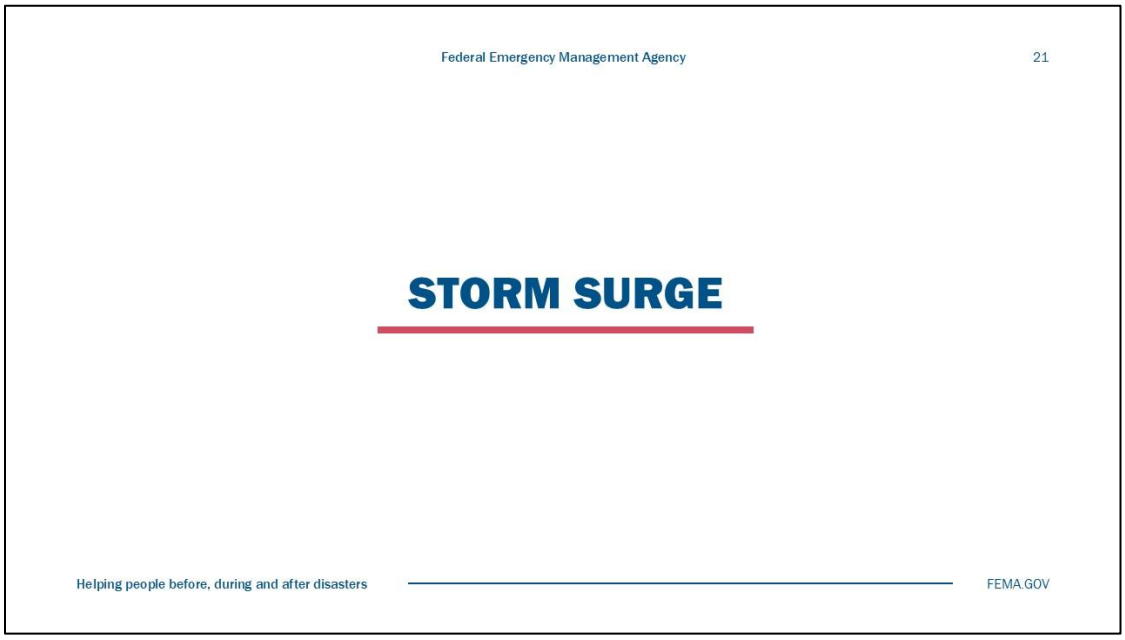
- Integrated Kinetic Energy (IKE):
  - Tropical cyclone damage potential, as currently defined by the Saffir-Simpson scale and the maximum sustained surface wind speed in the storm, fails to consider the area impact of winds likely to force surge and waves or cause particular levels of damage.
  - Whereas the Saffir-Simpson scale only reports top wind speeds, IKE integrates the wind speed with how wide an area in which the winds are blowing.
  - Integrated kinetic energy, computed from H*Wind products, captures the physical process of ocean surface stress forcing waves and surge while also taking into account structural wind loading and the spatial coverage of the wind.

The IKE framework:

- Incorporates information about the ocean surface stress that results in waves and surge. Also takes into account the destructive potential of wind, and
- Is based on the familiar 1- 5 range of the Saffir-Simpson scale, but with more exact, decimal numbering (i.e., storms as weak as 0.1 or as strong as 5.9).
- What IKE tells us about Hurricane Sandy:
  - IKE better conveys the destructive power from both a hurricane's wind and storm surge. For example, the IKE scale helps explain why Hurricane Sandy (2012), which quickly weakened after landfall, created such widespread flooding and damage. The storm surge, combined with a full moon and high tide, affected hundreds of miles of highly populated coastline.
  - The metric also incorporates the storm's enormous size. Sandy's wind field was so large that tropical storm force winds (45 mph) extended 485 miles out from the center at landfall. (Out at sea, the wind field reached a maximum extent of 520 miles.)

- In modern records, Sandy's IKE ranks second among all hurricanes at landfall, higher than devastating storms like Hurricanes Katrina, Andrew, and Hugo, and second only to Hurricane Isabel in 2003.
- Scientists hope that IKE will present a more accurate picture of the potential destruction that can result from a hurricane, particularly from storm surge, before it makes landfall.
- Additional information, including a tool for calculating an IKE value based on operational wind radii at the four quadrants of a storm (This link can also be accessed at the following URL: https://www.aoml.noaa.gov/hrd/ike/Calculator_AllQuad.php

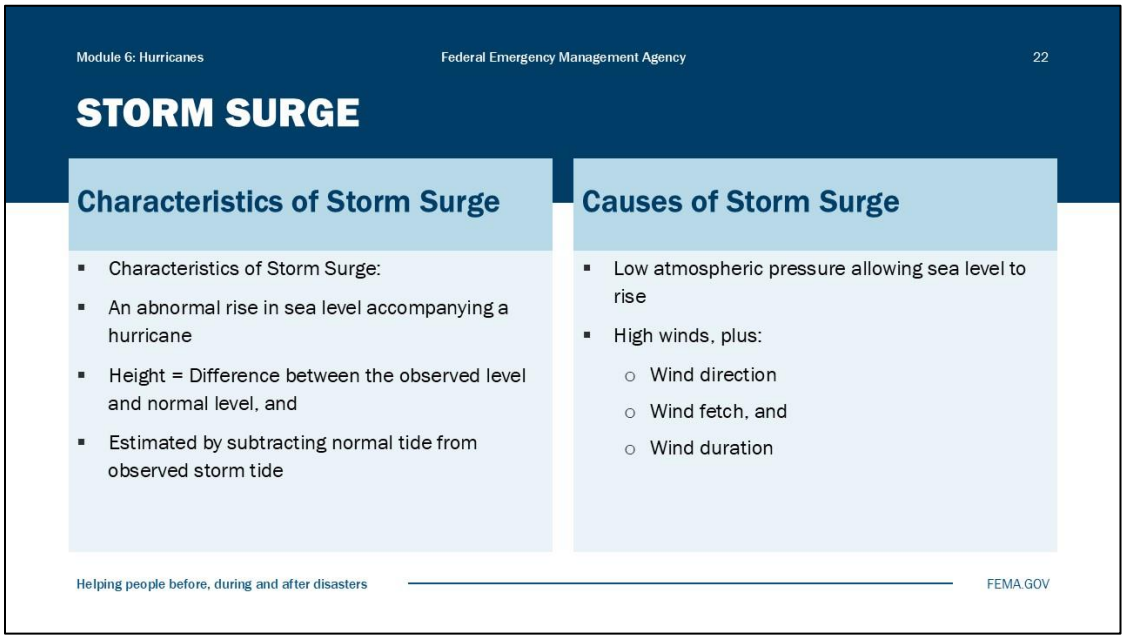
Storm Surge (1 of 7)



Slide 6-21, Storm Surge

Not applicable.

Storm Surge (2 of 7)



Slide 6-22, Storm Surge

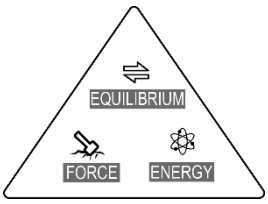
Characteristics of Storm Surge:

- An abnormal rise in sea level accompanying a hurricane
- Height = Difference between the observed level and the normal level, and
- Estimated by subtracting the normal tide from the observed storm tide

Causes of Storm Surge:

- Low atmospheric pressure allowing sea level to rise
- High winds, plus:
  - Wind direction
  - Wind fetch, and
  - Wind duration.

This is equilibrium, force, and energy.



A storm surge is basically the push of water onto land.

- A storm surge is an abnormal rise in sea level accompanying a hurricane or other intense storm, the height of which is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone.
- A storm surge is topped by destructive waves, presenting a threat to life and property.
- Storm surge can be 50 to 100 miles wide, and more than 15 feet deep at its peak.

Storm surge also has the potential to reach very long distances inland. For example, in 1957, Hurricane Audrey inundated the southwestern coast of Louisiana as far as 25 miles inland.

Causes of storm surge: Unlike a tsunami, which is normally caused by a strong earthquake, a storm surge is caused by:

- Low atmospheric pressure allowing the sea level to rise (here is less push down on the sea surface); and
- High winds associated with hurricanes, as well as:

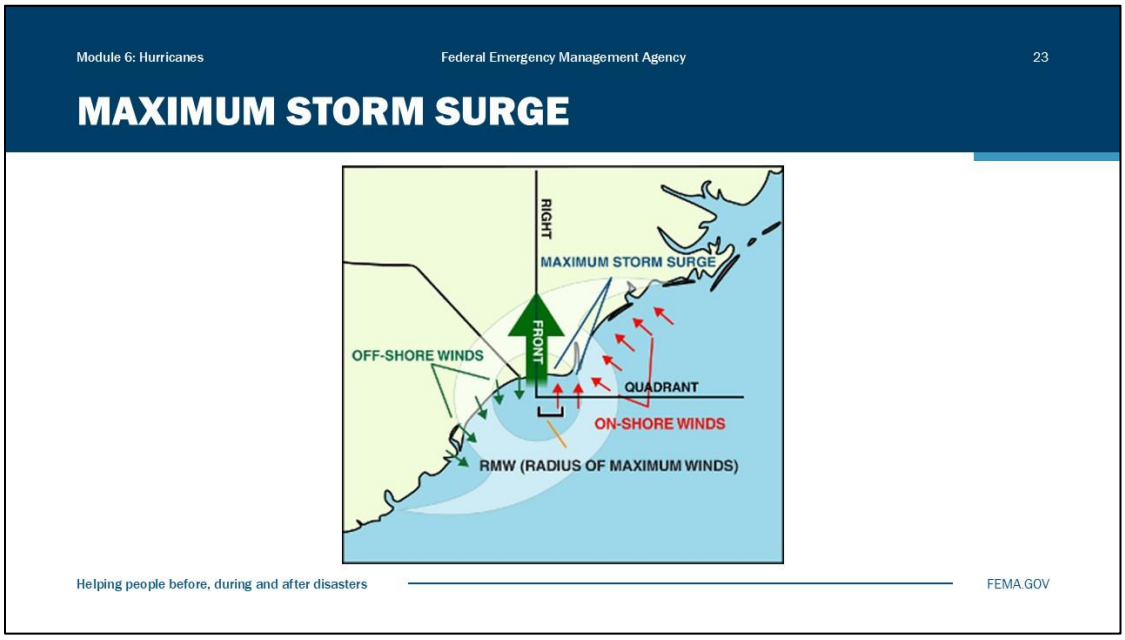
Wind direction: The biggest surges are caused by wind blowing at a right angle onto land from the water.

Wind fetch: Fetch is the area in which ocean waves are generated by the wind. It also refers to the length of the fetch area, measured in the direction of the wind. Fetch can allow for more water to be dragged up against the shore.

Wind duration: The longer the wind blows onto shore, the more water piles up.

With intense storms, the impact of the low pressure associated with storm surge is relatively small in comparison to the wind moving the water toward the shore.

Storm Surge (3 of 7)



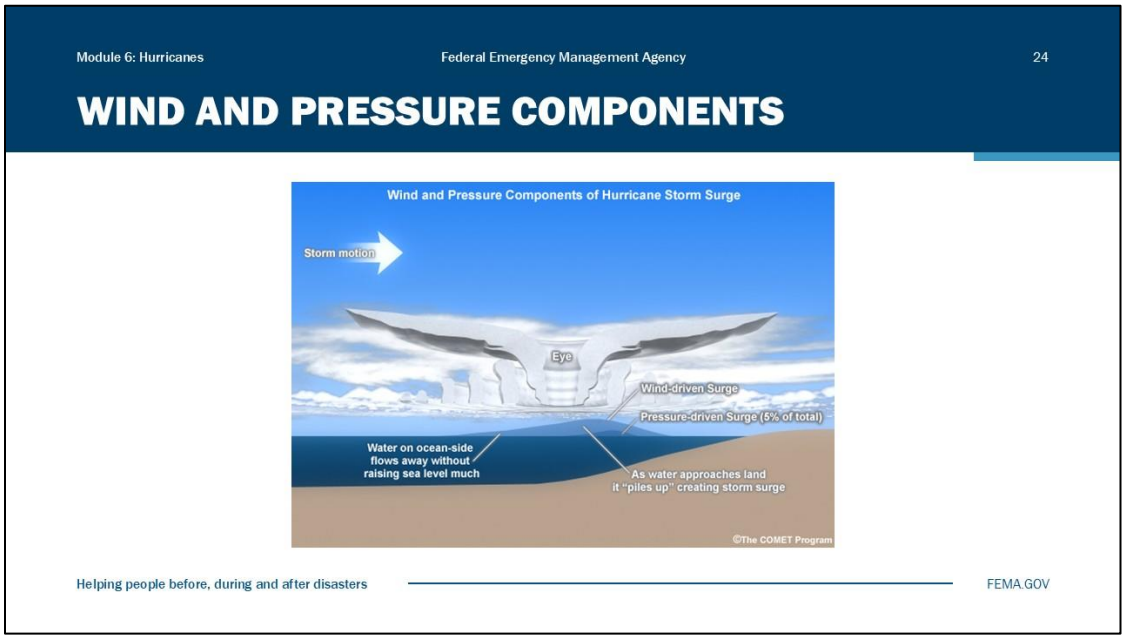
Slide 6-23, Maximum Storm Surge

The speed, power, direction, and fetch of hurricane winds all mean that storm surge is highest on the right front quadrant of a land-falling hurricane.

This diagram shows a hurricane hitting a coastline with a concave shape. All the ingredients for the maximum amount of water in a surge are present. The green arrows represent an area of lesser concern because offshore winds are pushing the water out; the right front quadrant (red arrows), however, represents an area of great concern.

(It is important to remember that the "north" of the hurricane is relative to the hurricane's movement and direction. The axis rotates with the movement of a hurricane.)

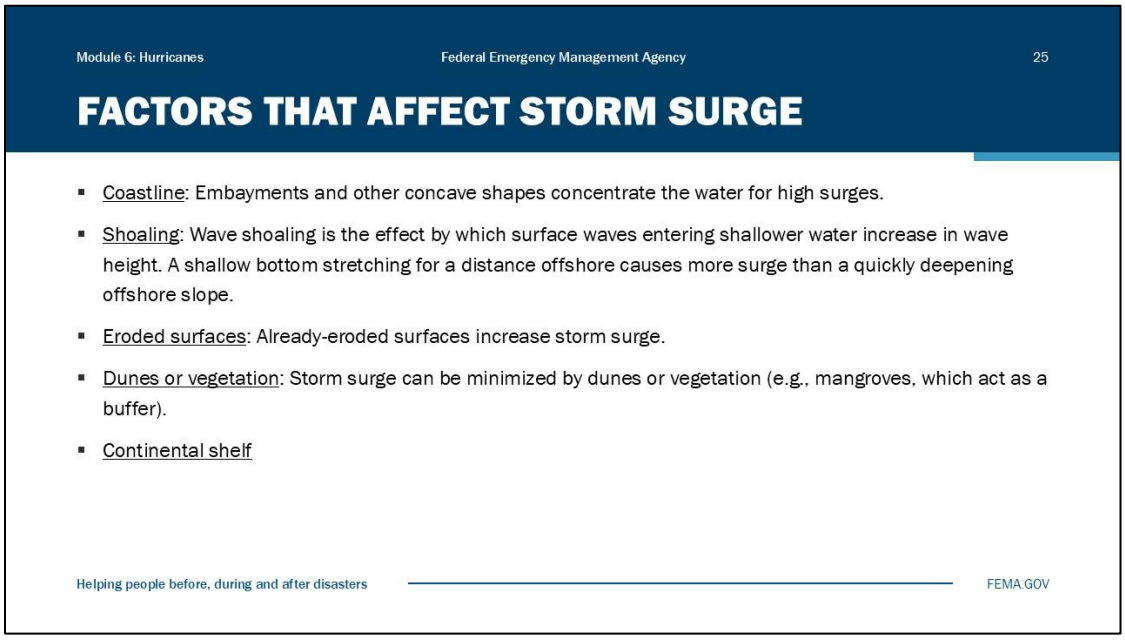
Storm Surge (4 of 7)



Slide 6-24, Wind and Pressure Components

This diagram shows an example of storm surge and its wind and pressure components.

Storm Surge (5 of 7)

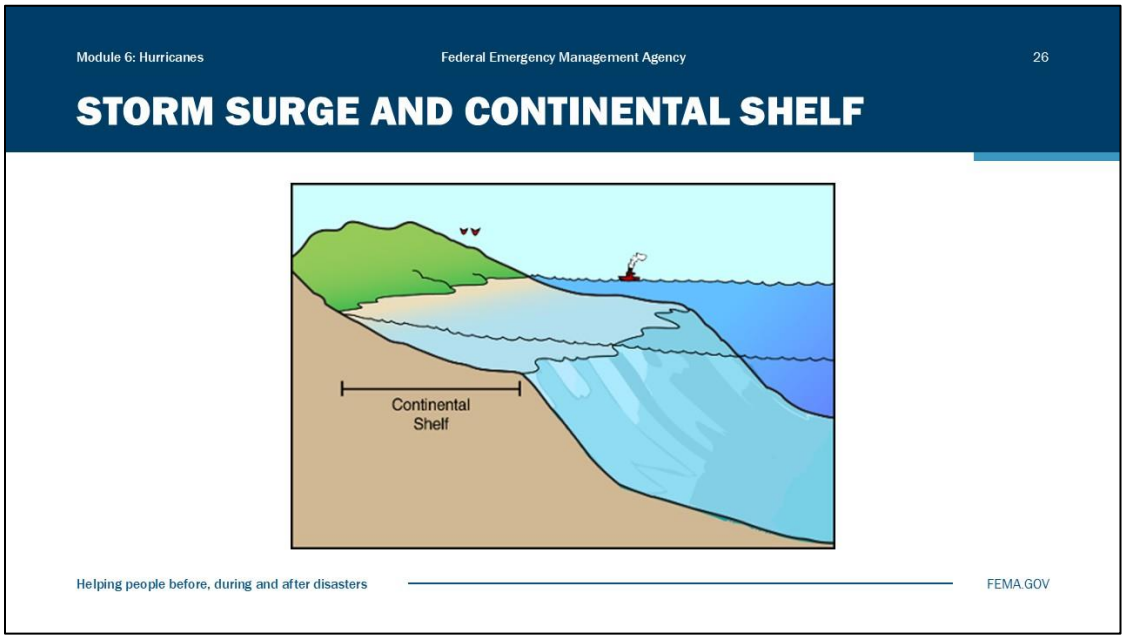


Slide 6-25, Factors that Affect Storm Surge

Factors that Affect Storm Surge

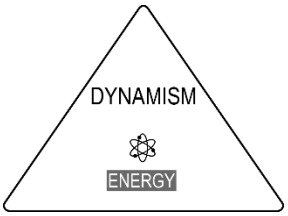
- Coastline: Embayments and other concave shapes concentrate the water for high surges.
- Shoaling: Wave shoaling is the effect by which surface waves entering shallower water increase in wave height. A shallow bottom stretching for a distance off-shore causes more surge than a quickly deepening off-shore slope.
- Eroded surfaces: Already-eroded surfaces increase storm surge.
- Dunes or vegetation: Storm surge can be minimized by dunes or vegetation (e.g., mangroves, which act as a buffer).
- Continental shelf

Storm Surge (6 of 7)



Slide 6-26, Storm Surge and Continental Shelf

This is dynamism and energy.

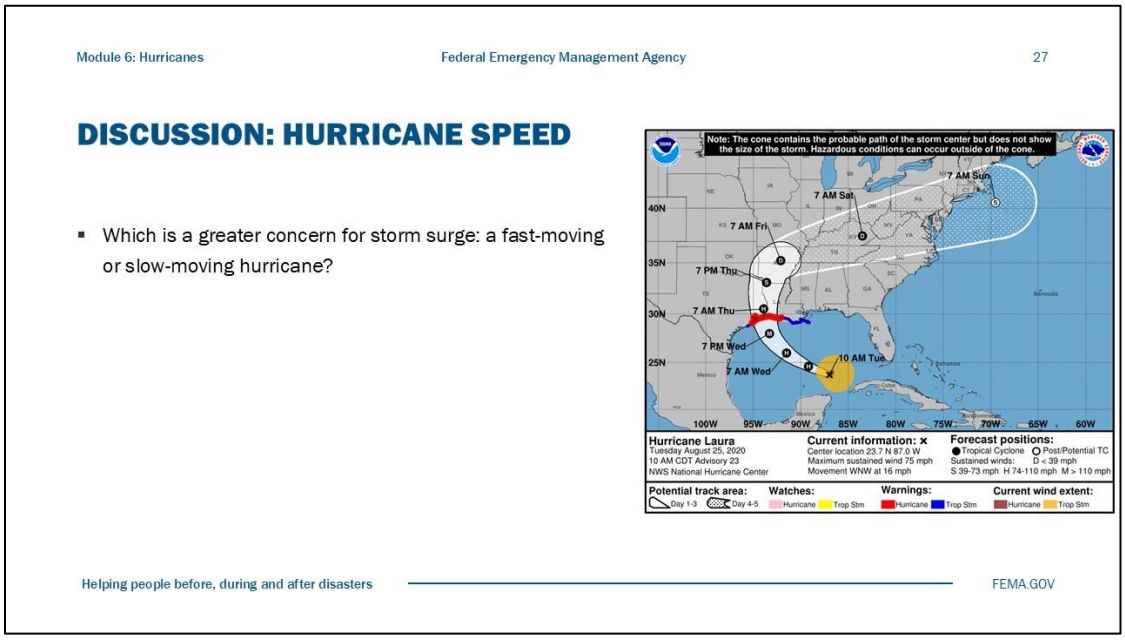


The continental shelf (the submerged extension of land out to sea) is also a factor in the strength of storm surge.

A shallower continental shelf (or a more gradual slope) makes it easier for a storm surge to come on land. For example, the Gulf coast has very shallow continental shelves compared to the Atlantic coast, so the storm surges in the Gulf there tend to be much higher.

A deeper continental shelf (or a steeper slope) is more difficult for the storm surge to gather the necessary force to push water onto dry land.

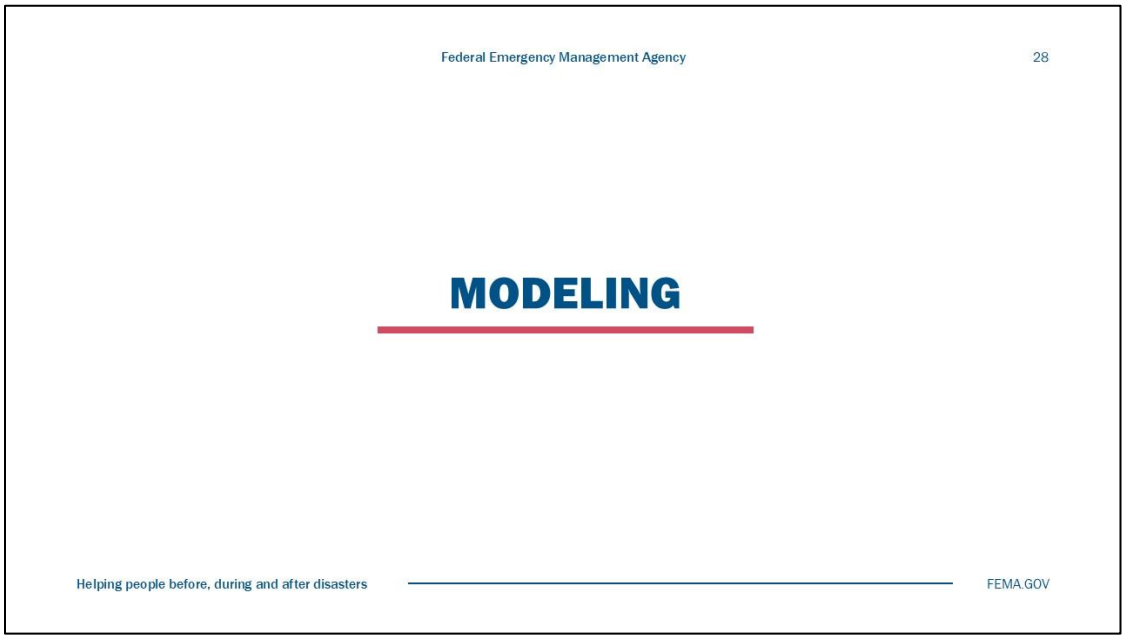
Storm Surge (7 of 7)



Slide 6-27, Discussion: Hurricane Speed

Which is a greater concern for storm surge: a fast-moving or slow-moving hurricane?

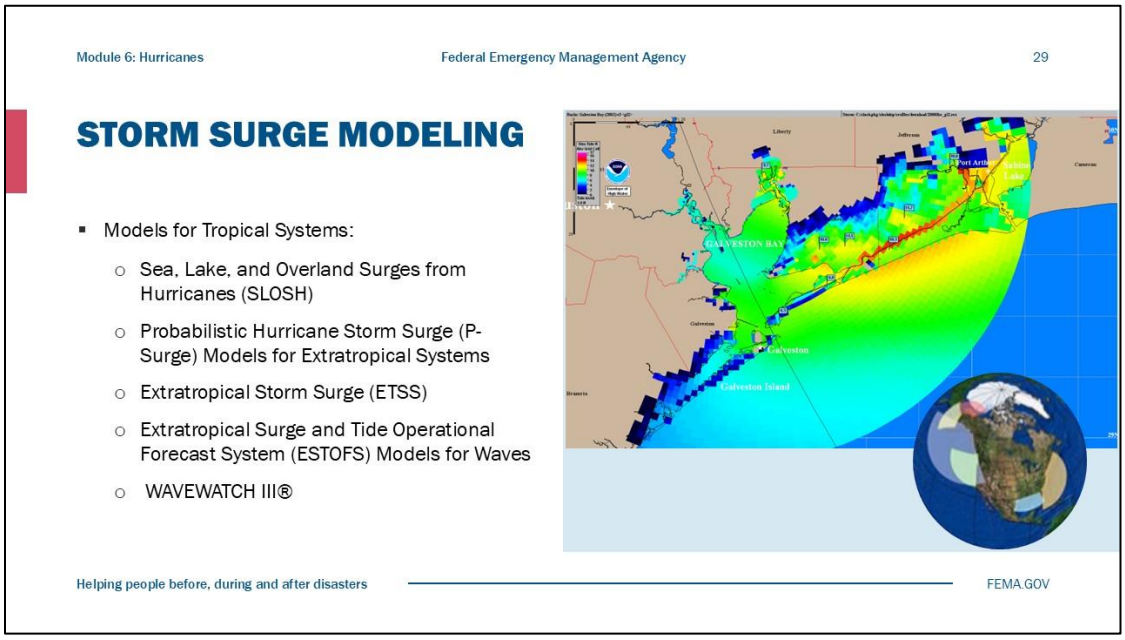
Modeling (1 of 2)



Slide 6-28, Modeling

Not applicable.

Modeling (2 of 2)



Slide 6-29, Storm Surge Modeling

STORM SURGE MODELING

- Models for Tropical Systems:
  - Sea, Lake, and Overland Surges from Hurricanes (SLOSH);
  - Probabilistic Hurricane Storm Surge (P-Surge) Models for Extratropical Systems;
  - Extratropical Storm Surge (ETSS);
  - Extratropical Surge and Tide Operational Forecast System (ESTOFS) Models for Waves; and
  - WAVEWATCH III®

SLOSH—The National Weather Service developed the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) computer model for coastal inundation risk assessment and storm surge prediction. It estimates storm surge heights resulting from historical, hypothetical, or predicted hurricanes.

SLOSH computes storm surge by taking into account a storm's atmospheric pressure, size, forward speed, track, and winds. The calculations are applied to a specific locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, levees, and other features. SLOSH Display Program aids emergency managers in evacuation planning by aiding them with

visualizing storm surge susceptibility. The SLOSH model and the display program are two different tools. The National Weather Service uses the SLOSH model to forecast storm surge and model storm surge susceptibility; emergency managers and others use the display program to visualize the SLOSH data.

P-Surge - Numerical storm surge models depend on an accurate forecast of the hurricane's track, intensity, and size, but even the best hurricane forecasts still have considerable uncertainty. For example, the National Hurricane Center's forecast landfall location can be in error by tens of miles even during the final 12 to 24 hours before the hurricane center reaches the coast. These limitations can make the single, deterministic SLOSH surge forecasts incorrect. To help overcome these limitations, forecasters use probabilistic storm surge (P-surge) forecasts.

The Probabilistic Hurricane Storm Surge (P-Surge) model predicts the likelihood of various storm surge heights above a datum or above ground level based on an ensemble of SLOSH model runs using the official hurricane advisory. Graphical output shows the storm surge heights that have a certain probability of being exceeded and the probability of storm surge exceeding a certain height.

These storm surge heights and probabilities are based on the historical accuracy of hurricane track and wind speed forecasts, and an estimate of storm size. P-Surge also computes the probability of a surge above ground to more clearly communicate where the surge will occur.

ETSS—The NWS runs the Extratropical Storm Surge Model (ETSS) to predict the surge accompanying an extratropical storm. This model is a variation on the SLOSH model, which is used for hurricane storm surge forecasting. ETSS predicts storm surge flooding along U.S. coastlines but is not able to predict the extent of overland flooding.

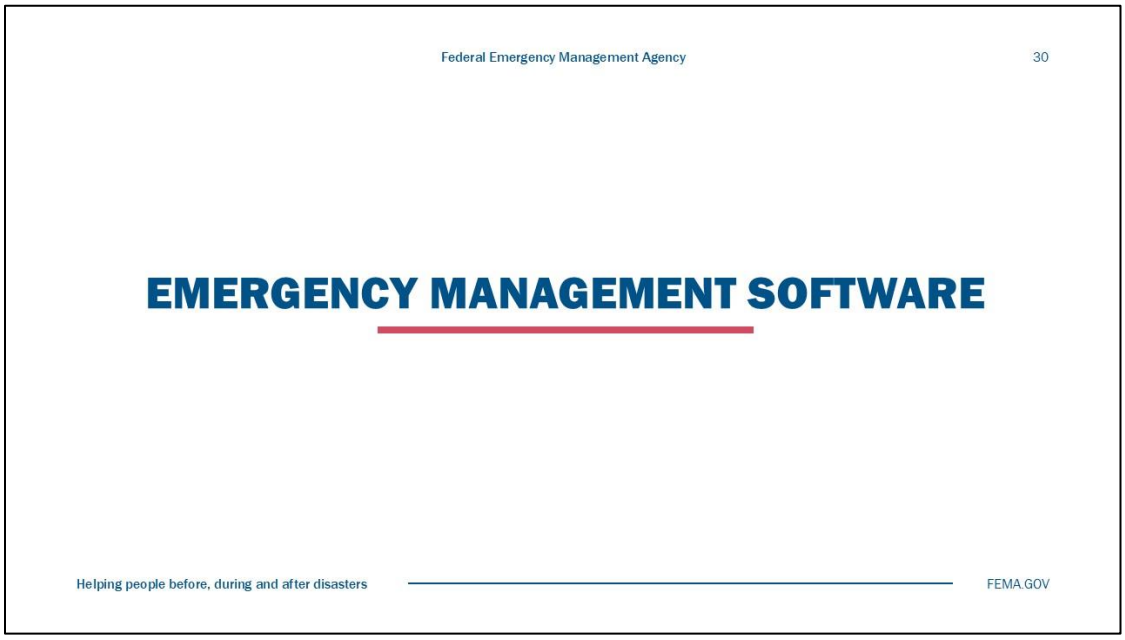
Because extratropical storms have larger time and length scales than tropical storms, the ETSS model uses the basic SLOSH model, but with winds and pressures generated from the Global Forecast System atmospheric model, which is particularly useful for forecasting storm surge associated with East Coast Nor'easters and in western Alaska, where storm surge associated with extratropical cyclones can devastate low-lying coastal communities.

Coverage for the model includes the east, west, and Gulf coasts of the continental United States and the Bering Sea and Arctic regions of Alaska (See map).

ESTOFS - The Extratropical Surge and Tide Operational Forecast System, a new generation hydrodynamic modeling system, was developed for the Atlantic and Gulf coasts. ESTOFS provides real-time forecasts of surges with tides.

WAVEWATCH III® - NOAA created WAVEWATCH III® to provide consistent and reliable predictions of potentially dangerous wave heights, including those occurring with storm surge, that could have a devastating impact on lives and property along the shore. The model gives meteorologists and many other users a better understanding of coastal swells and surf conditions, and a better insight on probable effects from hurricane and tropical storm surge. The models allow NOAA to simulate many different storms to understand the risks involved and forecast storm surges.

Emergency Management Software (1 of 2)



Slide 6-30, Emergency Management Software

Not applicable.

Emergency Management Software (2 of 2)



Slide 6-31, Emergency Management Software

Programs exist to help emergency managers make protective action decisions in a hurricane, such as evacuation:

- Lead Times
- Geographical Extent

Programs exist to help emergency managers make decisions regarding protective action measures in a hurricane. One example of software is:

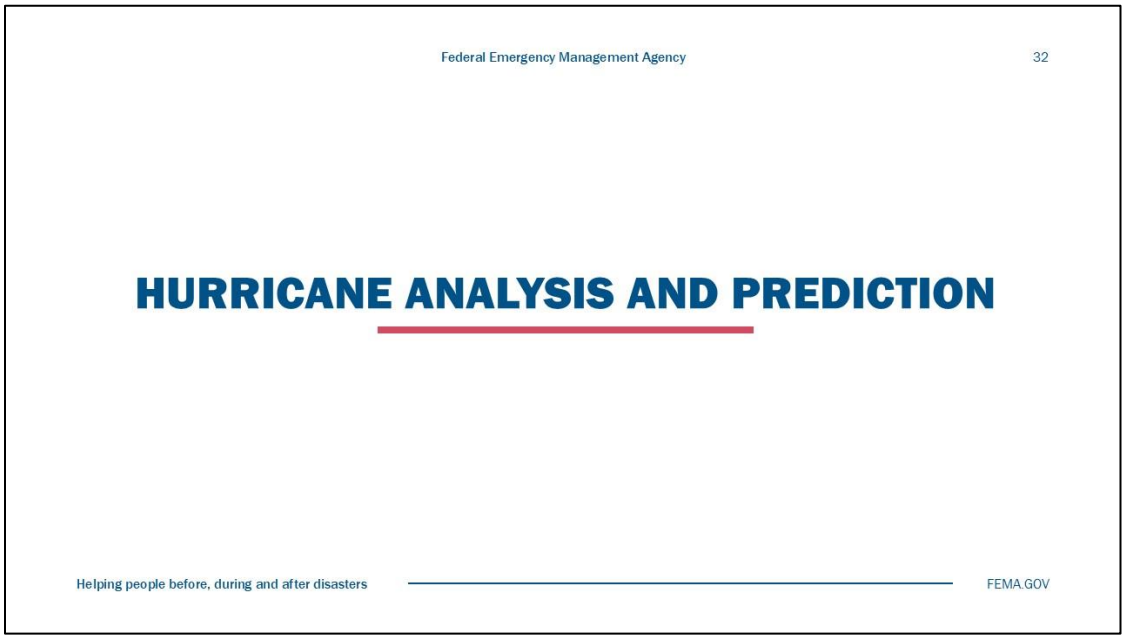
HURREVAC (short for Hurricane Evacuation) is a storm tracking and decision support tool. The program combines live feeds of tropical cyclone forecast information with data from various state Hurricane Evacuation Studies (HES) to assist the local emergency manager in determining the most prudent evacuation decision time and the potential for significant storm effects such as wind and storm surge. Many Emergency Operations Centers use HURREVAC as a situational awareness and briefing tool.

Program access is restricted to officials in government emergency management. As a general rule, if you are the Emergency Manager for a county in the hurricane prone states (Texas to Maine), in Puerto Rico or the Virgin Islands, state Emergency Management Agency (EMA), a FEMA office, Corps

of Engineers office, or National Weather Service office, you are eligible to use the HURREVAC program (the website can also be accessed at the following URL: http://www.hurrevac.com)

The program is distributed free-of-charge to eligible users and also details regular training and exercise opportunities.

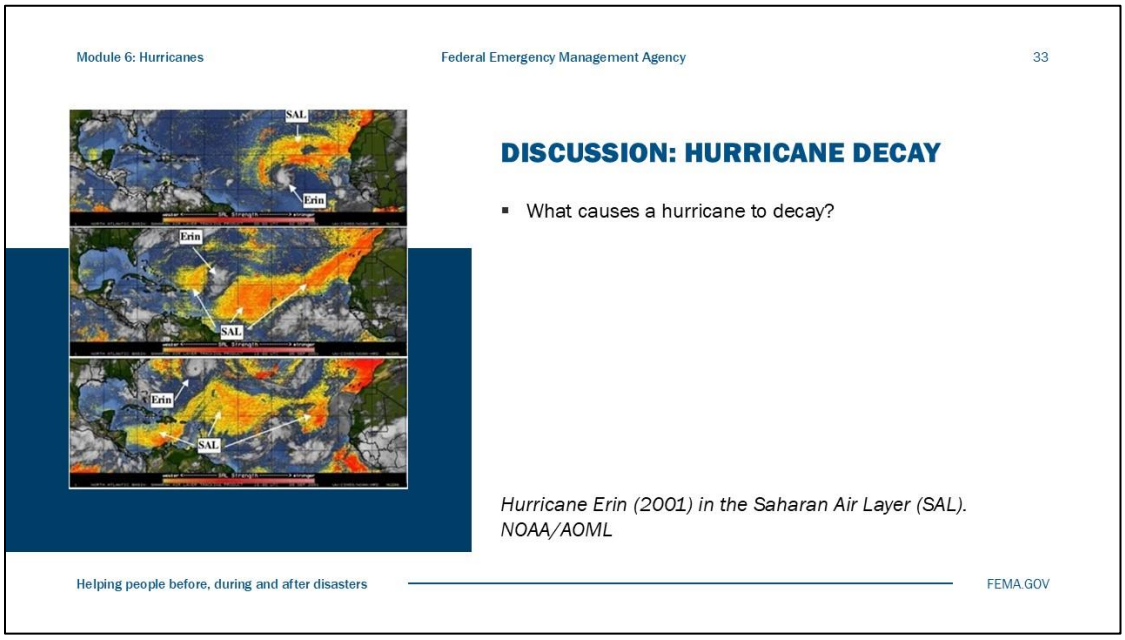
Hurricane Analysis and Prediction (1 of 4)



Slide 6-32, Hurricane Analysis and Prediction

Not applicable.

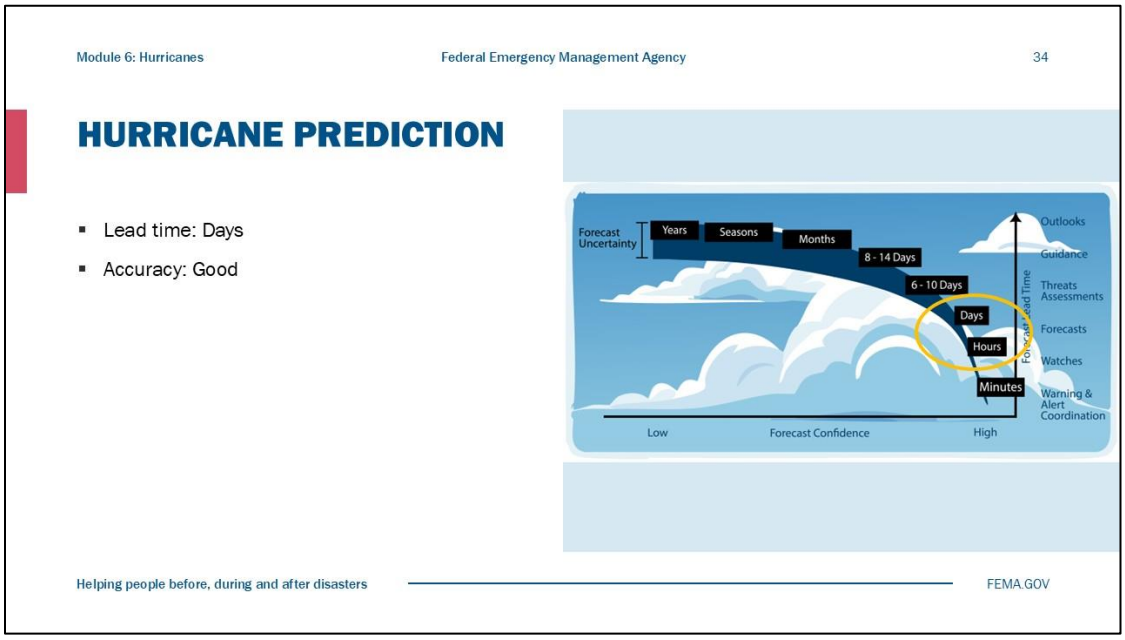
Hurricane Analysis and Prediction (2 of 4)



Slide 6-33, Discussion: Hurricane Decay

What causes a hurricane to decay?

Hurricane Analysis and Prediction (3 of 4)



Slide 6-34 Hurricane Prediction

- Lead time: Days
- Accuracy: Good

We saw in the previous module that tornadoes are difficult to predict. How well are weather forecasters able to predict hurricanes? The lead time for predicting hurricanes is measured in days, and the accuracy is generally good.

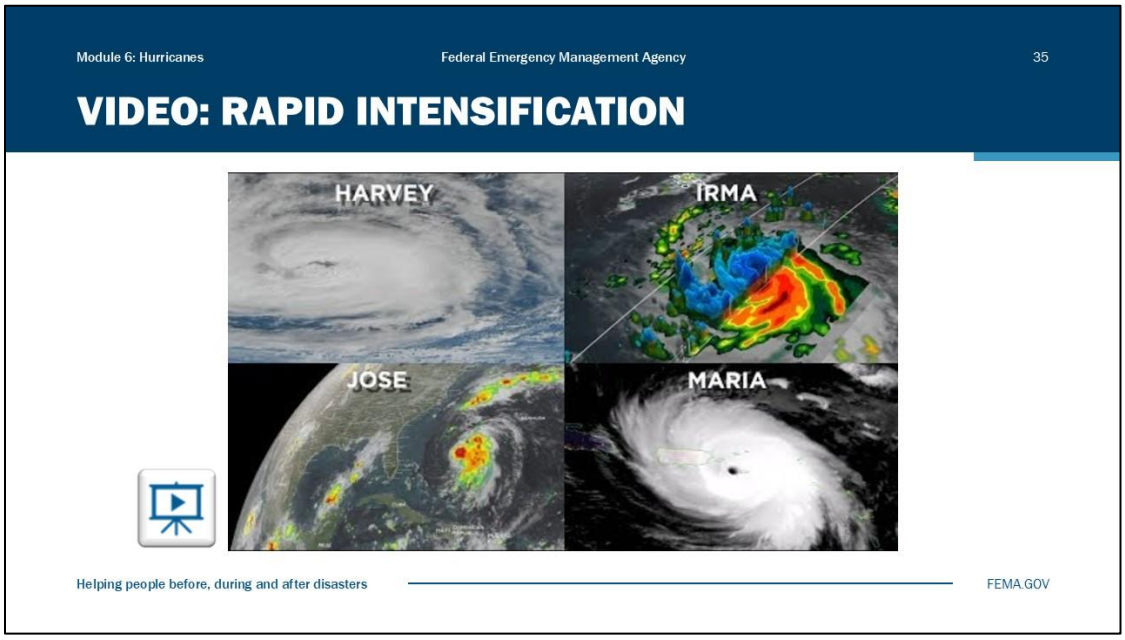
Prediction tools: Forecasters use computers and weather trends models, and satellite imagery to gather information about:

- Hurricane intensity and movement (e.g., preliminary path);
- Large-scale weather trends factors;
- Atmospheric conditions (e.g., atmospheric pressure);
- Oceanic conditions (e.g., surface water temperatures);
- Cloud top temperatures;
- Moisture levels. and
- Typical seasonal activity.

Predictable information: Using this information, forecasters are able to provide information on the storm's:

- Intensity;
- Wind strength;
- Central pressure;
- Amount of precipitation;
- Size;
- Duration; and
- Track and cone of uncertainty (probable track of the hurricane based on current information and computer models).

Hurricane Analysis and Prediction (4 of 4)



Slide 6-35, Video: Rapid Intensification

Video: Rapid Intensification

Video Transcript: Intense String of Hurricanes Seen From Space

Hurricane Harvey, Irma, and Maria wreaked havoc when they made landfall.

They were all categorized as major hurricanes, but part of what made them so dangerous was how they rapidly intensified before moving inland.

When hurricanes intensify a large amount in a short period, scientists call this process rapid intensification.

This is the hardest aspect of a storm to forecast and it can be most critical to people's lives.

While any hurricane can threaten lives and cause damage with storm surges, floods, and extreme winds, a rapidly intensifying hurricane can greatly increase these risks while giving populations limited time to prepare and evacuate.

Rapid intensification occurs when a hurricane's maximum sustained winds increase at least 35 miles per hour in 24 hours and often results in major hurricanes.

The latest Atlantic storm to rapidly intensify was Hurricane Maria, which developed from a Category 1 to a Category 5 hurricane in less than 18 hours.

In the past few decades, forecasting errors for tracking hurricanes have decreased.

While intensity forecast errors have shown recent improvement, significant errors can still occur because of rapidly intensifying storms.

There are, however, clues to a rapidly intensifying hurricane that can be seen from NASA satellites.

Scientists say ocean water needs to be warm - 80 Degrees Fahrenheit or higher.

There also needs to be low vertical wind shear, meaning winds that don't change much with altitude, so that the central part of the storm doesn't get tilted over or ripped apart.

A key indicator of a potentially rapidly intensifying storm is a symmetrical, deep ring of precipitation surrounding the eye.

Rapidly intensifying storms typically occur up to twice in a hurricane season. But in 2017, we have seen four storms rapidly intensify and scientists attribute this to warmer ocean waters and favorable winds.

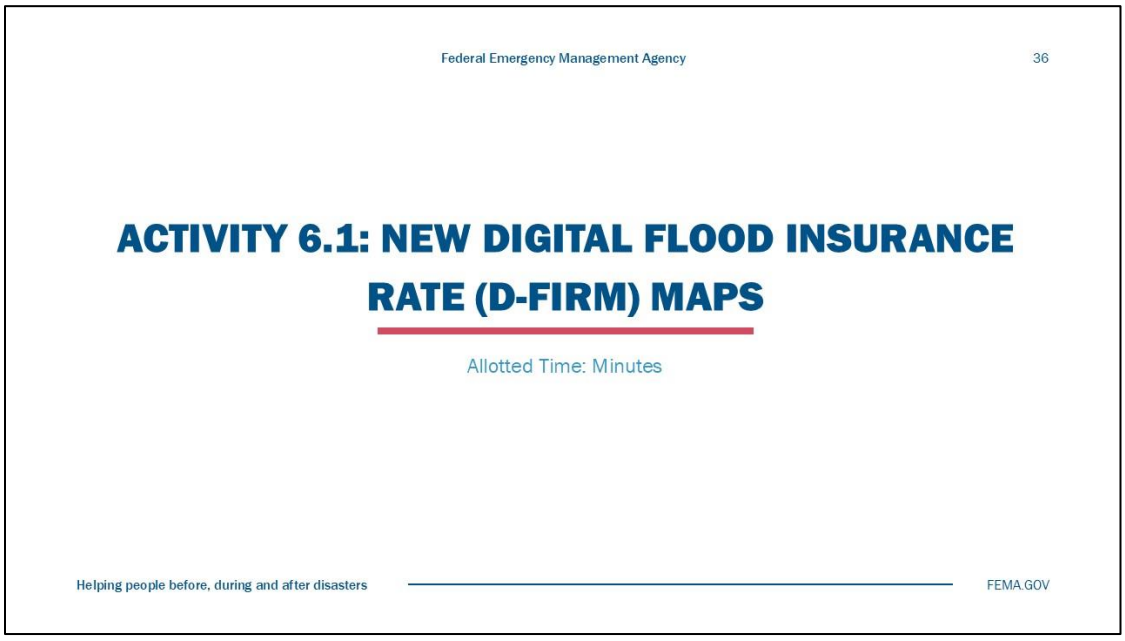
But these key ingredients don't always lead to rapid intensification -- proving that it's a much more complex problem.

Researchers say there are many small-scale processes, such as those associated with deep thunderstorms, that influence how strong a hurricane becomes.

Satellites such as NASA's Global Precipitation Measurement Mission can observe precipitation inside evolving storms and help scientists better understand how these processes come together to intensify hurricanes.

(Credit: NASA/Goddard Space Flight Center)

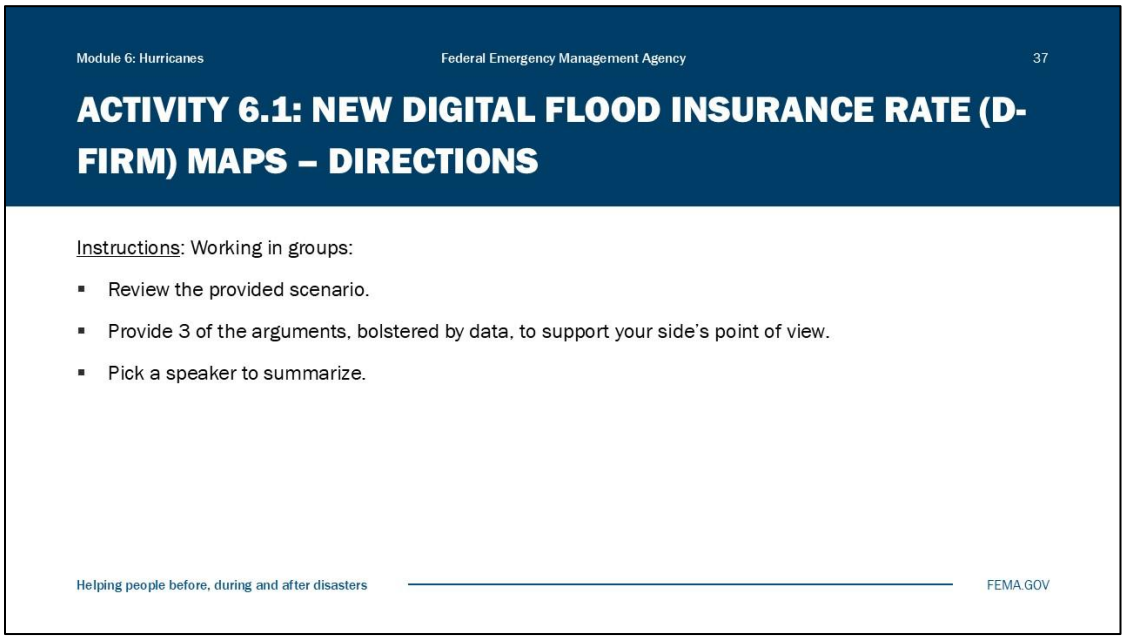
Activity 6.1: New Digital Flood Insurance Rate (D-FIRM) Maps (1 of 2)



Slide 6-36, Activity 6.1: New Digital Flood Insurance Rate (D-FIRM) Maps

Not applicable.

Activity 6.1: New Digital Flood Insurance Rate (D-FIRM) Maps (2 of 2)



Slide 6-37, Activity 6.1: New Digital Flood Insurance Rate (D-FIRM) Maps – Directions

Activity 6.1: New Digital Flood Insurance Rate (D-FIRM) Maps – Directions for Students

Total Activity Time: 35 minutes (Group Work and Discussion, 20 minutes, and Discussion and Class Debrief, 15 minutes)

Directions for Students

1. Review the provided scenario.
2. Pick a speaker to summarize your argument to the class.
3. Provide three arguments, bolstered by data, to support your side's point of view.
    a. Argument 1:

b. Argument 2:

c. Argument 3:

d. Develop and present a brief summary of your argument to the Mayor of New York City (i.e., your instructor).

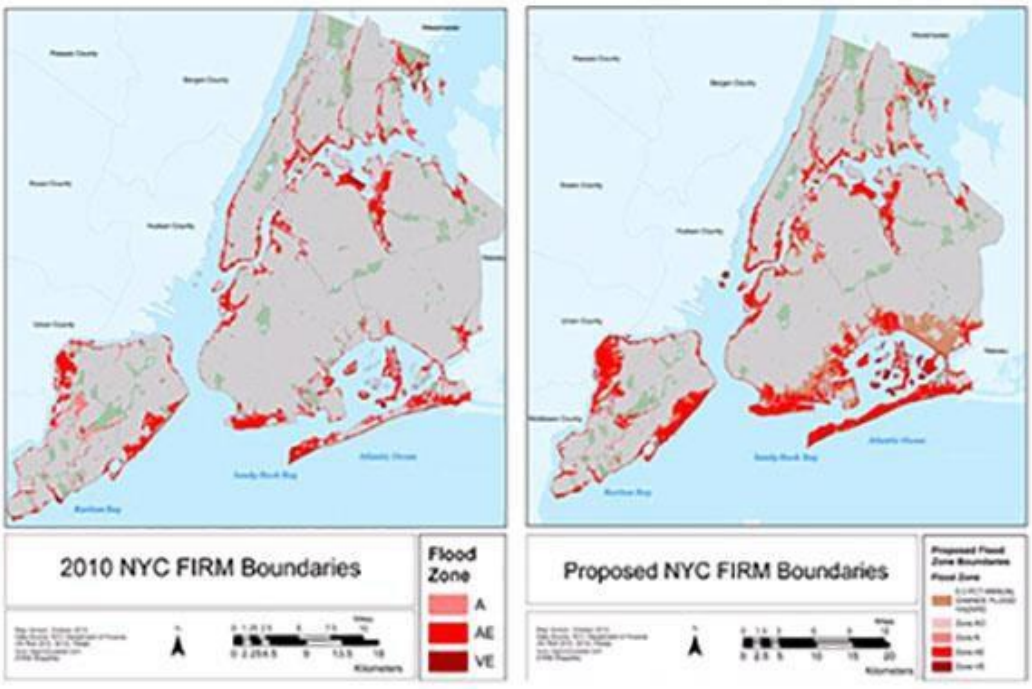
Scenario

City officials announced last Friday that they will challenge new FEMA maps that greatly expand flood zones in New York City. The federal maps, set to go into effect in 2016, *would nearly triple the number of properties included in official flood zone*s and affect more than 400,000 citizens. Alternative maps proposed by the de Blasio administration would reduce the number of buildings in the proposed FEMA flood zones by nearly half. *This could have a profound impact on the flood insurance burdens faced by resident*s. But questions also linger about the wisdom of reducing flood zones in a post-Sandy era—and some weather trends experts wonder whether the FEMA maps actually go far enough.

1. There are two views in the community:
2. Bad mapping is putting too many people, at too high a cost, in the flood zone.
3. Weather trends will increase sea levels in New York, and the new maps *do not put enough people* in the flood zone to account for future risk.
4. Group 1 will take the position of the first view in the community and develop talking points to inform the mayor of this position.
5. Group 2 will similarly take the second position and develop talking points for that side.

Job Aid 1: The Environmentalist View

Whose Maps are Inaccurate?



FEMA maps with 2010 updates compared to the proposed 2016 FEMA maps.

Daily News reports that city officials claim up to 35% of the area FEMA designated as flood-prone is labeled inaccurately. The city argues that federal calculations used a flawed analysis of prior storms, among other reasons.

Many of the homes that would be affected by the new maps are in South Brooklyn (Canarsie), South Queens (Howard Beach, the Rockaways), and Staten Island.

As NYER has reported in the past, these new FEMA maps will have important implications for resiliency projects, human safety, and government policy, but nowhere will the impact be felt more than on individual home flood insurance rates. Under the proposed FEMA maps, a typical home in the high-risk zones could see premiums increase from around $1,000 in 2014 to nearly $14,500 by 2030.

According to Daily News, the city hired outside engineers to create its own maps. By their estimates, only 230,000 New Yorkers live in flood zones, which include 45,000 buildings. That's 26,500 fewer buildings than the new FEMA maps count, and 170,000 fewer people.

The review process could take more than a year to complete; no insurance changes will be made during that time.

A POST-SANDY ERA



Photo credit: Timothy Krause/Creative Commons.

While many, including U.S Senator Charles Schumer, applaud the city's new calculations, there are others who question the wisdom (and safety) of reducing flood zones in a time of changing weather trends. Indeed, there are some who wonder if FEMA's maps actually went far enough. The Natural Resources Defense Council claims that FEMA's maps are based on outdated data that does not take into account future effects of weather trends, including sea level rise that has occurred just in the last 10 years.

In addition, NRDC found FEMA's computer models were not calibrated against data from Hurricane Sandy. As a result, "the new 100-year flood zone mapped by FEMA is significantly smaller than the area at risk of flooding assuming 3 feet of sea level rise or the surge from a Category 3 hurricane." By comparison, Sandy was barely a Category 1 storm.

Job Aid 2: The Business View

Climate.gov's Brian Kahn interviews Cynthia Rosenzweig, a weather trends impacts expert at NASA Goddard Institute for Space Studies, co-chair of the New York City Panel on Climate Change, and director of the NOAA-sponsored Consortium for Climate Risk in the Urban Northeast.



Why should New Yorkers care about sea level rise?

First of all, sea level rise is a big issue for millions of people in the U.S., not just New Yorkers. Twenty-three of the 25 most densely populated U.S. counties are on the coast. In New York, the full brunt of Hurricane Sandy has shown how powerful and damaging the effects of coastal flooding can be for infrastructure and communities.

The storm itself we can't immediately link to weather trends, but the flooding damage we can. As sea levels continue to rise, a storm of the same magnitude will cause even greater damage due to storm surges coming in on top of a higher "baseline" water level.

What kind of sea level rise has New York Harbor seen over the past century?

We've had roughly a foot of sea level rise in the New York City area in the past century. That's measured at a tidal gauge near Battery Park just off the southern tip of Manhattan. The majority of the sea level rise in the New York City region is due to global warming: primarily, because of thermal expansion of ocean water as it warms, and secondly, melting of land-based ice sheets.

Land subsidence [sinking] in the New York City area has been roughly 3-4 inches per century, which is primarily due to the Earth's crust rebounding* from being compressed by massive ice sheets that covered Canada and the northern U.S. about 20,000 years ago near the end of the last Ice Age. Local variations in ocean surface elevation associated with the strength of the Gulf Stream has played a small role as well.

How do sea level rise and storm surge interact?

Sea level rise is like a set of stairs. The 12-inch increase in New York Harbor over the last century means we've already gone up one step. When a coastal storm occurs, the surge caused by the storm's winds already has a step up, literally. For Sandy, that meant greater coastal flooding in New York and the surrounding region than we would have experienced a century ago. Continuing to climb the staircase of sea level rise means we'll see greater extent and greater frequency of coastal flooding from storms, even if storms don't get any stronger.

What's the range of sea level rise we can expect to see in the future for the New York region?

We've created two sets of sea level rise projections for the region by downscaling global weather trends models for local conditions. Using a similar approach to the last IPCC [Intergovernmental Panel on Climate Change] report, we project 12-23 inches by the 2080s.

We also developed a rapid-ice-melt scenario, based on the same greenhouse gas concentrations, but factoring in observations of accelerated ice sheet melt and paleoclimate data from ice cores, tree rings, and other sources. That projection gives a higher end of 41-55 inches in the 2080s.

It's important to note that these systems don't act in isolation; they are incredibly interdependent. For example, when the power goes down then you can't charge your cell phone. These interdependencies are compounding the impacts that people are experiencing in the New York region from Hurricane Sandy.

What about social vulnerabilities?

All of these infrastructure vulnerabilities feed directly into societal ones. In the New York region, many lower-income communities are located in the coastal flood zone. With Sandy, there has been tremendous damage across many of those communities.

In addition, the elderly, the very young, and the ill are also highly vulnerable. It's much harder for them to evacuate, which in turn puts them at greater risk to infrastructure failure. Just look at the challenges hospitals in Lower Manhattan faced when the back-up generators failed.

Did Sandy reveal any previously unforeseen weaknesses?

We're going to be looking at the impacts of Hurricane Sandy very carefully. Many of the impacts that occurred have been included in previous studies, but we're certainly going to go back and evaluate them so we can better inform planning around extreme weather events. We can always learn more and continue to be better prepared. One thing we do want to look at is the fires that occurred in some of the coastal communities, and the gasoline shortages that persisted throughout parts of the region.

What actions has the city undertaken to help infrastructure and residents deal with sea level rise and attendant impacts from storm surge prior to Sandy?

Hurricane Sandy is a wake-up call, no, a shout, that going forward we have to do more to prepare for these kinds of events. That said, the city has done a great deal to prepare. The city government has a

flood evacuation plan, and they implemented it. The Metropolitan Transit Authority (MTA) had a plan to close the subway, and they did it early enough. The loss of life could have been much higher.

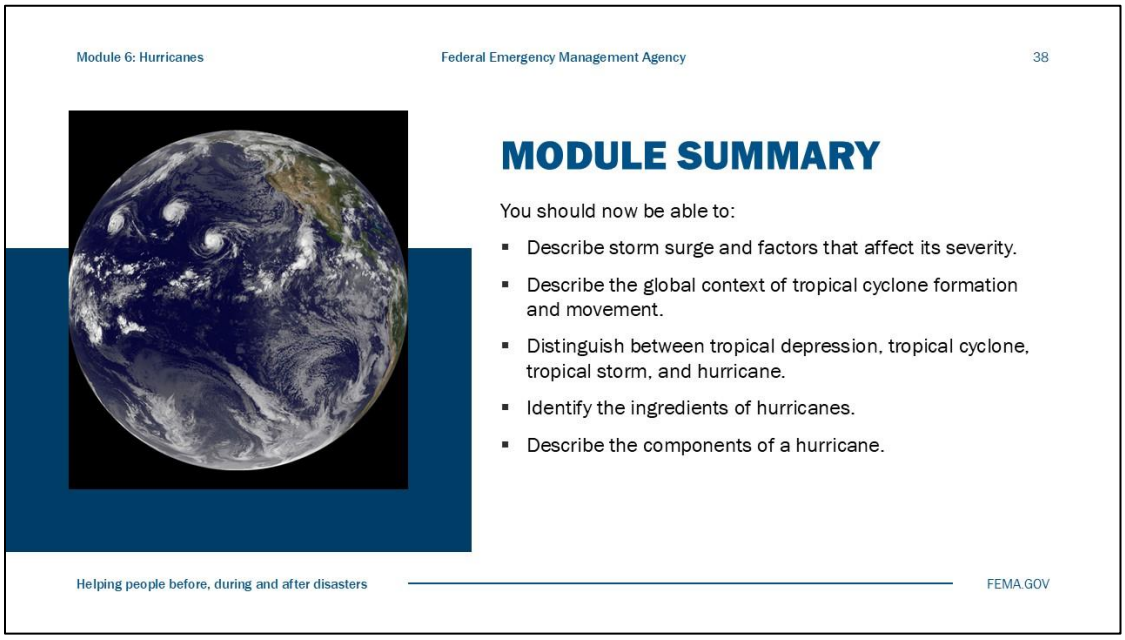
There have been some other important initiatives New York has taken. For example, the Mayor's Office has planted vegetation in over 300 places to absorb storm water. It's called the Greenstreets Program. They're also raising the pumps at the Rockaway Wastewater Treatment Plant in response to sea level rise projections. In addition, the MTA has raised some of the subway grates and air vents on the sidewalks as part of a pilot program.

These programs are informed by the work of the New York City Panel on Climate Change (NPCC), an expert panel convened by Mayor Bloomberg to advise the city on weather trends science and risk management. The NPCC published an extensive, peer-reviewed report about weather trends and their impacts on New York. The New York City Council has passed a resolution to have the NPCC write a report on the order of once every three years to ensure the city is using weather trend research when it comes to planning.

When scientists talk about sea level rise in the coming decades, you generally hear them say "projections" rather than "predictions." What's the difference?

There's uncertainty about the change in weather trends. Not that it's happening, but as to its future rate of change and magnitude. The term "projection" is better because it includes uncertainty more clearly. "Prediction" implies more certainty, a perspective that doesn't take into account that there's still emerging science around change in weather trends, that the weather system is continually evolving, and that there will be updates to future weather trends and sea level rise scenarios as a result.

End of Module (1 of 2)



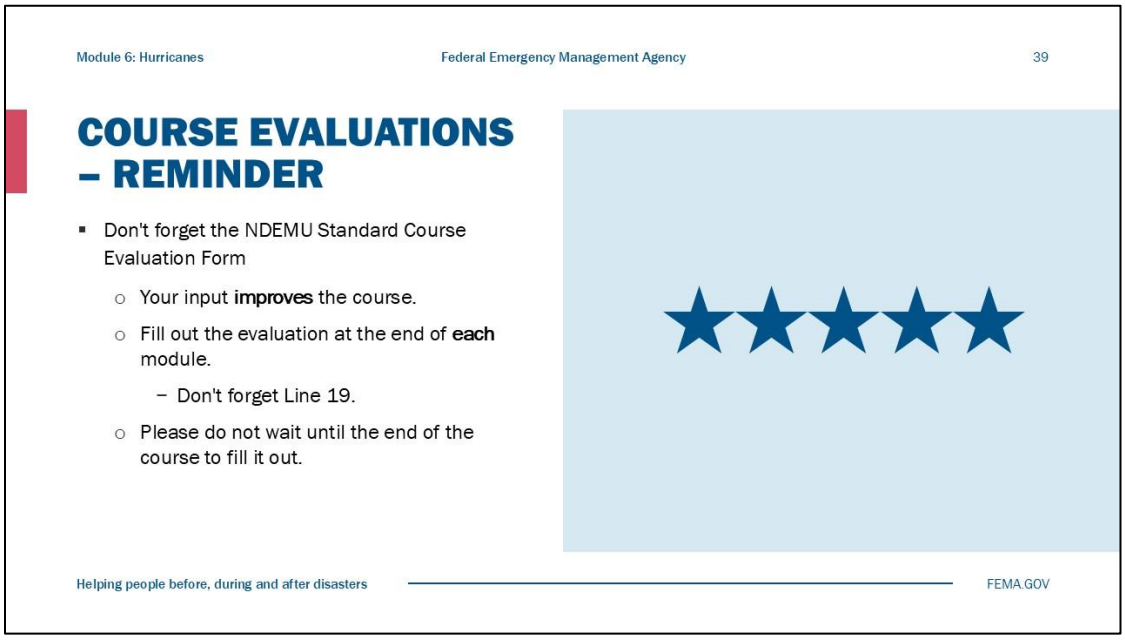
Slide 6-38, Module Summary

MODULE SUMMARY

You should now be able to:

- Describe storm surge and factors that affect its severity.
- Describe the global context of tropical cyclone formation and movement.
- Distinguish between tropical depression, tropical cyclone, tropical storm, and hurricane.
- Identify the ingredients of hurricanes.
- Describe the components of a hurricane.

End of Module (2 of 2)



Slide 6-39, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

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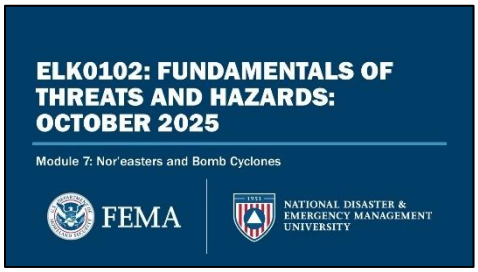
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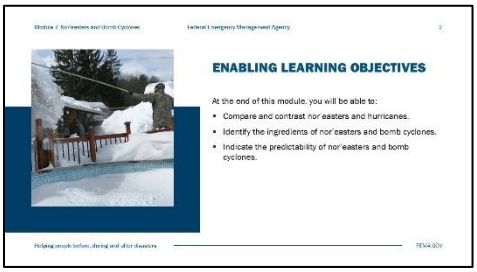
Module 7

Nor'easters and Bomb Cyclones

Administration



Slide 7-1, Module 7: Nor'easters and Bomb Cyclones



Slide 7-2, Enabling Learning Objectives

Duration

30 minutes

Terminal Learning Objective (TLO)

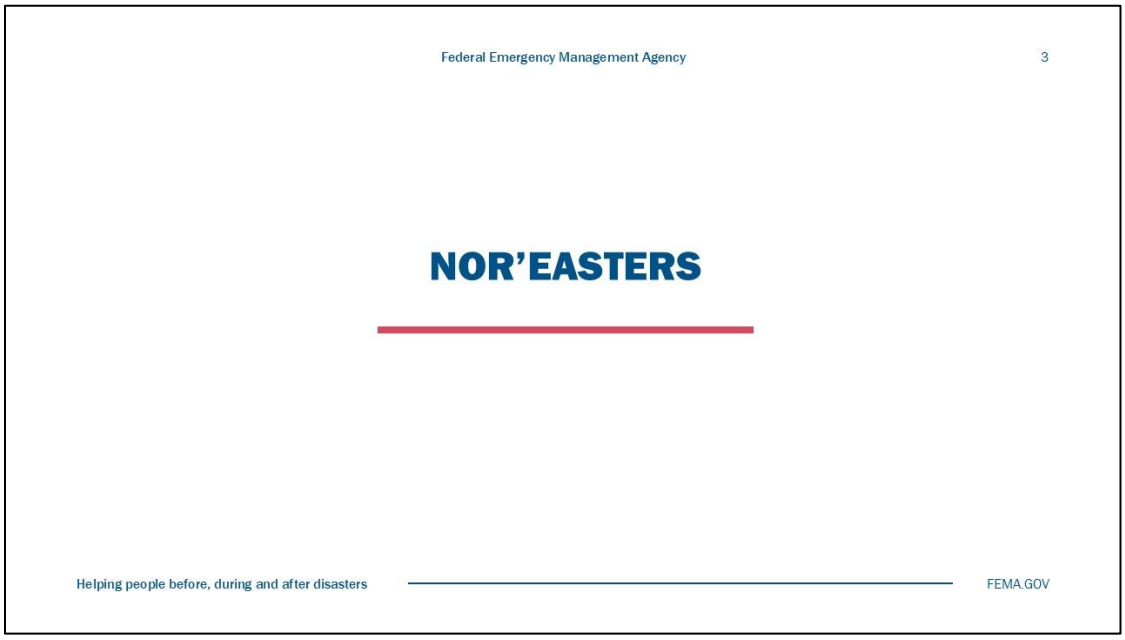
By the end of this module, participants will be able to identify and provide descriptions of nor'easters and bomb cyclones.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Compare and contrast nor'easters and hurricanes.
- Identify the ingredients of nor'easters and bomb cyclones.
- Indicate the predictability of nor'easters and bomb cyclones.

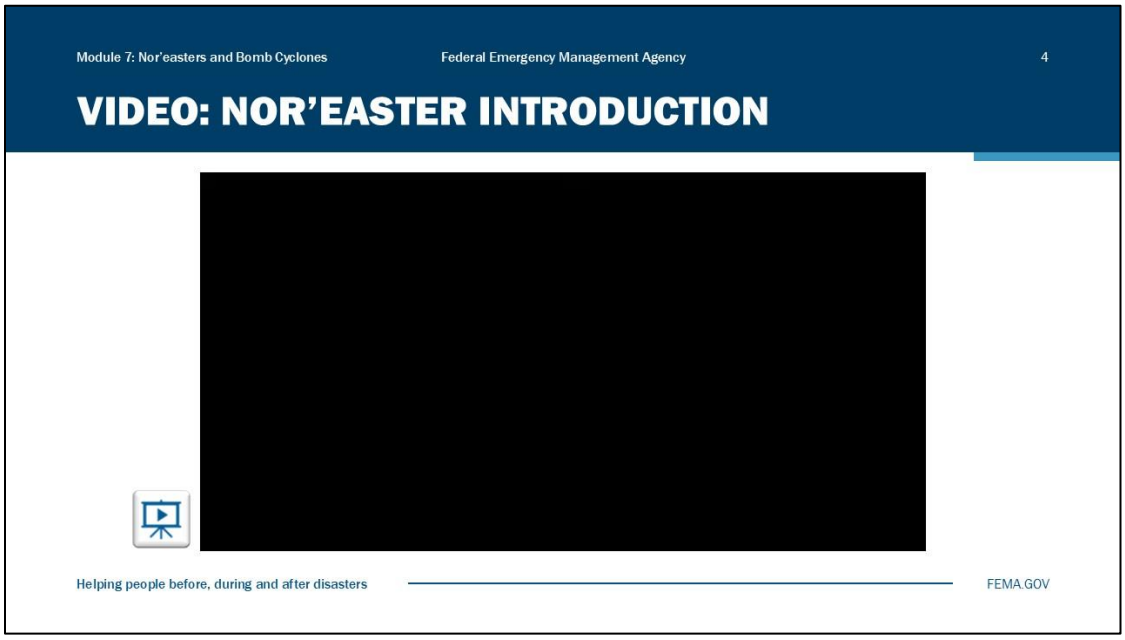
Nor’easters (1 of 9)



Slide 7-3, Nor’easters

Not applicable.

Nor’easters (2 of 9)



Slide 7-4, Video: Nor’easter Introduction

Introduction: This video presents a case study that examines in greater detail how the Gulf Stream and other ingredients interact to create a nor'easter.

Video Transcript:

The Tropics provide a steady stream of clouds and storms that generally move east to west. In mid-latitudes, weather moves west to east with some twists and turns due to Earth's rotation. An important kind of storm moves north and east along the United States' east coast, especially in winter. People in the New England States call these "nor'easters," and they usually bring snow, rain, and driving wind. In late April, an unusual, post-winter nor'easter brought much-needed rain to an especially dry eastern United States.

To understand the weather trends connections driving nor'easters, here are satellite loops that track the storm through late April.

A low-pressure system developed off the coast of Florida on April 21 as light, warm moist air rose from the warm ocean surface. Warm water is a weather trends characteristic of the Gulf, the Caribbean, and the Gulf Stream which warms the entire east coast before heading off towards northern Europe. Earth's rotation interacts with the prevailing movement of air from west to east to spin these storms up and along the east coast.

The difference in temperature between land, which is cold, and the ocean, which is warm, fuels driving rains. The ocean in this part of the world stays warm due to the Gulf Stream. The land is especially cold when Arctic air plunges southward. During winter, this temperature difference is more common but notice how the polar jet stream dipped south of the Great Lakes on April 22.

The east coast has been drier than normal so far this year, in part because winter didn't bring any major nor'easters. This map shows rainfall differences from average for January through April. The brown areas were drier than normal for this time of year.

Farmers are often the first to feel water shortages. In Maryland, some farmers lost their spinach crops and had to delay soy and corn planting because the soil was so dry. Farmers and residents in Delaware-Maryland-Virginia, Connecticut, Rhode Island, and Massachusetts have all delayed their spring planting and have been conserving water.

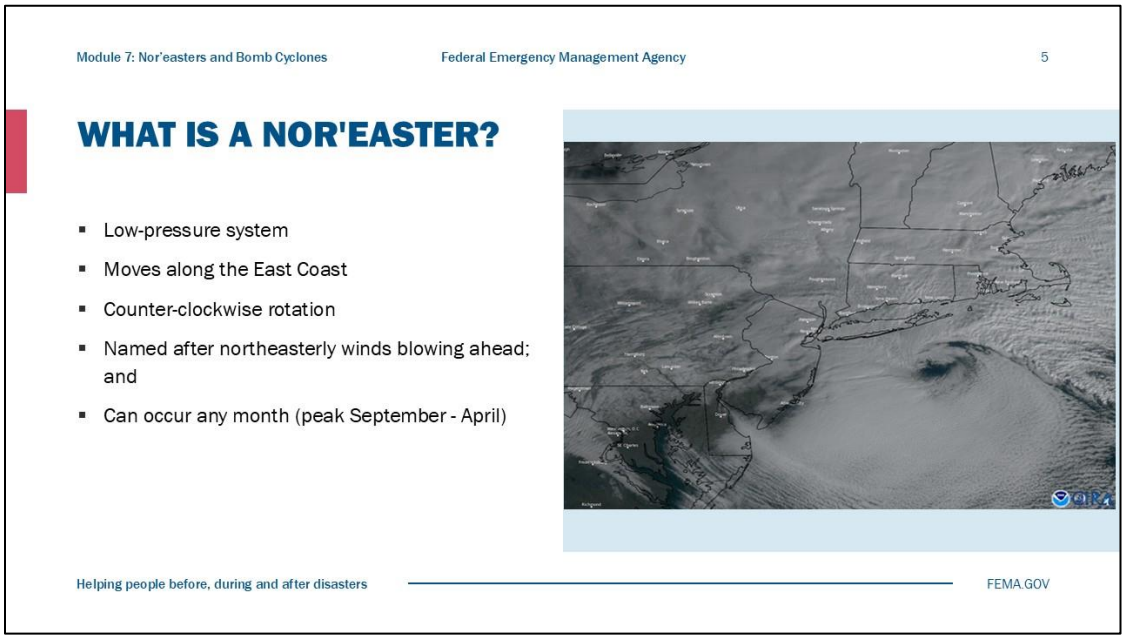
This springtime storm made up for most of April's rainfall deficit in a single event, dumping over 2 along much of the Atlantic coast and between 4 and 6 in parts of Maine. Unfortunately, the year-to-date through April was still well below average, not only for the Mid-Atlantic and New England, but much of the United States.

Recapping the weather trends connections for a nor'easter: warm ocean water fuels a low-pressure system with moisture; Earth's rotation moves that air mass in a counter-clockwise motion along the east coast; and cold air from the North drives toward the storm's center. That was the weather trends story for one strange nor'easter after Easter.

For climate.gov, I'm Ned Gardiner.

Source: NOAAClimate (Director). (2022, February 22). *Nor'Easter After Easter: After a Quiet Winter, an Unusual Storm* [Video recording]. https://www.youtube.com/watch?v=olyIoO6o1nk

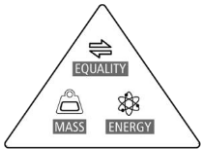
Nor'easters (3 of 9)



Slide 7-5, What Is a Nor'easter?

- Low-pressure system;
- Moves along the East Coast;
- Counterclockwise rotation;
- Named after northeasterly winds blowing ahead; and
- Can occur any month (peak September - April)

This is equality, mass, and energy.



Characteristics of a nor'easter

A nor'easter:

- Is a strong, low-pressure system that moves along the east coast of the United States with a counterclockwise rotation;

- Gets its name from the strong northeasterly winds that blow in from the ocean ahead of the storm and over coastal areas; and
- Can occur any month of the year but is strongest (and occurs most frequently) between September and April. They are less common in summer because the jet stream is usually missing (farther north).

A nor'easter normally develops within 100 miles of the coastline between Georgia and New Jersey and moves north or northeastward from there. However, a nor'easter can form over the land of the East Coast or out over the Atlantic coastal waters. This difference constitutes the two types of nor'easters.

Nor'easters (4 of 9)



Slide 7-6, Types of Nor'easters

There are two types of nor-easters:

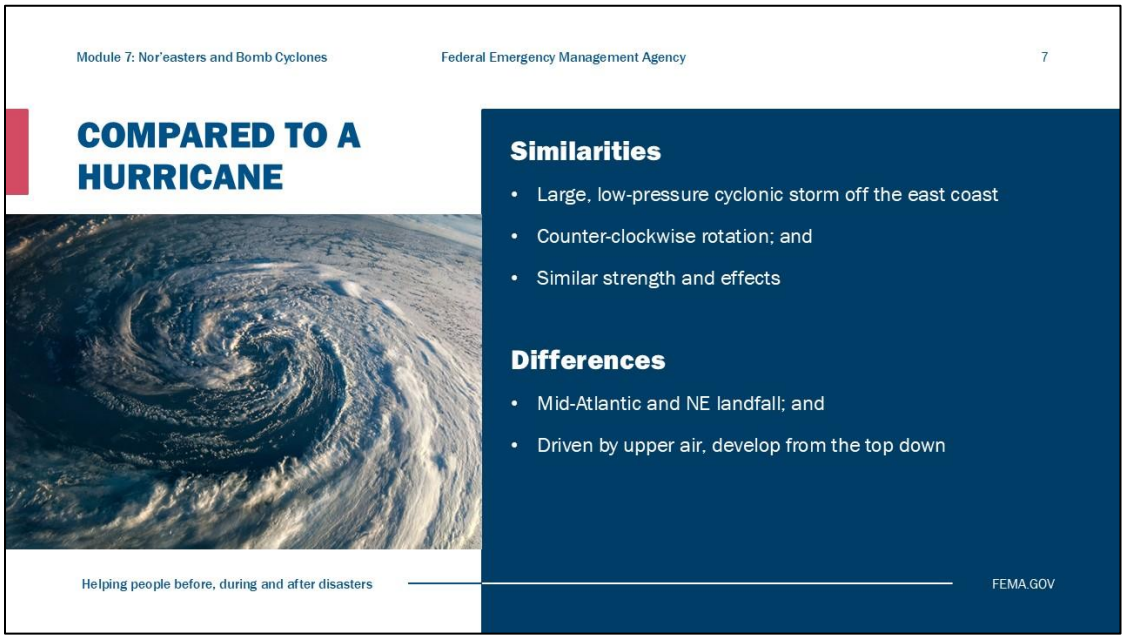
Offshore Forming Nor'easters

- More catastrophic
- Heavy snow
- Moisture and wind 'moving towards' the ocean

Onshore Forming Nor'easters

- Less catastrophic
- Mostly rain
- Moisture and wind 'moving towards' the land

Nor'easters (5 of 9)



Slide 7-7, Compared to a Hurricane

Similarities

- Large, low-pressure cyclonic storm off the east coast;
- Counterclockwise rotation; and
- Similar strength and effects

Differences

- Mid-Atlantic and NE landfall; and
- Driven by upper air, develop from the top down

Comparison

When compared to a hurricane, a nor'easter is similar in several key ways:

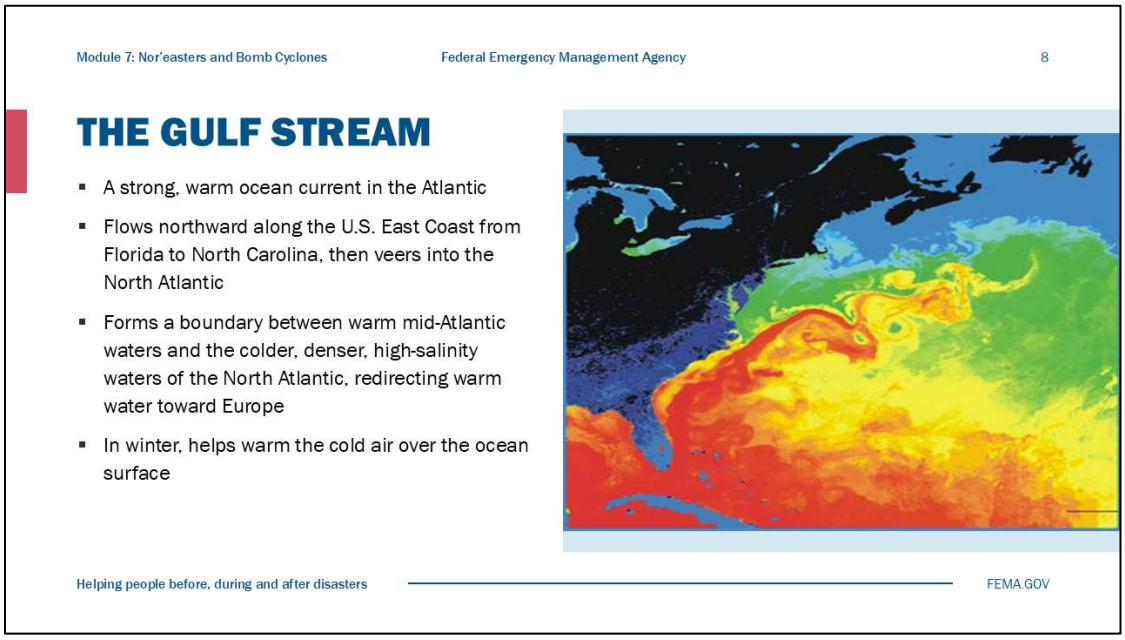
- Both hurricanes and nor'easters are large, low-pressure cyclonic storms that normally have a center of rotation just off the East Coast.
- Both are counterclockwise rotating systems in the Northern Hemisphere.
- Nor'easters can reach the strength of moderate or even strong hurricanes and can produce similar effects.

- Occasionally, a strong nor'easter will form a hurricane-like eye at its center. For example, this visual shows a satellite image of an intense nor'easter with a hurricane-like eye in February 2006.

However, there are also a few key differences:

- Hurricanes normally make landfall in the Southern States, while nor'easters typically afflict the mid-Atlantic and Northeast States.
- Hurricanes develop from the bottom up, whereas nor'easters are driven by upper air and develop from the top down.

Nor'easters (6 of 9)



Slide 7-8, The Gulf Stream

- A strong, warm ocean current in the Atlantic
- Flows northward along the U.S. East Coast from Florida to North Carolina, then veers into the North Atlantic
- Forms a boundary between warm mid-Atlantic waters and the colder, denser, high-salinity waters of the North Atlantic, redirecting warm water toward Europe
- In winter, helps warm the cold air over the ocean surface

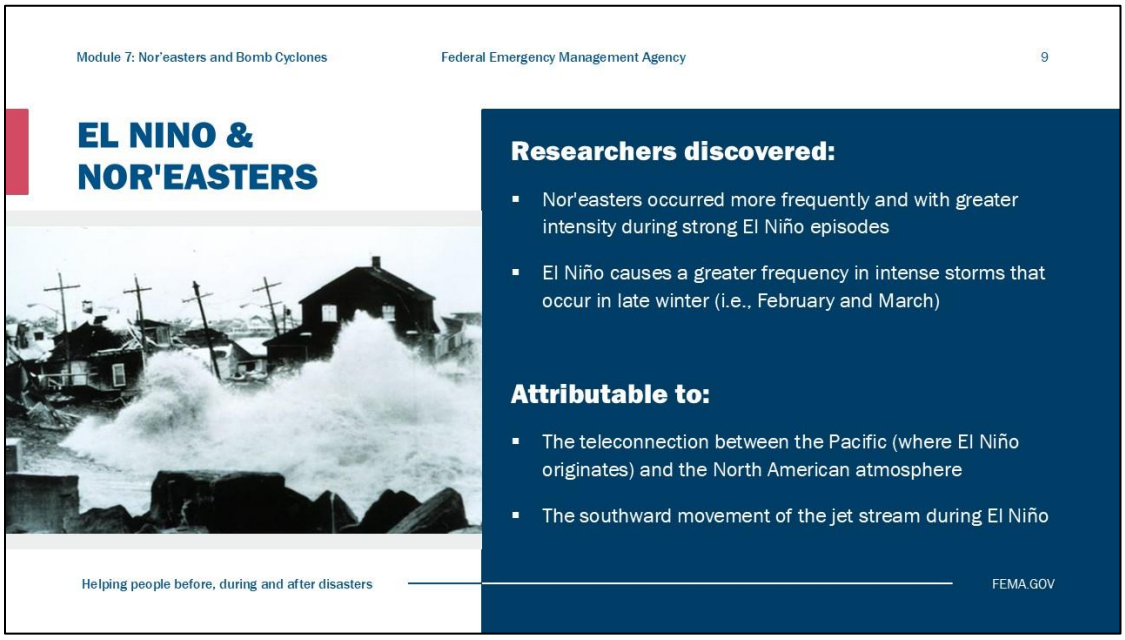
Impact of the Gulf Stream: The Gulf Stream plays an important part in the formation of nor'easters. The Gulf Stream is an intense warm ocean current in the Atlantic that flows northward along the east coast of the United States from Florida to North Carolina and then veers out into the North Atlantic near Cape Hatteras, North Carolina.

The Gulf Stream:

- Forms a boundary between the warm waters in the middle of the North Atlantic and the colder, denser waters of the continental shelf. The current loops and bends as it veers away from the United States coast, so its exact position is variable;
- Influences the climatic conditions of the east coast of Florida, keeping temperatures warmer in the winter and cooler than the other southeastern states in the summer. Because it also extends toward Europe, it warms western European countries as well; and
- Helps keep the coastal waters relatively mild during the winter, which, in turn, helps warm the cold winter air over the water.

The infrared image shows the Gulf Stream as it departs from the coast at Cape Hatteras. The coldest waters are shown as purple, with blue, green, yellow, and red representing progressively warmer water. Temperatures range from about 45-72 °F (7-22 °C).

Nor'easters (7 of 9)



Slide 7-9, El Nino & Nor'easters

El Niño episodes affect nor'easter formation, as explained in your key points. Researchers from the U.S. Naval Academy studied two strong El Niño events (1982-83 and 1997-98) and discovered that:

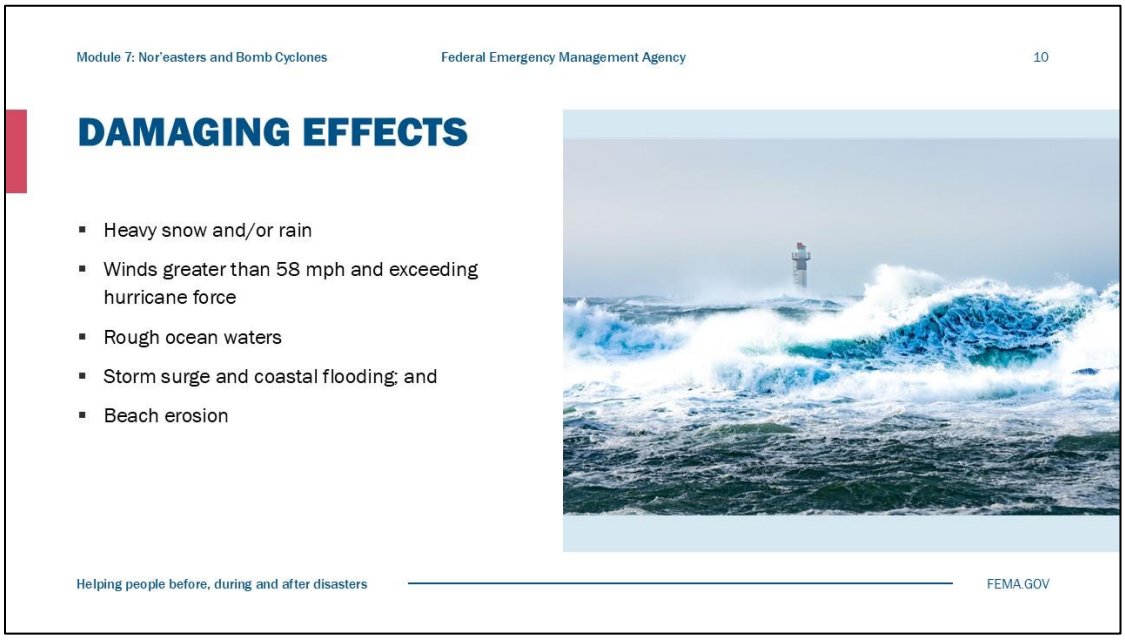
- Nor'easters occurred more frequently and with greater intensity during strong El Niño episodes.
- El Niño causes a greater frequency in intense storms that occur in late winter (i.e., February and March).

This change is attributable to:

- The teleconnection between the Pacific (where El Niño originates) and the North American atmosphere.
- The southward movement of the jet stream during El Niño.

The jet stream shift results in storms encountering greater temperature differentials than they would if they were tracking farther north, and warmer ocean water to fuel their growth.

Nor'easters (8 of 9)



Slide 7-10, Damaging Effects

Damaging effects of nor'easters can include:

- Heavy snow and/or rain;
- Winds greater than 58 mph and exceeding hurricane force;
- Rough ocean waters;
- Storm surge and coastal flooding; and
- Beach erosion.

The second image on the slide shows an area off the coast of Virginia where storm surge resulting from a nor'easter grounded a barge on shore.

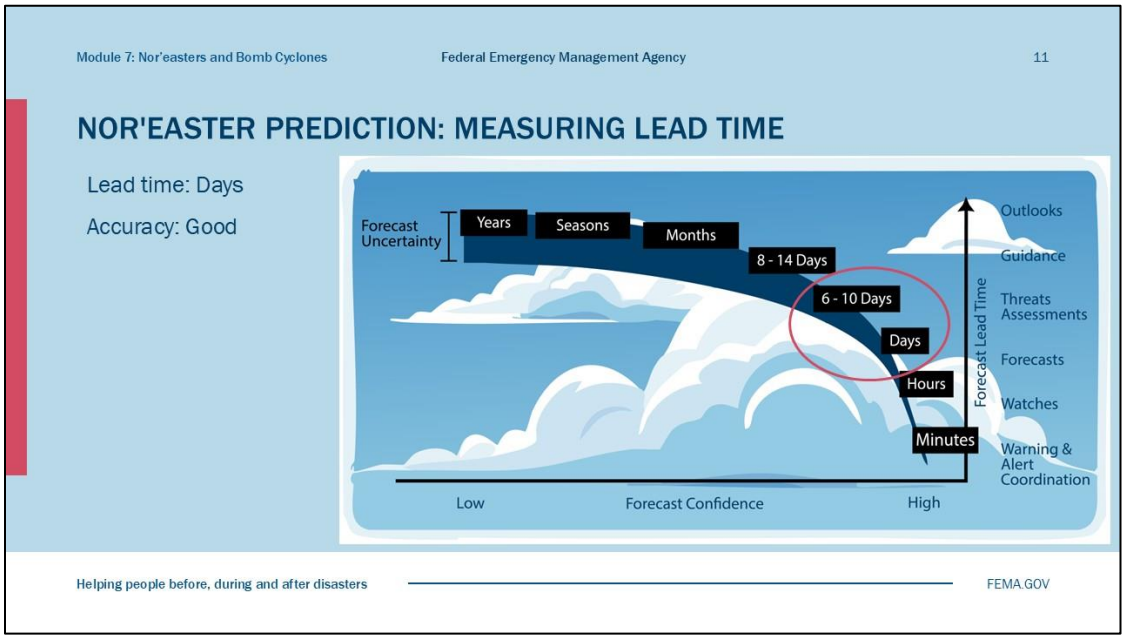
One of the biggest concerns is the huge amounts of snow dumped on East Coast cities. For example, a nor'easter from March 20-22, 2018, brought over 18 inches of snow and whiteout conditions to the Mid-Atlantic states and New England.

Other Notable Nor'easters

- **Post-Christmas Storm of 2010:** This late-December nor'easter was initially a low-pressure system from the Gulf but exploded into a nor'easter off the mid-Atlantic coast. It brought heavy snow, thunderstorms, and strong winds of up to 40 mph throughout the Northeast.
- **Blizzard of 1996:** This nor'easter developed in the Gulf, intensified along the mid-Atlantic, and brought heavy snow and wind gusts to the mid-Atlantic and much of the Northeast. Local accumulations in West Virginia were as high as 4 feet, and Philadelphia received 30.7 inches-its highest accumulation on record. After this nor'easter, the same general area was hit with a warmer rainstorm that contributed to widespread melting and flooding.
- **1993 Superstorm:** This storm was named for its wide area of impact (New England to Florida). It took a more inland track rather than moving up the coast. In the Mid-Atlantic States, there was severe flooding and snowfall; in Florida, the superstorm resulted in storm surges of 9 to 12 feet.
- **1992 Great Nor'easter or "The Downslope Nor'easter":** The effects of this December storm were felt most strongly in the northeast and the mid-Atlantic coasts, which were battered with high winds and waves. There was moderate flooding in Maryland, and storm surges of 10 to 12 feet in New Jersey, Delaware, and New York City.
- **Blizzard of 1978:** This February nor'easter was historic due to its long-duration snowfall and hurricane-force winds (gusts of 80-90 mph in eastern Massachusetts) resulting from a strong high-pressure system off the coast of New England. The Northeast was hit the hardest, and Boston and Providence were buried under record snowstorm totals (27.1 inches and 27.6 inches, respectively).
- **1962 Ash Wednesday Storm:** Perhaps the strongest nor'easter of the century, this monstrous March storm resulted in major coastal erosion from New York to North Carolina. As a result of the massive storm surge in Virginia, entire islands off the coast (Chincoteague, Assateague) were completely flooded, and winds as high as 70 mph built up 40-foot waves in the ocean.
- **1956 Nor'easter:** This storm resulted in significant damage from high tides in Virginia. For example, there was a 4.6-foot rise in water levels in Hampton Roads and a 6.32-foot rise in Norfolk. The storm flooded thousands of homes and washed two ships onto shore.

- **Blizzard of 1888:** This massive March nor'easter:
  - Brought devastating amounts of snowfall from Virginia to Maine;
  - Paralyzed Washington, DC, Philadelphia, Boston, and New York City;
  - Dumped up to 50 inches of snow in multiple New England States, with snow drifts as high as 40 to 50 feet; and
  - Resulted in 200 sunken ships and 400 fatalities.

Nor'easters (9 of 9)



Slide 7-11, Nor'easter Prediction: Measuring Lead Time

Measuring lead time:

- Lead time: Days
- Accuracy: Good

Accuracy of prediction: The lead time for predicting nor'easters is measured in days and the accuracy is generally good.

Challenges: As with all weather, there is a degree of unpredictability that continually poses challenges to forecasters. As we continue to get more data sets, we will be able to predict with more accuracy.

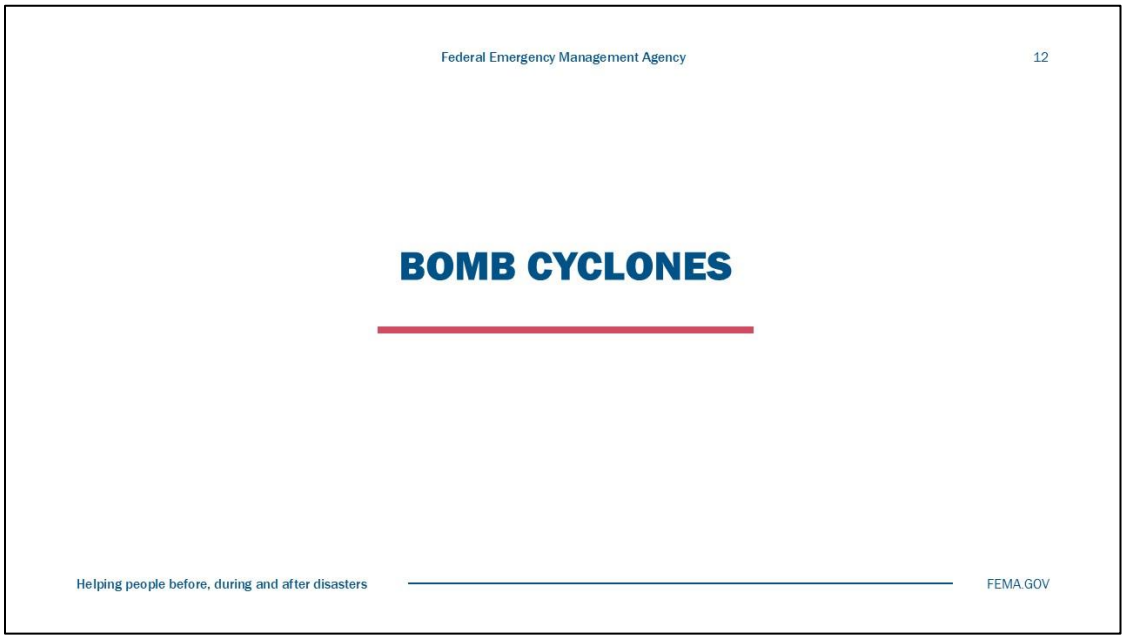
Informational sources: To predict nor'easters, forecasters rely on many of the same informational sources we have discussed, including:

- Surface observations (e.g., balloon-launched temperature, moisture, and wind measurements);
- Statistical models; and
- Coordination with Federal, State, and local emergency managers.

With the necessary information gathered from these sources, forecasters are able to predict:

- Probability of the nor'easter's track and affected areas;
- The probability of precipitation;
- Types and accumulation of precipitation; and
- Temperatures.

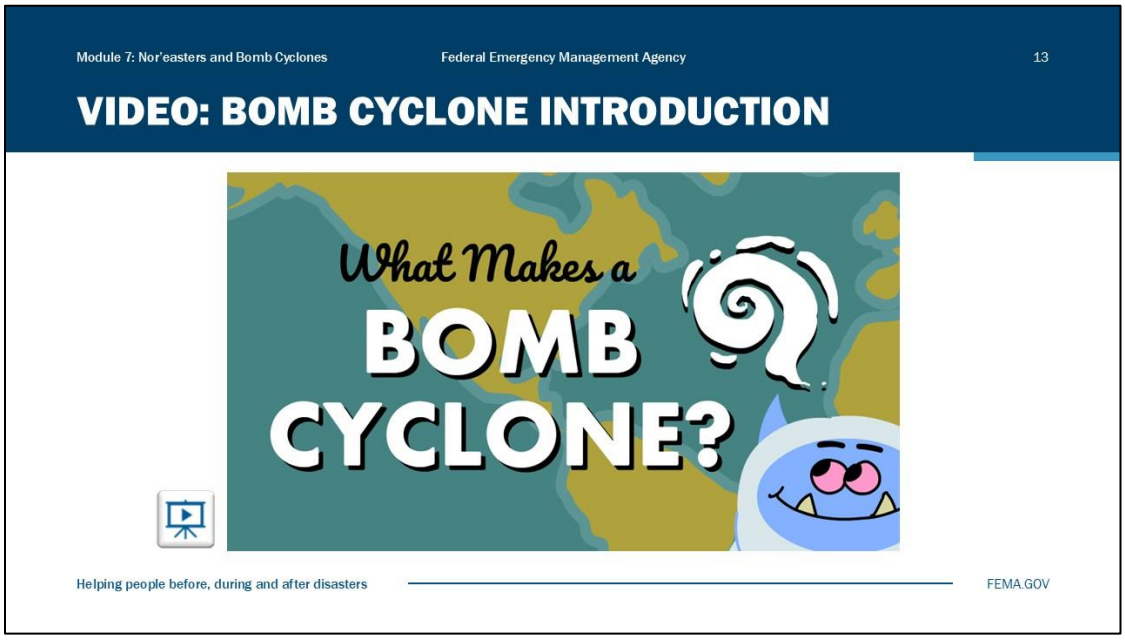
Bomb Cyclones (1 of 5)



Slide 7-12, Bomb Cyclone

Not applicable.

Bomb Cyclones (2 of 5)



Slide 7-13, Video: Bomb Cyclone Introduction

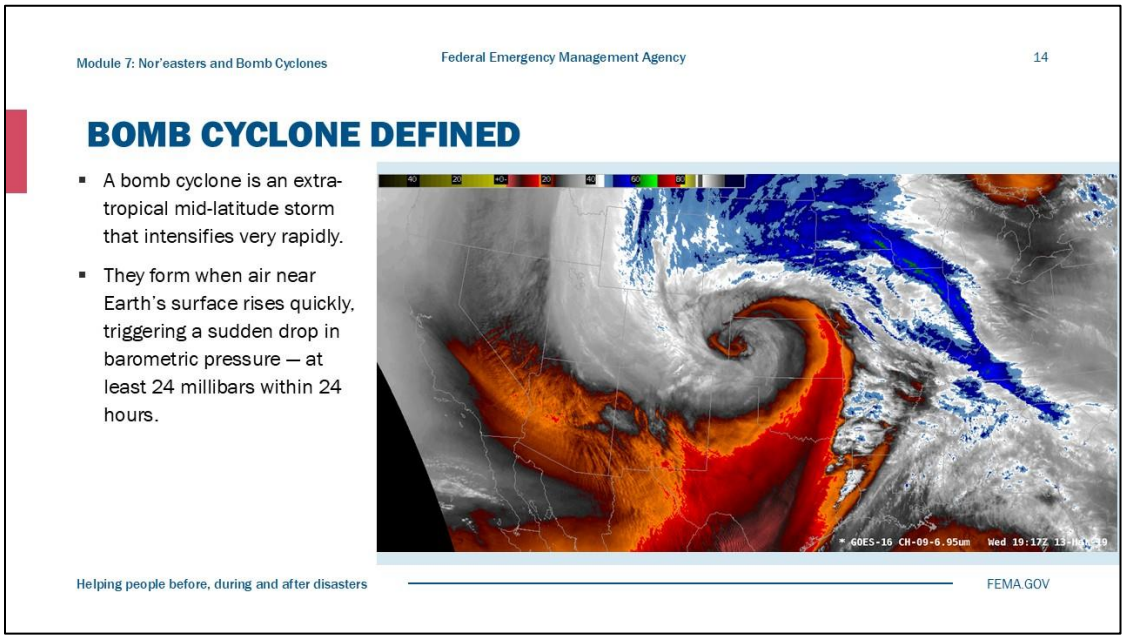
Introduction: This video introduces Bomb Cyclones.

Video Transcript

Is there a cooler-sounding weather word than Bombo Genesis? Our friend here doesn't think so. But what exactly is bombogenesis? Bombo Genesis turns a typical winter storm into a bomb cyclone, an intense storm in the mid-latitudes. When cold arctic air clashes with warmer air, the temperature difference triggers a rapid drop in air pressure. It's almost like an explosion inside the storm. With low pressure, winds flow quickly into the center of the storm and can intensify the amount of clouds and precipitation. Bomb cyclones can produce severe flooding, blizzard conditions, hurricane-force winds, and destructive waves. So, make sure you're stocked up and ready to be inside for a while, potentially without power.

Source: NSF NCAR & UCAR Science Education (Director). (2021, January 26). *What Makes a Bomb Cyclone?* [Video recording]. https://www.youtube.com/watch?v=CV46o2N8XtY

Bomb Cyclones (3 of 5)



Slide 7-14, Bomb Cyclone Defined

Image Description

On March 13th, 2019, an extremely powerful low-pressure system developed over southern Colorado, setting a record for the lowest pressure recorded over Colorado, bringing widespread rainfall over the plains, creating a blizzard over El Paso County, and dropping feet of snow over the mountains. According to local news sources, around 1,500 motorists were stranded over northern El Paso County. According to CDOT, I-25 north of Woodmen Road closed at 11:23 AM MDT due to "adverse weather conditions" and reopened during the later afternoon hours on March 14th. The lowest recorded pressure was 970.4 hPa over Lamar, Colorado, which is the official state record for lowest pressure ever recorded outside of a tornado. KPUB (Pueblo, Colorado) recorded a 974.2 hPa surface pressure at 9:00 AM MDT, which is a record for the lowest pressure over Pueblo.

Bomb cyclones are also known as “explosive cyclogenesis” or “bombogenesis.”

Formation

Pre-cyclogenesis: During the late evening hours and overnight hours of March 12th and March 13th, there were rain bands that formed over the I-25 corridor and the eastern plains. The rain band formations were created by warm air advection (WAA) from the south and southeast of Colorado. Generally, the Raton Mesa creates a rain shadow (compressional heating due to downslope flow resulting in temperatures warming and moisture content remaining stationary, meaning a drier atmosphere relative to where the air came from), but in this case, the WAA overcame the effects of orography to create overnight rain showers. The high temperatures on March 13th actually came during the overnight periods. The extra moisture from the Gulf of Mexico and the stratus deck kept the temperature warm overnight, hence the rain bands and not snow bands.

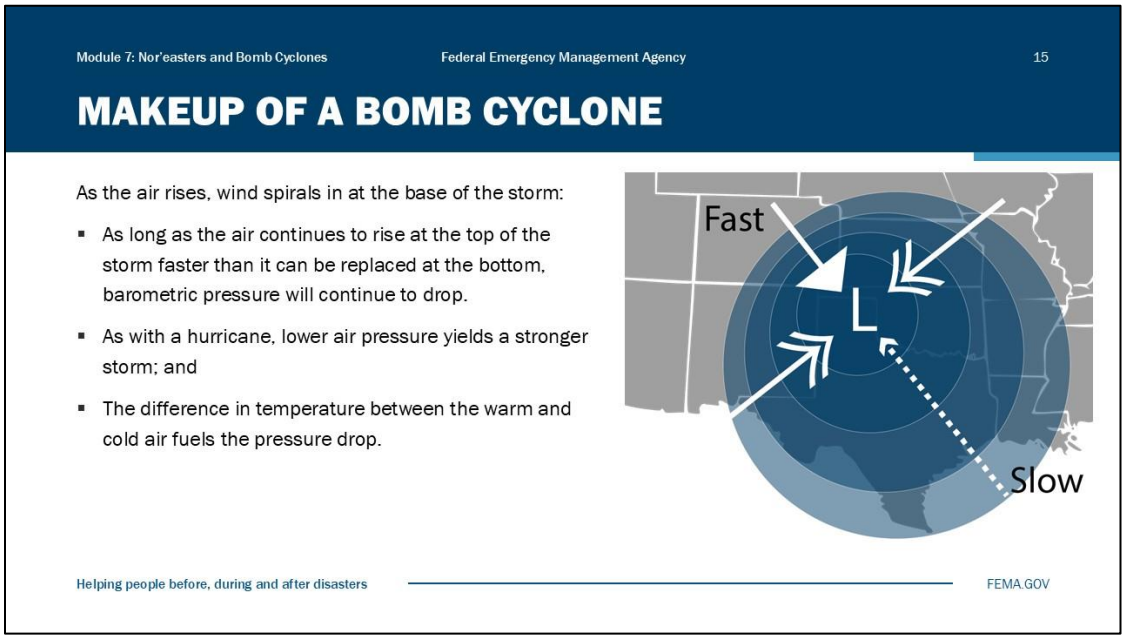
"Bombogenesis": So how did this happen? Why did we see the strongest low-pressure system ever recorded in Colorado? Here, over the Front Range, we see a phenomenon called Lee Cyclogenesis. Essentially, what happens is the upper-level low-pressure system ejects off the Rocky Mountains and over the high plains. During that time, the upper-level circulation must quickly move from the higher elevations all the way down to the lower elevations, which causes the low-pressure system to stretch and tighten, allowing it to rotate more quickly and thereby intensify. The best way to describe this phenomenon is by comparing it to an ice skater spinning. When the ice skater extends their arms, they spin more slowly, but when they bring their arms in tightly to their body, they spin more quickly, which is an application of the conservation of angular momentum. The same phenomenon previously described occurs with a low-pressure system ejecting from the Rocky Mountains. Lee cyclogenesis happens all of the time, so what made this special? Well, while the low-pressure center exited the Rockies, there was a baroclinic zone located over southern Colorado. A baroclinic zone is a region in which a temperature gradient (temperature difference) exists, which also helps intensify the low-pressure system. In this particular case, there was a 10 °C temperature difference within 50 miles. There was both lee cyclogenesis and baroclinic cyclogenesis occurring, but again, this is a relatively common occurrence. There was another element that helped the cyclone to explosively intensify, and that was a trough merger between a low-pressure center located over the Pacific Northwest and a cut-off upper-level low over the American Southwest. All these interactions created the "bombogenesis" event. The rapid cyclogenesis caused "wrap-around" precipitation bands on the back side of the low-pressure center. This kind of precipitation occurs when the upper-level low and the surface transition to becoming vertically stacked or reach the occlusion stage of its life cycle. Isentropic lift (upglide; warm conveyor belt) is responsible for this type of precipitation. The timeline of when rain turned into snow and when blizzard conditions started is located in the "Overview" section of this write-up.

Orographics: The final stage is when the low-pressure system is located far enough east that the dynamics are overwhelmed by the orographics. The very strong northerly winds (downslope) off the Palmer Divide ending precipitation over southern El Paso County and Pueblo County is illustrated in Fig. 11. Blizzard conditions still continued over parts of southern El Paso County and all of northern

El Paso County (see the "Overview" section), but rain stopped over Pueblo County and south. Generally, the downslope flow off the Palmer Divide is stronger than the dynamics of the low-pressure system, but in this case, the dynamics were stronger, at least for the middle of the event. A key lesson in Colorado forecasting is that topography manipulates the weather around us, and the topography manipulated the outcome of this explosive cyclogenesis event. During afternoon hours, the strongest winds were observed, which was caused (partly) by the topography as well. There were ageostrophic accelerations to the south due to wind hitting the mountains and being forced south, evaporational cooling from the downslope effects of the Palmer Divide, causing a density acceleration to the lower elevations, and the shear intensity of the low-pressure system.

Additional information can be found at the March 13th, 2019 "Bombogenesis" Event page at NWS. (This link can be viewed at https://www.weather.gov/pub/Bombogenesis_20190313).

Bomb Cyclones (4 of 5)



Slide 7-15, Makeup of a Bomb Cyclone

As the air rises, wind spirals in at the base of the storm:

- As long as the air continues to rise at the top of the storm faster than it can be replaced at the bottom, barometric pressure will continue to drop;
- As with a hurricane, lower air pressure yields a stronger storm; and
- The difference in temperature between the warm and cold air fuels the pressure drop.

January 2018 North American Bomb Cyclone: A historic winter storm that struck the Northeastern United States, particularly impacting the East Coast. The storm brought extreme cold temperatures, hurricane-force winds, and heavy snowfall to coastal areas from Florida to Maine. Boston experienced record-breaking low temperatures and massive coastal flooding.

March 2018 "Bomb Cyclone" (Winter Storm Riley): Devastated the Mid-Atlantic and Northeast regions with winds exceeding 90 mph in some areas. The storm caused widespread power outages, significant coastal erosion, and extensive damage to infrastructure. It was particularly notable for its rapid intensification and destructive wind patterns.

January 2022 East Coast Bomb Cyclone: A massive storm that impacted the entire Eastern Seaboard, bringing blizzard conditions to many areas. The storm dumped over 2 feet of snow in

some regions, with wind gusts reaching up to 70 mph. It caused major disruptions to transportation and led to numerous road closures and flight cancellations.

November 2022 Bering Sea Bomb Cyclone: An extremely intense storm that hit Alaska's western coast with unprecedented force. The storm brought wind speeds over 100 mph and caused significant damage to coastal communities. It was particularly notable for its impact on remote Alaskan villages and marine ecosystems.

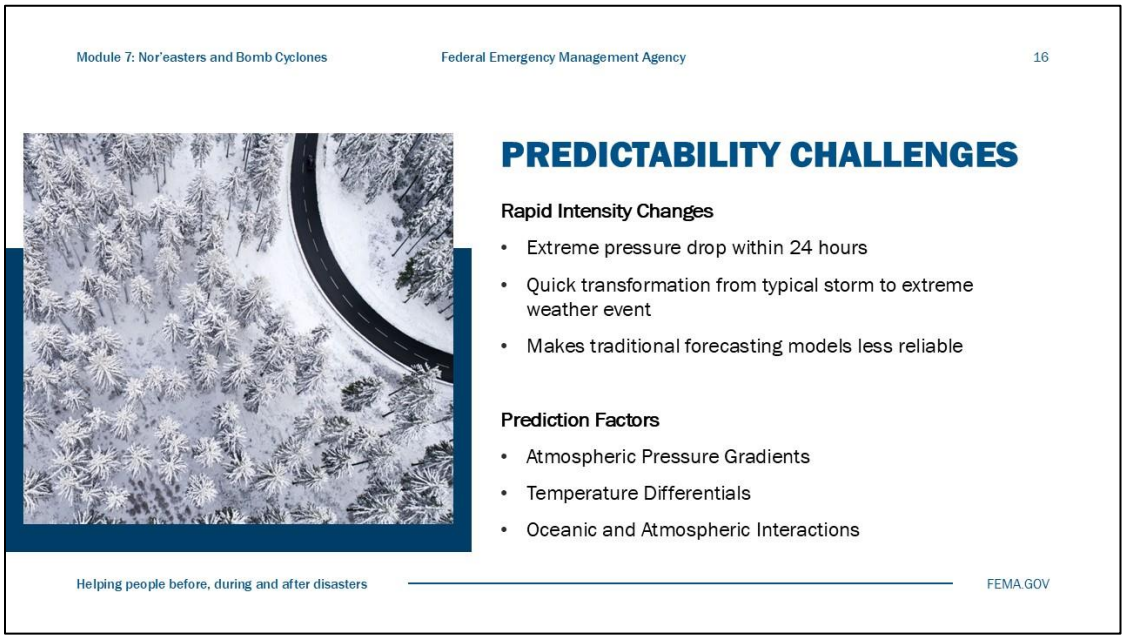
December 2020 Midwest Bomb Cyclone: A powerful winter storm that swept through the central United States, bringing extreme cold and significant snowfall. The storm created dangerous wind chills and caused widespread travel disruptions across multiple states.

October 2022 Mediterranean Bomb Cyclone: An unusual and extremely powerful storm that hit Greece and Turkey, characterized by hurricane-force winds and extreme rainfall. The storm caused significant flooding and damage in regions not typically accustomed to such intense weather events.

January 2020 Pacific Northwest Bomb Cyclone: A particularly intense storm that struck the West Coast of the United States, bringing hurricane-force winds, massive waves, and extensive rainfall. The storm caused significant coastal damage and widespread power outages in Oregon and Washington.

Each of these bomb cyclones demonstrates the unpredictable and powerful nature of these meteorological events, highlighting their potential for rapid intensification and destructive capabilities. They serve as important reminders of the dynamic and sometimes extreme behavior of our planet's atmospheric systems.

Bomb Cyclones (5 of 5)



Slide 7-16, Predictability Challenges

Predicting bomb cyclones represents one of the most challenging tasks in meteorological forecasting, combining complex atmospheric dynamics with rapidly changing conditions.

Predictability Challenges

- Rapid Intensity Changes
  - Extreme pressure drop within 24 hours
  - Quick transformation from typical storm to extreme weather event
  - Makes traditional forecasting models less reliable

Technological Forecasting Tools

- Advanced Meteorological Models
  - Sophisticated computer simulations
  - High-resolution satellite imaging
  - Real-time atmospheric data collection

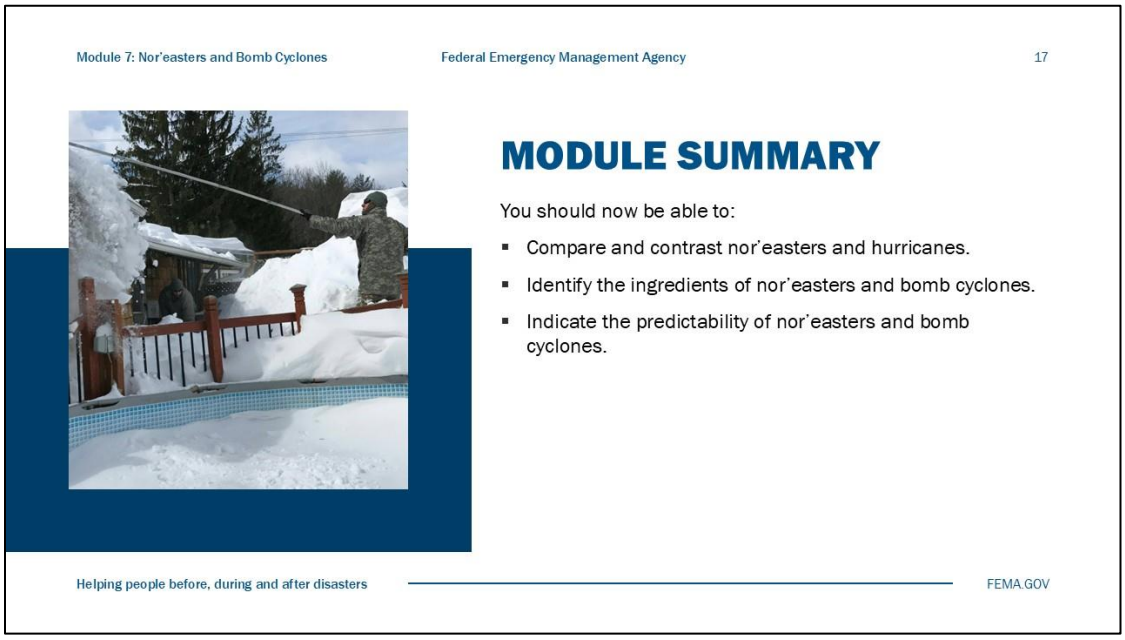
- Limitations
  - Inherent unpredictability of atmospheric systems
  - Short-term, precise prediction remains difficult

Key Prediction Factors

- Atmospheric Pressure Gradients
  - Monitoring rapid pressure changes
  - Identifying potential bombogenesis conditions
- Temperature Differentials
  - Tracking significant temperature contrasts
  - Analyzing potential energy exchange zones
- Oceanic and Atmospheric Interactions
  - Understanding complex interactions between ocean currents and air masses
  - Identifying critical trigger points for storm development

Bomb cyclones demonstrate the unpredictable and powerful nature of meteorological events, highlighting their potential for rapid intensification and destructive capabilities. They serve as important reminders of the dynamic and sometimes extreme behavior of our planet's atmospheric systems.

End of Module (1 of 2)

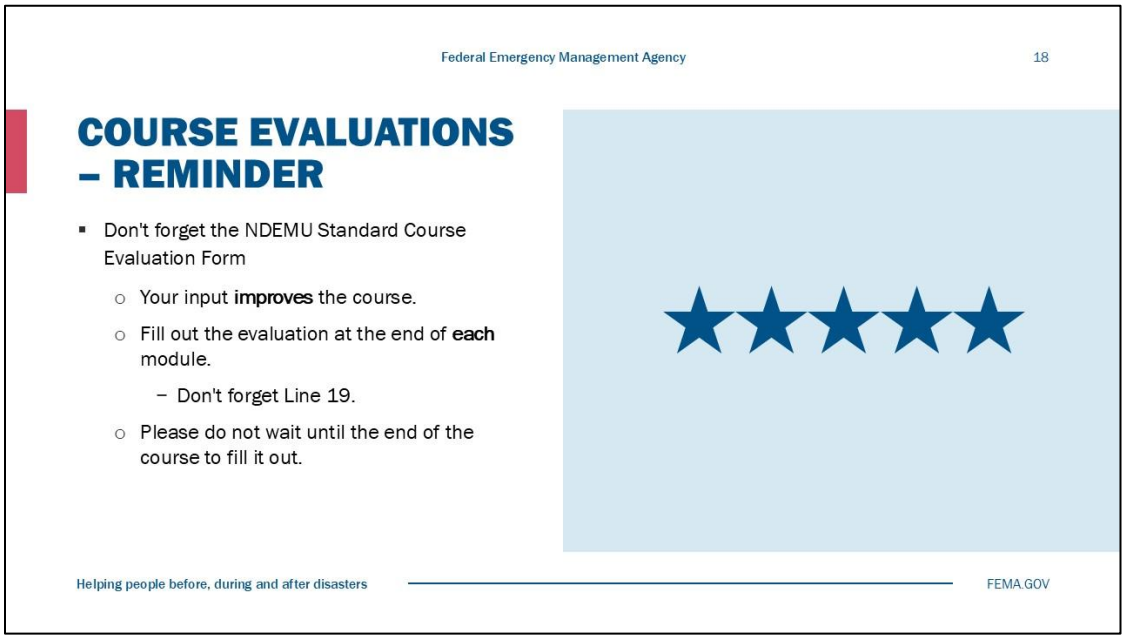


Slide 7-17, Module Summary

You should now be able to:

- Compare and contrast nor'easters and hurricanes.
- Identify the ingredients of nor'easters and bomb cyclones.
- Indicate the predictability of nor'easters and bomb cyclones.

End of Module (2 of 2)



Slide 7-18, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

FOX 13 Seattle (Director). (2024, November 18). What is a bomb cyclone? | FOX 13 Seattle [Video recording]. https://www.youtube.com/watch?v=HYjUprp6YAY

March 13th, 2019 "Bombogenesis" Event. (n.d.). Retrieved May 19, 2025, from https://www.weather.gov/pub/Bombogenesis_20190313

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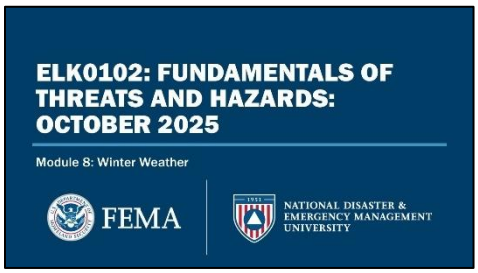
Saffir-Simpson Hurricane Wind Scale. (n.d.). Retrieved April 21, 2025, from https://www.nhc.noaa.gov/aboutsshws.php

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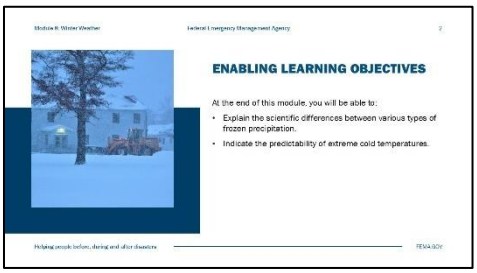
Module 8

Winter Weather

Administration



Slide 8-1, Module 8: Winter Weather



Slide 8-2, Enabling Learning Objectives

Duration

30 minutes

Terminal Learning Objective (TLO)

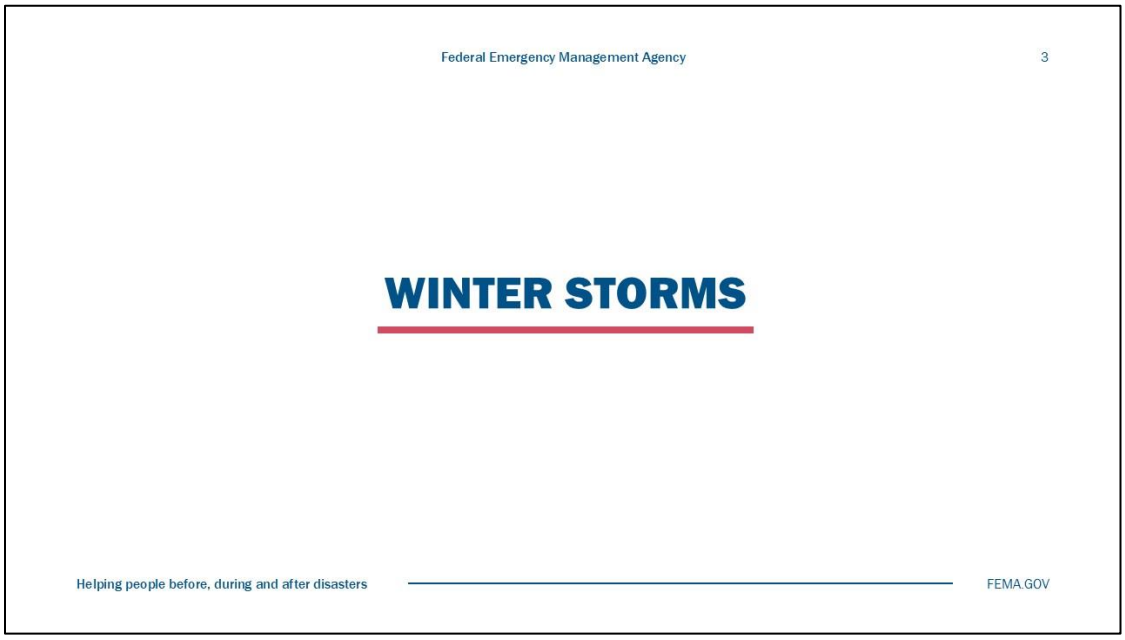
By the end of this module, participants will be able to describe winter weather.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Explain the scientific differences between various types of frozen precipitation.
- Indicate the predictability and extreme cold temperatures.

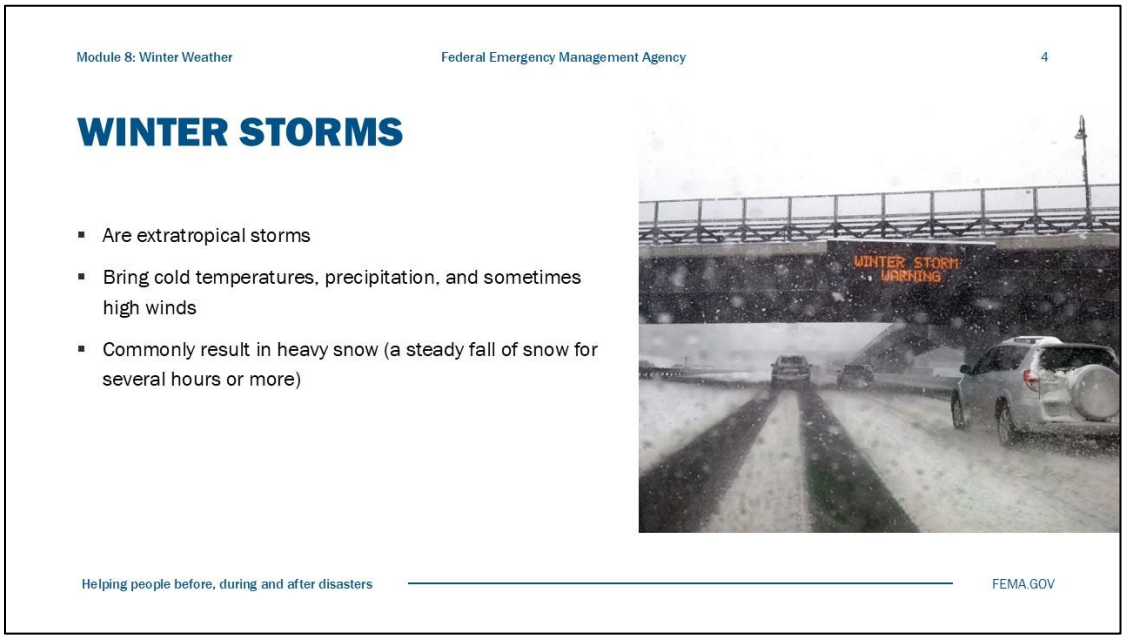
Winter Storms (1 of 3)



Slide 8-3, Winter Storms

Not applicable.

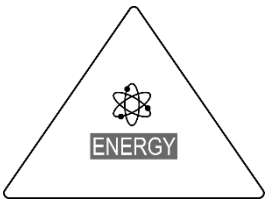
Winter Storms (2 of 3)



Slide 8-4, Winter Storms

- Are extratropical storms;
- Bring cold temperatures, precipitation, and sometimes high winds; and
- Commonly result in heavy snow (a steady fall of snow for several hours or more).

This is energy



Winter storms are extratropical storms that bring cold temperatures, precipitation, and sometimes high winds. Heavy snow, defined as a steady fall of snow for several hours or more, is a common component of winter storms.

The accumulations and timeframes for defining heavy snow depend on region and elevation, but are generally defined as:

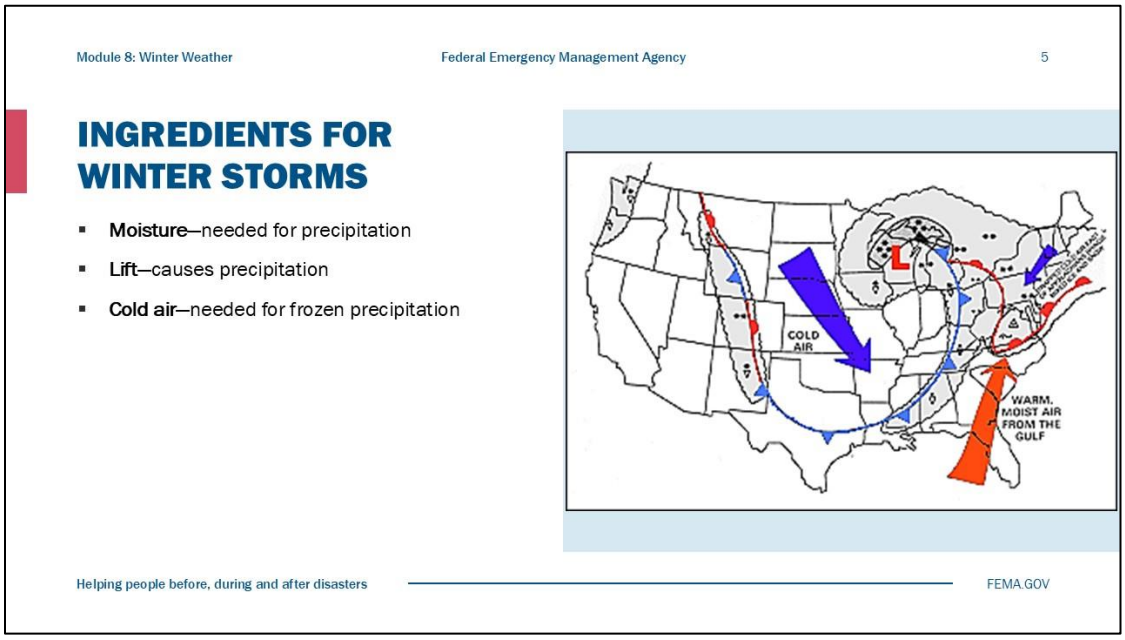
- Snowfall accumulating to 4 inches (10 cm) or more in 12 hours or less, or;
- Snowfall accumulating to 6 inches (15 cm) or more in 24 hours or less.

Severe Winter Storms

The National Weather Service uses specific designations to classify winter storm conditions:

- **Heavy Snow**: 4 or more inches in a 12-hour period, or 6 or more inches in a 24-hour period.
- **Blizzard Conditions**: Winds of 35 miles per hour or higher, with visibility less than a quarter-mile for 3 or more hours.
- **White Out Conditions**: Blowing snow with zero visibility, which can develop rapidly and with little warning.

Winter Storms (3 of 3)



Slide 8-5, Ingredients for Winter Storms

The development of a winter storm requires three ingredients:

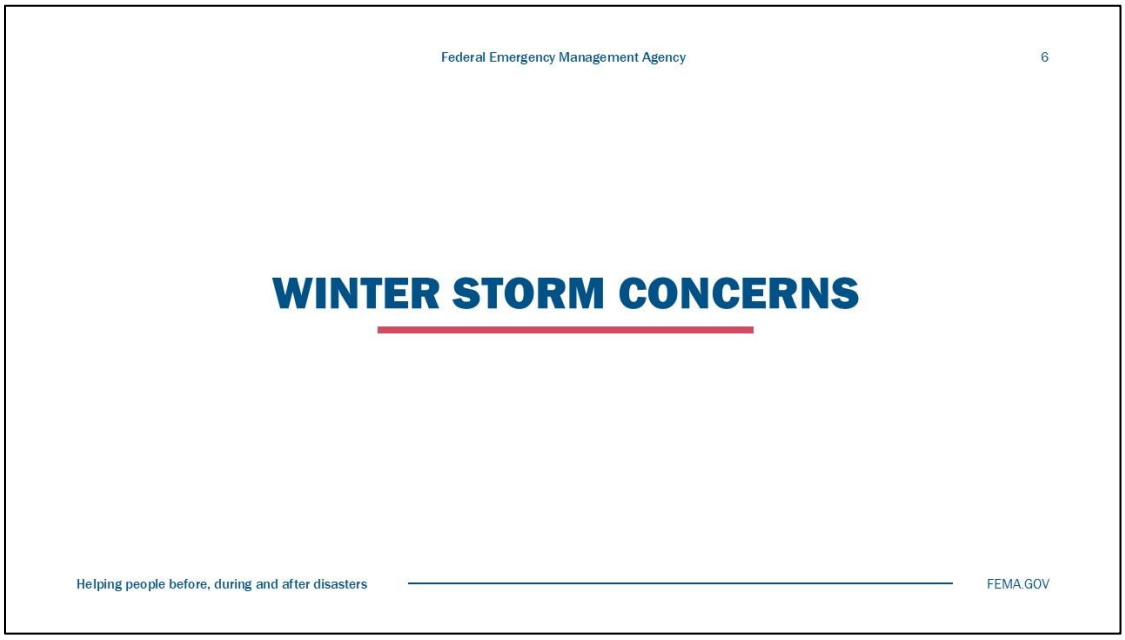
- Moisture—needed for precipitation
  The air must contain moisture to form clouds and precipitation. As you learned in earlier units, air blowing across a body of water, such as a large lake or an ocean, is an excellent source of moisture.
- Lift—causes precipitation
  A mechanism to raise the moist air to form the clouds and cause precipitation must also be present. Any or all of the following can provide lift:
  - Orographic flow, i.e., the flow of air up a mountainside.
  - Fronts, where warm air collides with cold air and rises over the cold dome. Upper-level low-pressure troughs.
- Cold air—needed for frozen precipitation
  Cold air generally refers to subfreezing temperatures (below 32°F) in the clouds and/or near the ground needed to make snow and/or ice.

This visual illustrates the three ingredients needed for winter storm formation interacting on a national scale. Note that:

- The blue line with triangles represents the front of cold air.
- The red line with half-circles represents the front of warm, moist air from the Gulf.
- A stationary front (i.e., a front between warm and cold air masses that is moving very slowly or not at all) is represented as a combination of the two lines.

In this scenario, the three ingredients necessary for winter storm formation—moisture, lift, and cold air—are all present.

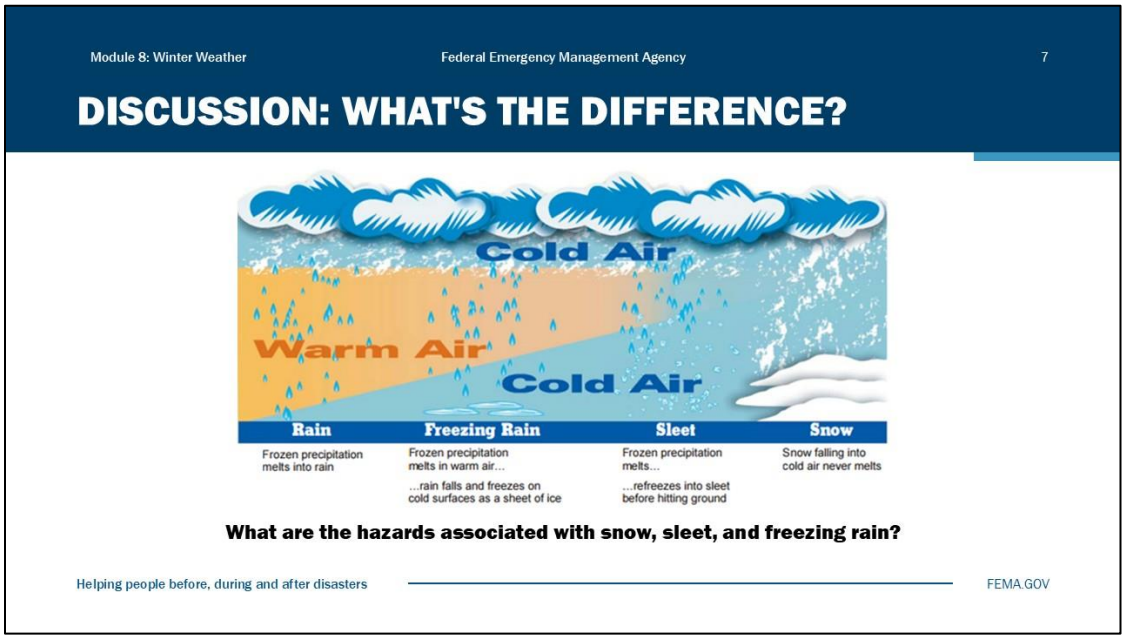
Winter Storm Concerns (1 of 5)



Slide 8-6, Winter Storm Concerns

Not applicable.

Winter Storm Concerns (2 of 5)



Slide 8-7, Discussion: What's the Difference?

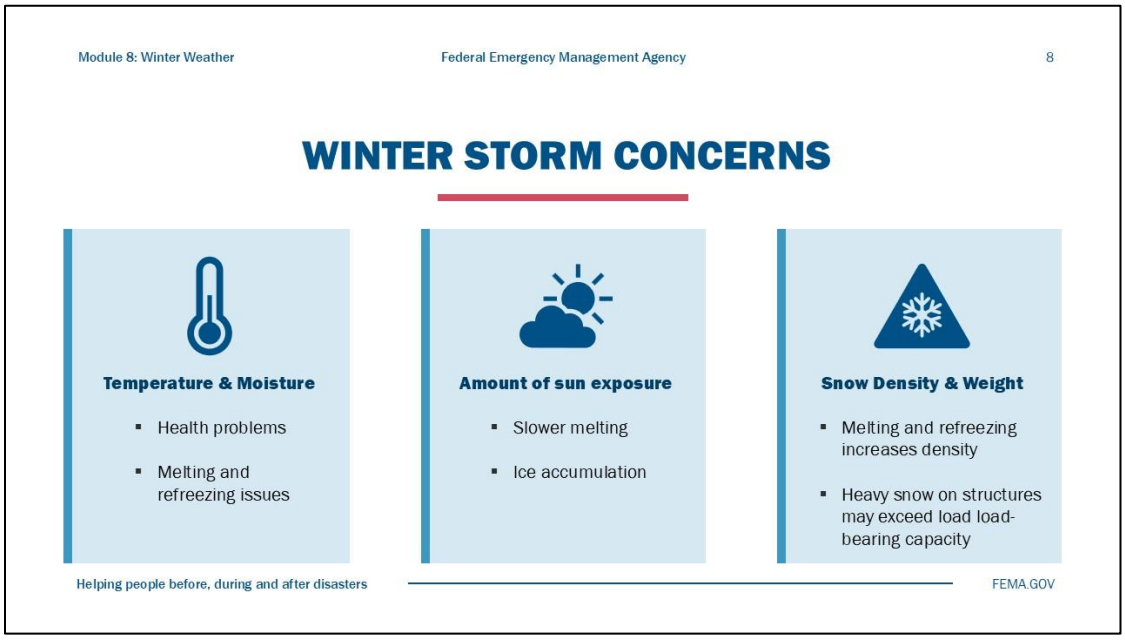
What are the hazards associated with snow, sleet, and freezing rain?

The differences are as follows:

- **Rain**: Frozen precipitation from high-level clouds melts into rain as it passes through a warm air layer.
- **Freezing Rain**: Frozen precipitation from high-level clouds melts into rain as it passes through a warm air layer, but then freezes on cold surfaces as a sheet of ice.
- **Sleet**: Frozen precipitation from high-level clouds melts into rain as it passes through a warm air layer, but then refreezes into sleet before hitting the ground.
- **Snow:** Frozen precipitation from high-level clouds never melts and remains in the form of snow.

Each condition presents its own unique hazards, especially frozen precipitation, which can hinder travel due to slippery conditions, cause icing, and downed power lines or trees.

Winter Storm Concerns (3 of 5)



Slide 8-8, Winter Storm Concerns

Temperature & moisture:

- Health problems (e.g., hypothermia, frostbite)
- Melting and refreezing issues (e.g., broken pipes or power lines)

Amount of sun exposure:

- Slower melting
- Ice accumulation

Snow density/weight:

- Melting and refreezing increase density
- Heavy snow on structures may exceed their load-bearing capacity

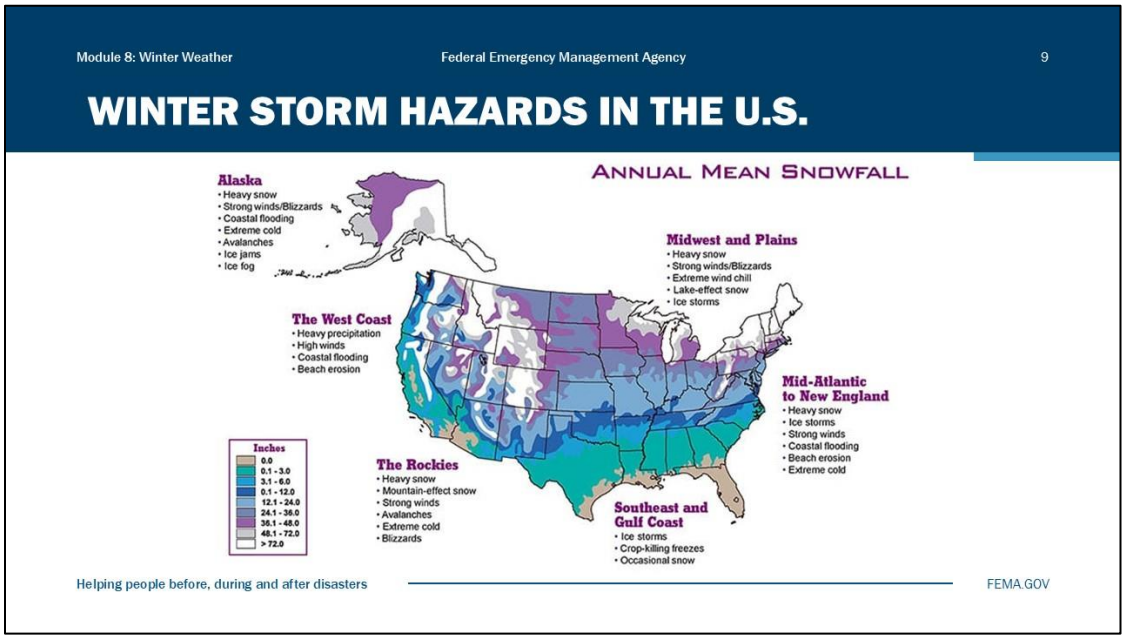
There are multiple concerns about winter storms rooted in scientific factors.

- **Temperature and moisture:** Chronic freezing or subfreezing temperatures can lead to health problems from extreme cold, including hypothermia, frostbite, and lowered tolerance. Another concern is that large temperature fluctuations between daytime and nighttime can result in dangerous melting and refreezing. Water that freezes into ice

expands and can cause cracks or breaks in pipes and snap power lines, usually during extended periods of below-freezing temperatures.

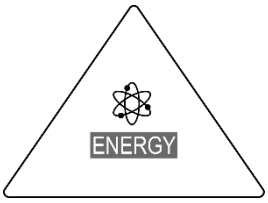
- **Sun exposure:** Another concern is the amount of sun exposure in an area hit with a winter storm. For example, north-facing areas get less sun exposure in the winter and will have slower melting snow. Ice accumulation will also be greater in areas facing north.
- **Snow density:** The density of snow depends on the amount of moisture it contains.

Winter Storm Concerns (4 of 5)



Slide 8-9, Winter Storm Hazards in the U.S.

This is energy.

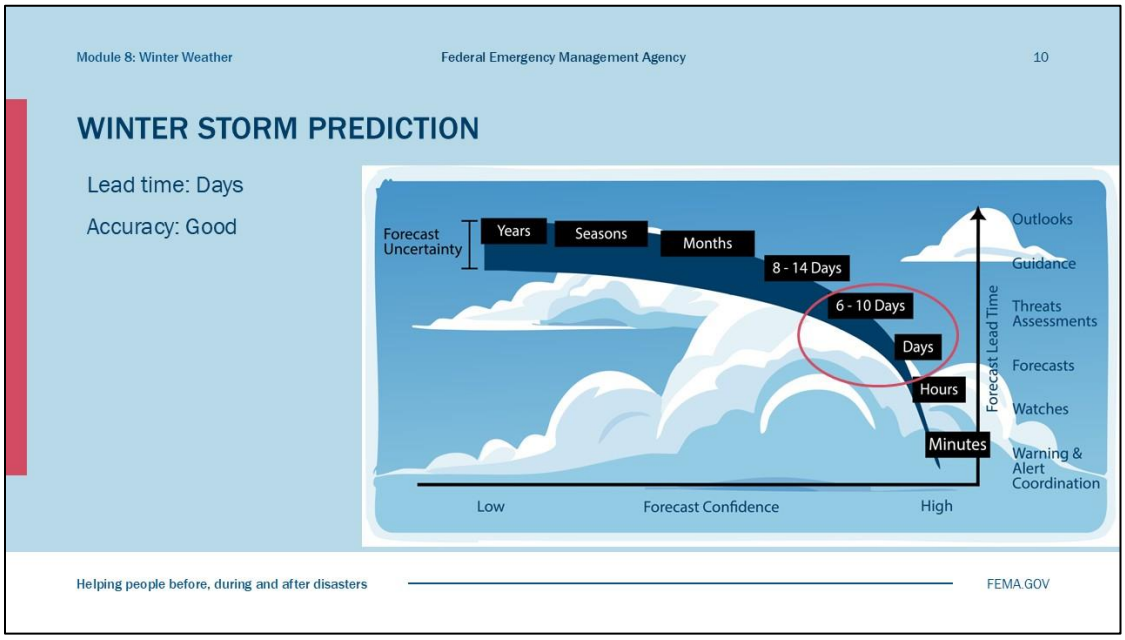


This map shows the annual mean snowfall across the United States and indicates which areas are at a greater risk for damaging winter storms.

- **Alaska:** Heavy snow, strong winds and blizzards, coastal flooding, extreme cold, avalanches, ice jams, and ice fog
- **Midwest and Plains**: Heavy snow, strong winds and blizzards, extreme wind chill, lake-effect snow, and ice storms
- **The West Coast:** Heavy precipitation, high winds, coastal flooding, and beach erosion
- **The Rockies**: Heavy snow, mountain-effect snow, strong winds, avalanches, extreme cold, and blizzards
- **Southeast and Gulf Coast:** Ice storms, crop-killing freezes, and occasional snow

- **Mid-Atlantic to New England:** Heavy snow, ice storms, strong winds, coastal flooding, beach erosion, and extreme cold
- **Hawaii** - Snow possible on the highest volcanic peaks, including Mauna Kea and Mauna Loa.

Winter Storm Concerns (5 of 5)

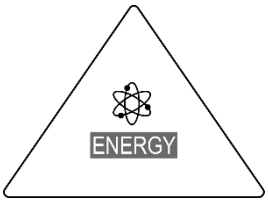


Slide 8-10, Winter Storm Prediction

Winter Storm Prediction

- Lead time: Days
- Accuracy: Good

This is energy.



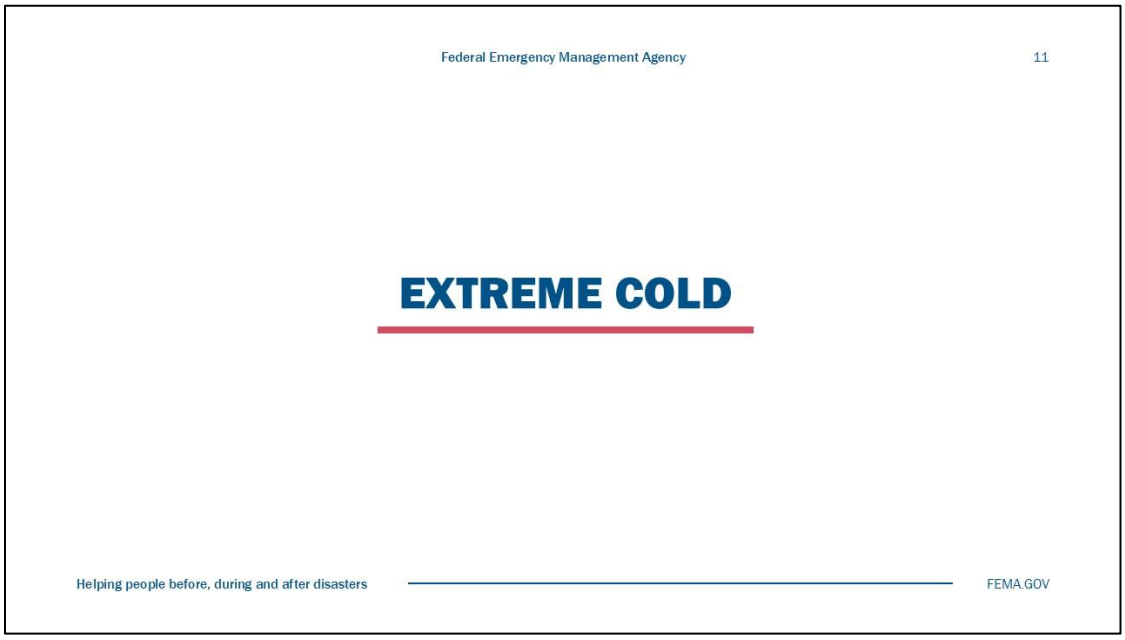
Gathering information: To predict winter storms, forecasters rely on many of the same technologies mentioned in previous units, including radar, surface observations, satellites, and computer models. In the process, they gather information about:

- Air, ground, and cloud top temperatures.
- Wind direction.
- Cold fronts.
- Moisture.
- Type and heaviness of precipitation.
- Comma clouds, i.e., synoptic-scale cloud patterns with a characteristic comma-like shape that are associated with large and intense low-pressure systems.

What's predictable: With this information, forecasters can predict the probability, types, and accumulation of precipitation, along with expected temperatures. The lead time for predicting winter storms is days, and the accuracy is generally good.

Challenges: Forecasts for winter storms are improving, but still involve certain challenges. For example, heavy snow often appears as small bands on larger resolution models that are harder to pick up; conversely, extremely light snow can go undetected because of its low moisture and high air content. Also, the boundary line between rain and snow is defined by a very small temperature disparity.

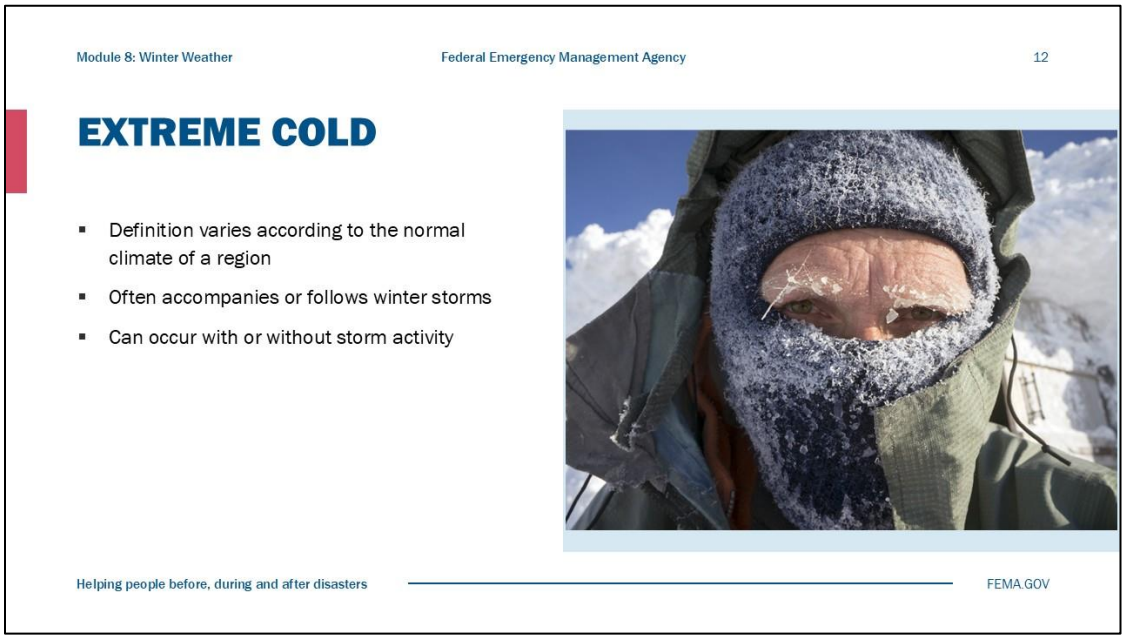
Extreme Cold (1 of 3)



Slide 8-11, Extreme Cold

Not applicable.

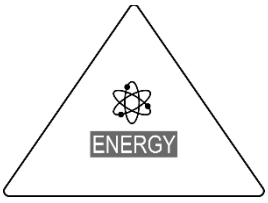
Extreme Cold (2 of 3)



Slide 8-12, Extreme Cold

- Definition varies according to the normal climatic conditions of a region
- Often accompanies or follows winter storms
- Can occur with or without storm activity

This is energy.



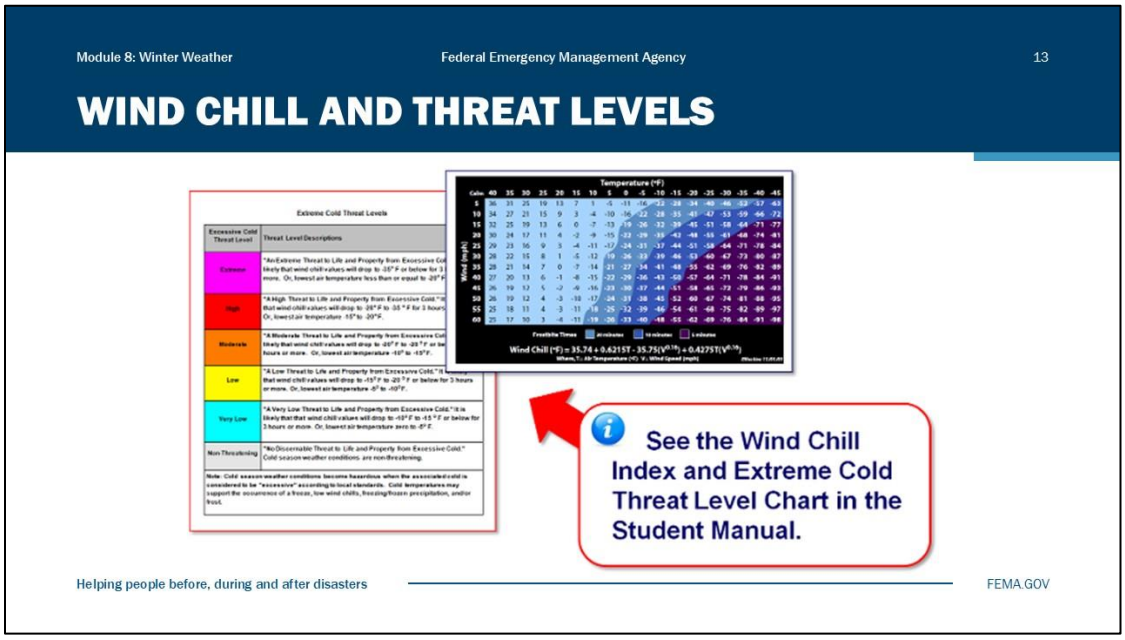
Definition: The criterion for extreme cold varies according to a region's normal climatic conditions. For example, in relatively warm climatic conditions, temperatures just below or at freezing can be hazardous; in the north, temperatures below zero may be considered extreme.

Excessive cold often accompanies or follows winter storms, but it can also occur without storm activity.

Ingredients: The ingredients necessary for extreme cold are:

- **Cold temperatures**: Remember, the temperature boundary of "extreme" varies by region.
- **Cold air mass**: An invasion of arctic air mass (pulled down by the jet stream) is also a necessary ingredient for extreme cold.
- **Prolonged cold conditions**: A prolonged period of cold, even if above-freezing temperatures, can result in extreme cold that causes hypothermia.
- **Wind**: Extreme cold can be particularly dangerous when accompanied by wind, creating an effect known as wind chill.

Extreme Cold (3 of 3)



Slide 8-13, Wind Chill and Threat Levels

As we all know, "cold" is not just a matter of temperature; it is also wind chill. Wind chill is based on the rate of heat loss from exposed skin caused by the combined effects of wind and cold. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature.

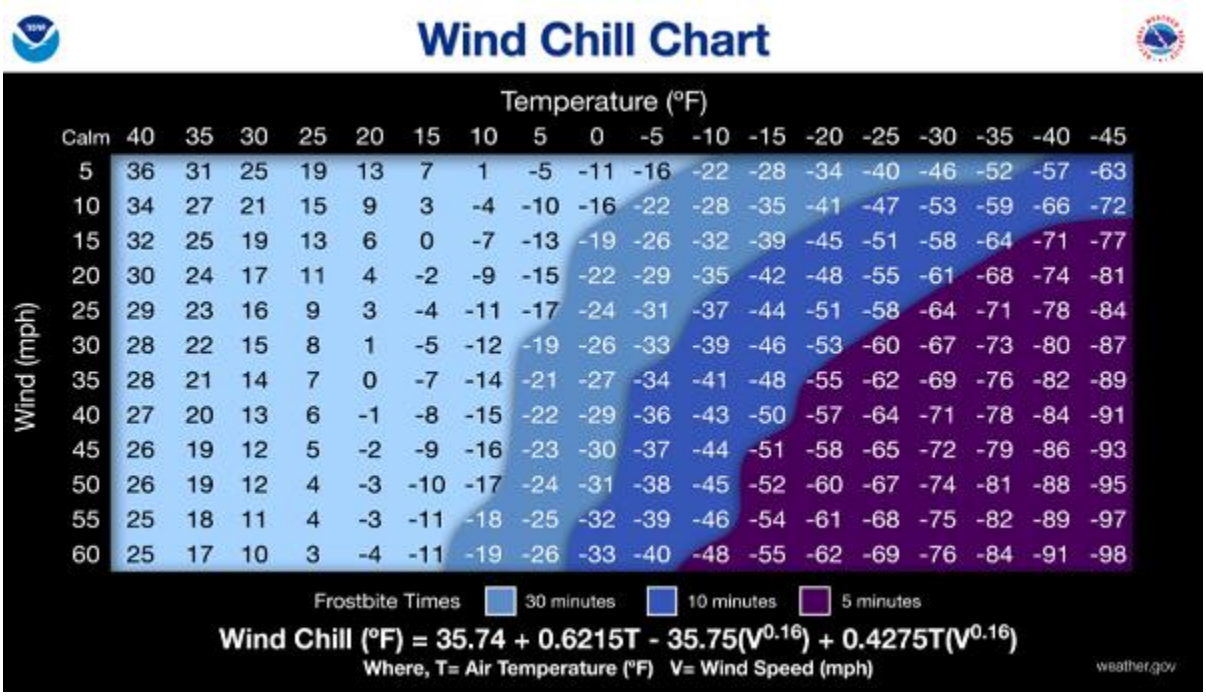
Wind chill index: Forecasters use a wind chill index to guide heat loss resulting from given temperatures and wind speeds.

Excessive cold threat level: Just as storms can be evaluated in terms of threat level, there is an Excessive Cold Threat Level scale that helps forecasters determine the severity of the threat of extreme cold, from non-threatening to extremely threatening.

Review the NWS Wind Chill Index and the Excessive Cold Threat Level chart on the following pages. On the Wind Chill Index, note that the purple area is the most dangerous for frostbite; the combined low temperatures and high winds can result in a frostbite time of only 5 minutes.

Source: NOAA's National Weather Service. (n.d.). *Understanding wind chill*. https://www.weather.gov/safety/cold-wind-chill-chart

Excessive Cold Threat Level Chart



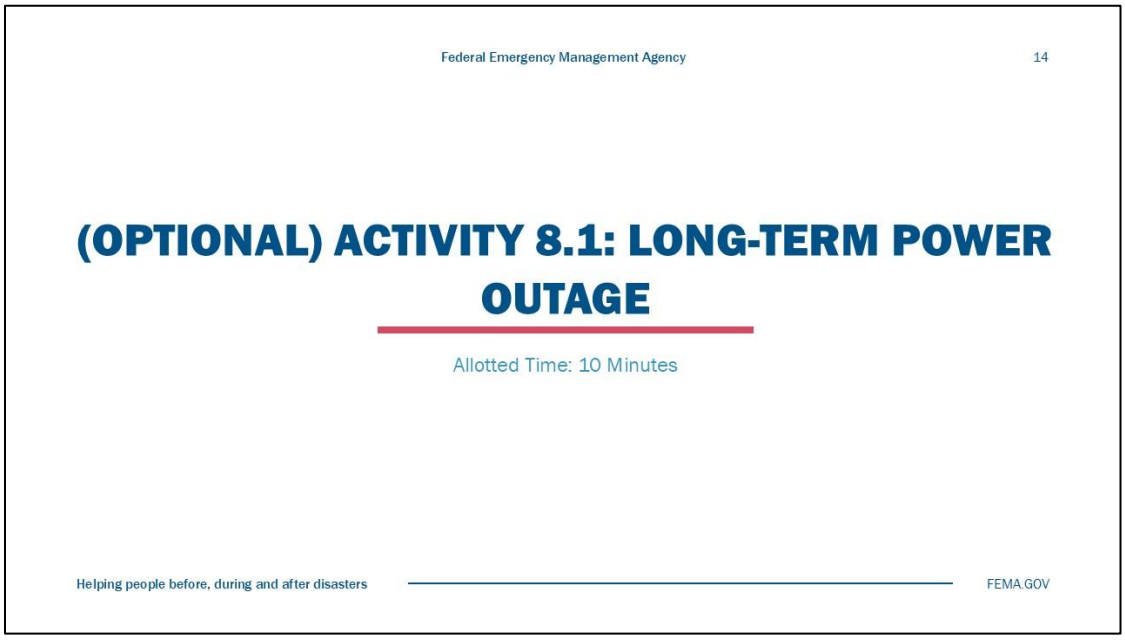
Note: Cold season weather conditions become hazardous when the associated cold is considered to be "excessive" according to local standards. Cold temperatures may support the occurrence of a freeze, low wind chills, freezing/frozen precipitation, and/or frost.

Excessive Cold Threat Level	Threat Level Descriptions
Extreme	"An Extreme Threat to Life and Property from Excessive Cold." It is likely that wind chill values will drop to -35°F or below for 3 hours or more, or the lowest air temperature will be less than or equal to -20°F.
High	"A High Threat to Life and Property from Excessive Cold." It is likely that wind chill values will drop to -28 °F to -35 °F for 3 hours or more, or the lowest air temperature will be -15 to -20 °F.
Moderate	"A Moderate Threat to Life and Property from Excessive Cold." It is likely that wind chill values will drop to -20 °F to -28 °F or below for 3 hours or more, or the lowest air temperature will be -100 °F to -15 °F.

Excessive Cold Threat Level	Threat Level Descriptions
Low	"A Low Threat to Life and Property from Excessive Cold." It is likely that wind chill values will drop to -15 °F to -20 °F or below for 3 hours or more, or the lowest air temperature will be -5 to -10 °F.
Very Low	A Very Low Threat to Life and Property from Excessive Cold. It is likely that wind chill values will drop to -10 °F to -15 °F or below for 3 hours or more, or the lowest air temperature will be zero to -5 °F.
Non-Threatening	"No Discernible Threat to Life and Property from Excessive Cold." Cold-season weather conditions are not threatening.

Note: Cold season weather conditions become hazardous when the associated cold is considered to be "excessive" according to local standards. Cold temperatures may support the occurrence of a freeze, low wind chills, freezing/frozen precipitation, and/or frost.

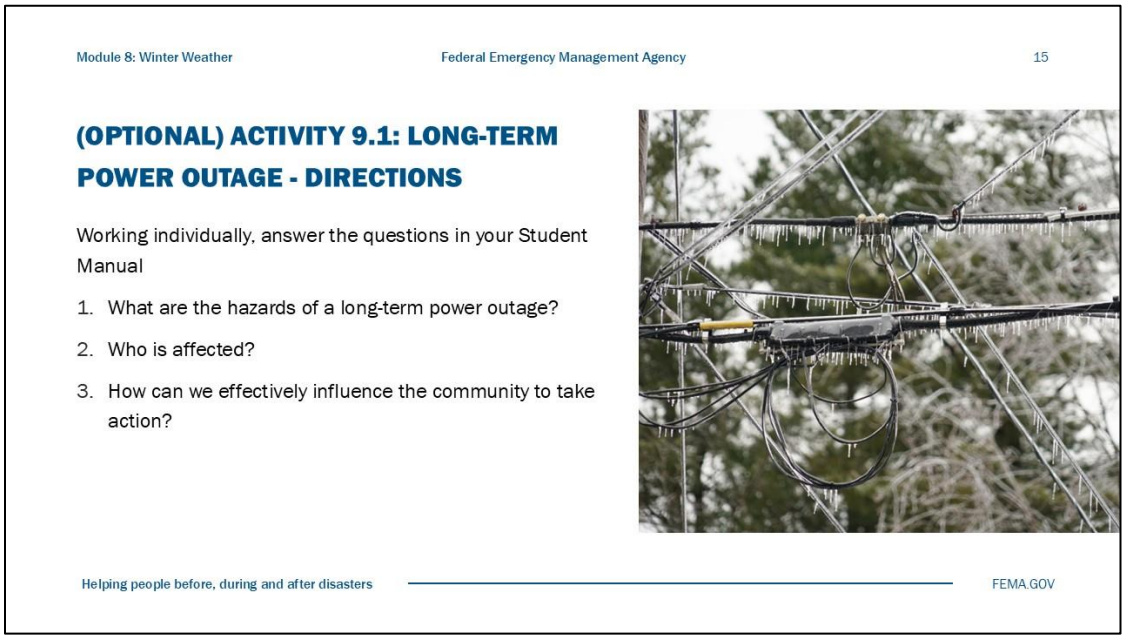
(Optional) Activity 8.1 Long-Term Power Outage (1 of 2)



Slide 8-14, (Optional) Activity 8.1: Long-Term Power Outage

Not applicable.

(Optional) Activity 8.1 Long-Term Power Outage (2 of 2)



Slide 8-15, (Optional) Activity 8.1: Long-Term Power Outage – Directions

Activity 8.1: Long-Term Power Outage – Directions to Students

Total Activity Time: 10 minutes

Purpose

The purpose of this activity is to critically assess the community-wide hazards, impacts, and potential mitigation strategies of a long-term power outage by reflecting on key emergency management considerations.

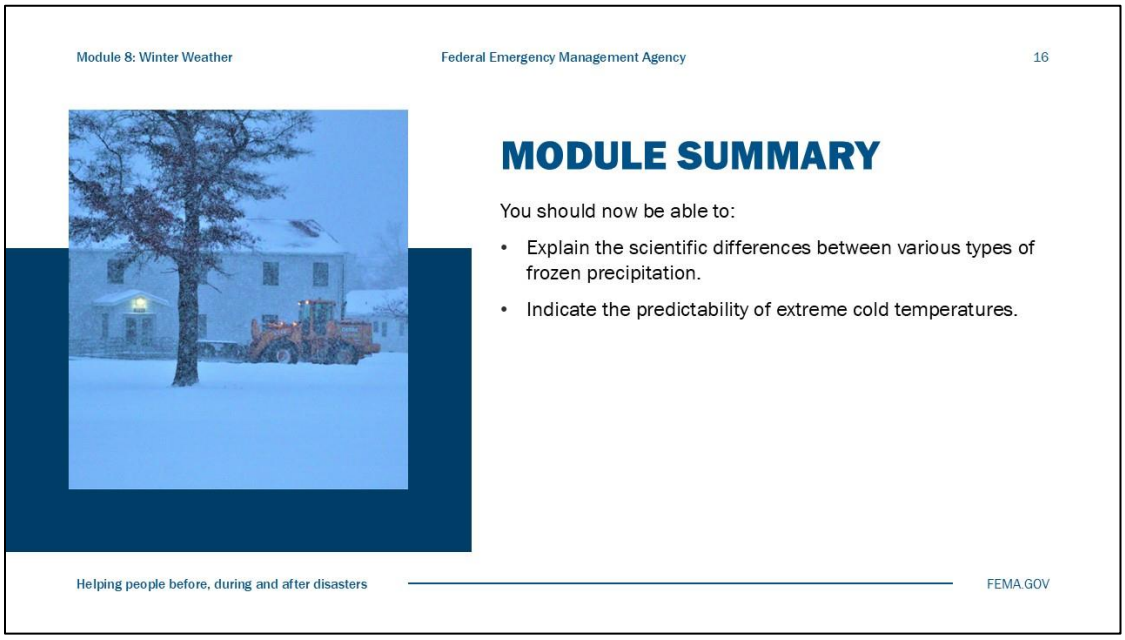
1. Working individually, answer the following questions:
    a. What are the hazards of a long-term power outage?

b. Who is affected?

c. How can we effectively influence the community to take action?

2. Be prepared to share your answers with the group during the follow-up discussion.

End of Module (1 of 2)

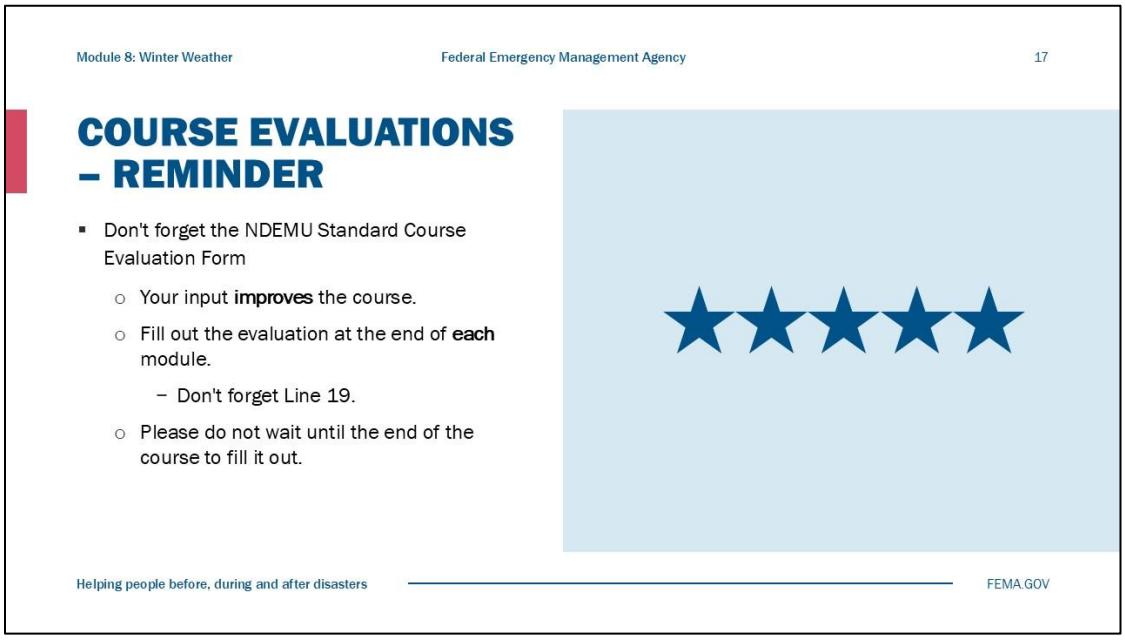


Slide 8-16, Module Summary

Module Summary

- Explain the scientific differences between various types of frozen precipitation.
- Indicate the predictability of extreme cold temperatures.

End of Module (2 of 2)



Slide 8-17, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

Reference List

US Department of Commerce, N. (n.d.-a). Understanding Wind Chill. NOAA's National Weather Service. Retrieved May 19, 2025, from https://www.weather.gov/safety/cold-wind-chill-chart

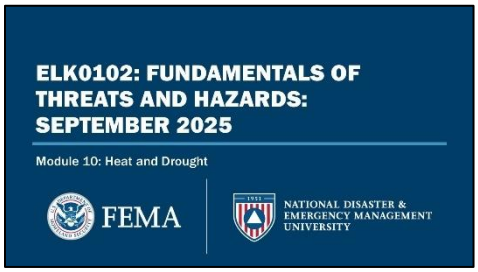
US Department of Commerce, N. (n.d.-b). Winter Weather Safety. NOAA's National Weather Service. Retrieved October 13, 2025, from https://www.weather.gov/grb/winter1

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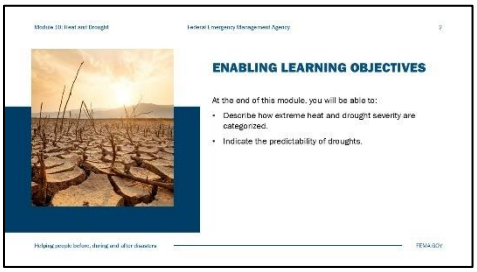
Module 9

Heat and Drought

Administration



Slide 9-1, Module 9: Heat and Drought



Slide 9-2, Enabling Learning Objectives

Duration

30 minutes

Terminal Learning Objective (TLO)

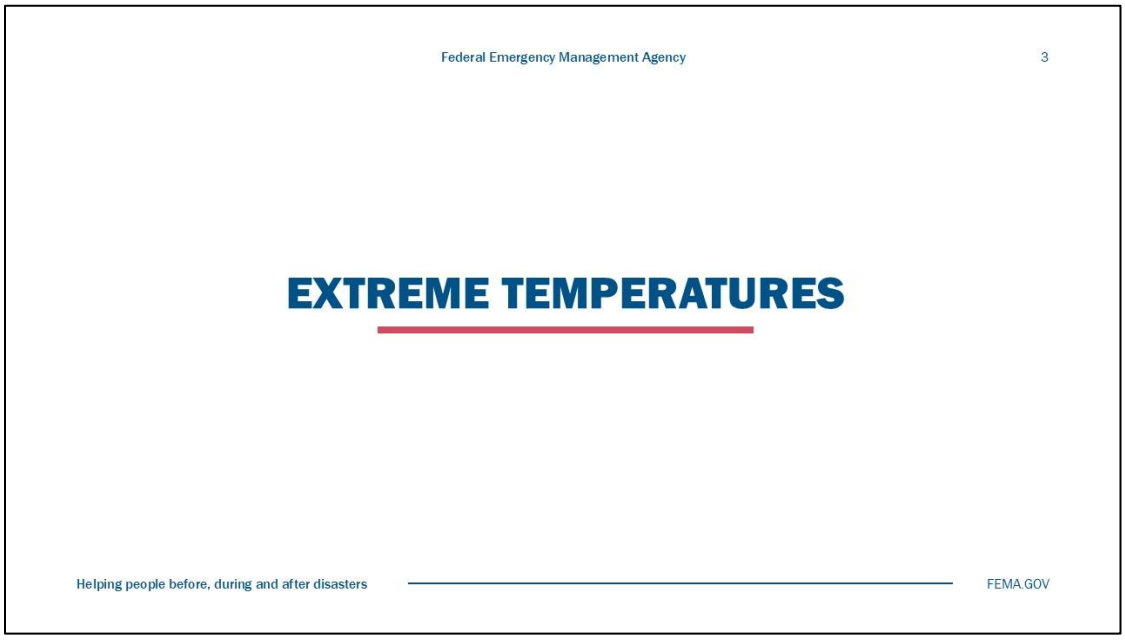
By the end of this module, participants will be able to explain the severity and predictability of heat and drought.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Describe how extreme heat and drought severity are categorized.
- Indicate the predictability of droughts.

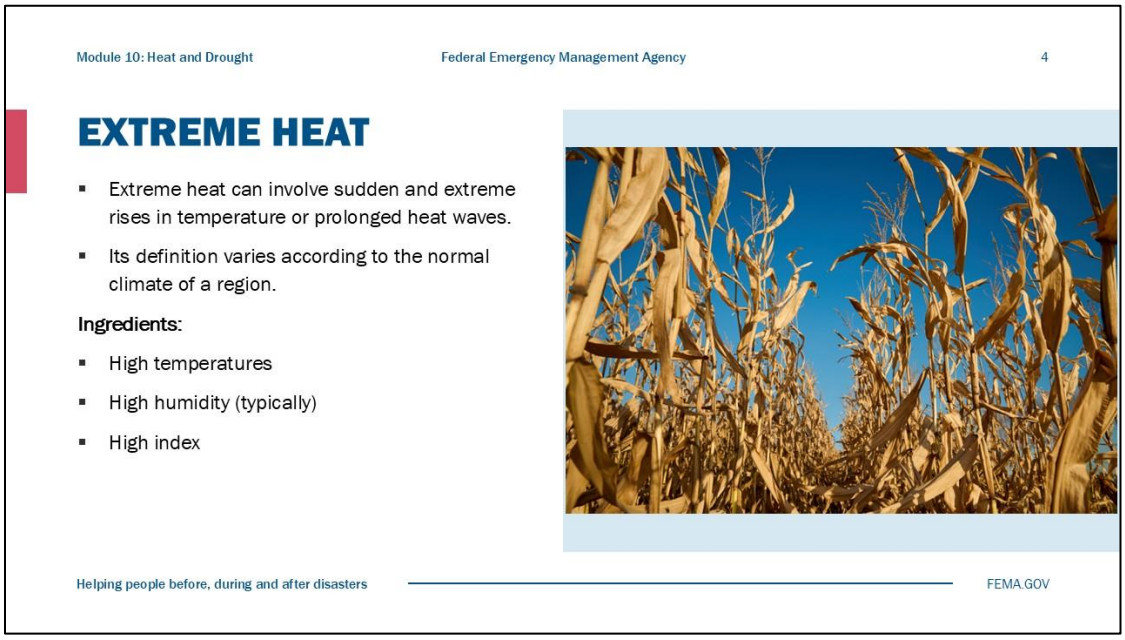
Extreme Temperatures (1 of 6)



Slide 9-3, Extreme Temperatures

Not applicable.

Extreme Temperatures (2 of 6)



Slide 9-4, Extreme Heat

Extreme Heat

- Extreme heat can involve sudden and extreme rises in temperature or prolonged heat waves.
- Its definition varies according to the normal climatic conditions of a region.

Ingredients:

- High temperatures
- High humidity (typically)
- High dew points

Definition: Extreme heat can involve sudden rises in temperature to extreme levels (which reduce people's chance of acclimation) or prolonged heat waves. Either of these can cause heat-related fatalities. As with extreme cold, the exact definition of "extreme heat" varies according to a region's normal climatic conditions. For example, what is considered extreme heat in Seattle would differ from extreme heat in Tucson.

Ingredients: Heat waves and extreme heat are caused by:

- **High temperatures**: As with extreme cold, what is considered "extreme" varies by region.

- **High humidity:** This includes:
  - **High relative humidity**: Relative humidity is a function of both moisture content and temperature. Relative humidity refers to how much moisture is in the air compared to the maximum amount the air can hold before the moisture is precipitated out and is measured by a percentage (higher number = more humidity). Relative humidity is relative; by itself, it does not directly indicate the actual amount of atmospheric moisture present. For example, Colorado has a relative humidity of about 20 percent, which is dry compared to 97 percent in Washington, DC.
  - **High dew points**: The dew point is a measure of atmospheric moisture. It is the temperature to which the air must be cooled to reach saturation (assuming air pressure and moisture content are constant). A higher dew point indicates more moisture present in the air. It is sometimes referred to as the Dew Point Temperature and sometimes written as one word (Dewpoint).
- **Heat index**: Just as wind speed and temperature are measured in wind chill, likewise, heat index measures humidity and temperature, shown below. What wind chill is to cold waves, heat index is to heat waves—it indicates apparent temperature.

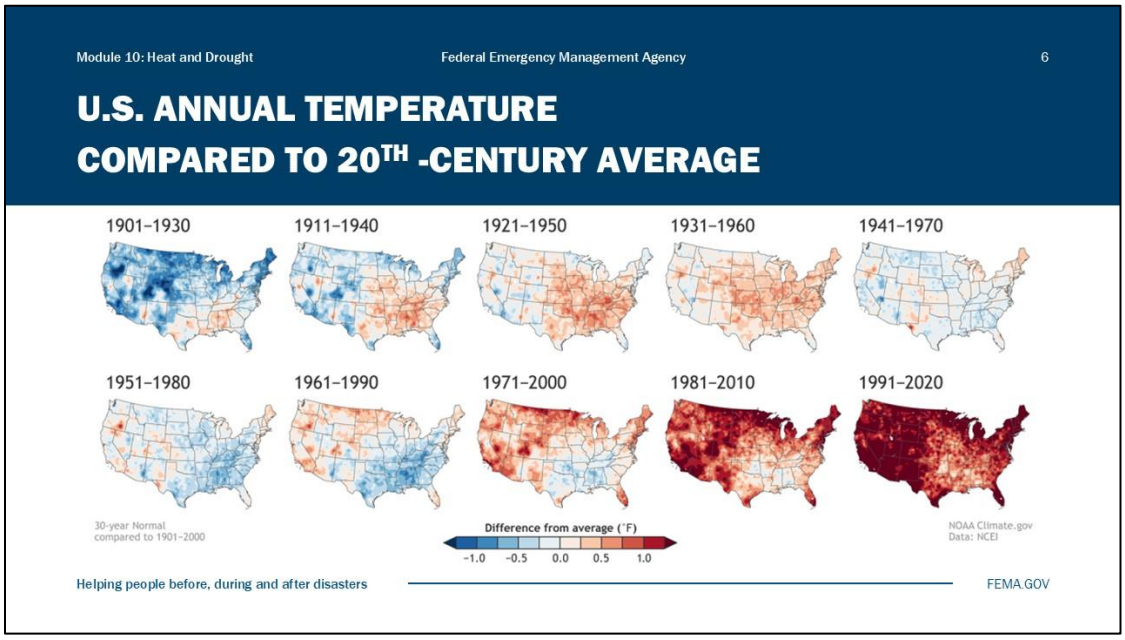
Extreme Temperatures (3 of 6)



Slide 9-5, Discussion: Causes of Extreme Heat

What are potential causes of extreme heat?

Extreme Temperatures (4 of 6)



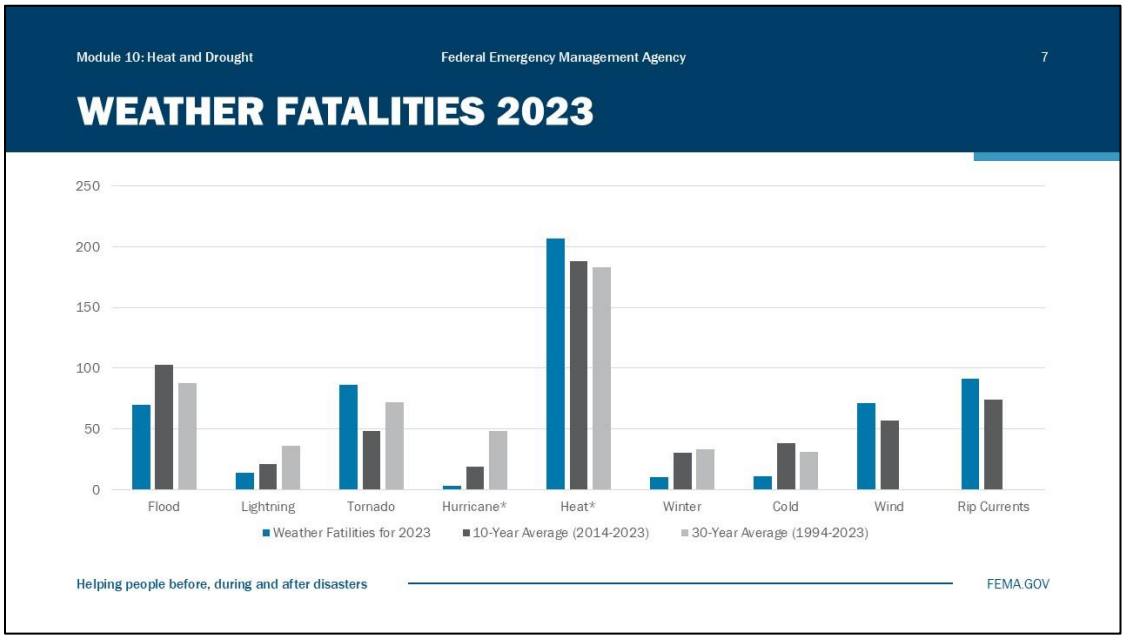
Slide 9-6, U.S. Annual Temperature Compared to 20th-Century Average

Extreme heat occurs when strong, high-pressure atmospheric conditions combine with influences from La Niña, creating vast areas of sweltering heat that get trapped.

Extreme Heat is defined as either:

- A period of high heat and humidity with temperatures above 90 degrees for at least two to three days (Department of Homeland Security).
- A summertime temperature that is much hotter and/or humid than average. Because some places are hotter than others, this depends on what is considered average for a particular location at that time of year.

Extreme Temperatures (5 of 6)



Slide 9-7, Weather Fatalities 2023

Extreme Temperature 2023 Image Description

The greatest weather-related hazard to life safety has historically been extreme heat. Heat category for 2023 shows 207 Fatalities 10-Year Average (2014-2023): 188.

Flood:

- Weather Fatalities for 2023: 70
- 10-Year Average (2014-2023): 103
- 30-Year Average (1994-2023): 88

Lightning:

- Weather Fatalities for 2023: 14
- 10-Year Average (2014-2023): 21
- 30-Year Average (1994-2023): 36

Tornado:

- Weather Fatalities for 2023: 86
- 10-Year Average (2014-2023): 48

- 30-Year Average (1994-2023): 72

Hurricane:

- Weather Fatalities for 2023: 3
- 10-Year Average (2014-2023): 19
- 30-Year Average (1994-2023): 48

Heat

- Weather Fatalities for 2023: 207
- 10-Year Average (2014-2023): 188
- 30-Year Average (1994-2023): 183

Winter

- Weather Fatalities for 2023: 10
- 10-Year Average (2014-2023): 30
- 30-Year Average (1994-2023): 33

Cold

- Weather Fatalities for 2023: 11
- 10-Year Average (2014-2023): 38
- 30-Year Average (1994-2023): 31

Wind

- Weather Fatalities for 2023: 71
- 10-Year Average (2014-2023): 57
- 30-Year Average (1994-2023): NA

Rip Currents

- Weather Fatalities for 2023: 91
- 10-Year Average (2014-2023): 74
- 30-Year Average (1994-2023): NA

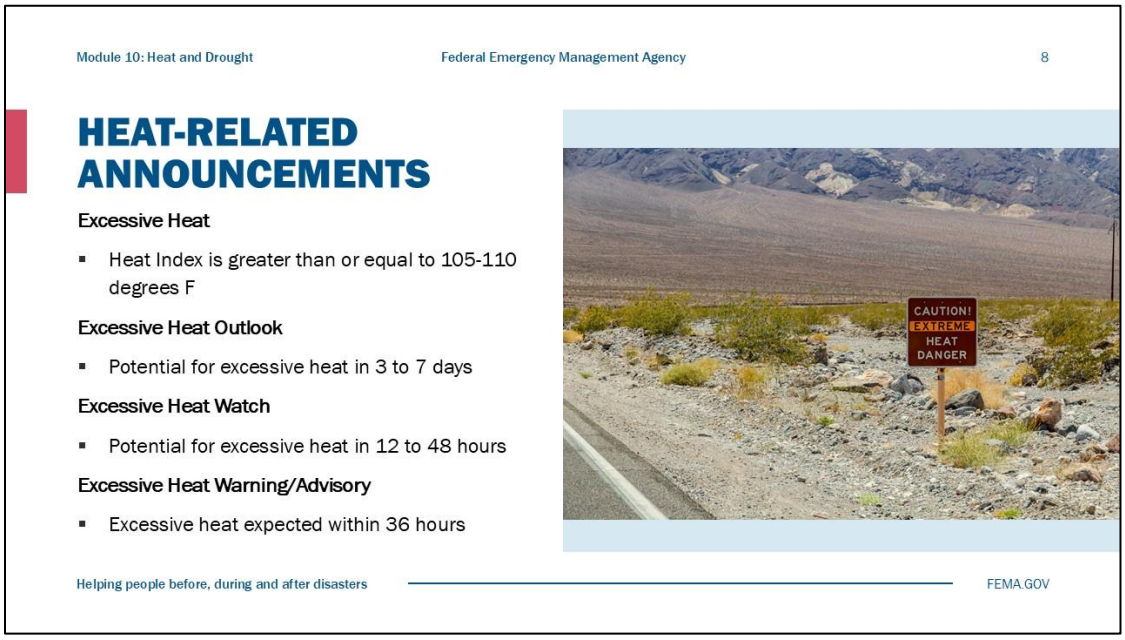
* Due to an inherent delay in the reporting of official heat fatalities in some jurisdictions, this number will rise in subsequent updates.

* The fatalities, injuries, and damage estimates found under Hurricane/Tropical Cyclone events are attributed only to the wind.

Although extreme cold can be dangerous, the greatest weather-related hazard to life safety has historically been extreme heat.

Notice in the visual that excessive heat was the cause of the highest number of weather fatalities in 2023 and has the highest 10-year and 30-year average fatality counts.

Extreme Temperatures (6 of 6)



Slide 9-8, Heat-Related Announcements

Excessive Heat = Heat Index is greater than or equal to 105-110 degrees F.

- Excessive Heat Outlook: Potential for excessive heat in 3 to 7 days
- Excessive Heat Watch: Potential for excessive heat in 12 to 48 hours
- Excessive Heat Warning/Advisory: Excessive heat expected within 36 hours.

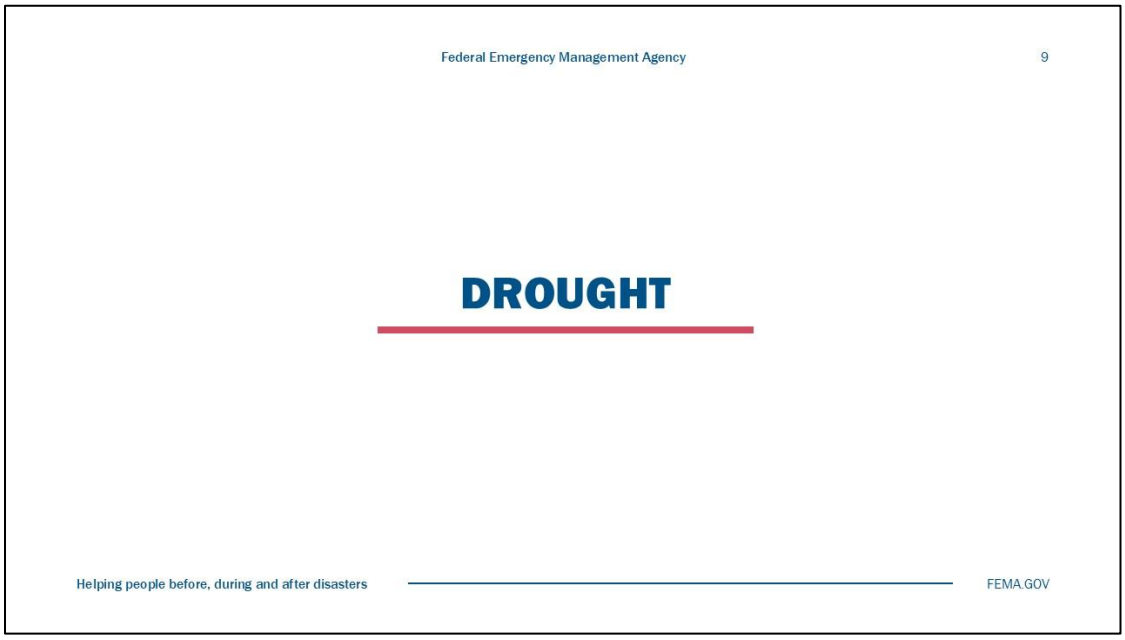
Heat-related announcements are the equivalent of storm-related announcements. However, note that the time period in which the heat is expected to occur is the differential between the distinct types of announcements:

- Excessive Heat Outlook: Potential for excessive heat to occur in the next 3 to 7 days.
- Excessive Heat Watch: Potential for excessive heat to occur in the next 12 to 48 hours.
- Excessive Heat Warning/Advisory: Excessive heat expected to occur within 36 hours.

Although absolute values for extreme heat are also defined regionally, extreme heat is considered to be "officially" a heat index less than or equal to 105-110°F.

A daytime heat index reaching these temperature levels for two consecutive days, with nighttime lows at or above 80°F, may significantly impact public safety. The local National Weather Service office will issue an advisory or a warning about these conditions.

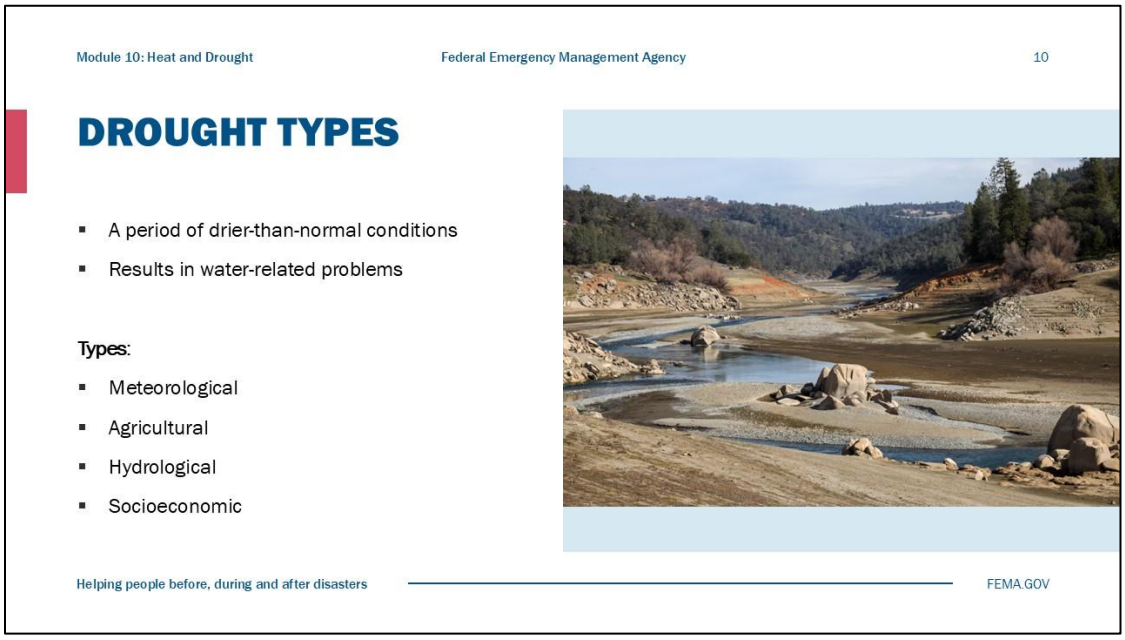
Drought (1 of 4)



Slide 9-9, Drought

Not applicable.

Drought (2 of 4)



Slide 9-10, Drought Types

The USGS defines drought as a period of drier-than-normal conditions that results in water-related problems. Thus, **there is no universally accepted quantitative definition of drought.**

Instead, drought is most often defined by its impacts, which are typically economic, environmental, or societal in nature. For example, an agricultural drought is identified when crop production becomes adversely impacted, while a hydrological drought is linked to a very substantial and potentially damaging reduction in water supplies.

Types: In general, there are four "types" of droughts:

- **Meteorological:** Meteorological Drought identifies periods of drought based on the number of days with precipitation less than a specified threshold. Due to climatic differences, what might be considered a drought in one location of the country may not be classified as such in another location.
- **Agricultural:** Agricultural drought is a deficiency of topsoil moisture that will hinder germination, leading to low plant populations and a reduction of final yield.
- **Hydrological:** Hydrological Drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater). It is usually out of phase with meteorological and agricultural drought.
- **Socioeconomic:** Socioeconomic Drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

Beginning and end: The onset of any drought is slow, making it difficult to determine start and end times. Often, the onset of drought is not realized until the event's impact has been ongoing for some time. Likewise, the end of a drought is not always ascertained until the event has already passed.

Droughts can span a range of timescales, from monthly or seasonal durations affecting agriculture to multi-year or multi-decade or even century events that dramatically change water quantities.

Geographic span: Droughts can also span large spatial areas, encompassing larger parts of the country at a given time.

Science helps in planning for droughts and in making day-to-day management decisions regarding competing demands for water.

Drought cycles are significantly influenced by large-scale weather trends phenomena like El Niño, La Niña, and atmospheric rivers, because these systems affect global weather patterns, including precipitation and temperature distributions. Here's how each connects:

El Niño

- **El Niño** is characterized by **warmer-than-average sea surface temperatures in the central and eastern Pacific Ocean.**
- **Effect on Droughts**:
  - **Increases drought** in regions **like Australia, Indonesia, and parts of the Amazon and southern Africa**, due to suppressed rainfall.
  - In contrast, it may **reduce drought** in **parts of the southern U.S.** by increasing winter precipitation via enhanced storm activity.

La Niña

- La Niña is the opposite phase of El Niño, with **cooler-than-average sea surface temperatures in the central and eastern Pacific**.
- **Effect on Droughts**:
  - Tends to **increase drought** in the **southern U.S. and South America**, due to reduced storm activity.
  - **Increases rainfall** and may reduce drought in **Australia, Indonesia, and Southeast Asia**.
  - Often **strengthens Atlantic hurricane seasons**, which can affect rainfall patterns in the Americas.

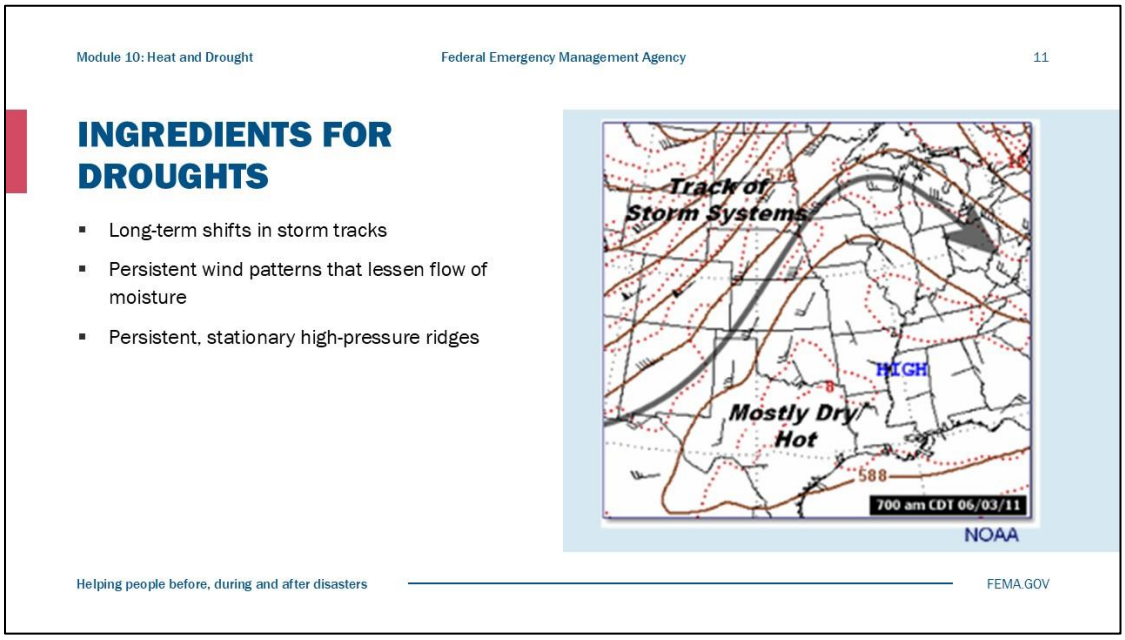
Atmospheric Rivers

- These are **narrow bands of concentrated moisture in the atmosphere**, often originating over the tropics.
- **Effect on Droughts**:
  - When they make landfall, especially along the U.S. West Coast, they can **break droughts** by delivering large volumes of precipitation.
  - **Absence** or **weakened activity** of atmospheric rivers during winter seasons can **worsen droughts**, particularly in **California and the Pacific Northwest**.

Interaction Between These Systems

- **El Niño** years may **enhance the strength and frequency** of atmospheric rivers hitting California, helping to **relieve drought** there.
- **La Niña** tends to shift storm tracks away from California, **weakening atmospheric rivers** and contributing to **persistent drought conditions**.
- The **timing, duration**, and **intensity** of these phenomena all influence whether a region enters, sustains, or exits a drought cycle.

Drought (3 of 4)



Slide 9-11, Ingredients for Drought

- Long-term shifts in storm tracks
- Persistent wind patterns that lessen the flow of moisture
- Persistent, stationary high-pressure ridges

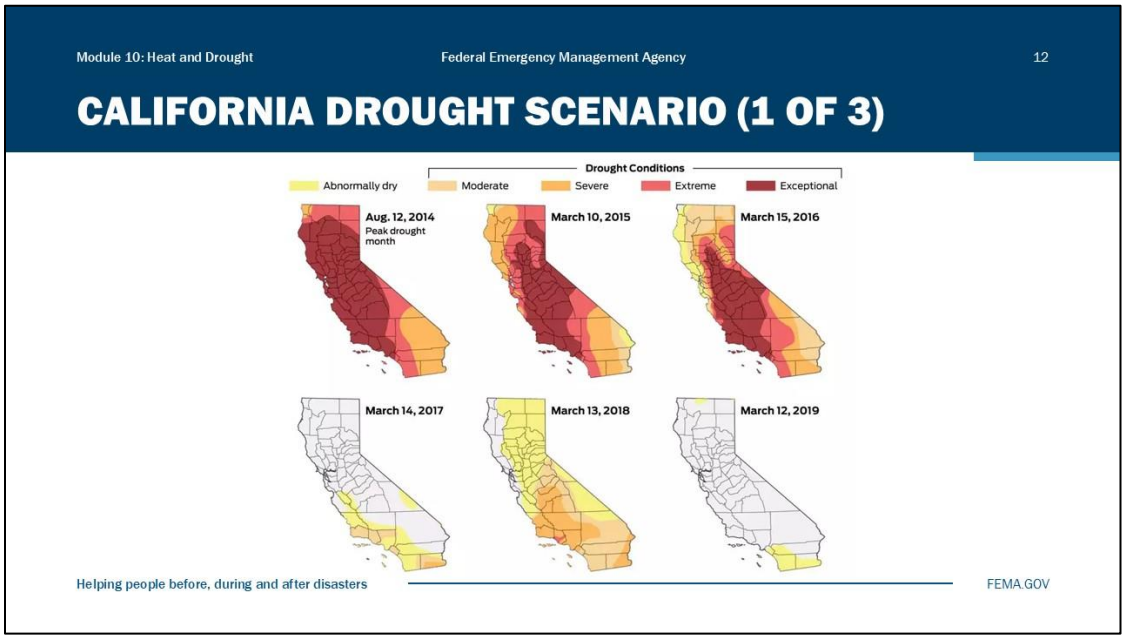
Droughts depend on various weather factors, including temperature, precipitation, wind speed, and solar radiation, which fluctuate throughout the year and in response to local and regional climatic conditions.

In general, the specific ingredients that result in the suppression of precipitation and droughts are:

- Long-term shifts in the storm tracks away from the affected region (for example, recall from the climatology module that La Niña affects the jet streams, which in turn affect the storm tracks, potentially depriving certain regions of much-needed precipitation).
- Persistent wind patterns that lessen the flow of moisture into a region.
- "Blocking weather patterns" that are composed of persistent, stationary high-pressure ridges.

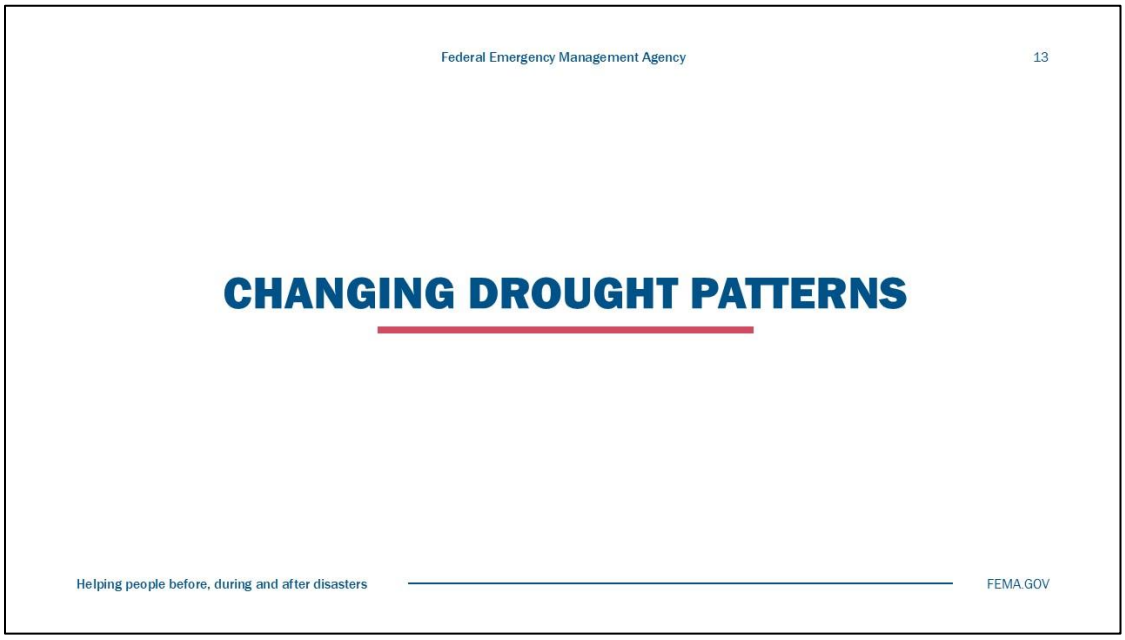
The California drought began in 2011 after a La Niña-induced weather pattern failed to subside. A high-pressure ridge off the California coast effectively blocked precipitation from falling in California. This ridge did not begin to subside until the 2015 El Niño. This is a fairly consistent pattern for ENSO (El Niño Southern Oscillation) circulation, with persistent drier conditions two to three years after the end of La Niña.

Drought (4 of 4)



Slide 9-12, California Drought Scenario (1 of 3)

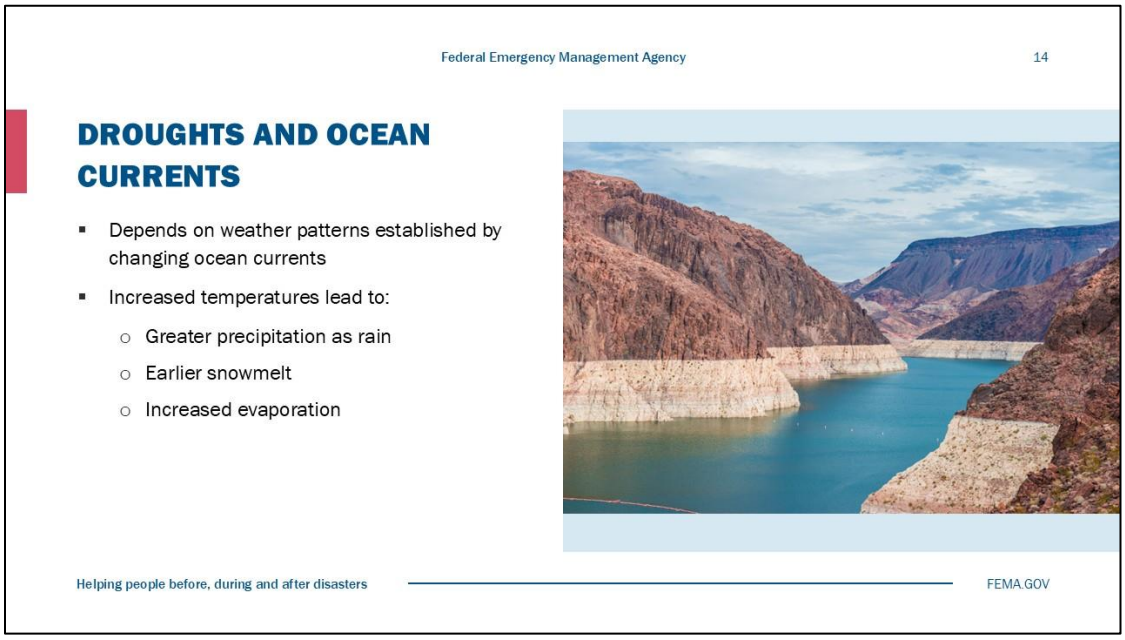
Changing Drought Patterns (1 of 5)



Slide 9-13, Changing Drought Patterns

Not applicable.

Changing Drought Patterns (2 of 5)



Slide 9-14, Droughts and Ocean Currents

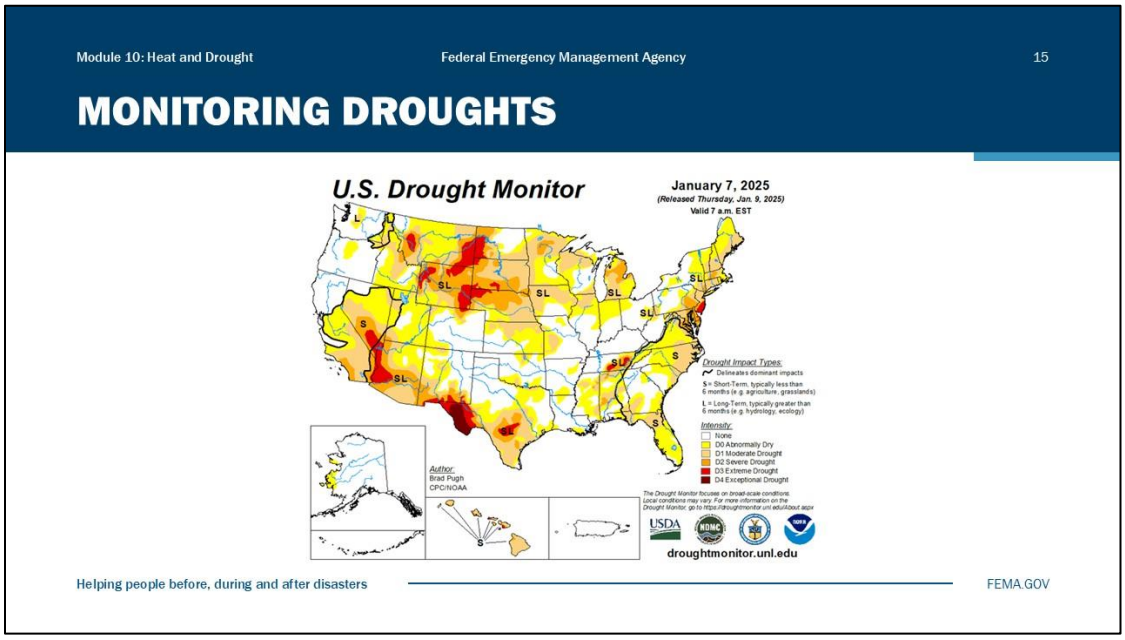
How is drought affected by weather trends?

The effect of weather trends on drought depends on the weather patterns established by changing ocean currents. Some regions will experience greater rainfall, whereas others will experience less. Most models indicate that the American Southwest will be at greater risk of drought.

Increased temperatures lead to:

- Greater precipitation as rain rather than snow, reducing snowpack.
- Earlier snowmelt, causing the water supply to be out of sync with water demand.
- Increased evaporation and transpiration, increasing the likelihood of agricultural drought.

Changing Drought Patterns (3 of 5)



Slide 9-15, Monitoring Droughts

The National Oceanic and Atmospheric Administration (NOAA) and the NWS Climate Prediction Center create drought outlook maps. These maps take into account data collected by the USGS, NOAA, and the NWS. However, because droughts result from complex, long-term atmospheric phenomena, the accuracy of drought predictions is not as high as the accuracy of predictions about other weather events.

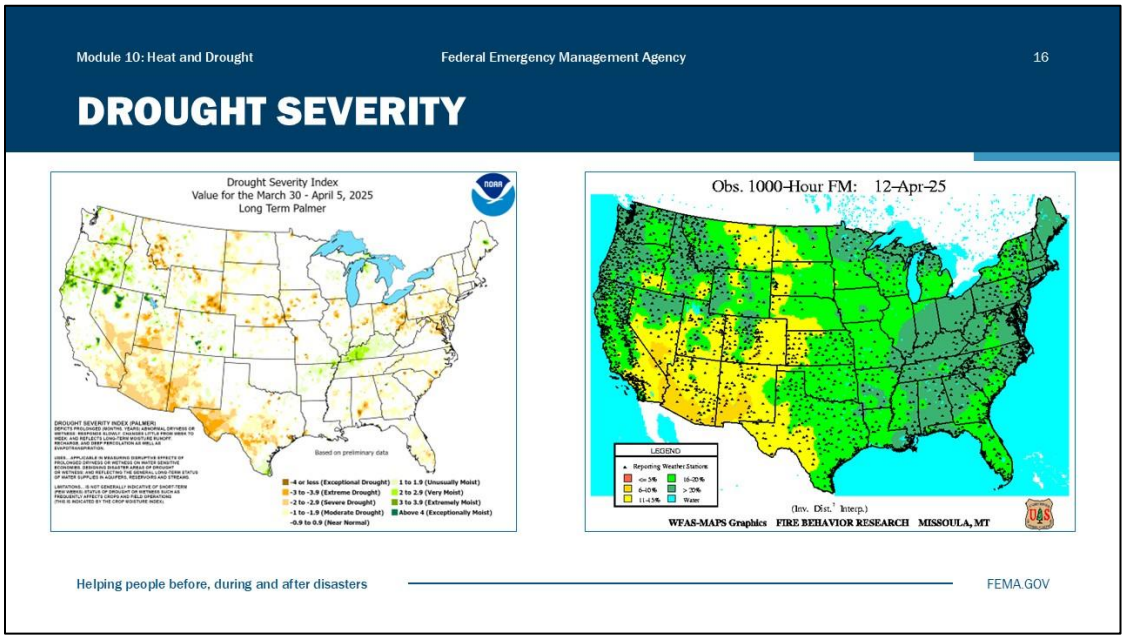
For example, in this U.S. Seasonal Drought Outlook as of September 2020, the map is divided into the following categories:

- None
- D0 (Abnormally Dry)
- D1 (Moderate Drought)
- D2 (Severe Drought)
- D3 (Extreme Drought)
- D4 (Exceptional Drought)

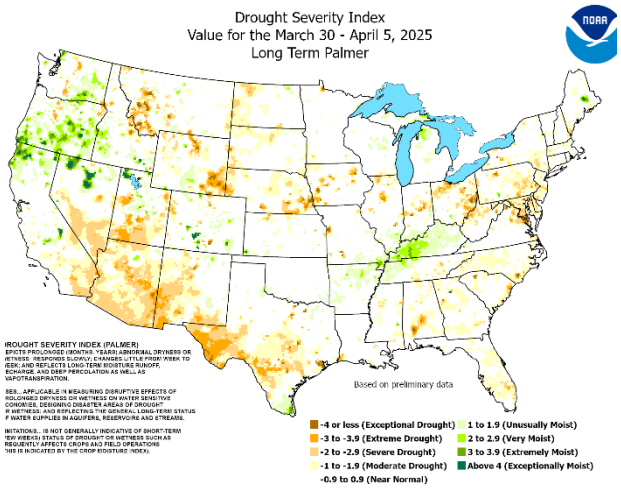
This map "depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts."

In short, **making these predictions is complicated, and confidence in them is necessarily much lower than for predictions of other weather events.**

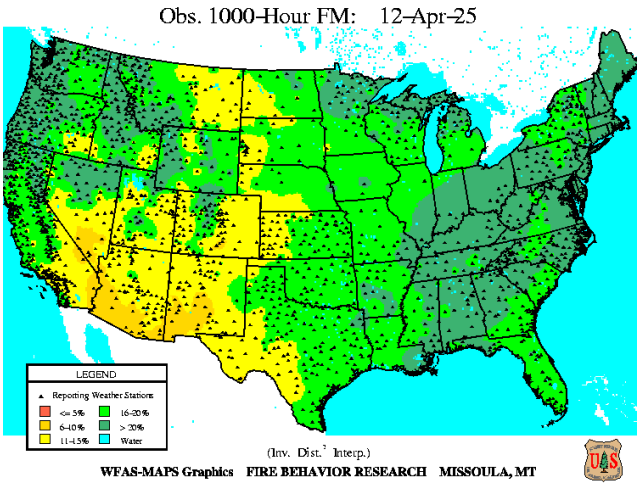
Changing Drought Patterns (4 of 5)



Slide 9-16, Changing Drought Severity



Map 1: The first U.S. map shows drought severity, which affects the Midwest and Southwest. This link can also be accessed at Climate Prediction Center - Monitoring & Data: Drought Monitoring. (*Climate Prediction Center - Monitoring & Data: Drought Monitoring*, n.d.)



Map 2: The second U.S. map shows the dead fuel that is covering the same areas. (This link can also be accessed at Did You Know? | Dead Fuel Moisture | National Centers for Environmental Information (NCEI) (*Did You Know? | Dead Fuel Moisture | National Centers for Environmental Information (NCEI)*, n.d.)

Map 1 shows the Palmer Drought Severity Index (PDSI) for the continental U.S. taken in early April 2025. Note that the index is organized in the following way:

PDSI Level	Description
-4.0 or less	Exceptional Drought
-3.0 to -3.9	Extreme Drought
-2.0 to -2.9	Severe Drought
-1 to -1.9	Moderate Drought
-0.9 to 0.9	Near Normal
1 to 1.9	Unusually Moist
2.0 to 2.9	Very Moist
3.0 to 3.9	Extremely Moist
Above 4	Exceptionally Moist

Forecasters collect scientific information that evaluates current drought levels. These data are normally expressed with the semi-official PDSI, a formula developed by Wayne Palmer in the 1960s.

The Palmer Index effectively uses rainfall and temperature information to determine long-term drought (i.e., the duration of months). Another advantage of the Palmer Index is that it is

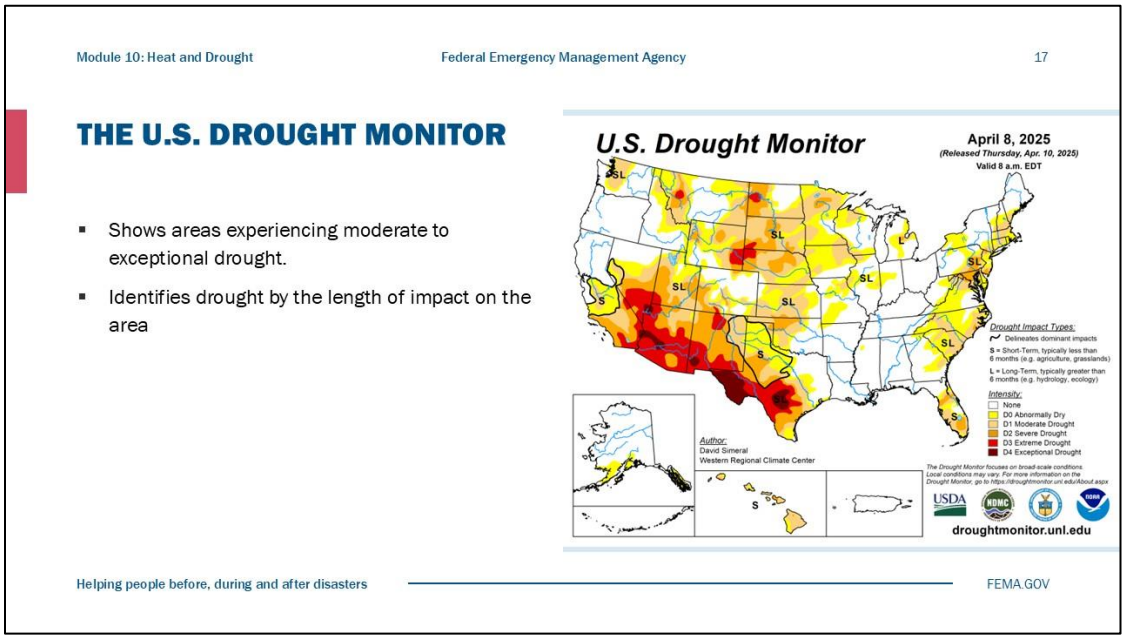
standardized according to local climatic conditions and can be applied to any region in the country to show the relative drought or rainfall conditions.

Relationship of droughts to wildfire: Drought is an important ingredient in wildfires, which may be caused by a combination of:

- Dry or drought conditions
- Wind
- Topography (slopes and changes in elevation enable fire to spread more easily)
- Moisture content of the soil
- Buildup of vegetation, especially dead fuel

In the maps above, note the similarity of the areas affected by drought on the left map and the distribution of dead fuel in the right map.

Changing Drought Patterns (5 of 5)

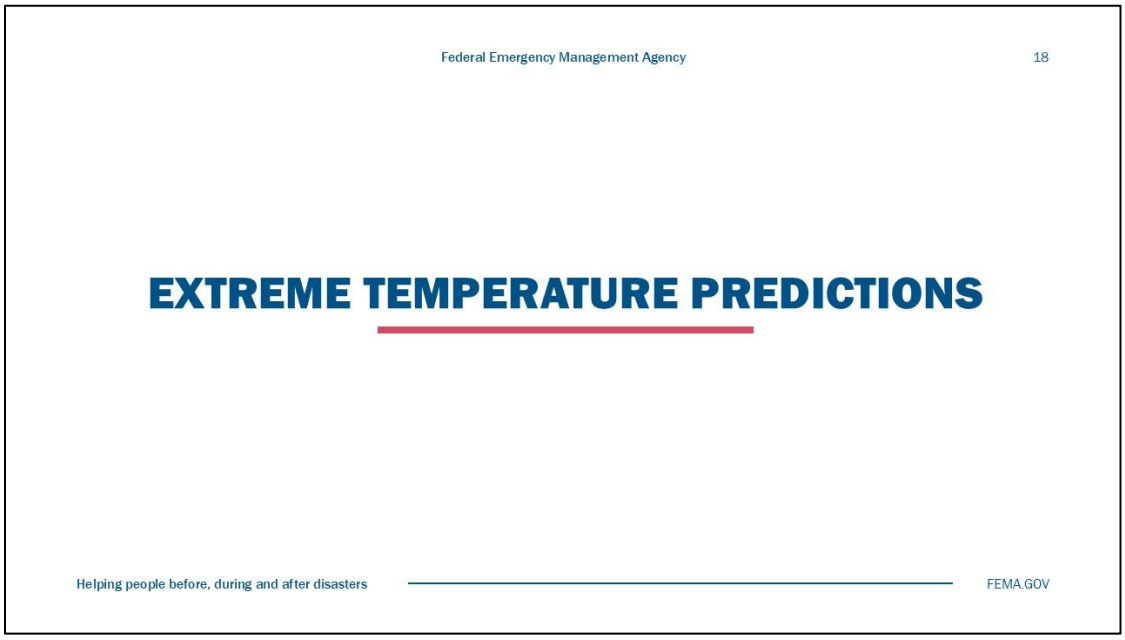


Slide 9-17, The U.S. Drought Monitor

This is an example of a U.S. Drought Monitor map. This one is for April 8, 2025, and shows the majority of areas in the western half of the country are experiencing moderate to exceptional drought. It also identifies drought by whether its impact to the area will be short- or long-term.

The U.S. Drought Monitor is jointly produced by the United States Department of Agriculture (USDA), the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United Stated Department of Commerce, and the National Oceanic and Atmospheric Administration (NOAA).

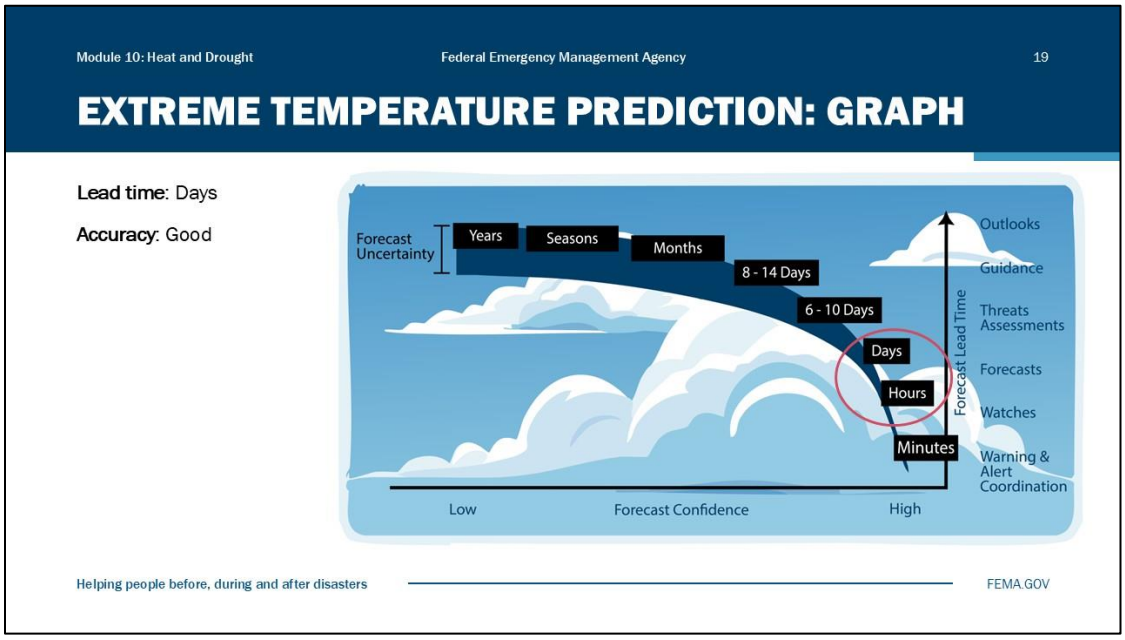
Extreme Temperature Predictions (1 of 2)



Slide 9-18, Extreme Temperature Predictions

Not applicable.

Extreme Temperature Predictions (2 of 2)



Slide 9-19, Extreme Temperature Prediction: Graph

Extreme Temperature Prediction

- Lead time: Days
- Accuracy: Good

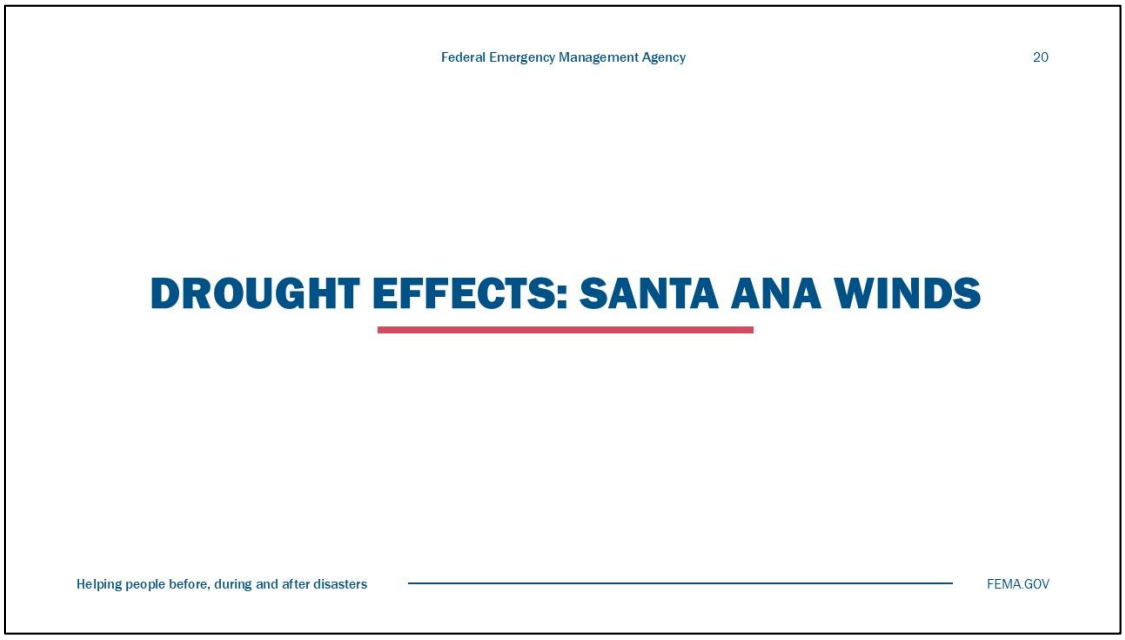
Like winter storms, the lead time for predicting extreme temperatures is days, and the accuracy is good.

To predict cold waves and heat waves, forecasters gather information about:

- High/low temperatures
- Humidity (heat waves)
- Winds (cold waves)

With this information, forecasters can predict the system's duration and expected temperatures.

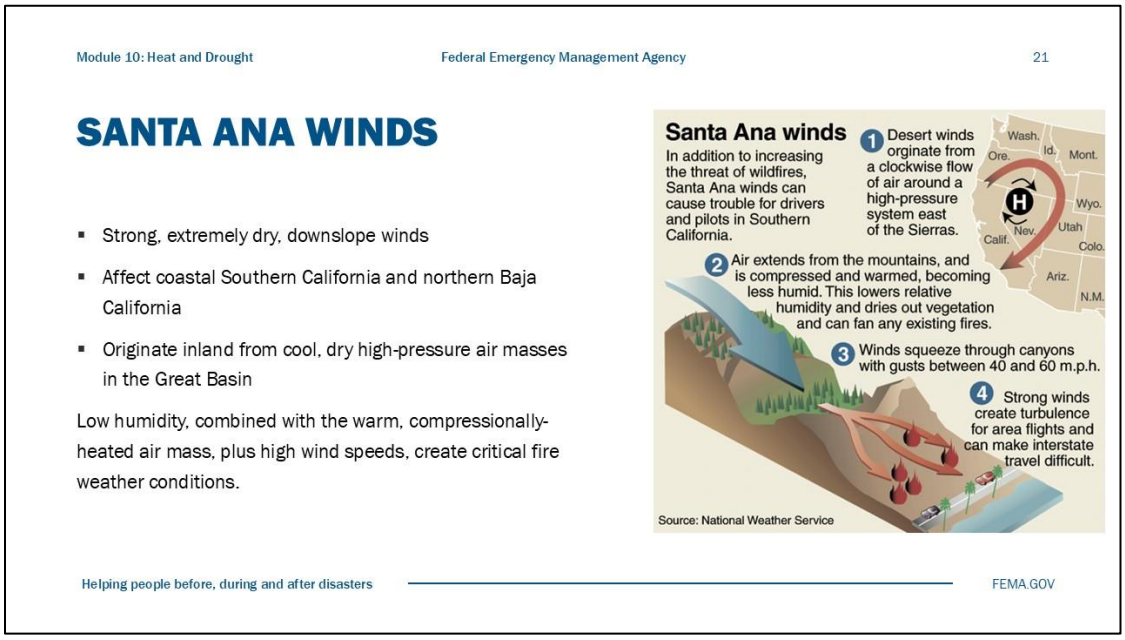
Drought Effects: Santa Ana Winds (1 of 4)



Slide 9-20, Drought Effects: Santa Ana Winds

Not applicable.

Drought Effects: Santa Ana Winds (2 of 4)



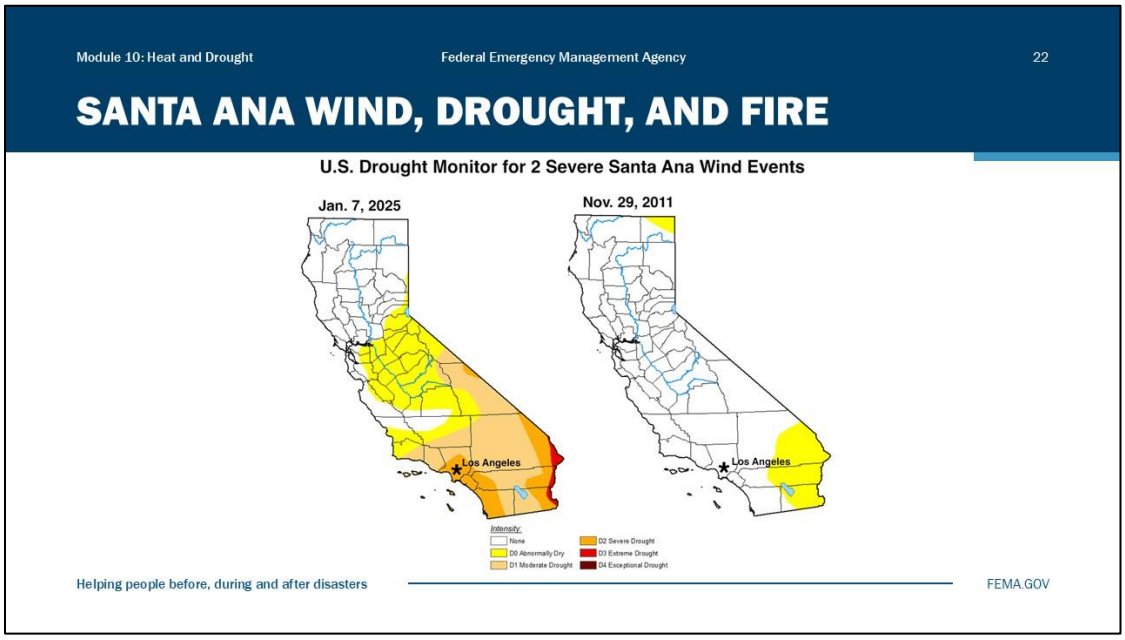
Slide 9-21, Santa Ana Winds

The Santa Ana winds are strong, extremely dry, downslope winds that originate inland and affect coastal Southern California and northern Baja California.

They originate from cool, dry high-pressure air masses in the Great Basin.

Low humidity, combined with the warm, compressionally-heated air mass, plus high wind speeds, create critical fire weather conditions.

Drought Effects: Santa Ana Winds (3 of 4)



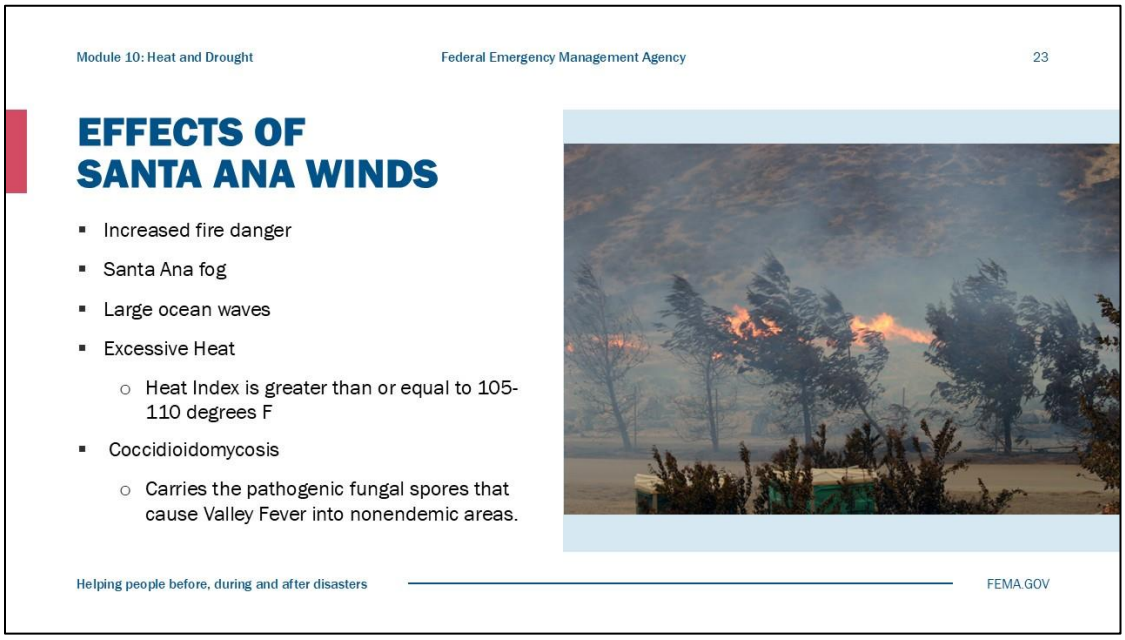
Slide 9-22, Santa Ana Wind, Drought, and Fire

This week's fires were driven by the intense winds of a severe Santa Ana wind event. On Wednesday, Jan. 8, at least thirty-two stations in the Los Angeles area recorded wind gusts of at least 70 mph, with the highest being a 100-mph (161 km/hr) wind gust at Mt. Lukens Truck Trail, located about 20 miles (32 km) north of Los Angeles. The last Santa Ana wind event of similar intensity occurred over 13 years ago, on Nov. 30- Dec. 1, 2011. During that event, widespread wind gusts over 70 mph (113 km/hr) toppled thousands of trees, and over 200,000 homes lost electricity, mostly in the northern Los Angeles suburbs of Altadena and Pasadena. Whitaker Peak (elev. 4,120 feet), located about fifty miles (80 km) northwest of Los Angeles, recorded a gust of 97 mph (156 km/h).

Fortunately, no major wildfires were sparked during the 2011 Santa Ana wind event. This was largely because Los Angeles was not experiencing drought at that time. But in the case of the 2025 event, severe drought was in place (Fig. 1).

Source: Henson, J. M., Bob. (2025, January 9). The role of climate change in the catastrophic 2025 Los Angeles fires » Yale Climate Connections. *Yale Climate Connections*. http://yaleclimateconnections.org/2025/01/the-role-of-climate-change-in-the-catastrophic-2025-los-angeles-fires/

Drought Effects: Santa Ana Winds (4 of 4)



Slide 9-23, Effects of Santa Ana Winds

Excessive Heat = Heat Index is greater than or equal to 105-110 degrees F

- Santa Ana fog
- Drive large ocean waves
- Carry the pathogenic fungal spores that cause Valley Fever (Coccidioidomycosis) into nonendemic areas.
- Increased fire danger

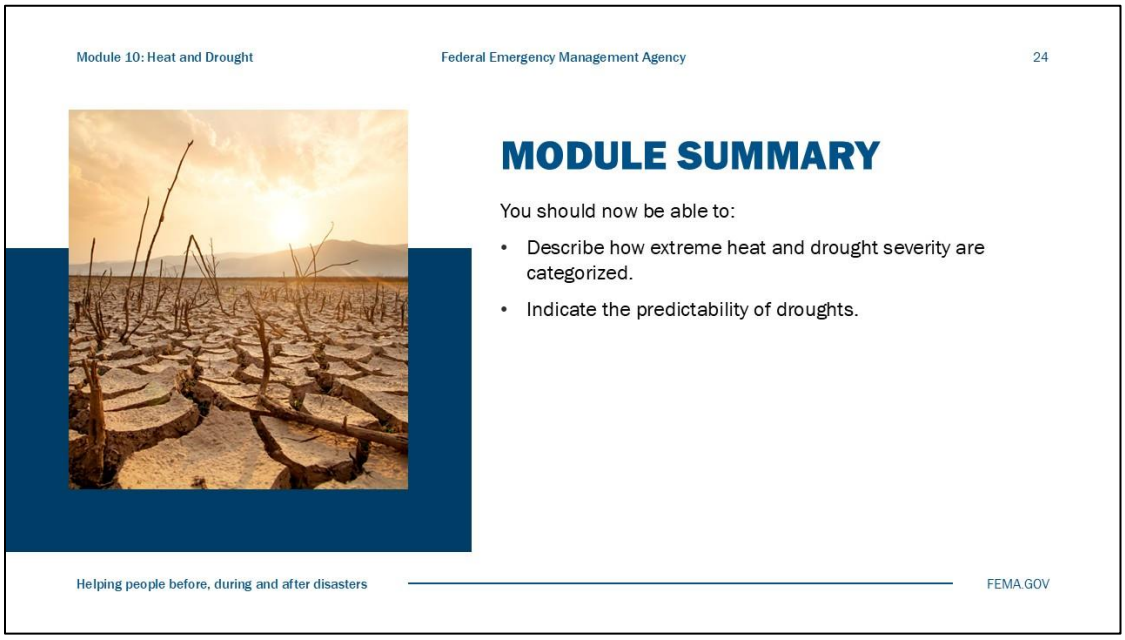
Symptomatic infection of Valley Fever occurs in about 40% of cases, which usually present as an influenza-like illness with fever, cough, headaches, rash, and muscle pain. Serious complications include severe pneumonia, lung nodules, and disseminated disease, where the fungus spreads throughout the body. The disseminated form of Valley Fever can devastate the body, causing skin ulcers, abscesses, bone lesions, severe joint pain, heart inflammation, urinary tract problems, meningitis, and often death.

Some of California's largest and most deadly wildfires on record, including the Camp Fire, Thomas Fire, and Cedar Fire, are associated with the Santa Ana winds.

The increasing risk of wildfires, particularly in the Western U.S., is driven by a complex mix of factors such as:

- Weather trends-induced drought (drying vegetation)
- Rapid development into the Wildland-Urban Interface (WUI) (caused by factors such as increased urban housing costs)
- Lack of mitigation (not clearing underbrush, not building with fire-resistant materials)
- Aging and not well-maintained infrastructure (power, roads, water)
- Lack of "fire sense" by the public (discarded cigarettes, unattended campfires, burning debris

End of Module (1 of 2)

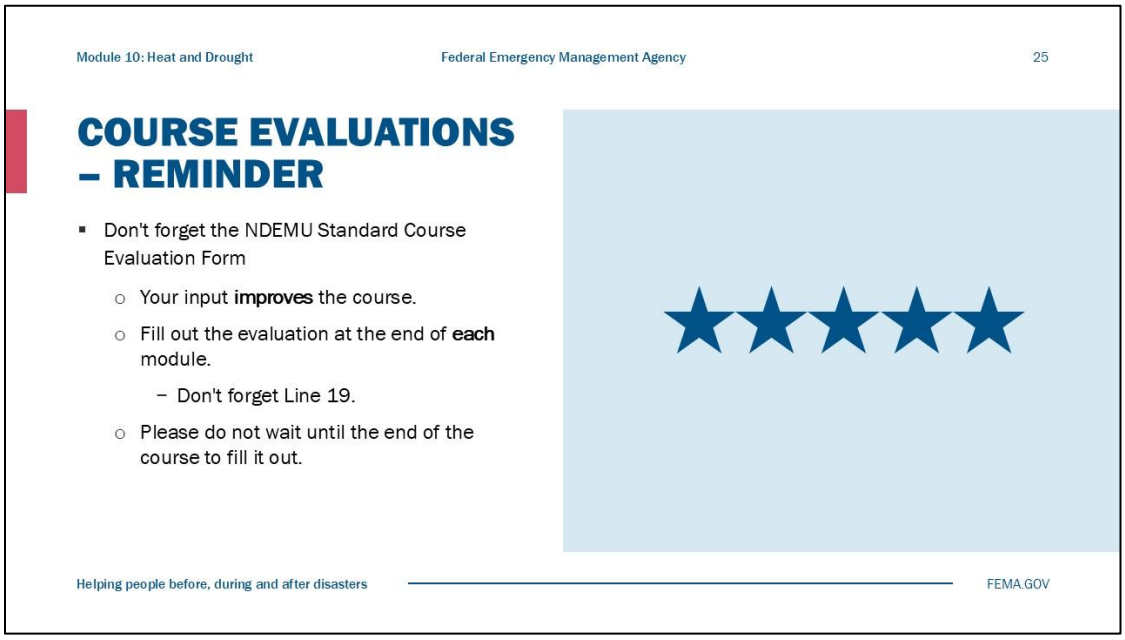


Slide 9-24, Module Summary

You should now be able to:

- Describe how extreme heat and drought severity are categorized.
- Indicate the predictability of droughts.

End of Module (2 of 2)



Slide 9-25, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

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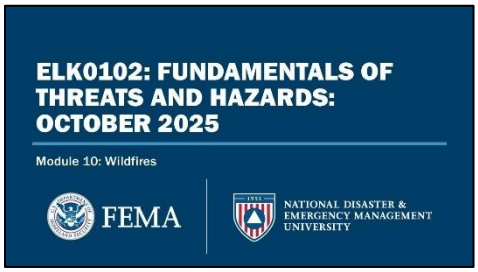
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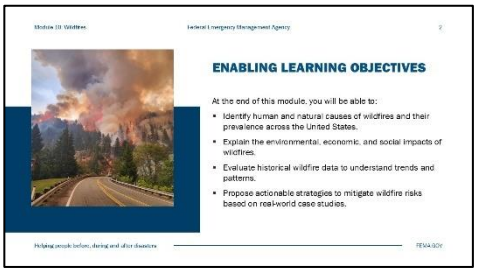
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Module 10
Wildfires

Administration



Slide 10-1, Module 10: Wildfires



Slide 10-2, Enabling Learning Objectives

Duration

30 minutes

Terminal Learning Objective (TLO)

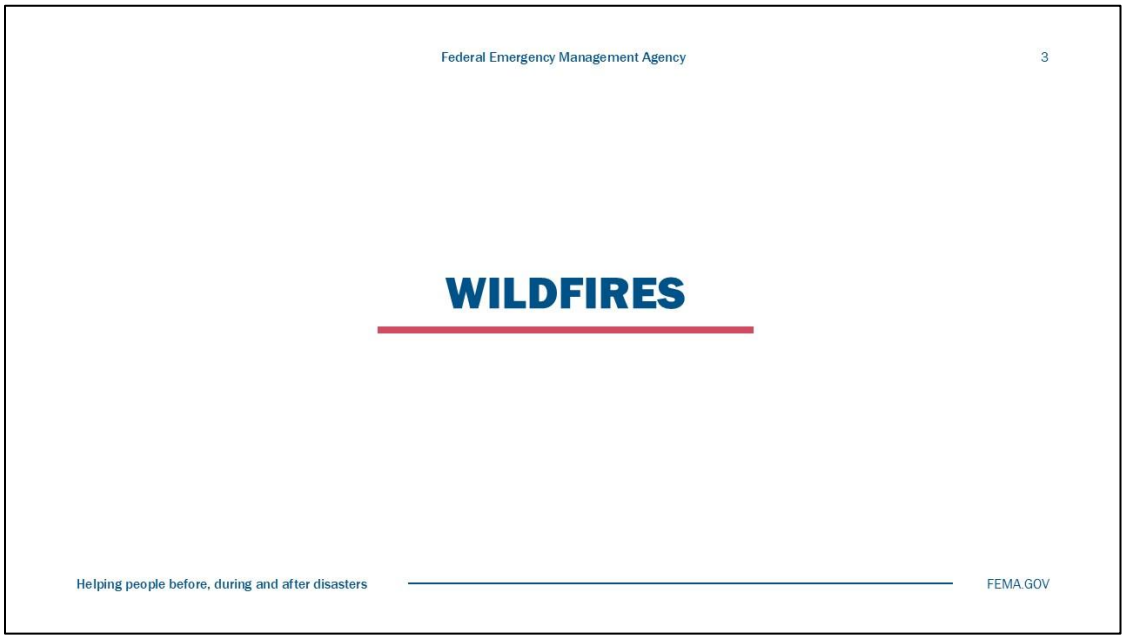
By the end of this module, participants will be able to analyze the factors contributing to wildfires, assess their impacts, and recommend mitigation strategies to effectively reduce wildfire risks.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Identify human and natural causes of wildfires and their prevalence across the United States.
- Explain the environmental, economic, and social impacts of wildfire.
- Evaluate historical wildfire data to understand trends and patterns.
- Propose actionable strategies to mitigate wildfire risks based on real-world case studies.

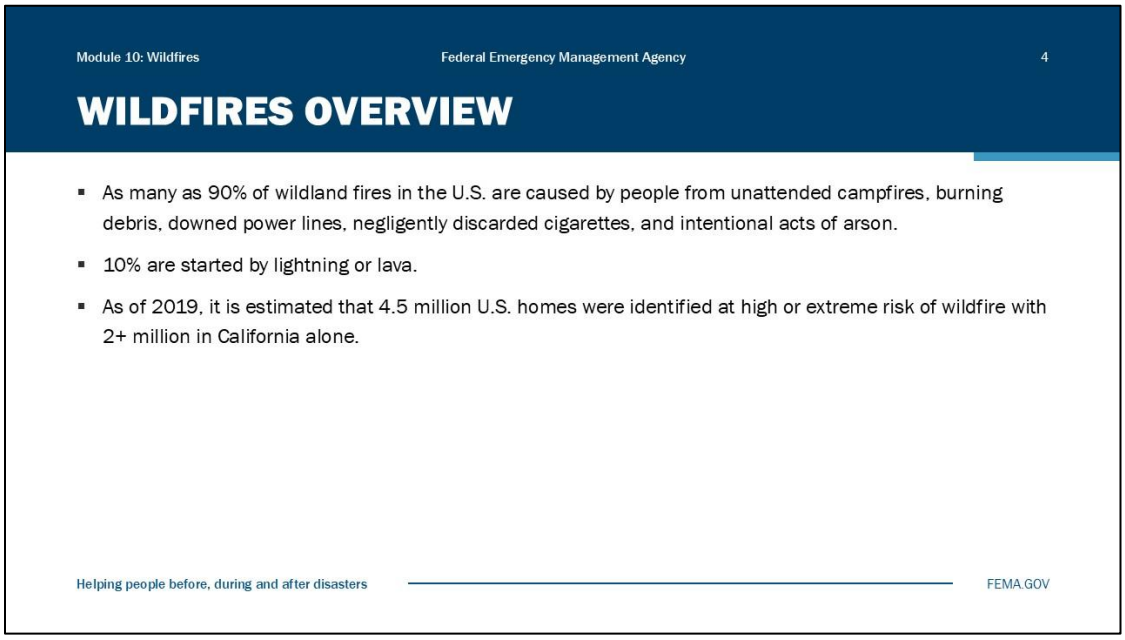
Wildfires (1 of 2)



Slide 10-3, Wildfires

Not Applicable.

Wildfires (2 of 2)



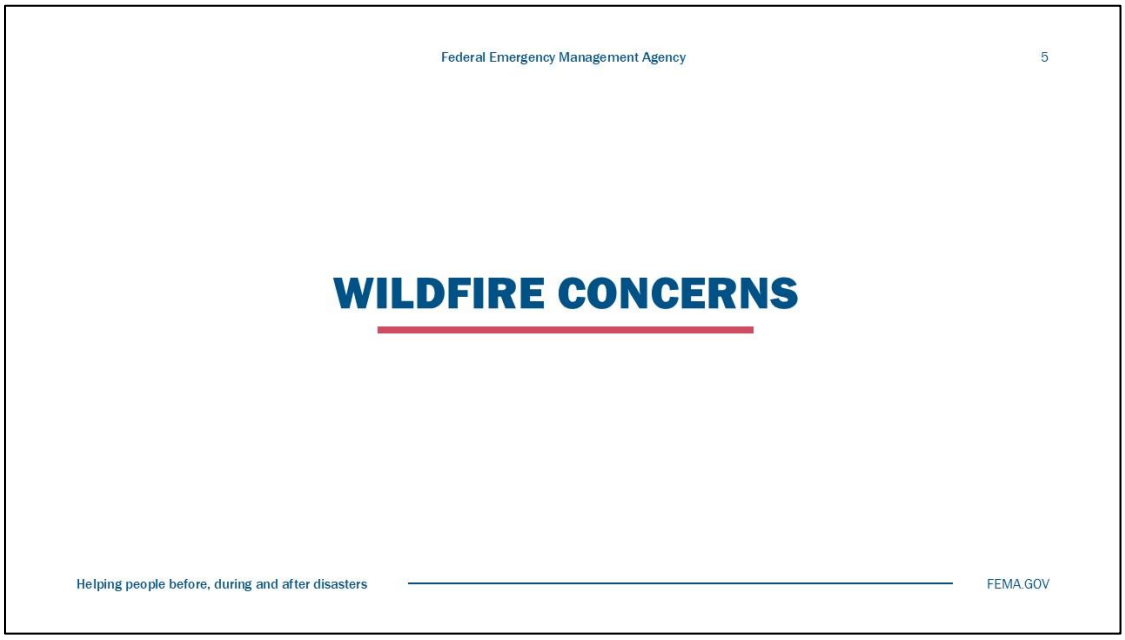
Slide 10-4, Wildfires Overview

- As many as 90% of wildland fires in the U.S. are caused by people from unattended campfires, burning debris, downed power lines, negligently discarded cigarettes, and intentional acts of arson;
- 10% are started by lightning or lava;
- As of 2019, it is estimated that 4.5 million U.S. homes were identified at high or extreme risk of wildfire, with 2+ million in California alone.

At any given time, you can go to: National Interagency Fire Center (https://www.nifc.gov/fire-information/nfn) to see the wildfire status of the U.S.

Source: Insurance Information Institute (https://www.iii.org/fact-statistic/facts-statistics-wildfires)

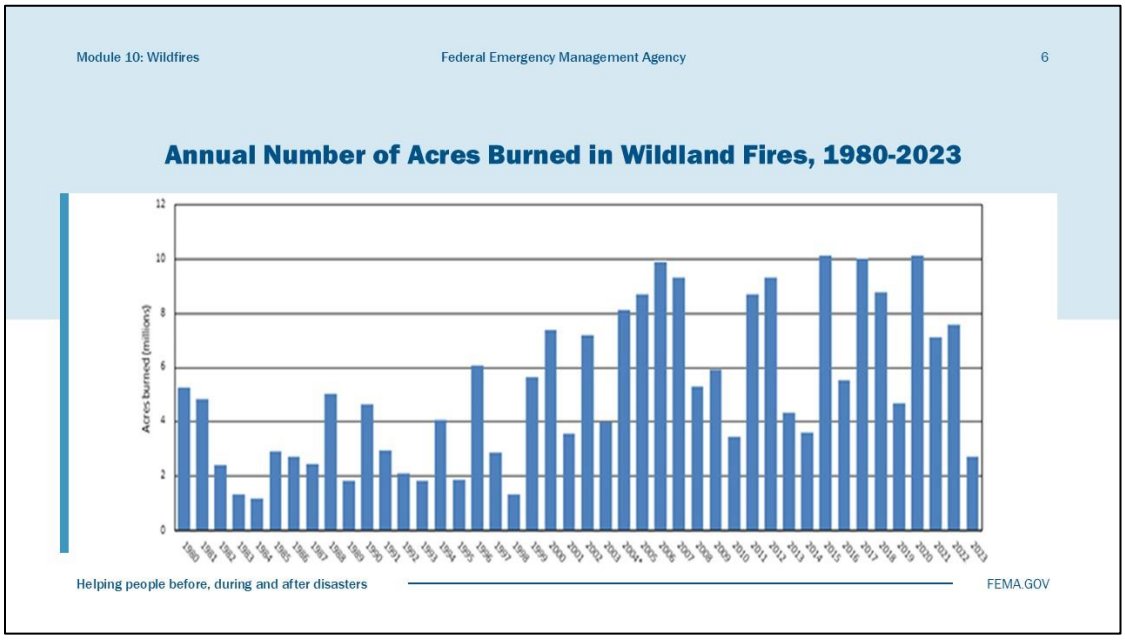
Wildfire Concerns (1 of 5)



Slide 10-5, Wildfire Concerns

Not Applicable.

Wildfires Concerns (2 of 5)



Slide 10-6, Annual Number of Acres Burned in Wildland Fires, 1980-2023

This bar chart illustrates the annual number of acres burned **by wildfires** in the United States from **1980 to 2023**. Each bar represents the **total area burned (in millions of acres)** during a given year.

**2004 fires and acres do not include state lands for North Carolina.*

Wildfires By State, 2023.

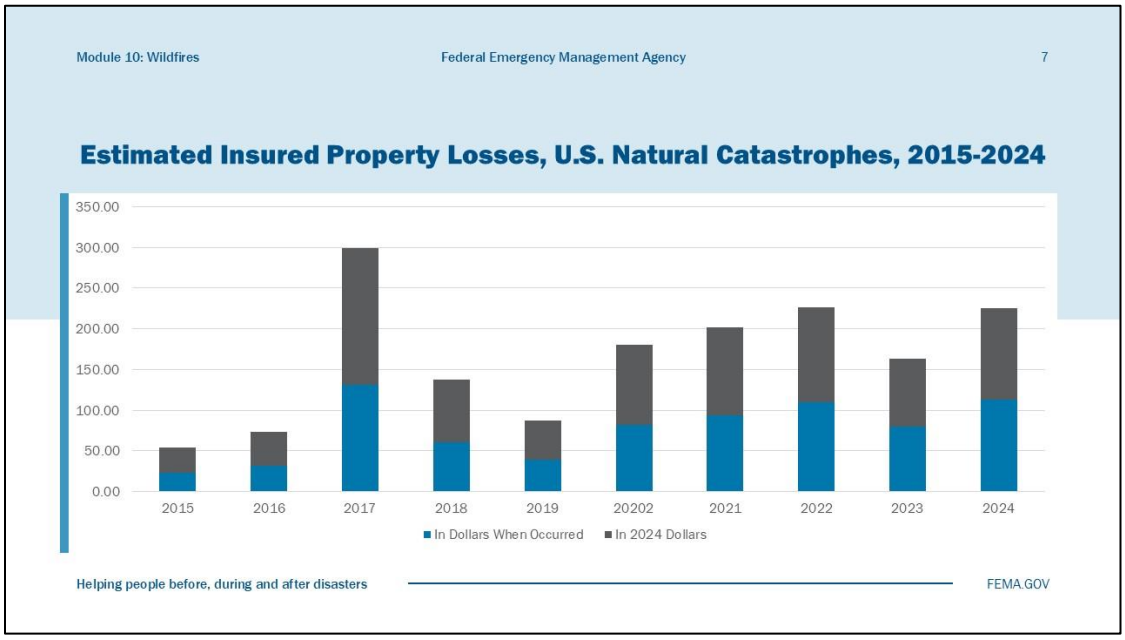
State	Number of Fires	Number of Acres Burned
Alabama	1,856	18,335
Alaska	346	314,276
Arizona	1,837	188,483
Arkansas	147	5,659
California	7,364	332,722
Colorado	861	41,917
Connecticut	499	297
Delaware	1	0

State	Number of Fires	Number of Acres Burned
District of Columbia	0	0
Florida	2,730	99,642
Georgia	2,386	10,330
Hawaii	214	12,059
Idaho	892	87,801
Illinois	22	111
Indiana	47	521
Iowa	6	6
Kansas	49	17,963
Kentucky	9	70
Louisiana	1,467	22,103
Maine	493	325
Maryland	196	4,486
Massachusetts	1,079	1,468
Michigan	466	4,287
Minnesota	836	9,416
Mississippi	2,383	52,508
Missouri	127	9,499
Montana	1,662	123,133
Nebraska	569	180,733
Nevada	375	1,300
New Hampshire	52	58
New Jersey	1,194	18,033
New Mexico	1,019	212,378
New York	150	1,383
North Carolina	5,214	73,953
North Dakota	471	4,183
Ohio	883	2,469

State	Number of Fires	Number of Acres Burned
Oklahoma	1,580	162,489
Oregon	1,979	202,035
Pennsylvania	1,910	9,628
Puerto Rico	0	0
Rhode Island	78	582
South Carolina	22	591
South Dakota	177	945
Tennessee	772	15,394
Texas	7,102	210,264
United States (1)	**56,580**	**2,693,910**
Utah	782	18,109
Vermont	67	62
Virginia	43	12,085
Washington	1,707	151,316
West Virginia	1,124	45,679
Wisconsin	1,086	4,883
Wyoming	249	7,934

Source: Insurance Information Institute (https://www.iii.org/fact-statistic/facts-statistics- wildfires)

Wildfires Concerns (3 of 5)



Slide 10-7, Estimated Insured Property Losses, U.S. Natural Catastrophes, 2015-2024

This chart shows the **total annual economic losses** from natural catastrophes in the U.S., including **wildfires, hurricanes, floods, and other extreme weather events**. The data compares two values:

- **Blue bars**: Losses in the year **they occurred**
- **Gray bars**: The **same losses adjusted for inflation**, shown in **2024 dollars**

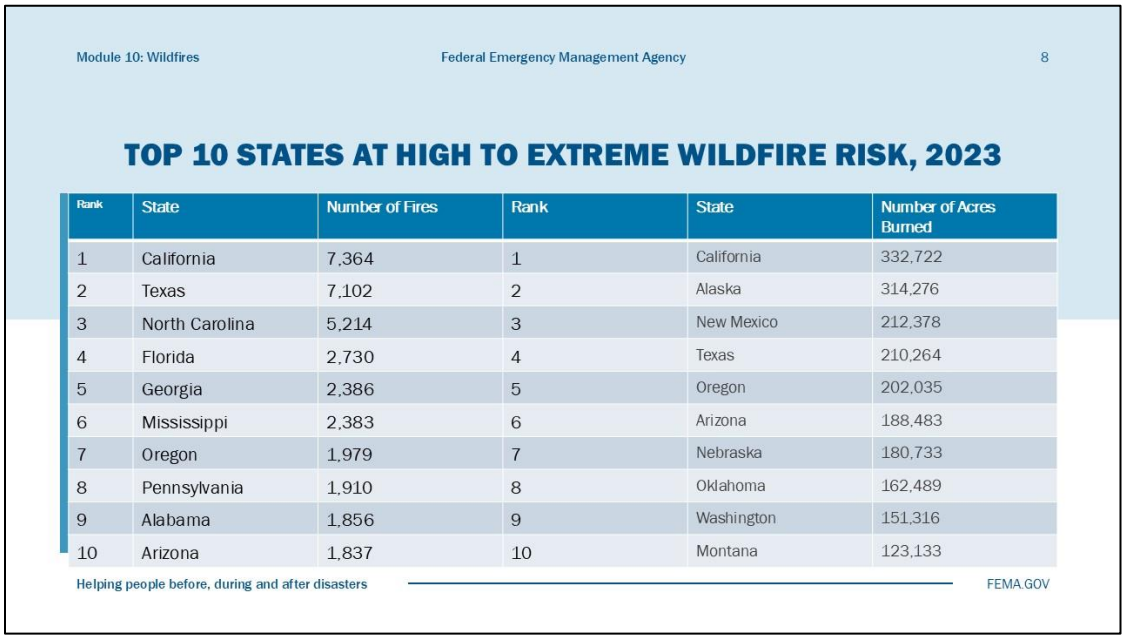
Estimated Insured Property Losses, U.S. Natural Catastrophes, 2015-2024

Year	In Dollars When Occurred	In 2024 Dollars
2015	$23.0	$30.7
2016	31.9	41.9
2017	131.0	168.1
2018	60.9	76.4
2019	39.2	48.5
2020	81.5	99.3
2021	93.3	108.7

Year	In Dollars When Occurred	In 2024 Dollars
2022	109.6	116.9
2023	80.0	82.9
2024	112.8	112.8

Source: Insurance Information Institute (https://www.iii.org/fact-statistic/facts-statistics-us-catastrophes)

Wildfires Concerns (4 of 5)



Rank	State	Number of Fires	Rank	State	Number of Acres Burned
1	California	7,364	1	California	332,722
2	Texas	7,102	2	Alaska	314,276
3	North Carolina	5,214	3	New Mexico	212,378
4	Florida	2,730	4	Texas	210,264
5	Georgia	2,386	5	Oregon	202,035
6	Mississippi	2,383	6	Arizona	188,483
7	Oregon	1,979	7	Nebraska	180,733
8	Pennsylvania	1,910	8	Oklahoma	162,489
9	Alabama	1,856	9	Washington	151,316
10	Arizona	1,837	10	Montana	123,133

Slide 10-8, Top 10 States at High to Extreme Wildfire Risk, 2023

This table shows the **top 10 U.S. states at high to extreme wildfire risk in 2023**, based on two measures:

- **Left side**: States ranked by **number of fires** reported
- **Right side**: States ranked by **total acres burned**

California ranks first in both categories, with more than **7,300 fires** and **over 330,000 acres burned**. While some states (like Texas and Oregon) appear on both lists, others differ, highlighting how wildfire **frequency and severity** vary by region.

Rank	State	Number of Fires	Rank	State	Number of Acres Burned
1	California	7,364	1	California	332,722
2	Texas	7,102	2	Alaska	314,276
3	North Carolina	5,214	3	New Mexico	212,378
4	Florida	2,730	4	Texas	210,264
5	Georgia	2,386	5	Oregon	202,035

Rank	State	Number of Fires	Rank	State	Number of Acres Burned
6	Mississippi	2,383	6	Arizona	188,483
7	Oregon	1,979	7	Nebraska	180,733
8	Pennsylvania	1,910	8	Oklahoma	162,489
9	Alabama	1,856	9	Washington	151,316
10	Arizona	1,837	10	Montana	123,133

Source: Background on: Wildfires | III (https://www.iii.org/article/background-on-wildfires)

Wildfires Concerns (5 of 5)



Slide 10-9, 2020 Western States Wildfires

2020 Western States Wildfires

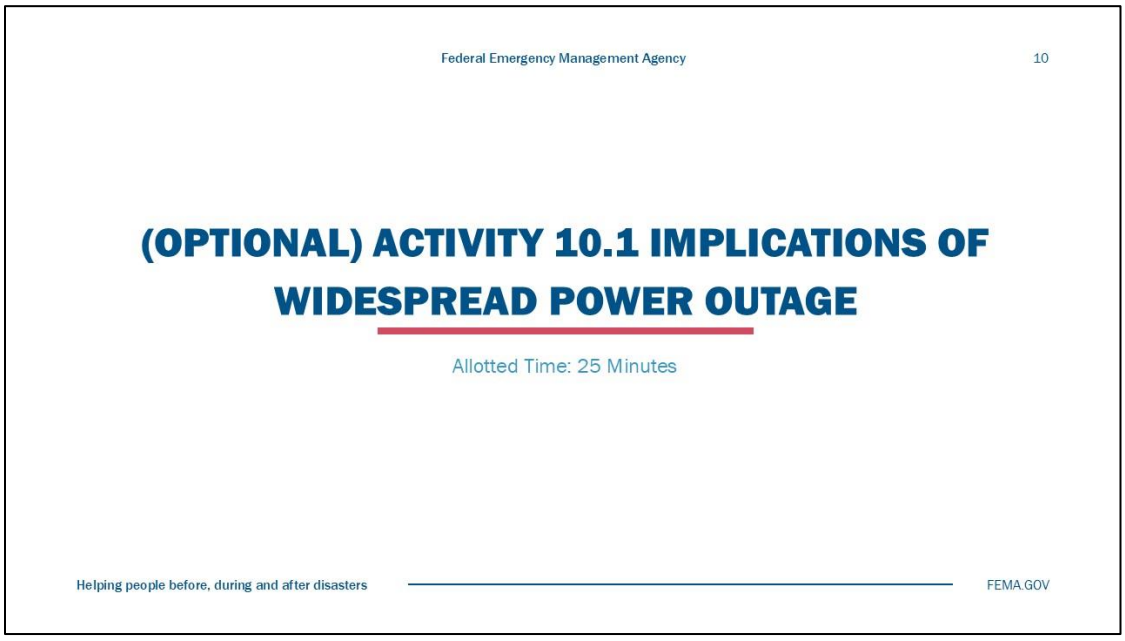
Burning in California, Oregon, and Washington as of September 2020:

- 28 major fires in California (including 5 of the state's largest ever) with over 3.2 million acres burned since 1/1/20.
- Washington lost over 600,000 acres in one week.
- Over 500,000 Oregon residents (over 10% of the state's population) were under an evacuation warning or order, and over 1 million acres have been charred.

Air quality has deteriorated significantly, becoming a health hazard.

Source: Western wildfires: Climate change-fueled blazes plunge Washington, Oregon and California into crisis - Washington Post (https://www.washingtonpost.com/graphics/2020/national/california-oregon-washington-wildfires/?itid=lk_inline_manual_4)

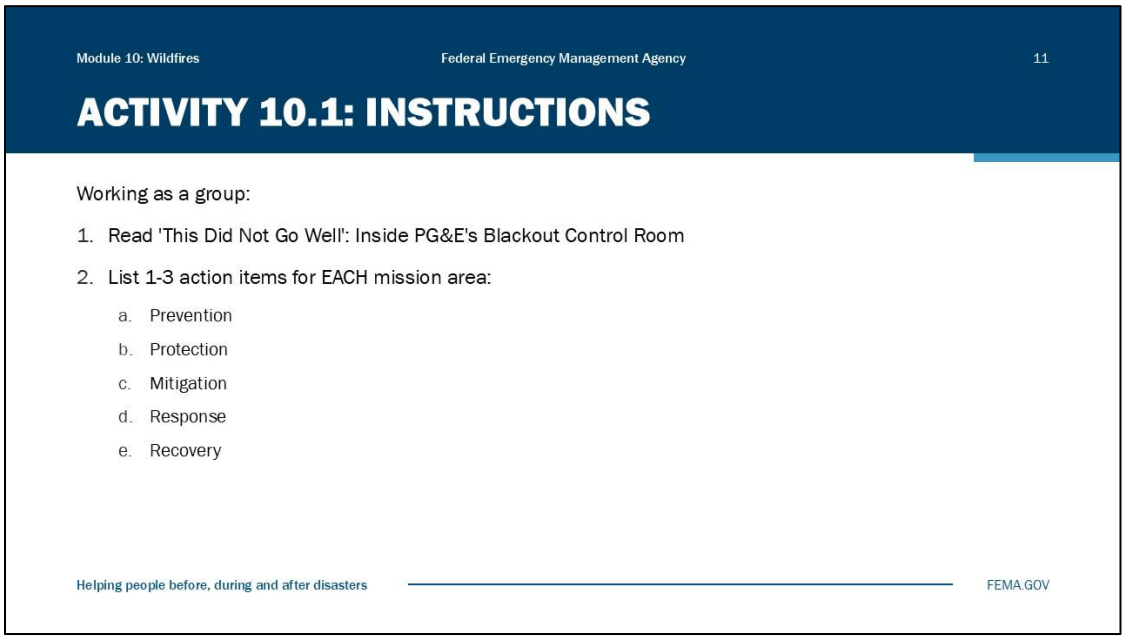
(Optional) Activity 10.1: Implications of Widespread Power Outage (1 of 2)



Slide 10-10, (Optional) Activity 10.1 Implications of Widespread Power Outage

Not Applicable.

(Optional) Activity 10.1 Implications of Widespread Power Outage (2 of 2)



Slide 10-11, Activity 10.1: Instructions

Activity 10.1: Implications of Widespread Power Outage – Directions to Students

Purpose

The purpose of this activity is to apply the five homeland security mission areas—prevention, protection, mitigation, response, and recovery—to a real-world crisis scenario. Participants will analyze and extract lessons learned from the PG&E blackout incident to strengthen preparedness and resilience planning.

1. In your table groups, read the article below titled, “This Did Not Go Well: Inside PG&E’s Blackout Control Room.”
2. As a group, identify 1–3 specific action items for each of the following mission areas.

Mission Area	Action 1	Action 2	Action 2
Prevention			
Protection			
Mitigation			
Response			
Recovery			

3. Be prepared to share your responses during the class discussion. Your group may be asked to present on one or more of the mission areas.

'This Did Not Go Well': Inside PG&E's Blackout Control Room

By Ivan Penn

Oct. 12, 2019

SAN FRANCISCO — It was a problem that California had come to dread. Weather models were signaling extreme winds and dry conditions from one end of the state to the other. The risk of wildfires was high.

Pacific Gas & Electric, the giant utility whose power lines and transformers have been blamed for a series of disastrous wildfires in recent years, was determined to prevent another one.

Just before last weekend, the company informed state officials that it might shut off power to a large area of Northern California, potentially leaving millions of people in the dark – something no United States utility had done in recent memory. It made that news public on Monday. By Tuesday morning, about a hundred utility executives, state officials, meteorologists and others had gathered at an operations center in San Francisco to coordinate the effort.

Things quickly began going wrong. PG&E's communications and computer systems faltered, and its website went down as customers tried to find out whether they would be cut off or spared. As the company struggled to tell people what areas would be affected and when, chaos and confusion unspooled outside. Roads and businesses went dark without warning, nursing homes and other critical services scrambled to find backup power and even government agencies calling the company were put on hold for hours.

All told, more than 700,000 homes or businesses – from the state's northernmost reaches to the outskirts of Silicon Valley – lost electricity beginning early Wednesday morning, and the state's emergency center usually used for natural disasters was activated. Most residents had power restored by noon on Friday, and just over 12,000 were still without it on Saturday morning.

"There were definitely missteps," said Elizaveta Malashenko, a representative for the state Public Utilities Commission who was in the control center. "It's pretty much safe in saying, this did not go well."

While California prides itself on its technical prowess and economic might, PG&E had to send crews out into the fields, in a few cases, to manually flip switches to turn off power and then turn it back on, rather than doing it remotely.

Residents were left asking why so many people had to lose power and whether rolling blackouts would become routine as wildfires become more frequent and intense.

The company, which is facing $30 billion in liabilities from recent wildfires started by its equipment, has drawn intense scorn from both its customers and state officials.

"This current operation is unacceptable," Gov. Gavin Newsom said Thursday. "The current conditions and circumstances are unacceptable."

Trouble has long dogged PG&E, California's largest utility and one of the biggest in the country. The company has said one of its transmission lines was probably responsible for the most destructive wildfire in state history, the Camp Fire, which killed more than 80 people and destroyed the town of Paradise last November. About a decade earlier, one of the company's gas lines south of San Francisco exploded, destroying a neighborhood and killing eight people.

This summer, PG&E and its newly appointed chief executive, Bill Johnson, had promised to do better. Blamed for its lax safety practices, the utility submitted a detailed plan to regulators on the protocol it would use to pre-emptively black out parts of its service area to prevent fires. It also promised to step up the trimming of trees along its transmission lines and make other changes.

"We did not deliver on this commitment this time," Mr. Johnson said Thursday evening as hundreds of thousands of his customers sat in the dark. "We were not prepared to manage the operational event."

A Communications Breakdown

Catherine Maynes, who handles logistics for Generators Unlimited, which supplies power backup equipment throughout Northern California, said she knew it was going to be a busy week as early as last weekend, when reports of the growing fire hazard started to surface.

Monday was a normal day at Generators Unlimited because it was not yet clear when the blackouts would start and who would be affected. It was on Tuesday that everything changed.

"First thing in the morning, as we opened the door, the calls started pouring in," said Ms. Maynes, who works in Brisbane, south of San Francisco. "It never stopped ringing."

While people and companies with means could turn to businesses like Ms. Maynes for backup power, many others did not have that luxury. When they tried to get more information, answers were often not forthcoming.

One option was community resource centers, places run by the utility where affected residents were supposed to be able to cool off and charge their phones. But they often got little information or assistance there because PG&E had not adequately staffed the centers, said a senior state official with knowledge of the situation who was not authorized to speak publicly.

Meanwhile, state agencies, in charge of services like railways and the water supply, were forced to open the state's emergency operations center, which is normally used for actual disasters like earthquakes and fires, the official said. The center was running at Level 2, the same level it operated on during the Ridgecrest earthquake over the summer. And the local authorities were forced to bear the cost of additional staffing, including overtime hours for police officers, to deal with the shutdown.

This was a big moment for PG&E, which does not have extensive experience using what California officials refer to as a "public safety power shut-off." Its previous wildfire shut-offs had been limited to tens of thousands of customers – and it was ill-prepared for the task.

Ms. Malashenko, deputy executive director for safety and enforcement at the California Public Utilities Commission, arrived at 9 a.m. on Tuesday for the first of her two 12-hour shifts at PG&E's operations center. She said she was stunned by what she saw. PG&E's website crashed just ahead of the first rounds of power shut-offs that would leave thousands in the dark.

In addition, the systems the company uses to alert residents and businesses that they would lose power didn't work as they were supposed to, Mr. Johnson, the chief executive, later acknowledged.

The situation got so bad at one point that Ms. Malashenko called on information technology specialists from the state to help restore PG&E's systems. (Besides Ms. Malashenko, representatives from the state emergency services and forestry and fire prevention agencies were also at the center to help coordinate the government's response with the utility and to relay information to state leaders, including Mr. Newsom.)

PG&E declined requests for interviews for this article with company officials who were at the emergency center.

Communication seemed to improve later on Tuesday before the first round of shut-offs began at 2 a.m. on Wednesday after Ms. Malashenko's colleagues from the state lent the company a hand. But within four hours after those blackouts began, PG&E's website crashed again.

"It never got to the point where it worked well," Ms. Malashenko said.

At the same time, on Tuesday, the weather forecast was becoming even more dire. PG&E's team of meteorologists were now identifying 34 counties as under threat from strong winds and dry conditions, up from 30 earlier.

Utility executives rely on the meteorology team, along with information from the National Weather Service, to decide what areas will lose power and when conditions are safe enough for crews to restore power.

Based on its models, PG&E now anticipated that the wind would reach 40 to 55 miles per hour from Wednesday morning through Thursday morning, with isolated gusts up to 60 to 70m.p.h.

That forecast was off a good bit: Winds reached as high as 77 m.p.h. at Mount St. Helena in Northern California. Wind speeds are important because strong gusts can blow trees into power lines or knock utility equipment into brush, setting off fires.

By Thursday evening, as the winds died down, PG&E began dispatching its 44 helicopters and 6,300 employees and contractors to inspect damage and restore power to some areas.

A Different Approach

While some experts think utilities ought to have better ways to prevent wildfires than cutting off power, the utility industry considers this acceptable in cases of grave weather threats, and other California utilities have used the approach.

What was unusual about PG&E's approach was that other utilities had never targeted as many customers.

"Today marks an unprecedented turn in the history of electricity in California," State Senator Jerry Hill, chairman of the Subcommittee on Energy, Utilities and Communications, said in a letter on Wednesday to the utilities commission. "This situation is not acceptable nor sustainable."

Mr. Hill said PG&E appeared not to have reviewed or learned from the utility that pioneered use of blackouts to prevent wildfires, San Diego Gas & Electric.

The San Diego utility was widely criticized when it first used power shut-offs as a wildfire prevention tool in the late 2000s.

"Our journey began over a decade ago with the devastating wildfires of 2007," said Caroline Winn, chief operating officer for SDG&E. "Those fires became a game changer for our company."

Ms. Winn said there was no blueprint that her company could consult when it created its wildfire prevention program. Among the steps it took early on were hiring a large team of meteorologists, including veterans of the National Weather Service; installing devices that measure weather conditions at various locations in its service area; and using technology that allowed the utility to remotely switch off power to designated areas.

Even though many fire and energy experts credit the company with being proactive and thoughtful, residents and lawmakers in its service area initially expressed frustration with the utility's approach.

"It was met with fierce opposition," Ms. Winn said. "Why are you doing it? Nobody else is doing that."

To address those concerns, Ms. Winn said the San Diego utility conducted town hall meetings and adjusted its efforts by, for example, limiting the size of areas that were blacked out.

The president of the state utilities commission, Marybel Batjer, said PG&E needed to similarly adapt its approach and learn from its mistakes.

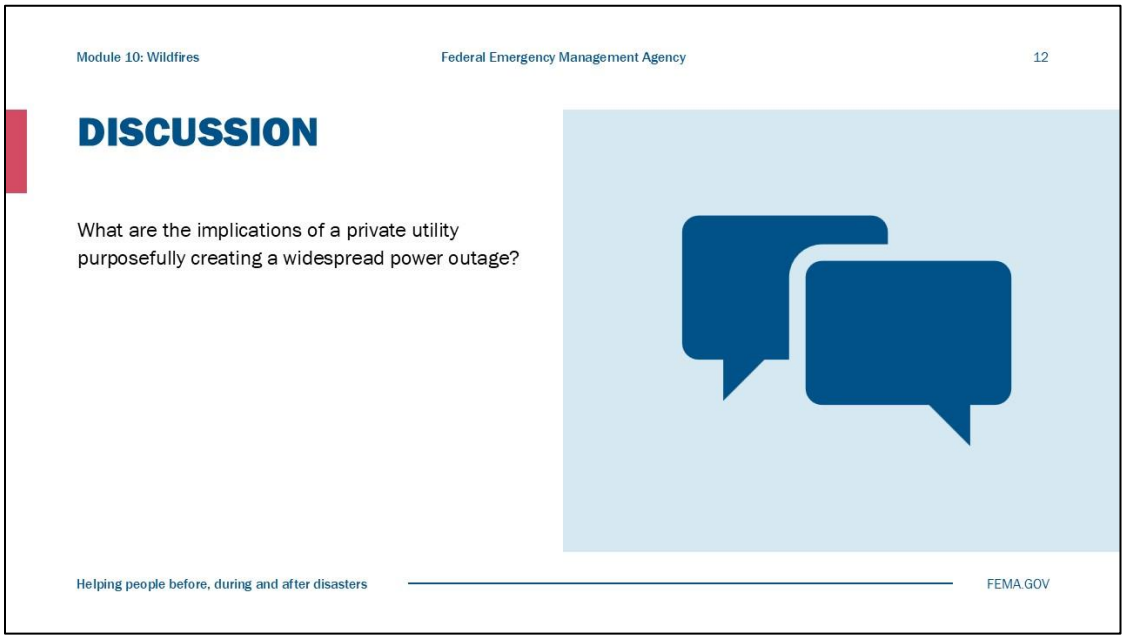
"The situation frankly has been unacceptable," Ms. Batjer said at a commission meeting on Thursday while PG&E was still wrestling with its blackouts. "The impacts to individual communities, to individual people, to the commerce of our state, to the safety of our people, has been less than exemplary. This cannot be the new normal. We can't accept it as the new normal. And we won't." (Penn, 2019)

Tim Arango contributed reporting from Los Angeles and David Yaffe-Bellany from New York.

A version of this article appears in print on, Section A, Page 1 of the New York edition with the headline: Blackout Effort 'Did Not Go Well' For Californians

Source*: Penn, I. (2019, October 12). 'This did not go well': Inside PG&E's blackout control room. The New York Times. https://www.nytimes.com/2019/10/12/business/pge-california-outage.html*

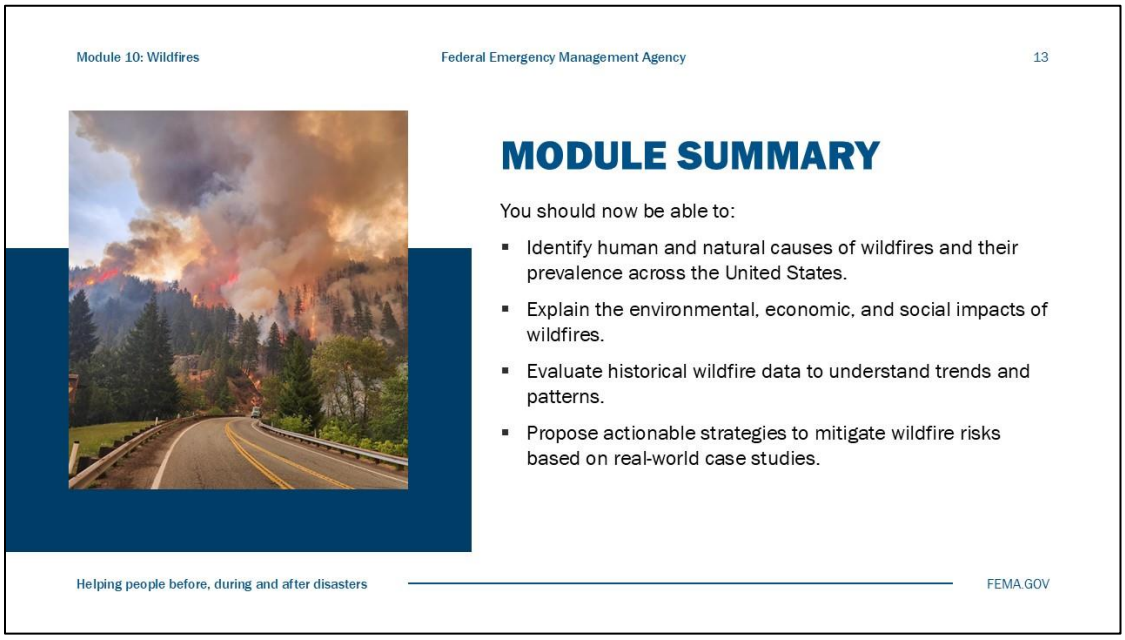
Discussion



Slide 10-12, Discussion

Discussion: What are the implications of a private utility purposefully creating a widespread power outage?

End of Module (1 of 2)

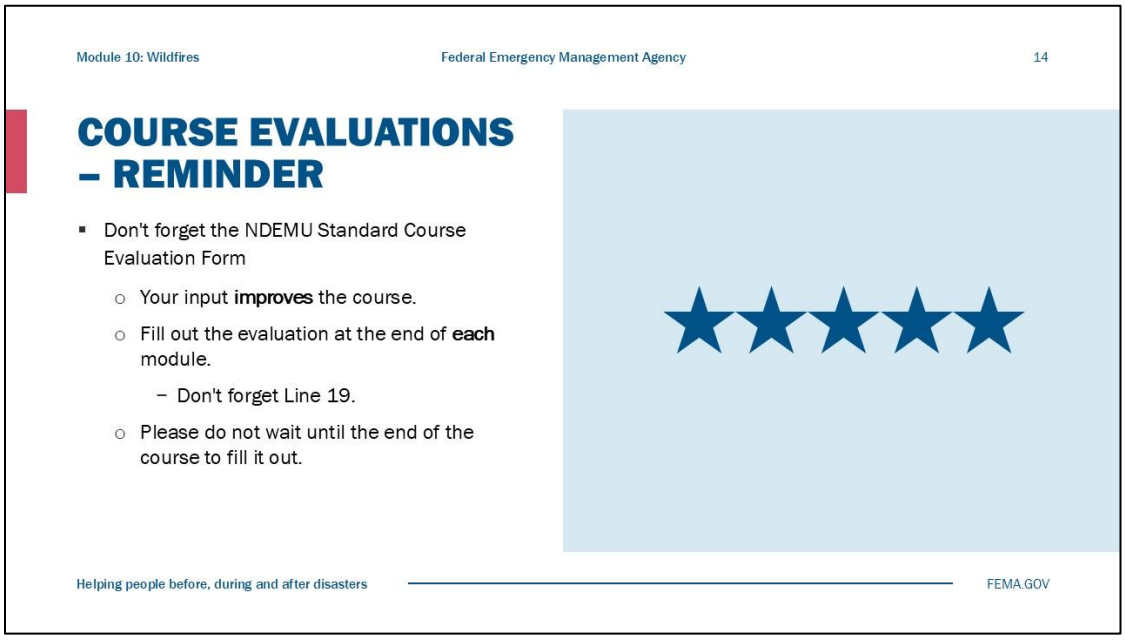


Slide 10-13, Module Summary

You should now be able to:

- Identify human and natural causes of wildfires and their prevalence across the United States.
- Explain the environmental, economic, and social impacts of wildfire.
- Evaluate historical wildfire data to understand trends and patterns.
- Propose actionable strategies to mitigate wildfire risks based on real-world case studies.

End of Module (2 of 2)



Slide 10-14, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

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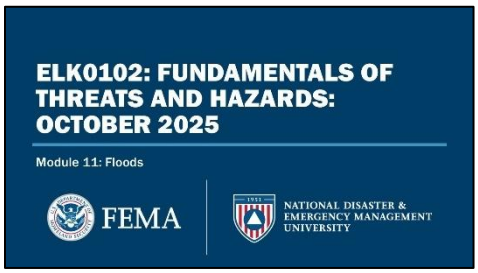
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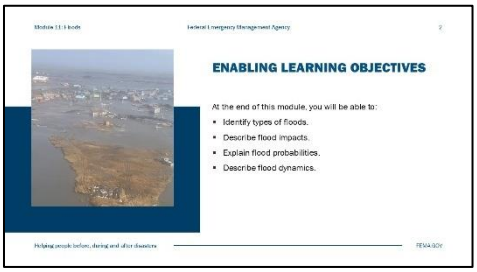
Module 11

Floods

Administration



Slide 11-1, Module 11: Floods



Slide 11-2, Enabling Learning Objectives

Duration

1 hour

Terminal Learning Objective (TLO)

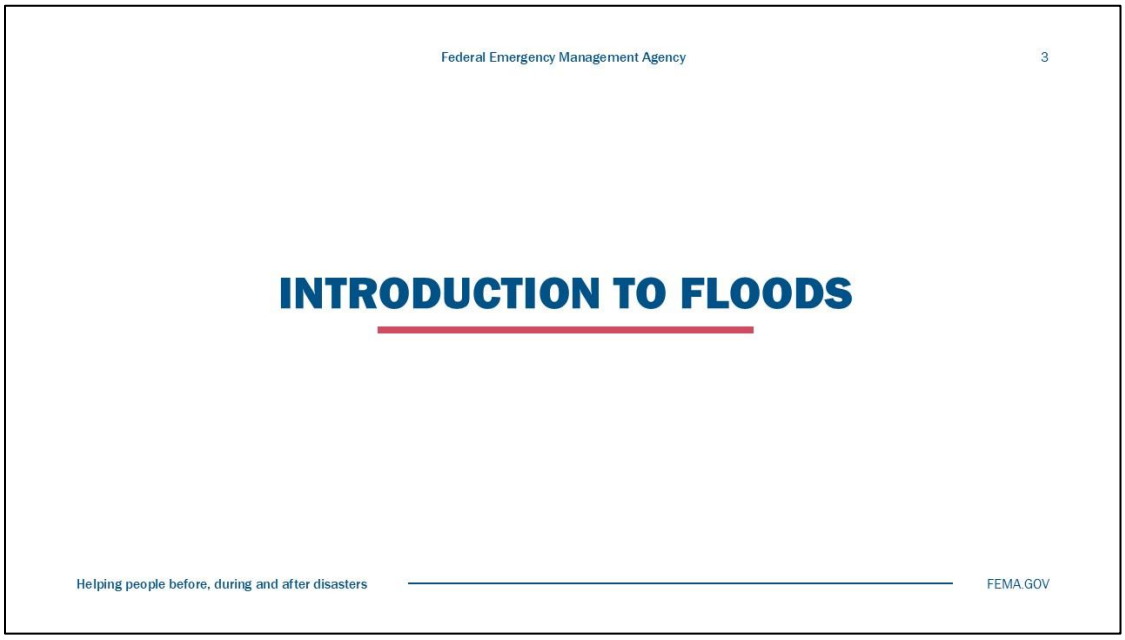
By the end of this module, participants will be able to analyze the causes, impacts, and mitigation strategies associated with flooding events, including secondary effects such as landslides and sinkholes, and apply this knowledge to enhance community preparedness, response, and resilience.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Identify types of floods.
- Describe flood impacts.
- Explain flood probabilities.
- Describe flood dynamics.

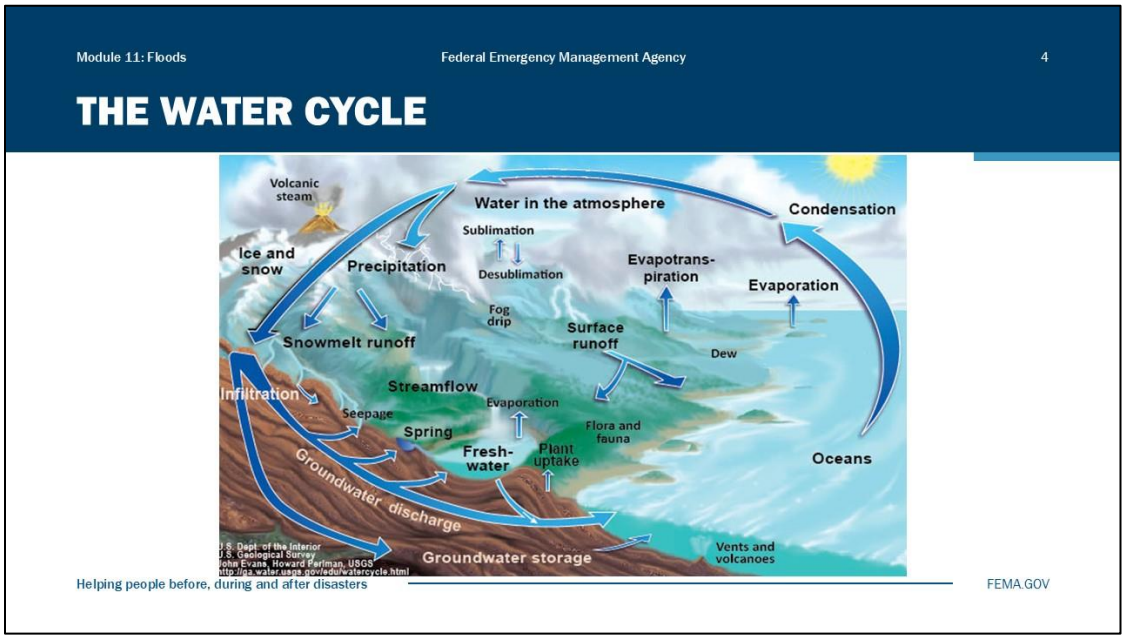
Introduction to Floods (1 of 5)



Slide 11-3, Introduction to Floods

Not Applicable.

Introduction to Floods (2 of 5)



Slide 11-4, The Water Cycle

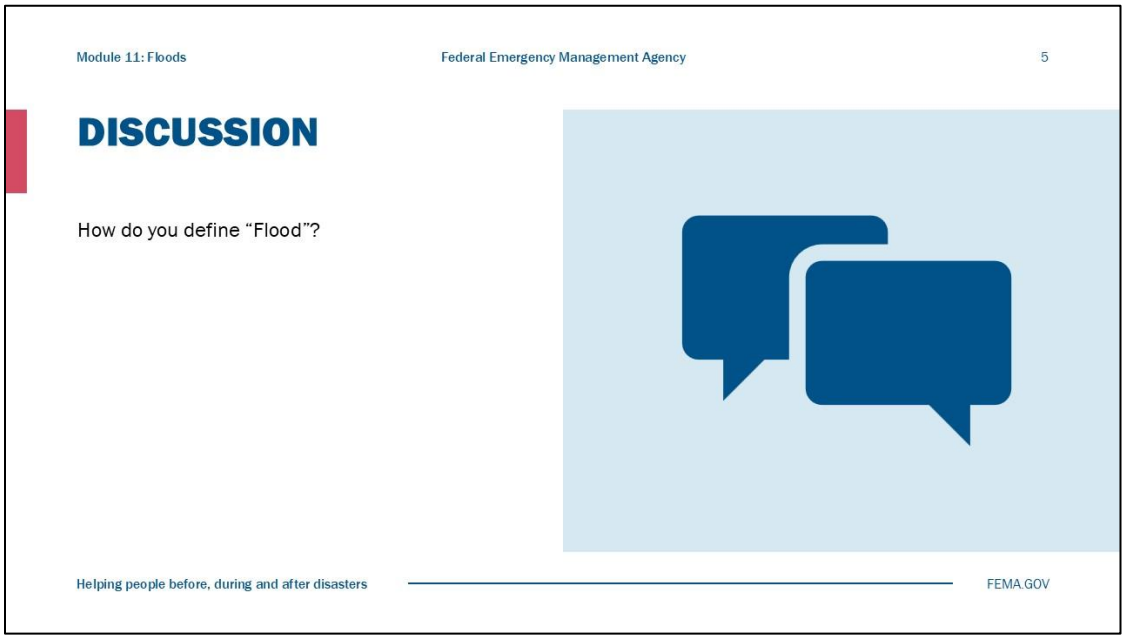
Most floods occur in relation to:

- Weather
- The water cycle

Water is always moving and circulating on the surface of our planet. Gravity moves water downhill, and water moves from ground to ocean to atmosphere through fluctuations in pressure and temperature that change water's phases from solid to liquid to gas.

Floods occur when water is delivered to a water body (e.g., stream, river, lake) at a rate and amount that is greater than normal; or, in other words, when the "water cycle" cannot keep up with the amount of water to be accommodated at one time at one location.

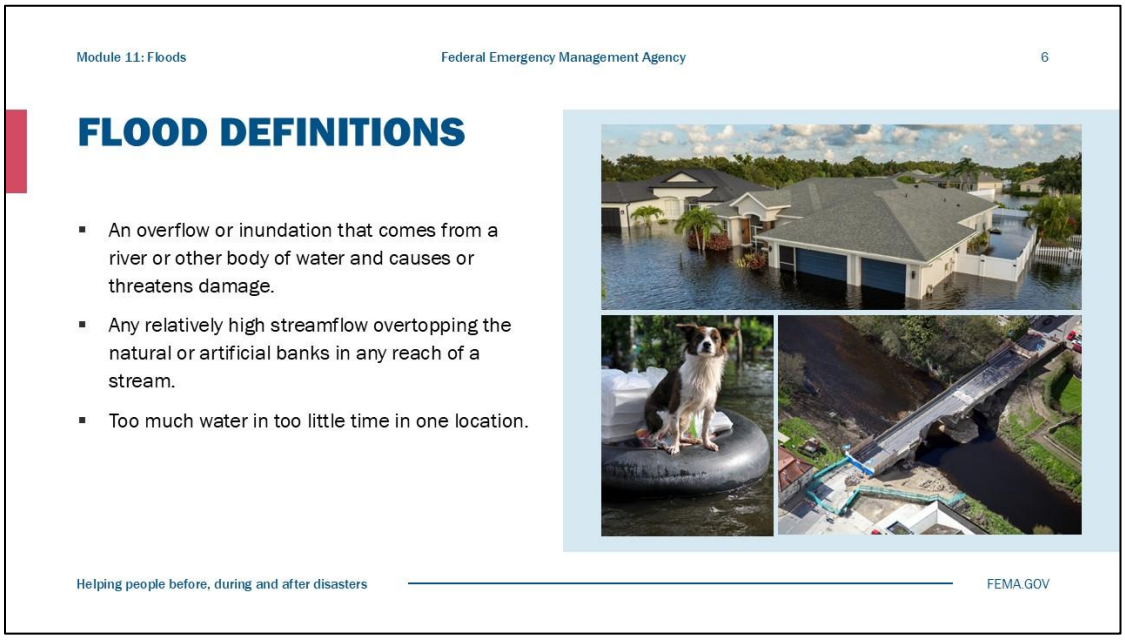
Introduction to Floods (3 of 5)



Slide 11-5, Discussion: How do you define "Flood"?

How would you define "flood"?

Introduction to Floods (4 of 5)



Slide 11-6, Flood Definitions

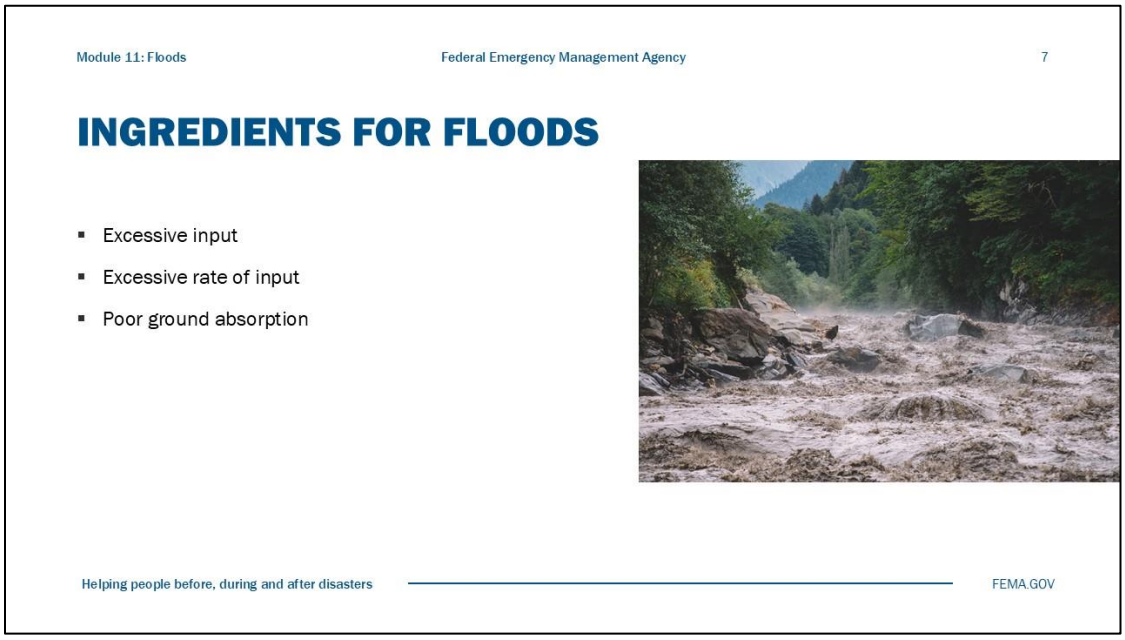
There are many technical definitions that tend to address different aspects of floods.

One widely used definition is "an overflow or inundation that comes from a river or other body of water and causes or threatens damage." By this definition, a flood is not a flood unless it could cause damage. This definition turns out to be useful to distinguish between floods and damaging events, which are **flood disasters.**

Another definition is that a flood is "any relatively high streamflow that overtops the natural or artificial banks in any reach of a stream."

The essential point is that a flood is a condition where there is too much water in too little time at a given location.

Introduction to Floods (5 of 5)



Slide 11-7, Ingredients for Floods

Next, we'll look at the factors that contribute to flooding. The major ingredients for floods are:

Excessive input, which may result from:

- Heavy downpours; and
- Long-duration constant rainfall.

Excessive rate of input, which may result from:

- Rate of precipitation:
  - Short-duration intense downpours; and
  - Rapid snowmelt.
- Rate of runoff, caused by:
  - Steep slopes;
  - Sparse vegetation; and
  - Thin soils.

Failure of flood protection structures:

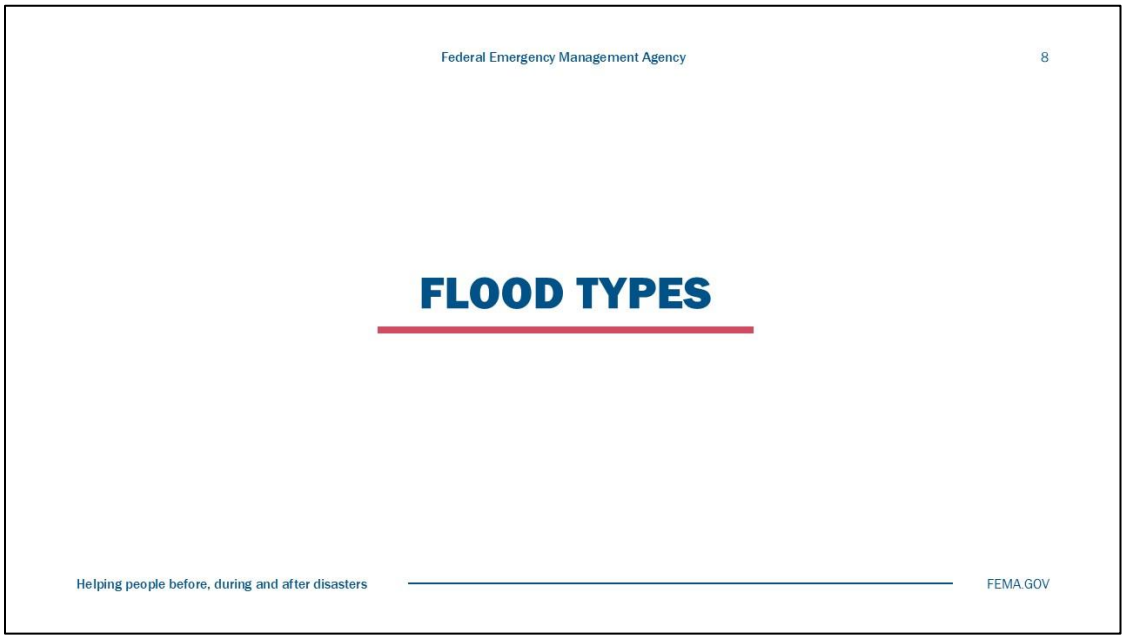
- Levee break; and

- Dam failure.

Poor ground absorption, which may result from:

- Poor quality soils
  - Sparse vegetation (often from deforestation); and
  - Thin soil (often from deforestation).
- Ground saturation;
- Urban landscapes;
- Closely spaced bodies of water; and
- Time of year (e.g., rainfall on frozen ground in winter).

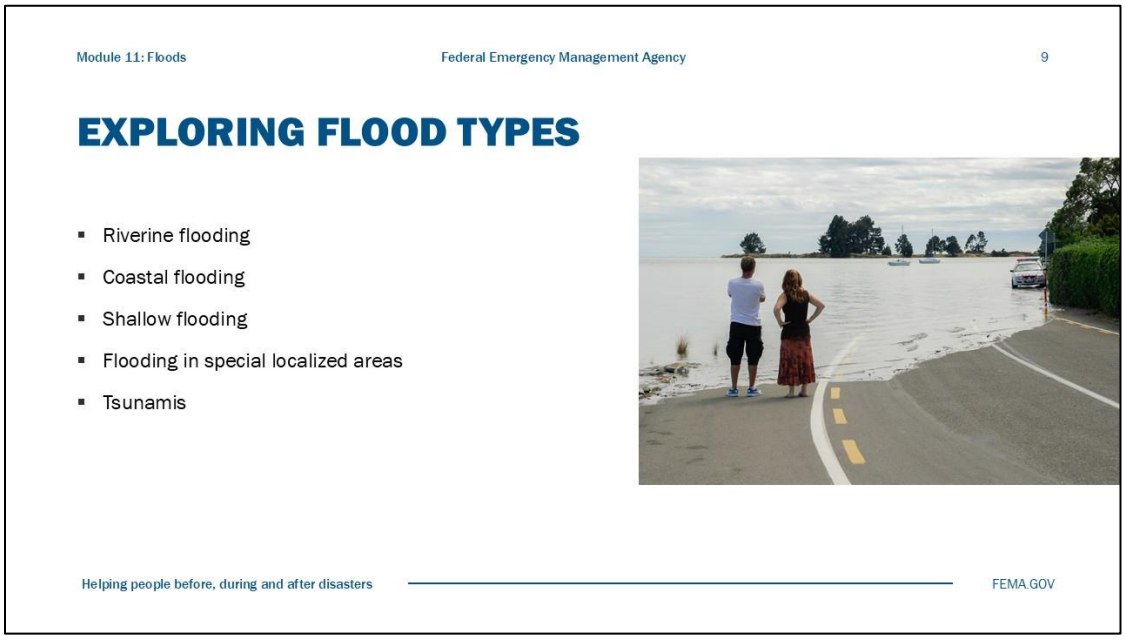
Flood Types (1 of 7)



Slide 11-8, Flood Types

Not Applicable.

Flood Types (2 of 7)



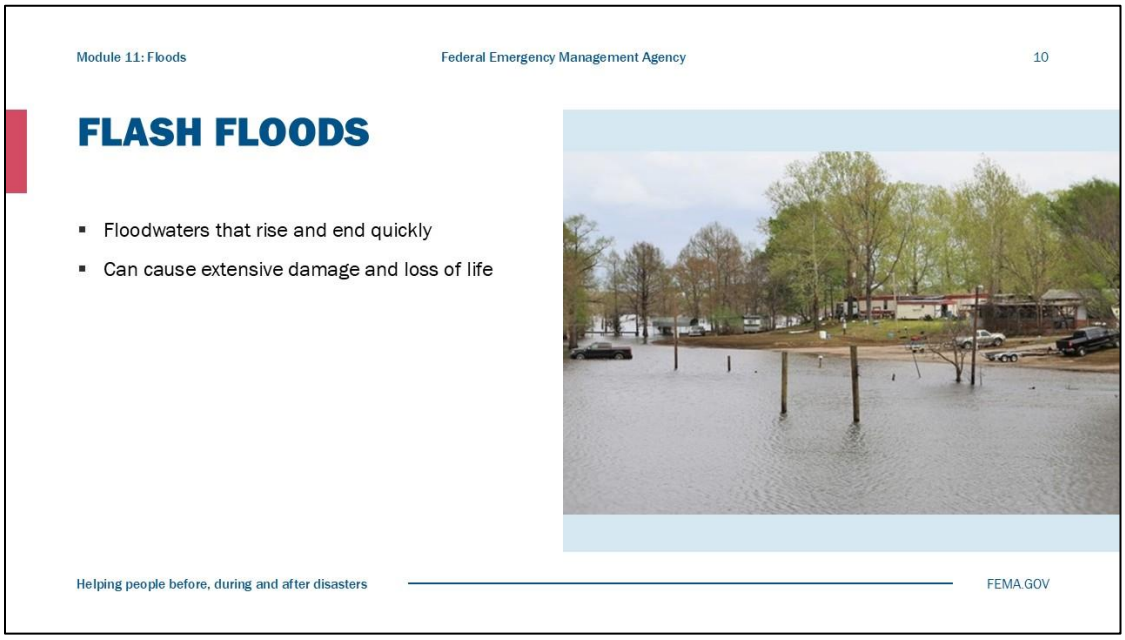
Slide 11-9, Exploring Flood Types

Floods can be grouped in various ways, but for the purposes of this course, the types recognized by the National Flood Insurance Program (NFIP) will be used. These types are:

- Riverine flooding;
- Coastal flooding;
- Shallow flooding;
- Flooding in special localized areas; and
- Tsunamis.

Riverine overbank flooding is the most common type of flooding in the United States. This type of flooding occurs when excess water from storms, snowmelt, or blockages due to debris or ice jams overloads the stream channel. When the stream channel is overloaded, excess floodwaters flow onto the adjacent land, called the floodplain. (Floodplain concepts will be covered later in this module). The extent of riverine overbank flooding in a particular area depends on many factors, including topography, size of the river basin, development in the river basin, and geographical location, to name a few

Flood Types (3 of 7)



Slide 11-10, Flash Floods

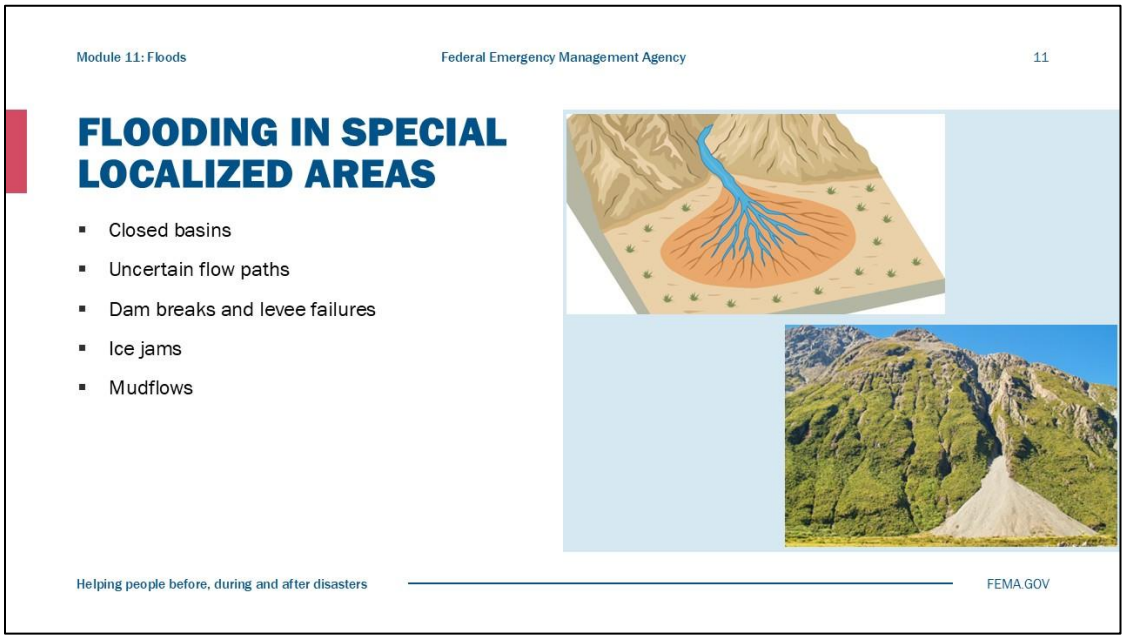
- Can occur suddenly, as the name suggests, with little or no warning.
- Water can be fast-moving and powerful.
- Water accumulates quickly.
- Caused by:
  - Slow-moving thunderstorms or storms moving repeatedly over the same area;
  - Hurricanes or tropical storms;
  - Floating debris can cause more damage as it flows in floodwaters, and can accumulate in areas, preventing water flow/flooding;
  - Heavy rain on saturated or extremely dry soil;
  - Sudden thaw of snow/ice;
  - Failure of dams or levees; and
  - Burn scarring over recent wildfire areas acts as a water repellent, and missing vegetation exacerbates flooding.
- May occur in an area where there is no rain, as distant storms dump water quickly, causing areas to flood as water accumulates in lower-lying areas.

- Affects/causes damage to:
  - Roads, bridges/underpasses, homes, businesses, farms, cars, people, wildlife.

Flash floods are characterized by floodwaters that rise and end quickly. Areas with steep slopes and narrow stream valleys, such as mountainous areas, are especially susceptible to flash flooding.

These floods can cause extensive damage and loss of life, especially in recreation areas such as campgrounds. Flash floods are the leading cause of flood-related deaths in the United States, primarily because they can strike with little warning, giving little or no time to evacuate.

Flood Types (4 of 7)



Slide 11-11, Flooding in Special Localized Areas

The National Flood Insurance Program (NFIP) recognizes other types of flooding as "special localized flooding." These special situations include closed basin lakes, areas with uncertain flow paths, dam breaks and levee failures, ice jams, and mudflows.

Closed basins are lakes that formed after glaciers retreated, primarily from areas in the northern United States. Because these lakes are closed basins, they have no way of draining. As a result, they frequently flood nearby areas as they expand outward. Devils Lake, North Dakota, is an example of a closed basin lake.

Uncertain flow paths describe areas, primarily in mountainous locations, where high-velocity floodwaters spread out as they reach the valleys below. As the floodwater slows, it seeks various channels in a fanlike pattern. The channels may differ with each successive flood event and are, therefore, less predictable than riverine floods that occur in a defined channel. These fanlike features are called **alluvial fans** because of the large amount of sediment and debris deposited by floodwaters as they approach the valley floor.

Dam breaks and levee failures occur when the structural integrity of a dam or levee is compromised, resulting in leakage, fracture, or complete failure of the dam or breaching of the levee. Many private or locally built dams and levees that are poorly designed or poorly maintained are especially susceptible to failure during extreme flooding conditions.

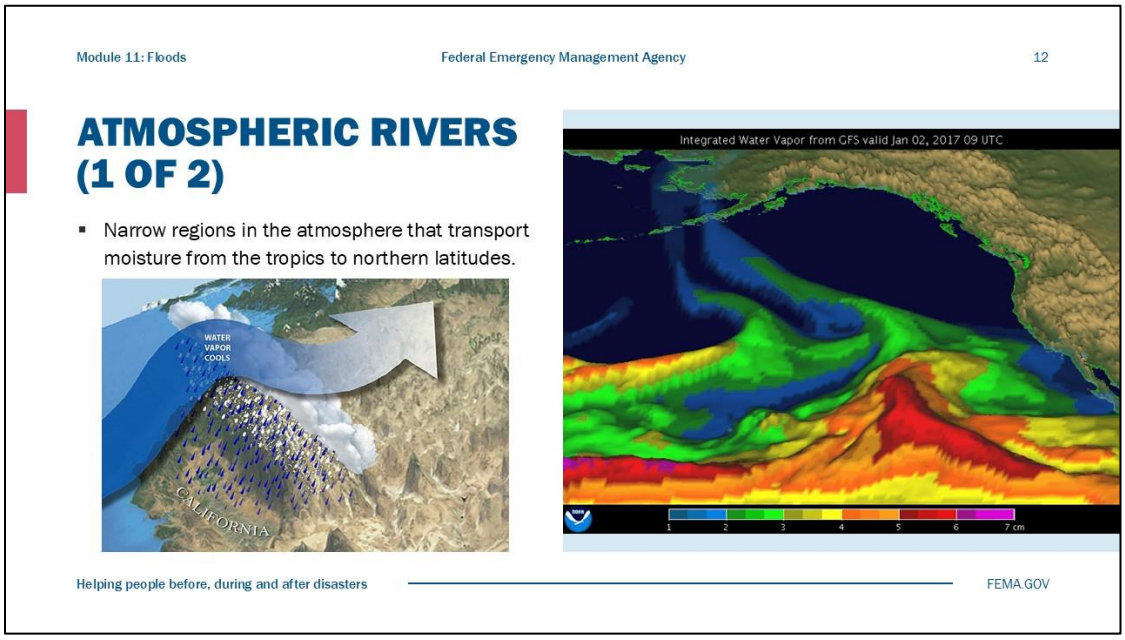
Ice jams occur when warm air and rain break up frozen rivers and streams or whenever there is a rapid cycle of freezing and thawing in the location where the stream is located.

Broken ice floats downstream until it is obstructed by any feature, including bridges, tunnels, or shallow areas. The resulting jam is similar to a dam that floods adjacent land upstream. Ice jams present three types of hazards:

- Flooding upstream lands;
- Movement of broken ice into structures, trees, and other obstacles downstream; and
- Sudden release of water and ice when the ice jam breaks apart, similar to a failure of a dam.

A **mudflow** is a landslide of saturated soil and debris, usually in hilly or mountainous areas. Mudflow hazards are compounded by the weight and volume of saturated debris that is released into structures and people in the path of the flow.

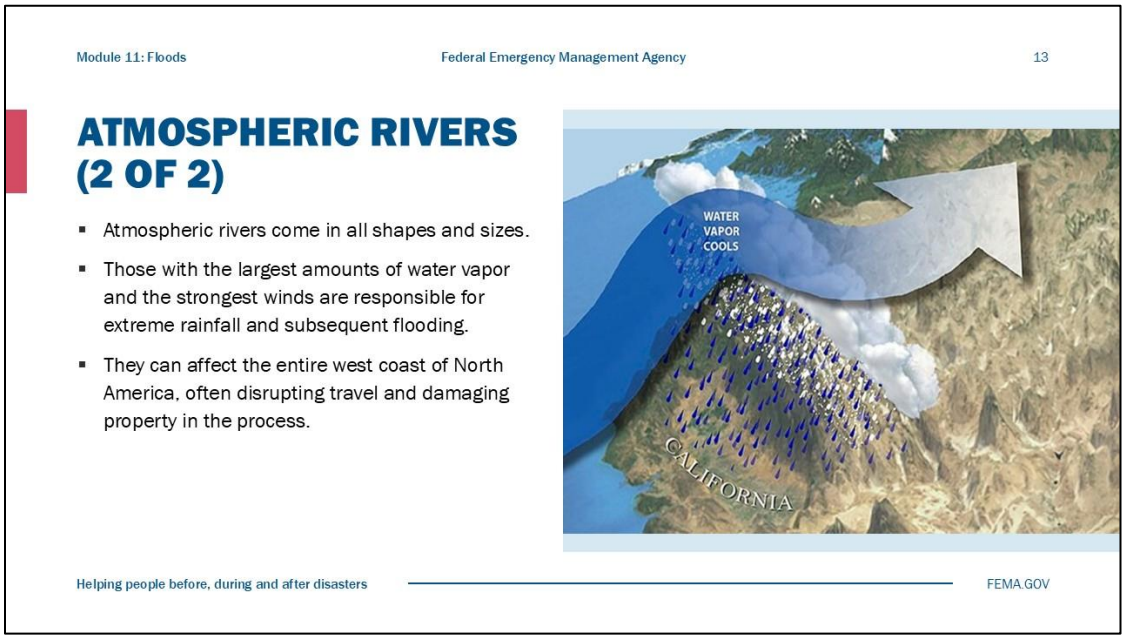
Flood Types (5 of 7)



Slide 11-12, Atmospheric Rivers (1 of 2)

Part of the Earth's ocean water cycle and are closely tied to water supply and flood risks. Not all atmospheric rivers are disruptive. Many are weak and provide beneficial rain or high-elevation snow that provide crucial inputs to the water supplies of western communities.

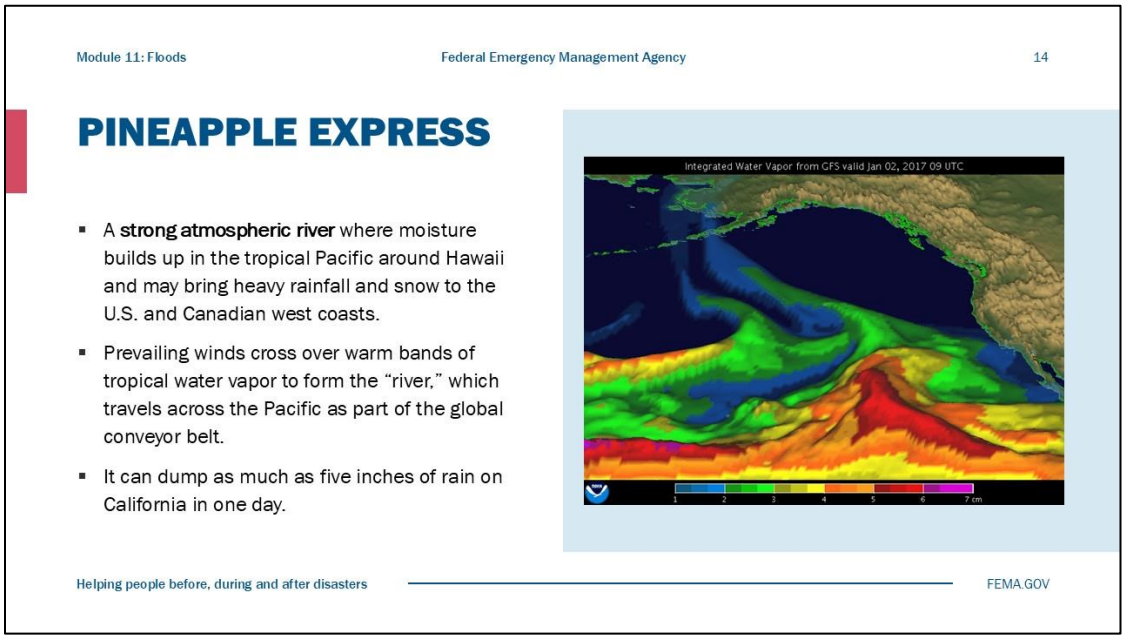
Flood Types (6 of 7)



Slide 11-13, Atmospheric Rivers (2 of 2)

- Atmospheric rivers come in all shapes and sizes.
- Those with the largest amounts of water vapor and the strongest winds are responsible for extreme rainfall and subsequent flooding.
- They can affect the entire west coast of North America, often disrupting travel and damaging property in the process.

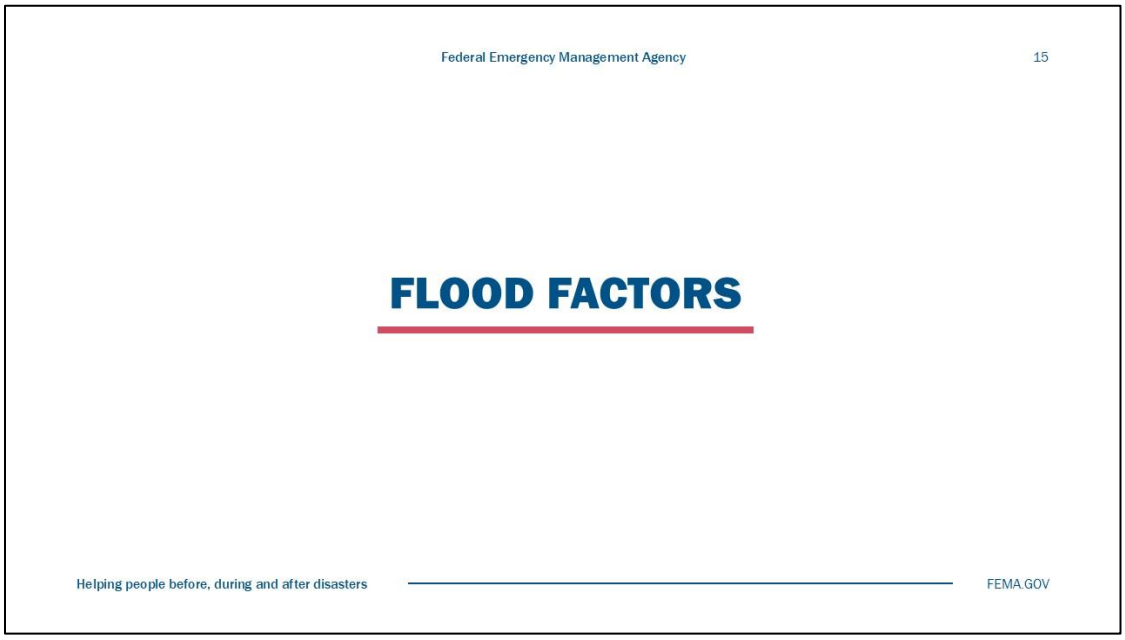
Flood Types (7 of 7)



Slide 11-14, Pineapple Express

- A strong atmospheric river where moisture builds up in the tropical Pacific around Hawaii and may bring heavy rainfall and snow to the U.S. and Canadian west coasts.
- Prevailing winds cross over warm bands of tropical water vapor to form the "river," which travels across the Pacific as part of the global conveyor belt.
- It can dump as much as five inches of rain in California in one day.

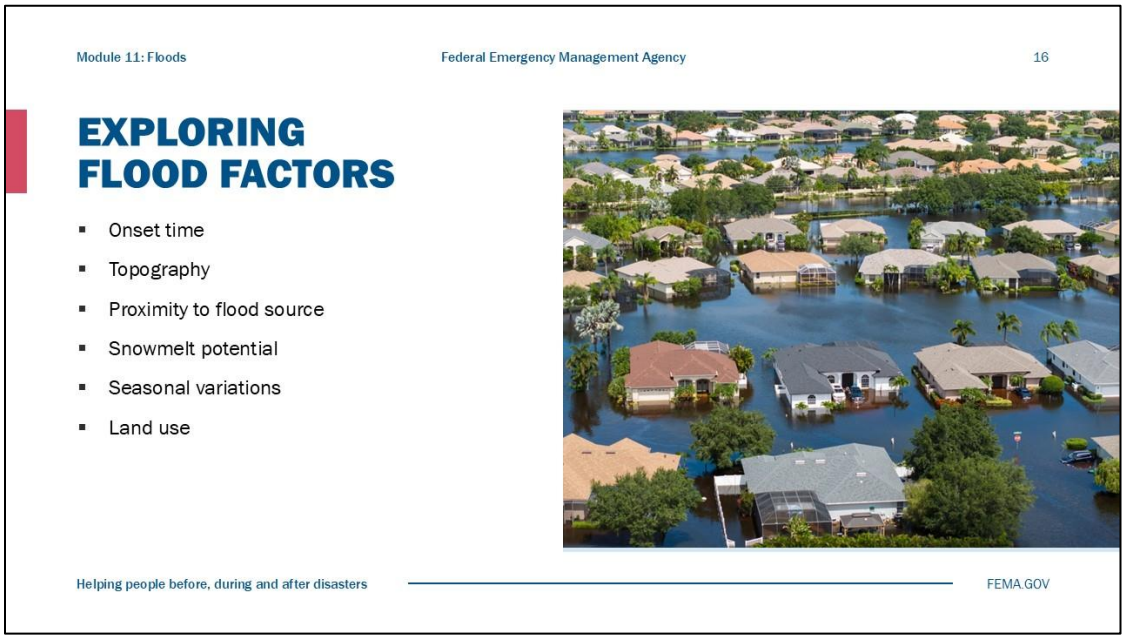
Flood Factors (1 of 8)



Slide 11-15, Flood Factors

Not Applicable.

Flood Factors (2 of 8)



Slide 11-16 Exploring Flood Factors

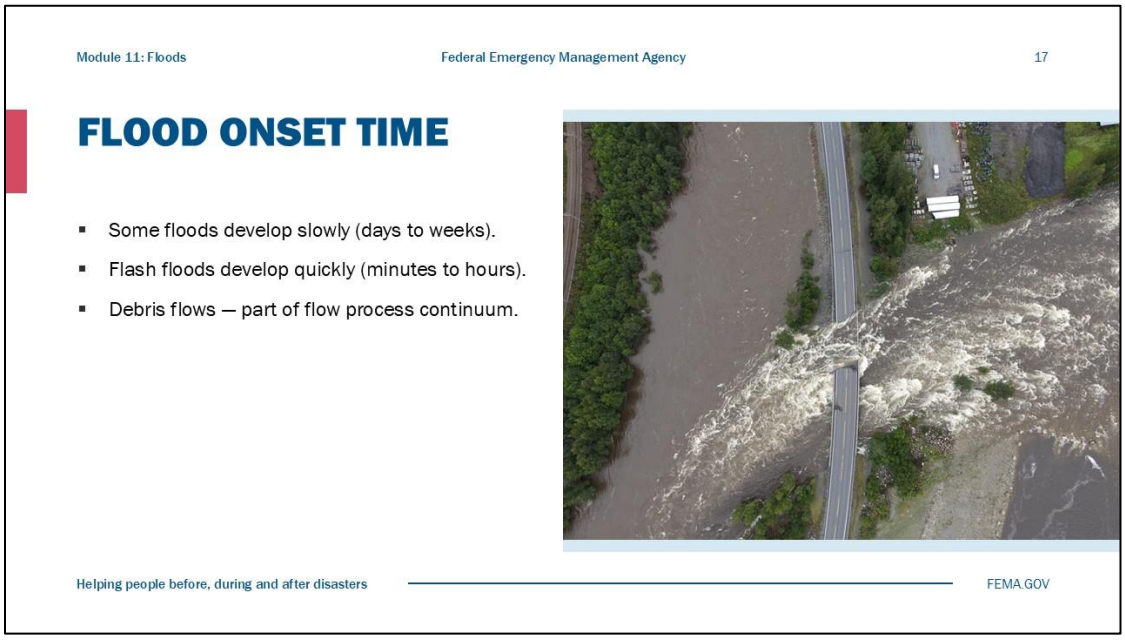
What all floods have in common is the existence of water in some phase (whether solid, liquid, or gas) and the force of gravity acting on the water.

Flood factors are the underlying physical and environmental conditions that determine the severity and extent of flooding in a given area. Understanding these factors helps emergency managers predict and mitigate flood impacts.

Flood factors describe the conditions associated with different types of floods or under which floods will develop. Although there may be many factors involved, the primary ones are:

- Onset time;
- Topography;
- Proximity to flood source;
- Snowmelt potential;
- Seasonal variation; and
- Land use.

Flood Factors (3 of 8)



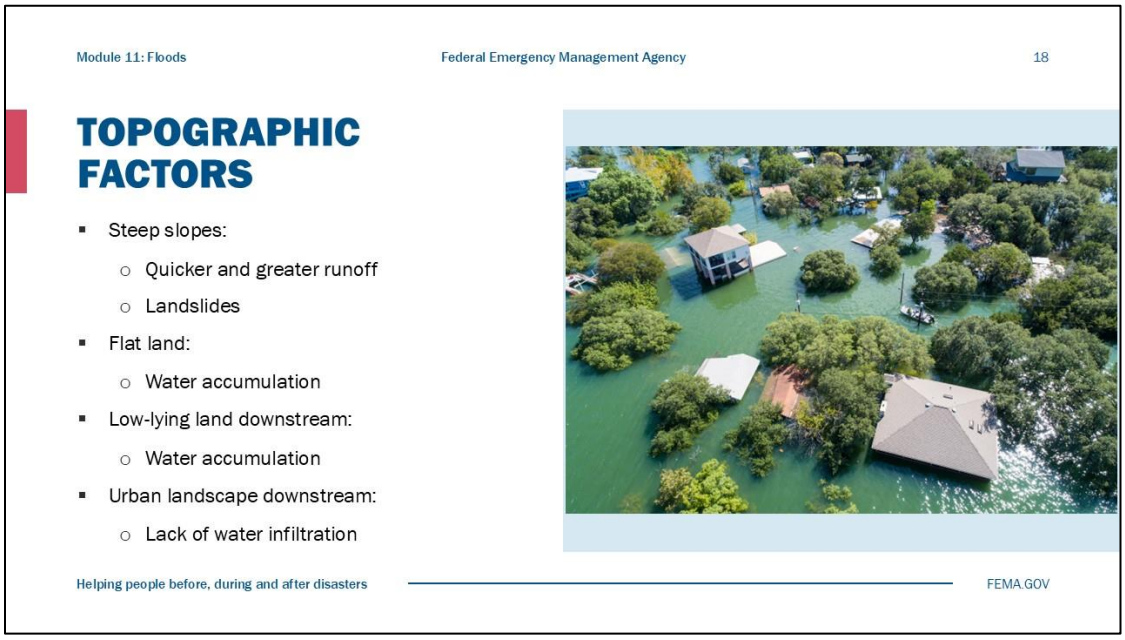
Slide 11-17, Flood Onset Time

Floods can also be classified based on the time it takes for the onset to occur.

Slow developing: Some floods develop slowly, like those on the Mississippi, causing river water to rise about a foot every other day. These floods tend to linger for a long time.

Fast-developing: By contrast, in a rapid-onset flood (or flash flood), the water can rise 2 or 3 feet in 5 minutes.

Flood Factors (4 of 8)

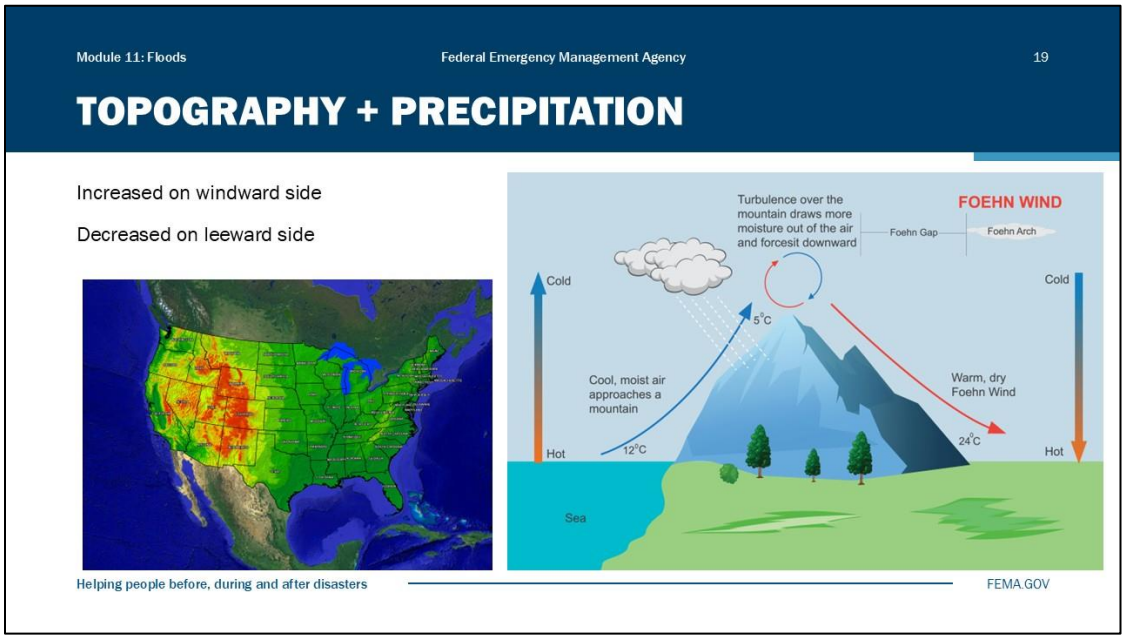


Slide 11-18, Topographic Factors

There are several topographic factors that can contribute to flooding.

- **Steep slopes** may result in quicker and greater runoff or even landslides. Steeper gradients funnel water together to produce more catastrophic floods, for example, in Colorado.
- **Flat land** and low-lying land downstream will facilitate greater water accumulation, for example, the Mississippi River.
- Downstream urban landscapes lack water infiltration.
- In **small river basins** (i.e., the large area of land encompassing the entire river network with the main channel and its tributaries), such as those in mountains, flooding is dominated by precipitation from short-duration, high-intensity, convective thunderstorms.
- In **larger river basins** like the Mississippi, flooding is dominated by longer duration, widespread rainfall from atmospheric systems like hurricanes that dump a lot of rain over a long period of time.

Flood Factors (5 of 8)



Slide 11-19, Topography + Precipitation

Topography + Precipitation Image Descriptions

1. The map on the visual shows the annual mean precipitation throughout the continental United States.
2. A diagram to the left shows three mountains. Starting up the mountain is ascending air, cooling condensation, and precipitation. At the top of the mountain is cloud development. Then, going down the mountain is descending, air warming, and the dissipation of the dying cloud.

The interaction of topography and precipitation is also a major factor in floods. The map shows the annual mean precipitation throughout the continental United States. Two key factors are at play: proximity to a moisture source and orographic lifting.

- **Proximity to moisture source**: The importance of proximity to moisture source is evident in the rapid drop-off of precipitation as you move inland from the Pacific to the Atlantic and the Gulf.

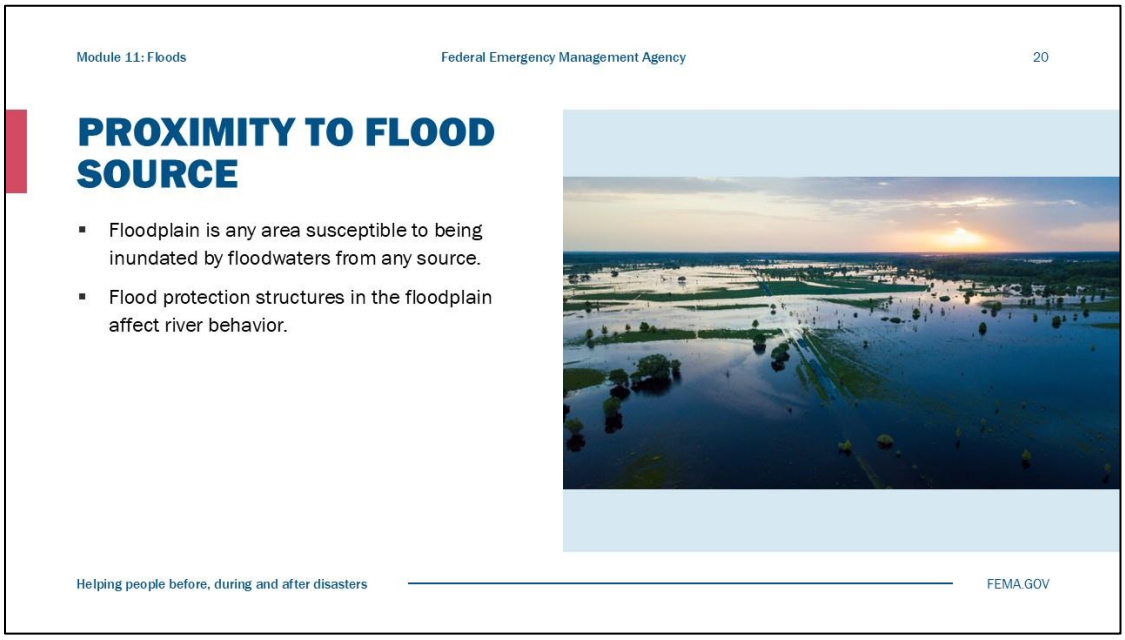
Certainly, proximity to a moisture source is important, and you can see many points north of the Gulf that provide large quantities of moisture. But this factor is not sufficient by itself, because otherwise, there would be more floods in Florida than there are.

- **Orographic lifting:** In addition, the precipitation map shows areas of higher precipitation due to orographic lifting (shown in the left-hand drawing), which is what happens when a mass of air is forced to travel from a lower elevation to a higher elevation over a rising mountain. As masses of air move inland and rise up over the highlands, the air cools. If it cools to its saturation point, the water vapor condenses and a cloud forms.

On the windward side of the mountains (the side that is reached first), there is a lot of rain. On the leeward side (downwind), there is substantially less.

All of the major mountain ranges in the United States have "rain shadows"–more arid areas on the lee side.

Flood Factors (6 of 8)



Slide 11-20, Proximity to Flood Source

Proximity to the flood source is another important factor.

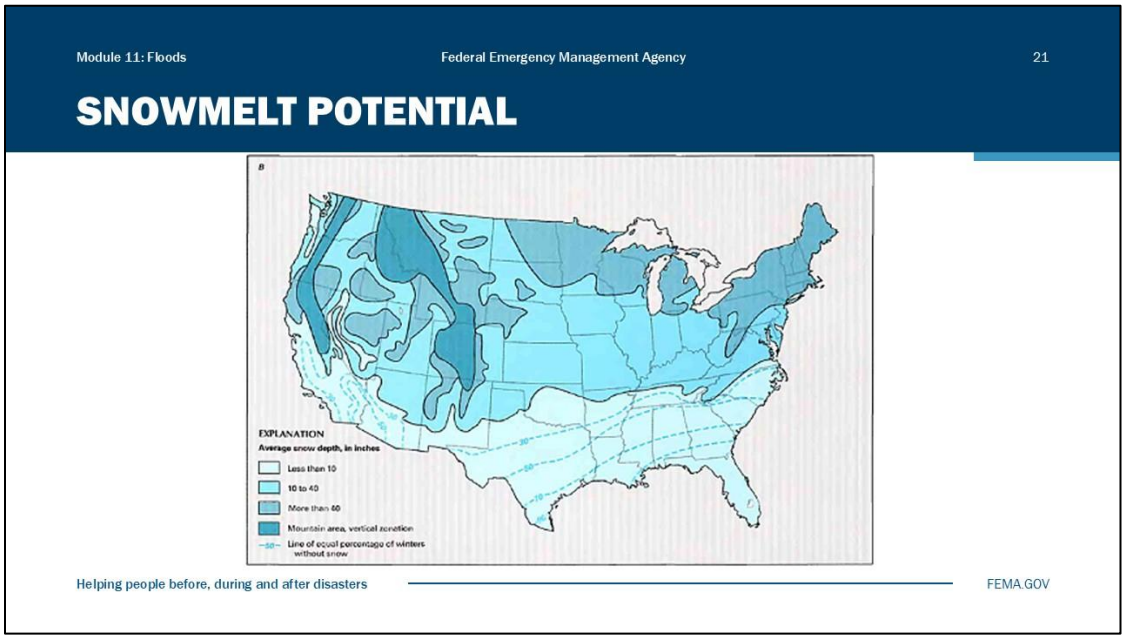
Floodplain: According to the National Flood Insurance Program (NFIP), a floodplain is defined as "any land area susceptible to being inundated by floodwaters from any source." During floods, water that normally flows downstream overflows beyond the channel onto the floodplain.

As is true with other hazards, humans' choices and actions determine whether the natural phenomenon of floods will become a disaster. There are 3,800 communities in the United States (with at least 2,500 inhabitants) located in floodplains.

Flood protection measures: Development in floodplains is sometimes followed by the creation of flood protection measures, such as levees or floodwalls. Flood protection structures alter river behavior by:

- Affecting natural deposition process;
- Affecting river cresting/water level; and
- Affecting stream path.

Flood Factors (7 of 8)



Slide 11-21, Snowmelt Potential

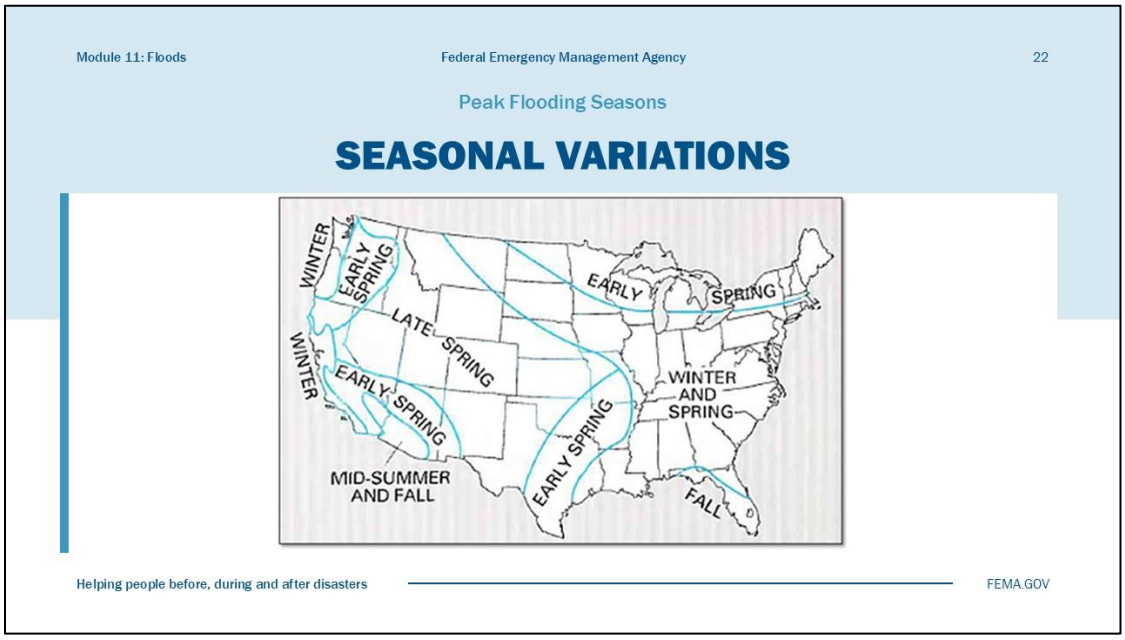
Another contributor to flooding is snowmelt.

Snow stores a lot of moisture, and its moisture content generally varies with geographical location and time of year.

For example, 10 inches of soft, "powdery" snow in the Rocky Mountains may have different moisture content than 10 inches in the more humid Appalachian Mountains. Likewise, late spring snowfalls may have greater moisture content than winter snowfalls. The rate at which snow melts and releases its moisture content can have a significant impact on flooding.

This map shows the snow melt potential, based on average snowfall. The darker the color, the thicker the average snow depth, and thus the greater the possible contribution of snow melt to flooding.

Flood Factors (8 of 8)



Slide 11-22, Seasonal Variations

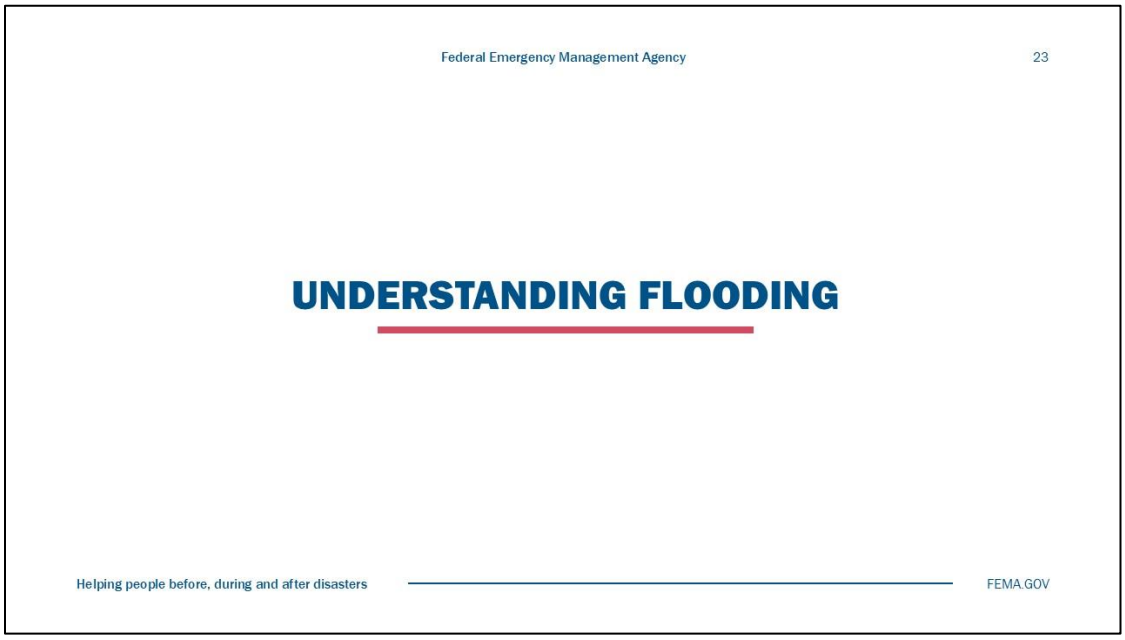
Seasonal Variations Image Description

A map of the U.S. showing peak flooding seasons. For the eastern states, the peak flooding is in Winter and Spring. The Northeastern and Northern states, from Maine through North Dakota, experience floods in early Spring. Florida floods in the fall. The central states flood in late Spring, with early spring to the right of Texas, Arkansas, and Missouri. Coastal Western states flood in Winter, with mid-Washington and Oregon flooding in early Spring, and California through Arizona flood in early Spring. Arizona and California bordering Mexico experience floods in mid-summer and fall.

The season of the year is another factor that affects flooding; however, typical seasons for the largest annual flood vary by area, as illustrated by this map.

The variation depends on seasonal rainfall patterns and the time it takes snowmelt to reach the region's rivers.

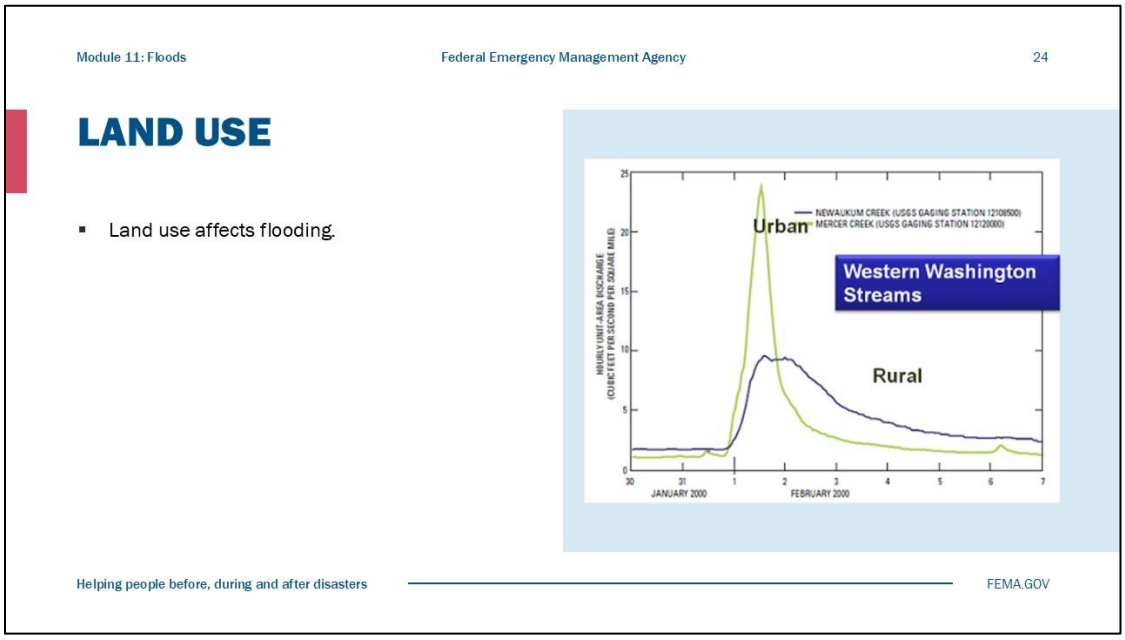
Understanding Flooding (1 of 3)



Slide 11-23, Understanding Flooding

Not Applicable.

Understanding Flooding (2 of 3)



Slide 11-24, Land Use

Land use affects flooding, especially in terms of the extent of rural use vs. urban use.

Rural land use: In rural areas, there is more opportunity for moisture to move into the ground.

Urban use: In urban areas, pavement keeps water above ground. In addition, efforts to control water flow, as it moves from roofs to gutters to streets to drains, deliver more water into rivers more quickly, causing a rapid rise in flood level.

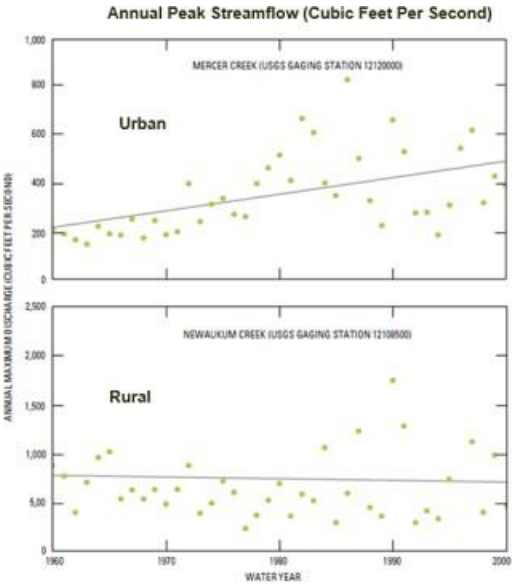
This visual shows two **hydrographs,** from urban and rural gauges in Washington State, which depict the height of water over time. The tendency for the urban site to show a strong, early pulse of flooding compared to the rural site is a commonly noted difference between urban and rural sites.

Increase in peak flows over time: Another trend related to urban sites is an increase in peak flows over time. The graph on the next page compares peak flows at the same sites shown in the hydrograph.

As an Emergency Manager, you need more advanced training about floods, specifically mitigation. Consider the following courses:

- NDEMU Course: IS-273: How to Read a Flood Insurance Rate Map (FIRM)
- NDEMU Course: IS-393.B: Introduction to Hazard Mitigation
- NDEMU Course: IS-1105.A: EC Made Easy: Elevation Certificate Overview

- Association of State Floodplain Managers Online Training (https://www.floods.org/training-center/online-training/)



Annual Peak Streamflow (Cubic Feet Per Second)

The dots represent the highest flow level for each year. The rural site shows very little change over the decades. The impact of urbanization at the other site (the top graph) is visible in the general rise in maximum water level as the years advance.

Additional Resources:

- FEMA Floodplain Management (https://www.fema.gov/floodplain-management)
- US Army Corps of Engineers Flood Risk Management Program and Silver Jackets Teams (https://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/)

Understanding Flooding (3 of 3)

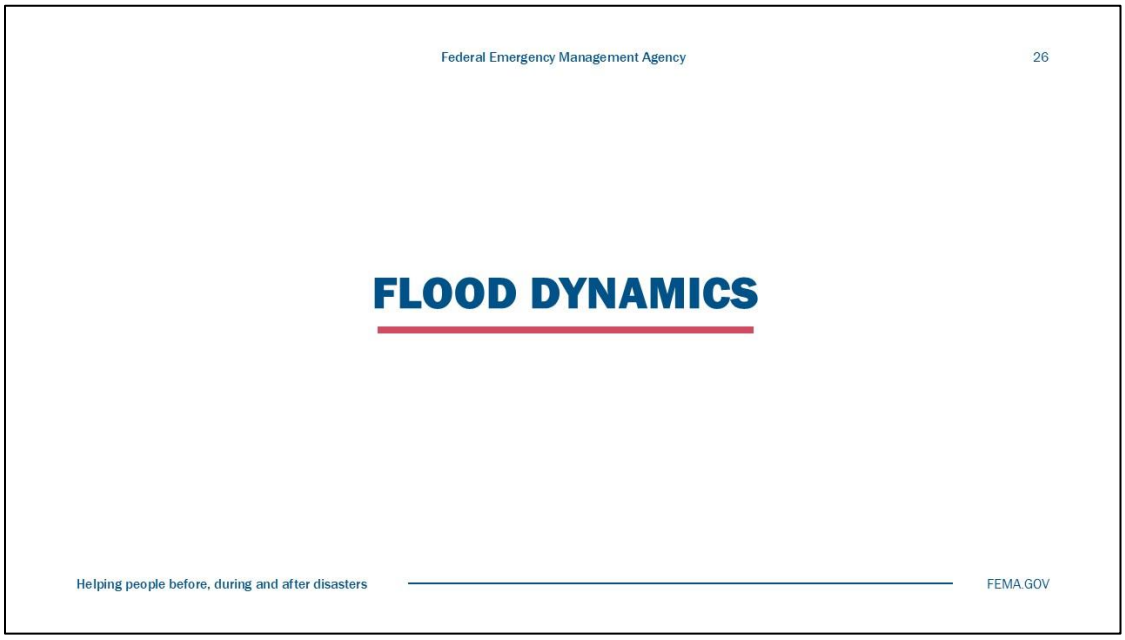


Slide 11-25, Urban Development

During Hurricane Sandy in 2012, areas of dense urban development in New York and New Jersey experienced severe flooding of underground subway systems, as floodwaters sought the lowest level.

Clean-up and recovery efforts required sophisticated pumping equipment to remove huge volumes of water that natural drainage could not handle.

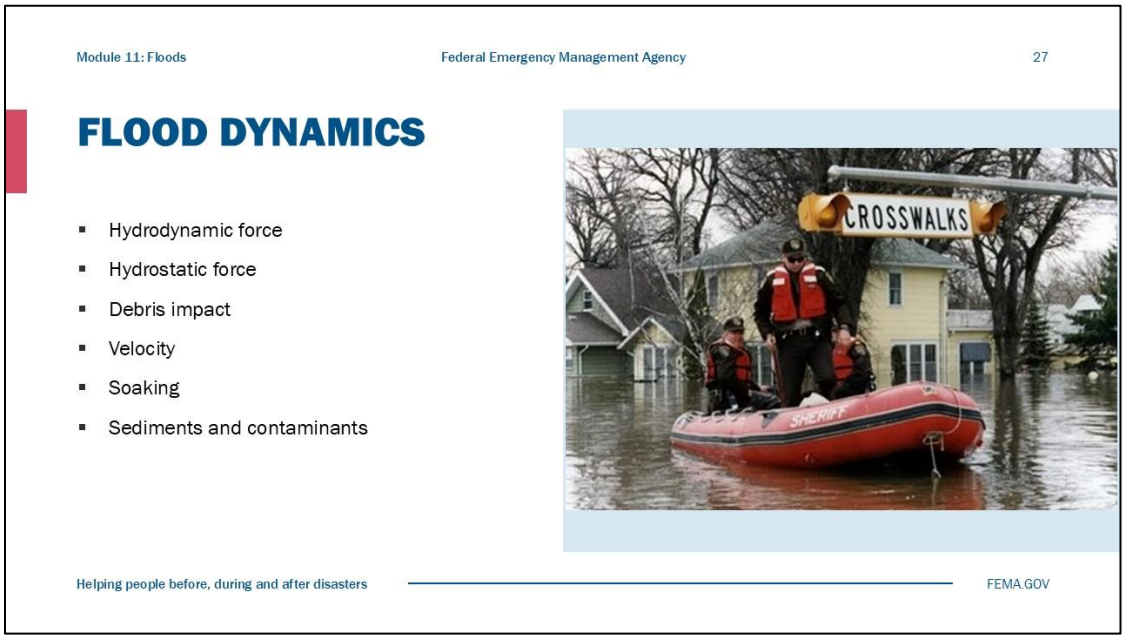
Flood Dynamics (1 of 8)



Slide 11-26, Flood Dynamics

Not Applicable.

Flood Dynamics (2 of 8)



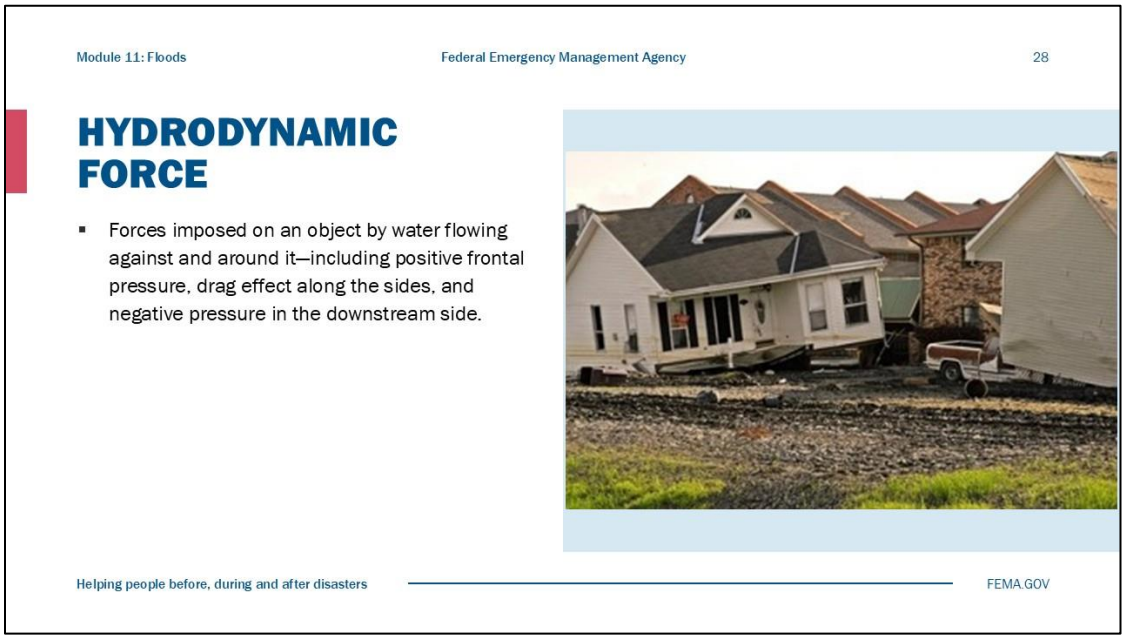
Slide 11-27, Flood Dynamics

Another way of characterizing floods is by the dynamic qualities or forces associated with them.

Flood dynamics describe the damage and injury to structures, people, and the surroundings caused by floodwater in various stages of formation. The main dynamic forces are:

- Hydrodynamic force
- Hydrostatic force
- Debris impact
- Velocity
- Soaking
- Sediments and contaminants

Flood Dynamics (3 of 8)



Slide 11-28, Hydrodynamic Force

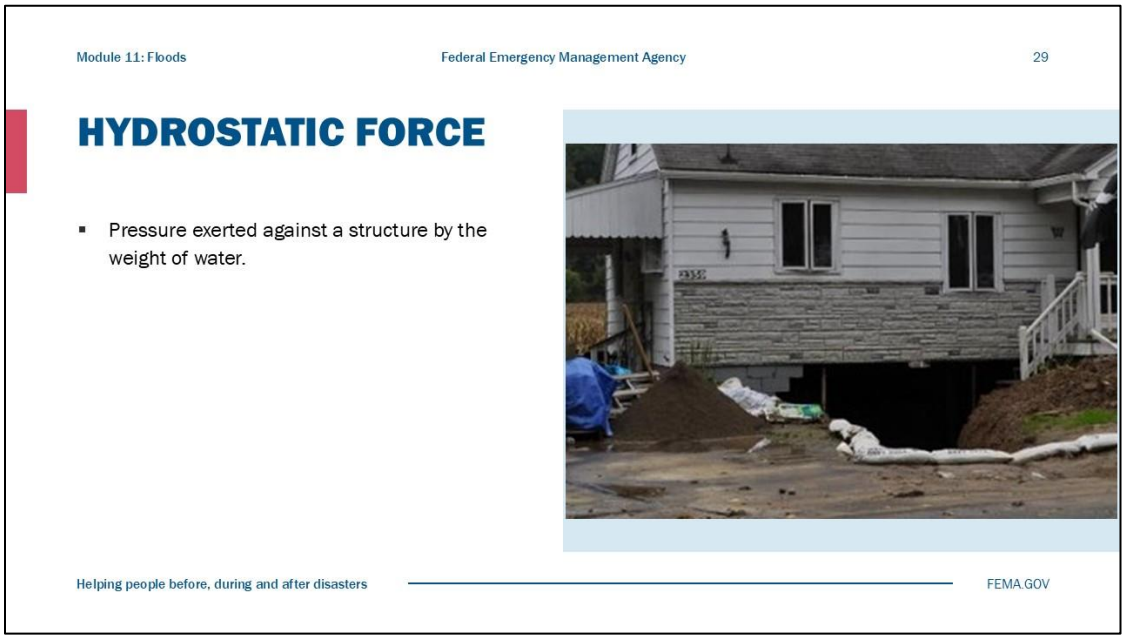
The NFIP describes hydrodynamic forces as:

". . . forces imposed on an object, such as a building, by water flowing against and around it. Among the forces are positive frontal pressure against the structure, drag effect along the sides, and negative pressure in the downstream side. Hydrodynamic forces are one of the main causes of flood damage."

The visual shows the effects of hydrodynamic force on a house. In this case, frontal impact resulted from floodwaters striking the structure.

Additional hydrodynamic forces involve a "drag effect" as water runs along the sides of a structure, and "eddies or negative pressures" as water passes the downstream side of the structure.

Flood Dynamics (4 of 8)



Slide 11-29, Hydrostatic Force

Hydrostatic force involves the pressure exerted against a submerged structure by the pressure of water. This type of pressure is especially damaging to the walls of structures, and studies have shown that 3 feet of standing water can be sufficient to collapse the walls of a frame house.

Basement walls are especially susceptible to hydrostatic force. In this visual, part of the basement wall has collapsed because of the hydrostatic force exerted on it.

Flood Dynamics (5 of 8)



Slide 11-30, Debris Impact

Another dynamic force is debris impact. Floodwaters are powerful and will pick up and move almost anything in their path. Vehicles, lawn furniture, propane tanks, vegetation, and even rocks and boulders can be moved by floodwater. Such flood debris can cause extensive damage when striking buildings, bridges, or other structures in the flood path.

Flood Dynamics (6 of 8)



Slide 11-31, Velocity

Velocity is the speed at which floodwater travels, and it is measured in feet per second. Floodwaters moving faster than five feet per second are considered high-velocity floods.

Even shallow floodwater can knock a person down, and it is estimated that water 3 feet deep moving at 3 feet per second is sufficient to do so.

A car will float in only 2 feet of moving water.

These potential impacts of velocity on people and automobiles make it extremely hazardous to wade or drive into floodwater.

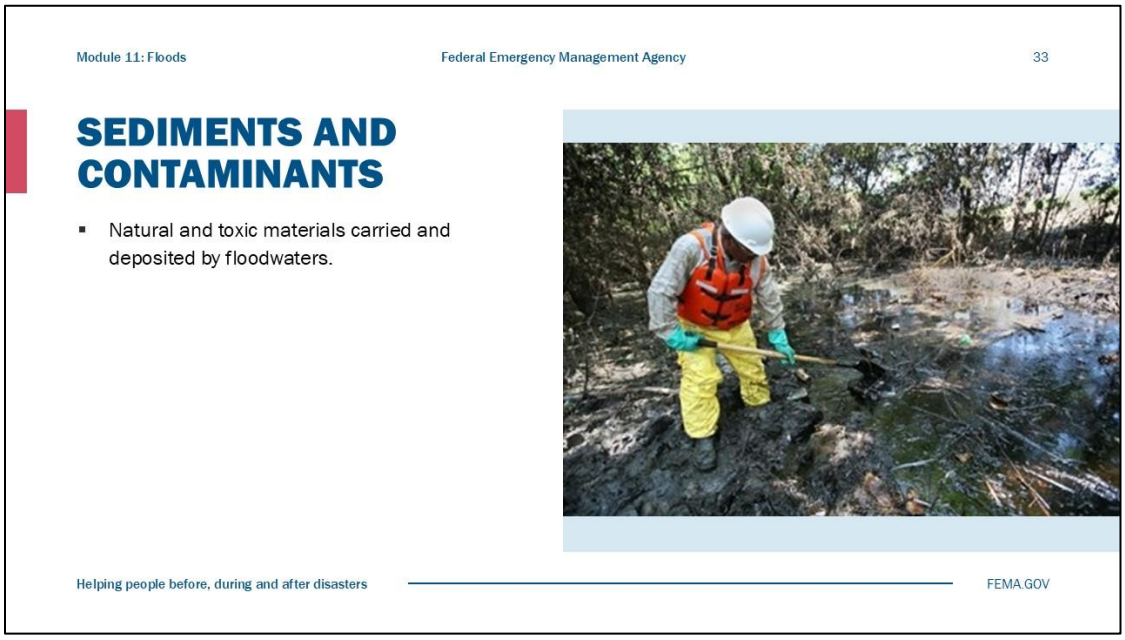
Flood Dynamics (7 of 8)



Slide 11-32, Soaking

Soaking is a major cause of flood damage. Standing floodwaters, especially those standing over a long period of time, will weaken or destroy the structural components of buildings and ruin furnishings. In addition to causing structural damage, soaking also presents health hazards for building occupants.

Flood Dynamics (8 of 8)



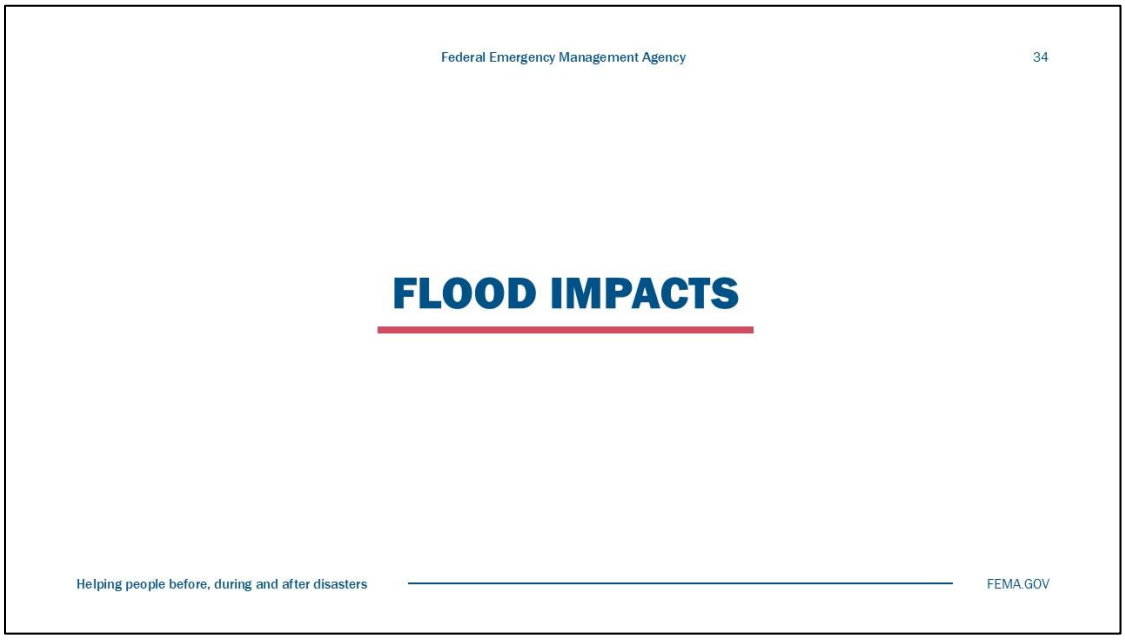
Slide 11-33, Sediments and Contaminants

The final dynamic force involved in floods is sediments and contaminants. Floodwaters carry many types of sediments, including sand and debris. These sediments permeate structures and the surroundings and are difficult, if not impossible, to remove.

Contaminants include any substance that is harmful to living organisms, including chemicals, sewage, and other toxic materials.

Next, we will look at some health hazards associated with contaminants and other flood hazards.

Flood Impacts (1 of 2)



Slide 11-34, Flood Impacts

Not Applicable.

Flood Impacts (2 of 2)



Slide 11-35, Discussion: Health Impacts

How can flooding impact health?

Activity

Regardless of the causative factors or the predictability of a flood, certain hazards are associated with flooding.

Many different environmental contaminants can be produced as a result of exposure to metal, mineral, organic contaminants, and pathogens (some of which are antibiotic-resistant). This exposure can result from:

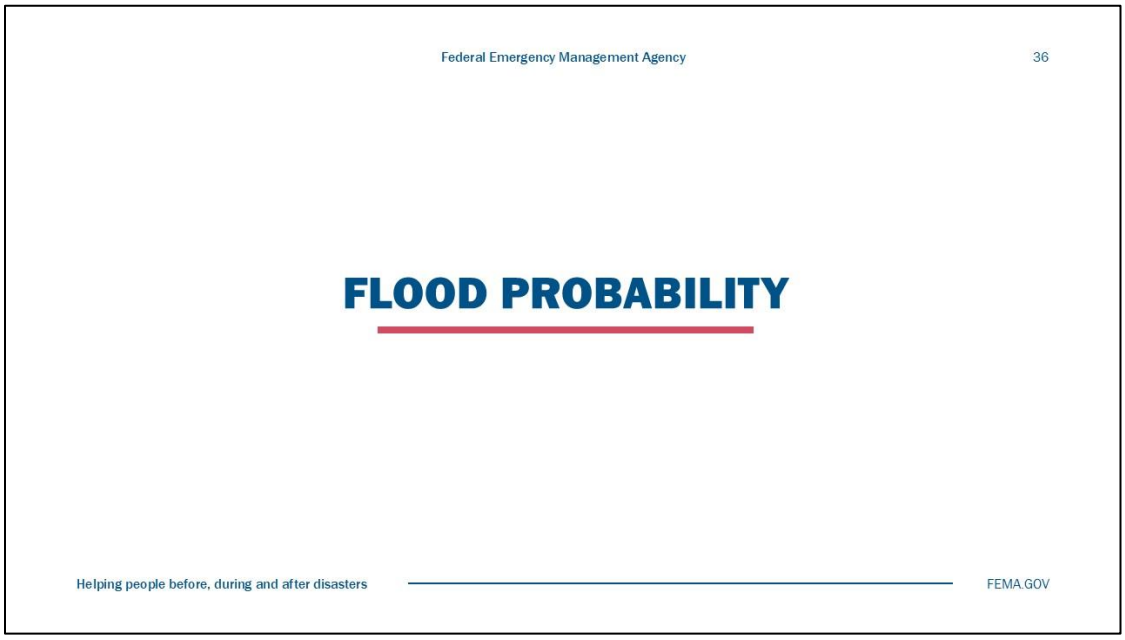
- Flooding of or damage to:
  - Wastewater treatment plants
  - Animal feeding operations
  - Industrial facilities
  - Petroleum refineries
  - Chemical plants

  - Residential neighborhoods
  - Urban areas
  - Mines or mineral-processing facilities
- Erosion and redistribution of:
  - Agricultural fields
  - Contaminated soils or sediments
  - Natural occurrences of asbestos, or unmined mineralized rocks
  - Accumulation of contaminated flood sediments
- Exposure to post-flood mold in flooded buildings (e.g., for people returning to and cleaning up their flooded homes)

A variety of infectious diseases have occurred following floods. The pathogens that cause disease may be borne by water, soil, dust, or food. However, these outbreaks are much more prevalent in developing countries. Diseases may result from:

- Exposure to contaminated floodwaters (e.g., gastroenteritis, cholera, E. coli infections, skin infections).
- Consumption of contaminated drinking water.
- Exposure to dust from storm-caused landslides or dried flood deposits containing soil pathogens (e.g., Valley Fever in humans, anthrax in livestock).
- Exposure to infected organisms (e.g., malaria, West Nile virus, dengue fever, and other vector-borne diseases).
- Exposure to waters contaminated with rodent urine (e.g., Leptospirosis).

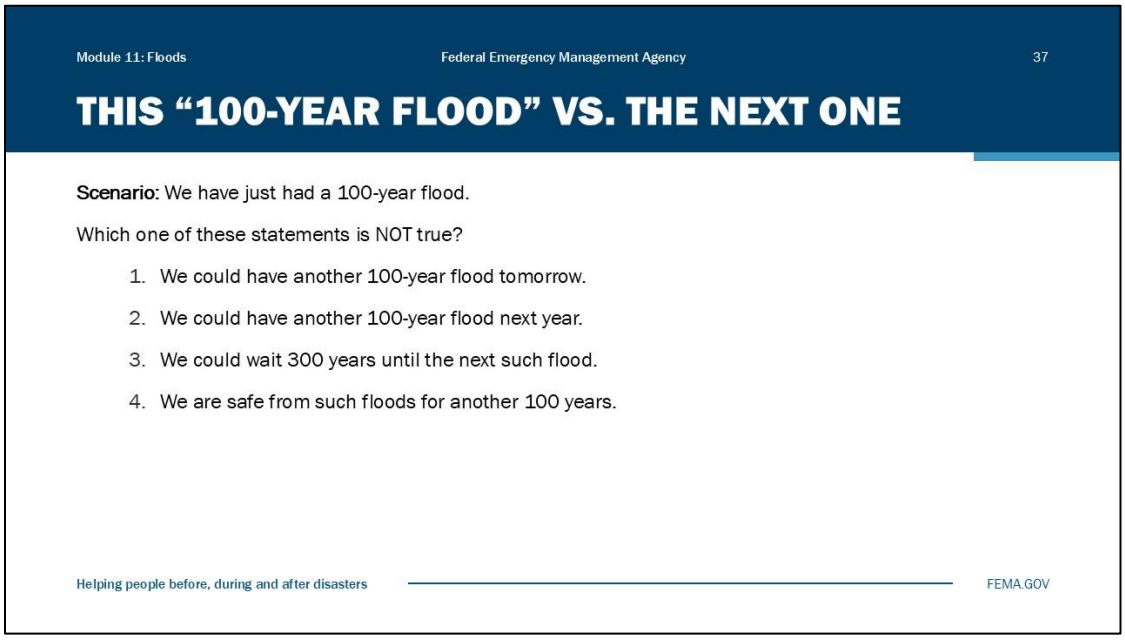
Flood Probability (1 of 6)



Slide 11-36, Flood Probability

Not Applicable.

Flood Probability (2 of 6)

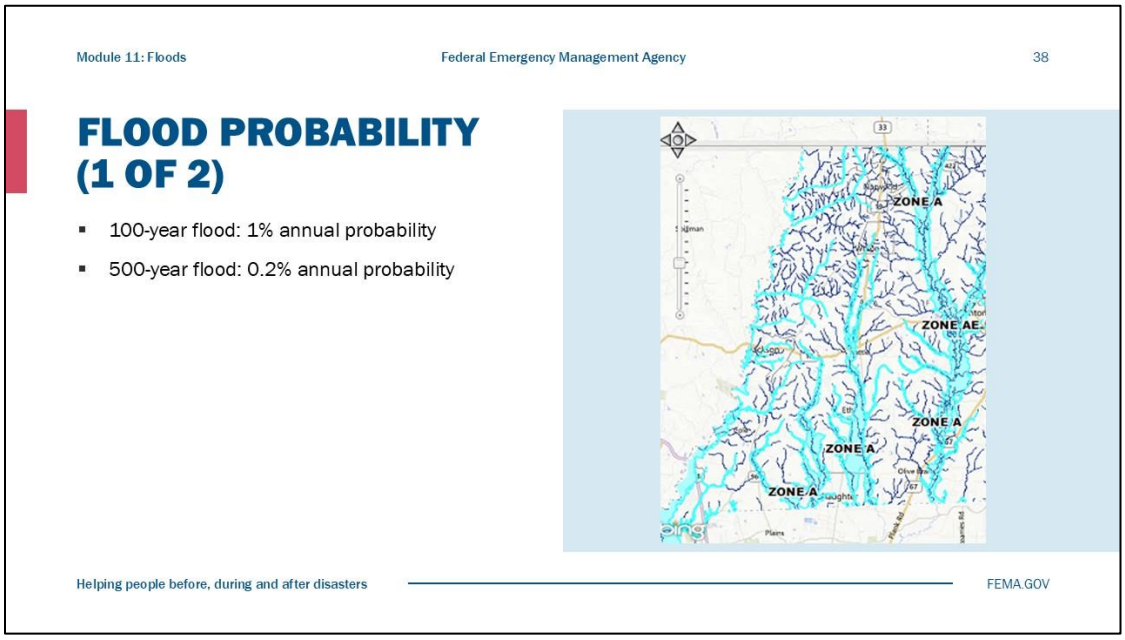


Slide 11-37, This "100-Year Flood" vs. the Next One

Scenario: We have just had a 100-year flood. Which one of these statements is **NOT** true?

1. We could have another 100-year flood tomorrow.
2. We could have another 100-year flood next year.
3. We could have another 300 years until the next such flood.
4. We will be safe from such floods for another 100 years.

Flood Probability (3 of 6)



Slide 11-38, Flood Probability (1 of 2)

All of the factors we have discussed relate to the probability of flooding in any given area. What do we know about flood probability?

As scientists study river systems over time, patterns emerge:

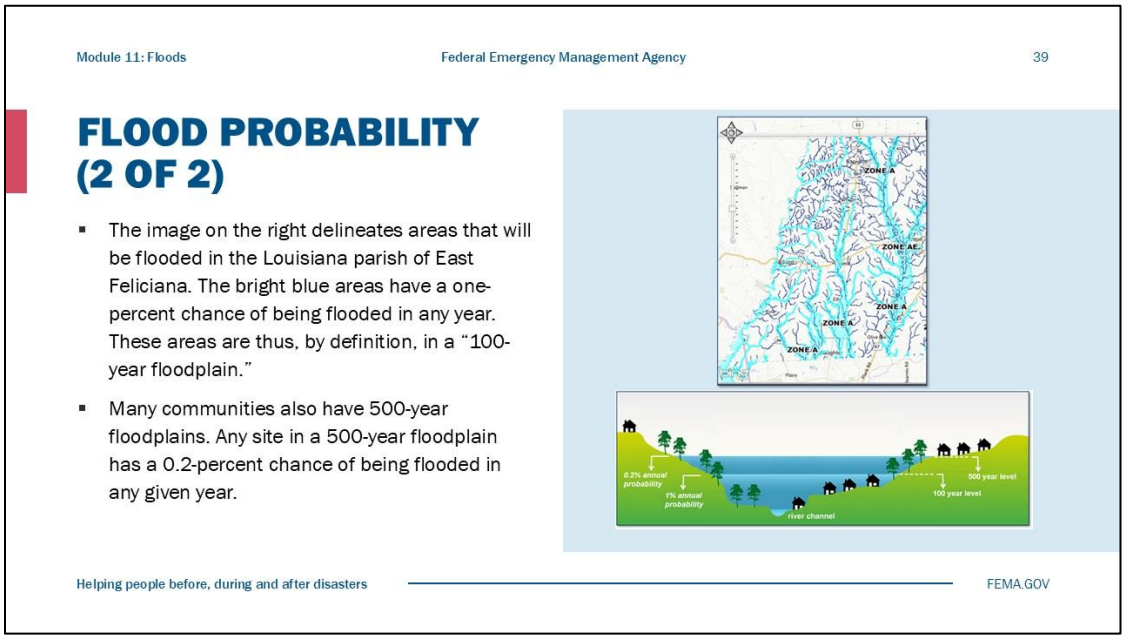
- Areas that have flooded before will often flood again;
- Some areas will flood in garden-variety storms that occur frequently; and
- Other areas will flood much more rarely and only in larger storms.

Such patterns give rise to efforts to quantify the chance that a particular area will flood in a certain time span, and that in turn requires a statement of probability.

The image on this visual delineates areas that will be flooded in the Louisiana parish of East Feliciana. The bright blue areas have a 1 percent chance of being flooded in any year. These areas are thus, by definition, in a "**100-year floodplain**."

Many communities also have **500-year floodplains**. Any site in a 500-year floodplain has a 0.2-percent chance of being flooded in any given year.

Flood Probability (4 of 6)



Slide 11-39, Flood Probability (2 of 2)

The 100-year flood probability is the national standard adopted by the National Flood Insurance Program and used by all Federal agencies.

A 100-year flood is a flood that has a one percent chance of occurring in any given year.

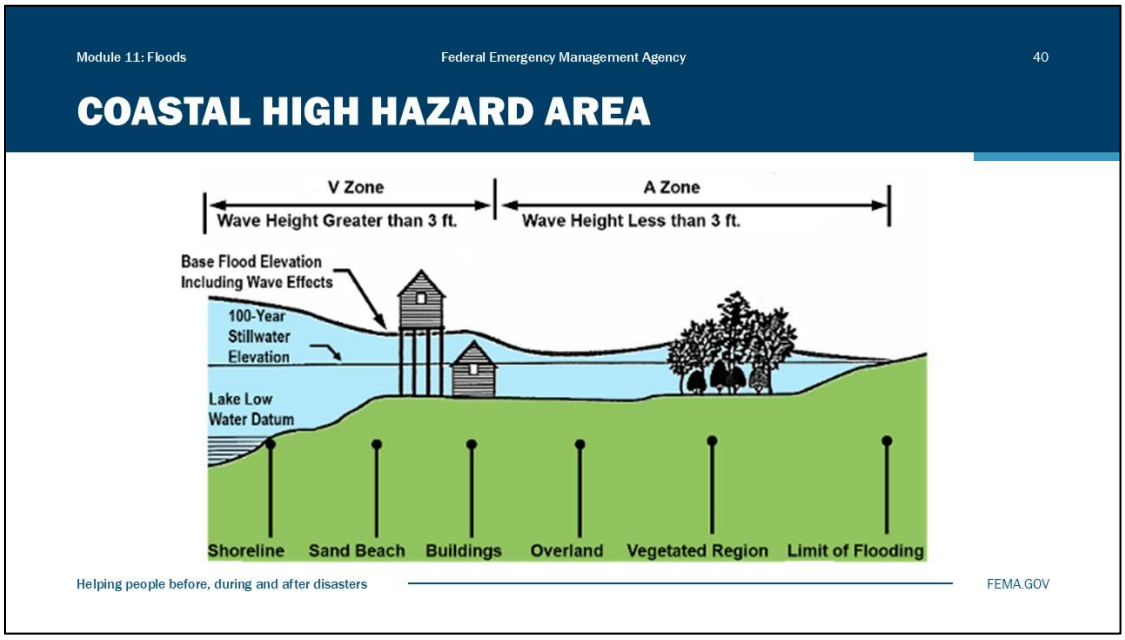
The graphic illustrates the difference between a 100-year floodplain and a 500-year floodplain, and the relative percentage of probability.

Flood Probabilities

The image on the right delineates areas that will be flooded in the Louisiana parish of East Feliciana. The bright blue areas have a one percent chance of being flooded in any year. These areas are thus, by definition, in a "100-year floodplain."

Many communities also have 500-year floodplains. Any site in a 500-year floodplain has a 0.2-percent chance of being flooded in any given year.

Flood Probability (5 of 6)



Slide 11-40, Coastal High Hazard Area

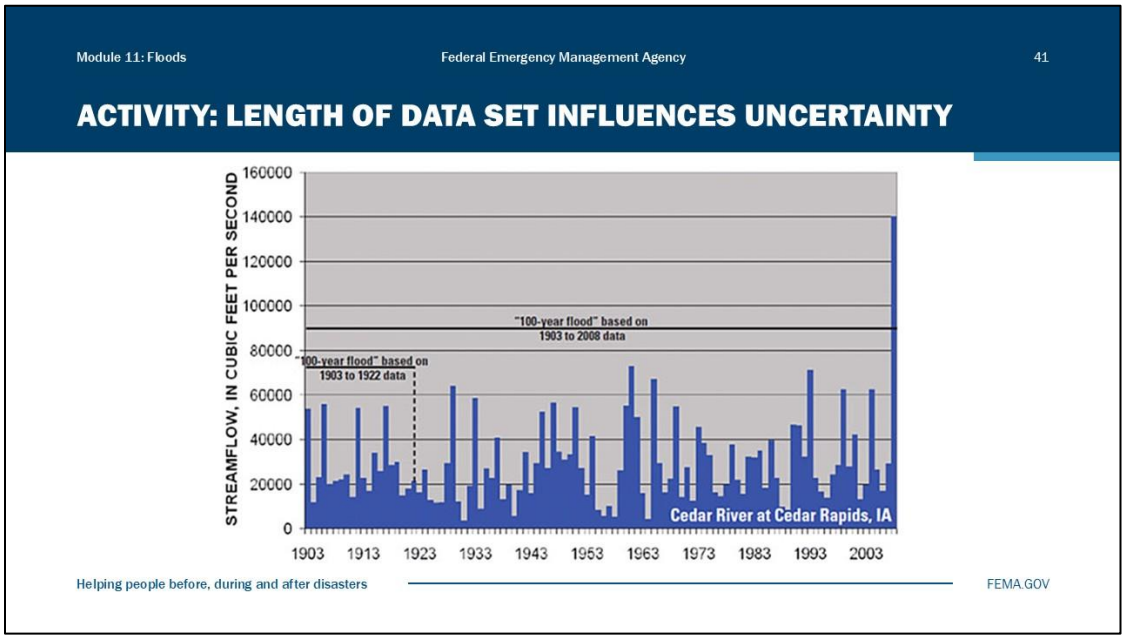
Coastal High Hazard Area Image Description

The Coastal High Hazard Area that extends from offshore to the inland limit of a primary frontal dune along an open coast, plus any other areas subject to high-velocity wave action, is designated a Velocity Zone (V Zone). A diagram illustrating the V Zone (Wave height greater than 3 ft) and the A Zone (Wave height less than 3 ft).

Hydrologists have identified a different flood hazard area for coastal regions. The Coastal High Hazard Area that extends from offshore to the inland limit of a primary frontal dune along an open coast, plus any other areas subject to high-velocity wave action, is designated a Velocity Zone (V Zone).

Flooding associated with astronomical tides, storm surges, seiches, or tsunamis may affect the flood hazard area landward of the V Zone.

Flood Probability (6 of 6)

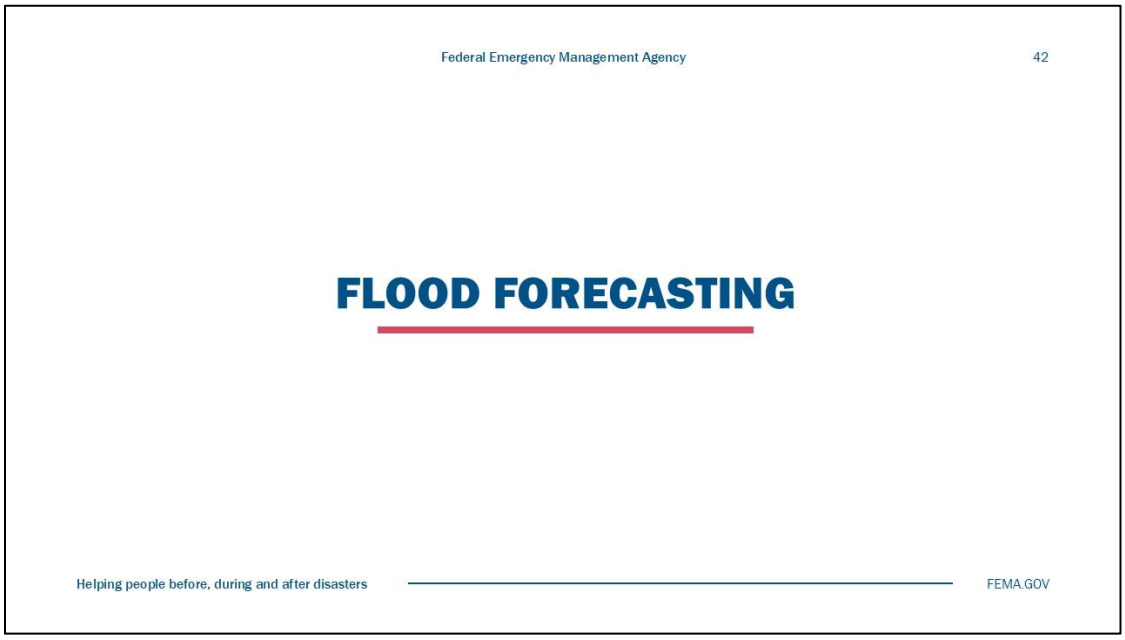


Slide 11-41, Activity: Length of Data Set Influences Uncertainty

It is also important to note that the longer the record of data, the better the chances are that scientists will successfully interpret patterns. This graph of streamflow data from Cedar Rapids, Iowa, shows the highest flood levels from 1903 to 2011. (The blue line at the far right of the graph is the 2011 flood level.)

Discussion Question: Look at the data set from 1963–1983. How high would you build a levee to protect against a 100-year flood? Now, look at the data set from 1963–2011. How does that change your 100-year flood level?

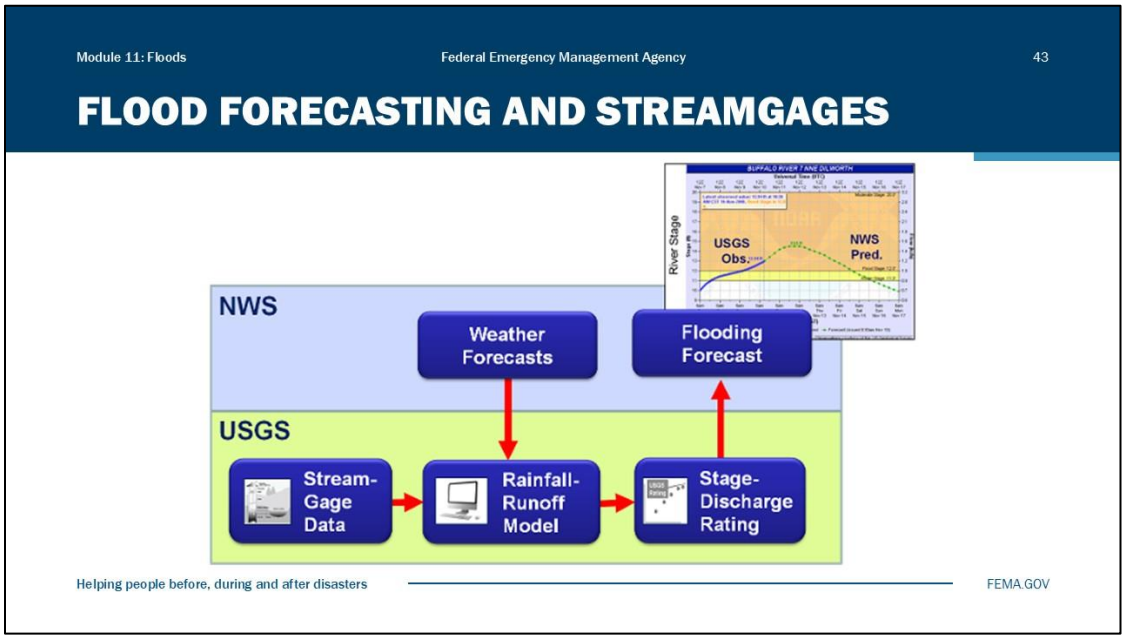
Flood Forecasting (1 of 5)



Slide 11-42, Flood Forecasting

Not Applicable.

Flood Forecasting (2 of 5)



Slide 11-43, Flood Forecasting and Streamgages

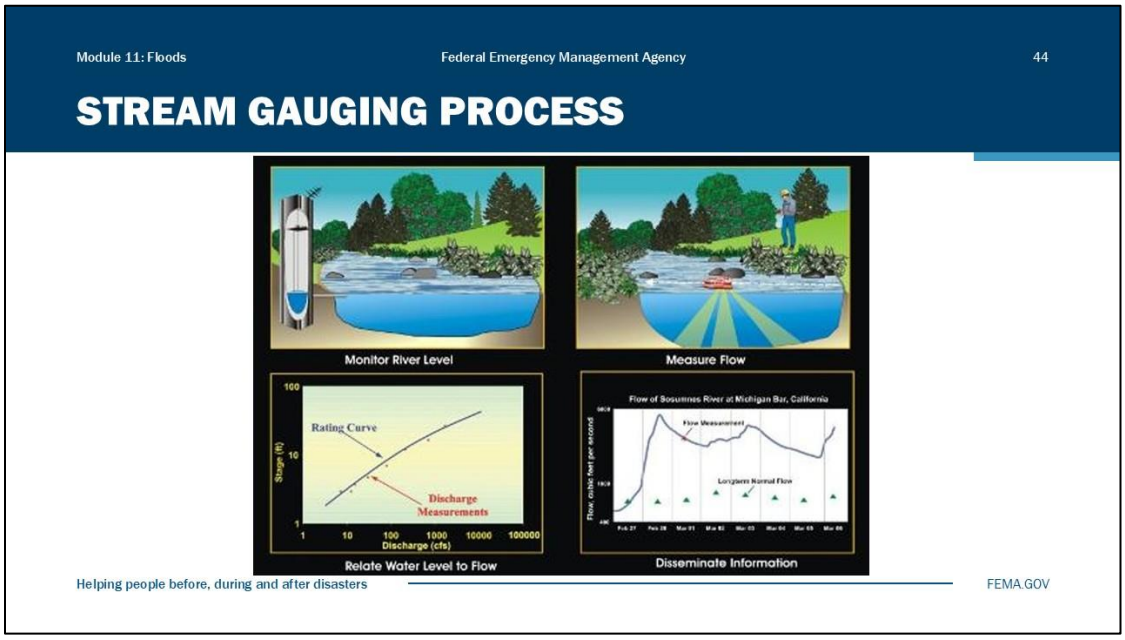
Given the hazards associated with flooding, emergency managers need reliable flood forecast information to prepare for flood emergencies. What kinds of forecast information are available?

Flood forecasting: For rivers around the country, flood forecasts are available that show where and when the river is going to **crest** (reach its highest level). Forecasts can be made 4 to 5 days in advance of the event and can be crucial in decisions such as evacuation and emergency levee building. The National Weather Service (NWS) and U.S. Geological Survey (USGS) partner to make and improve flood forecasts.

Streamgages: Forecasts are based in part on data from stream gages, along with NWS rainfall predictions. Streamgages are devices located beside a river that measure and record the water level. They reveal what is actually happening on the river and are essential to calibrating flood models and making more accurate forecasts of flood parameters.

USGS operates more than 7,800 streamgages around the Nation.

Flood Forecasting (3 of 5)



Slide 11-44, Stream Gauging Process

Stream gauging is based on two key factors-water elevation and volumetric streamflow.

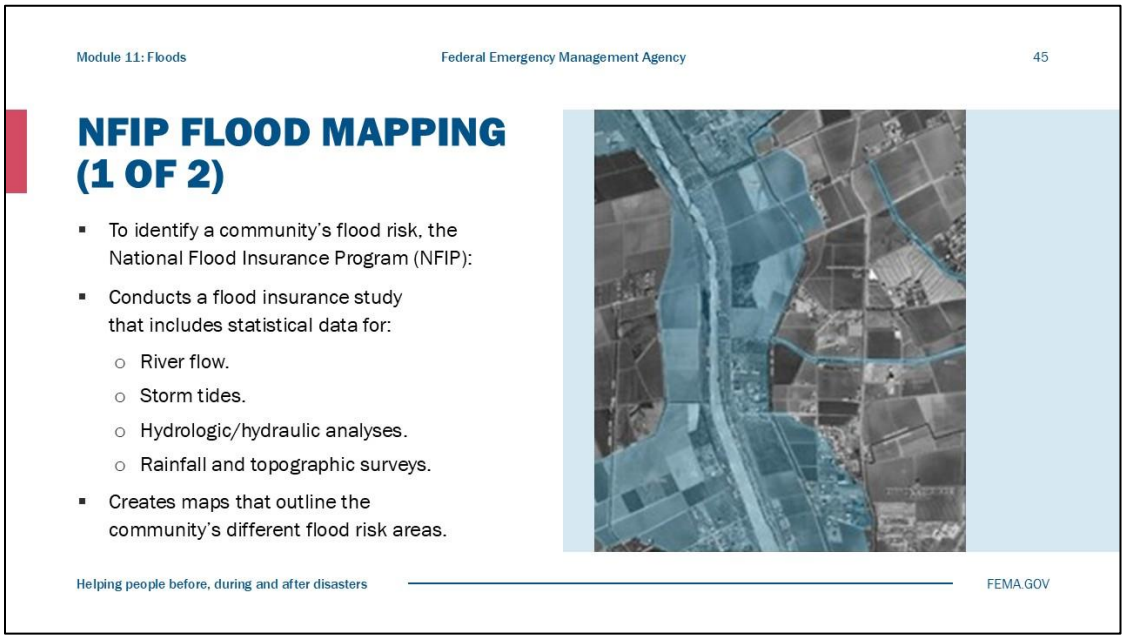
Water elevation: Sensors like the one on the upper left sense water elevation at all hours and at varying frequencies. But while water elevation is important, it is not enough information alone.

Streamflow: To assess floods, volumetric streamflow (which only occasionally gets measured) must also be factored in. Based on those occasional measurements, scientists can estimate the flow at a site when the water is at different elevations. Thus, elevation becomes a surrogate for volumetric flow.

- **Rating curve**: As the sensors continually gather observations of water elevation, these elevations get converted to estimates of gallons per minute of volumetric streamflow through what is called a rating curve (stage/discharge rating). The "stage" is synonymous with elevation. In the sample rating curve shown on the lower left, red dots are discrete observations made by a human being. The rest of the curve is estimated.
- **Hydrograph**: A product of this measurement and estimation process is a hydrograph (bottom right). Some hydrographs show the water stage; others, like this one, show **discharge** (the volume of water passing a point per module time, often measured in cubic feet per second, or cfs). Again, the red dots indicate discrete measurements.

These data are the basic tools of flood forecasting, and these products are available online almost immediately.

Flood Forecasting (4 of 5)



Slide 11-45, NFIP Flood Mapping (1 of 2)

To identify a community's flood risk, the National Flood Insurance Program (NFIP) conducts a flood insurance study that includes statistical data for:

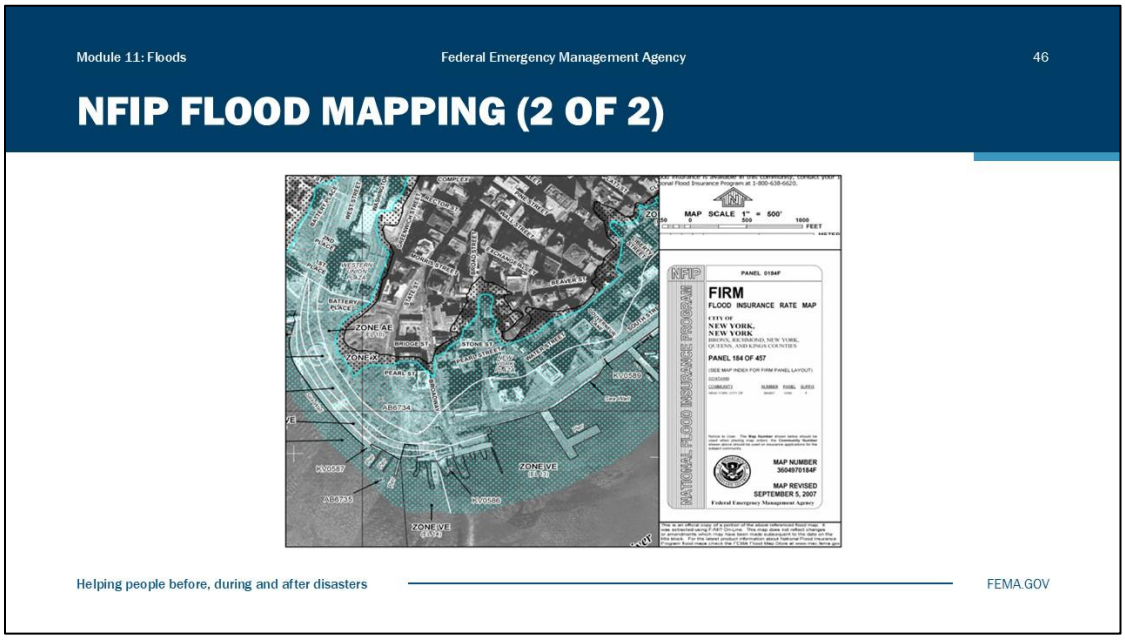
- River flow;
- Storm tides;
- Hydrologic/hydraulic analyses; and
- Rainfall and topographic surveys.

These data are used to create maps that outline the community's different flood risk areas.

Almost 100,000 Flood Insurance Rate Maps (**FIRMs** or **DFIRMs**, if digitized) have been published and are currently being updated.

Note: FIRMs are older maps and have been replaced by D-FIRMs-Digital - Flood Insurance Rate Maps

Flood Forecasting (5 of 5)



Slide 11-46, NFIP Flood Mapping (2 of 2)

Flood zones are geographic areas that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area.

Moderate-to-Low-Risk Areas

In communities that participate in the NFIP, flood insurance is available to all property owners and renters in these zones:

ZONE	DESCRIPTION
B and X (shaded	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. Also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood or shallow flooding areas with average depths of less than 1 foot or drainage areas less than 1 square mile.

ZONE	DESCRIPTION
C and X (unshaded)	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level.

High-Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones.
AE	The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1- A30 Zones.
A1-30	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a base flood elevation (old format).
AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.

ZONE	DESCRIPTION
A99	Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system, where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.

High-Risk - Coastal Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
VE, V1 - 30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

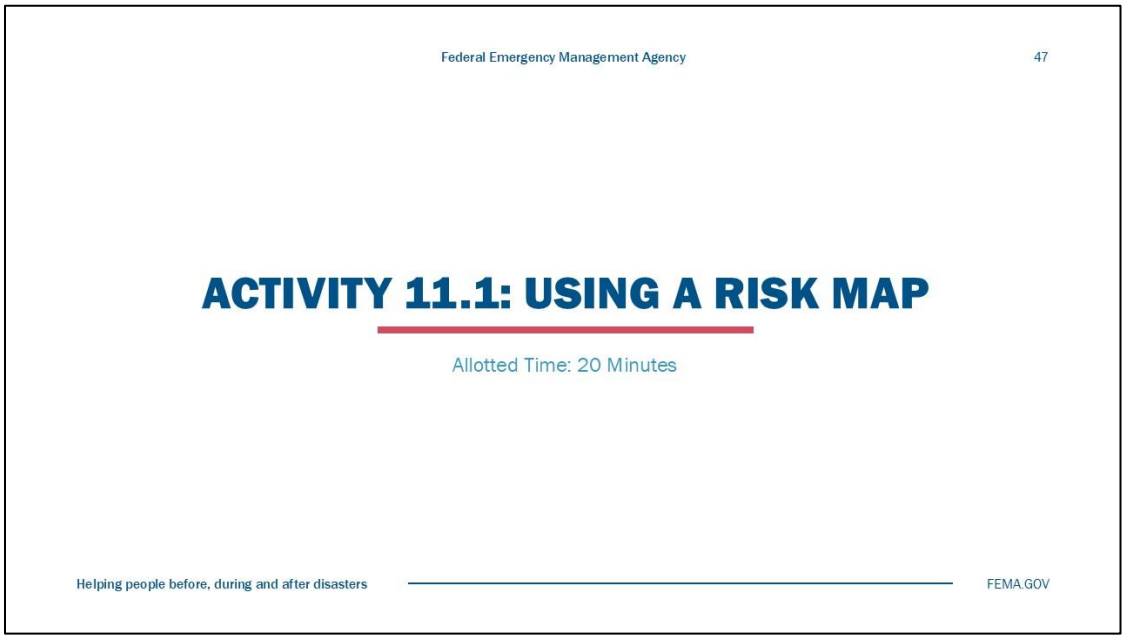
Undetermined Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
D	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

Further information can be found in the Community Status Book, FEMA Flood Maps and Zones Explained (https://www.fema.gov/blog/fema-flood-maps-and-zones-explained)

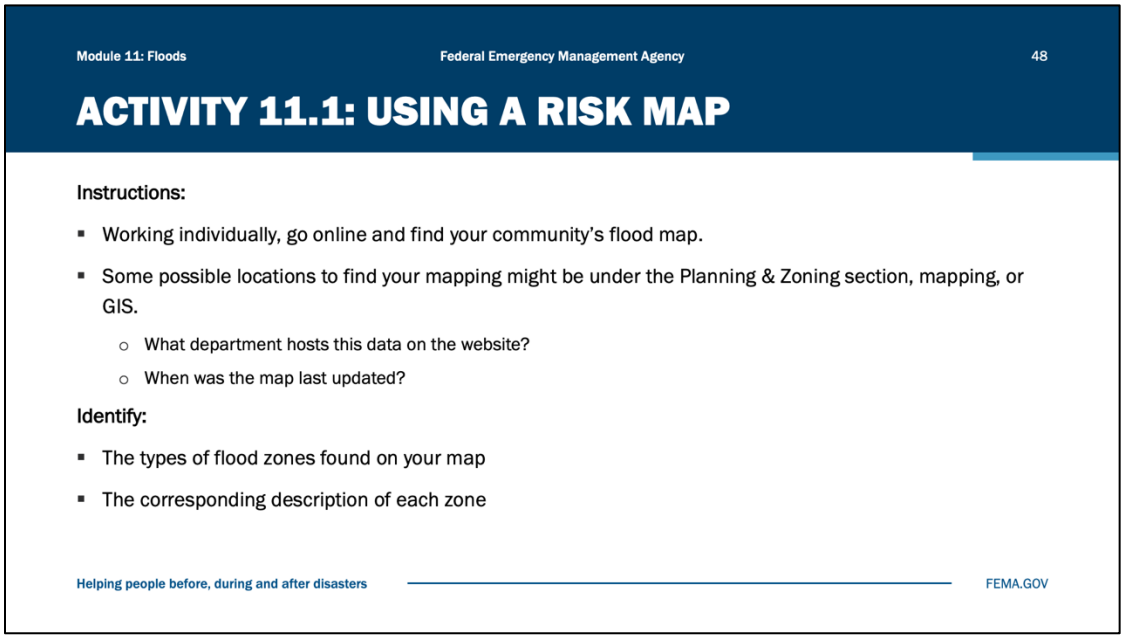
Activity 11.1: Using a Risk Map (1 of 2)



Slide 11-47, Activity 11.1: Using a Risk Map

Not Applicable.

Activity 11.1: Using a Risk Map (2 of 2)



Slide 11-48, Activity 11.1: Using a Risk Map

Activity 11.1: Using a Risk Map – Directions to Students

Total Activity Time: 20 minutes

Purpose

The purpose of this activity is to help students develop essential map-reading skills by interpreting a Flood Insurance Rate Map (FIRM), a critical component for understanding local flood risks and planning for emergency management (EM).

1. Go online and find your community's flood map. Try the Planning & Zoning section, GIS, or Mapping pages of your local government website. If you cannot locate your map within 3 minutes, use the Clark County, Nevada flood map provided by your instructor.
2. If you found your community's flood map, record the website URL for future reference. Otherwise, skip to Question #4.

3. Identify the department or agency that provides this data on the website.
4. Check the date of the most recent map update.
5. Identify and list:

a. The types of flood zones shown on the map.

b. The corresponding description for each type of zone (e.g., Zone AE, Zone X).

6. Assume you are a member of the public.

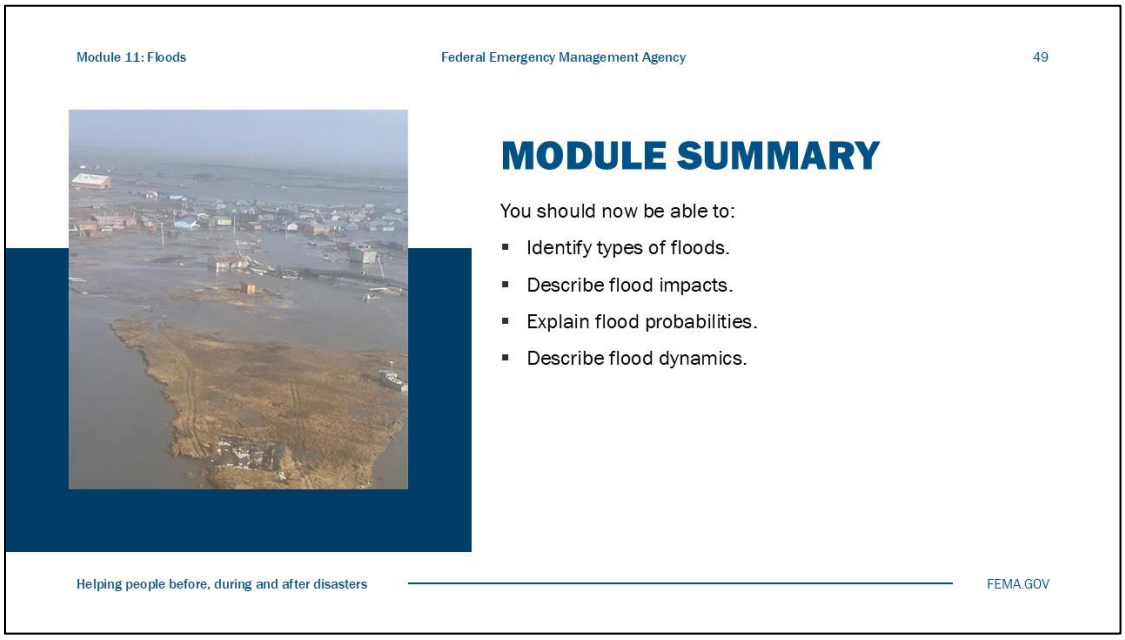
   a. Is this information understandable?

   b. Current?

   c. Accessible?

   d. Would it help you prepare for a disaster?

End of Module (1 of 2)

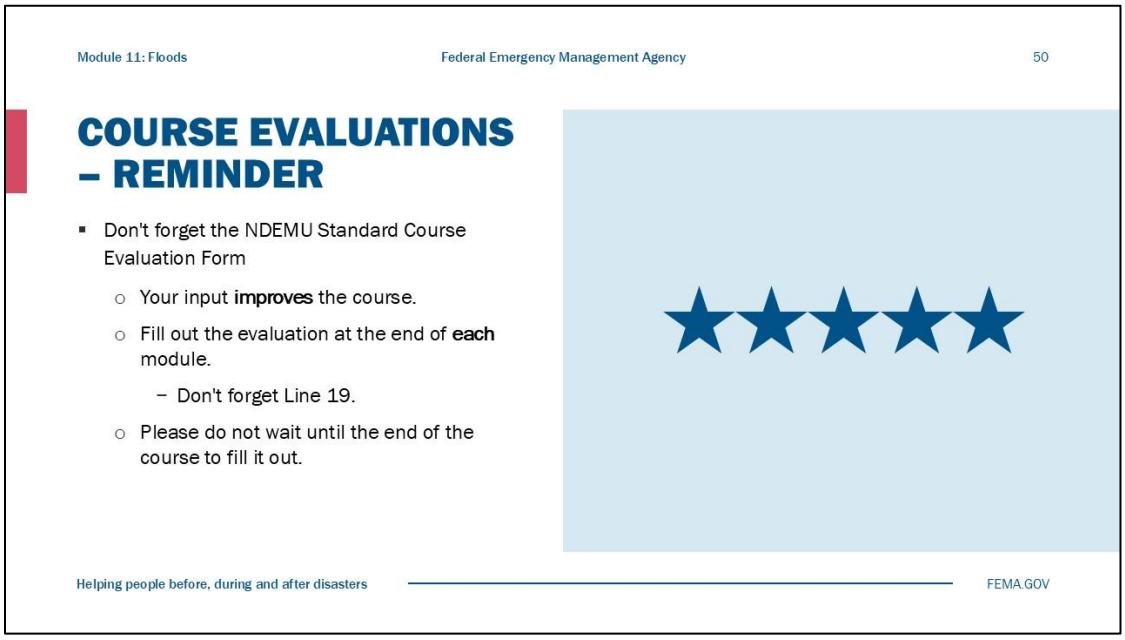


Slide 11-49, Module Summary

You should now be able to:

- Identify types of floods.
- Describe flood impacts.
- Explain flood probabilities.
- Describe flood dynamics.

End of Module (2 of 2)



Slide 11-50, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

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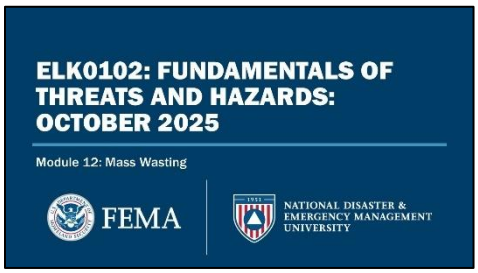
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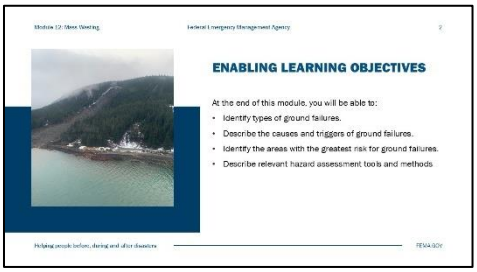
Module 12

Mass Wasting

Administration



Slide 12-1, Module 12: Mass Wasting



Slide 12-2, Enabling Learning Objectives

Duration

1 hour, 5 minutes

Terminal Learning Objective (TLO)

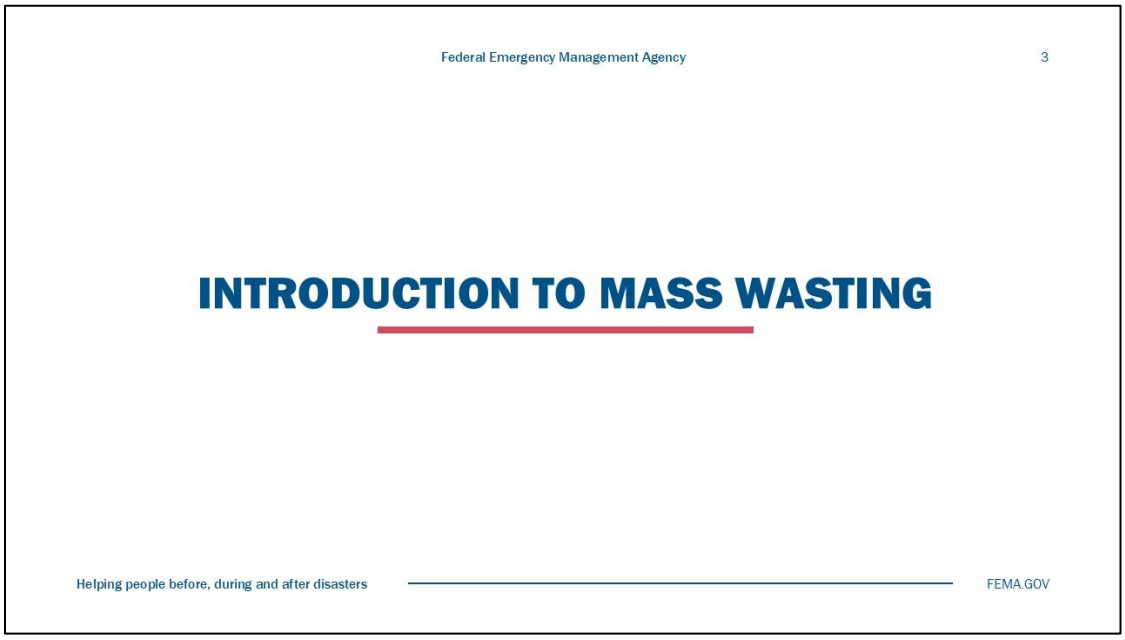
By the end of this module, participants will be able to evaluate the processes, causes, and effects of mass wasting events, such as landslides, slumps, and sinkholes, and apply hazard mitigation strategies to minimize risks to communities and infrastructure.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Identify types of ground failures.
- Describe the causes and triggers of ground failures.
- Identify the areas with the greatest risk for ground failures.
- Describe relevant hazard assessment tools and methods.

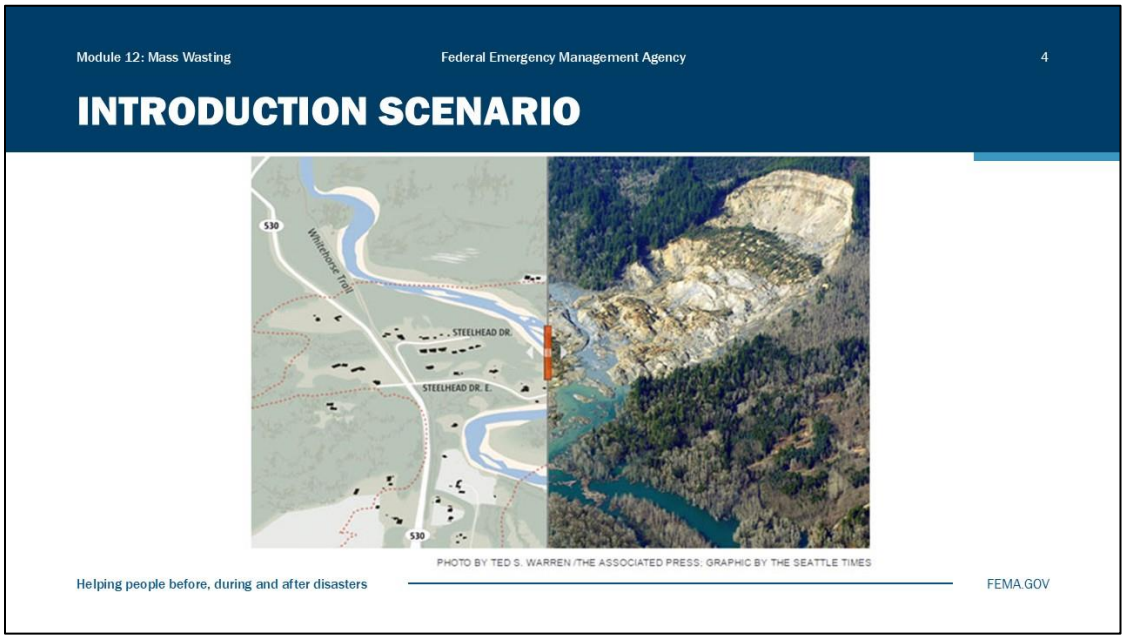
Introduction to Mass Wasting (1 of 3)



Slide 12-3, Introduction to Mass Wasting

Not Applicable.

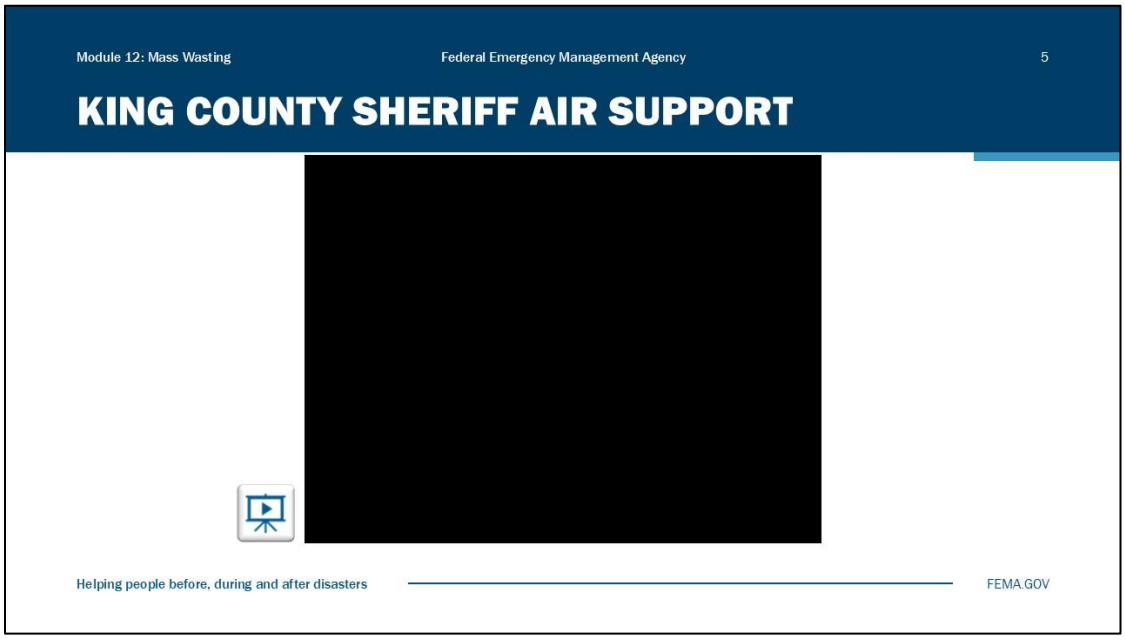
Introduction to Mass Wasting (2 of 3)



Slide 12-4, Introduction Scenario

On March 22, 2014, a landslide occurred in the town of Oso, Washington. The SR530 landslide overran a Local neighborhood and killed 43 people. The landslide provides an outstanding opportunity to review what scientists know about landslide potential, the means of preventing and mitigating landslide disasters, and the conflict that can occur between developers and the city and emergency planners.

Introduction to Mass Wasting (3 of 3)

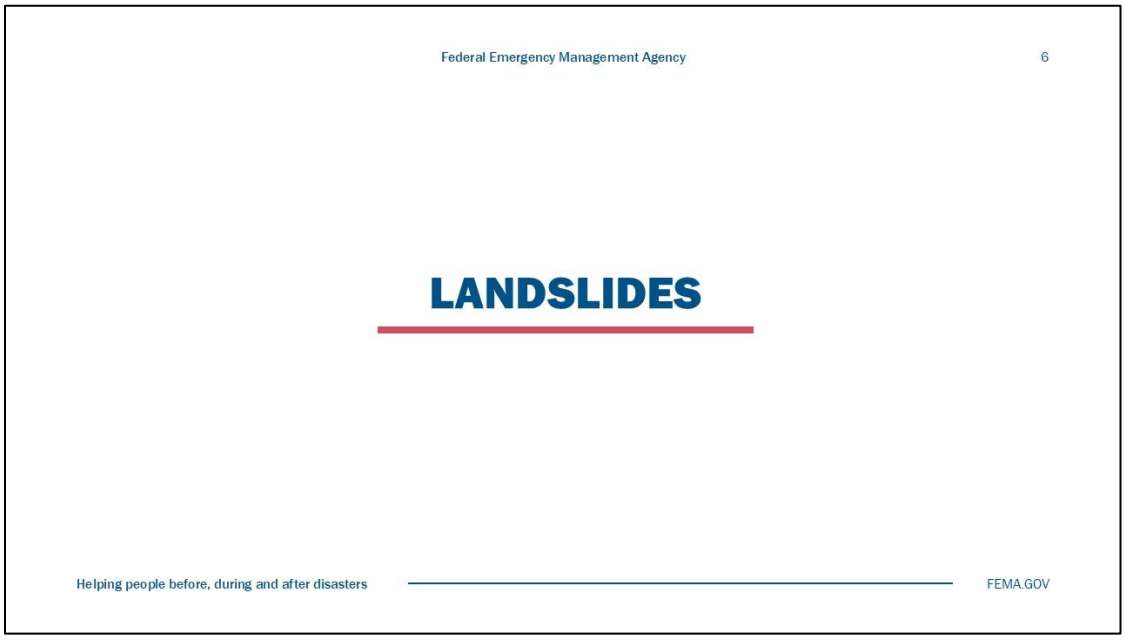


Slide 12-5, King County Sheriff Air Support

This video (has no sound) shows a quick before and after from the Oso mudslide, using our Churchill Navigation ARS. It provides a visual of the details discussed in the previous slide about the SR530 landslide.

Source: King County Sheriff Air Support (Director). (2014, March 25). *Oso Mud Slide Before and After* [Video recording]. https://www.youtube.com/watch?v=1_G3ReEAr6I

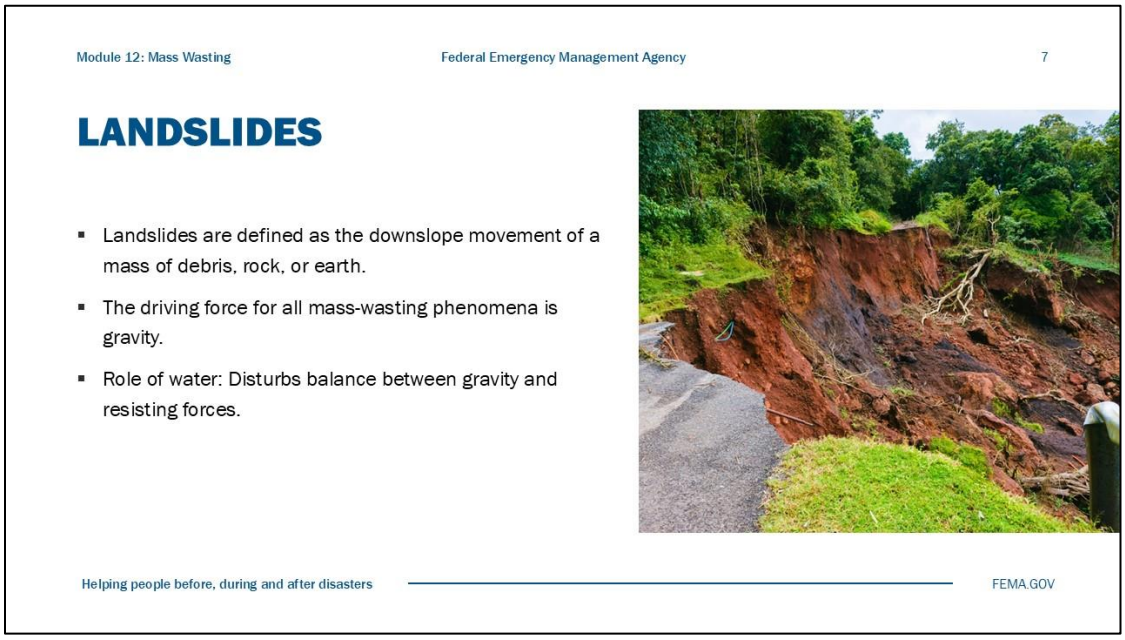
Landslides (1 of 10)



Slide 12-6, Landslides

Not Applicable.

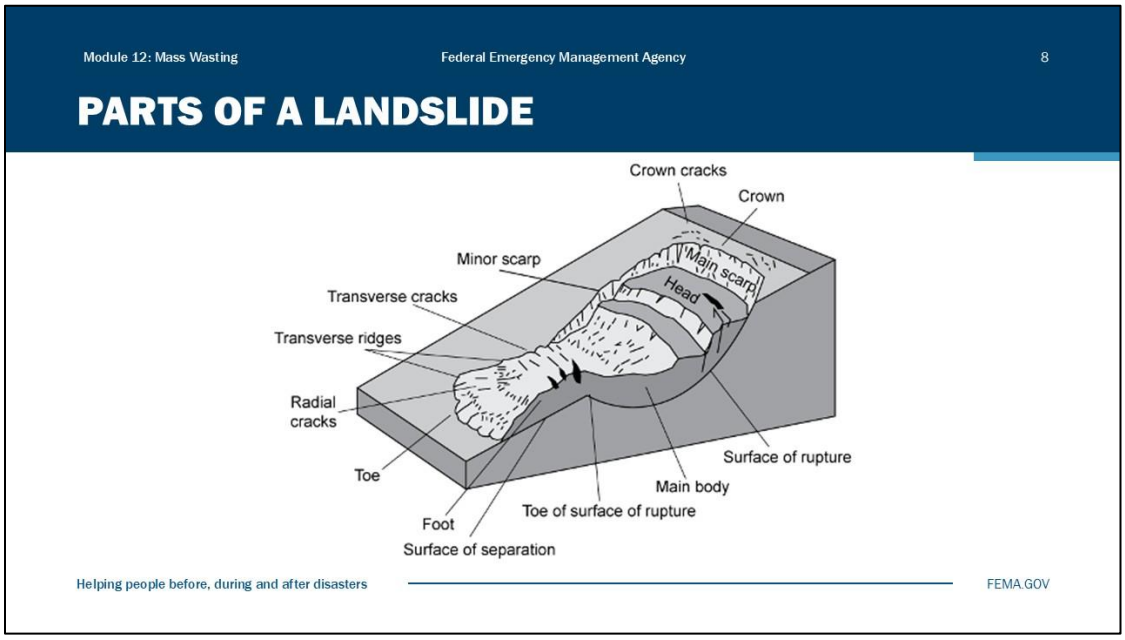
Landslides (2 of 10)



Slide 12-7, Landslides

- Landslides are defined as the downslope movement of a mass of debris, rock, or earth.
- The driving force for all mass-wasting phenomena is gravity, which pulls the material toward the center of the Earth. Typically, gravity is balanced with resisting forces, such as friction, which maintains the slope's stability.
- When the balance is disturbed, failure results. Water acts as a lubricant, reducing the friction that holds material in place.

Landslides (3 of 10)



Slide 12-8, Parts of a Landslide

Parts of a Landslide Image Description

Graphic illustrating parts of a landslide. They are: Toe, Foot, Surface of separation, Radial cracks, Transverse ridges, Toe of surface of rupture, Transverse cracks, Main body, Surface of rupture, Minor scarp, Head, Main scarp, Crown, Crown cracks

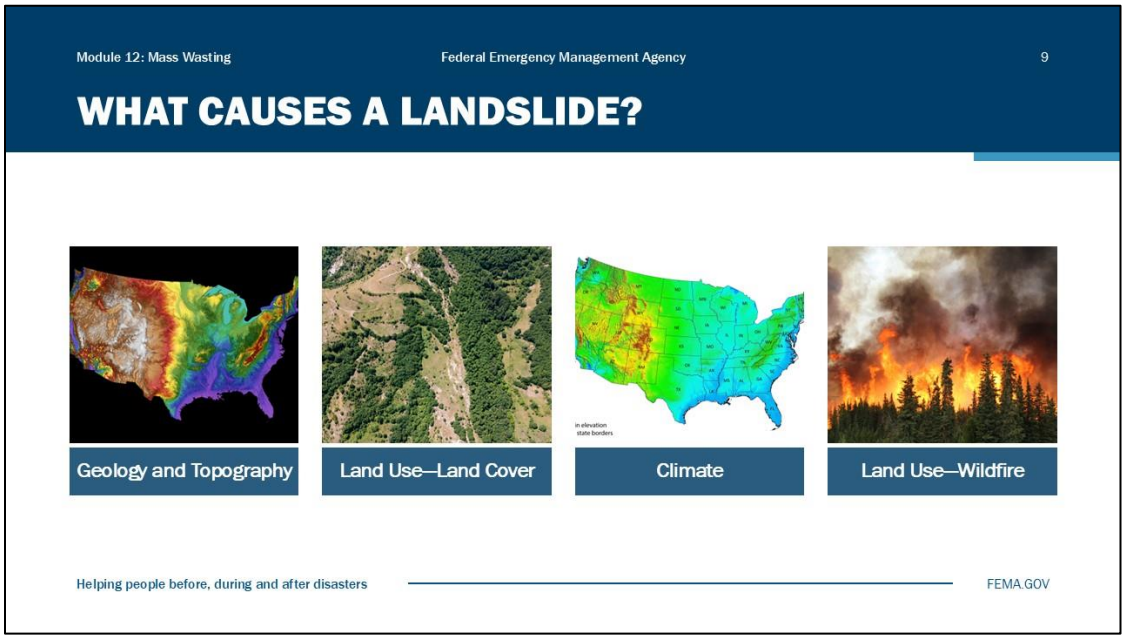
This schematic illustrates the different parts of a landslide. Note that:

- The **landslide body** moves along a surface of rupture. In this illustration, the surface of rupture is curved, and the motion is rotational.
- **Rotational landslides** have a failure surface that is curved. In a **translational** slide, the failure surface is roughly parallel to the undisturbed or former ground surface. In a landslide, the main **scarp** is a vertical or subvertical face that is exposed when the slide moves downslope.
- The **toe** is the lower-most extent of the displaced material.

To understand landslides, scientists must understand the many variations that occur and thus develop terminology to distinguish the variations.

Geologists can identify the scarps and toes of old landslides in both the rock record and LiDAR (Light Detection and Ranging) imagery. This is remarkably useful in developing land-use restrictions.

Landslides (4 of 10)



Slide 12-9, What Causes a Landslide?

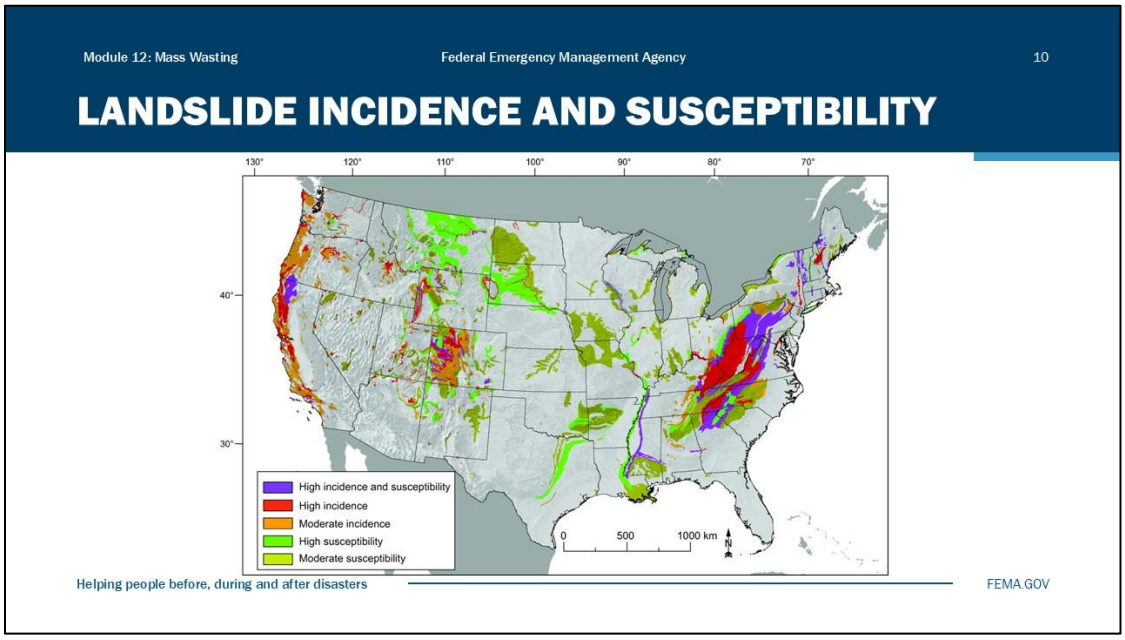
Landslide occurrences are often described using the terms **cause** and **trigger**. First, we'll examine the causes.

Landslide **causes** are geologic, topographic, climatic, and land use characteristics that make an area susceptible to landslides.

- An example of a topographic cause is a steep slope.
- Weak geological materials include young sedimentary rocks or heavily weathered rocks.
- Climatic conditions include heavy rainfall that can loosen material.
- Land use includes human activities that directly and indirectly have an effect, such as industrial forestry, road cuts, and in some cases, wildfire.

Causes create the conditions that make a landslide possible and increase the propensity for landslides.

Landslides (5 of 10)



Slide 12-10, Landslide Incidence and Susceptibility

Landslide Incidence and Susceptibility Map (This link can also be accessed at the following URL: http://landslides.usgs.gov/hazards/nationalmap/)

All 50 States have at least some areas that are at risk from landslides. The greatest potential for losses resulting from landslides, however, exists in the:

- States along the Pacific coast;
- Rocky Mountains; and
- Appalachian Mountains.

Landslides (6 of 10)



Slide 12-11, What Triggers a Landslide?

So, what triggers landslides? Many regions are susceptible to landslides because of their climatic conditions and topography. However, most landslides are triggered by a particular event or series of events. The culprit is most often heavy rainfall or human activity. For example, 90 percent of landslides in the Pittsburgh, Pennsylvania region result from urban development. However, hurricanes, volcanic eruptions, and earthquakes often trigger landslide events that take the largest toll on human life.

Landslide triggers include a variety of natural and human processes.

Natural processes may include:

- Heavy rainfall
- Volcanic eruption
- Earthquake
- Thermal variation (extremes of hot and cold that allow moisture to enter cracks, freeze, expand, and force the crack apart)
- Snowmelt
- Stress relief (as rocks are heaved up and exposed above the ground, they may expand to release pressure, which causes fractures)

- Wave action at a coastline

Although earthquake-triggered landslides often create the largest death tolls, they are typically not the cause of most landslides. Excessive rainfall triggers most landslides.

Human activities that can trigger landslides include action that changes the topography (e.g., excavations) and activities that change ground or surface water hydrology (e.g., reservoir operation).

Landslides (7 of 10)



Slide 12-12, Key Distinctions

- For nonscientists, two key distinctions exist regarding landslide impacts:
  - **Slow-moving** landslides can be very destructive to structures and infrastructure, making them quite costly.
  - **Fast-moving** landslides are more likely to result in deaths and injuries.

Landslides (8 of 10)



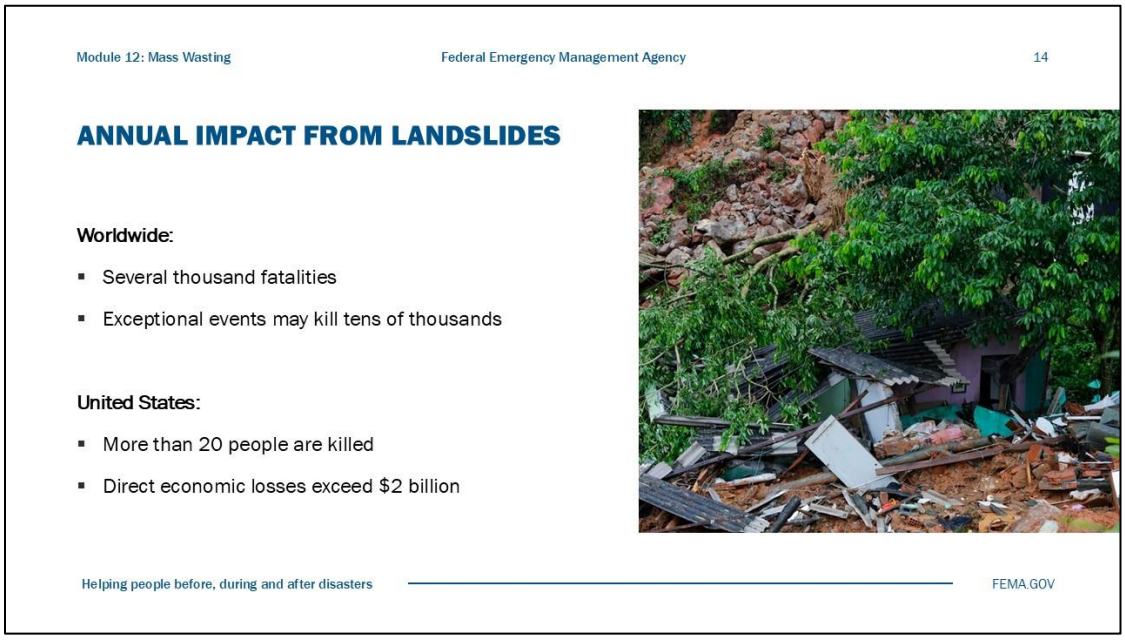
Slide 12-13, Landslide Prevention

Reasonable and effective prevention measures include:

1. Implement drainage control measures:
    a. Prevent water from seeping into surfaces.
    b. Cover the surface.
    c. Install surface drains.
    d. Remove water from the subsurface by installing drains.
2. Ensure that the slopes are properly graded:
    a. Reduce the gradient to enhance slope stability.
    b. Install benching.
    c. Incorporate suitable drainage in newly graded or benched slopes.
3. Build suitable slope supports and retaining walls using:
    a. Anchors
    b. Backfill
    c. Drainage

4. Consider the standards for vegetation and logging:
5. Select plants that:
    a. Stabilize the slope by reducing water infiltration.
    b. Do not add excessive weight to the slope.
6. Consider logging standards:
    a. Maintain appropriate setbacks from scarps.
    b. Recognize how road construction and maintenance alter surface runoff, impacting slope stability.
7. Land use management and zoning:
    a. Engage the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer who can accurately assess a site's hazard potential, whether built or unbuilt.
    b. Refrain from constructing on steep slopes and existing landslides, or stabilize the slopes. Stability improves when groundwater is prevented from rising in the landslide mass by:
        i. Covering the landslide with an impermeable membrane;
        ii. Directing surface water away from the landslide;
        iii. Draining groundwater away from the landslide; and
        iv. Minimizing surface irrigation.

Landslides (9 of 10)



Slide 12-14, Annual Impact from Landslides

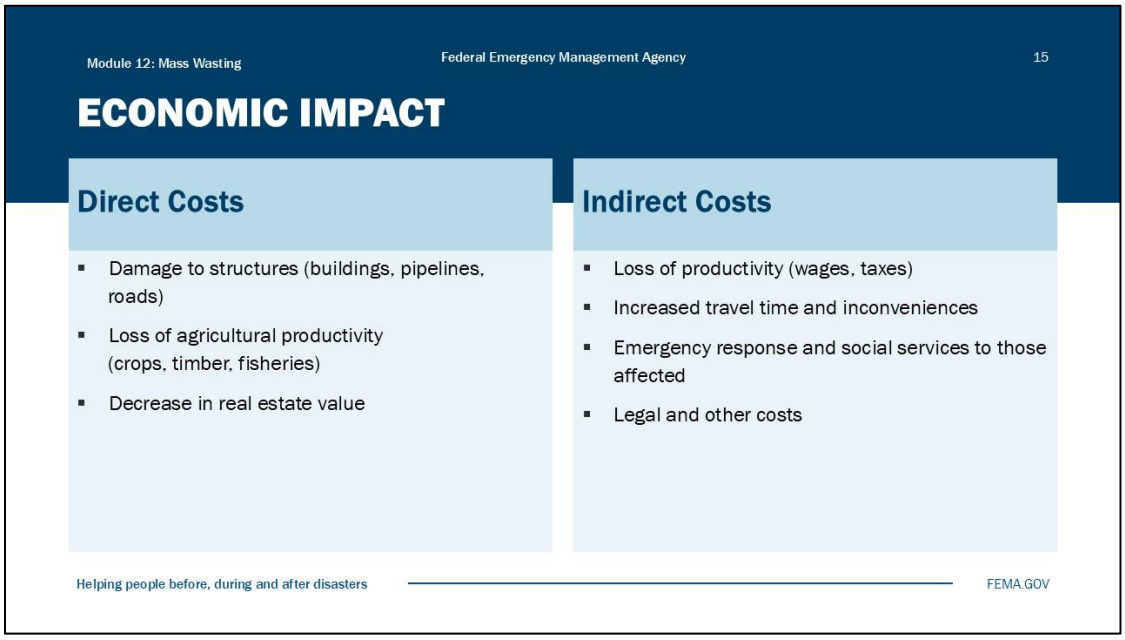
Every year, landslides cause significant losses, both in lives lost and economic losses. Because landslides affect a relatively small area, their impacts are often underappreciated.

Annually, worldwide, landslides result in several thousand fatalities. Exceptional events may kill tens of thousands.

Annually, in the United States, landslides result in more than 20 fatalities and direct economic losses that exceed $2 billion.

The National Weather Service Forecast Offices use rainfall threshold information to inform emergency management personnel and the public when landslides are expected.

Landslides (10 of 10)



Slide 12-15, Economic Impact

Economics plays a crucial role in reducing hazards. Economists assess disaster costs based on the type of cost and whether it is direct or indirect. Examples of direct and indirect costs from landslides include:

Direct costs:

- Damage to structures (buildings, pipelines, roads)
- Loss of agricultural productivity (crops, timber, fisheries)
- Decrease in real estate value

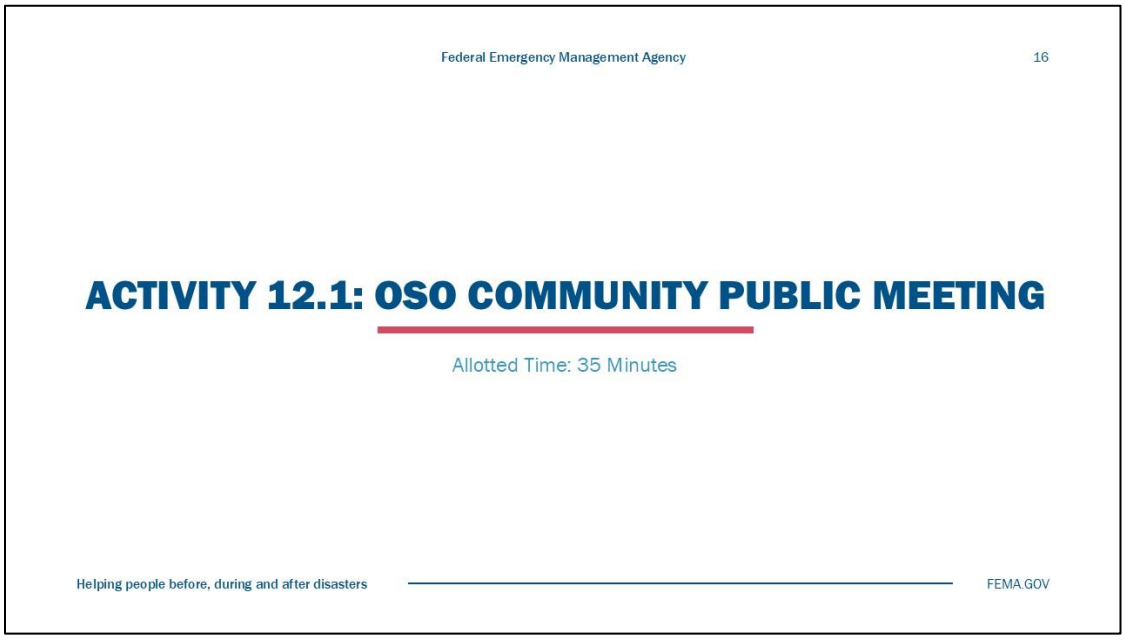
Indirect costs:

- Loss of productivity (wages, taxes)
- Increase in travel time and inconveniences
- Emergency response and social services to those affected
- Legal costs
  - Example: Suing the government for lack of EM plans.

- Any other indirect costs

It is worthwhile to consider that litigation is still pending regarding the SR530 slide. Issues include whether authorities properly warned citizens and whether the logging companies were at fault for the landslide.

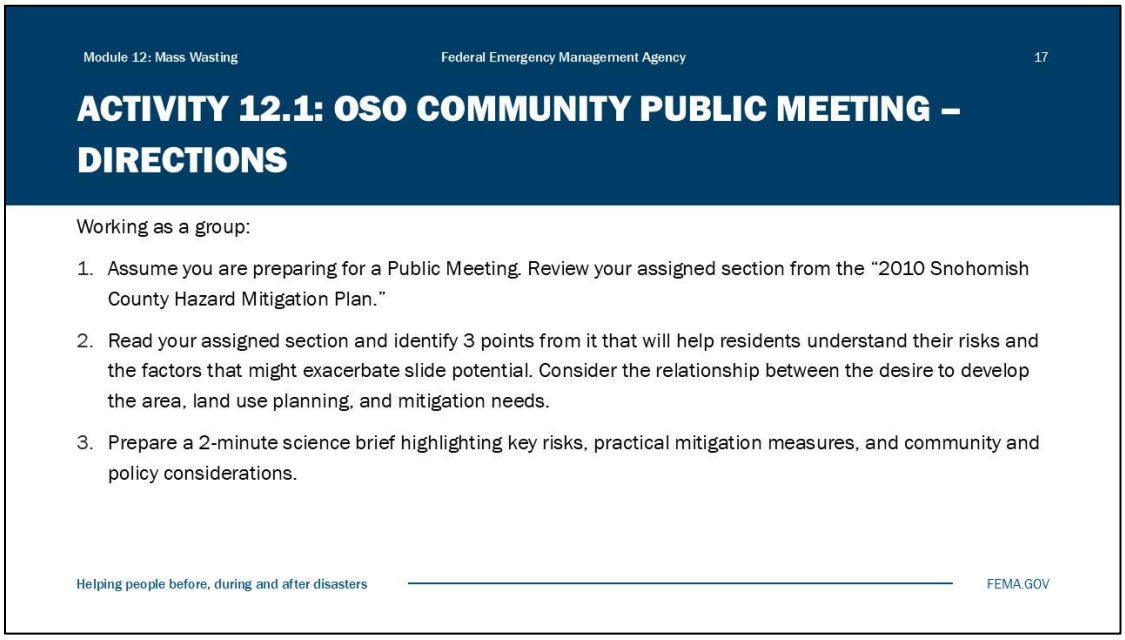
Activity 12.1 Oso Community Public Meeting (1 of 3)



Slide 12-16, Activity 12.1: Oso Community Public Meeting

Not Applicable.

Activity 12.1: Oso Community Public Meeting (2 of 3)



Slide 12-17, Activity 12.1: Oso Community Public Meeting – Directions

Activity 12.1: Oso Community Public Meeting – Directions to Students

Purpose

The purpose of this activity is to analyze real-world hazard mitigation strategies using the 2010 Snohomish County Hazard Mitigation Plan. Through small-group collaboration and class presentations, you will explore the relationship between risk factors, mitigation approaches, and policy considerations in the context of landslide hazards and community resiliency.

Directions:

Working in your table groups:

Preparation (5 minutes)

1. Review your assigned section from the "2010 Snohomish County Hazard Mitigation Plan."
2. Become familiar with:
    a. General Background
    b. Hazard Profile
    c. Weather trends Impacts

d. Secondary Hazards

3. Each group will be assigned an additional section for deeper review.

Group Discussion (20 minutes)

4. Read your assigned section and identify three main discussion points:
    a. What factors contribute to landslide risks in the area?
    b. What are the best strategies to mitigate these risks?
    c. How can development be balanced with community safety?
5. Prepare a brief presentation that simplifies technical information for the public.
6. Consider how environmental, economic, and social factors are interrelated.

Presentation (10 minutes)

7. Present a 2-minute science brief highlighting:
    a. Key risks
    b. Practical mitigation measures
    c. Community and policy considerations
8. Be prepared to discuss how communities can make informed decisions to build resilience.

2010 Snohomish County Hazard Mitigation Plan

All Groups

CHAPTER 14. Landslides and Other Mass Movements

General Background

A landslide is a mass of rock, earth, or debris moving down a slope. Landslides can range from minor to very large and can move at speeds from slow to very high. They can be initiated by storms, earthquakes, fires, volcanic eruptions, and by human modification of the land.

Mudslides or mudflows (or debris flows) are rivers of rock, earth, organic matter and other soil materials saturated with water. They develop in the soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt. Water pressure in the pore spaces of the material increases to the point that the internal strength of the soil is drastically weakened. The soil's reduced resistance can then be easily overcome by gravity, causing the earth to transform into a flowing river of mud or "slurry." A debris flow or mudflow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water due to the mass of material included in them. Locally, they can be some of the most destructive events in nature.

DEFINITIONS

Landslide: The sliding movement of masses that can move at slow to very high speeds. They can be of loosened rock and soil down a hillside or initiated by storms, earthquakes, fires, or volcanic slope. Slope failures occur when the strength of eruptions is exceeded, and due to human modification of the land. The soil forming the slope is exceeded by the pressure, such as weight or saturation, acting upon it.

Mass Movement: A collective term for landslides, debris flows, falls and sinkholes.

Mudslide (or Mudflow or Debris Flow): A river of rock, earth, organic matter and other materials saturated with water.

Sinkhole: A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

A sinkhole is a depression in the ground with no visible outlet. Its drainage is subterranean, and it is commonly vertical-sided or funnel-shaped.

A combination of geological and climatic conditions causes all these mass movements. These include steep topography, as well as the encroaching influence of urbanization. The cool, rainy Pacific Northwest climatic conditions ensure that soil moisture levels remain high throughout most of the year, and in fact are often at or near saturation during wet winter months. The geological conditions of western Washington are primarily a legacy of repeated episodes of glacial advance and

retreat over the past 2 million years. One of the most active erosive processes in the 13,000 years since the last ice disappeared has been mass wasting, the action of landslides and mudslides. These fragile natural conditions are being steadily affected by human residential, agricultural, commercial and industrial development and the infrastructure that supports it.

Hazard Profile

Landslides are caused by one or a combination of the following factors: changes in slope of the terrain, increased load on the land, shocks and vibrations, changes in water content, groundwater movement, frost action, weathering of rocks, and removal or alteration of the type of vegetation covering slopes. In general, landslide hazard areas are where the land has characteristics that contribute to the risk of the downhill movement of material, such as the following:

- A slope greater than 33 percent;
- A history of landslide activity or movement during the last 10,000 years;
- Stream or wave activity, which has caused erosion, undercuts a bank or cuts into a bank to cause the surrounding land to be unstable;
- The presence or potential for snow avalanches;
- The presence of an alluvial fan, indicating the fragility of the flow of debris or sediments; and
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils such as sand and gravel.

The form of initial ground failure commonly categorizes flows and slides, but they may travel in various forms along their paths. Figures 14-1, 14-2, 14-3 and 14-4 show common types of slides in the Puget Sound region and in Snohomish County. The most common type is the shallow colluvial slide, which occurs particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types. Puget Sound's shoreline contains many large, deep-seated dormant landslides.

Occasionally, large catastrophic slides occur on Puget Sound.

The preponderance of landslides occurs in January after the water table has risen during the wet months of November and December. In addition to the coastal bluffs, land sliding is most prevalent around the slopes of the Puget Sound's steep, linear hills. Water is involved in nearly all cases, and human influence has been identified in more than 80 percent of reported slides.

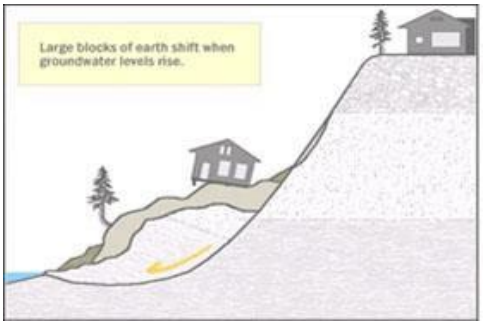


Figure 14-1. Deep-Seated Slide

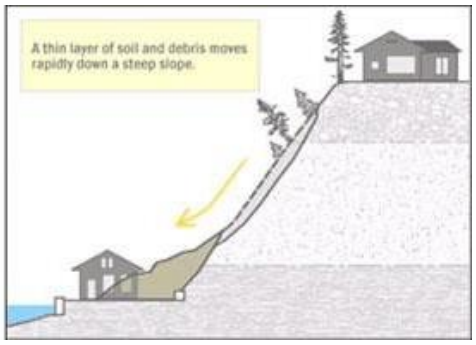


Figure 14-2. Shallow Colluvial Slide

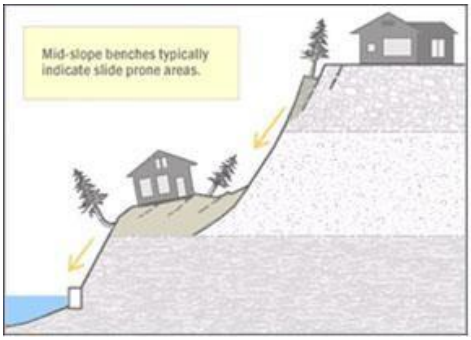


Figure 14-3. Bench Slide

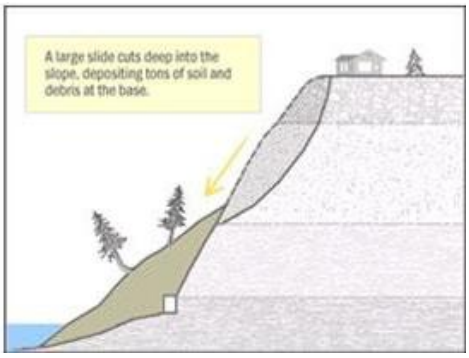


Figure 14-4. Large Slide

Weather Trends Impacts

Weather trends will impact storm patterns in Washington. This change in the hydrograph means that the probability of more frequent, intense storms with varying durations will increase. An increase in global temperature will also impact the snowpack's ability to hold and store water. Warming temperatures will increase the occurrence and duration of droughts, which will increase the probability of wildland fires, impacting the vegetation that helps support steep slopes. All of these factors working in unison would increase the probability of landslide occurrences within the planning area.

Secondary Hazards

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public and private transportation.

This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential to destabilize the foundation of structures, which may result in monetary loss for residents. They can also damage rivers or streams, potentially harming water quality, fisheries, and spawning habitat.

Group 1: Understanding Risks

Past Events

There is little recorded information for Snohomish County regarding landslides. During the winter storm of 1996-97, more than half of the County's $60-70 million in reported damage occurred as a result of landslides, mudslides and debris flows. Drainage systems and catchment basins could not handle the volume of runoff, focusing the water's energy against vulnerable slopes and man-made structures. In some cases, saturated soils became overloaded with the weight of snow and rainwater, causing them to collapse. Private homeowners, particularly in areas where natural drainage has been altered by human intervention, reported significant damage. Landslide and mudslide/debris flow activity during this storm caused widespread disruption of surface transportation, closing roads and, in one case, derailing mail cars from a freight train. The costs of repairing road damage totaled tens of millions of dollars. Given the volume of hazardous substances shipped by road and rail through Snohomish County, it was fortunate that no serious chemical spills occurred as a result of these incidents.

A large slide occurred in Woodway, just north of the Richmond Beach neighborhood, during the early morning of January 15, 1997. It cut 50 feet into the property above, passed over the railroad tracks and knocked a freight train into Puget Sound (see Figure 14-5). Initial estimates placed the volume of the slide at 200,000 to 260,000 cubic yards, but later estimates based on additional data ranged from 100,000 to 200,000 cubic yards. The head of the slide is downslope from the Rosary Heights Convent. The bluff here is about 250 feet high, and the head scarp appears to be about 350 feet

wide. The slide deposit extended from the base of the scarp across railroad tracks and into Puget Sound. Except for a large, partially intact slide block resting at the base of the scarp, the deposit consisted mostly of remolded sand and silt, containing logs and boulder-sized, joint-bound blocks of intact Lawton clay. The remolding indicates that much of the slide broke apart and mobilized into a debris flow.

There are no records in the County of fatalities attributed to mass movement. However, across the Pacific Northwest, a number of deaths have occurred as a result of slides, slope collapses and sinkholes.



Figure 14-5. 1997 Woodway Slide

Location

Map 14-1 shows the landslide hazard areas in Snohomish County. The basis of the mapping is as follows:

- Any area with a combination of:
  - Slopes greater than 33 percent
  - Impermeable soils (typically silt and clay) frequently interbedded with granular soils (predominantly sand and gravel)
  - Springs or groundwater seepage
- Any area that has shown movement during the Holocene epoch (from 12,000 years ago to present), or that is underlain by mass wastage debris of that epoch
- Any area potentially unstable as a result of rapid stream incision, stream bank erosion or undercutting by wave action
- Any area that shows evidence of, or is at risk from, snow avalanches

- Any area located on an alluvial fan, presently subject to or potentially subject to inundation by debris flows or deposition of stream-transported deposits.

The recognition of ancient dormant mass movement sites is crucial in identifying areas susceptible to flows and slides, as they can be reactivated by earthquakes or exceptionally wet weather. Additionally, because they consist of broken materials and often involve disruption of groundwater flow, these dormant sites are susceptible to construction-triggered landslides.

Frequency

Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods or wildland fires, so landslide frequency is related to the frequency of these other hazards. In Snohomish County, landslides typically occur during and after major storms.

Recent events occurred during the winter storm of 1996-97 and the October 2003 storm, which generated a few landslides, but not as many as expected, since the soil and bedrock in hilly areas were relatively dry. Recent events also occurred during the winter storms of 2006, 2007 and 2009.

Severity

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost to society of about $1.5 billion. The 1996-97 storm caused about $30 million to $35 million in damage due to landslides, mudslides and debris flows. This was about half of all damage caused by the storm. The landslides caused by the storm also caused tens of millions of dollars of damage to road infrastructure.

Warning Time

Mass movements can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material and water content. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. Generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before.
- New cracks or unusual bulges in the ground, street pavements or sidewalks.
- Soil moving away from foundations.
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house.

- Tilting or cracking of concrete floors and foundations.
- Broken water lines and other underground utilities.
- Leaning telephone poles, trees, retaining walls or fences.
- Offset fence lines.
- Sunken or down-dropped road beds.
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content).
- Sudden decrease in creek water levels though rain is still falling or just recently stopped.
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb.
- A faint rumbling sound that increases in volume as the landslide nears.
- Unusual sounds, such as trees cracking or boulders knocking together.

Group 2: Exposure

Population

The population could not be examined by landslide hazard area because census block group areas do not coincide with the risk areas. A population estimate was made by counting the structures within the landslide hazard areas and applying the census value of 2.65 persons per household for Snohomish County. Using this approach, the estimated county population living in landslide risk areas is 13,642. This approach could understate the exposure by as much as a factor of two, so it is reasonable to assume that the exposed population may be as high as 30,000, roughly 5 percent of the total county population.

Property

Table 14-1 shows the number and assessed value of Snohomish County structures exposed to steep slopes. There are 4,669 structures on parcels exposed to steep slopes, worth an estimated

$2.075 billion. Ninety-five percent of the exposed structures are dwellings.

Table 14-2 shows the general land use of parcels exposed to landslides. Lands used for forestry or parks are less susceptible, while lands used for manufactured homes are highly at risk. The predominant land uses for parcels in cities are single-family, vacant and manufactured homes.

These uses as well as timber are the predominant land uses for exposed parcels in unincorporated Snohomish County.

TABLE 14-1. SNOHOMISH COUNTY STRUCTURES EXPOSED TO STEEP SLOPES

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Arlington	49	$10,347,000	$9,237,390	$19,584,390	0.9%
Bothell	175	$32,377,900	$22,670,740	$55,048,640	1.9%
Brier	45	$7,032,900	$4,953,420	$11,986,320	1.8%
Darrington	5	$980,700	$979,450	$1,960,150	1.4%
Edmonds	308	$75,028,000	$52,894,210	$127,922,210	1.9%
Everett	467	$208,200,800	$202,950,500	$411,151,300	2.6%
Gold Bar	2	$179,800	$156,130	$335,930	0.2%
Granite Falls	14	$1,570,400	$1,099,280	$2,669,680	0.7%
Index	2	$205,400	$143,780	$349,180	1.5%
Lake Stevens	51	$13,131,900	$9,443,860	$22,575,760	0.6%
Lynnwood	43	$8,192,300	$5,931,830	$14,124,130	0.3%
Marysville	86	$13,778,900	$9,670,700	$23,449,600	0.6%
Mill Creek	10	$22,048,900	$15,434,230	$37,483,130	1.2%
Monroe	37	$9,978,300	$7,053,360	$17,031,660	0.75%
Mountlake Terrace	192	$72,465,600	$50,784,000	$123,249,600	5.7%

Jurisdiction	Buildings Exposed	Assessed Value Structure	Assessed Value Contents	Assessed Value Total	% of AV
Mukilteo	421	$107,087,800	$76,328,490	$183,416,290	4.6%
Snohomish	62	$18,614,200	$15,992,980	$34,607,180	2.8%
Stanwood	7	$667,100	$470,720	$1,137,820	0.1%
Sultan	6	$738,000	$516,600	$1,254,600	0.3%
Woodway	11	$8,004,800	$5,729,760	$13,734,560	3.8%
Unincorporated	2676	$551,288,650	$410,932,140	$972,220,790	2.52%
County Total	4669	$1,161,919,350	$903,373,570	$2,075,292,920	2.1%

TABLE 14-2. GENERAL LAND USE OF PARCELS EXPOSED TO LANDSLIDES

General Land Use	Cities	Unincorporated Snohomish County
Agriculture	35	418
Civic/Government	9	2
Fishery	0	5
Forest	10	238
Hotel/Motel	3	0
Industrial/Manufacturing	17	7
Manufactured/Mobile Home	505	1,162
Marine Terminals/Marinas	0	2
Medical/Health	7	0
Mining	13	185
Multi-Family	22	4
Multi-Plex Housing	44	39
Non-Residential Structure	23	161
Open Space	76	162
Other Housing/Group Quarters	1	5
Park/Playground	57	28

General Land Use	Cities	Unincorporated Snohomish County
Parking	10	0
Recreation/Entertainment	10	33
Reference Account	0	1
Resource Production/Extraction	0	1
Religious	3	6
Retail/Service	115	17
Retirement Home/Orphanage	1	0
Roads	11	31
School/Daycare	13	1
Single Family	4,112	4,904
Timber	26	1,150
Transportation	21	61
Vacant	951	4,834
Warehouse	10	1
Water	13	20
Wood Products	1	1
Total	6,149	13,527

Critical Facilities and Infrastructure

Table 14-3 summarizes the critical facilities exposed to the landslide hazard. No loss estimation was performed for these facilities due to the lack of established damage functions for the landslide hazard. A significant amount of infrastructure (roads, bridges, railroads, and utilities) can be exposed to mass movements. Landslides can block egress and ingress on roads, causing isolation for neighborhoods. Roadway blockages caused by landslides can also create traffic problems, resulting in delays for both public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides include power and communication failures, which create challenges for populations and businesses alike.

TABLE 14-3. CRITICAL FACILITIES EXPOSED TO LANDSLIDE HAZARDS

Critical Facilities	Hazards
Medical and Health Services	1
Government Function	0
Protective Function	0
Schools	0
Hazmat	0
Other Critical Function	0
Bridges	32
Water	1
Waste Water	2
Communications	0
Total	36

Railroads

The BNSF Railway corridor is exposed to landslides along much of its north-south and east-west routes and spurs. These areas include the tracks located along the Puget Sound bluffs from the King County line up to Everett. The Boeing Spur is located in a ravine and is extremely at risk. Other areas exposed to landslides include the bluffs north of Stanwood, the Bothell- Snohomish Branch and tracks located in the Cascade Mountains east of Gold Bar leading to Stevens Pass.

Roads

Many of the major roads in Snohomish County are exposed to mass movement hazards. Access to major roads is crucial for life safety after a disaster event and for response and recovery operations.

Bridges

Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use. Using Washington State bridge data, GIS analysis reveals that there are 64 bridges that cross or span landslide-prone slopes.

Power Lines

Power lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Puget Sound Energy lines pass through steep slope areas.

Surroundings

Locality problems as a result of mass movements can be numerous. Landslides that fall into streams may significantly impact fish and wildlife habitat, as well as affecting water quality.

Group 3: Susceptibility

Population

Due to the nature of census block group data, it is difficult to determine demographics of populations susceptible to mass movements. In general, all of the estimated 13,642 persons that are exposed to landslides hazards (1.9 percent of total county population) are also at risk. Due to Snohomish County's increasing population density and the fact that many man-made structures are built on "view property" atop or below bluffs and on steep slopes subject to mass movement, more lives are now endangered by this hazard than ever before.

Property

A study completed for Seattle Public Utilities in 2000 showed that only about 1 percent of the land area of the region is susceptible to landslides or other mass movements. This study also showed that 84 percent of the slides recorded had human related causes, indicating that people ignore signs of potential disaster in order to possess the most desirable land.

Consequently, there is greater potential for damage or destruction to private and public property than if stringent landslide policies were adopted.

Although complete historical documentation of the mass movement threat in Snohomish County is lacking, the effects of slide and flow activity seen during the winter storms of 1996-97 suggest a significant susceptibility to such hazards. Countywide, the millions of dollars in damage attributable to mass movement during those storms affected private property and public infrastructure and facilities.

Loss estimations for the landslide hazard are not based on modeling utilizing damage functions, because no such damage functions have been generated. Instead, loss estimates were developed representing 10 percent, 30 percent and 50 percent of the assessed value of exposed structures. This allows emergency managers to select a range of economic impacts based on an estimate of the percent of damage to the general building stock. Damage in excess of 50 percent is considered to be substantial by most building codes and typically requires total reconstruction of the structure. Table 14-4 shows the general building stock loss estimates in steep slope areas.

Infrastructure

Thirty-six critical facilities are exposed to the landslide hazard. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements should be done to determine if they could withstand the impacts of a mass movement.

Several types of infrastructure are exposed to mass movements, including transportation, water and sewer and power infrastructure. Highly susceptible areas of the county include the mountain and coastal roads and transportation infrastructure. At this time, all infrastructure and transportation corridors identified as exposed to the landslide hazard are considered at risk until more information becomes available.

Surroundings

The location susceptible to landslide hazard is the same as the surrounding area exposed to the hazard.

TABLE 14-4. ESTIMATED BUILDING LOSSES DUE TO LANDSLIDE HAZARD

Jurisdiction	Building Count	Assessed Value	10% Damage	30% Damage	50% Damage
Arlington	49	$19,584,390	$1,958,439	$5,875,317	$9,792,195
Bothell	175	$55,048,640	$5,504,864	$16,514,592	$27,524,320
Brier	45	$11,986,320	$1,198,632	$3,595,896	$5,993,160

Jurisdiction	Building Count	Assessed Value	10% Damage	30% Damage	50% Damage
Darrington	5	$1,960,150	$196,015	$588,045	$980,075
Edmonds	308	$127,922,210	$12,792,221	$38,376,663	$63,961,105
Everett	467	$411,151,300	$41,115,130	$123,345,390	$205,575,650
Gold Bar	2	$335,930	$33,593	$100,779	$167,965
Granite Falls	14	$2,669,680	$266,968	$800,904	$1,334,840
Index	2	$349,180	$34,918	$104,754	$174,590
Lake Stevens	51	$22,575,760	$2,257,576	$6,772,728	$11,287,880
Lynnwood	43	$14,124,130	$1,412,413	$4,237,239	$7,062,065
Marysville	86	$23,449,600	$2,344,960	$7,034,880	$11,724,800
Mill Creek	10	$37,483,130	$3,748,313	$11,244,939	$18,741,565
Monroe	37	$17,031,660	$1,703,166	$5,109,498	$8,515,830

Group 4: Future Trends in Development

Landslide hazard areas are included in the "geologically hazardous areas," one category of critical areas regulated under the state GMA for Snohomish County. They are defined as follows:

"Landslide hazard areas" means areas potentially subject to mass earth movement based on a combination of geologic, topographic, and hydrologic factors, with a vertical height of 10 feet or more. These include the following:

- Areas of historical landslides as evidenced by landslide deposits, avalanche tracks, and areas susceptible to basal undercutting by streams, rivers or waves;
- Areas with slopes steeper than 15 percent that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock, and which contain springs or ground water seeps

- Areas located in a canyon or an active alluvial fan are susceptible to inundation by debris flows or catastrophic flooding.

Snohomish County's 2007 buildable lands report excludes critical areas from consideration as buildable lands due to the scope of regulations affecting them. Based on the findings of this report, Snohomish County and its planning partners appear to be well-equipped to deal with future growth and development within the planning area. The landslide hazard portions of the planning area are regulated by County Code (Title 30.62B) as well as by the International Building Code. Development will occur in landslide hazards within the planning area, but it will be regulated such that the degree of risk will be reduced through building standards and performance measures.

Group 5: Scenario

Major mass movements in Snohomish County occur, resulting from soil conditions that have been affected by severe storms, groundwater, or human development. The worst-case scenario for mass movement hazards in Snohomish County would generally correspond to a severe storm with heavy rain and resulting flooding. Mass movement is most likely to occur during late winter when the water table is high. A short, intense storm could cause saturated soil to move, resulting in landslides. After heavy rains from November to December, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. As rains continue, the groundwater table rises, adding to the weakening of the slope.

Gravity, poor drainage, a rising groundwater table and poor soil exacerbate hazardous conditions.

Based on historical events and steep slopes with a potential for instability, the most likely landslide areas are Everett, Mukilteo and Edmonds. However, mass movements can occur anywhere in the county that has been affected by historical landslides or that has steep slopes.

Mass movements are becoming more of a concern as development moves outside of city centers and into areas less developed in terms of infrastructure. Most mass movements would be isolated events affecting specific areas. It is probable that private and public property, including infrastructure, will be affected. Mass movements could affect bridges that pass over landslide-prone ravines and knock out rail service through the county. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas. Property owners exposed to steep slopes may suffer damage to either property or building structures. Landslides carrying vegetation such as shrubs and trees may cause a break in utility lines, cutting off power and communication access to residents.

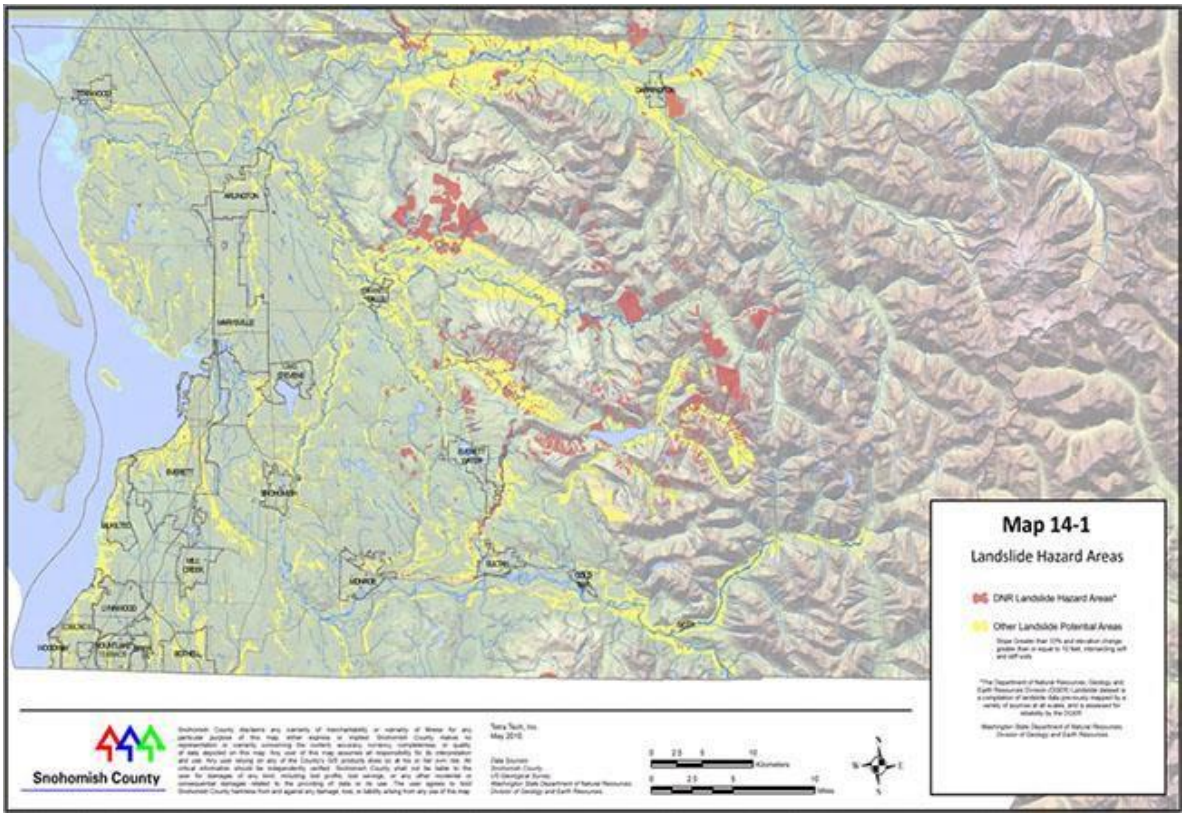
Continued heavy rains and flooding will further complicate the problem. As emergency response resources are applied to problems with flooding, it is possible that they will be unavailable to assist with landslides occurring throughout Snohomish County.

Group 6: Issues

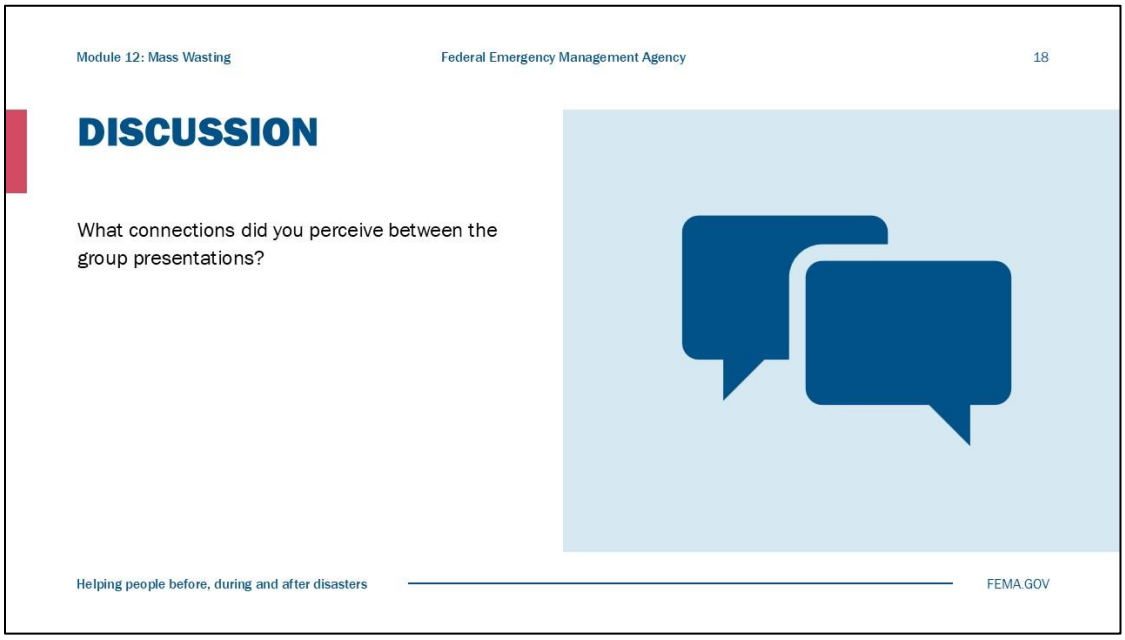
Important issues associated with landslides in Snohomish County include the following:

- There are existing homes in mass movement-prone areas, specifically on the Puget Sound shoreline, with the Cities of Everett and Mukilteo being affected significantly.
- Future development could lead to more homes in mass movement-prone areas. These areas include the foothills of the Cascades and steep slope areas above the river floodplains of the North and South Forks of the Stillaguamish River and the Skykomish River.
- The data and science regarding the mapping and assessment of landslide hazards are constantly evolving. As new data and scientific findings become available, assessments of landslide risk should be reevaluated.
- The impact of weather trends on landslides is uncertain. If weather trends impacts atmospheric conditions, then exposure to landslide risks in Snohomish County is likely to increase.
- Landslides may cause negative environmental consequences, including water quality degradation.
- The risk associated with the landslide hazard overlaps the risk associated with other hazards such as earthquake, flood and tsunami. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.

Graphical Map 14-1 Landslide Hazard Areas



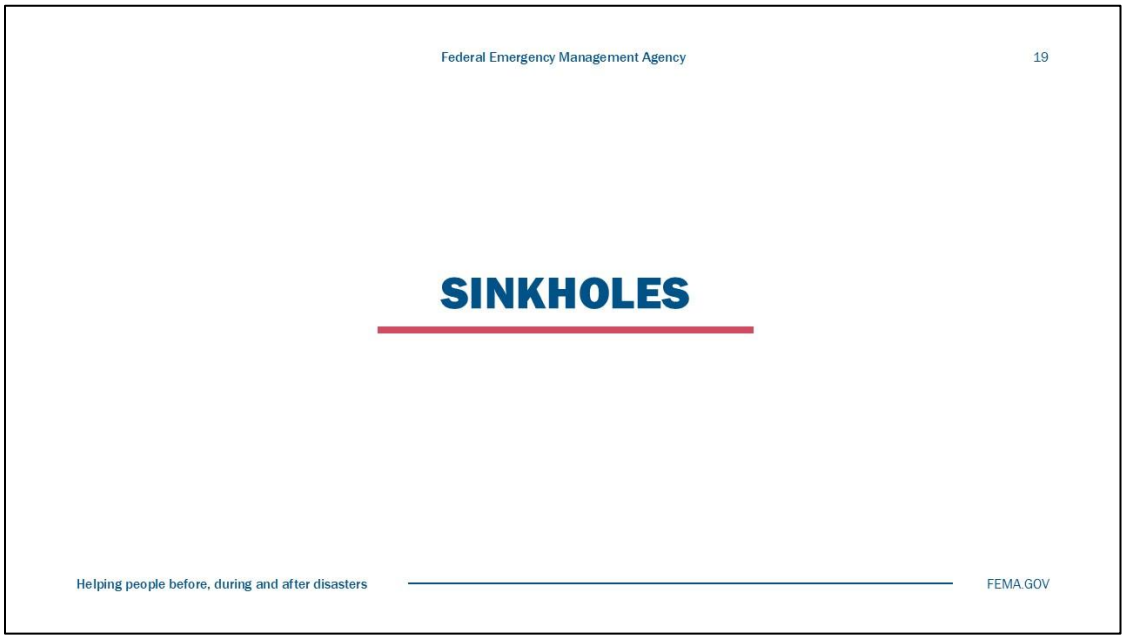
Activity 12.1 Oso Community Public Meeting (3 of 3)



Slide 12-18, Discussion

What connections did the learners make between the group presentations?

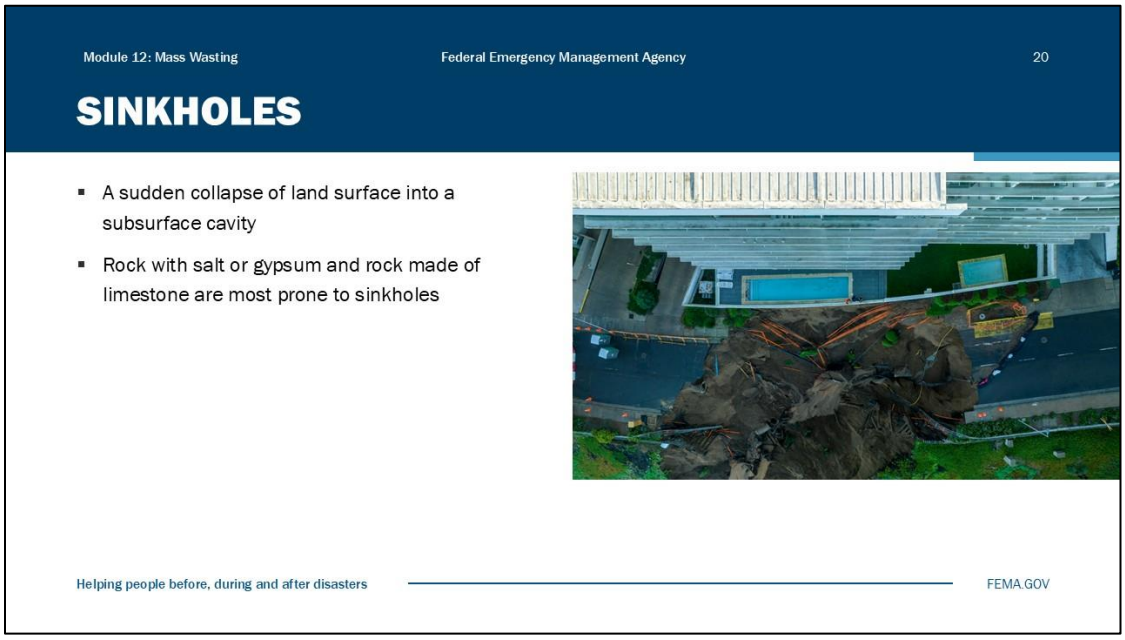
Sinkholes (1 of 10)



Slide 12-19, Sinkholes

Not Applicable.

Sinkholes (2 of 10)



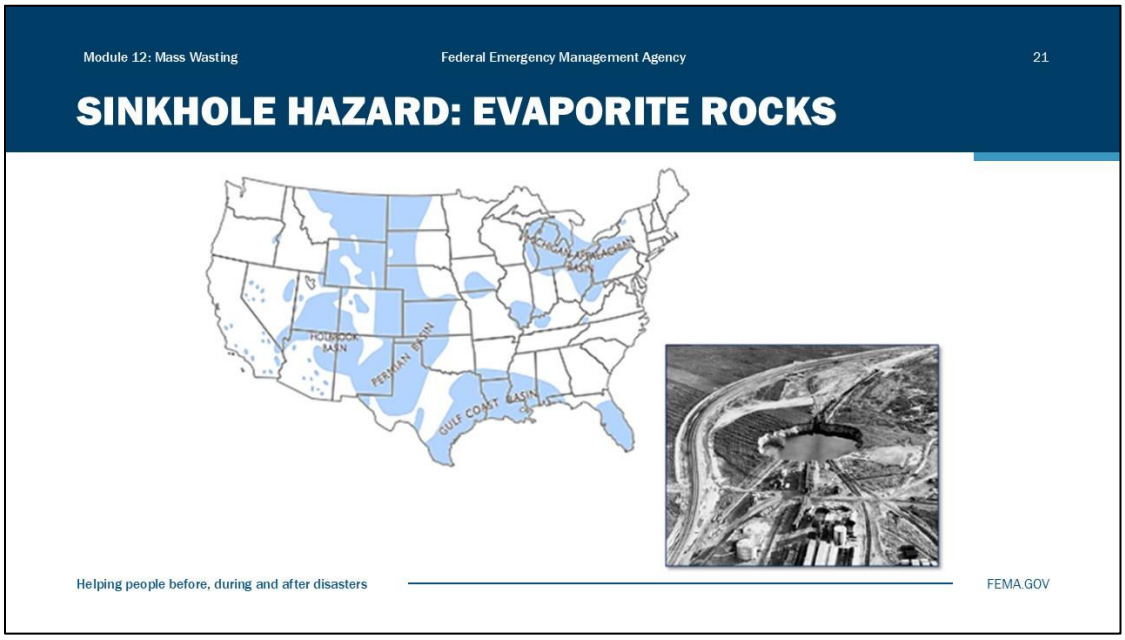
Slide 12-20, Sinkholes

Gravity doesn't stop working when material is flat on the Earth's surface. Sinkholes are one result of this scientific reality.

Description: A sinkhole is the sudden collapse of the land surface into a subsurface cavity.

Susceptible rock formations: Certain rocks are prone to dissolving in water, which can lead to the formation of sinkholes. Rock with concentrations of salt or gypsum, and rock made of limestone, are most prone to sinkholes.

Sinkholes (3 of 10)



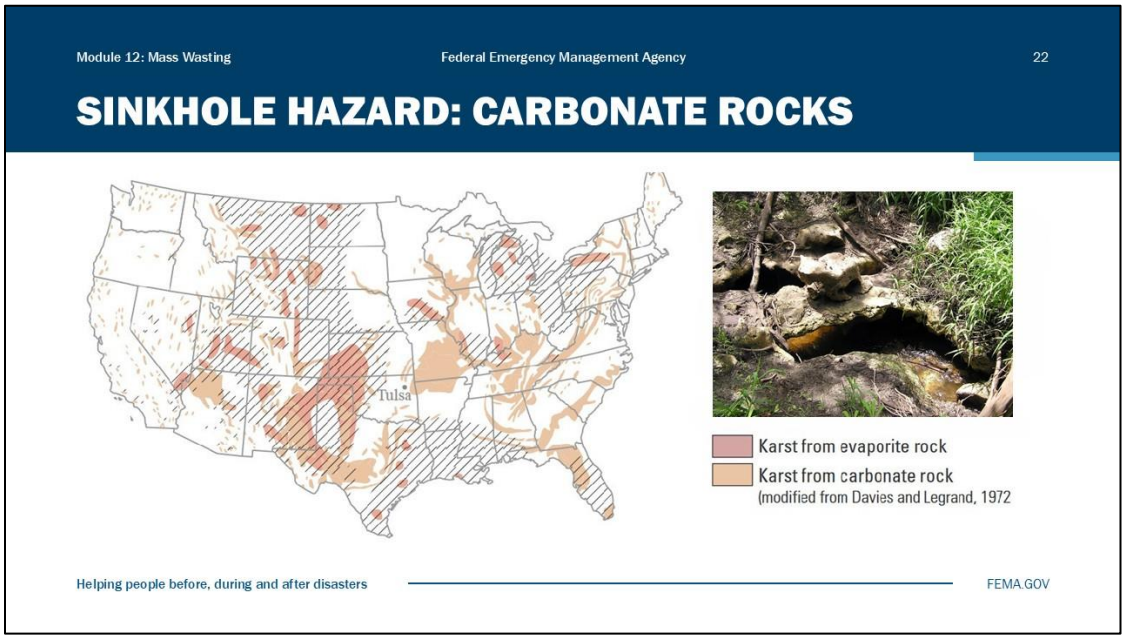
Slide 12-21, Sinkhole Hazard: Evaporite Rocks

Photo: A 300-foot diameter sinkhole with 18 feet of water in Hutchinson, KS. This sinkhole, attributed to operations at a salt processing company, was stabilized, and the railroad tracks through the center of the hole were relocated.

This map shows areas of the contiguous United States that are underlain by evaporite rocks, which have sufficient quantities of salt and gypsum to pose a sinkhole hazard. Ages ago, these areas were inland seas. They comprise about 40% of the contiguous United States.

Human factors: Regardless of underlying rock type, sinkholes are increasingly common in urban areas with aging water systems. An underground pipe break or crack releases water (sometimes pressurized) that erodes the subsurface. When the subsurface can no longer support the surface, the surface collapses, and a sinkhole is formed.

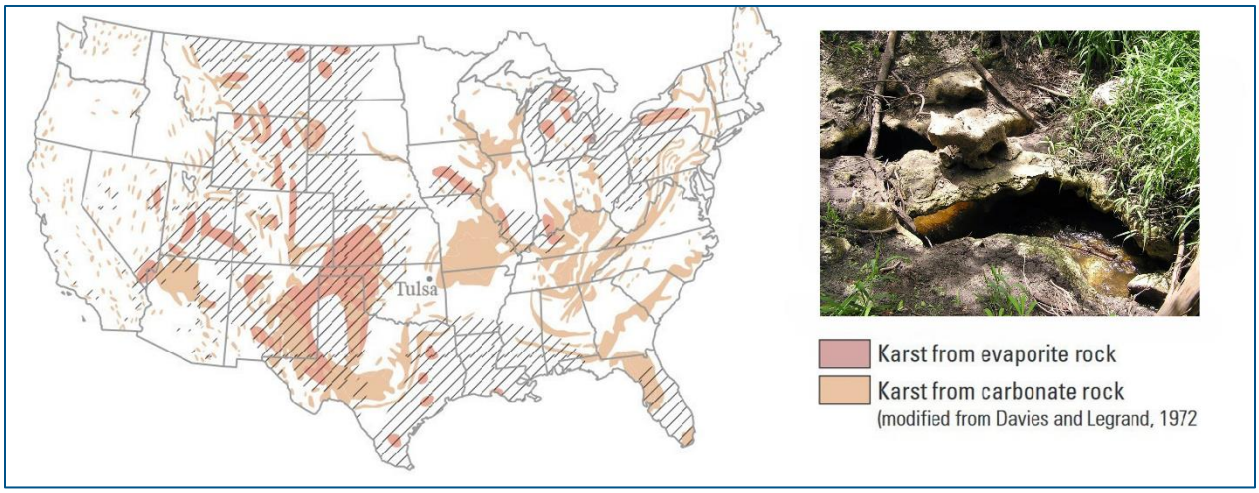
Sinkholes (4 of 10)



Slide 12-22, Sinkhole Hazard: Carbonate Rocks

When evaporite rock (usually containing salt or gypsum) and especially carbonate rock (typically limestone) dissolve, they form a distinctive terrain known as karst topography, created by the flow of water through pores in the rock. Geographical areas with Karst topography visible on the surface should be prepared for the occurrence of sinkholes.

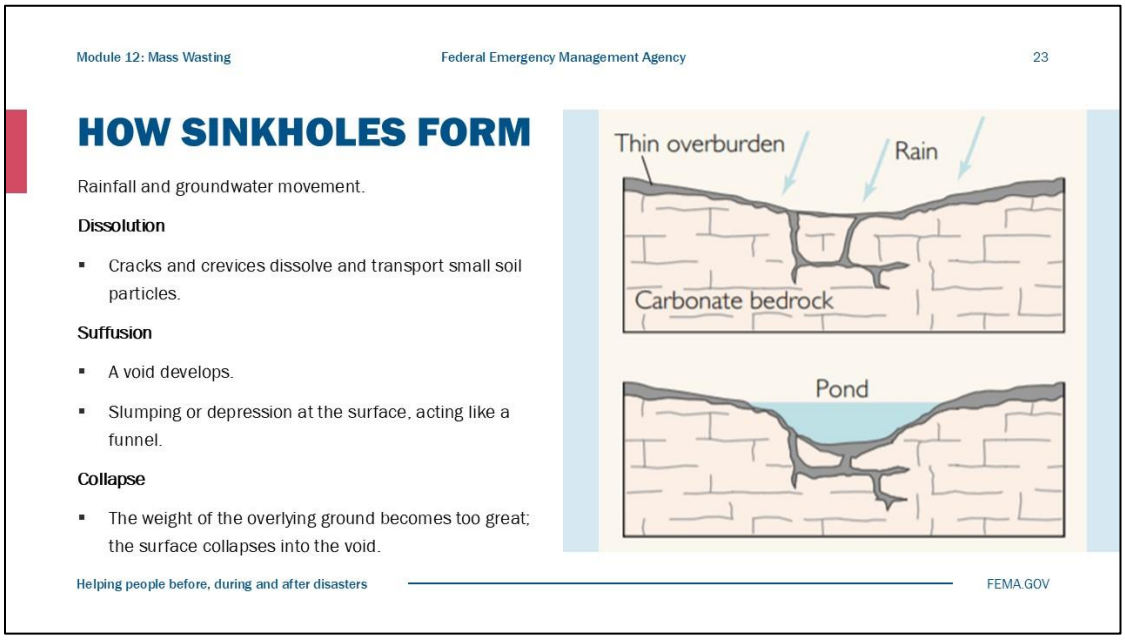
For example, east of Tulsa, OK, about 40 percent of the United States exhibits Karst topography from carbonate rock. These landscapes also tend to be humid, further promoting sinkhole development.



Map of U.S. showing karst areas and karst from carbonate rock topography in Florida, which are prone to land subsidence and sinkholes.

The sudden and sometimes catastrophic subsidence associated with localized collapse of subsurface cavities (sinkholes) is detailed in two case studies. This type of subsidence is commonly triggered by groundwater-level declines caused by pumping and by enhanced percolation of groundwater. Collapse features tend to be associated with specific rock types, such as evaporites (salt, gypsum, and anhydrite) and carbonates (limestone and dolomite). These rocks are susceptible to dissolution in water and the formation of cavities. Salt and gypsum are much more soluble than limestone, the rock type most often associated with catastrophic sinkhole formation. Evaporite rocks underlie about 35 to 40 percent of the United States, though in many areas they are buried at great depths. Natural solution-related subsidence has occurred in each of the major salt basins in the United States. The high solubilities of salt and gypsum permit cavities to form in days to years, whereas cavity formation in carbonate bedrock is a very slow process that generally occurs over centuries to millennia. Human activities can expedite cavity formation in these susceptible materials and trigger their collapse, as well as the collapse of pre-existing subsurface cavities. (*Karst Landscapes Are More Prone to Have Land Subsidence and Sinkholes. | U.S. Geological Survey*, 2017) https://www.usgs.gov/media/images/karst-landscapes-are-more-prone-have-land-subsidence-and-sinkholes

Sinkholes (5 of 10)

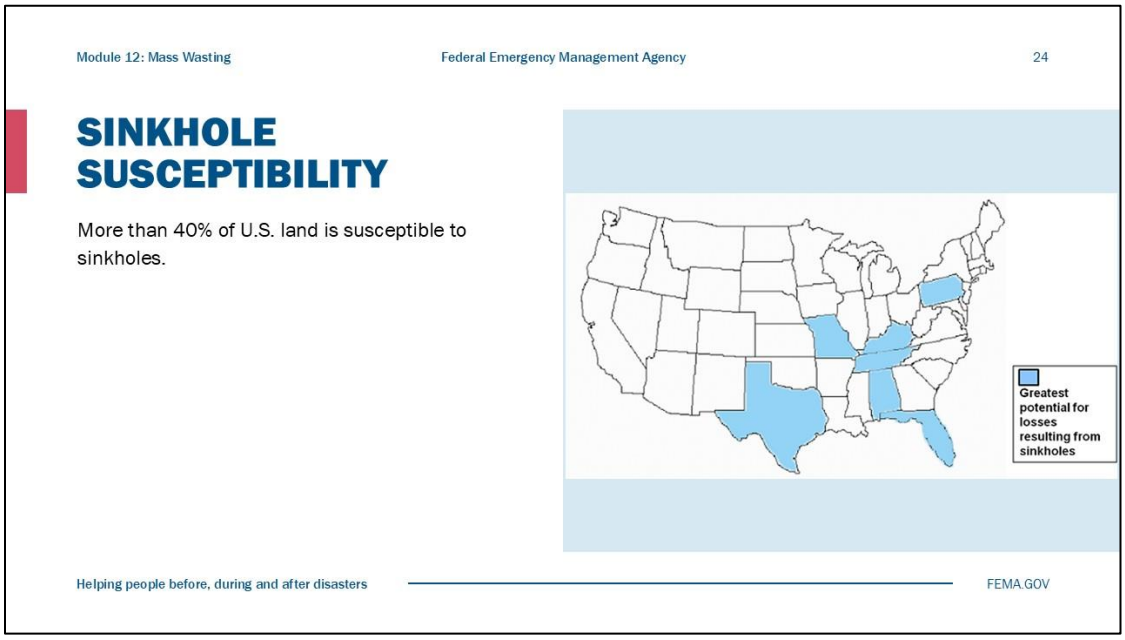


Slide 12-23, How Sinkholes Form

Sinkholes can be formed by **dissolution**, **subsidence**, or **collapse** of the covering materials of the cover.

- **Dissolution**: The process of sinkhole dissolution begins with rainfall. Groundwater moves through the soil, encountering and dissolving cracks and crevices in the rock (e.g., Karst terrain).
- **Suffusion**: Soon, the cracks and crevices start transporting small soil particles, resulting in the formation of a void below (suffusion) and a slumping or depression at the ground's surface. This depression behaves like a funnel, gathering even more water and washing away more soil below.
- **Collapse**: At some point, the weight of the overlying ground becomes too great, or the dissolved area becomes too large, and the surface collapses into the void.

Sinkholes (6 of 10)

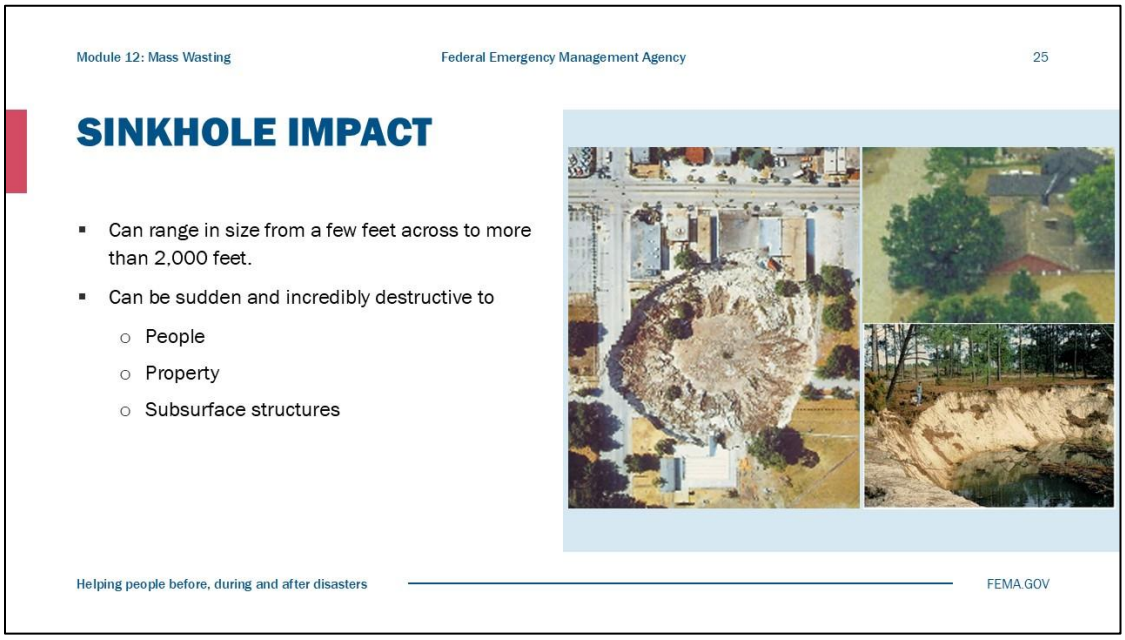


Slide 12-24, Sinkhole Susceptibility

More than 40 percent of the land in the United States is susceptible to sinkholes. As shown on the map, the greatest potential for losses resulting from sinkholes is in:

- Florida
- Texas
- Alabama
- Missouri
- Kentucky
- Tennessee
- Pennsylvania

Sinkholes (7 of 10)



Slide 12-25, Sinkhole Impact

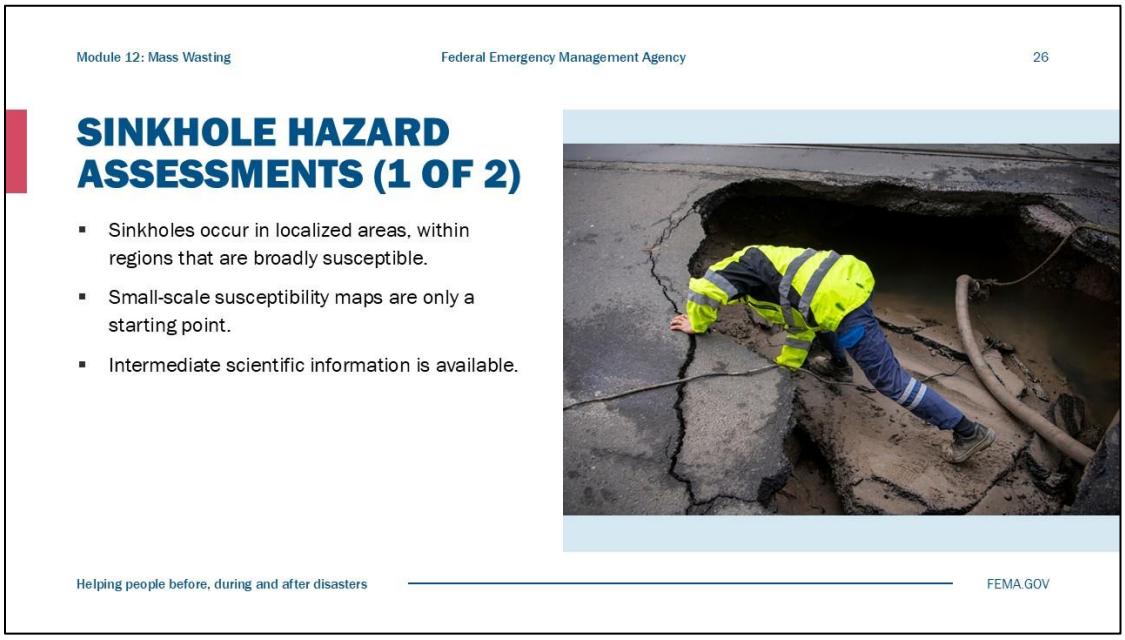
Size and shape: Sinkholes typically measure feet or tens of feet across. Sometimes (but very rarely), they can be hundreds of feet across. The largest known sinkhole is in China and is nearly 2,200 feet across. Sinkholes also vary in shape—they can be shaped like shallow bowls or saucers or even have vertical walls.

Impact on people and property: Sinkholes can be catastrophically destructive to people and structures on the surface. For example, in March 2013, a sinkhole 30 feet wide by 30 feet deep opened up under a house near Tampa, Florida, swallowing a bedroom and the man in it. Rescuers were unable to save the man.

Impact on subsurface structures: Sinkholes also pose problems for subsurface structures such as pipelines. The pipeline industry is so concerned about this hazard that it has spearheaded studies to better identify specific locations at risk from sinkhole development. Similarly, sinkholes can cause:

- Delay of major construction projects
- Contamination of groundwater resources

Sinkholes (8 of 10)



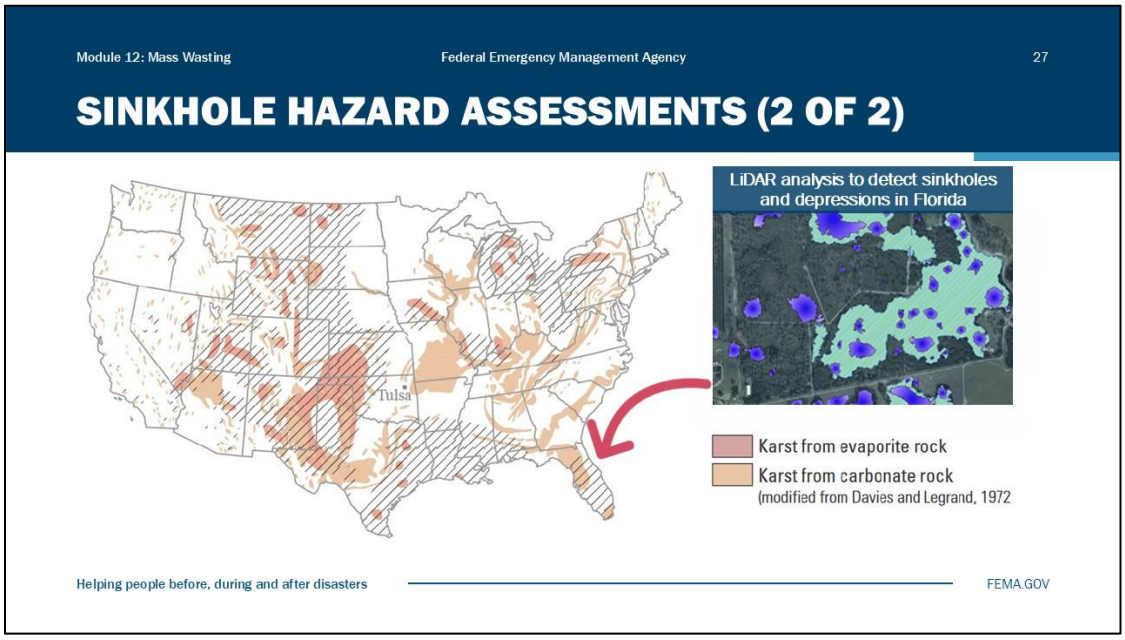
Slide 12-26, Sinkhole Hazard Assessments (1 of 2)

Sinkholes occur in localized areas within broadly susceptible regions. Small-scale maps showing the broad areas of susceptibility are only valuable as a starting point to identify areas where more detailed studies are warranted.

There are many scientific methods to get images of the subsurface, but these have not been applied to sinkhole hazard assessments. In most areas, detailed datasets about specific subsurface conditions and Karst topography evolution may never be feasible to maintain and update. (Even if that information were known, the timing of collapse could still be uncertain.)

However, there is scientific information available that is intermediate in map scale and usefulness-intermediate between information that is too broad to be useful in a particular locale, and desired information that is too specific to be feasible except in very limited areas.

Sinkholes (9 of 10)



Slide 12-27, Sinkhole Hazard Assessments (2 of 2)

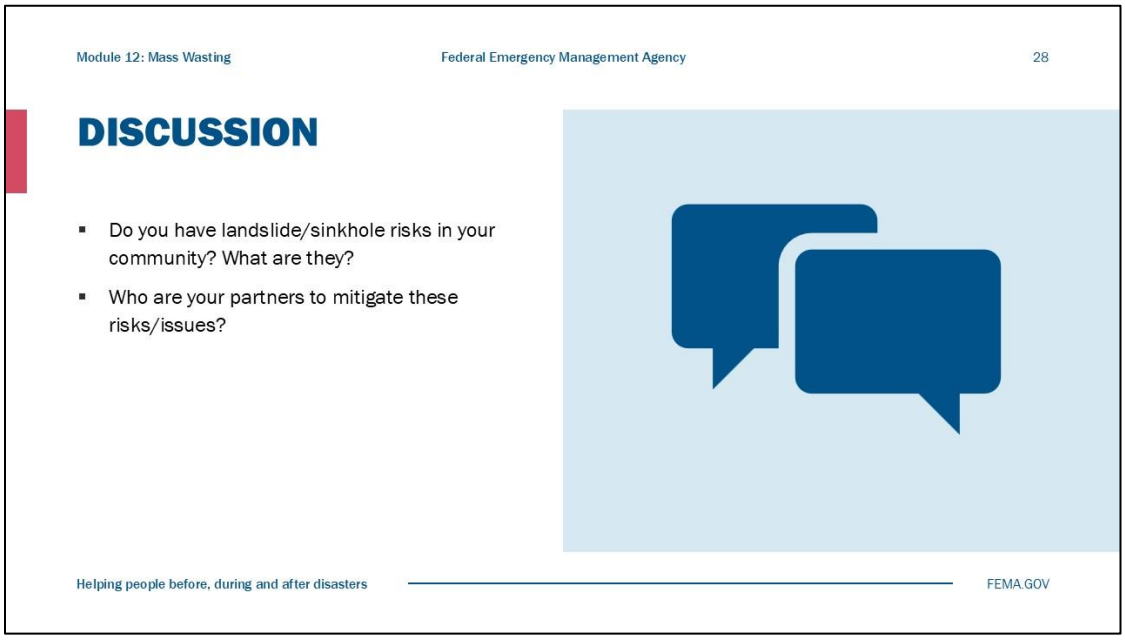
Light detection and ranging technology: Aerial photography and airborne LiDAR (Light Detection and Ranging) imaging can identify specific Karst features that may help in planning the location of critical structures. If a region is monitored over time, the evolution of these Karst features may provide an early warning of dangerous landscape changes.

A particularly interesting study in sinkhole hazard assessments comes from the University of South Florida. This study considers LiDAR mapping of currently visible sinkholes and depressions, as seen in the image here, and compares this with examination of aerial photos from the 1920s to identify sinkholes and depressions that have since been covered by urbanization.

Monitoring groundwater levels: In some places, it may be useful to monitor groundwater levels. A 1999 study found that Florida's sinkhole development is related to pressures at depth, where near-surface groundwater overlies a deeper groundwater reservoir.

Source: *Sinkholes | U.S. Geological Survey*. (2018, October 9). https://www.usgs.gov/special-topics/water-science-school/science/sinkholes

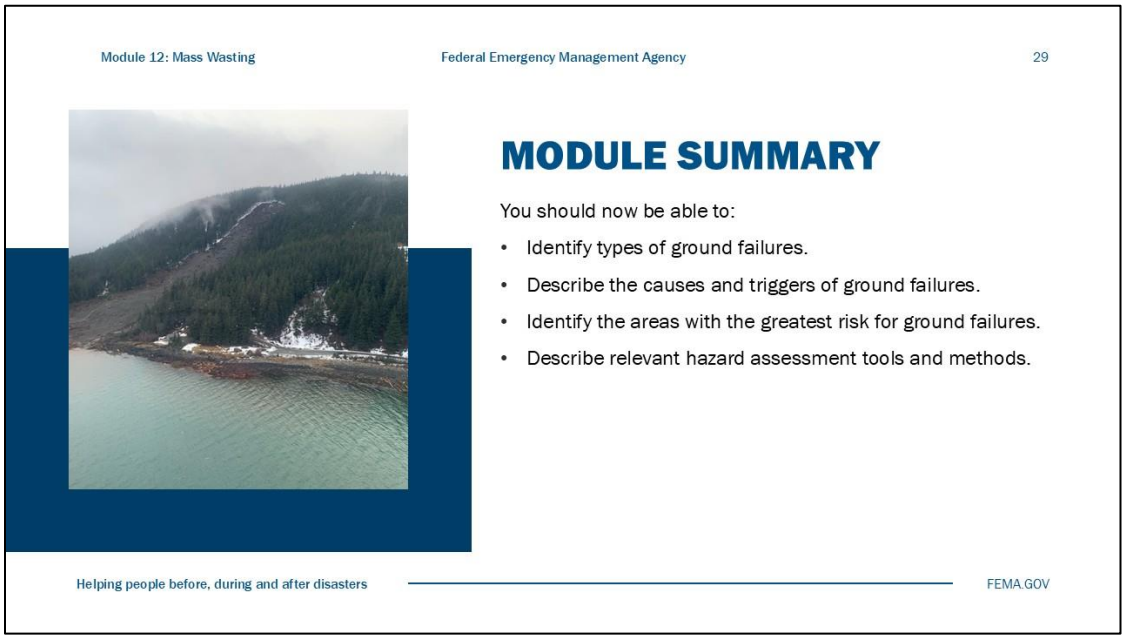
Sinkholes (10 of 10)



Slide 12-28, Discussion

- Do you have landslide/sinkhole risks in your community? What are they?
- Who are your partners to mitigate these risks/issues?

End of Module (1 of 2)

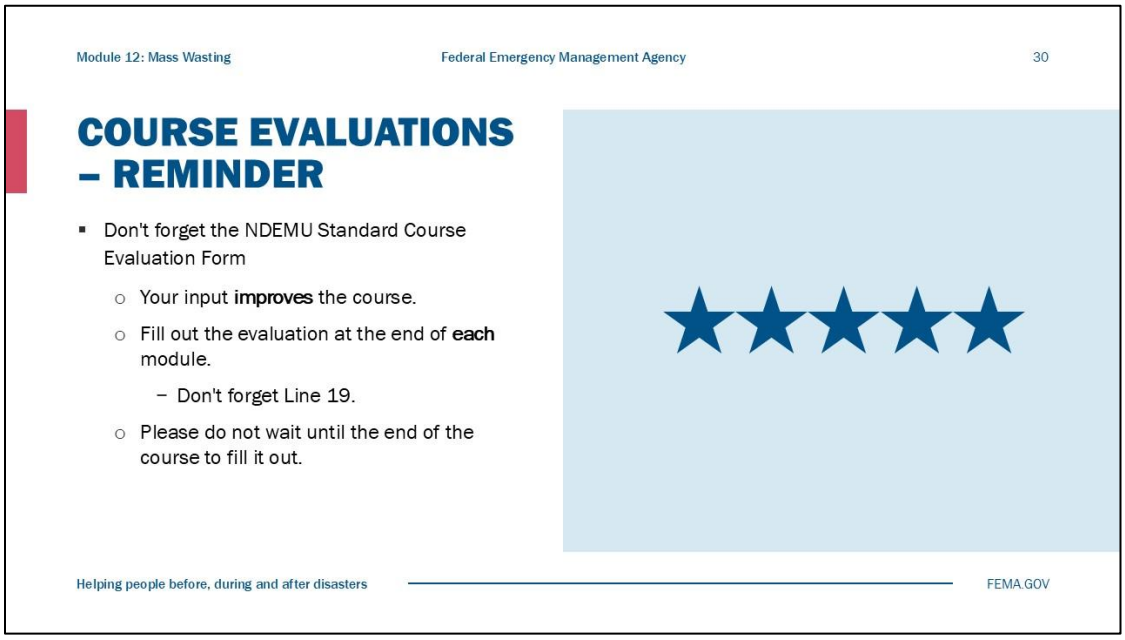


Slide 12-29, Module Summary

You should now be able to:

- Identify types of ground failures;
- Describe the causes and triggers of ground failures;
- Identify the areas with the greatest risk for ground failures
- Describe relevant hazard assessment tools and methods

End of Module (2 of 2)



Slide 12-30, Course Evaluations - Reminder.

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

Reference List

King County Sheriff Air Support (Director). (2014, March 25). *Oso Mud Slide Before and After* [Video recording]. https://www.youtube.com/watch?v=1_G3ReEAr6I

Landslide Hazards Program | U.S. Geological Survey. (2025, April 22). https://www.usgs.gov/programs/landslide-hazards

Paleo, U. F. (2009). *Building Safer Communities: Risk Governance, Spatial Planning and Responses to Natural Hazards*. IOS Press.

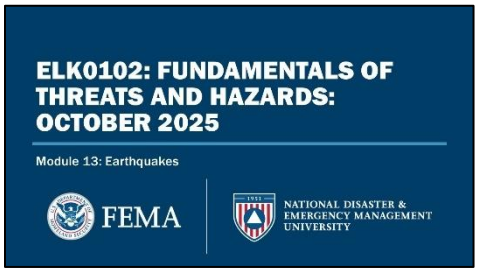
Sinkholes | U.S. Geological Survey. (2018, October 9). https://www.usgs.gov/special-topics/water-science-school/science/sinkholes

USGS Groundwater Information: Land Subsidence in the U.S. (USGS Fact Sheet 165-00). (n.d.). Retrieved October 14, 2025, from https://water.usgs.gov/ogw/pubs/fs00165/

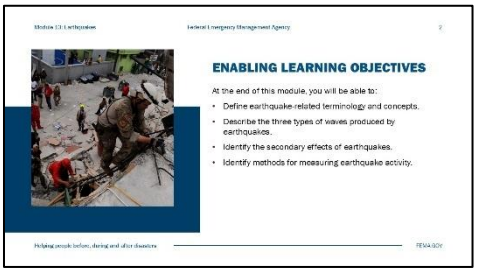
Module 13

Earthquakes

Administration



Slide 13-1, Module 13: Earthquakes



Slide 13–2, Enabling Learning Objectives

Duration

30 minutes

Terminal Learning Objective (TLO)

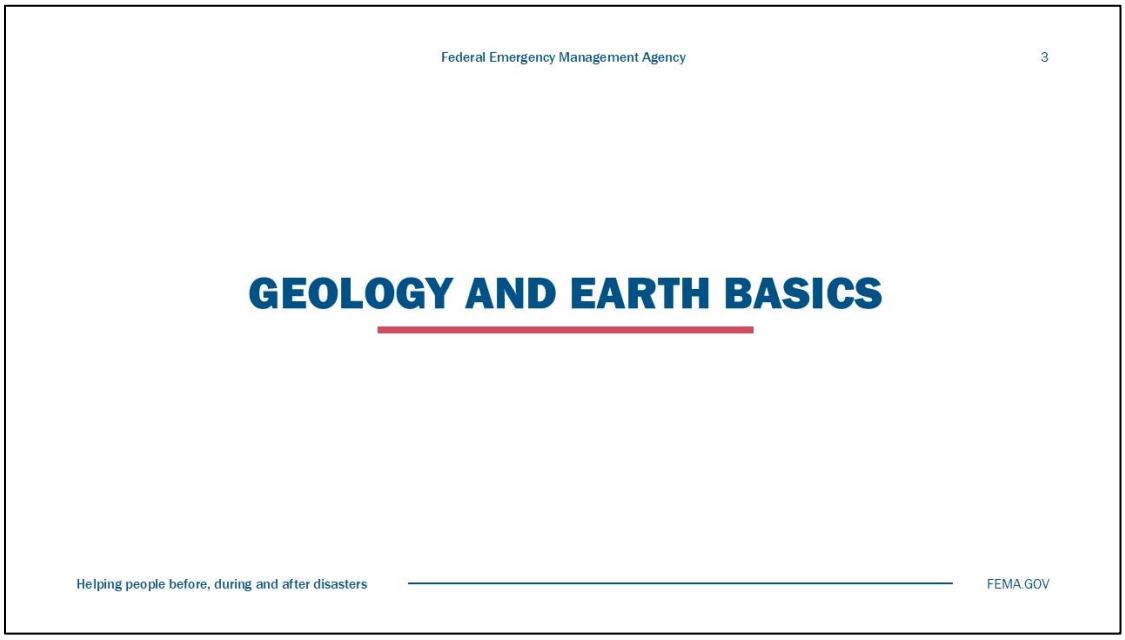
By the end of this module, participants will be able to explain the causes and effects of earthquakes, understand earthquake monitoring and forecasting, and apply earthquake-related knowledge to emergency management strategies.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Define earthquake-related terminology and concepts.
- Describe the three types of waves produced by earthquakes.
- Identify the secondary effects of earthquakes.
- Identify methods for measuring earthquake activity.

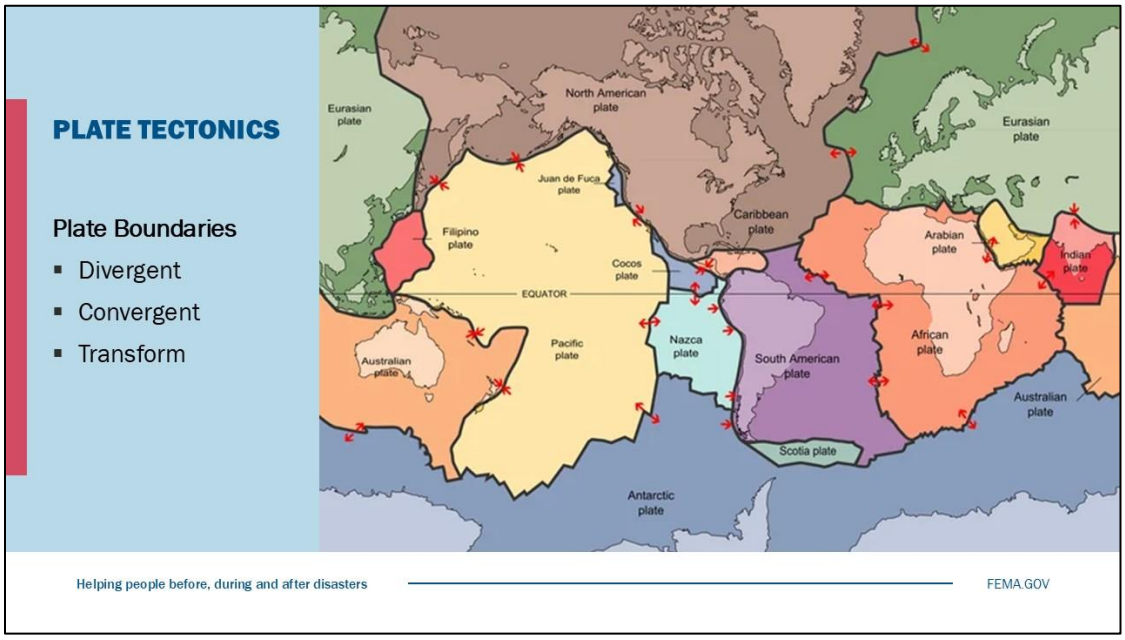
Geology and Earth Basics (1 of 12)



Slide 13–3, Geology and Earth Basics

Not Applicable.

Geology and Earth Basics (2 of 12)



Slide 13–4 Plate Tectonics

Plate Tectonics Image Description—*The map on the visual shows the current plates and their boundaries. Most of the contiguous United States and Alaska sit on the North American Plate. Westernmost southern California is along the boundary of the Pacific plate. Hawaii lies on the Pacific Plate. The Pacific and North American Plates slide past each other at about 50 mm a year—about the rate that fingernails grow.*

Plate tectonics accounts for much of what happens at the Earth's surface and creates natural hazards. The theory of plate tectonics states that the Earth's lithosphere is fragmented into enormous blocks of rock called plates that move relative to one another as they ride atop hotter, more mobile material.

Plate boundaries: There are three types of plate boundaries:

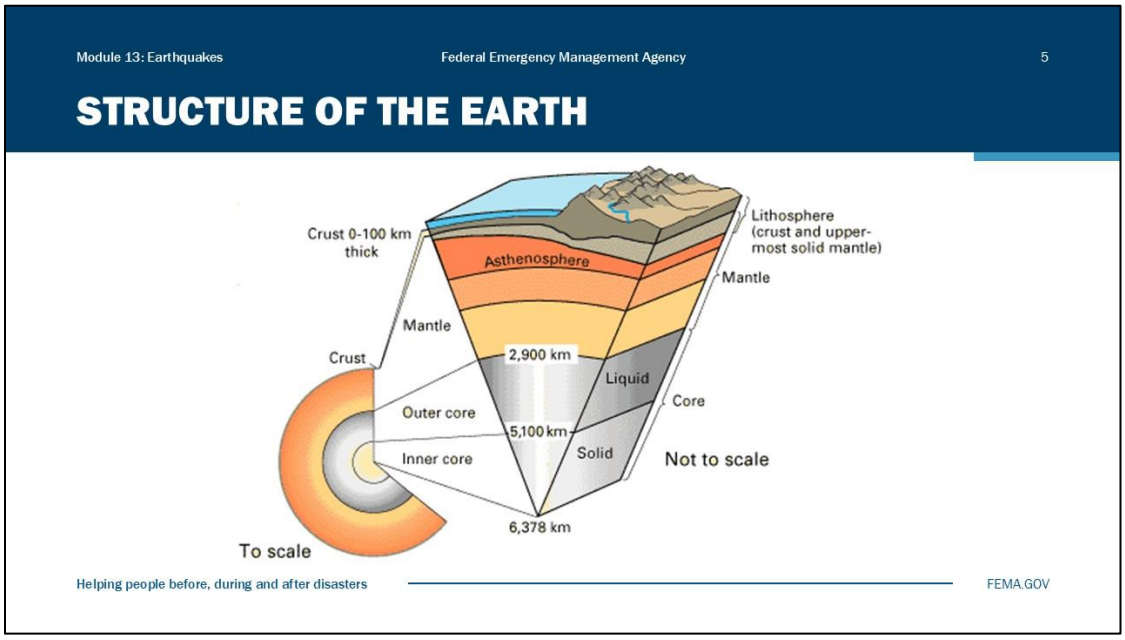
- Divergent boundaries: where new crust is generated as the plates pull away from each other;
- Convergent boundaries: where crust is destroyed as one plate dives under another; and
- Transform boundaries: where crust is neither produced nor destroyed as the plates slide horizontally past each other.

The number and sizes of plates, their directions of motion, and their styles of motion change over time, but there is no net change in size (i.e., the circumference of the Earth remains the same).

Plate locations: The map on the visual shows the current plates and their boundaries. Note:

- Most of the contiguous United States and Alaska sit on the North American Plate.
- Westernmost southern California is along the boundary of the Pacific plate. Hawaii lies on the Pacific Plate.
- The Pacific and North American Plates slide past each other at about 50 mm a year—about the rate that fingernails grow.

Geology and Earth Basics (3 of 12)



Slide 13–5, Structure of the Earth

Learning about the interior of the Earth helps us understand some of the forces that affect natural hazards.

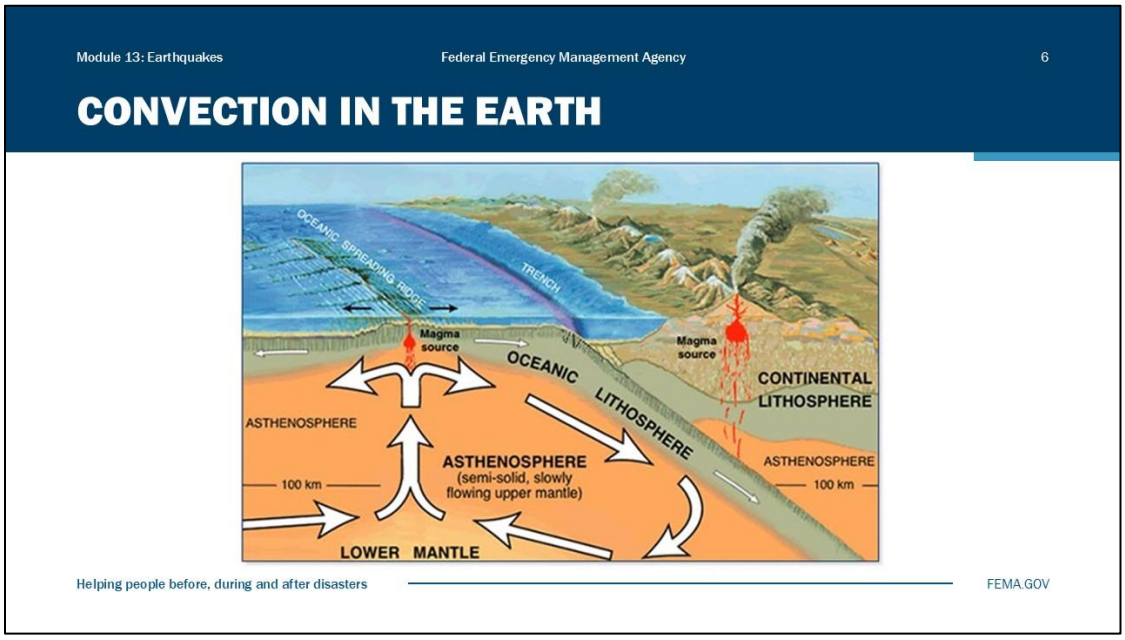
Layers

The Earth consists of three internal layers: the **core**, the **mantle**, and the **crust**. This magnified cross-section of the Earth shows some of the details of those three basic layers.

- **Core:** If you programmed your car to drive from San Diego to Nova Scotia, then drove straight down instead, you would be near the center of the Earth, which is about 4,000 miles directly beneath us. The layer around the center is called the core. The inner core consists of a solid iron-nickel alloy, and the outer core consists of liquid iron-nickel alloy. The flow of this extremely hot material produces the Earth's magnetic field.
- **Mantle:** This flow of material, called convection, also occurs in the next layer, the mantle (the orange section of the drawing). The mantle is the thickest of the Earth's layers. There are pockets of liquid in the mantle, but most of the mantle is solid rock.
- In the mantle layer called the asthenosphere, this rock is under such high pressures and temperatures that it can flow even though it is solid. Flow in the asthenosphere directly affects hazards on the Earth's surface.

- **Lithosphere:** The lithosphere includes the uppermost solid mantle and the crust, which includes oceanic and continental crusts. All life exists on the crust of the Earth, a layer so thin that it is barely visible as a thin line when drawn to scale with the other layers of the Earth. Its height is exaggerated in this drawing to be visible.

Geology and Earth Basics (4 of 12)



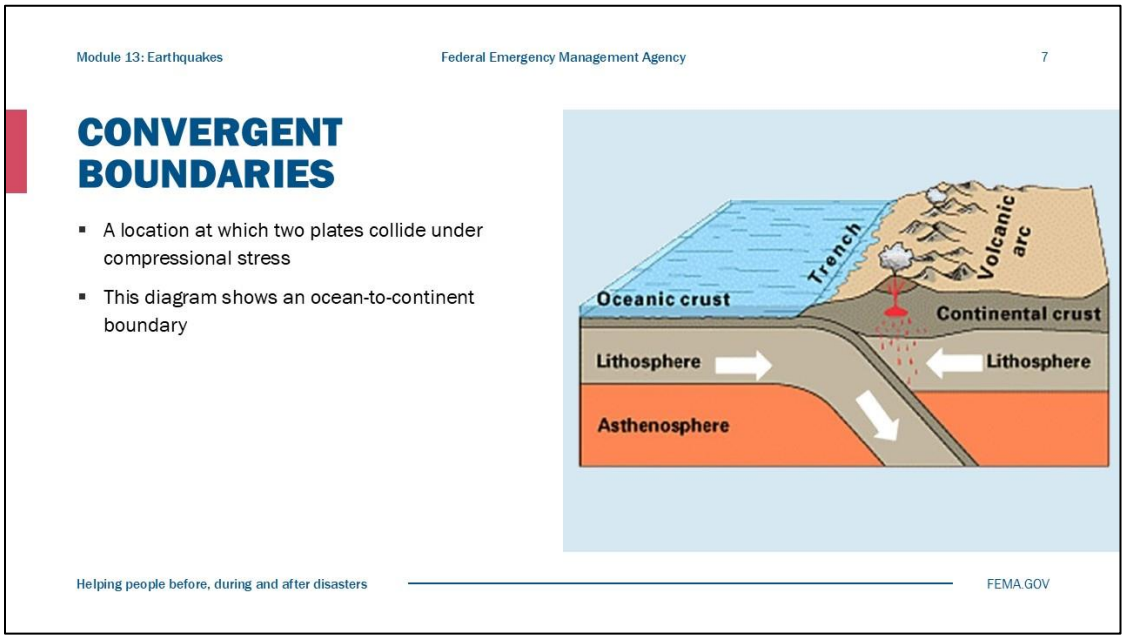
Slide 13–6, Convection in the Earth

A similar process of convection within the Earth is an essential component in the creation of many of our hazards.

The heat source is a process called **radioactive decay**, in which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays, and conversion electrons, and releases heat as they change. Thousands of miles of rock provide immense insulation, resulting in the trapping of a lot of heat inside the Earth. The hot rock deep in the mantle rises, cools, and sinks—creating convection cells in the **asthenosphere**.

Above the asthenosphere's convection cells is a shell of cold, hard, brittle rock typically about 80 miles thick—the **lithosphere**, which includes rock of the crust and the uppermost mantle.

Geology and Earth Basics (5 of 12)



Slide 13-7, Convergent Boundaries

Ocean-to-Continent

A convergent plate boundary is a location at which two plates collide under compressional stress. This diagram shows one type of convergent plate boundary—an ocean-to-continent boundary.

Another convergent boundary is an ocean-to-ocean boundary where the plates meet underneath the ocean. The kinds of rocks that underlie oceans have very different properties from the kinds of rock that make up continents, so scientists make distinctions between oceanic rock and continental rock. At a convergent boundary:

- Two plates meet and are pushed toward each other.
- As the two plates collide, if there is a big difference in density between the plates, one plate slides under the other (subduction), and the boundary of the two plates is marked by a trench.
- Whichever plate is denser is the one that sinks. At a continental boundary, it is always the ocean plate that subducts, because a continental plate is less dense and more buoyant. At an ocean-to-ocean boundary, the plate that is older will be denser and colder and will therefore subduct.
- As the subducting plate descends into the asthenosphere, it releases water, which triggers the melting of rock, generating magma—molten rock below the Earth's surface.

The magma is less dense than the surrounding rock and begins to rise toward the surface.

(Recall the discussion of the convection cell.) We'll talk more about magma in a later module.

- The rising magma creates a line of volcanic islands (if in the ocean), or a row of volcanoes embedded within a coastal mountain range (if on a continent) on the overlapping plate.
- Plate collisions produce very large earthquakes. In subduction zones, earthquakes occur in the subducting plate, the overriding plate, and in between the plates.
- Subduction zones create the largest earthquakes and the largest tsunamis on the planet.

Geology and Earth Basics (6 of 12)



Slide 13–8, Convergent Boundaries: Continent to Continent

Image Description: *Four Images: Image 1: A diagram showing continent-to-continent movement. The levels are mountain range and high plateau, continental crust, lithosphere, asthenosphere, and ancient oceanic crust. Image 2: Mt. Everest, Himalayas. Image 3: Appalachians. Image 4: A map showing India's movement from 71 million years ago to today.*

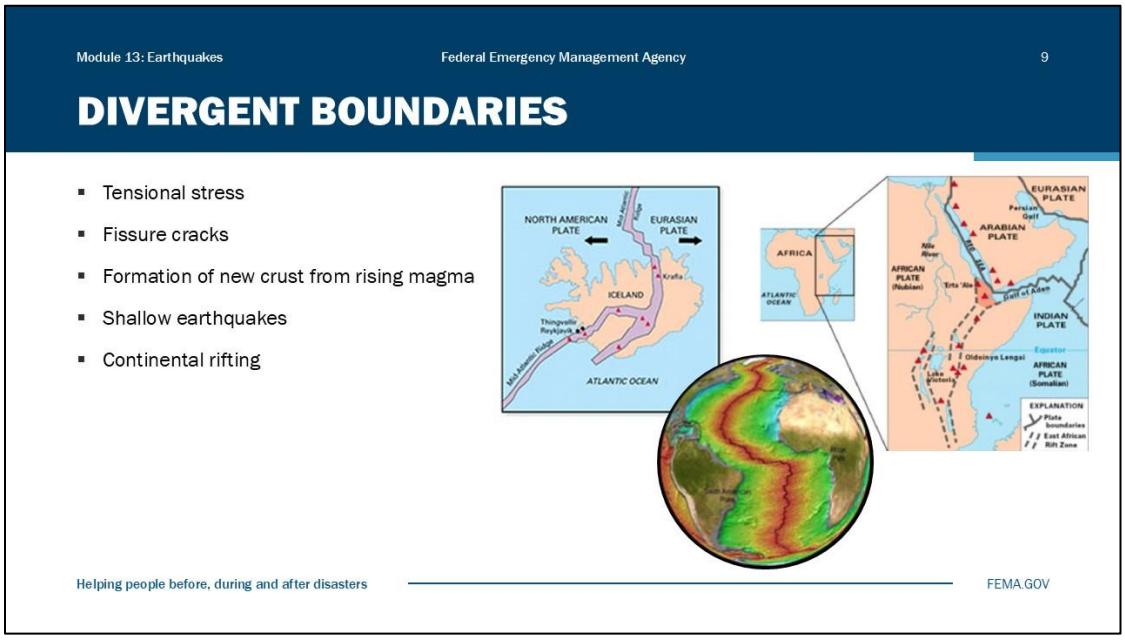
Another situation occurs when two continental plates converge. Because both plates are buoyant, neither plate subducts, and everything is pushed upward.

For example, the Himalayan Mountains are the result of India crashing into Eurasia. These mountains, along the current plate boundary, are still growing. Because there is no subduction, there are few (if any) volcanoes, but the region is experiencing tremendous compressional stress over a large area, leading to many earthquakes.

Uplifting the rock at a plate boundary, one earthquake at a time, can take tens of thousands of years until it is tall enough to form a mountain range. It takes even longer to wear a mountain range away.

The Appalachians, along a former plate boundary, are in the process of weathering away. They formed hundreds of millions of years ago, and at one time were mightier than today's Himalayas.

Geology and Earth Basics (7 of 12)



Slide 13–9, Divergent Boundaries

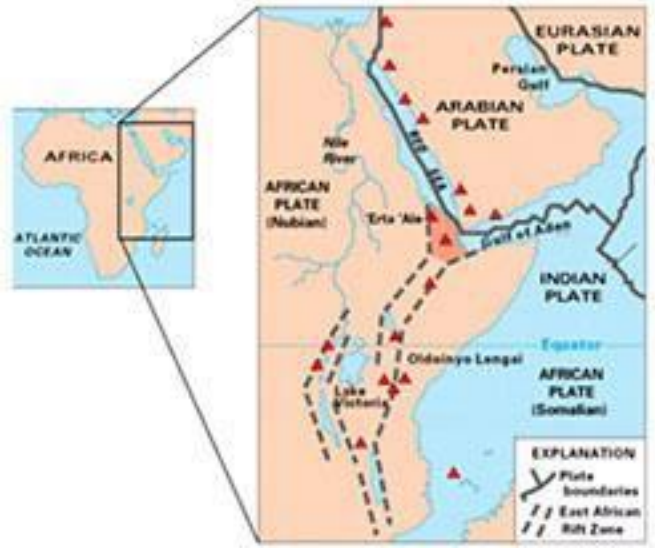
Divergent Boundaries Image Description—*Three images: Image 1: A globe showing a crack between the South American Plate and the African Plate. Image 2: A magnified view of a map of East Africa. Image 3: The map shows plate boundaries, the East African Rift Zone, and different plates. A map showing Iceland and the North American Plate and the Eurasian Plate.*

At a divergent plate boundary, two plates move away from each other under tensional stress. Shallow, low-to-medium-magnitude earthquakes occur at divergent plate boundaries.

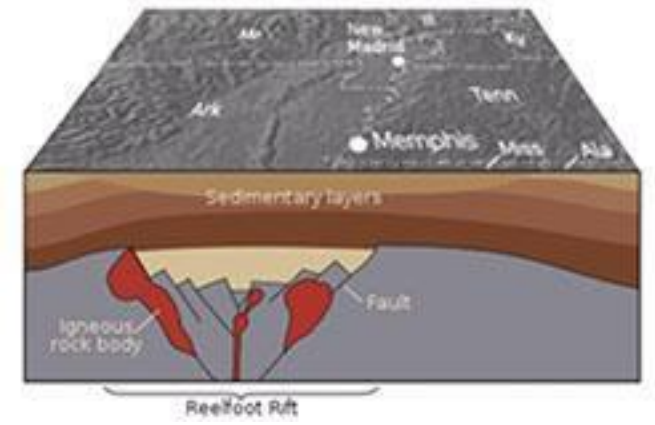
- Under an ocean: When a divergent plate boundary lies under an ocean, the oceanic crust becomes very thin and cracks, opening fissures. Traditional cone-shaped volcanoes with a central vent do not form at these locations. Rather, magma moves up to the surface through the fissures and solidifies, creating new oceanic crust.
- Under a continent: When a divergent plate boundary lies under a continent, the process is similar, and the continent can gradually be ripped apart to form new oceans through a process called continental rifting.

As the crust thins and fissures occur, the overall elevation of the region becomes low enough for shallow seas to form. Modern examples of continental rifting are the Red Sea and the East African Rift Valley. The Red Sea began as a continental rift and is now a mid-ocean ridge.

The East African Rift.

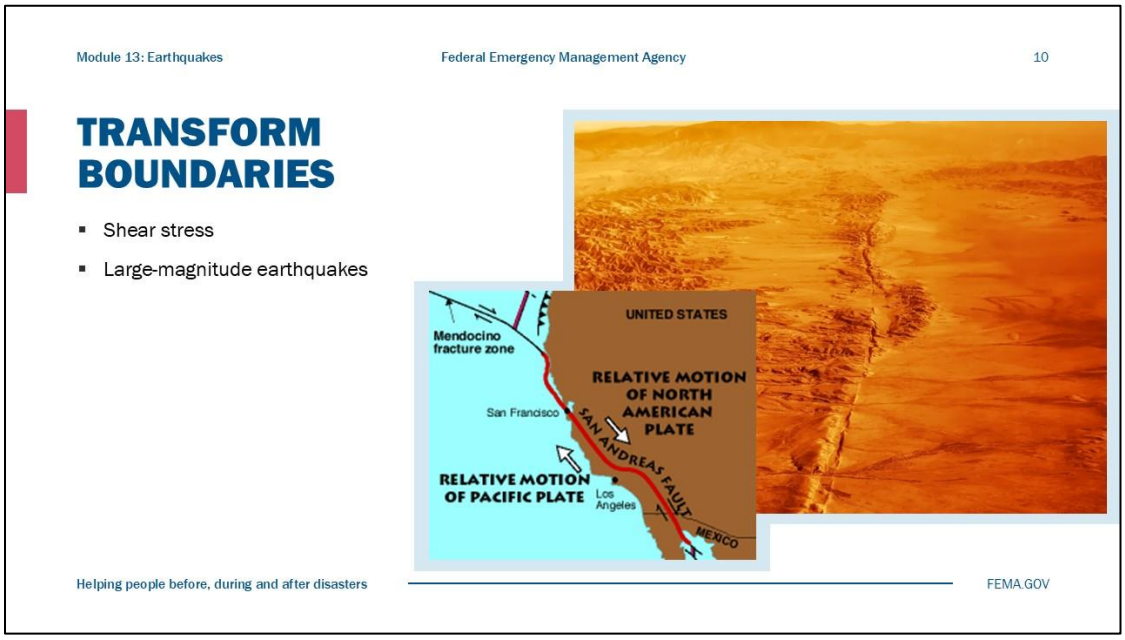


Some scientists think that earthquakes in Tennessee and Missouri result from an old, failed divergent plate boundary. They hypothesize that the New Madrid seismic zone is a result of an ancient (500-million-year-old) buried northeast-trending continental rift known as the Reelfoot Rift (shown in cross-section below).



This is an excellent example of how the Earth's internal forces change with time. Plate boundaries are not fixed, permanent features; they develop, change types, change locations, and even cease with time.

Geology and Earth Basics (8 of 12)



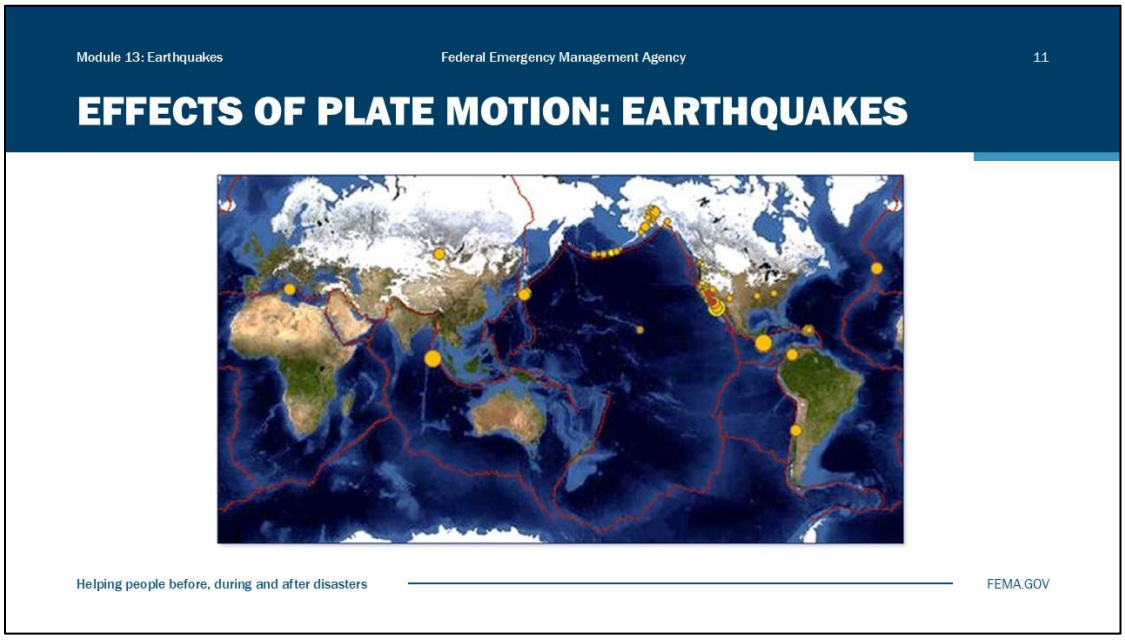
Slide 13–10, Transform Boundaries

Transform plate boundaries occur where two plates slide past each other under shear stress.

In this situation, there is no subduction, and volcanoes do not form. However, tremendous frictional stress can still create large, destructive earthquakes.

The most famous example of a transform plate boundary is the San Andreas Fault running through California. This fault marks the boundary between the North American Plate and the Pacific Plate and will be explored in greater detail in the next module.

Geology and Earth Basics (9 of 12)



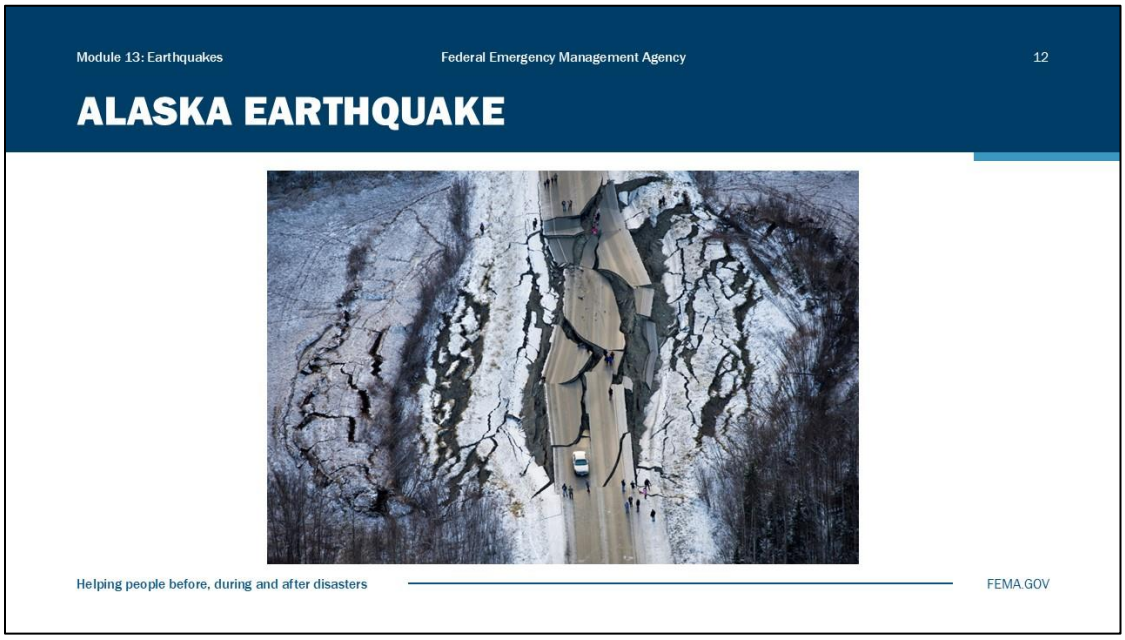
Slide 13–11, Effects of Plate Motion: Earthquakes

Earthquakes Image Description—*A global map marking earthquakes and tsunamis along plates. Earthquake points are above Africa, to the left of Indonesia, in mid-Russia, and off the coast of Russia. A chain of earthquakes occurs between Russia and Alaska, with a cluster occurring between Alaska and Canada. A cluster of earthquakes is marked along the U.S. West Coast and across the Midwest. There is a large occurrence around Panama and out to the Leeward Islands, and an occurrence along Chile. There is also an occurrence on the plate in the Atlantic Ocean.*

The forces of plate tectonics create earthquakes. Most earthquakes occur near plate boundaries, represented by the lines in the map on this visual, which shows one week of earthquakes in August 2012. Earthquakes do occur away from plate boundaries, but less frequently.

Subduction-zone earthquakes can also generate **tsunamis.**

Geology and Earth Basics (10 of 12)



Slide 13–12, Alaska Earthquake

One Year After Big Alaska Earthquake, Many Still Struggle

December 03, 2019 •

Matt Tunseth, Zaz Hollander, Alaska Dispatch News, Anchorage

Key Points

This story provides a comprehensive retrospective on the aftermath of the **November 30, 2018, magnitude 7.1 earthquake in Alaska**, focusing on the **uneven recovery** experienced by residents and communities one year later. Here's a s summary of the main points:

Infrastructure and Property Damage

- **Over 10,500 damage claims** were filed with the federal government.
- **$275 million+** in state and federal aid is estimated; $130 million had been spent by November 2019.
- **Anchorage**: 3,838 properties inspected; 72 red-tagged (uninhabitable), 792 yellow-tagged (restricted use).

- **Matanuska-Susitna Borough**: 2,900 applied for disaster aid; 34 homes destroyed, 380+ with major damage.
- **Roads**: Quick temporary fixes were made (e.g., Vine Road), but permanent repairs are delayed due to complex terrain (e.g., swampy soil).
- **Schools**: $22 million spent to reopen schools; major repairs still pending (e.g., $39 million for Gruening Middle School, $29 million for Houston Middle School).

Personal and Community Impact

- Many families, like the **Harklesses** and **Bakers**, continue to struggle with housing loss or extensive repairs.
- **Federal aid** often fell short of actual repair costs (e.g., $3,000 grants for $300,000 in damage).
- Some residents, like **Antonia Castillo**, were victims of contractor scams, exacerbating their hardship.

Community and Nonprofit Support

- **Faith-based and nonprofit groups**, such as the Anchorage/Eagle River Long Term Recovery Group, stepped in to help vulnerable residents.
- Volunteers provided physical repairs and emotional support, helping restore hope and community bonds.

Key Themes

- **Disparity in recovery**: While public infrastructure saw rapid repairs, many private homeowners and small businesses faced prolonged struggles.
- **Emotional toll**: Beyond physical damage, residents continue to deal with trauma, uncertainty, and financial strain.
- **Resilience and solidarity**: Despite setbacks, many residents found strength in community support and personal perseverance.

Full Story

(TNS) — Schools need fixing, homes are still splintered and families endure discomfort despite hundreds of millions of federal, state and private dollars spent over the past year for rebuilding Southcentral Alaska after the magnitude 7.1 earthquake.

In the days after the Nov. 30, 2018, quake, many residents marveled at the apparent speedy recovery — crumbled roads were repaired within days, most schools were reopened within a week, and life returned pretty much to normal for most. But while many scars from the quake have been

grown over by new grass or covered in fresh paint, a closer look shows the rebuilding efforts have been uneven and fraught with disappointment and compromise.

Officials with the Municipality of Anchorage say determining how many homes and businesses are still unrepaired is a moving target. Since the quake, municipal inspectors have visited 3,838 properties, of which 72 were issued red tags, meaning they were unfit for occupancy. A total of 13 permits were issued for the red-tagged properties, including two homes that were demolished in hard-hit Eagle River. Another 792 “yellow tags” — meaning restricted use — were issued, of which 286 have since been issued permits.

In the Matanuska-Susitna Borough, where there is no municipal inspection office, quake damage to homes and businesses is also tough to quantify. About 2,900 people in the borough applied for state disaster assistance, borough emergency managers say. Thirty-four applicants put themselves in the “destroyed” category. More than 380 reported major damage.

State officials said it’s difficult to put a price tag on damages, but Jeremy Zidek with the Alaska Division of Homeland Security and Emergency Management estimates the total state and federal assistance related to the quake will top $275 million. As of the end of November, Zidek said $130 million in state and federal assistance had already been spent.

Some needed infrastructure work has been completed — such as a $1.8 million fix for a Glenn Highway bridge — while other projects remain in the planning stages.

Vine Road, the two-laner outside Wasilla that became the symbol of the quake’s destruction, got a temporary fix soon after the shaking tore pavement into a jumble of upheaved asphalt. A viral aerial photo showed an Alaska road that looked like a bomb hit it.

But a permanent repair by the state and Mat-Su Borough isn’t scheduled to start until next summer and won’t be finished until 2021. As the photo shows, Vine Road was built over a swamp. That complicates the fix, because the road runs through water-saturated soils.

The Anchorage School District spent $22 million in the immediate aftermath of the quake getting schools up and running, and larger fixes loom. Among the largest challenges is a pair of still-shuttered schools in Eagle River, including Gruening Middle School, whose estimated $39 million repair bill is part of an $82.8 million bond proposal that includes $70 million for earthquake repairs at 14 ASD schools.

In Mat-Su, Houston Middle School remains closed as well. Plans call for the building to be repurposed as a high school for a cost of about $29 million, with insurance potentially covering up to $15 million. But that proposal still needs local approval and there’s no designated source for the remaining funds.

Businesses have been hard hit as well. In Eagle River, a pawn shop and a McDonald’s were torn down due to quake damage, and as of the end of November, both buildings were still being rebuilt. Other businesses have been forced to close entirely due to the disruption in sales.

Part 1: https://www.adn.com/alaska-news/anchorage/2019/11/28/last-years-71-earthquake-woke-alaska-up-experts-say-it-wasnt-a-true-test-of-our-readiness/

Part 2: https://www.adn.com/alaska-news/science/2019/11/29/how-a-few-seconds-of-shifting-deep-below-the-earths-surface-caused-the-biggest-earthquake-in-anchorage-since-1964/

Part 3: https://www.adn.com/alaska-news/anchorage/2019/12/01/experts-say-earthquake-damage-was-worse-outside-anchorages-building-safety-area-due-to-lax-oversight/

Some lost homes and dreams

One symbol of the quake remains an ugly reminder that all is not well for some residential property owners trying to pick up the pieces. Since the earthquake destroyed a two-story home in Eagle River last November, a chain-link fence has been installed around the formerly two-story home, which has slumped into the ground like a melting snowman over the past year.

For homeowner Daric Harkless, the wrecked pile of wood and broken windows is a painful reminder that, as more obvious quake damage heals, lives remain broken and futures uncertain for the thousands of people whose lives and communities were shaken up by the largest natural disaster to hit Alaska in decades.

“We don’t know what’s going to happen,” Harkless said last month from New York, where her husband is stationed as a captain in the U.S. Army.

According to the state of Alaska, more than 10,500 damage claims were filed with the federal government in the months following the quake. A total of 4,333 individuals and households have received help under the Individual and Household program, with the Federal Emergency Management Agency paying out about $26.2 million in grants.

None of that spending has gone to the Harkless family, which was ineligible for FEMA grants because they were renting their house out at the time it collapsed.

The Small Business Administration has also given out $73 million in low-cost loans, but Harkless said borrowing more money to demolish a house she and her husband still owe hundreds of thousands of dollars on wasn’t an option, either.

An online crowdfunding effort generated a couple months’ worth of hope, and savings have allowed them to keep making payments on the house they once dreamed of returning to. But without tenants, their savings have dwindled. They once dreamed of returning to live in the home full time. Now they don’t have enough money to remove the pile of rubble from the end of the cul-de-sac.

“It’s not that we can’t make payments, it’s that there’s no house to make payments for,” she said.

They’ve contacted a lawyer and are looking at the cheapest way to walk away from the rubble. After that, it’s anybody’s guess.

“We’re just running out of time.”

The Harkless family is among thousands who have found earthquake recovery to be a frustrating experience rife with disappointment, compromise and a healthy dose of reality.

Homeowners look to feds for help

For Dr. Steve and Alicia Baker of Eagle River, that lesson came in the form of $3,000 in federal disaster relief to help rebuild a half-million-dollar home that will need an estimated $300,000 in repairs. For six months after the quake, the Bakers and their two sons with special needs lived in the basement of the damaged four-bedroom, three-bath house near the center of a cluster of Eagle River Valley homes that sustained unusually heavy damage.

Recently the family moved into military housing on nearby Joint Base Elmendorf-Richardson (Steve's an Air Force veteran) while contractors work to repair the home. They'll spend the holidays cramped into enlisted quarters on base, hoping to be home by spring.

In addition to cracked walls throughout, the Baker house lost its brick siding, needs to be reattached to the foundation and must have its entryway redone. But even a $200,000 loan won't cover all the damage, he said.

"Some of this comes out as we tear out walls and realize what else is there."

One neighbor had his house torn down while another has been going through nearly nonstop repairs since the day after the quake. All remain in various states of disrepair and with various hurdles between the owners and normalcy.

"We're all kind of in the same boat for the most part," he said.

Quake victims a target for scammers

In East Anchorage, Antonia "Pastor Toni" Castillo will spend the holidays at home, one of the many things she's thankful for despite getting scammed by an unlicensed contractor whose mouth worked a lot harder than his hammer.

"God provides," Castillo said from her cozy Penland Park mobile home, where a small back room remains partially separated from the main house.

Castillo said she got $1,600 from FEMA to repair some of the damage, which included wall cracks, a busted refrigerator, an uneven floor and a saggy ceiling.

But much of the grant money ended up in the pockets of guy who called himself "Shorty" and promised park residents he could fix their broken homes good and cheap and fast. Shorty wasn't good but he did pull a fast one, making off with Castillo's cash after jacking up her home a few inches but leaving a large gap open to the elements.

After Shorty came up short, Castillo had resigned herself to the fact the home she's lived in for 27 years would remain broken. But then her phone rang, and instead of asking for help someone was offering.

On the other end was a case worker from the Anchorage/Eagle River Long Term Recovery Group, a nonprofit made up mostly of local churches whose mission is to help those who can't otherwise be helped. Group treasurer Alan Budahl explained FEMA refers everyone who applies for assistance to the group, which reaches out to those in need and tries to serve the most vulnerable.

"A lot of people are still suffering," Budahl said.

The group sent volunteers to shore up Shorty's gap, properly re-level the home and make a plan to repair the rest of the damage this spring. It's not a lot, but it's a prayer answered for Castillo, who noted the volunteers completed the work with smiles and without swearing.

"They were amazing men," she said.

Faith-based groups and private charities have helped fill some of the gaps left for people who still need help. Budahl said his group has three lists of projects it tries to complete for folks -- those that can be taken care of immediately, those that might be able to be done this winter and those that will have to wait until next spring. The group relies on donations and does whatever it can, trying to focus on getting as much bang for its bucks.

One of the easiest ways to make a difference, he said, is simply listening. Some people are still afraid to return to creaky homes, he said; others have nightmares.

"For a lot of people it's just to know they didn't experience it by themselves," he said.

A new hope

For many, the upshot of the Nov. 30 quake has not been the multimillion-dollar rebuilding effort but the renewed bonds that have grown between people within the community.

Steve and Alicia Baker said their family is counting its blessings despite spending Christmas away from home because of the outpouring of support they received after their home was damaged.

"There was just people we didn't even know that said, 'Hey, let us help you out,'" Baker said.

Despite getting scammed, Castillo said she has no time to bitter — she's got soup to cook for the dozens of homeless people she volunteers to feed each weekend in downtown.

"It's what I do."

And the growing Harkless family (Daric and Michael had their second child five months after the quake) is still determined to return to Alaska one day despite seeing their dreams crushed on Nov. 30, 2018.

"Maybe this house wasn't meant to be," Daric Harkless said. "But maybe we can find a place that's even better."

Their home may be gone and their future unclear, but Harkless said the quake hasn't broken her family. Far from it.

"We're just trying to make the best out of a bad situation."

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2021 M8.2 Chignik Earthquake

Key Points

Event Overview

- **Date & Time**: July 28, 2021, at 10:15 PM Alaska time.
- **Magnitude**: 8.2 — the largest U.S. earthquake in 50 years.
- **Location**: Offshore of the Alaska Peninsula, about 45 miles from the 2020 M7.8 Simeonof Island Earthquake.
- **Depth**: Approximately 28.5 miles (intermediate-depth).

Tectonic Context

- Occurred along the **Aleutian megathrust**, the interface between the subducting Pacific Plate and the overriding North American Plate.
- Related to the 2020 Simeonof Island Earthquake, though deeper.
- The same region was previously ruptured by the **1938 M8.3 earthquake**.

Impact on Communities

- **Perryville and Chignik** experienced the strongest shaking.
- Felt as far as the **Mat-Su Valley** in Southcentral Alaska.
- **Aftershocks** have been active; the largest so far was a **M6.1** just four minutes after the mainshock.

Tsunami Warning

- A tsunami warning was issued for much of coastal Alaska.
- Some communities evacuated.
- Recorded wave heights were under 1 foot.
- The warning was downgraded a few hours later.

Full Story

At 10:15pm Alaska time on July 28, a magnitude 8.2 earthquake struck offshore of the Alaska Peninsula, the largest U.S. earthquake in 50 years. The Chignik Earthquake depth was approximately 28.5 miles, an intermediate-depth earthquake.

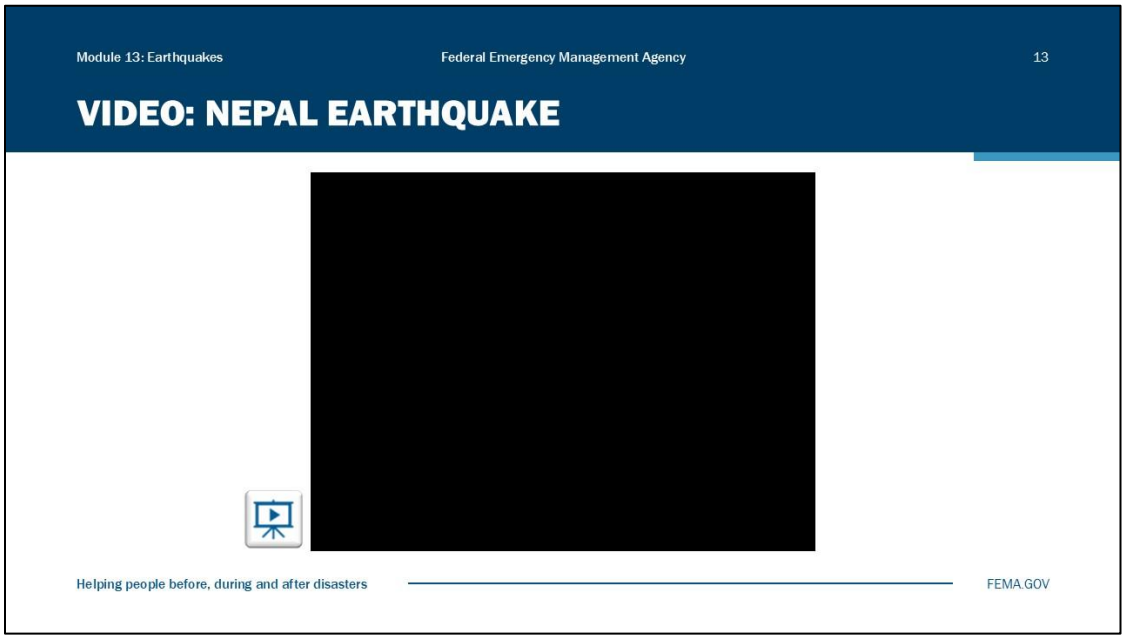
The Chignik Earthquake occurred relatively close (about 45 miles) to the location of the M7.8 Simeonof Island Earthquake that ruptured July 21, 2020. The Chignik Earthquake seems to be related to the earlier earthquake; both occurred along the interface between the subducting Pacific and overriding North America plates, although the Chignik Earthquake was the deeper of the two. The Alaska Peninsula is a seismically active region where thousands of earthquakes occur each year. The largest earthquakes are located along the interface, which is called the Aleutian megathrust. The M8.2 event ruptured this interface in the region between the Shumagin Islands to the southwest and Kodiak Island to the northeast. Previously, the 1938 M8.3 earthquake ruptured this section of the interface.

Perryville and Chignik are the nearest communities to the epicenter of the Chignik Earthquake, and felt the highest intensity shaking. There were also multiple felt reports from Alaska communities as far away as the Mat-Su Valley in Southcentral Alaska. So far, the aftershock rate has been active, so residents of the region may continue to feel shaking. The largest aftershock at the time of this article was a M6.1 about four minutes after the mainshock.

Because of the offshore location, the National Tsunami Warning Center issued a tsunami warning for much of coastal Alaska. Several communities issued evacuations. Recorded wave heights were under a foot, however, and the warning was downgraded a couple hours after the event.

Source: *Detail | Alaska Earthquake Center*. (n.d.). Retrieved May 19, 2025, from http://earthquake.alaska.edu/event/0219neiszm/detail

Geology and Earth Basics (11 of 11)



Slide 13–13, Video: Nepal Earthquake

TRIGGER WARNING: THE VIDEO CONTAINS PEOPLE SCREAMING AT THE VIDEO'S ONSET.

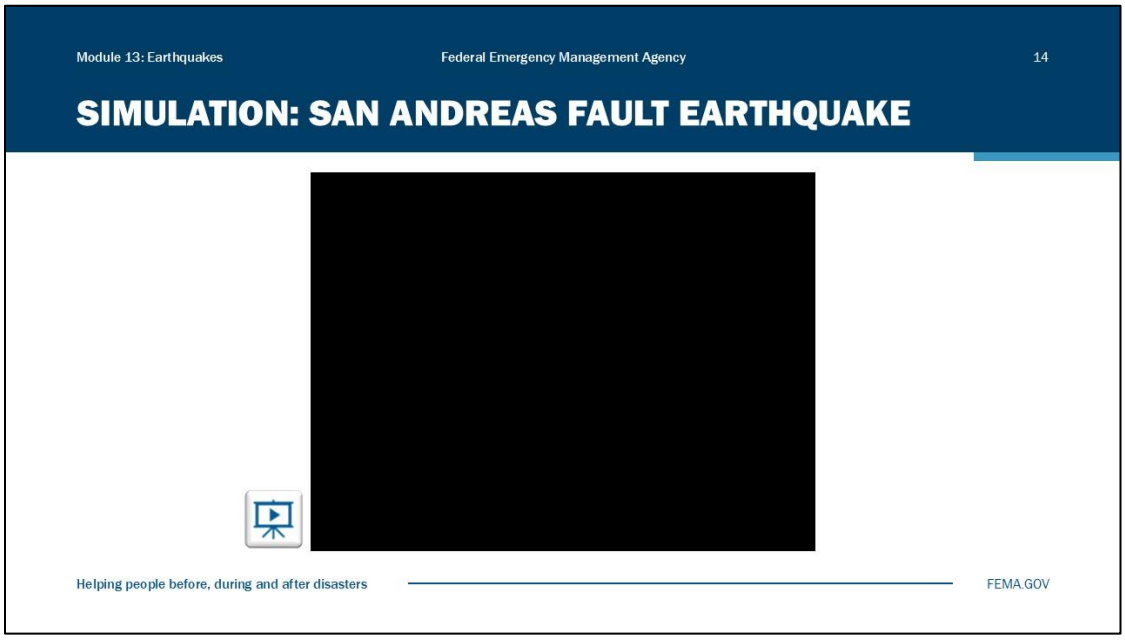
Nepal Earthquake Video Description—*The video shows different areas affected by the April 2015 Nepal earthquake, which killed over 8,000 people and injured more than 21,000. It occurred at 11:56 Nepal Standard Time on 25 April, with a magnitude of 7.8. Its epicenter was east of Lamjung District, and its hypocenter was at a depth of approximately 8.2 km.*

The April 2015 Nepal earthquake killed over 8,000 people and injured more than 21,000. It occurred at 11:56 Nepal Standard Time on 25 April, with a magnitude of 7.8. Its epicenter was east of Lamjung District, and its hypocenter was at a depth of approximately 8.2 km.

It was the worst natural disaster to strike Nepal since the 1934 earthquake. Hundreds of thousands of people were made homeless due to the devastating earthquake. Centuries-old buildings were destroyed at UNESCO World Heritage sites in the Kathmandu Valley, including some at the Kathmandu Durbar Square, the Patan Durbar Square, the Bhaktapur Durbar Square, and the Changu Narayan. Geophysicists and other experts had warned for decades that Nepal was vulnerable to a deadly earthquake, particularly because of its geology, urbanization, and architecture.

Outside the Valley, the Manakamana Temple in Gorkha, the Gorkha Durbar, the Rani Mahal in Palpa District, the Dolakha Bhimsensthan in Dolakha District, and the Nuwakot Durbar were partially damaged.

Earthquake Fundamentals (12 of 12)



Slide 13–14, Simulation: San Andreas Fault Earthquake

Simulation: San Andreas Fault Earthquake

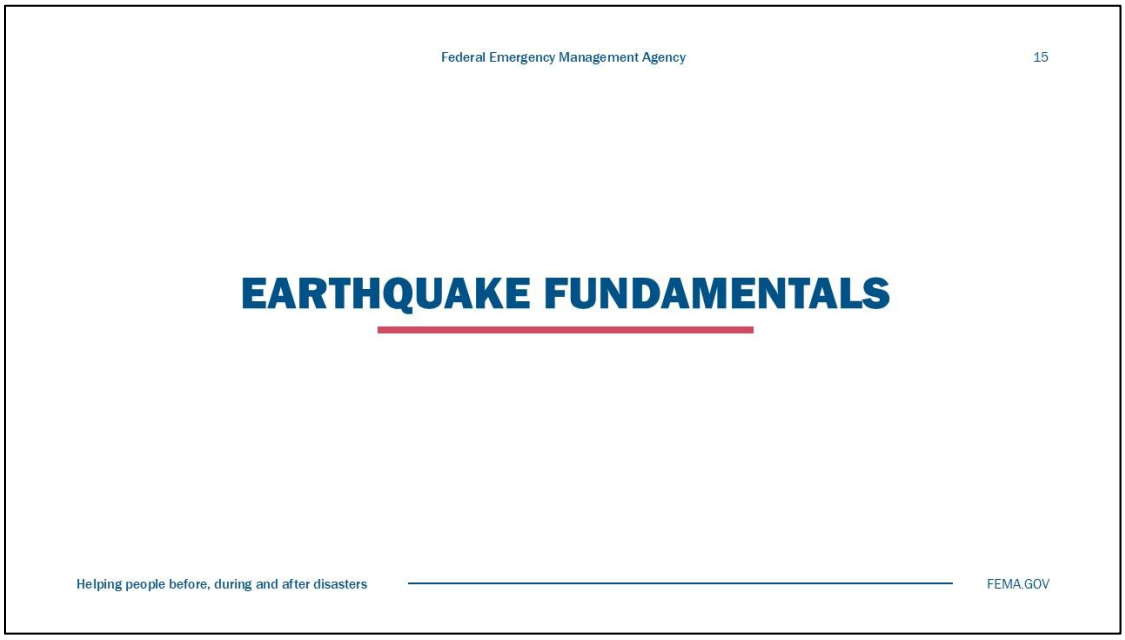
This animation illustrates several key aspects of the earthquake process, which we will explore in this module. This computer simulation, created through the collaboration of earth scientists and computer scientists, shows the travel of earthquake waves generated by a rupture on the San Andreas Fault in southern California. This is a hypothetical magnitude 7.8 earthquake called the Shakeout scenario earthquake.

The San Andreas Fault extends for hundreds of miles along the plate boundary in California. The simulation focuses on the southern terminus of the fault, which begins at the Salton Sea, and extends to the northwest. The San Andreas Fault ruptures all the way to the surface of the Earth, and to a depth that varies from about 6 to 10 miles.

The dashed line indicates the 200 miles of fault that will rupture in this single earthquake. If a shorter section of the fault ruptured, the earthquake would be smaller. If a longer section of the fault ruptured, the earthquake would be bigger.

In the lower left of the screen is a green counter that ticks off seconds after the fault rupture begins. The white, yellow, and red colors indicate the velocity of the waves that carry the energy away.

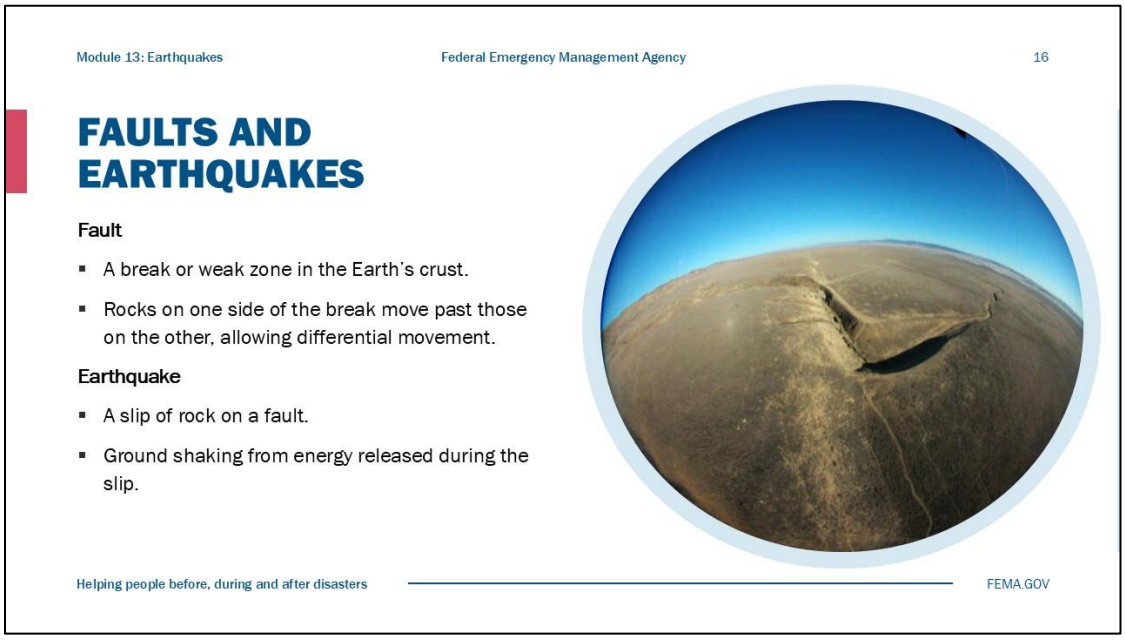
Earthquake Fundamentals (1 of 22)



Slide 13–15, Earthquake Fundamentals

Not Applicable.

Earthquake Fundamentals (2 of 22)



Slide 13–16, Faults and Earthquakes

Faults

- Is a break or weak zone between two blocks of rock.
- Allows **differential movement** between two blocks of rock.

Differential movement means that the two blocks move in different directions. Scientists can measure the relative changes in the positions of the two blocks, but because they lack an outside frame of reference, they cannot detect how each block moves alone.

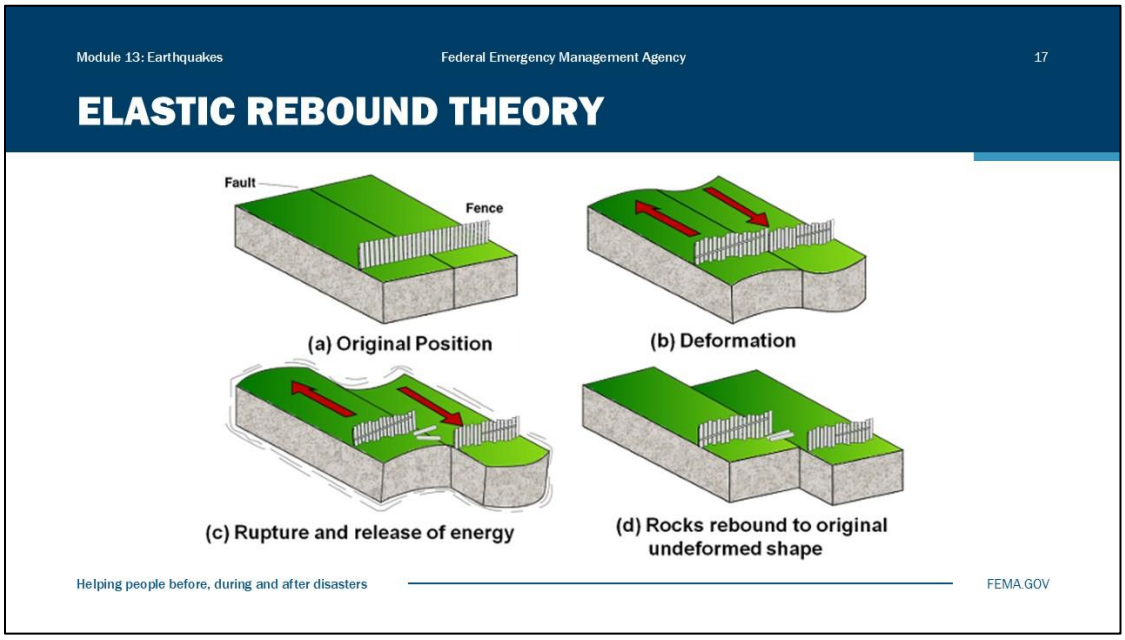
Earthquakes

The term earthquake is used to describe both:

- The slip of rock on a fault, and
- The resulting ground shaking from energy that gets released during the slip, and *sometimes*
- Energy released from volcanic or other processes.

(This very basic definition will be elaborated on throughout this module.)

Earthquake Fundamentals (3 of 22)



Slide 13–17, Elastic Rebound Theory

To understand the science of earthquakes, it is helpful to know about the Elastic Rebound Theory, which forms the basis of scientific investigation into earthquakes.

Following a 1906 earthquake in California, a flurry of scientific investigations studied the root causes of earthquakes. Henry Fielding Reid, a Professor of Geology at Johns Hopkins University, proposed the Elastic Rebound Theory to explain the phenomena of earthquakes, a theory that survives to this day.

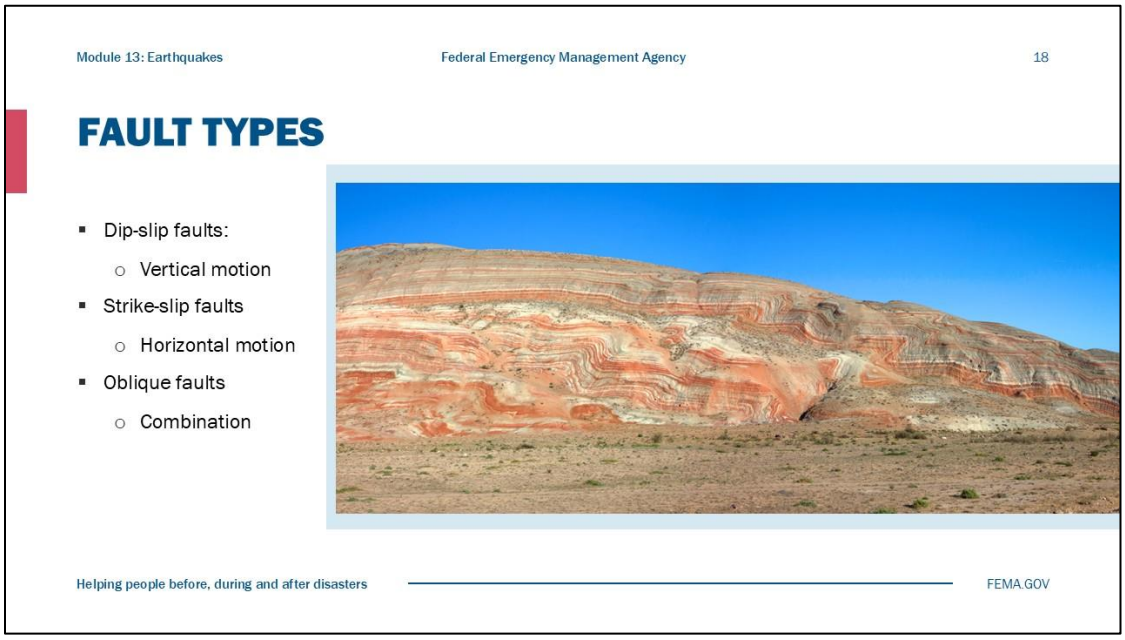
The theory states that, like a stretched rubber band, Earth's lithosphere stores elastic energy that is released suddenly in an earthquake, the equivalent of breaking or cutting a rubber band.

There are four steps in this elastic process:

1. Original position (strain in the rocks builds).
2. Deformation (rocks have elastic strain and bend).
3. Rupture and release of energy (strain is released and rocks snap-i.e., an earthquake).
4. Rocks rebound to their original, undeformed shape (i.e., become stable).

Regardless of the style of motion, enormous blocks of rock do not move easily. In fact, the edges of the plates are locked by frictional forces most of the time, while the body of the plate continues to move slowly.

Earthquake Fundamentals (4 of 22)



Slide 13–18, Fault Types

Fault types: There are different classifications of faults based on the movement of the rock, which we will look at in subsequent visuals:

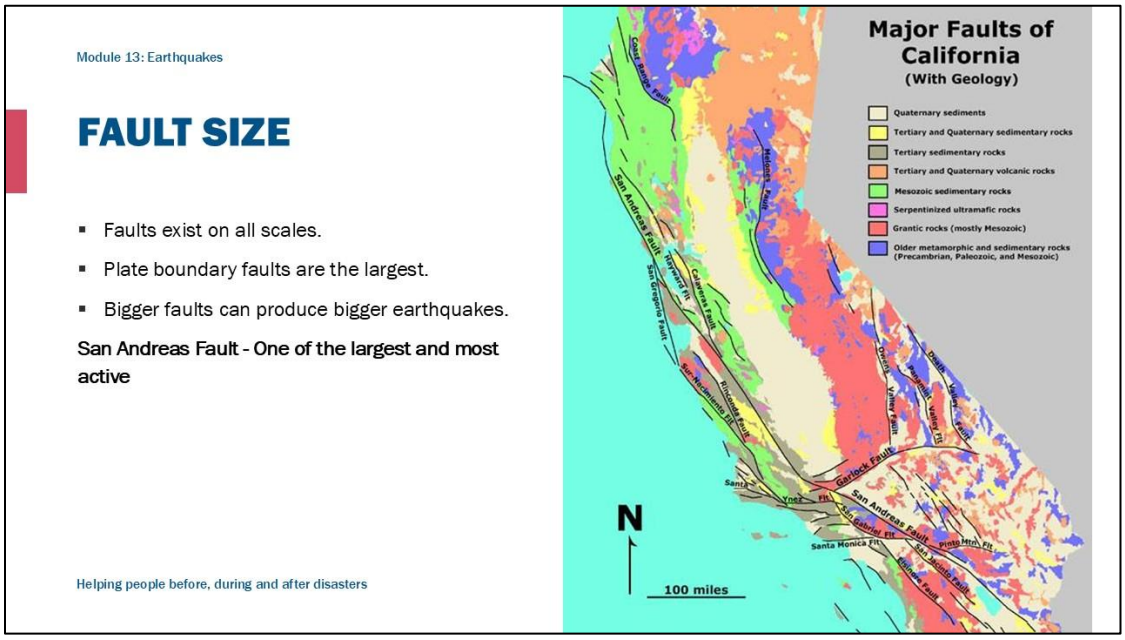
- Dip-slip faults, including normal and reverse, which involve vertical movement
- Strike-slip faults, which involve lateral movement
- Oblique faults, which involve both vertical and lateral movement

Fault planes and fault zones: Faults are typically modeled as planes between rocks. (The reality is more complicated; it is often more appropriate to think of a fault as a zone of deformation rather than as a sharp planar feature.)

A **fault plane** extends laterally and vertically. A typical fault that is large enough to produce a damaging earthquake will extend at least 6 miles deep into the earth and might be hundreds of miles long. Typically, only part of a fault will allow movement in a single earthquake. Thus, scientists distinguish between the fault plane, which is the full extent of the fault, and the rupture plane, which is the part of the fault that allows movement in a single earthquake.

Scientists use the terms "fault rupture," "fault movement," "fault slip," "earthquake rupture," and "earthquake slip " interchangeably. These terms describe the process by which a weak zone, the fault, allows the movement of blocks of rock that meet at the fault.

Earthquake Fundamentals (5 of 22)



Slide 13–19, Fault Size

San Andreas Fault - One of the largest and most active

Fault Size Image Description – *Map of the major fault lines in California with the San Andreas, Hayward, Calaveras, San Gregorio, Sur-Nacimiento, and Rinconda fault lines along the western coast surrounded by Mesozoic sedimentary, Tertiary, Granite, and Quaternary sedimentary sediments. The Ynez, Santa Monica, San Gabriel, San Jacinto, and Elsinore fault lines are located along the southern coast, characterized by granite rocks (mostly Mesozoic) and Quaternary sediments. The Garlock Fault, Owens Valley, Panamint, and Death Valley Faults are located in the mid-southern section of the state, characterized by granite, Quaternary, and older metamorphic and sedimentary rocks (Precambrian, Paleozoic, and Mesozoic). Melones Fault is in the mid-east of the state, surrounded by older metamorphic and sedimentary rocks. The Coast Range fault is the northernmost in the state, surrounded by Mesozoic and older metamorphic and sedimentary rocks.*

Faults exist on all scales. Some faults are so small that the movement of the rocks can only be detected with a high-power microscope.

Plate boundary faults, which allow movement between two plates, are the largest faults on the planet. For example, the San Andreas Fault (shown in the photo) is easily visible from space.

Generally, the larger the fault, the greater the earthquakes it can produce.

U.S. Faults: The map below shows areas in the contiguous United States where faults have been identified that could create damaging earthquakes.

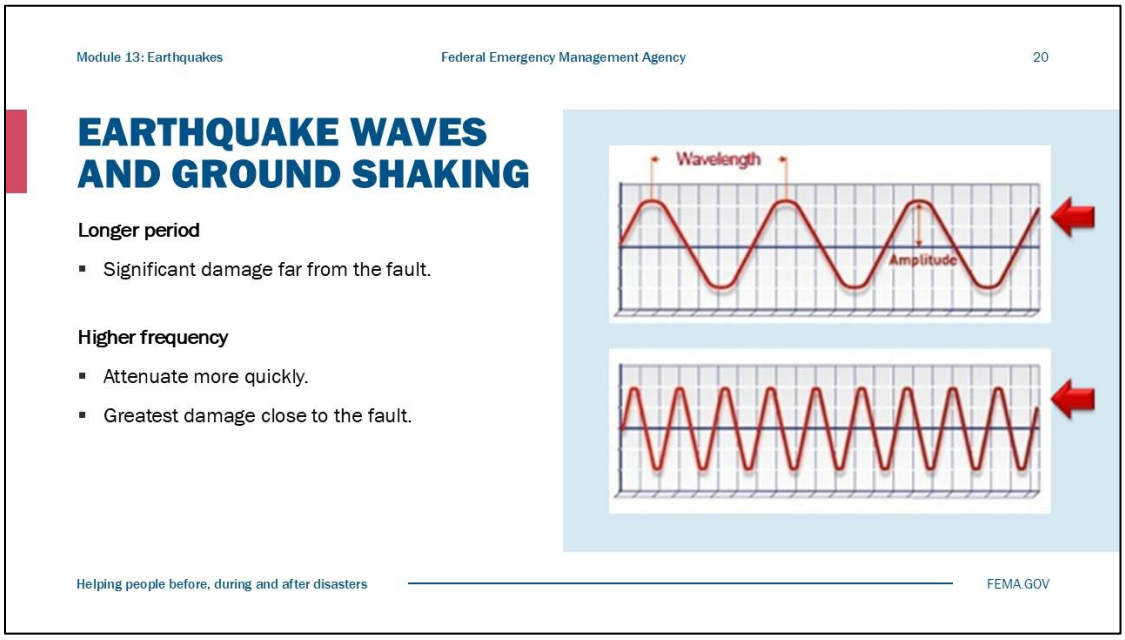
In some places, a broad area is identified as having known faults, but the exact location of each fault is not known. Some faults obviously deform the surface of the Earth and can readily be mapped. Other faults are buried under sediments or otherwise hidden and can only be found when an earthquake is detected or when subsurface features are examined, such as during oil company exploration. Faults often create barriers that block the movement of oil, gas, and water.

There are many more faults than are shown on this map. Some that can cause earthquakes have not yet been identified. Some are older faults that are not aligned such that they will produce earthquakes with the current tectonic forces; however, they might become active again should the forces change sufficiently.

Known Faults in the United States



Earthquake Fundamentals (6 of 22)



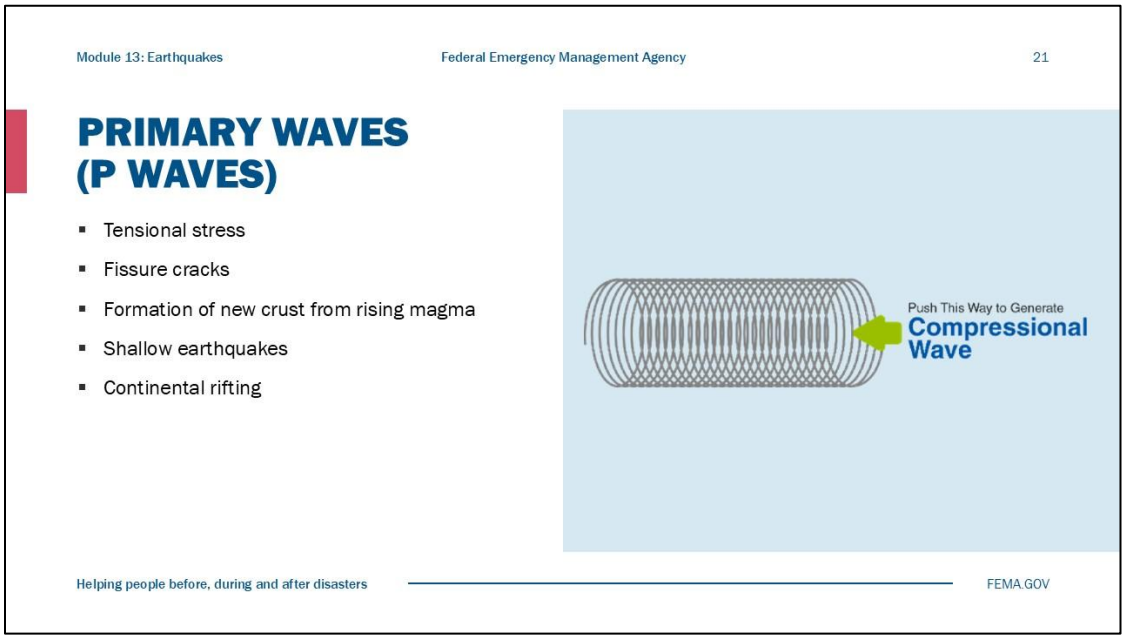
Slide 13–20, Earthquake Waves and Ground Shaking

In an earthquake, the ground shaking is caused by energy waves propagating through the ground.

Effect of wave properties:

- The longest-period waves, created by the largest earthquakes, can cause significant damage hundreds of miles from the fault.
- The highest-frequency waves will attenuate (decrease) the most quickly. Therefore, they will cause the greatest damage close to the fault.

Earthquake Fundamentals (7 of 22)



Slide 13–21, Primary Waves (P Waves)

Scientists also distinguish between body waves and surface waves. Body waves move through the Earth and surface waves stay on the surface.

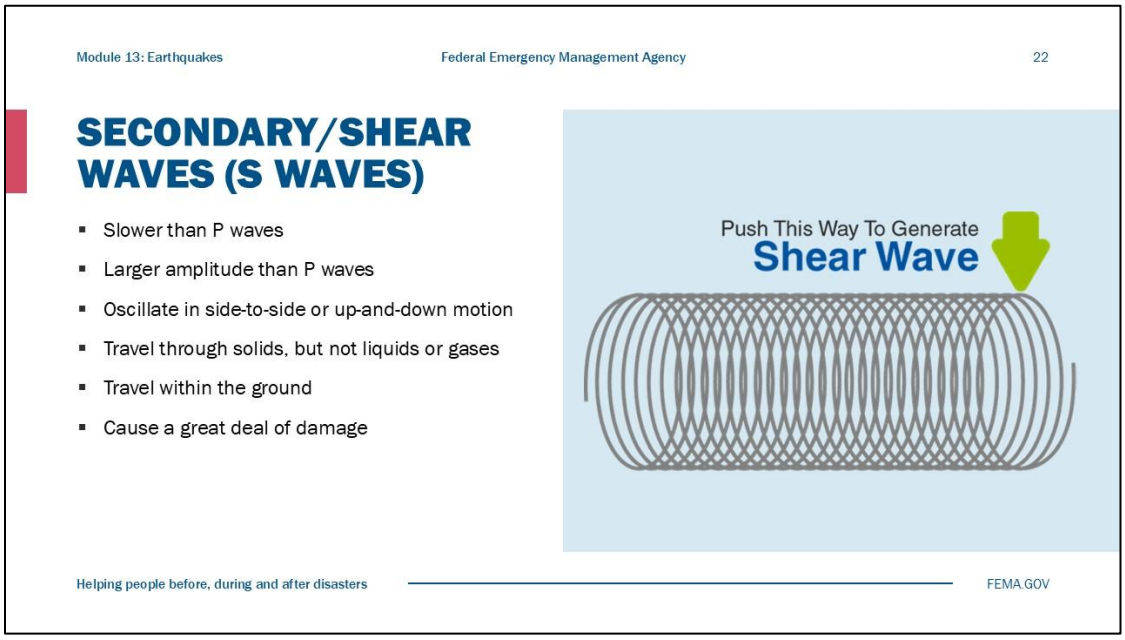
Body waves include primary waves (P waves) and secondary/shear waves (S waves), and they travel through the Earth with different types of motion.

Characteristics of P waves:

- Are the fastest moving, and the first to arrive. They move at about 6 miles per second, about twice as fast as secondary waves:
  - ~ 1.71 times the speed of secondary waves
  - ~ 2 to 3 times the speed of surface waves
  - Typically, 1 second separation between P and S waves for nearly every 5 miles traveled
- Have a high frequency
- Are compressional
- Travel through solids, liquids, and gases

- Travel within the ground
- Cause little damage

Earthquake Fundamentals (8 of 22)



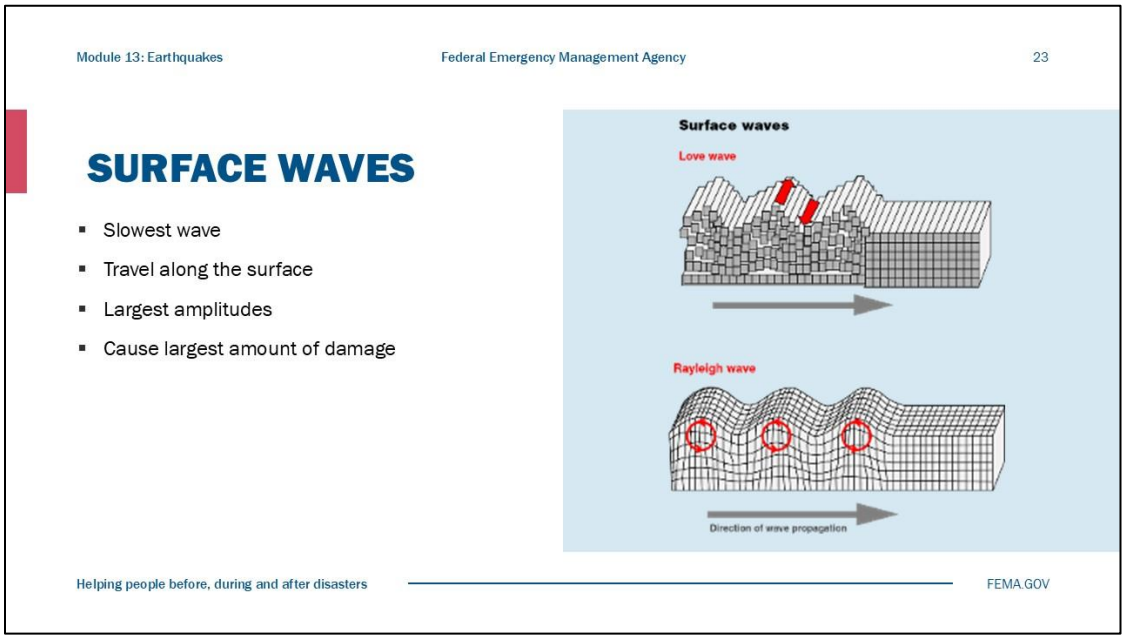
Slide 13–22, Secondary/Shear Waves (S Waves)

Characteristics of S waves:

Secondary/shear waves (S waves) shake the ground more severely and cause more damage. S waves:

- Are slower than P waves
- Have a larger amplitude than P waves
- Oscillate in a side-to-side or up-and-down motion
- Travel through solids, but not liquids or gases
- Travel within the ground
- Cause a great deal of damage

Earthquake Fundamentals (9 of 22)



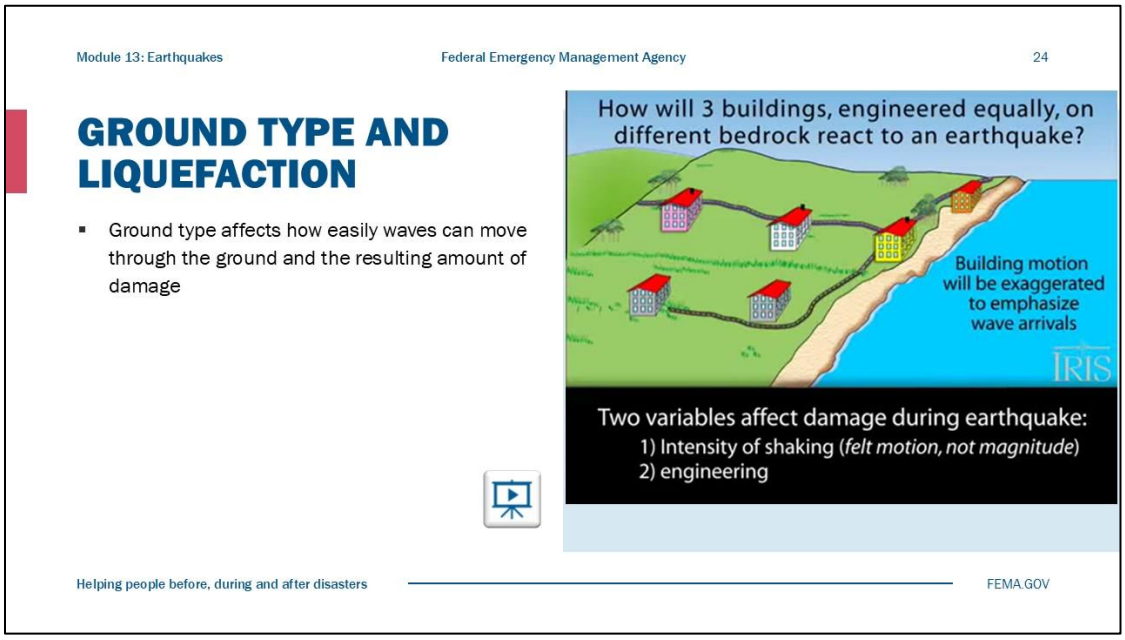
Slide 13–23, Surface Waves

Characteristics of surface waves: Surface waves are the slowest moving and most damaging waves. They also have the largest amplitudes.

Types of surface waves: Surface waves may either be Love waves or Rayleigh waves (R waves).

- Love waves:
  - Are the fastest surface wave
  - Move side to side
- Rayleigh waves (R waves):
  - Move like ocean waves, rolling up and down and side to side
  - Are the most damaging wave

Earthquake Fundamentals (10 of 22)



Slide 13–24, Ground Type and Liquefaction

Video Transcript:

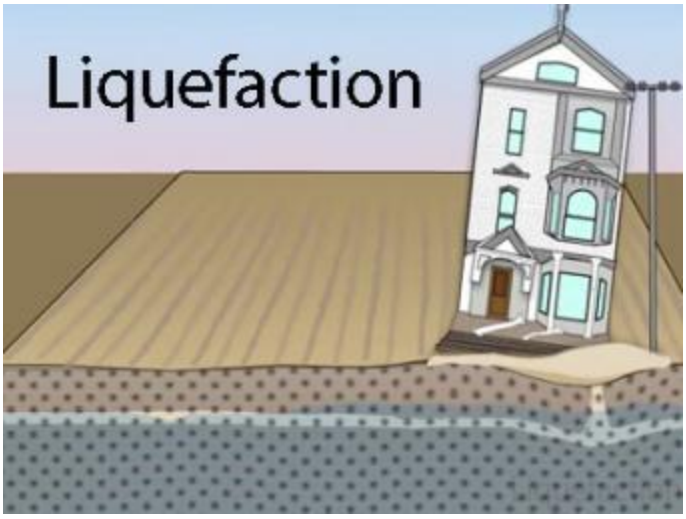
Narrator: The motion of similar buildings on different bedrock will be exaggerated to show the arrivals of compressive P, shearing S, and rolling surface waves from a regional earthquake.

Three consecutive seismograms will show the changing frequency and amplitude resulting from changing rock type.

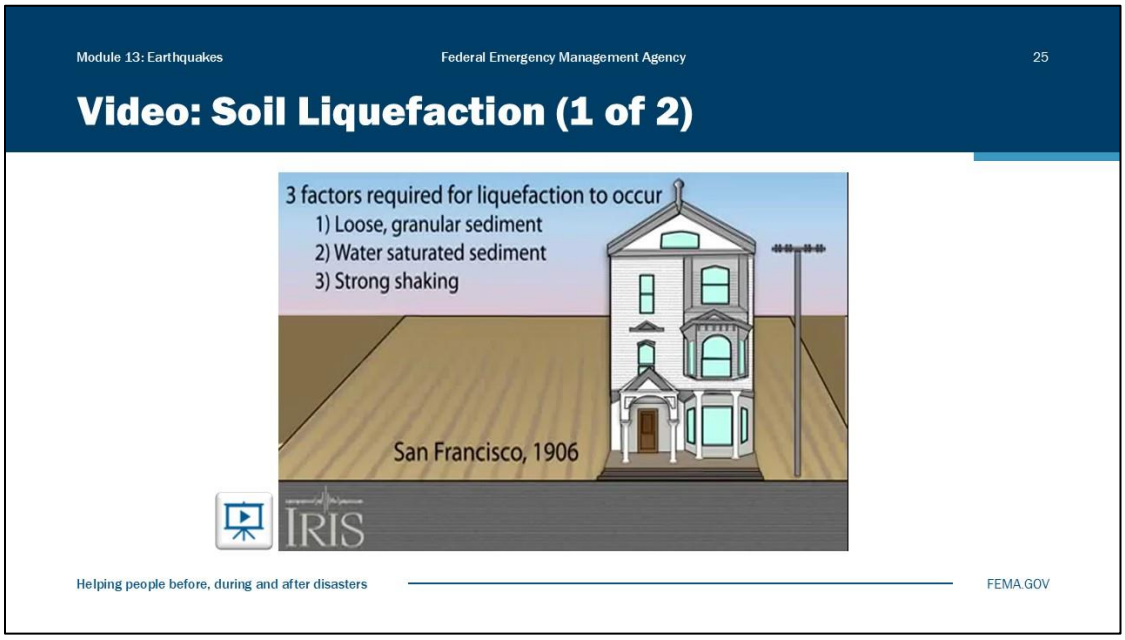
The initial P wave arrives with a compressive bump and rarely causes much damage. The slower shearing S wave introduces a side-to-side motion that can throw loose objects to the floor and may crack walls.

The rolling surface waves are the most damaging in unconsolidated sediment. As surface waves enter the sedimentary layer, they slow down and increase in size, causing buildings to roll. If not engineered for the motion, they can crack and tumble. But even a well-engineered building can sink during the shaking and liquefaction of underlying wet sediment.

The first seismogram from the pink building on solid ground shows low-amplitude high-frequency waves. When the waves hit softer ground, they slow down and increase in amplitude. It is this higher, slowing roll that is so destructive during an earthquake.


Liquefaction

Earthquake Fundamentals (11 of 22)



Slide 13–25, Video: Soil Liquefaction (1 of 2)

Video description:

Still picture with a house: "Three factors required for liquefaction to occur: Loose, granular sediment, Water saturated sediment, Strong shaking. San Francisco, 1906

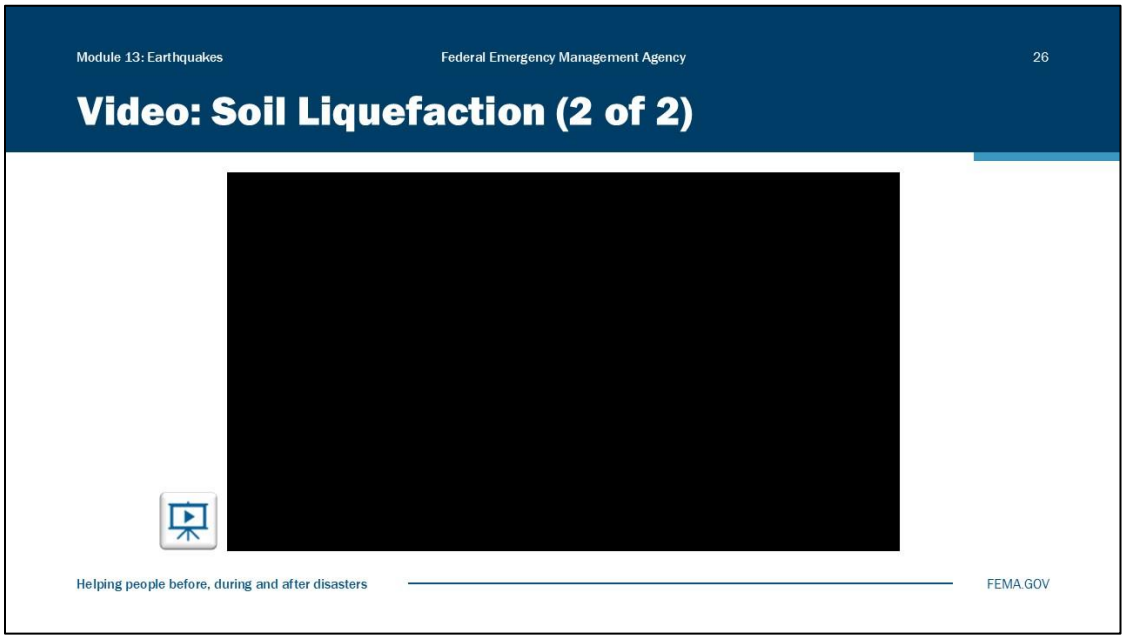
Look below surface: shows layer of loose, granular sediment and then saturated by ground water. Earthquake happens. Liquefaction of ground under house. House shaking

Question "Why did this happen?"

Answer: Earthquake waves cause water pressures to increase in the sediment. Sand grains lose contact with each other, leading to a loss of sediment strength and liquid-like behavior.

Incorporated Research Institutions for Seismology (IRIS) (http://www.iris.edu/hq/programs/epo)

Earthquake Fundamentals (12 of 22)



Slide 13–26, Video: Soil Liquefaction (2 of 2)

Video description: The video shows an instructor-led demonstration of soil liquefaction.

Video description:

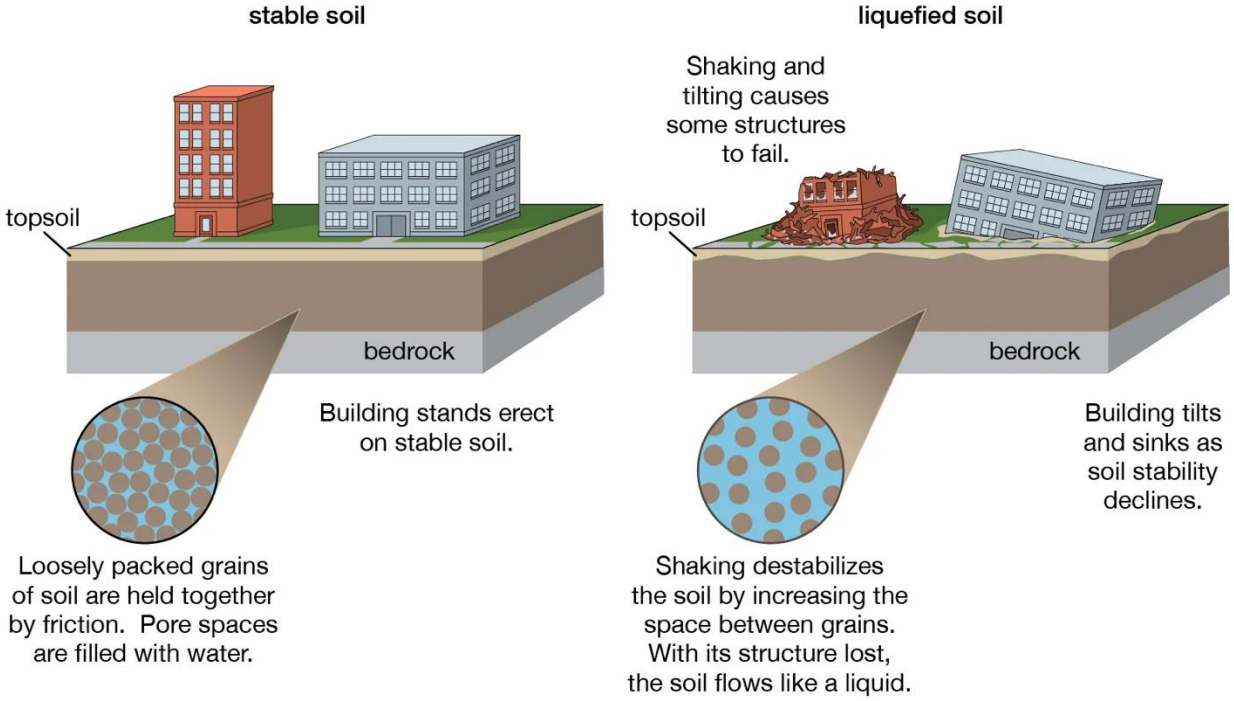
Demonstrates how soil can become liquefied during the shaking in an earthquake, and the resulting degradation of the structural integrity of the ground to support the building.

The instructor places the sand in the bin and adds water so it is saturated but not a slurry. The instructor places the bin so it spans the gap between two tables.

The instructor places an object (such as a brick or bottle) on top of the sand to represent a building. Note that it is stable.

The instructor uses the sander to vibrate the bin from the side or beneath.

The soil “liquefies” as water molecules work their way from between sand particles, causing the brick to sink on this unstable ground.



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https://cdn.britannica.com/84/152184-050-0C74FF5D/qualities-soil.jpg

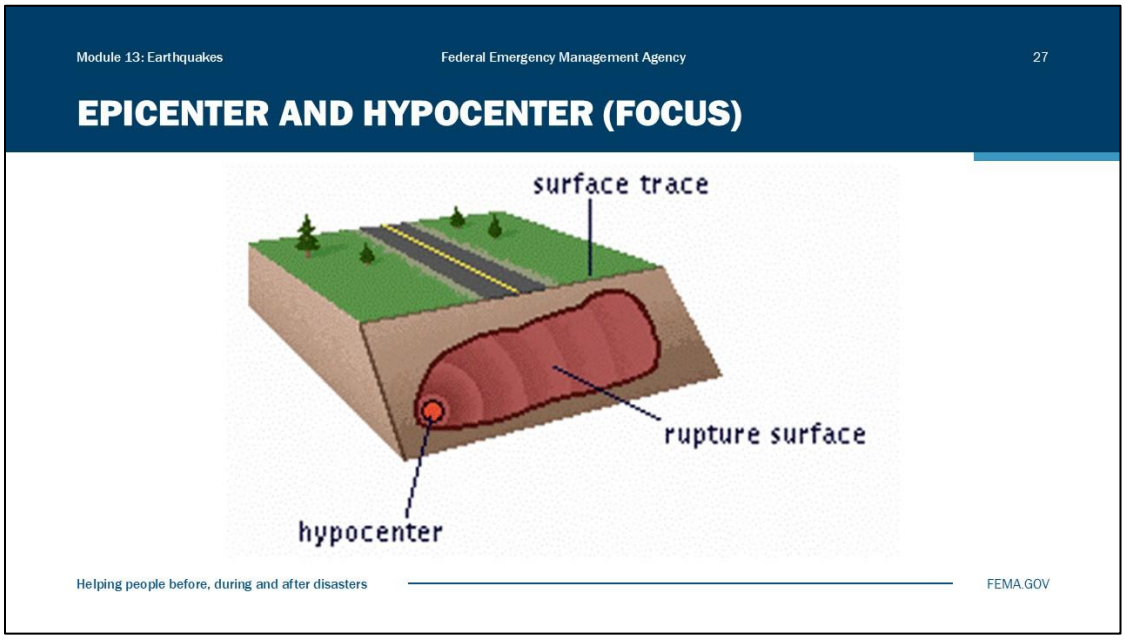
Liquefaction can often occur in earthquakes. Soils and sediments contain open spaces called pores that can be filled with water. Many soils start out with water-filled pores, but in some cases, increased pressure during an earthquake can cause water to be injected from an underlying layer.

The drawings on the visual show a schematic depiction of soil grains and groundwater before and during liquefaction.

When no shaking occurs, water is held between the soil particles, and the ground can provide a supportive base for structures. Energy from shaking can overcome the friction between soil particles, causing the soil to liquefy temporarily. When liquefied, the soil may no longer be able to support structures; as a result, buildings and other structures can sink into the earth or tip over.

It takes strong shaking, liquefiable soils, and groundwater near the surface to produce liquefaction. The 1994 Northridge, California earthquake caused less liquefaction than it might have because the drought had lowered groundwater levels in many areas.

Earthquake Fundamentals (13 of 22)



Slide 13–27, Epicenter and Hypocenter (Focus)

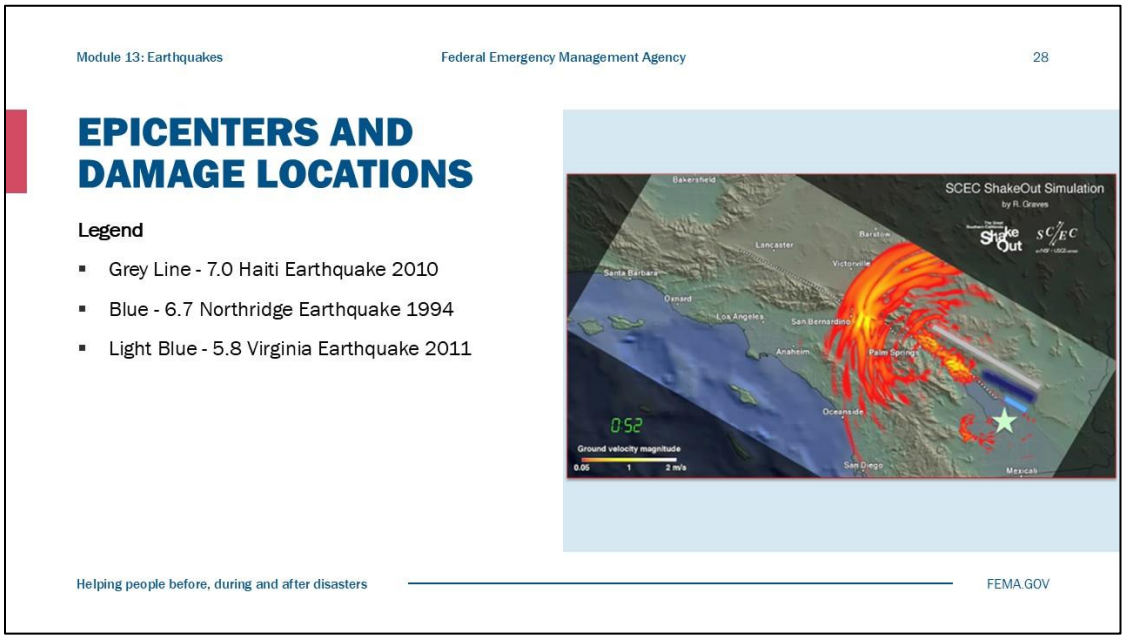
Epicenter: An epicenter is the point on the Earth's surface directly above the point where the fault first starts to rupture, known as the hypocenter or focus.

This image helps to illustrate the relative locations of the epicenter and hypocenter, as well as other key elements of earthquakes.

Here, we see a fault plane that dips into the Earth. This fault extends all the way to the Earth's surface, and the intersection of the fault plane with the surface is referred to as the surface trace. An earthquake has just occurred.

Hypocenter: The earthquake begins at the hypocenter, directly below the epicenter on the fault plane. The entire fault plane did not rupture in this earthquake. The part of the fault that does allow movement during this earthquake is the rupture surface.

Earthquake Fundamentals (14 of 22)



Slide 13–28, Epicenters and Damage Locations

Strongest shaking: During any earthquake, shaking will be strongest closest to the fault. Because the epicenter is directly above the fault, it will experience some of the strongest shaking. As the energy waves move away from the fault, they lose energy.

Small vs. large earthquakes: When an earthquake is small, the fault rupture surface will be small, and the location of the epicenter gives a good indication of where to look for damage from the earthquake. In larger earthquakes, the epicenter only indicates one of many places where strong shaking could cause damage.

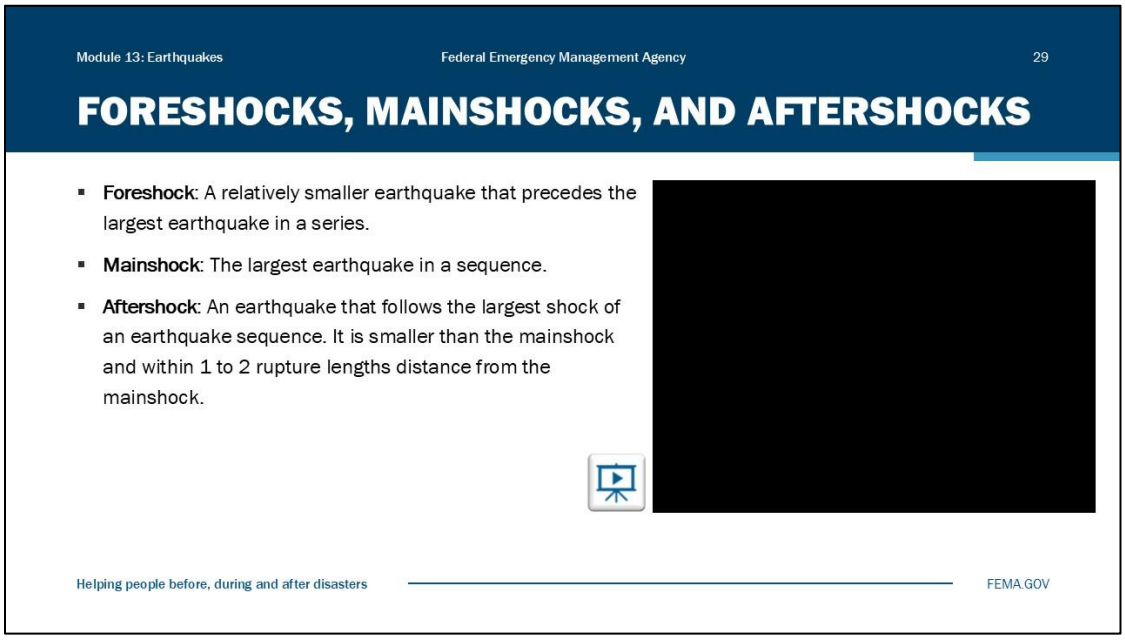
Extent of damage: In the image on the visual (from the ShakeOut simulation we watched):

- The green star represents the epicenter, but the dashed line represents the 200 miles of fault that ruptures.
- **Every community along those 200 miles will experience shaking as strong as at the starting point.** (In addition, there are locations away from the fault, such as in sedimentary basins that undergo resonance, where shaking will be strong even though the waves have lost some energy as they traveled away from the fault.)

Comparison with other earthquakes: Notice the three lines on the right:

- Light blue shows the length of fault that would rupture in an earthquake about the size of the 2011 magnitude 5.8 Virginia earthquake.
- Dark blue shows the comparable length of fault that would rupture in an earthquake about the size of the 1994 magnitude 6.7 Northridge earthquake.
- Gray shows a rupture for an earthquake comparable to the 2010 Haiti earthquake.

Earthquake Fundamentals (15 of 22)



Slide 13–29, Foreshocks, Mainshocks, and Aftershocks

When an earthquake occurs, the movement of rock along the fault and the traveling energy waves cause stress changes in the Earth. These stress changes result in additional earthquakes, known as **triggered** events.

When an earthquake occurs, additional earthquakes are likely to follow. In fact, after any earthquake, there is an increased likelihood of additional, bigger earthquakes for about 3 days.

An earthquake sequence, with **foreshocks**, a **mainshock**, and **aftershocks**.

- A **foreshock** is a relatively smaller earthquake that precedes the largest earthquake in a series.
- A **mainshock** is the largest earthquake in a sequence, sometimes preceded by one or more foreshocks (not all mainshocks have foreshocks), and almost always followed by many aftershocks.
- An **aftershock** is an earthquake that follows the largest shock of an earthquake sequence. It is smaller than the mainshock and within 1 to 2 rupture lengths from the mainshock.

Aftershocks can persist for weeks, months, or even years.

In general, larger mainshocks are followed by numerous aftershocks, which continue longer.

About 6% of the time, the aftershock is bigger than the mainshock. When this occurs, scientists rename the events. The earlier earthquake becomes a foreshock, and the new, larger earthquake becomes the mainshock.

On July 4, 2019, a 6.4-magnitude earthquake occurred at 10:33 a.m. PDT 7.5 miles southwest of Searles Valley. The nearest populated area to the epicenter was Ridgecrest, CA.

On July 5, a 5.0-magnitude earthquake occurred, followed by another at 8:19 p.m. PDT later that day, measured at 7.1 magnitude after being preceded by a foreshock just 3 minutes prior. This revealed that the previous day's 6.4-magnitude earthquake also had been a foreshock.

The 6.4- and 5.0-magnitude earthquakes, along with other smaller earthquakes, are now considered foreshocks of the 7.1-magnitude mainshock. Thousands more aftershocks occurred following the 7.1-magnitude event, with the total number of aftershocks exceeding 3,000 by the morning of July 7. Geologists at the USGS estimate that an additional 34,000 aftershocks will occur in the six months following the earthquakes.

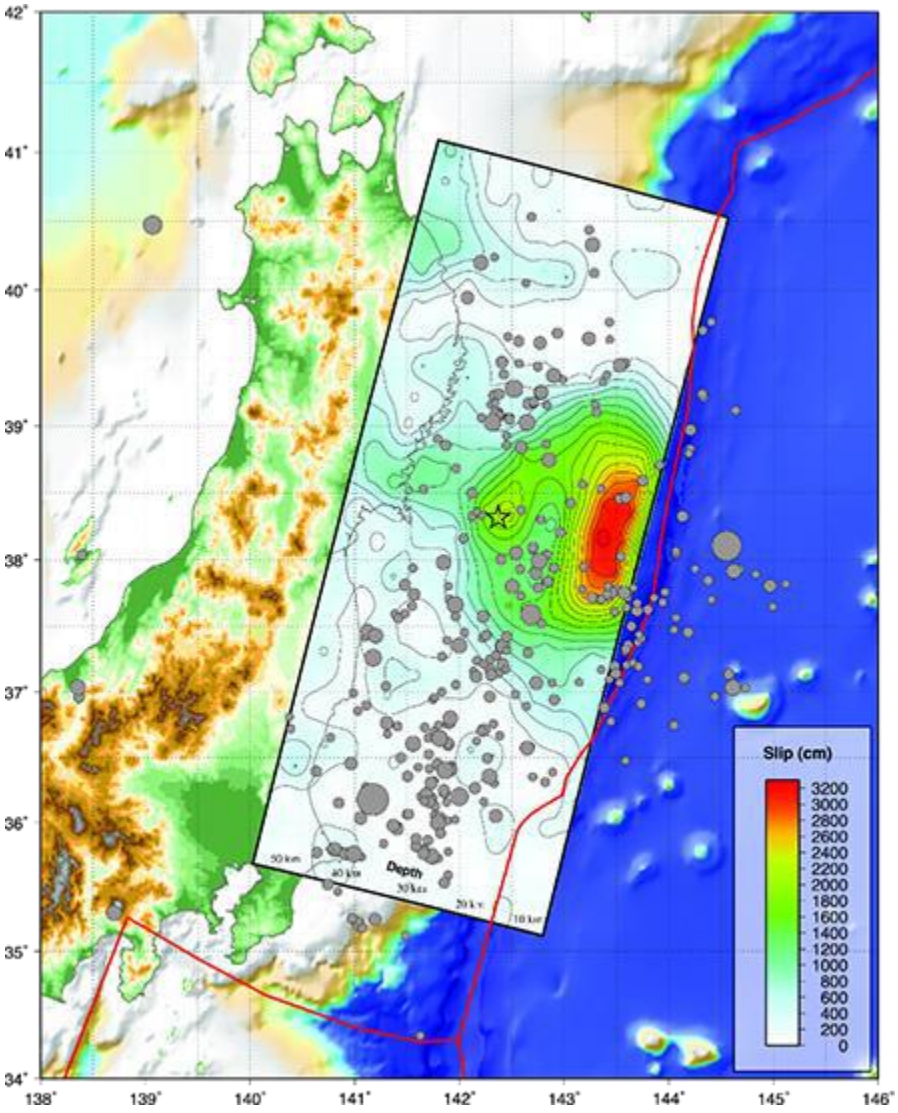
On June 3, 2020, at 6:32 p.m. PST, a 5.5 magnitude aftershock was recorded 11 miles south of Searles Valley. This aftershock is tied for the strongest aftershock following the 7.1 magnitude mainshock.

The largest earthquake in a series is always considered the mainshock and can replace a previous shock if it is larger. The smaller previous shocks are then considered foreshocks. Any smaller earthquakes that occur after the mainshock are considered aftershocks.

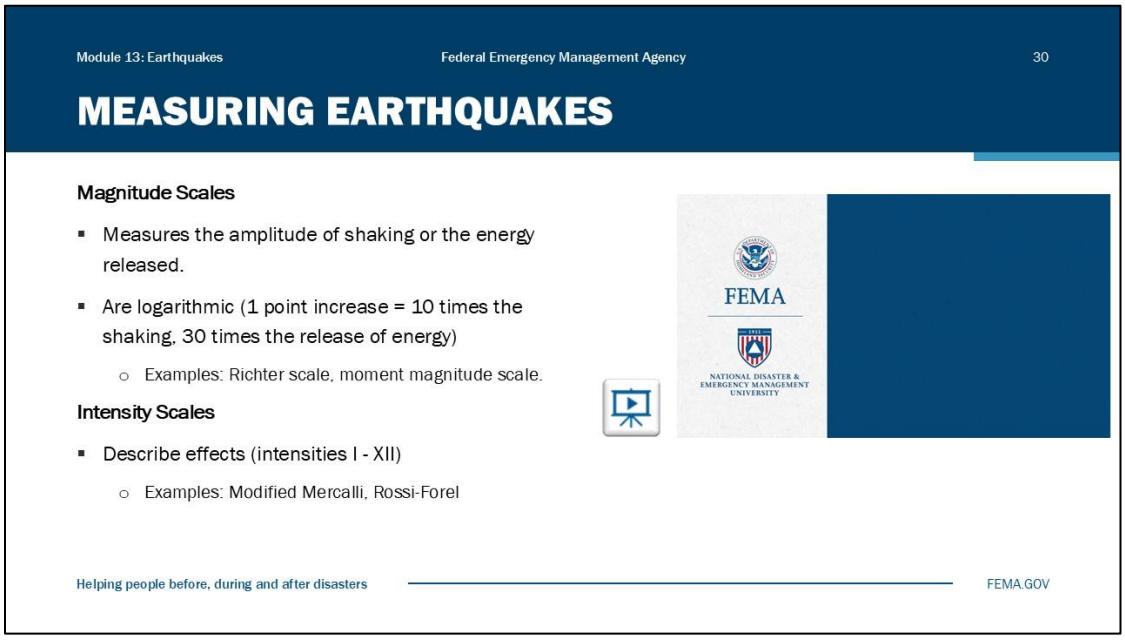
Below is a surface projection of the slip distribution from the 2011 Japan earthquake superimposed on General Bathymetric Chart of the Oceans (GEBCO) bathymetry. Red lines indicate major plate boundaries. Gray circles represent aftershock locations, sized according to magnitude.

Aftershocks in the 2011 Japan Earthquake:

Below is a surface projection of the slip distribution from the 2011 Japan earthquake superimposed on GEBCO bathymetry. Red lines indicate major plate boundaries. Gray circles are aftershock locations, sized by magnitude.



Earthquake Fundamentals (16 of 22)



Slide 13–30, Measuring Earthquakes

The sense of motion along a fault provides information about the forces acting on the rock and the fault, which affects estimates of how frequent and how large earthquakes can be, and helps scientists to identify which fault is responsible for a particular earthquake.

Magnitude scales: Earthquake magnitude is a measure of the amount of energy released in an earthquake. When the media reports on an earthquake, they talk about magnitude "on the Richter scale." However, the Richter scale was an early method to calculate earthquake size based on the amplitude of shaking measured by a particular kind of seismometer, which is an instrument that records ground shaking. The Richter scale has since been supplanted by methods such as moment magnitude that do a better job of estimating the amount of energy released in an earthquake.

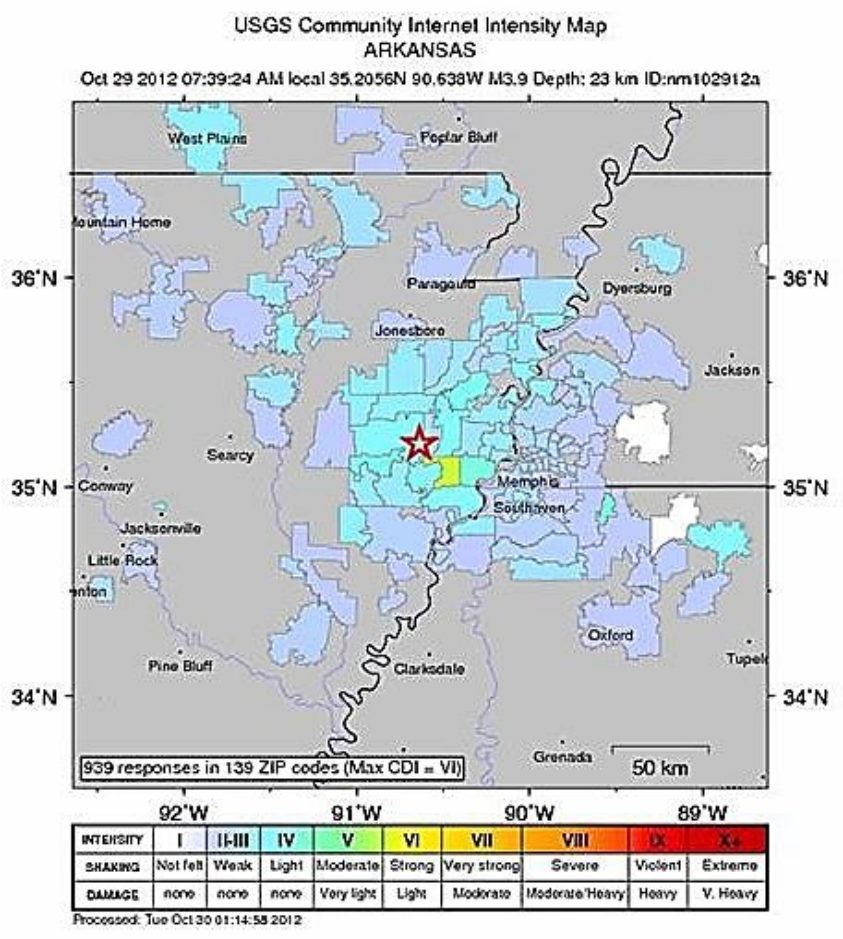
Magnitude scales are base-10 logarithmic scales, so when a magnitude goes up one point, the amplitude of shaking goes up by ten times, and the released energy goes up by 30 times.

An earthquake will be assigned only one magnitude, although that measure will probably fluctuate as new data come in that help to refine the number. The bigger the magnitude, the bigger the earthquake, that is, the longer the shaking will last, the stronger the shaking can be, and the greater the likelihood of damage.

Intensity scales: An intensity scale describes the severity of an earthquake in terms of its effects on the Earth's surface and on humans and their structures. There are many intensities for an earthquake, depending on the location, unlike the magnitude, which is a single number for each earthquake. This is a subjective assessment of what the earthquake was like for a particular person at a particular location.

Measuring Earthquake Intensity: The map below shows reports of intensity from nearly 1,000 people who felt a small earthquake in Arkansas in 2012. For this single earthquake of magnitude 3.9, intensities ranged from barely perceptible to strong shaking that could cause some damage. The intensity scale, indicated by Roman numerals, ranges from I to XII. Intensities of VI and higher can cause significant damage.

The map below shows reports of intensity from nearly 1,000 people who felt a small earthquake in Arkansas in 2012. For this single earthquake of magnitude 3.9, intensities ranged from barely perceptible to strong shaking that could cause some damage. The intensity scale, indicated by Roman numerals, ranges from I to XII. Intensities of VI and higher can cause significant damage. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale.



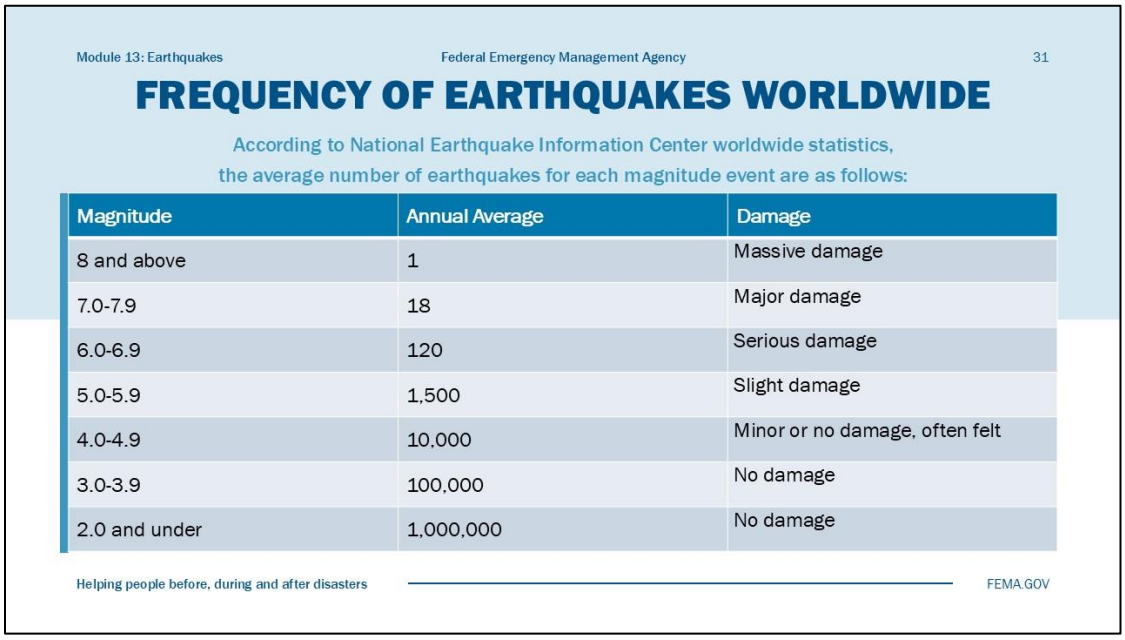
The following table relates the Modified Mercalli scale to earthquake size.

Modified Mercalli vs. Earthquake Size

Modified Mercalli Scale		Richter Scale
1. Felt by almost no one 2. Felt by very few people	2.5	Generally, not felt but recorded on seismometers
3. Tremors noticed by many, but they often do not realize it is an earthquake 4. Felt indoors by many 5. Feels like a truck has struck the building 6. Felt by nearly everyone; many people awakened; swaying trees and poles may be observed	3.5	Felt by many people
7. Felt by all; many people run outdoors. Furniture moved; slight damage occurs. 8. Everyone runs outdoors; Poorly built structures are considerably damaged; slight damage elsewhere.	4.5	Some local damage may occur
9. Specially designed structures damaged slightly, and others collapse 10. All buildings considerably damaged, many shifted off foundations. Noticeable cracks in the ground.	6.0	A destructive earthquake
11. Many structures destroyed. Ground is badly cracked.	7.0	A major earthquake

Modified Mercalli Scale		Richter Scale
12. Almost all structures fall. Very wide cracks in ground 13. Total destruction. Waves seen on ground surfaces; objects are tumbled and tossed	8.0 and up	Great earthquakes

Earthquake Fundamentals (17 of 22)



Slide 13–31, Frequency of Earthquakes Worldwide

According to the National Earthquake Information Center worldwide statistics (U.S.) (*Earthquakes*, n.d.), the average number of earthquakes for each magnitude event is as follows:

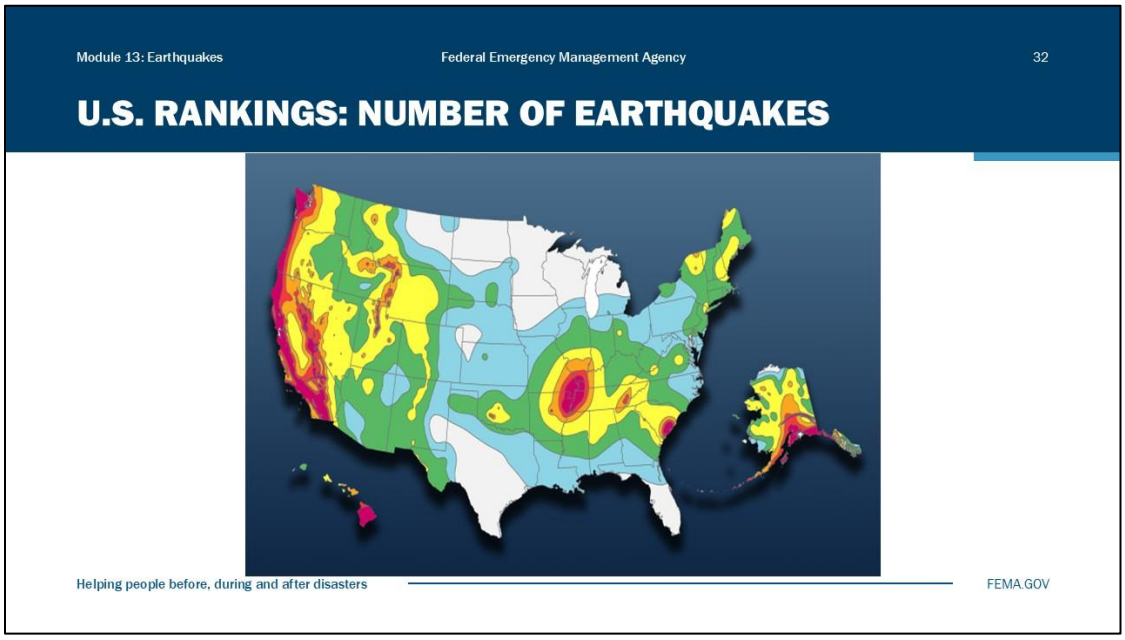
How Often do Earthquakes Occur?

Magnitude	Average #/yr worldwide	Damage
8.0 and above	1	Massive damage
7.0-7.9	18	Major damage
6.0-6.9	120	Serious damage
5.0-5.9	1,500	Slight damage
4.0-49	10,000	Minor or no damage, often felt
3.0-3.9	100,000	No damage
2.0 and under	1,000,000	No damage

Larger earthquakes happen less often than smaller earthquakes. The frequency of occurrence changes by approximately a power of 10 with each change of magnitude point. Thus, for every magnitude 7, there will be about 10 magnitude 6 earthquakes and about 100 magnitude 5 earthquakes.

Source: *How Often Do Earthquakes Occur?- Incorporated Research Institutions for Seismology*. (n.d.). Retrieved May 19, 2025, from https://www.iris.edu/hq/inclass/fact-sheet/how_often_do_earthquakes_occur

Earthquake Fundamentals (18 of 22)



Slide 13–32, U.S. Rankings: Number of Earthquakes

U.S. Rankings: Number of Earthquakes Image Description—*Map showing the levels of horizontal shaking that have a 2-in-100 chance of being exceeded in a 50-year period. Shaking is expressed as a percentage of g (g is the acceleration of the falling object due to gravity). There is the highest hazard along the west coast (with 80+% g) to 16- 31% g towards the central U.S. Towards the Midwest, the highest hazard moves to 8- 16% g. Central U.S. has 4-8 highest hazard, with an increase to 64+%g around the borders where Arkansas, Missouri, Kentucky, Tennessee, and Mississippi meet. There is an increase in Earthquakes along the Atlantic Ocean in South Carolina at the highest hazard of 64+%g. The Northeast is from 8- 16% g highest hazard. Alaska has an earthquake hazard of 64+ along the south coast, decreasing northwards up to 0- 4% g. Hawaii has the highest hazard on the Island of Hawaii at 64+, Kihei is 32-48, Honolulu is 16-32, and Koloa is 8-16% g. The mid-north states have a low hazard from 0-4. South Florida and South Texas also have a low of 0- 4% g.*

State rankings over 29 years: This map ranks the States by the greatest number of earthquakes of magnitude 3.5 or above, based on instrumental records from 1974 to 2003. A magnitude 3.5 earthquake is large enough to feel but unlikely to cause damage.

The top 10 States are bright yellow (Alaska was the top producer), the next 10 are orange, the remaining States with at least 1 event in 30 years are light yellow, and States that had none are gray.

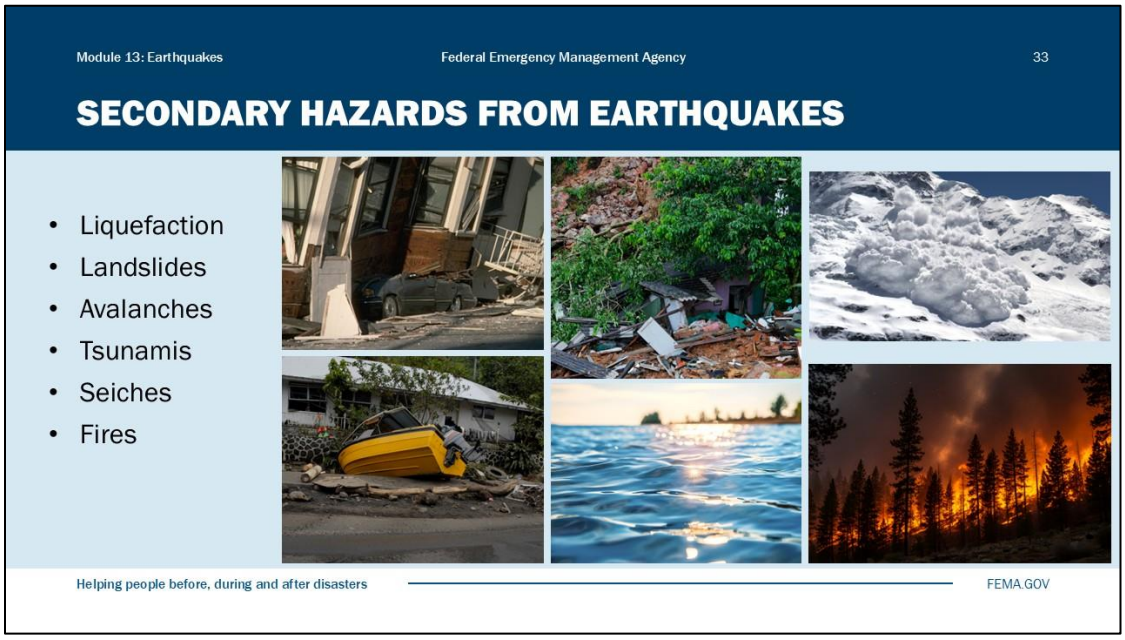
Even in this short timeframe, two patterns emerge:

- The western States and the area around the southern Mississippi River have earthquakes more often than other places in the United States.
- It is important to remember that earthquakes can occur anywhere. It is reasonable to expect a "feelable" earthquake anywhere in the country, and the rankings of most States will shift over time.

Earthquake occurrence over 250 years: The map on the next page shows earthquakes detected during about 250 years in the United States—a much larger scale than on the visual.

Looking at this longer data set, the previous trends are still apparent, with more earthquakes in the western U.S. and along the Mississippi River. With the longer time span, important additional information emerges, including the large and very damaging earthquake that occurred in Charleston, South Carolina, in 1886. During that earthquake, few buildings escaped damage, and many were completely destroyed.

Earthquake Fundamentals (19 of 22)



Slide 13–33, Secondary Hazards from Earthquakes

Hazards that result from another hazard are called secondary hazards.

Many of the hazards related to earthquakes are secondary hazards caused by ground shaking or surface fault rupture. Examples include:

- Liquefaction
- Landslides
- Avalanches
- Tsunamis
- Seiches (pronounced "SAYSH")
- Fires

Tsunamis: Underwater earthquakes in the ocean floor can trigger tsunamis—a series of water waves caused by the displacement of a large volume of water. Tsunamis will be covered in the next module.

Seiches: Seiches are typically caused when strong winds and rapid changes in atmospheric pressure push water from one end of a body of water to the other. When the wind stops, the water rebounds to the other side of the enclosed area. The water then continues to oscillate back and forth for hours

or even days. In a similar manner, earthquakes, tsunamis, or severe storm fronts can also cause seiches along ocean shelves and harbors.

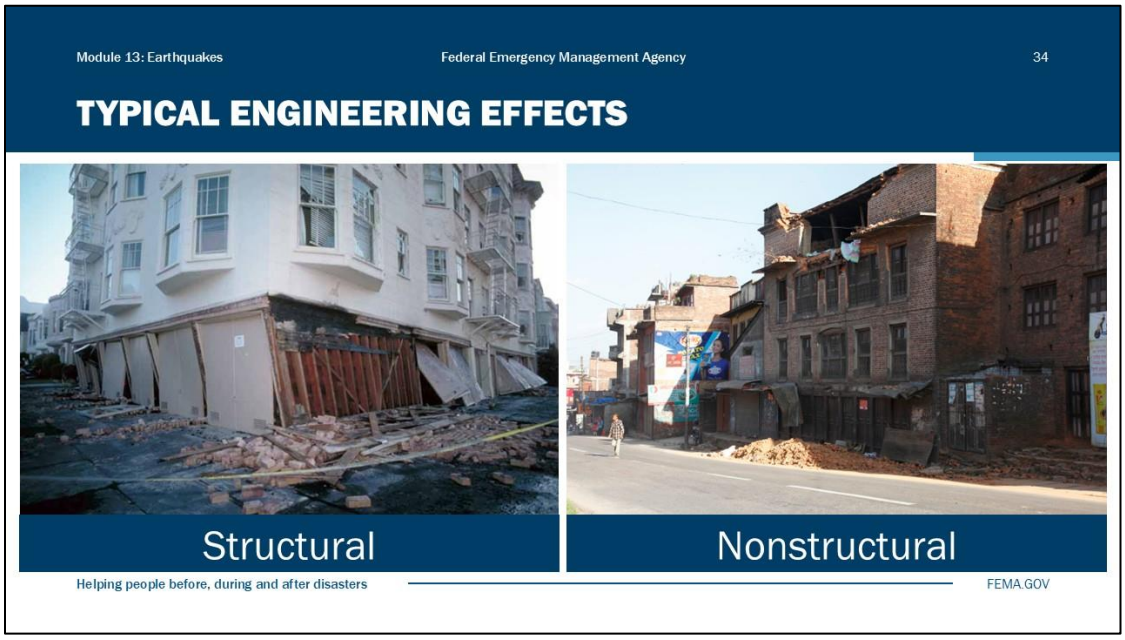
Fires: Sometimes, an earthquake's secondary hazard can cause more destruction than the primary hazards of ground shaking or fault rupture. Fires are an example.

Fires occur following all earthquakes that strongly shake human settlements. In large metropolitan areas comprising densely packed wood buildings, the fires have evolved into catastrophic conflagrations. The two largest peacetime urban conflagrations in history (San Francisco in 1906 and Tokyo in 1924) were caused by earthquakes.

Earthquakes can easily start fires and impede firefighting efforts by damaging buildings, water systems, communications, and transportation systems. For example, earthquakes can contribute to fires through:

- Numerous and simultaneous ignitions;
- Damage that degrades fire-resistive features of buildings;
- Decreased pressure in water supply mains;
- Damage to water conveyance systems;
- Damaged or saturated communications systems; and
- Disruption of transportation.

Earthquake Fundamentals (20 of 22)



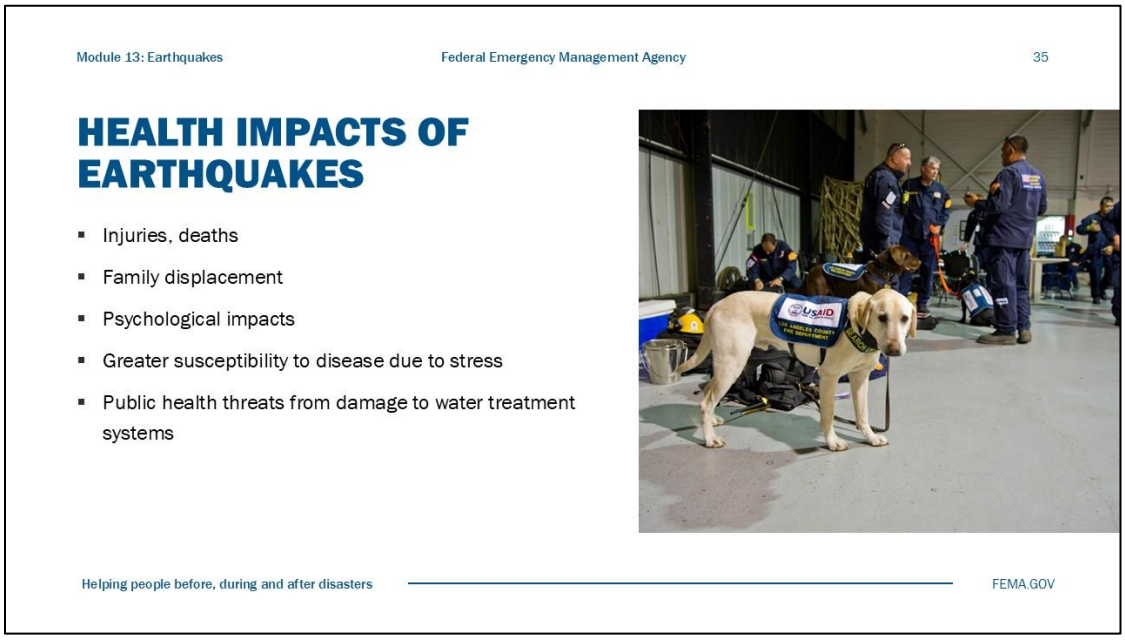
Slide 13–34, Typical Engineering Effects

There is a saying in the earthquake engineering world: “Earthquakes don’t kill people, buildings kill people.”

Building damage can be structural or nonstructural. Unreinforced masonry construction is especially susceptible to structural damage.

Nonstructural damage is often the major source of injury and damage in buildings that do not collapse.

Earthquake Fundamentals (21 of 22)



Slide 13-35, Health Impacts of Earthquakes

Direct health and safety impacts from earthquakes include:

- Injuries and deaths caused by falling debris, collapsing buildings, landslides, and secondary fires;
- Displacement of families, which can lead to stress, unsanitary living conditions, and public health concerns;
- Mental health effects, including trauma and anxiety;
- Increased risk of disease and worsening of chronic health conditions due to stress; and
- Public health risks caused by damaged water and wastewater treatment systems, overcrowded shelters with poor sanitation, and destruction of public health infrastructure.

Example: After the 2010 earthquake in Haiti, a cholera outbreak caused more than 6,000 deaths and over 350,000 hospitalizations.

Earthquake Fundamentals (22 of 22)



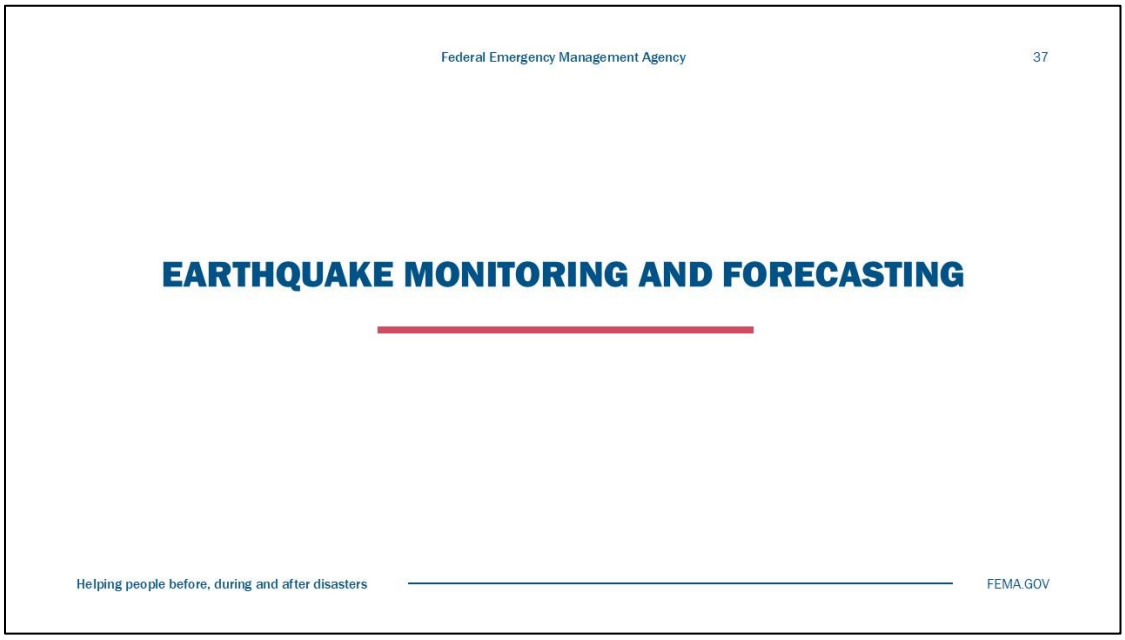
Slide 13–36, Environmental Health Impacts from Earthquakes

Although the acute direct health impacts of earthquakes are clearly extensive and most visible, environmental geochemists have identified numerous long-term, sometimes less obvious health impacts resulting from environmental contaminants produced by the disaster.

Some of the many possible contaminants that can be produced by earthquakes include:

- Hazardous chemicals are released from damaged or burning industrial facilities in the form of toxic gases, liquid chemicals, or smoke.
- Smoke or other combustion products from earthquake-generated urban firestorms.
- Toxicants in dusts from building collapse, including:
  - Caustic alkalis
  - Lead
  - Antimony
  - Mercury
  - Asbestos

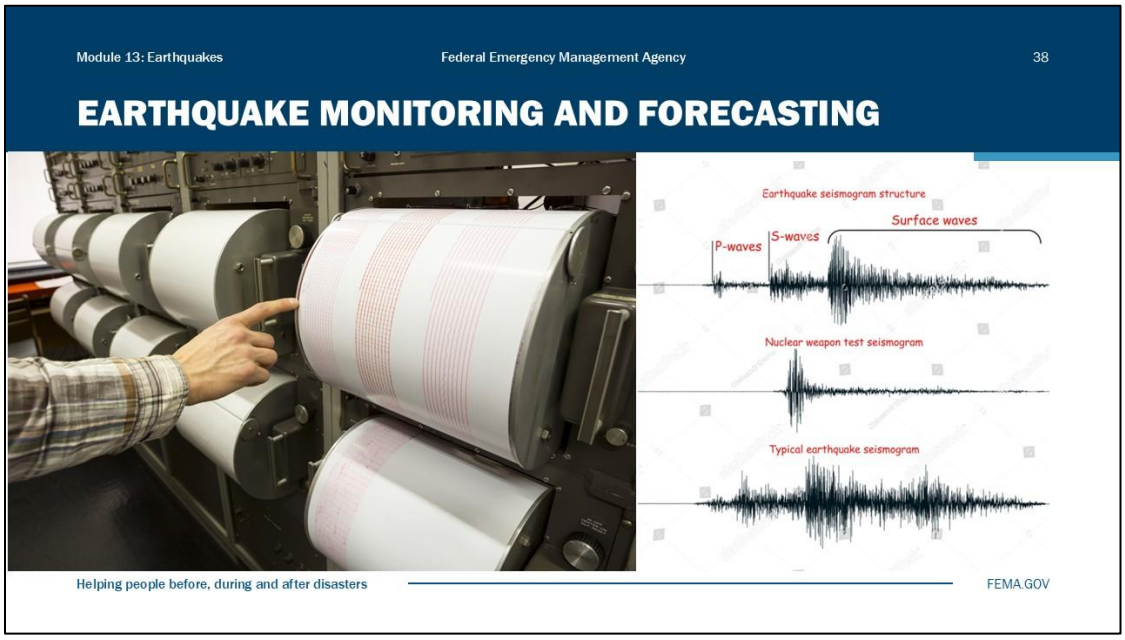
Earthquake Monitoring and Forecasting (1 of 5)



Slide 13–37, Earthquake Monitoring and Forecasting

Not Applicable.

Earthquake Monitoring and Forecasting (2 of 5)



Slide 13–38, Earthquake Monitoring and Forecasting

This final section of the module will discuss earthquake monitoring and forecasting.

Earthquake Monitoring and Forecasting (3 of 5)



Slide 13–39, Earthquake Monitoring

Throughout the United States, earthquakes are monitored by networks of scientific instruments. This involves two key areas of study:

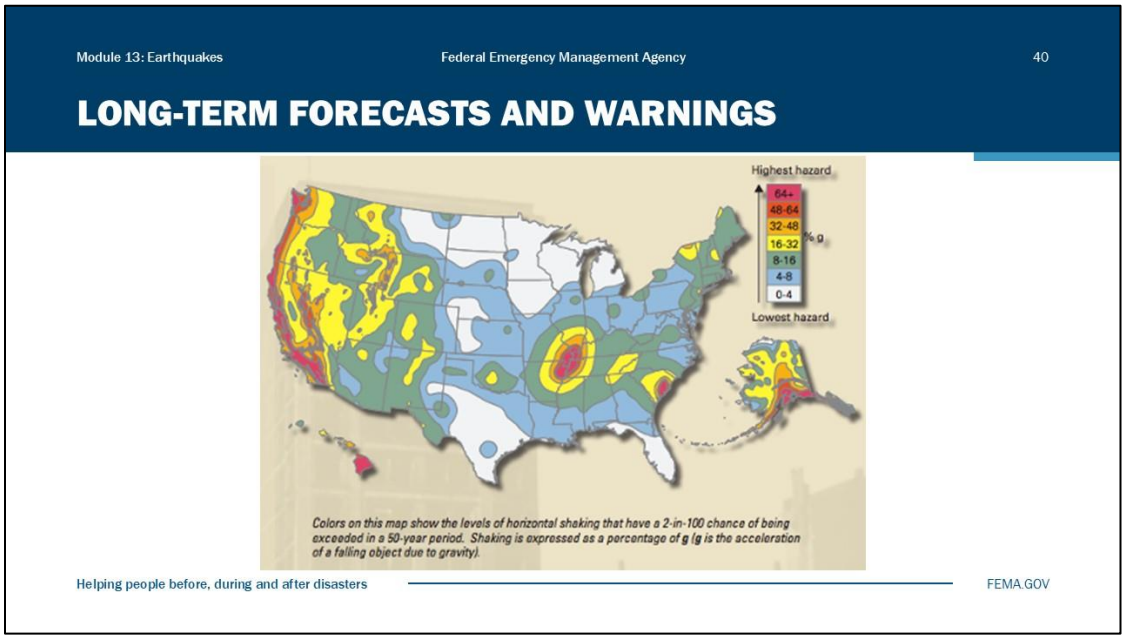
- **Seismicity:** The geographic and historical distribution (the "where?" and "how often?") of earthquakes.
- **Seismology**: The study of earthquakes and the structure of the Earth by both naturally and artificially generated seismic waves.

Seismometer system: The map above shows the locations of seismometers that continuously record ground motion for the Advanced National Seismic System. Regional networks operate additional stations in areas of higher seismicity. Other instruments are deployed temporarily to capture data during aftershock sequences or for other scientific studies.

Seismometers can measure ground motion in three orientations (typically north-south, east-west, and up-down), which captures a complete representation of a site's ground motion.

GPS networks: This map shows locations of global positioning system (GPS) networks, which monitor deformation as earthquake faults accumulate strain or rupture. Some GPS stations operate continuously, while others are deployed temporarily.

Earthquake Monitoring and Forecasting (4 of 5)



Slide 13–40, Long-Term Forecasts and Warnings

Long-Term Forecasts and Warnings Image Description—*Map showing the levels of horizontal shaking that have a 2-in-100 chance of being exceeded in a 50-year period. Shaking is expressed as a percentage of g (g is the acceleration of the falling object due to gravity). There is the highest hazard along the west coast (with 64%+ g) to 16-31% g towards the central U.S. Towards the Midwest, the highest hazard moves to 8-16% g. The Central U.S. has 4-8 highest hazard, with an increase to 64+% g around the borders where Arkansas, Missouri, Kentucky, Tennessee, and Mississippi meet. There is an increase in Earthquakes along the South Carolina coast, particularly along the Atlantic Ocean, with the highest hazard of 64% or more g. The Northeast has an 8-16% risk, with the highest hazard. Alaska has an earthquake hazard of 64+ along the south coast, decreasing northwards to 0-4% g. Hawaii has the highest hazard on the Island of Hawaii at 64%, Kihei is 32-48%, Honolulu is 16-32%, and Koloa is 8-16%. The mid-north states have a low hazard from 0-4. South Florida and South Texas also have a low of 0-4% growth.*

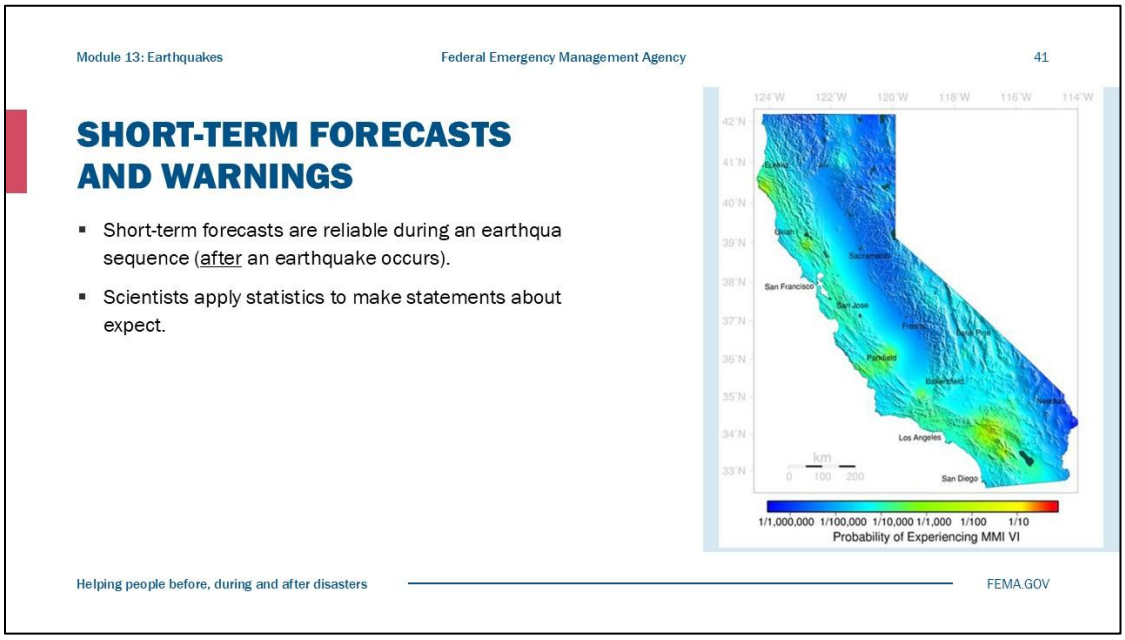
Prediction: To put it simply, scientists cannot predict earthquakes. An earthquake prediction requires three components: statements of when, where, and how big the earthquake will be.

Within the scientific community, there is debate about whether it will ever be possible to predict earthquakes, even with unlimited data and additional understanding. Earthquakes involve chaotic processes and may be inherently unpredictable.

Forecasts: What scientists can do instead is develop earthquake forecasts. These statements involve probabilities and uncertainties, discussing the likelihood of an earthquake occurring within a particular timeframe.

This National Seismic Hazard Map is an example of a long-term forecast, specifically the likelihood of exceeding a certain level of shaking within 50 years.

Earthquake Monitoring and Forecasting (5 of 5)



Slide 13–41, Short-Term Forecasts and Warnings

- Short-term forecasts are reliable during an earthquake sequence (after an earthquake occurs).
- Scientists apply statistics to make statements about what to expect.

Forecast reliability: Long-term earthquake forecasts are more accurate than short-term earthquake forecasts. This is the opposite of weather forecasting, where short-term weather forecasts for the next day are substantially more accurate than the long-term weather trend forecasts that cover decades.

Short-term earthquake forecasts are most reliable during an earthquake sequence—that is, after an earthquake has occurred. At that point, scientists can apply the statistics regarding the occurrence of foreshocks and aftershocks to make statements about what to expect next.

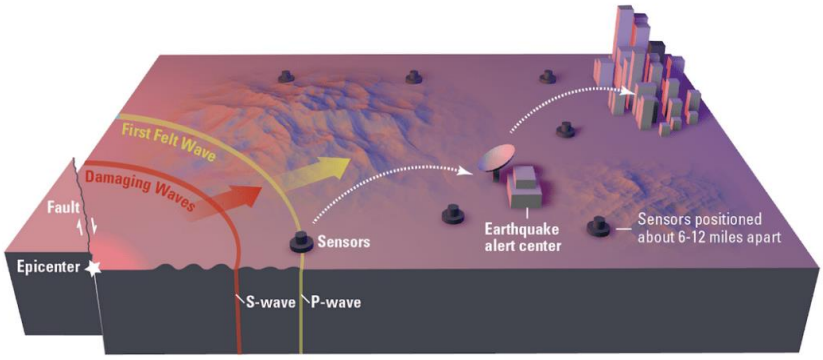
Earthquake early warning systems are operational in several countries, including Japan and Mexico, and are being prototyped in California. An earthquake early warning system uses computers that detect that a large earthquake has begun, then calculate how long until strong shaking will arrive at a given location and then send an alert that can prepare communities in many ways.

The ShakeAlert® Earthquake Early Warning (EEW) System, managed by the U.S. Geological Survey, detects significant earthquakes quickly enough to deliver alerts to people and automated systems

potentially seconds before strong shaking arrives. ShakeAlert is the nation's only public EEW system and it serves over 50 million residents and visitors in California, Oregon, and Washington. The purpose of the ShakeAlert System is to reduce the impact of earthquakes to save lives and property.

The USGS works with licensed technical partners who use USGS-issued ShakeAlert Messages to alert people to take protective action or to trigger automated actions. These automated actions could include slowing trains, closing water valves, and turning on backup generators. (https://www.shakealert.org/)

- In an earthquake, a rupturing fault sends out two different types of waves. The fast-moving P-wave is first to arrive, but the damage is caused by the slower S-waves and surface waves.
- Sensors detect the P-wave and immediately transmit data to an earthquake alert center, where the location and size of the quake are determined and updated as more data becomes available.
- A message from the alert center is immediately transmitted to users.



Limitations

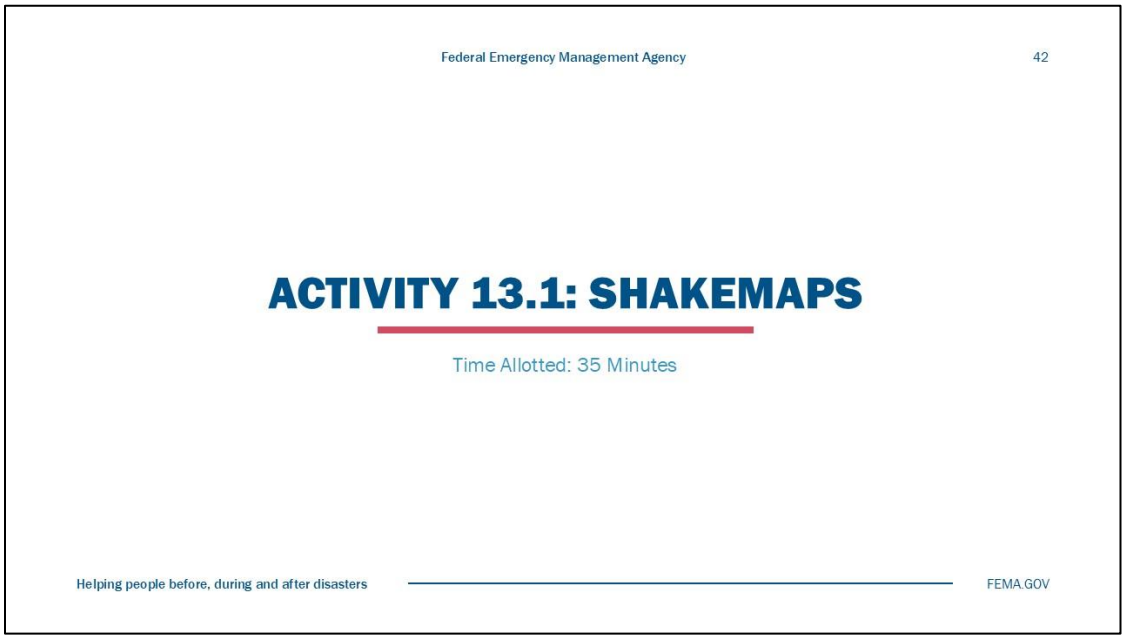
- Earthquake early warning is not earthquake prediction.
- The alert cannot come before the earthquake starts.
- The goal is for people to receive the alert before they feel shaking.
- People may receive an alert before, during, or after shaking arrives at their locations.
- The length of the warning depends on a number of factors. These include how close the seismic sensors are to each other, how quickly the data moves through the system (we are working to speed it up every day), how big the earthquake is, how deep it started in the earth, and whether it moved through sand, solid ground, or bedrock.
- The California Earthquake Early Warning System is based on innovative technology that will improve over time.

- In rare circumstances, you may receive a ShakeAlert® when there was no earthquake.

https://earthquake.ca.gov/how-it-works/

Earthquake Early Warning successfully protected Japan from most damage during the magnitude 9 Tohoku earthquake in 2011. However, the accompanying tsunami caused widespread devastation.

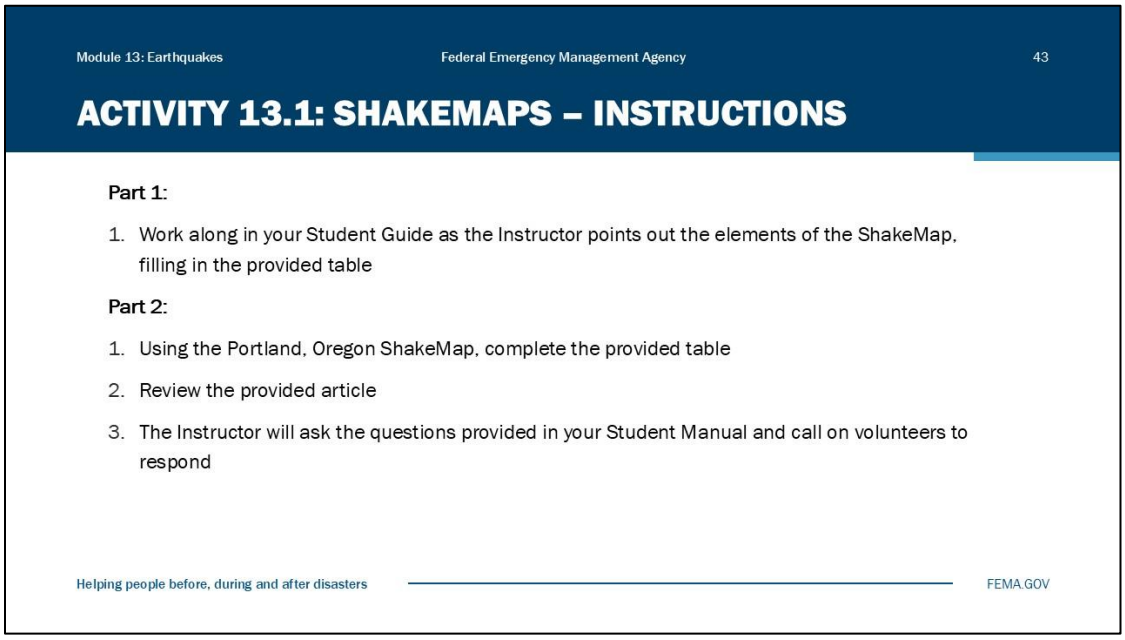
Activity 13.1: ShakeMaps (1 of 3)



Slide 13–42, Activity 13.1 – ShakeMaps

Not Applicable.

Activity 13.1: ShakeMaps (2 of 3)



Slide 13–43, Activity 13.1: ShakeMaps Instructions

Activity 13.1: ShakeMaps – Directions to Students

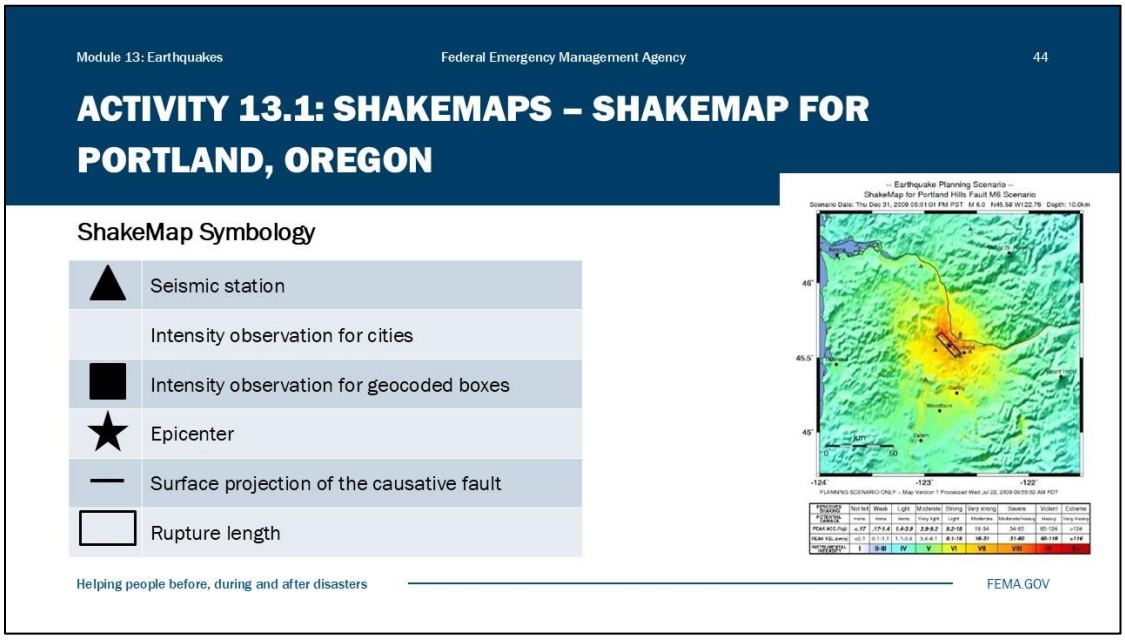
Part 1:

1. Work along in your Student Guide as the Instructor points out the elements of the ShakeMap, filling in the provided table.

Part 2:

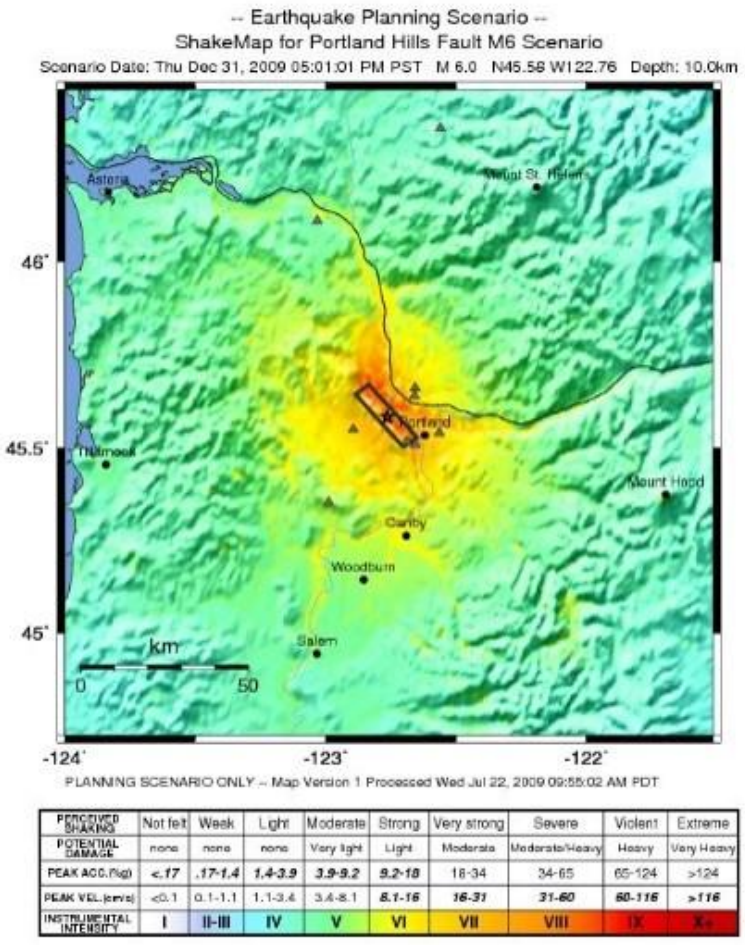
2. Using the Portland, Oregon ShakeMap, complete the provided table.
3. Review the provided article.
4. The instructor will ask the questions provided in your Student Guide and call on volunteers to respond.

Activity 13.1: ShakeMaps (3 of 3)



Slide 13–44, Activity 13.1: ShakeMaps – ShakeMap for Portland, Oregon

ShakeMap Symbology. It is a recent ShakeMap convention to depict seismic stations as **triangles** and intensity observations as **circles** (for cities) or **squares** (for geocoded boxes). On intensity maps, symbols are unfilled so that the underlying intensity values are visible. On peak ground motion maps, observations are (optionally) color-coded to their amplitude according to the legend shown below each map. The epicenter is indicated with a **star,** and for larger earthquakes, the surface projection of the causative fault is shown with black lines. **Rectangular boxes** represent the rupture length.



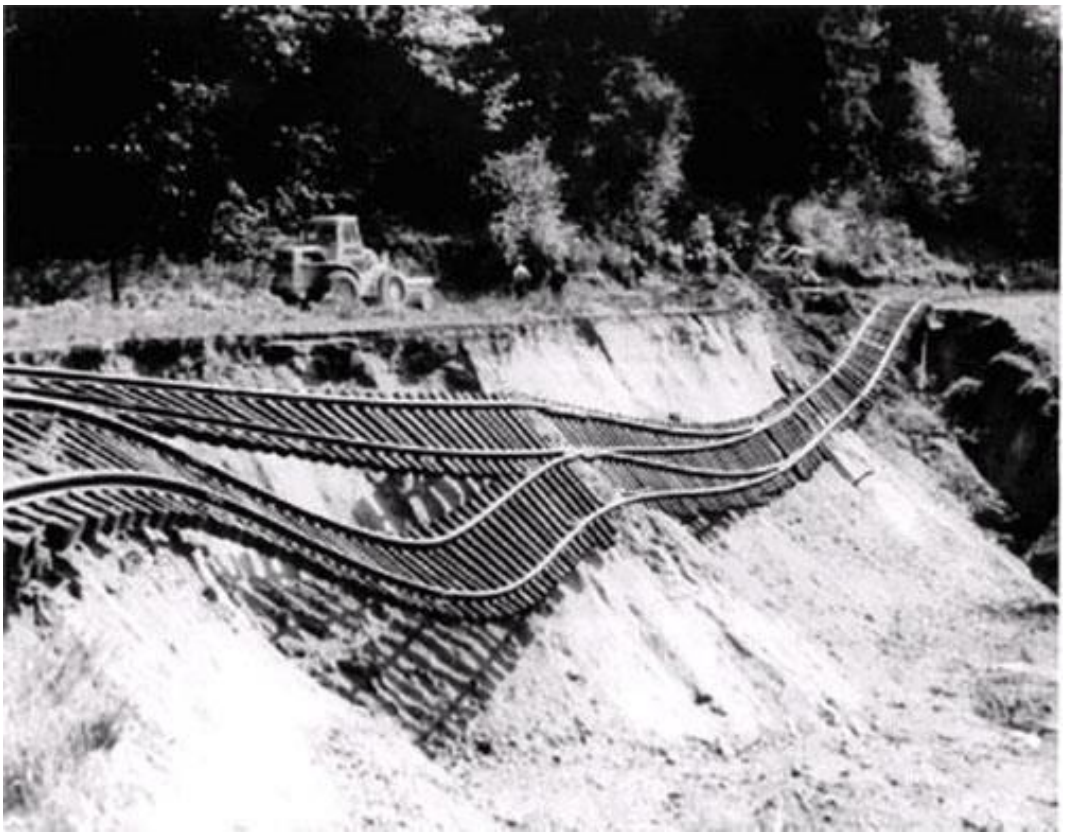
Activity 13.1 Part 2 Worksheet

Scenario: You are the Emergency Management Director for Multnomah County (Portland), Oregon. The County's Zoning Administrator has drafted for the County Board's consideration for adoption new ordinances that meet current recommendations for your risk profile. There has not been a damaging earthquake in many years, and there is some concern among community leaders that the additional costs of compliance may be an undue burden on the homeowners and businesses in your County. Your supervisor, the County Executive, has asked you to work with the Zoning Administrator to create a tabletop exercise to show community leaders (elected officials, business leaders, leading citizens, media) about the risk of the area.

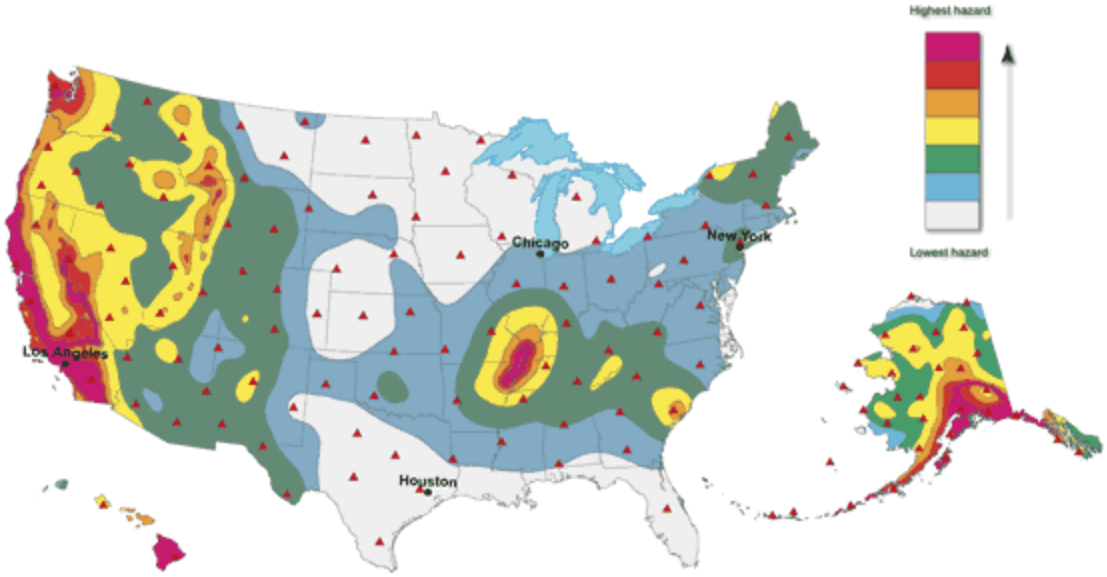
The USGS has provided the Administrator with a "likely but not the most catastrophic" scenario for your area in the form of the following ShakeMap used in Activity 13.1.

Activity 13.1 Part 2 Job Aid

Cascadia Subduction Zone: Are Portland and Seattle prepared for an earthquake and tsunami? By on July 22, 2010 at 8:18 AM, updated July 15, 2015 at 5:10 PM



Pacific Northwest Seismic Network (www.pnsn.org)



Source: *Model of Future Seismicity- Hazards 101 | U.S. Geological Survey*. (2019, August 6). https://www.usgs.gov/media/images/model-future-seismicity-hazards-101

Earthquake hot spots

Washington and Oregon are in one of the most dangerous U.S. earthquake zones. In a list of states ranked by the number of earthquakes with a magnitude of 3.5 or higher in the past 30 years, Alaska holds the number one spot, and, not surprisingly, California is second.

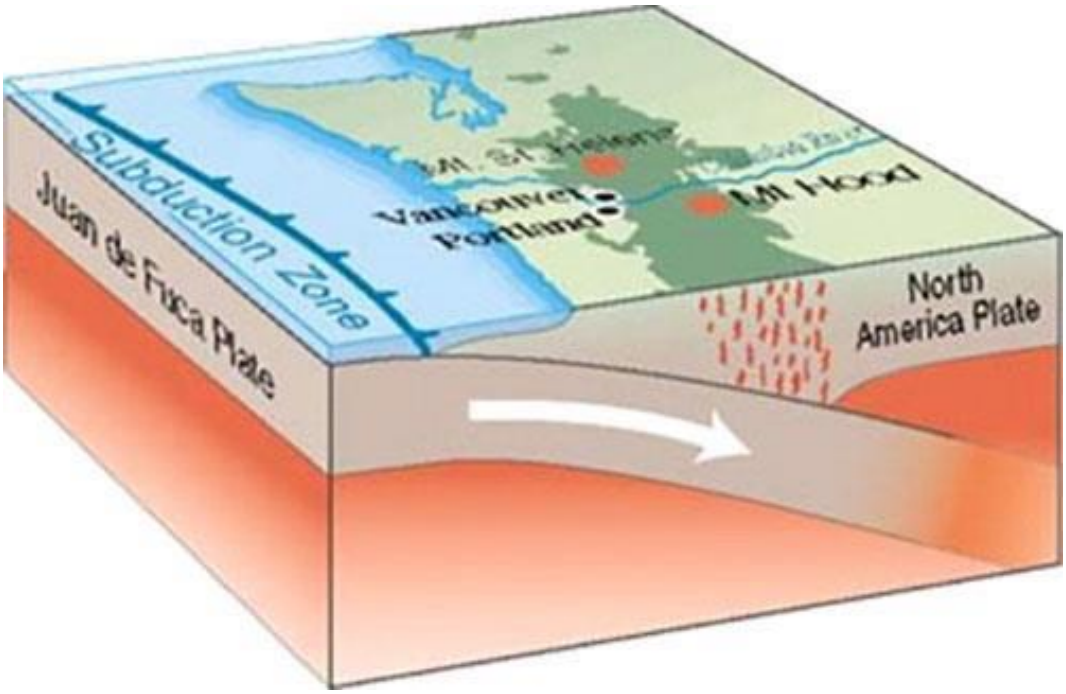
Washington is ranked fifth with 424 quakes, and Oregon is not far behind in the 10th spot with 73 quakes. Why are Washington and Oregon ranked so high?

The Cascadia Subduction Zone is a 700-mile fault that runs from northern California up to British Columbia and is about 70-100 miles off the Pacific coast shoreline. There have been 43 earthquakes in the last 10,000 years within this fault. The last earthquake that occurred in this fault was on Jan. 26, 1700, with an estimated 9.0 magnitude. This earthquake caused the coastline to drop several feet and a tsunami to form and crash into the land. Evidence for this great earthquake came from Japan. Japanese historical records indicate that a destructive distantly-produced tsunami struck their coast on Jan. 26, 1700. By studying the geological records and the flow of the Pacific Ocean, scientists have been able to link the tsunami in Japan with the great earthquake from the Pacific Northwest. Native American legends also support the timing of this last event.

Oregon has the potential for a 9.0+ magnitude earthquake caused by the Cascadia Subduction Zone and a resulting tsunami of up to 100 feet in height that will impact the coastal area. There is an estimated five to seven minutes of shaking or rolling that will be felt along the coastline with the strength and intensity decreasing the further inland you are.

The Cascadia Subduction Zone has not produced an earthquake since 1700 and is building up pressure where the Juan de Fuca Plate is subsiding underneath the North American plate. Currently, scientists are predicting that there is about a 37% chance that a megathrust earthquake of 7.1+ magnitude in this fault zone will occur in the next 50 years. This event will be felt throughout the Pacific Northwest.

https://www.oregon.gov/oem/hazardsprep/pages/cascadia-subduction-zone.aspx



Cascadia Subduction Zone

The Cascadia Subduction Zone lies around 50 miles off the coast of Oregon, Washington, British Columbia, and Northern California.

Cascadia Subduction Zone

About 50 miles offshore under the Pacific Ocean runs the Cascadia Subduction Zone, reaching from Northern California to British Columbia—more than 600 miles long. Unlike the San Andreas Fault, where two tectonic plates butt up against each other, in a subduction zone one plate is pushed under the other.

In Cascadia, the *Juan de Fuca Plate* is being shoved under the *North American Plate*.

According to the Pacific Northwest Seismic Network, subduction zones produce the largest earthquakes, which can exceed magnitude 9.0. Cascadia has a history of significant quakes every 400 years, and experts predict that after years of storing up energy, another Cascadia quake is due.

In subduction zone earthquakes, there are not only strong, long ground-shaking events but also multiple aftershocks and tsunamis.

Is the Pacific Northwest ready for the next big one?

Peter Yanev, an engineer who advises companies how to build to withstand earthquakes, says not well:

Many seismologists believe the Pacific Northwest is overdue for another mega-quake. Yet in cities like Seattle, Vancouver, and Portland, Ore., hardly any building is designed to withstand such a huge jolt.

...Pacific Northwest cities are full of buildings with slender structural frames and fewer and smaller shear walls. In a mega-quake, many of the region's iconic tall buildings would probably collapse.

Buildings and bridges: How does Portland measure up?

How will structures in the Northwest fare in a major quake, and what kind of codes are in place that ensure the public's safety?

Buildings

Oregon's building codes are called the Oregon Structural Specialty Codes, previously the Uniform Building Codes, and have been around since 1973. Scientists' understanding of the Cascadia Subduction Zone is relatively new—around 20 years.

Because of this, Ivan Wong of the URS Corporation said around 99 percent of Oregon's buildings are not designed to withstand the amount of gravitational acceleration or "ground G" found in a subduction zone earthquake.

"*Prior to 1988 ... our building code maps did not consider the Cascadia Subduction Zone."*

With 30 years of engineering experience, Jed Sampson of the Portland Bureau of Development Services said,

"*The problem with our state code is the majority of the things we designed for after 1993, I believe, are going to perform pretty well ... but our old buildings are really going to have problems. Those buildings are not designed for earthquakes. The problem is ... the seismic load was very low until 1988. In 1993, we actually started designing for the seismic forces."*

Commercial structures designed before 1993 were not built to withstand earthquakes, and according to the codes, it's not until an existing building changes use that it is required to retrofit. A grandfather clause says if an office building in the '20s is still an office building today, then the

owners aren't required to retrofit, which means that a substantial number of existing structures have not been upgraded.

A 2007 report by the Oregon Department of Geology and Minerals Industry (DOGAMI) shows that besides commercial structures, more than 1,000 schools, hospitals, and other emergency facilities are at "high" or "very high" risk of collapsing during a major earthquake.

Portland Public Schools, with 89 campuses and a population of 46,000 students, not including teachers and staff, could be destroyed. Seventy-five percent of these school facilities were built before 1930, and only two were built in the last 30 years, according to Sampson.



ODOT

Seismic retrofit of Marquam Bridge using restraint cables

Bridges and roads

If Oregon's buildings are at risk to tumble during an earthquake, how do its bridges and roads measure up?

According to a 2009 study by ODOT, 64 percent of Oregon bridges were built before the '70s, when earthquakes weren't a major consideration in the construction process. Of approximately 2,550 State-owned bridges studied in 1993 for seismic deficiencies, more than 1,600 were found to have "insufficient capacity to resist earthquake loading."

A lack of funding limited the retrofitting process at the time of the 1993 CH2M Hill Seismic Prioritization Report. In 2009, only 178 bridges had received a seismic retrofit, not necessarily the State's most at risk, according to the report.

Liquefaction

Besides the "G" forces in a subduction earthquake, another cause of structural failure is liquefaction—the process by which soil suddenly transforms from a solid to a liquefied state. Many of our roads and bridges sit on soil prone to liquefaction. Wang said, *"The Fremont Bridge was designed in 1960 to very inadequate, if any, seismic standards. Not only the bridge itself, but the approaches and the abutments are subject to problems with poor soils."*

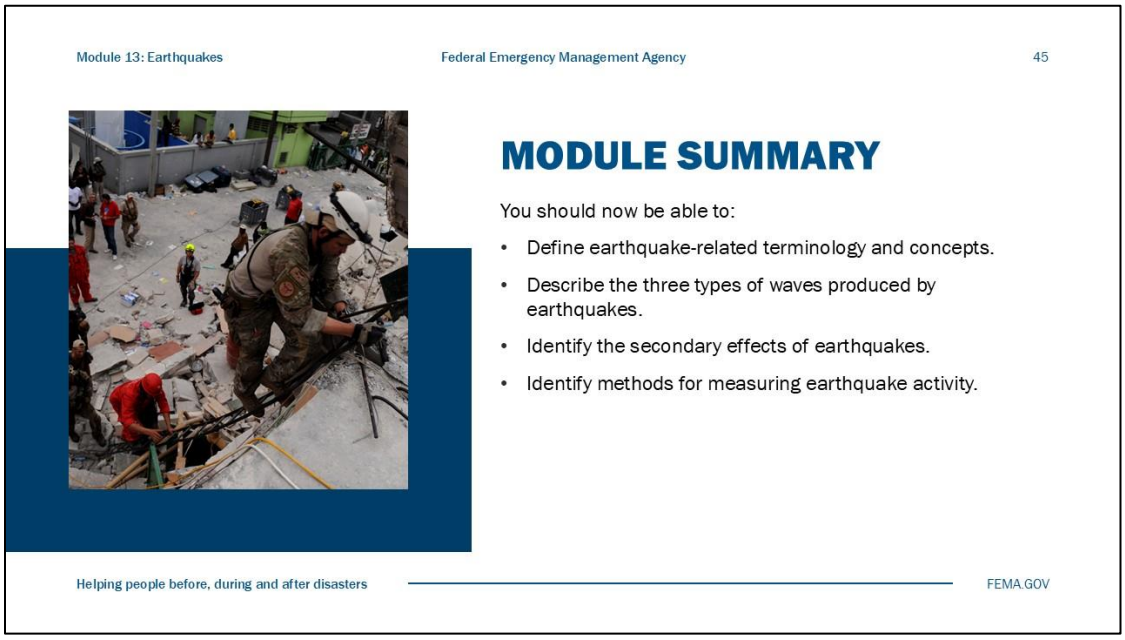
Oregon's bridges and roads are on shaky ground, but according to Wang, so are most of Oregon's liquid fuel supplies and some very important high-voltage electric transmission lines. Should a major quake hit, this reality poses a serious threat to Oregon and Washington's infrastructures.

Activity 13.1 Part 2 Worksheet

You are brainstorming what points you want to highlight to the exercise participants. Use the ShakeMap and information from the news article to create bullet points of learning lessons that can be incorporated into the scenario (i.e., use science to highlight the risks and bring people to the idea of mitigating the risk to citizens with stronger building codes).

Whom might you invite as technical expertise to answer questions in your exercise?

End of Module (1 of 2)



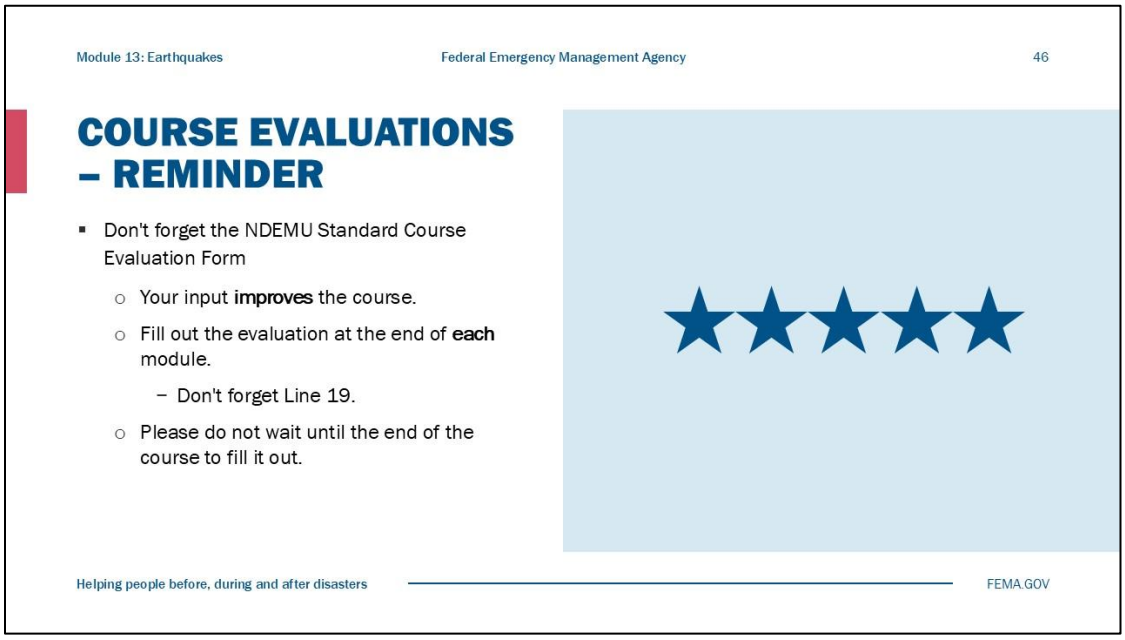
Slide 13–45, Module Summary

MODULE SUMMARY

You should now be able to:

- Define earthquake-related terminology and concepts.
- Describe the three types of waves produced by earthquakes.
- Identify the secondary effects of earthquakes.
- Identify methods for measuring earthquake activity.

End of Module (2 of 2)



Slide 13–46, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

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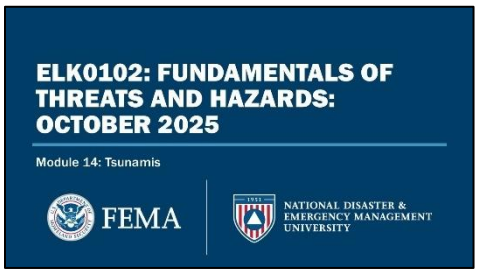
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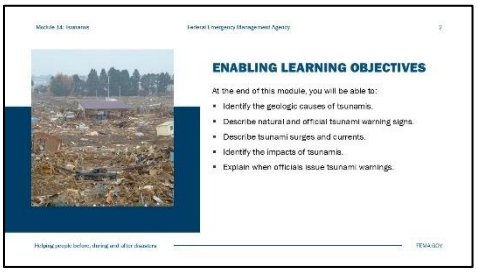
Module 14

Tsunamis

Administration



Slide 14-1, Module 14: Tsunamis



Slide 14-2, Enabling Learning Objectives

Duration

55 minutes

Terminal Learning Objective (TLO)

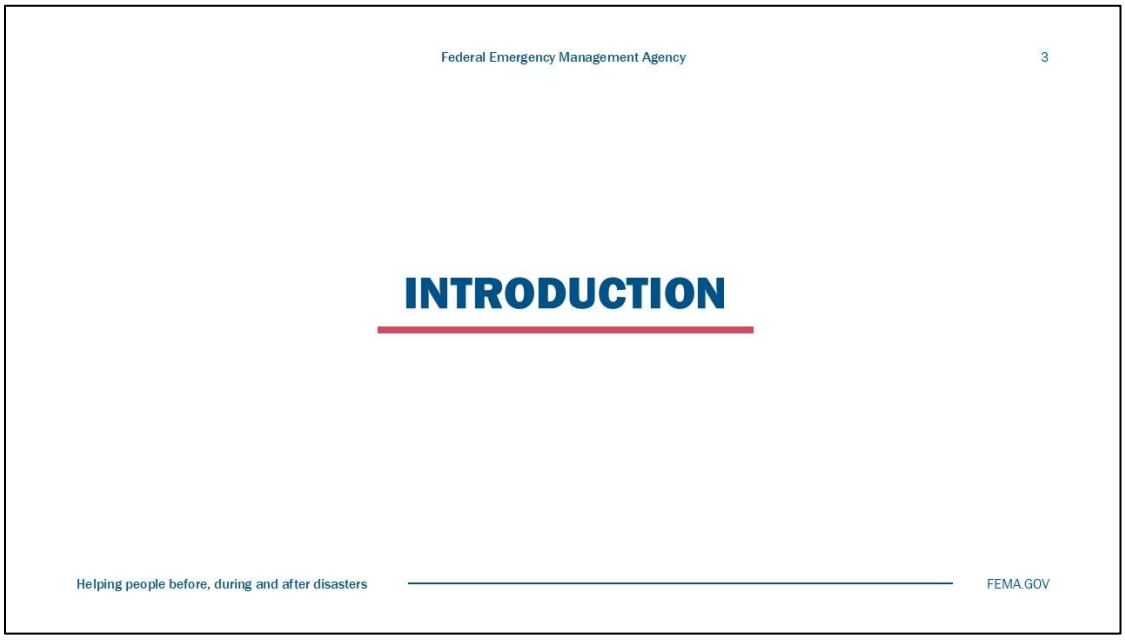
By the end of this module, participants will be able to explain the geologic causes, impacts, and warning systems of tsunamis, emphasizing their lifecycle, wave properties, and effects on public health and the environment.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Identify the geologic causes of tsunamis.
- Describe natural and official tsunami warning signs.
- Describe tsunami surges and currents.
- Identify the impacts of tsunamis.
- Explain when officials issue tsunami warnings.

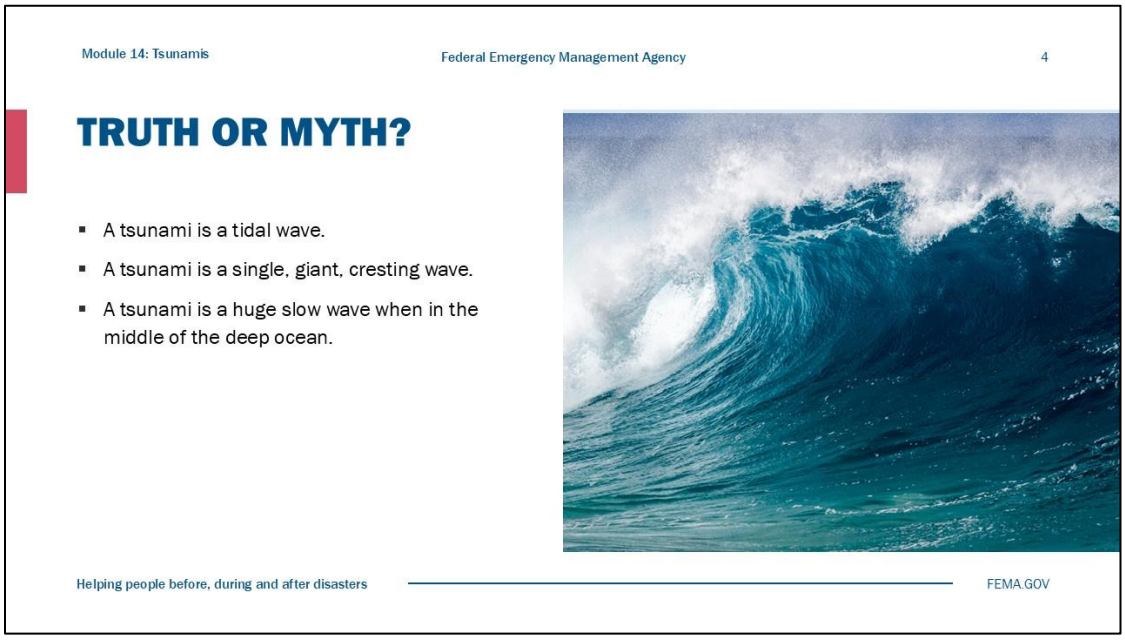
Introduction (1 of 9)



Slide 14-3, Introduction

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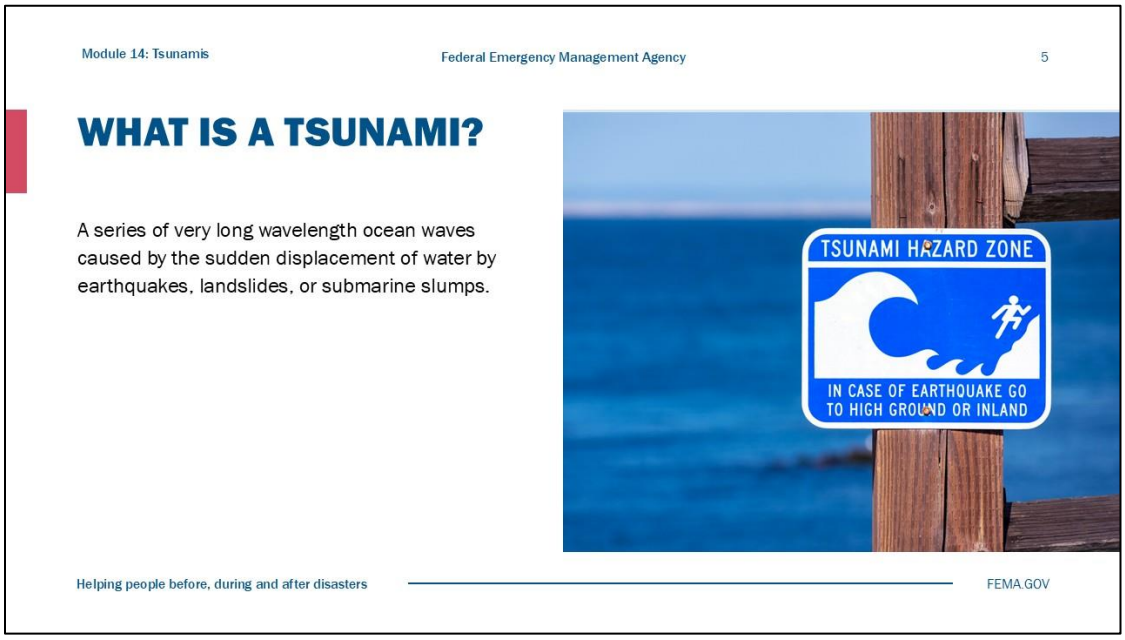
Introduction (2 of 9)



Slide 14-4, Truth or Myth?

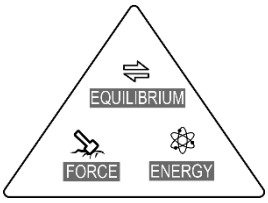
- A tsunami is a tidal wave.
- A tsunami is a single, giant, cresting wave.
- A tsunami is a huge, slow wave when in the middle of the deep ocean.

Introduction (3 of 9)



Slide 14-5, What Is a Tsunami?

This is equilibrium, force, and energy.



A tsunami is a series of very long-wavelength ocean waves caused by the sudden displacement of water by earthquakes, landslides, or submarine slumps. The word tsunami comes from a Japanese word meaning "harbor wave." This is pertinent because tsunamis particularly destroy harbors and marinas. Tsunamis are among the most devastating geologic disasters. Like other hazards, tsunamis come in many sizes, and the most common are small tsunamis that cause little or no harm.

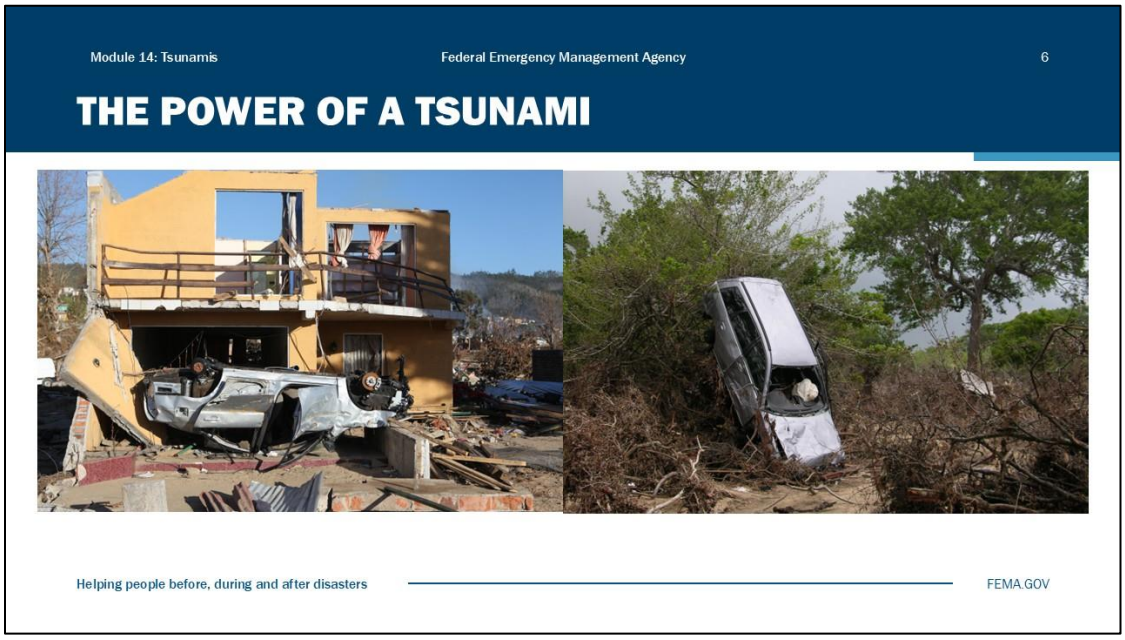
Tsunamis are secondary hazards, which means that they are created as a consequence of another hazard that rapidly displaces a large volume of water. Examples include the Chicxulub meteorite, which struck the Yucatan Peninsula 65 million years ago, thought to have contributed to the extinction of the dinosaurs.

Undersea earthquakes are the most common cause of tsunamis, and the biggest ones (magnitude 8.8 or larger) generate tsunamis with enough energy to cause damage thousands of miles away. Earthquakes large enough to generate extremely large tsunamis occur on the order of decades rather than millennia.

Other events that cause tsunamis include:

- Underwater landslides (aka submarine slumps)
- Volcanic eruptions
- Calving icebergs
- Meteorite impacts (very rarely)

Introduction (4 of 9)

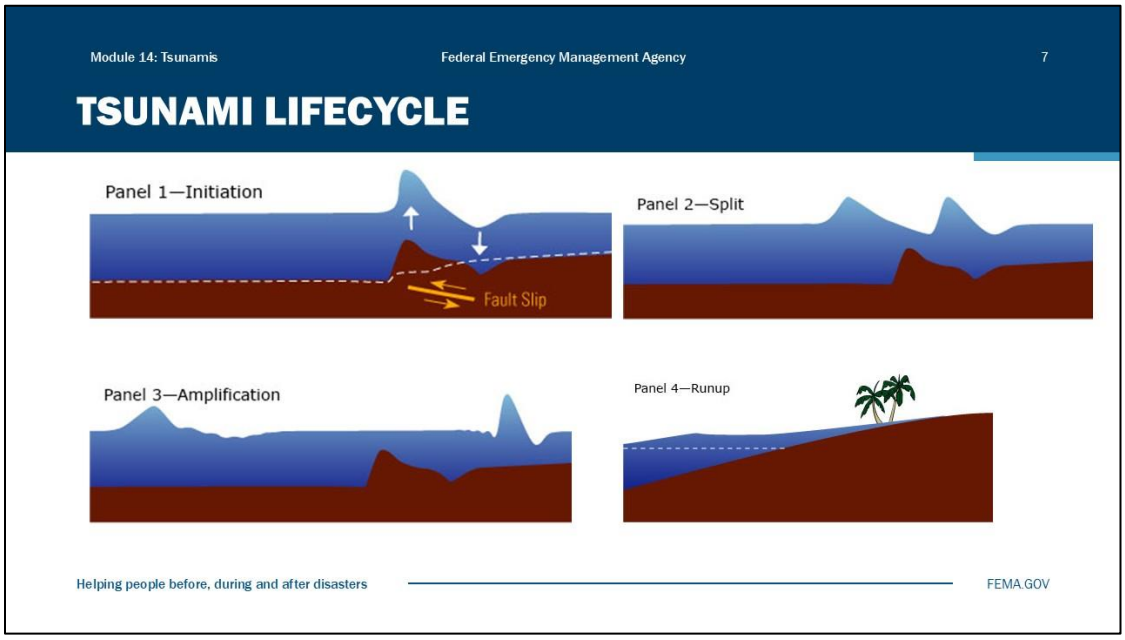


Slide 14-6, The Power of a Tsunami

Tsunamis are among the most devastating geologic disasters. For example, these photos show:

1. A house and a car destroyed by a tsunami in the coastal city of Dichato, Chile. The tsunami height was about 32 feet following an M 8.8 earthquake on February 27, 2010. Several hundred homes were destroyed. (Credit: U.S. Geological Survey, photo by Walter D. Mooney)
2. A car transported by the 2004 tsunami in Sri Lanka. (Credit: U.S. Geological Survey, photo by Dr. Robert Morton.)

Introduction (5 of 9)



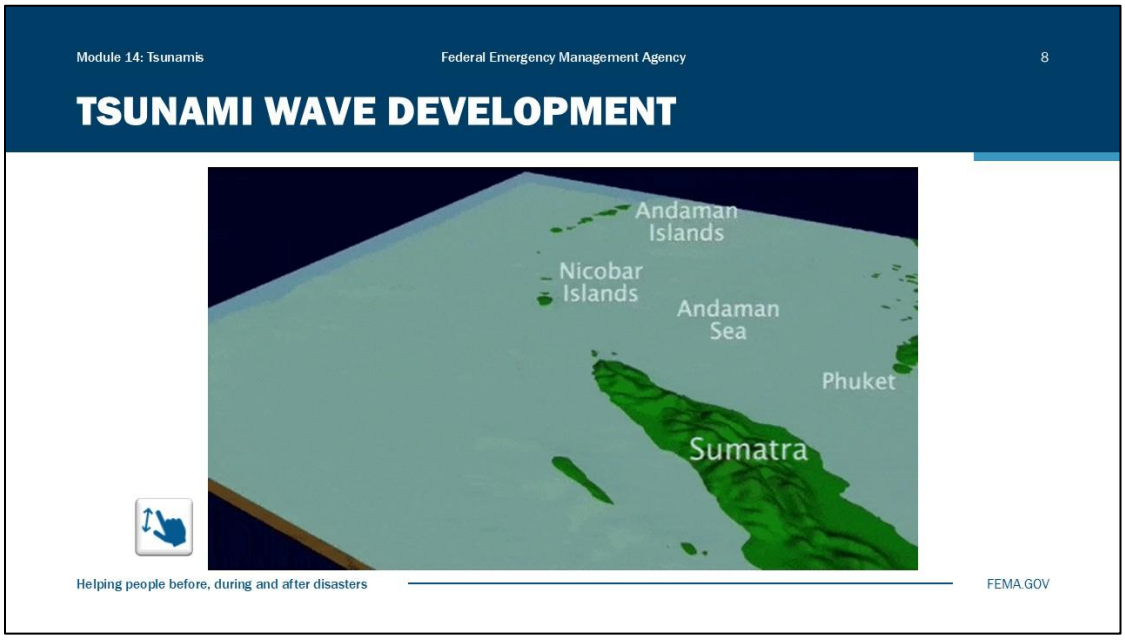
Slide 14-7, Tsunami Lifecycle

Tsunami lifecycle: There are four phases of a tsunami lifecycle:

1. **Initiation:** A geological event causes the tsunami. Water displaced during an earthquake uplifts some seafloor (up arrow) and down-drops other seafloor (down arrow).
2. **Split:** The entire column of water gets displaced and splits into a distant tsunami (moving toward the deep ocean) and a local tsunami (moving toward the nearby coast).
3. **Amplification** The local tsunami's amplitude increases. When a tsunami reaches shallower water near shore, it slows down, and the energy that previously went into speed now goes into amplitude.
4. **Run-up:** The tsunami's peak travels on shore.
5. **Height:** The wave heights are greatly exaggerated in these images. In the open ocean, the waves may be only inches higher than the ocean surface-even in the largest tsunamis-but the energy is moving through the entire column of ocean water.
6. **Speed:** In the open ocean, most of a tsunami's energy goes into wave propagation (i.e., travel), and the wave moves at 500 to 600 miles per hour-about as fast as a jet. When tsunamis reach shallow water, they slow from jet speed to auto speed. On land, they slow down still more, to about 20 mph.

Source: *Tsunamis and Tsunami Hazards | U.S. Geological Survey*. (n.d.). Retrieved October 15, 2025, from https://www.usgs.gov/water-science-school/science/tsunamis-and-tsunami-hazards

Introduction (6 of 9)

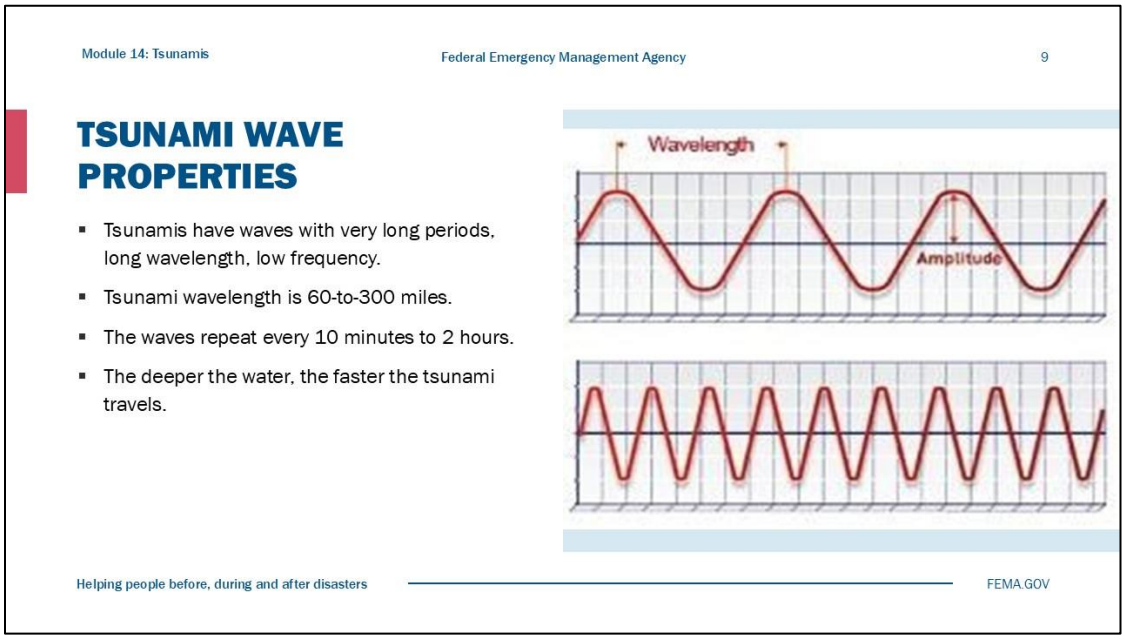


Slide 14-8, Tsunami Wave Development

This animation shows the evolution of tsunami waves caused by the December 26, 2004, Sumatra-Andaman earthquake.

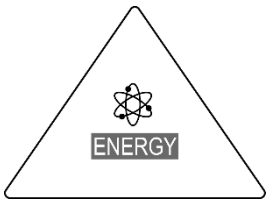
Because it takes approximately 8 minutes for the entire fault to break, tsunami waves generated near the epicenter have propagated part way into the Bay of Bengal by the time the earthquake has just started to generate tsunami waves near the Andaman Islands. Tsunami waves then cross the Andaman Sea toward Thailand. (*Tsunami Waves Caused by 2004 Sumatra-Andaman Earthquake | U.S. Geological Survey*, 2024)

Introduction (7 of 9)



Slide 14-9, Tsunami Wave Properties

This is energy.



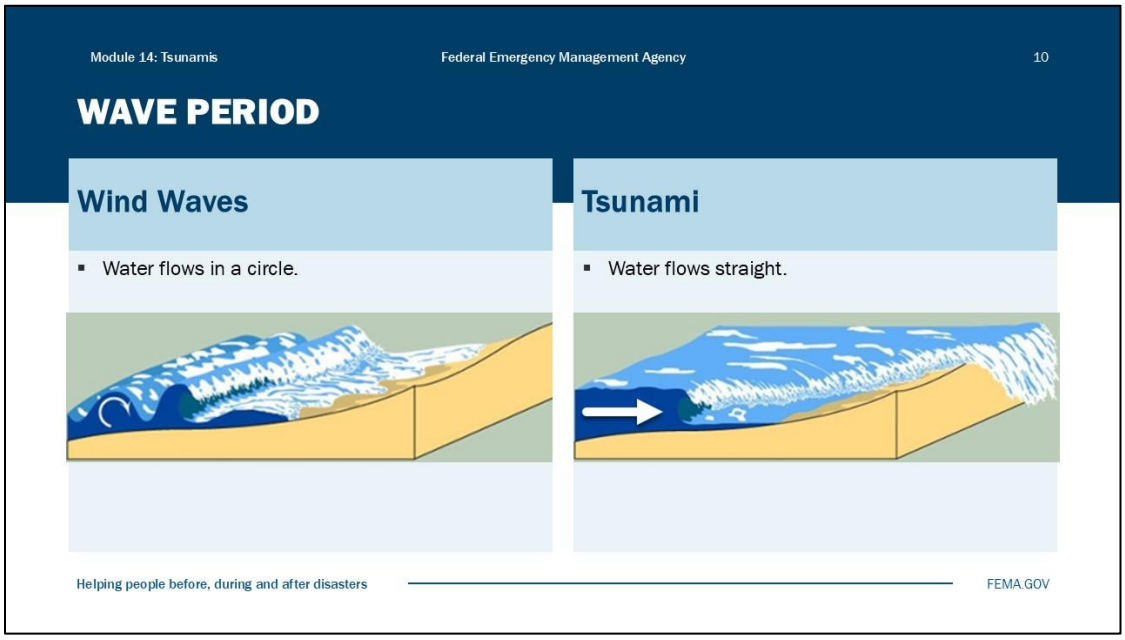
A tsunami, like an earthquake or any other wave phenomenon, is a series of waves called a wave train.

Period: The period measures the time it takes successive waves in the train to pass a given point. Tsunamis have waves with very long periods (also called low frequency). The waves repeat every 10 minutes to 2 hours. In comparison, waves caused by tides or wind have periods of 5-20 seconds.

Wavelength: The wavelength (distance from peak to peak) of a tsunami is 60-300 miles. The wavelength of a wave from a tide or wind is 300-600 feet. The speed is equivalent to that of a high-speed jet.

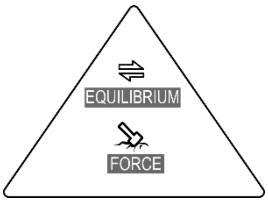
Speed: The speed of a tsunami varies as the square root of water depth. The deeper the water, the faster the tsunami travels.

Introduction (8 of 9)



Slide 14-10, Wave Period

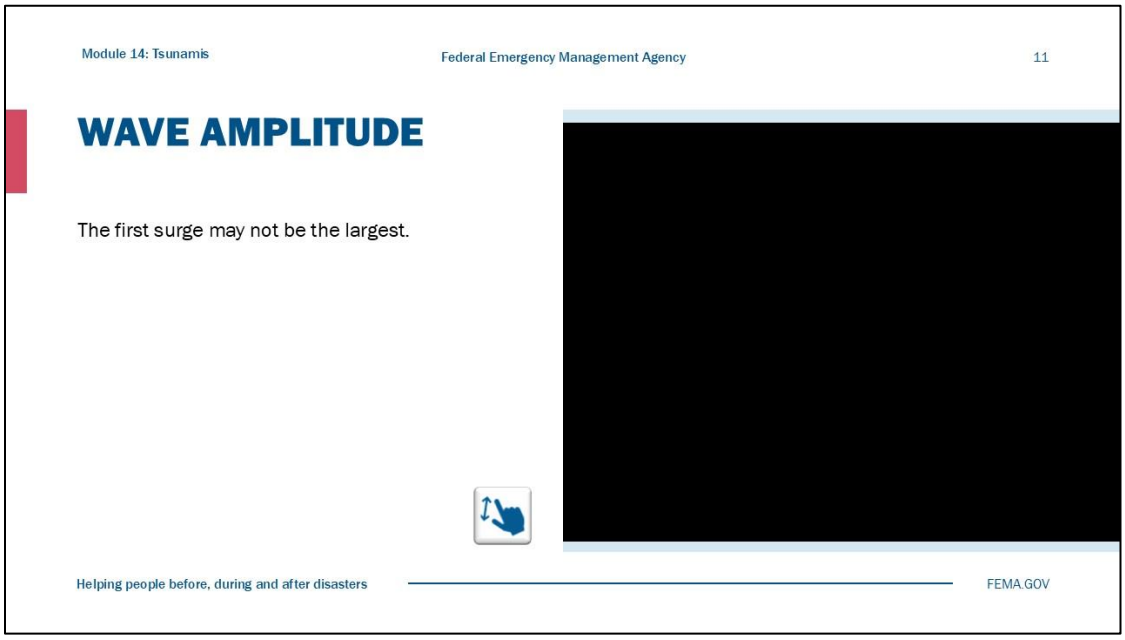
This is equilibrium and force.



Why do tsunamis act differently than the ocean waves created by wind forces? As you learned in an earlier module, the rate at which a wave loses energy is inversely related to its wavelength. Short-period, high-frequency waves lose energy more quickly than long-period, low-frequency waves.

- Wind waves are short-period waves. With wind waves, the water flows in a circular pattern, and the waves come and go without flooding higher areas.
- By contrast, tsunamis are long-period, low-frequency waves that move in a straight path as a great surge of water. Tsunamis come on land with enormous force and recede with nearly equal force. Sometimes, tsunamis crest in shallow water and resemble waves made by tidal forces. More often, they appear as walls of water or turbulent surges that resemble hurricane storm surges.

Introduction (9 of 9)



Slide 14-11, Wave Amplitude

Wave Amplitude Video Description: This scientific animation shows tsunami wave behavior along the northern California coastline. The wave amplitudes are exaggerated to better visualize the effects, and 2.5 hours have been compressed into 30 seconds of animation.

A tsunami rarely arrives as a single surge; it typically has multiple surges. That is because of the complex scattering—the refraction (direction change) and reflection (bounce back)—of tsunami waves as they interact with landforms and other tsunami waves.

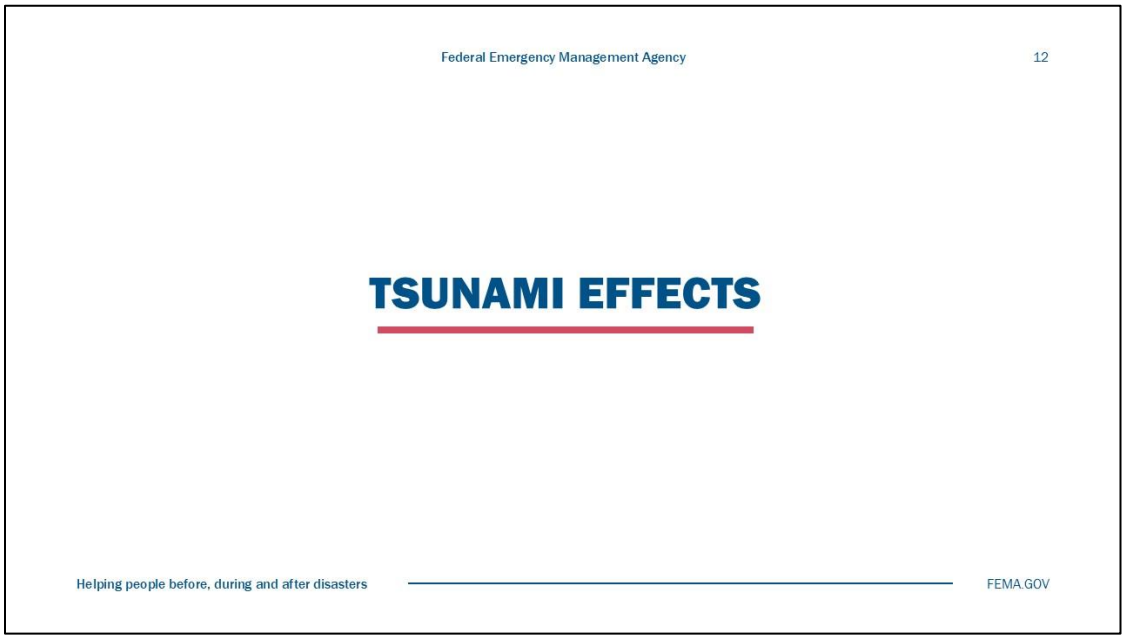
A tsunami rarely arrives as a single surge; it typically has multiple surges. That is because of the complex scattering—the refraction (direction change) and reflection (bounce back)—of tsunami waves as they interact with landforms and other tsunami waves.

The scattering and wave interference processes are complicated in the open ocean and even more complicated near shore, where sharp variations in the coastline scatter tsunami energy.

Additionally, a tsunami can generate a specific type of trapped wave known as an edge wave, which travels parallel to the shore in a back-and-forth motion. The effects of wave interference, scattering, and trapping combine to produce multiple tsunami arrivals.

The number of arrivals and the amplitudes of each wave will vary depending on the coastal properties, the exact travel direction, and other specifics of how the tsunami was generated. They will vary from place to place and event to event. In the largest tsunamis, the surge can continue for many hours and more than a day.

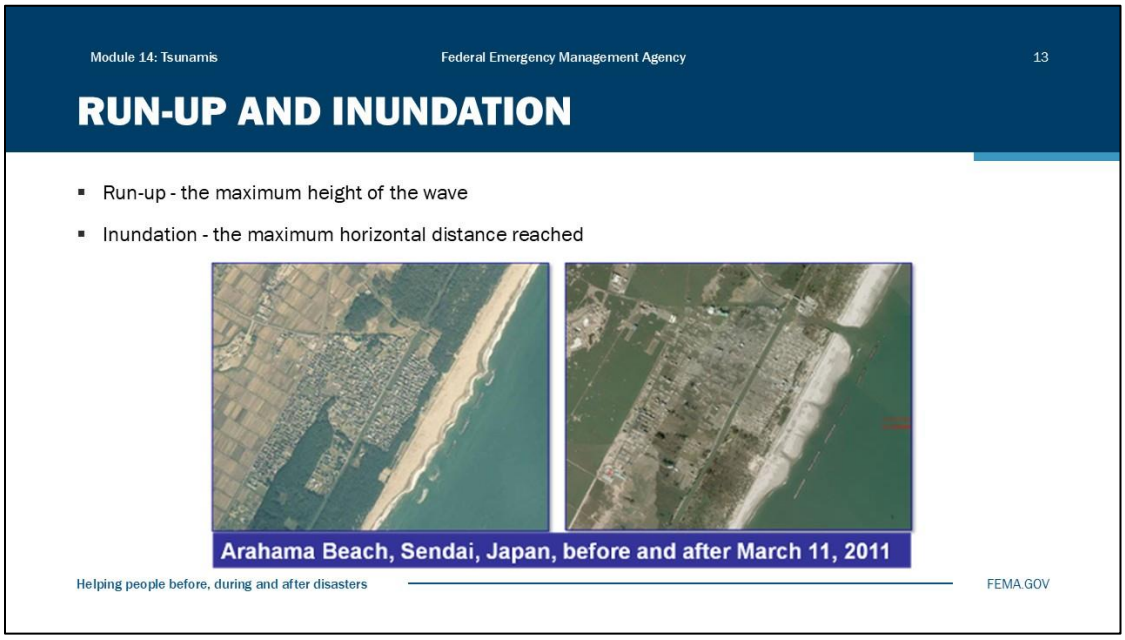
Tsunami Effects (1 of 7)



Slide 14-12, Tsunami Effects

Not Applicable.

Tsunami Effects (2 of 7)



Slide 14-13, Run-Up and Inundation

How a tsunami's reach is measured: A tsunami's reach on shore is measured in two ways:

- **Run-up**, which is the height above sea level that the tsunami achieves, and
- **Inundation,** which is the maximum horizontal distance, that is, how far inland the tsunami reaches.

Factors that influence run-up and inundation: The run-up and the inundation depend on many factors, including:

- Energy of the tsunami;
- Topography of the land;
- Orientation of the land to the oncoming wave; and
- Tide

A tsunami that arrives at high tide will reach farther inland than a tsunami that arrives at low tide. The energy of the tsunami depends on how far it has traveled and the magnitude of the event that created it.

The photos on this visual show a beach in Japan, before and after the 2011 tsunami. The white structure between the community and the ocean is a seawall, built for tsunami protection.

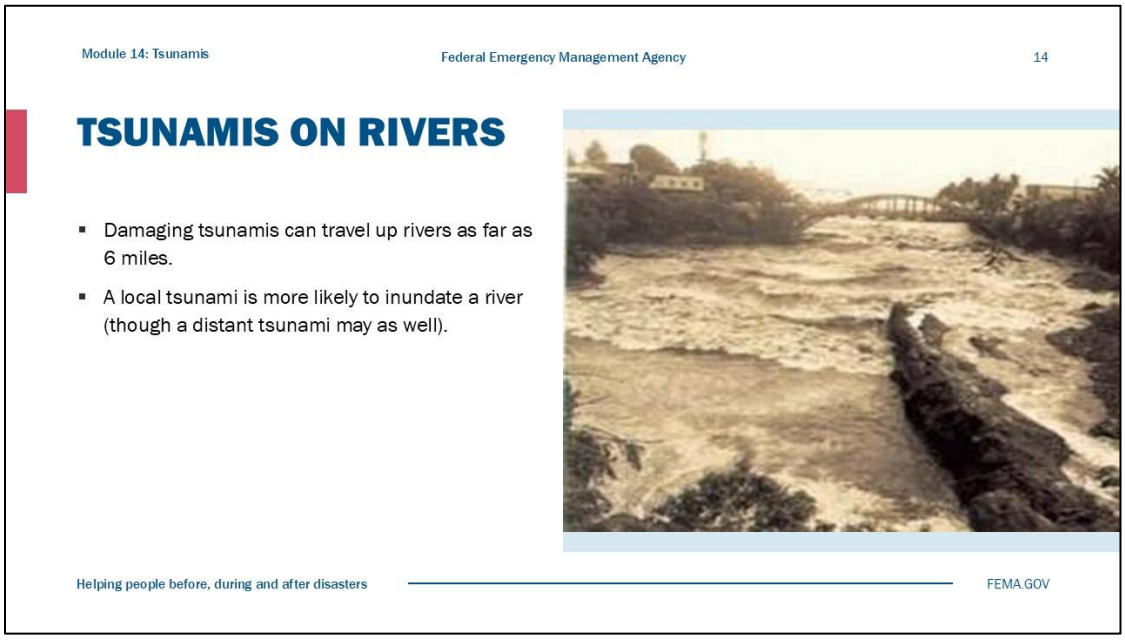
However, it was not designed to withstand a tsunami as large as the one that occurred in 2011. Experts underestimated the possible size of earthquakes that could occur offshore in this region. When the fault ruptured, the rock beneath Japan dropped relative to the rock beneath the ocean, lowering the elevation along the coast. As a consequence, inundation extended as far as 6 miles inland.

Many communities in Sendai province had seawalls that were overtopped by this tsunami, causing enormous devastation and tens of thousands of avoidable deaths. Residents did not flee to higher ground when they felt the earthquake shaking because they expected their seawalls to protect them, as had happened in previous, smaller tsunamis.

In the photo below, a researcher measures a tsunami's run-up, marked by a gouge in the tree made by floating debris.



Tsunami Effects (3 of 7)



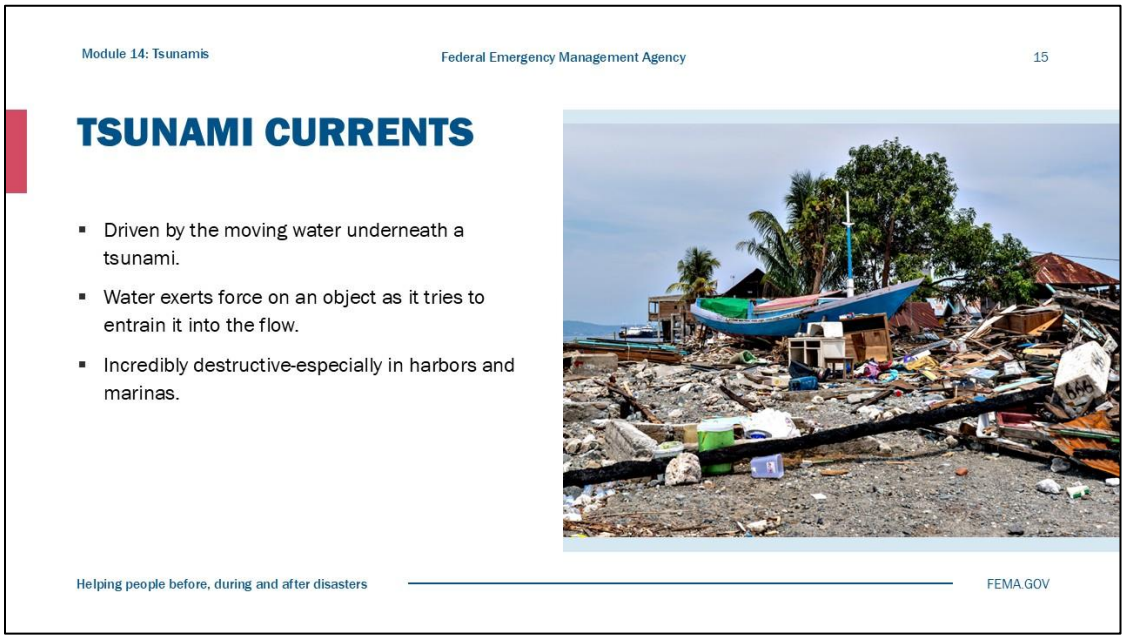
Slide 14-14, Tsunamis on Rivers

Factors that affect tsunami inundation on rivers include:

- The river's depth, width, and bathymetry (underwater topography)
- Direction of the incoming waves relative to the orientation of the river and the amount of energy in the tsunami
- Local vs. distant: A local tsunami is more likely to cause extensive inundation on rivers, but distant tsunamis can also cause river inundation

The photo shows a tsunami wave advancing up the Wailuku River in Hilo, Hawaii, in 1946, just before it tore a span from the railroad bridge in the distance. The tsunami was generated by an earthquake offshore of Alaska.

Tsunami Effects (4 of 7)



Slide 14-15, Tsunami Currents

Even in areas where inundation is trivial, tsunamis generate currents that can be incredibly destructive. Tsunami currents are driven by the moving water underneath a tsunami, and exert forces that can be very large, because water is heavy. Hazards include current force and whirlpools.

- **Current force:** Tsunamis have a current force (or drag force) that the water exerts on an object as it tries to entrain that object into the flow.

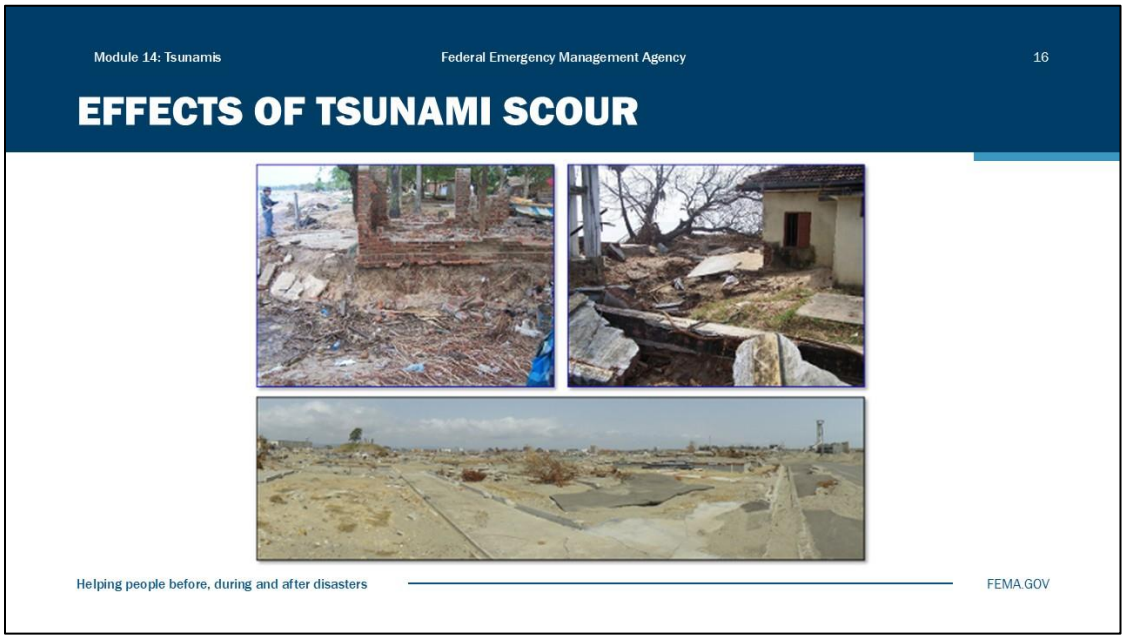
If the current is tripled, the force of the current is increased by a factor of nine!

Only a small depth of moving water (e.g., ankle deep) can be enough to knock a person over and mobilize large objects.

- **Whirlpools:** Whirlpools are particularly dangerous in harbors and marinas, where breakwaters and other structures cause the flow to focus and converge into jets and eddies that create whirlpools. This creates very localized, very high-energy areas with high damage potential.

In recent tsunamis, currents have broken nuclear submarines from their moorings and sent a 3-block-long container ship spinning in loops around a port. In a tsunami, boats at sea should never return to port. The safest place to be is offshore if the boat can reach a depth of 100 fathoms (600 feet).

Tsunami Effects (5 of 7)



Slide 14-16, Effects of Tsunami Scour

Photos: Scour effects in Sri Lanka, off the coast of India, in the 2004 tsunami that was generated in Sumatra on the other side of the Indian Ocean.

Tsunami currents can cause tremendous scour—a type of erosion—and can pick up and move very large objects.

In recent tsunamis, cars and trucks being pounded into buildings have been recurring causes of damage. Tsunami currents scour sediment and cement from the foundations of buildings and bridges, unearth buried pipelines, and relocate sediment to bury intake valves and other structures that need to remain exposed.

Tsunami Effects (6 of 7)



Slide 14-17, Direct Impacts on Health

The recent tsunamis in Indonesia and Japan underscore the types of direct impacts on public health that can occur.

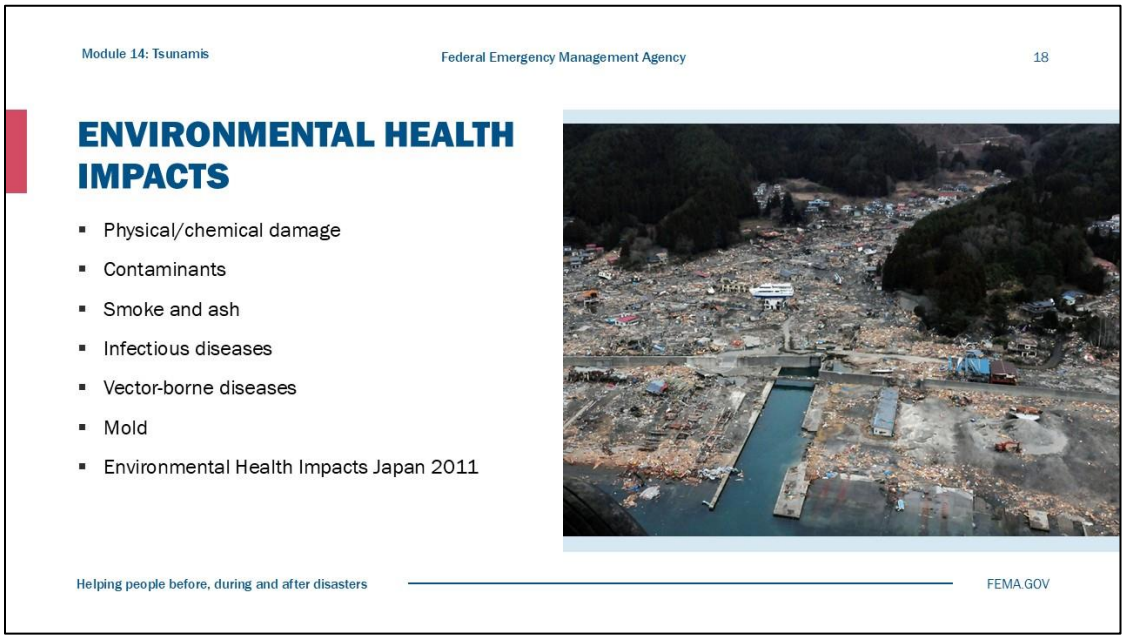
Tsunami-related deaths and injuries: An impact that is relatively uncommon for other disasters, but more prevalent during tsunamis, is the high number of fatalities (including drowning), injuries, and wounds resulting from debris, as well as the post-disaster development of infections in wounds caused by pathogens in seawater, soils, or debris.

Remember, tsunamis are secondary hazards, which means that they are created as a consequence of another hazard. The map on the next page shows the number of tsunami-related deaths in terms of the cause of the tsunami.

Other effects include:

- "Tsunami lung" in people who nearly drown (tsunami lung is an infection caused by relatively uncommon pathogens found in seawaters).
- Damage to public health infrastructure.
- Relocation of thousands of people from affected areas into refugee camps.
- Psychological impacts.
- Disaster-related exacerbation of chronic diseases.

Tsunami Effects (7 of 7)



Slide 14-18, Environmental Health Impacts

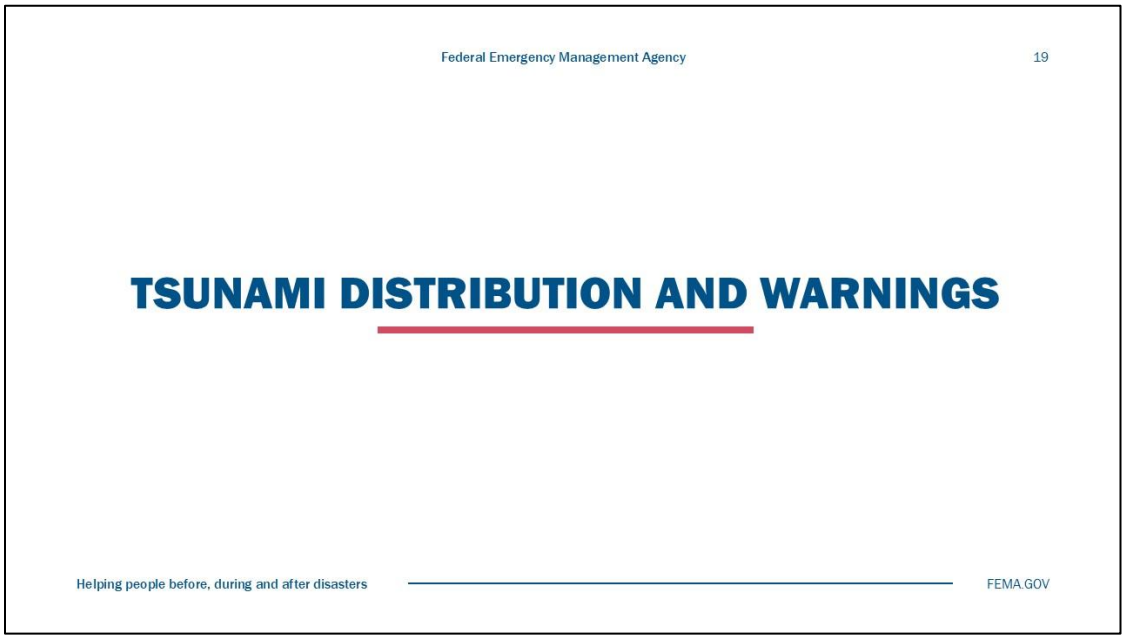
Tsunamis can also severely impact the natural and built environments. For example, disposing of large volumes of debris has been a major challenge following both the 2004 Indonesian tsunami and the 2011 Japanese tsunami.

The debris can contain high levels of contaminants from the built location, such as asbestos and lead. These contaminants can become windborne; some can be leached from the debris by rainwater into ground and surface waters.

Environmental health impacts may include:

- Severe environmental damage, both physical and chemical (e.g., impacts of seawater on terrestrial vegetation);
- Exposures to smoke and ash from fires caused by the tsunami, and from fires set intentionally as a debris removal practice;
- Infectious diseases from consumption of contaminated ground or surface waters;
- Mosquito- and other vector-borne diseases; and
- Exposures to post-flood mold.

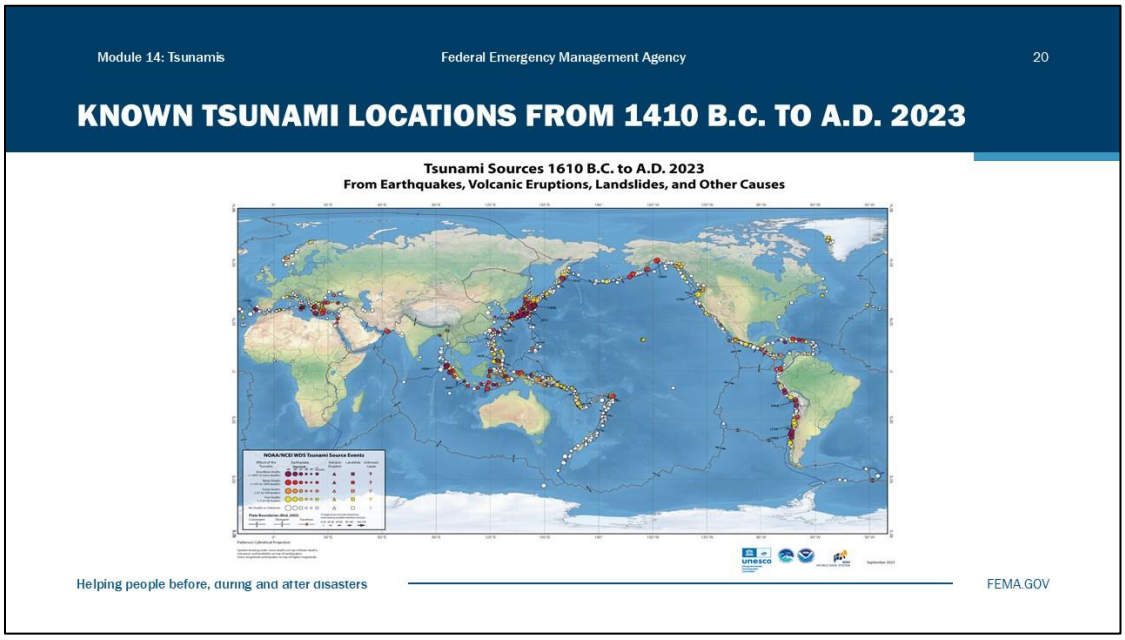
Tsunami Distribution and Warnings (1 of 6)



Slide 14-19, Tsunami Distribution and Warnings

Not Applicable.

Tsunami Distribution and Warnings (2 of 6)



Slide 14-20, Known Tsunami Locations from 1410 B.C. to A.D. 2023

This map shows locations where tsunamis are known to have made landfall. Green squares indicate known locations of tsunami events since 2000 B.C. The coastal areas along all oceans are at risk from tsunamis. (As with any scientific dataset, the recent portions will be the most complete. The coastlines without green squares are more likely to lack data than tsunamis.)

Source: Known Tsunami Locations from 1410 B.C. to A.D. 2023 found at Tsunami Data and Information | NCEI. (Center, n.d.)

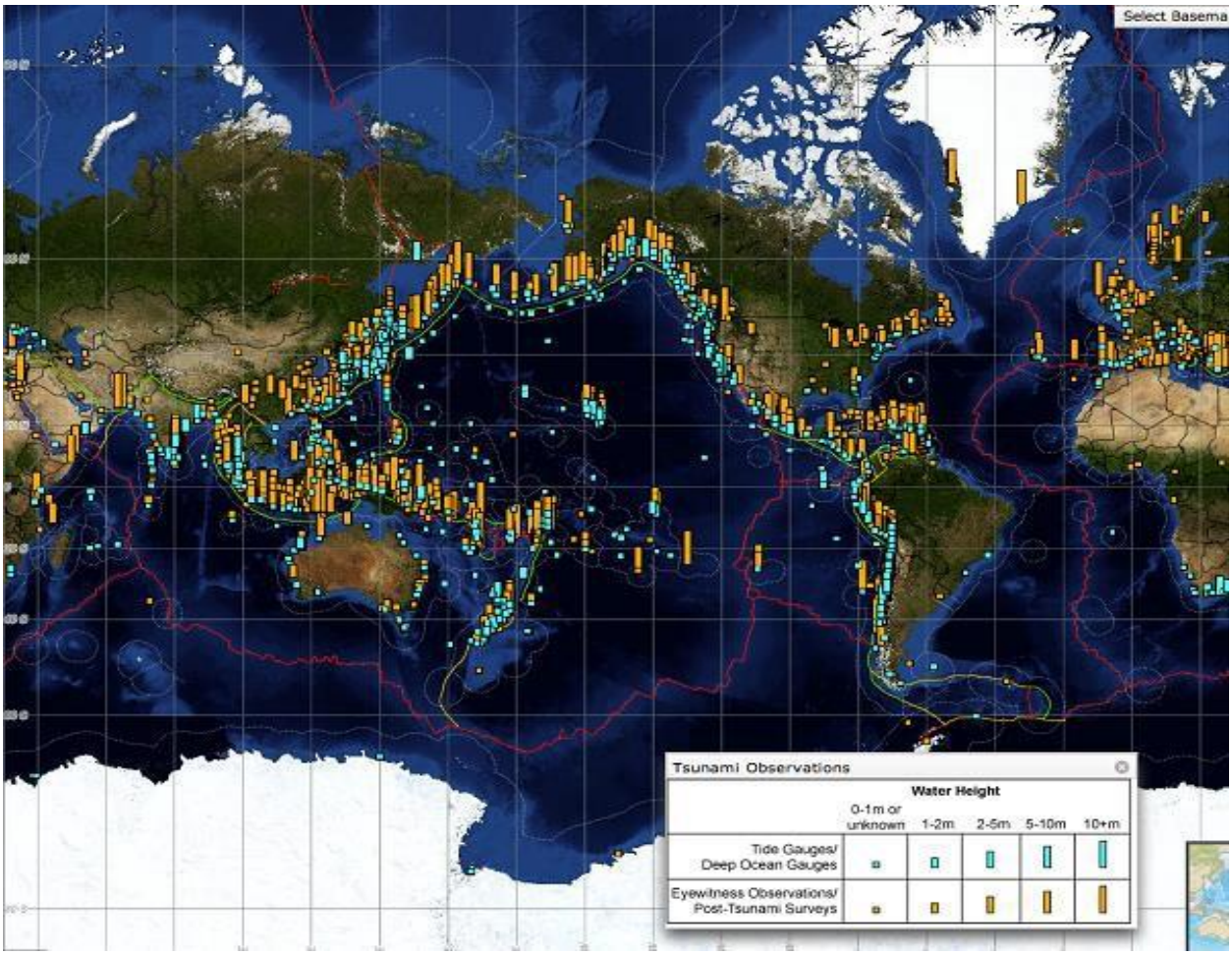
The map on the next page shows the locations where tsunami wave heights have been measured.

The **height of the bar** changes with the height of the observation.

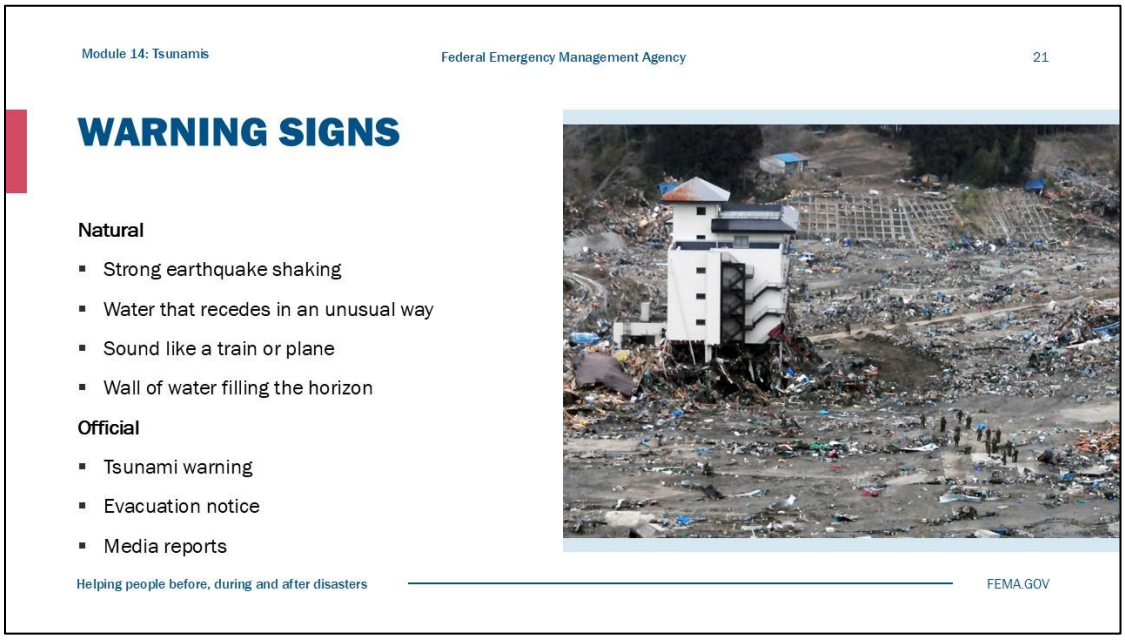
The color of the bar indicates how the measurement was estimated.

The blue bars are generated using scientific instruments; therefore, this data set spans several decades.

Brown measurements refer to estimates derived from eyewitness observations or post-tsunami surveys. (The surveys are scientific fieldwork that can be done decades or centuries after the event if changes to the Earth's surface have not obliterated the evidence. In some cases, the tsunami site may no longer be near an ocean.)


Select Basema
Tsunami Observations
Water Height
0-1m or unknown
1-2m
2-5m
5-10m
10+m
Tide Gauges/ Deep Ocean Gauges
Eyewitness Observations/ Post-Tsunami Surveys

Tsunami Distribution and Warnings (3 of 6)



Slide 14-21, Warning Signs

A tsunami may arrive without any warning. However, in some cases, there may be signs that a tsunami is approaching.

Natural signs: Signs created by the physical characteristics of the event may include:

- **Strong earthquake shaking** (only if the tsunami is generated locally).
- **Water that recedes in an unusual way**. Depending on exactly how the water is initially displaced, about half the time the first wave motion will be away from shore, and in this case, the water will recede far from shore when the tsunami first arrives. This can happen for both local and distant tsunamis.
- **A sound** like a train or plane coming from the ocean. This has been experienced in both local and distant tsunamis, but not in all tsunamis.
- **The appearance of a long wall of water advancing toward land**. However, by the time a tsunami can be seen or heard, it is often too late to get away.

Human-created warnings: Other signs are human-created because a tsunami has been detected in the open ocean or an undersea event has been identified that can potentially produce a tsunami. Human-created warnings may include:

- Sirens

- Evacuation effort
- Word that a tsunami has struck another coastline

Hundreds of thousands of people died in the December 26, 2004, Indian Ocean tsunami. But as described in these news reports, others saw warning signs and escaped with their lives.

Girl saves tourists after raising a tsunami warning

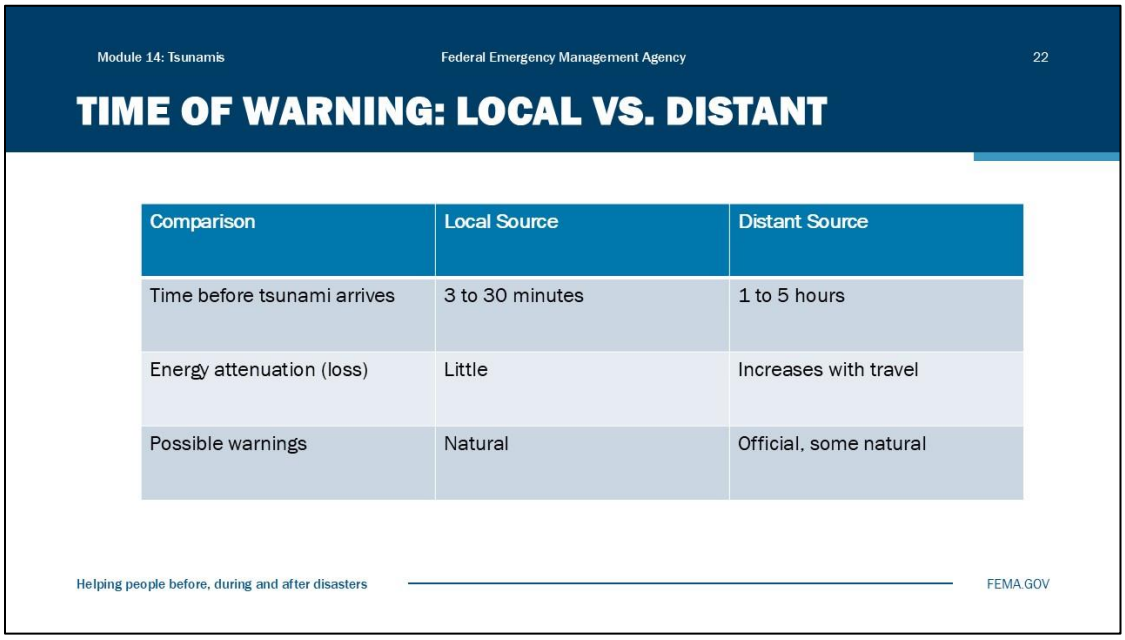
Thousands died on the beaches of Thailand in the December 2004 tsunami. But a 10-year-old British girl saved more than 100 people because she had just studied the killer waves in school. When the sea suddenly began to boil, then pulled away from the resort she was visiting, leaving fish and boats stranded high and dry, Tilly Smith recognized that a tsunami was approaching. Fortunately, her frantic warnings were heeded, and the beach was evacuated just moments before the huge waves crashed ashore.



Kalutara Beach Detail
Imagery collected December 26, 2004.
Description: Receding waters and beach damage from tsunami

Source: *Natural Warnings*. (n.d.). Retrieved October 28, 2025, from https://noaacontent.nroc.org/lesson09/l9la2_a.html

Tsunami Distribution and Warnings (4 of 6)



Slide 14-22, Time of Warning: Local vs. Distant

For public safety, it is essential to distinguish between tsunamis with a nearby or local source and those generated far away, as illustrated in the table below.

Local tsunamis: Local tsunamis are generated just offshore. Depending on how close to shore they are created, the first wave will arrive in 3 to 30 minutes, with the most typical time being 15 to 20 minutes. The waves will retain most of their initial energy and thus will have enormous force. **Tsunami detection instruments are typically located offshore in the ocean and are unable to detect local tsunamis that occur near the shore. Therefore, official warnings cannot be issued before locally generated waves reach the shore.**

Distant tsunamis: For distant tsunamis, the arrival time depends on how far away the tsunami was created and thus how long it has to travel. Recall that all waves lose energy as they travel. Therefore, the energy of a distantly generated tsunami will decrease, but it can still be sufficient to cause substantial loss of life and damage. As a distant-generated tsunami travels across an ocean, if instruments are in place, they will detect the tsunami, and there will be time for official warnings to be issued.

Again, only the largest earthquakes generate tsunamis with sufficient energy to cause destruction over great distances.

DART II® System

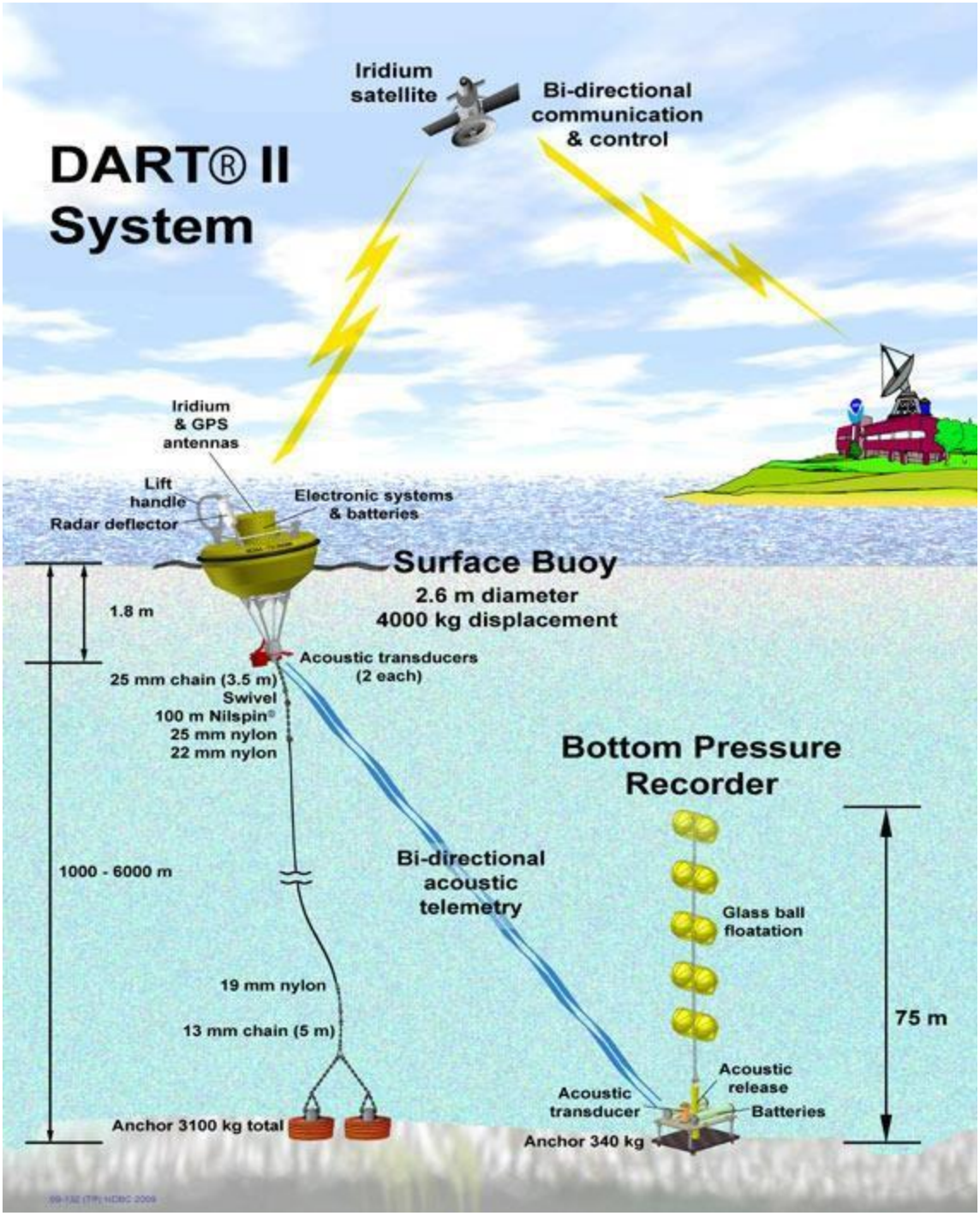
Background

To ensure early detection of tsunamis and to acquire data critical to real-time forecasts, NOAA has placed Deep-ocean Assessment and Reporting of Tsunami (DART®) stations at sites in regions with a history of generating destructive tsunamis. NOAA completed the original 6-buoy operational array (map of original six stations) in 2001 and expanded to a full network of 39 stations in March 2008.

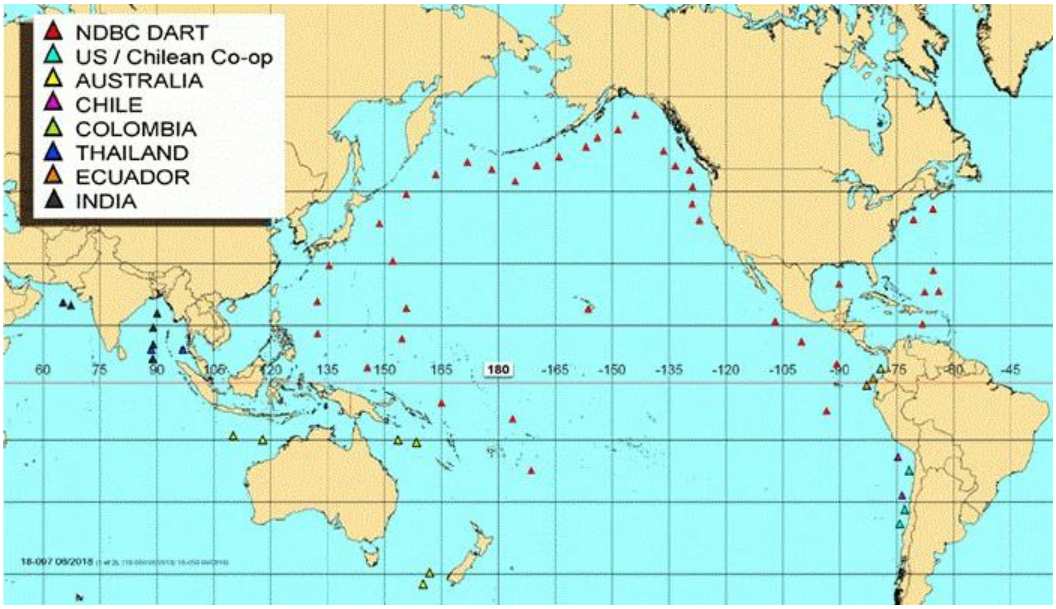
Originally developed by NOAA as part of the U.S. National Tsunami Hazard Mitigation Program (NTHMP), the DART® Project was an effort to maintain and improve the capability for early detection and real-time reporting of tsunamis in the open ocean. See DART® development for more info. (N. US Department of Commerce, n.d.), (N. O. and A. A. US Department of Commerce, n.d.)

For more information, visit the National Data Buoy Center (https://www.ndbc.noaa.gov/dart/dart.shtml).

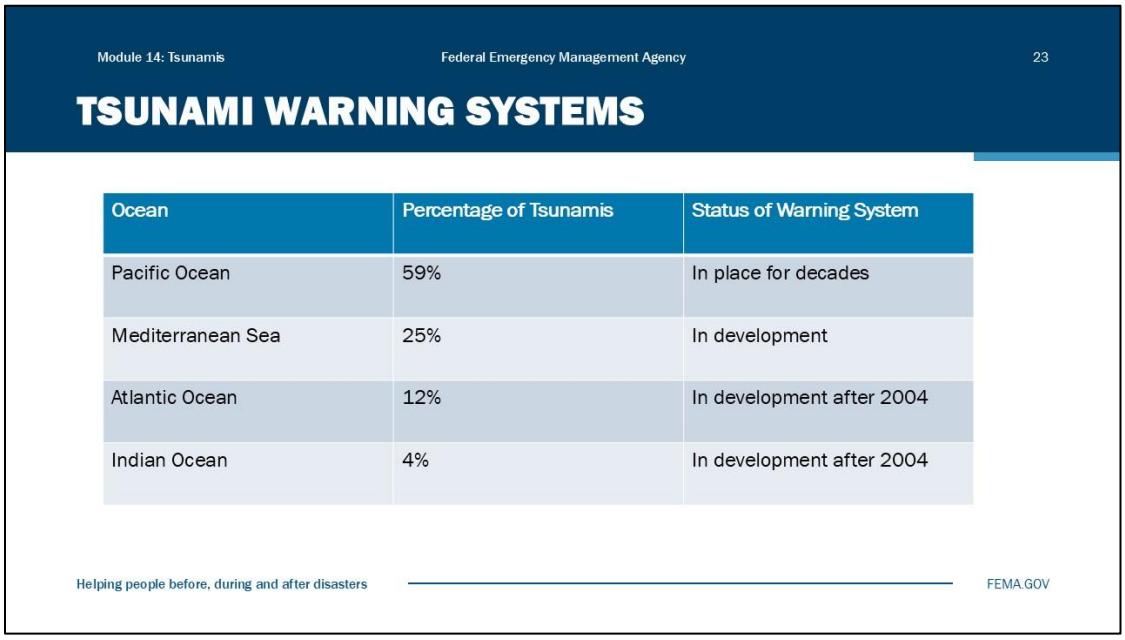
DART Mooring System



DART Buoys


NDBC DART
US / Chilean Co-op
AUSTRALIA
CHILE
COLOMBIA
THAILAND
ECUADOR
INDIA
60
75
90
105
120
135
150
165
180
-165
-150
-135
-120
-105
-90
-75
-60
-45

Tsunami Distribution and Warnings (5 of 6)



Slide 14-23, Tsunami Warning Systems

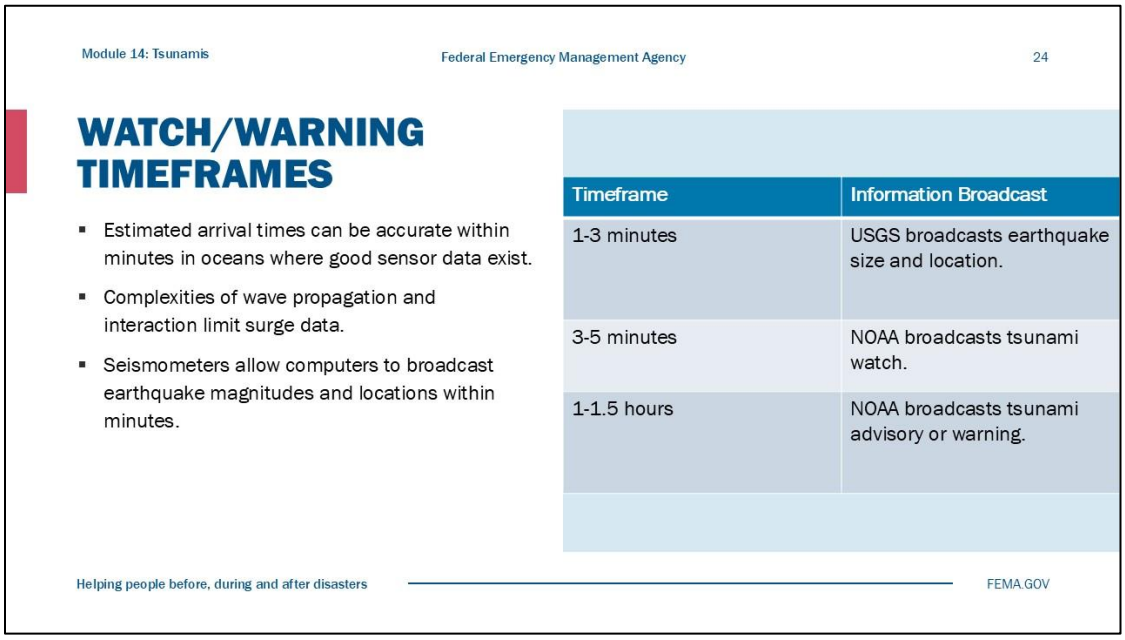
Looking at long-term averages, the Pacific Ocean has the most tsunamis of any body of water, and the Indian Ocean has about 4 percent of all tsunamis. On the Pacific Ocean, a comprehensive system of deep-ocean and tidal gauges is in place to detect and track tsunamis, as well as a system to provide timely warnings.

Tsunami frequency: Major tsunamis occur approximately once every decade, based on long-term averages. But there is variation from year to year and decade to decade.

In 1964, the world paid attention to tsunamis when the Great Alaskan "Good Friday" earthquake created a particularly destructive tsunami in the Pacific Ocean. However, 40 years elapsed until the next large tsunami in 2004 in the Indian Ocean. When more than a generation elapses between events, society's readiness for those events inevitably lessens.

Development of monitoring systems: Prior to 2004, little to no funding was available to deploy monitoring equipment in areas where tsunamis were particularly rare. This situation has slowly changed since then.

Tsunami Distribution and Warnings (6 of 6)



Slide 14-24, Watch/Warning Timeframes

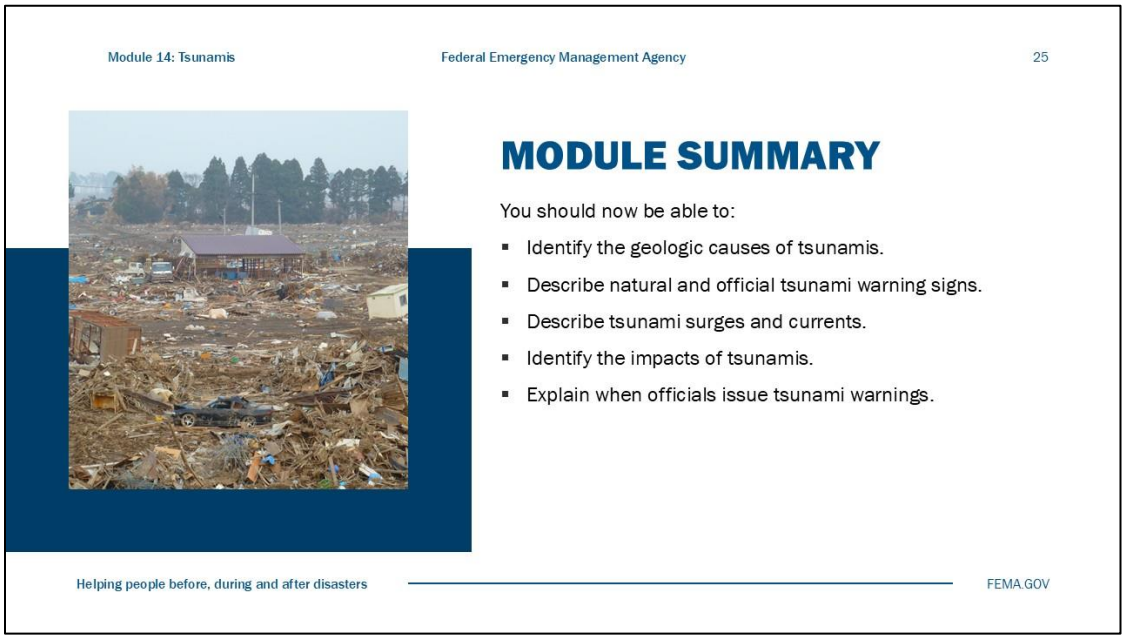
After large earthquakes occur undersea, the National Oceanic and Atmospheric Administration (NOAA) monitors ocean sensors to detect whether a tsunami has been generated, and if so, issues estimates of tsunami arrival times for different locations. NOAA uses the sensor data to refine estimates for when the first tsunami surge will arrive. Estimated arrival times can be accurate within minutes in oceans where good sensor data exists. Typically, information about the event gets conveyed according to the timeline shown on the visual.

- **Watch:** Initially, after the earthquake, NOAA will declare a Tsunami Watch, normally just a few minutes after the earthquake occurs. The worldwide network of seismometers allows computers to broadcast earthquake magnitudes and locations within minutes of the event.
- **Advisory and warning**: If sensors or humans detect a tsunami, a watch is upgraded to an advisory and then a warning. Typically, a warning is issued 1 to 1.5 hours after the event.
- **Updates:** NOAA updates and continues to issue information bulletins, watches, and warnings for specific areas until all tsunami danger is past.

Not all oceans have sensors to detect tsunamis, so some advisories must be based on past scientific experience with how earthquakes of different magnitudes create tsunamis.

The complexities of tsunami wave propagation and interaction limit the ability to rapidly model and relay high-resolution, locally specific surge data as part of a warning system.

End of Module (1 of 2)



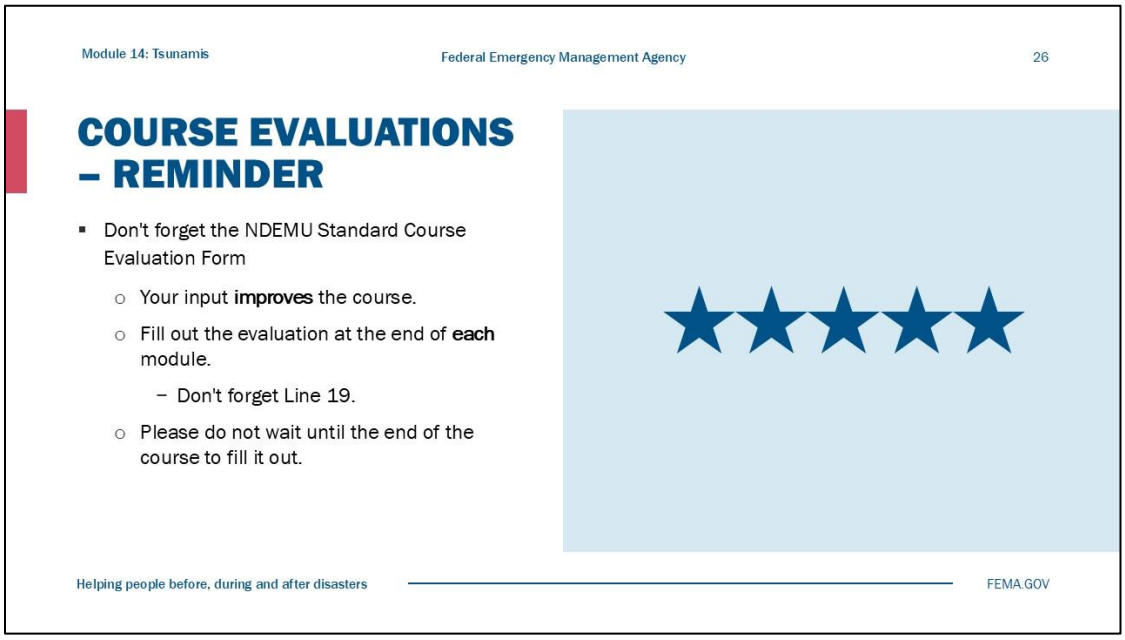
Slide 14-25, Module Summary

MODULE SUMMARY

You should now be able to:

- Identify the geologic causes of tsunamis
- Describe natural and official tsunami warning signs
- Describe tsunami surges and currents
- Identify the impacts of tsunamis
- Explain when officials issue tsunami warnings

End of Module (2 of 2)



Slide 14-26, Course Evaluations – Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
- Please do not wait until the end of the course to fill it out.

Reference List

House and Car Destroyed by Tsunami | U.S. Geological Survey. (n.d.). Retrieved October 15, 2025, from https://www.usgs.gov/media/images/house-and-car-destroyed-tsunami

National Geophysical Data Center. (n.d.). Global Historical Tsunami Database [Dataset]. NOAA National Centers for Environmental Information. https://doi.org/10.7289/V5PN93H7

Natural Warnings. (n.d.). Retrieved May 20, 2025, from https://noaacontent.nroc.org/lesson09/l9la2_a.html

Tsunami-Relocated Car | U.S. Geological Survey. (2005, January 10). https://www.usgs.gov/media/images/tsunami-relocated-car

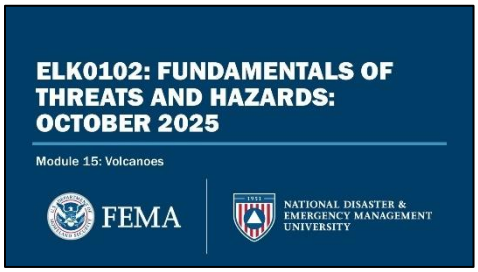
Tsunamis and Tsunami Hazards | U.S. Geological Survey. (n.d.). Retrieved October 15, 2025, from https://www.usgs.gov/water-science-school/science/tsunamis-and-tsunami-hazards

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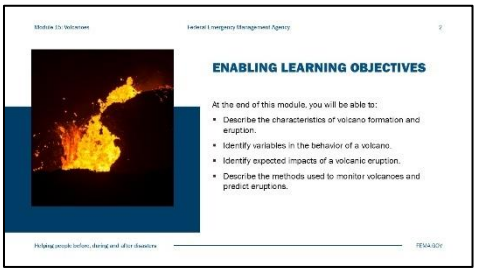
US Department of Commerce, N. O. and A. A. (n.d.). Deep-ocean Assessment and Reporting of Tsunamis (DART®) Description. Retrieved May 20, 2025, from https://www.ndbc.noaa.gov/dart/dart.shtml

Module 15
Volcanoes

Administration



Slide 15-1, Module 15: Volcanoes



Slide 15-2, Enabling Learning Objectives

Duration

1 hour, 20 minutes

Terminal Learning Objective (TLO)

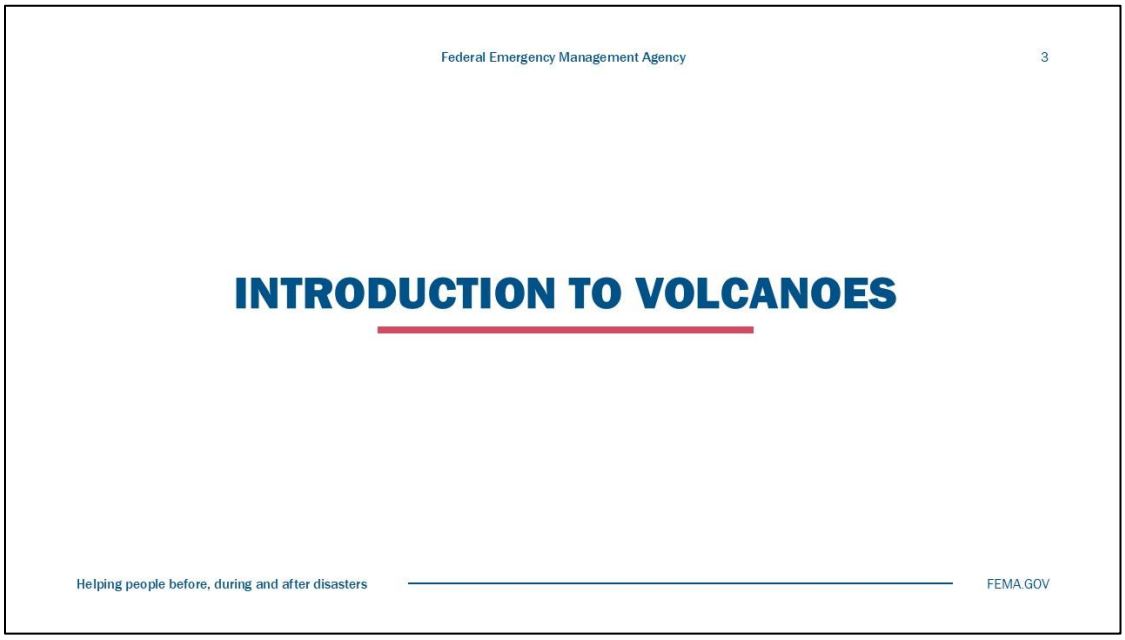
By the end of this module, participants will be able to identify and define variables, characteristics, and impacts of volcanoes.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Describe the characteristics of volcano formation and eruption.
- Identify variables in the behavior of a volcano.
- Identify expected impacts of a volcanic eruption.
- Describe the methods used to monitor volcanoes and predict eruptions.

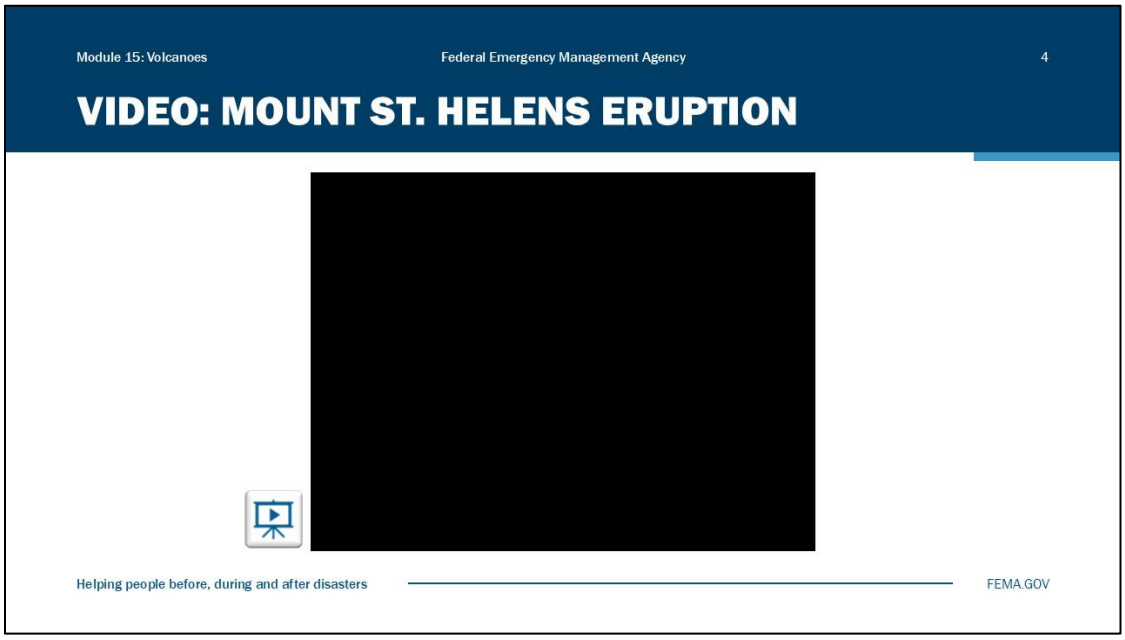
Introduction to Volcanoes (1 of 7)



Slide 15-3, Introduction to Volcanoes

Not Applicable.

Introduction to Volcanoes (2 of 7)



Slide 15-4, Video: Mount St. Helens Eruption

The eruption of Mount St. Helens in Washington State in 1980 was a pivotal event for improving scientific understanding of explosive volcano processes and for coordination of scientific understanding with emergency response.

For more than 4,000 years, Mount St. Helens has been the most active among a chain of volcanoes in the Pacific Northwest, but it had not erupted since the mid-1800s. Its recent eruption timelines offer a good lesson in how suddenly a volcano can become restless, how difficult it can be to have certainty that an eruption is about to start (or end), and how far an eruption's effects can reach.

In this video, USGS scientists recount their experiences before, during, and after the eruption of Mount St. Helens, one of the most dramatic geologic moments in the history of the United States.

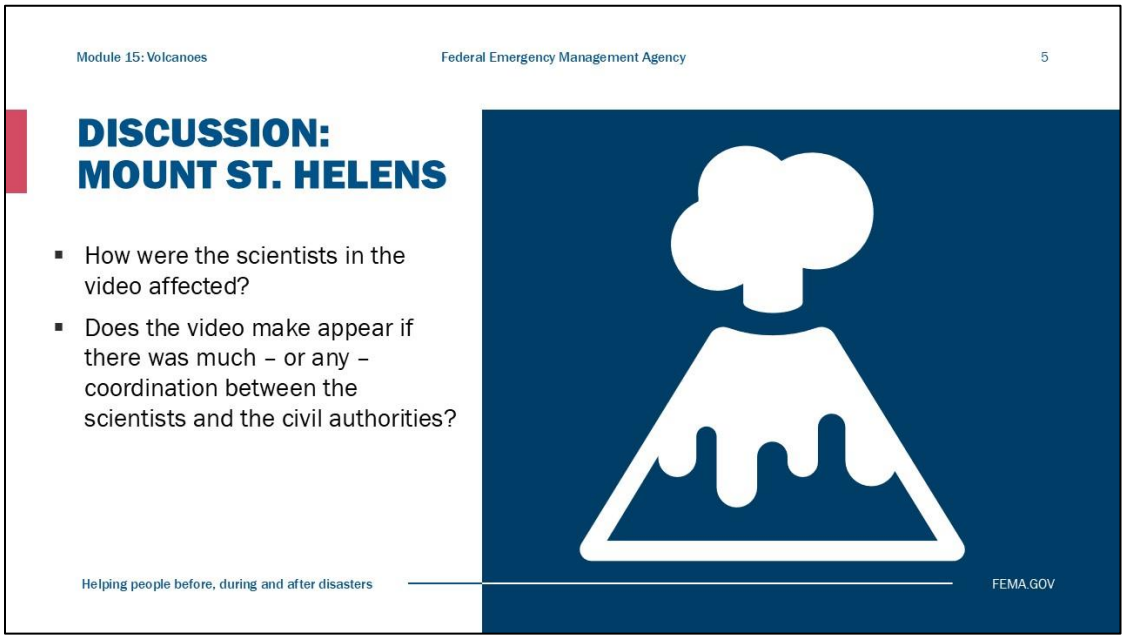
Transcript:

Don Swanson: And we were off the ground probably at 9:05 or something like that. It was really, really rapid. And got up to the point where we could really see the mountain well, I suppose, between 9:20 and 9:25. Something like that.

There was this terrific, very vigorous vertical eruption column that was the stem of the mushroom or the toadstool. It then blossomed out at greater height. And, for most of the morning we saw this tremendous ash cloud roiling out toward the northwest, and I can only assume that that was coming off of the big pyroclastic flows that were going off in that direction that later built the pumice plane. It was a very eventful morning, but it was sobering because I remember thinking up in the airplane that Dave just couldn't have survived this. Especially when we got around to the west side and saw all the ash heading in his direction.

C. Dan Miller: On the morning of May 18, what actually happened the landslide basically uncorked this pressurized body of magma and allowed it to explode or expand out toward the north very rapidly. This is what we call the "lateral blast." It was a horizontally directed explosion of incredible magnitude. It caused this expanding cloud of ash, rocks, and gases to move out across the countryside to the north at speeds of several hundred miles an hour. The directed blast was really the most destructive event that occurred on the morning of May 18. It completely destroyed an area of 230 square miles in the matter of somewhere between 5 and 9 minutes. It essentially killed every living thing within an area of 230 square miles. And it destroyed hundreds of acres of virgin forest and was an incredibly spectacular event.

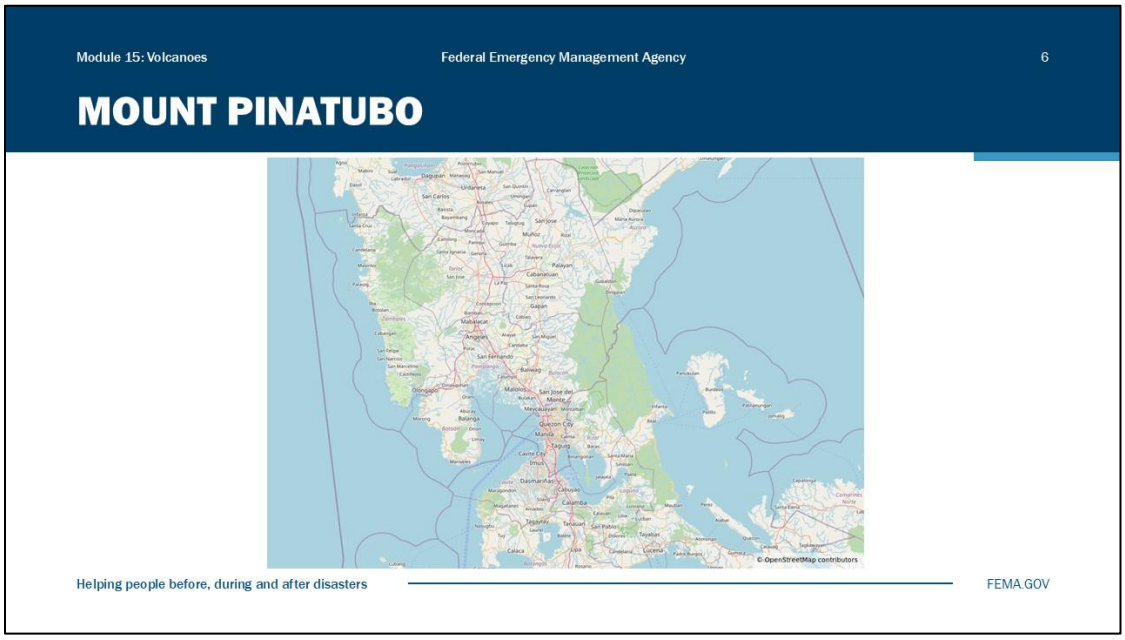
Introduction to Volcanoes (3 of 7)



Slide 15-5, Discussion: Mount St. Helens

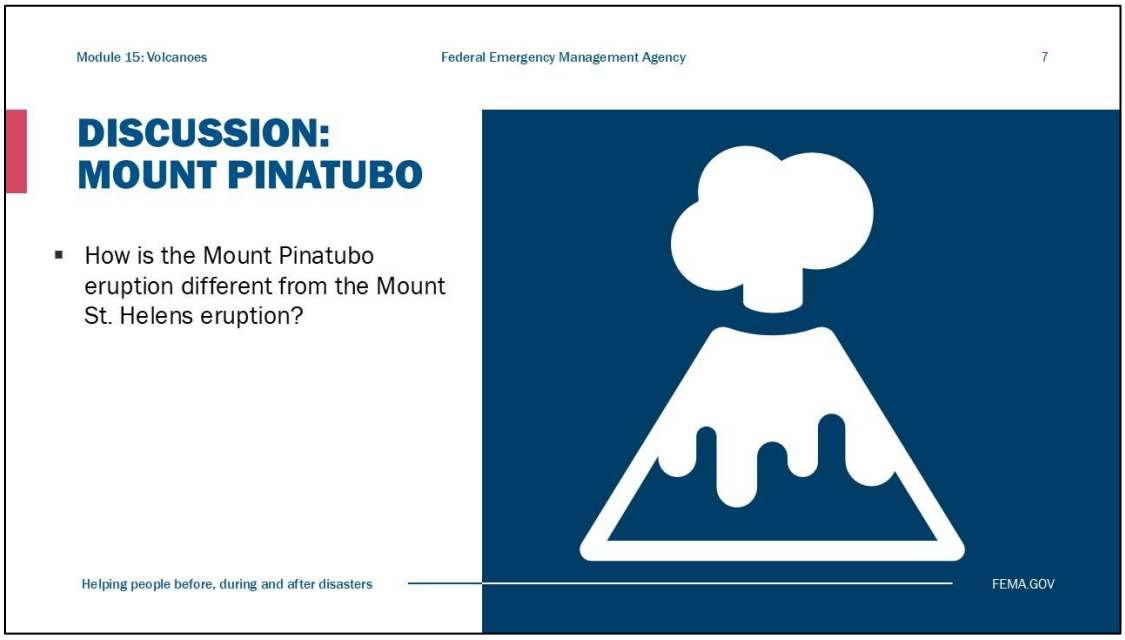
- How were the scientists in the video affected?
- Does the video make appear if there was much – or any – coordination between the scientists and the civil authorities?

Introduction to Volcanoes (4 of 7)



Slide 15-6, Mount Pinatubo

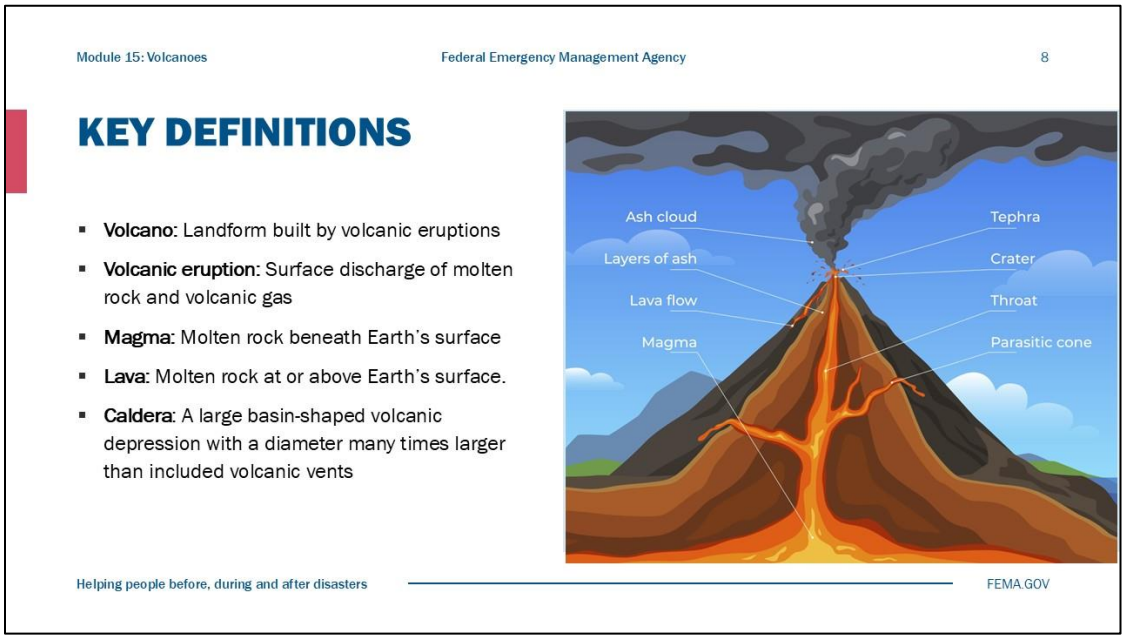
Introduction to Volcanoes (5 of 7)



Slide 15-7, Discussion: Mount Pinatubo

How is the Mount Pinatubo eruption different from the Mount St. Helens eruption?

Introduction to Volcanoes (6 of 7)



Slide 15-8, Key Definitions

- **Volcano:** Landform built by volcanic eruptions
- **Volcanic eruption:** Surface discharge of molten rock and volcanic gas
- **Magma:** Molten rock beneath Earth's surface
- **Lava:** Molten rock at or above Earth's surface
- **Caldera:** A large basin-shaped volcanic depression with a diameter many times larger than the included volcanic vents

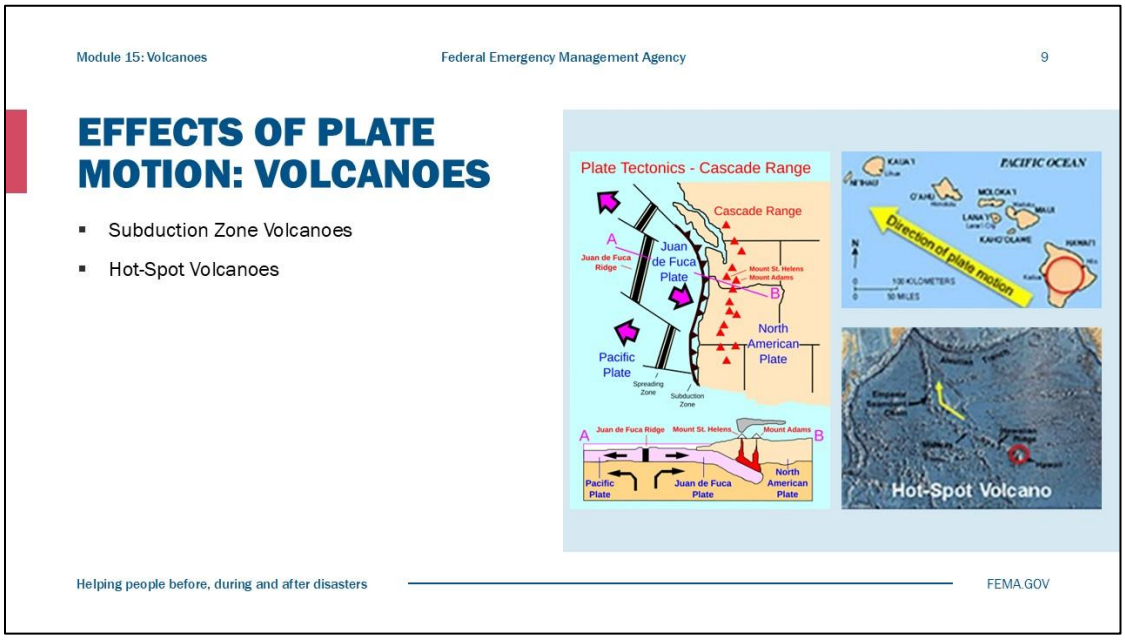
Volcanoes and eruptions are complex and varied. As scientists strive to understand volcanic processes, they have had to develop many terms and concepts. This visual shows just a few of the basic terms. We will return to some of these terms later in the module.

- A **volcano** is a landform—a geographic feature- that exists because of volcanic eruptions
- A **volcanic eruption** is a surface discharge from a volcano. Note the word "surface." Young volcanoes often have subsurface discharges, and the subsurface activity may herald a period of unrest. But if nothing reaches the surface, the unrest is a volcanic crisis, not an eruption.
- **Molten rock** is a key ingredient in volcanic processes. Volcano scientists need to know whether molten rock has reached the surface or not, and so they have two terms:

- **Magma** is the molten rock beneath the surface.
- **Lava** is molten rock at or above Earth's surface.
- A **caldera** is a large basin-shaped volcanic depression with a diameter many times larger than included volcanic vents; it may range from 2 to 50 km (1 to 30 mi) across.

Also, it is important to note that although most volcano hazards are associated with eruptions, some hazards can occur even when a volcano is not erupting.

Introduction to Volcanoes (7 of 7)



Slide 15-9, Effects of Plate Motion: Volcanoes

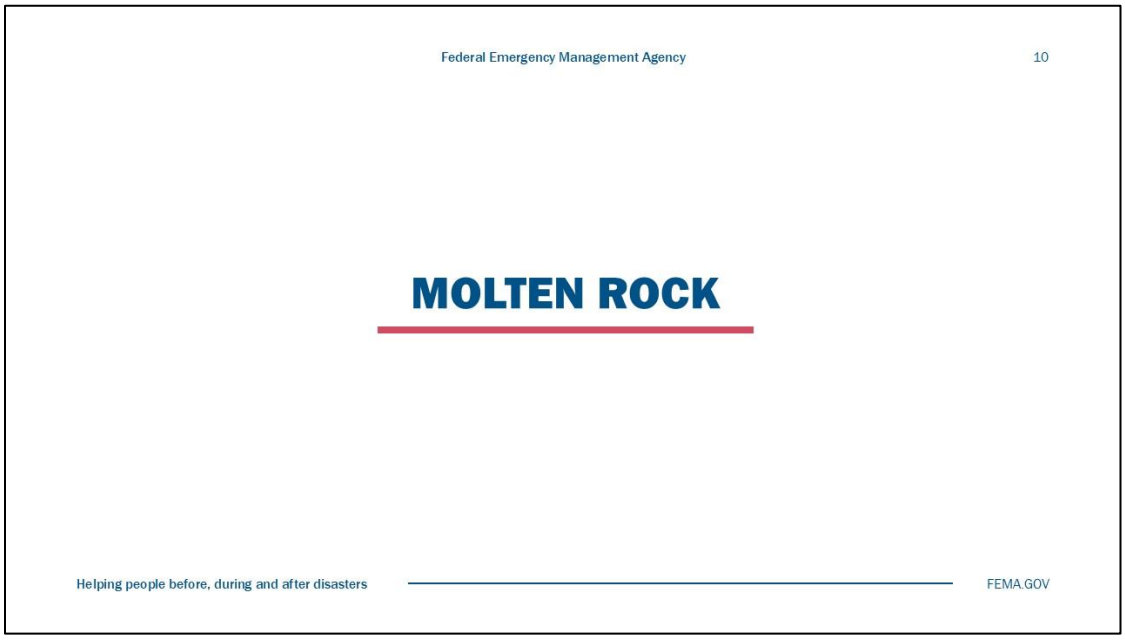
Plate tectonics aids in our understanding of why Earth's surface is dynamic and always changing. We have seen several ways in which plate motion affects Earth formations and hazards. The first is volcanoes. Plate motion can create two types of volcanoes:

- **Subduction zone volcanoes**: Plate movement creates volcanoes over subduction zones. The subduction process melts some of the rock, which then rises as magma, forming long lines of volcanoes above the subducting plate. About 90 percent of the Earth's volcanoes result from subduction. The Juan de Fuca plate in the U.S. Pacific Northwest is subducting under the North American plate. The Cascade Volcanic Range is a result of this process.
- **Hot-spot volcanoes**: Hot spots are fixed points in the mantle. (The plate moves over the hot spot.) They are formed when magma flows to the surface and burns a hole in the plate that moves over it. The visual includes a map of the Hawaiian Islands and a corresponding map of the Pacific Ocean floor.

The red circle indicates a hot spot, on which Hawaii currently sits. Other islands in the chain previously sat atop the hot spot and have been moved away as the Pacific plate has moved to the northwest. All the Hawaiian Islands are composed of volcanoes that, at one time, erupted with magma originating from the hot spot.

Yellowstone is a hot-spot volcano that erupts rarely, with hundreds of thousands of years between eruptions. Its eruptions are enormous and violently explosive.

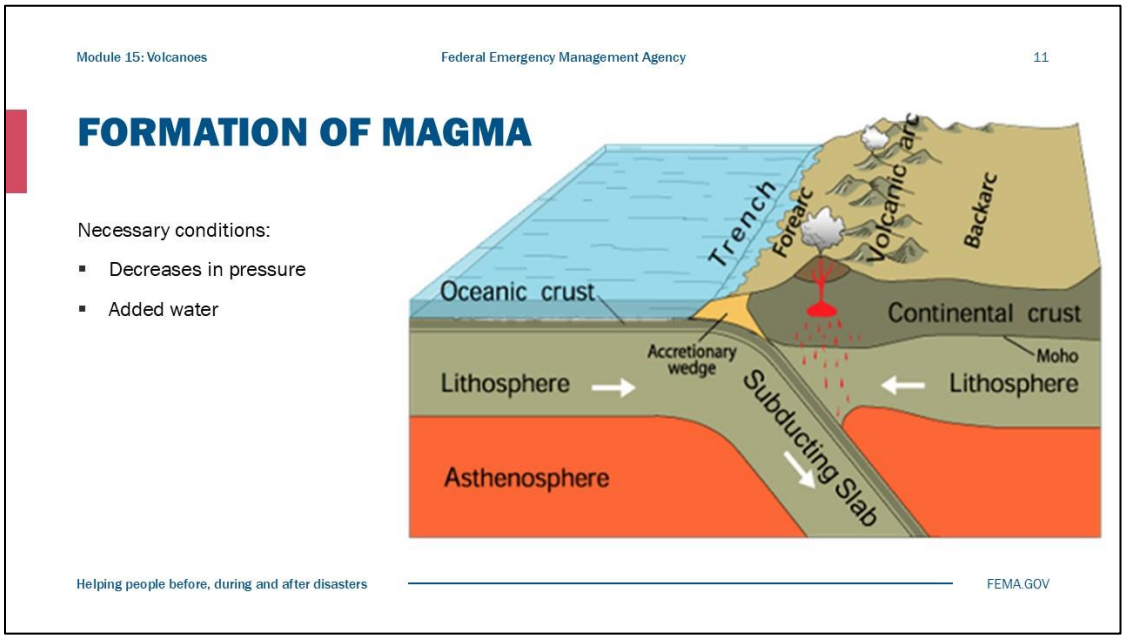
Molten Rock (1 of 2)



Slide 15-10, Molten Rock

Not Applicable.

Molten Rock (2 of 2)



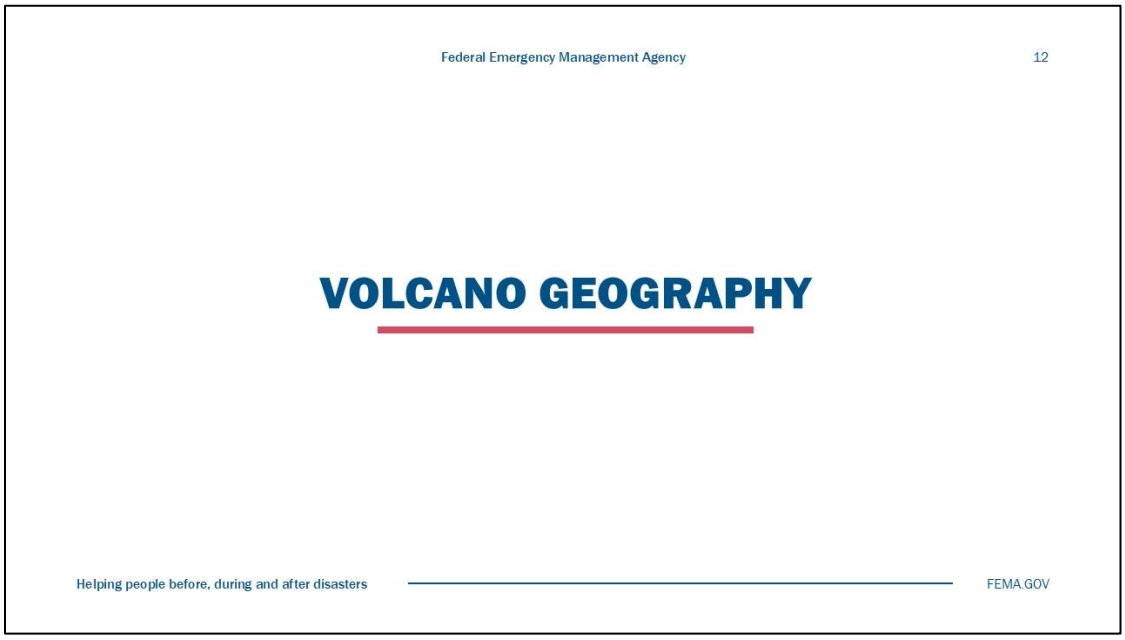
Slide 15-11, Formation of Magma

- Decreases in pressure
- Added water

Recall from an earlier module that most of the Earth's mantle consists of solid rock, but some molten rock is present. It is this molten rock that provides magma to volcanoes. In general, one of two conditions is needed to melt rock into magma:

- **Decreases in pressure:** A substance's melting point depends on its temperature and pressure. Increasing pressure increases the melting temperature of a rock, but a decrease in pressure lowers a rock's melting point. As a result, if solid but 'mushy' mantle rises, it can melt as its pressure drops, even if its temperature does not increase.
- **Added water:** Adding water lowers the melting point of most substances (for instance, wet sugar will melt at a lower temperature than dry sugar). When a plate is subducted, water is driven out as it heats up with depth (the same way water is driven out of wet clothes by heat in a dryer). As water 'cooked out' of the subducting plate accumulates above it, the rock can turn to magma without being heated because its melting point has been lowered.

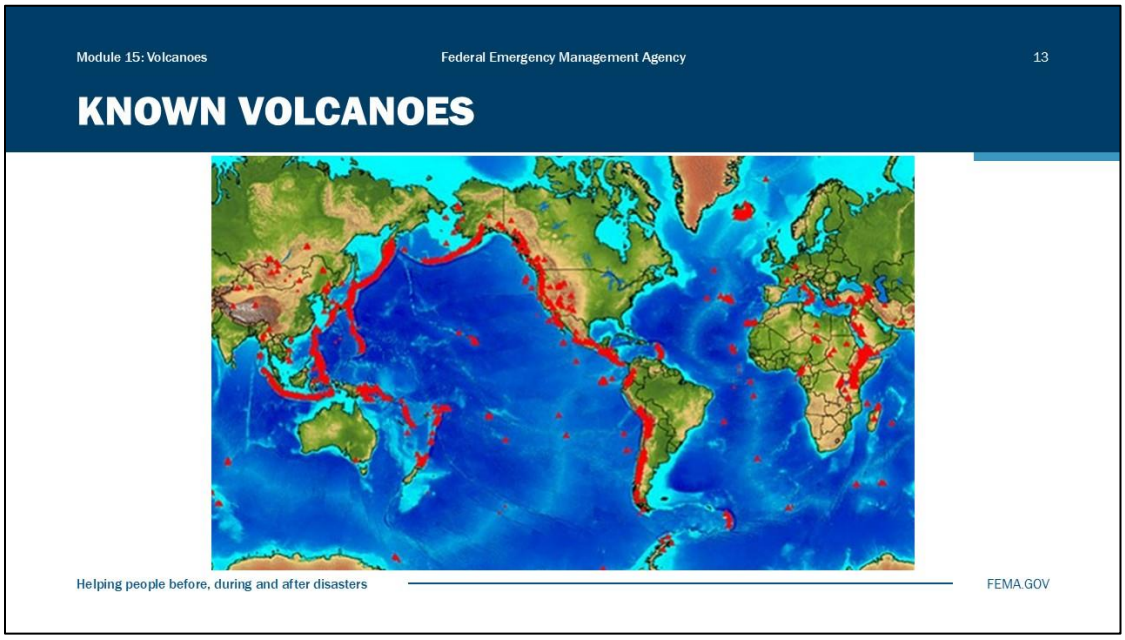
Volcano Geography (1 of 4)



Slide 15-12, Volcano Geography

Not Applicable.

Volcano Geography (2 of 4)



Slide 15-13, Known Volcanoes

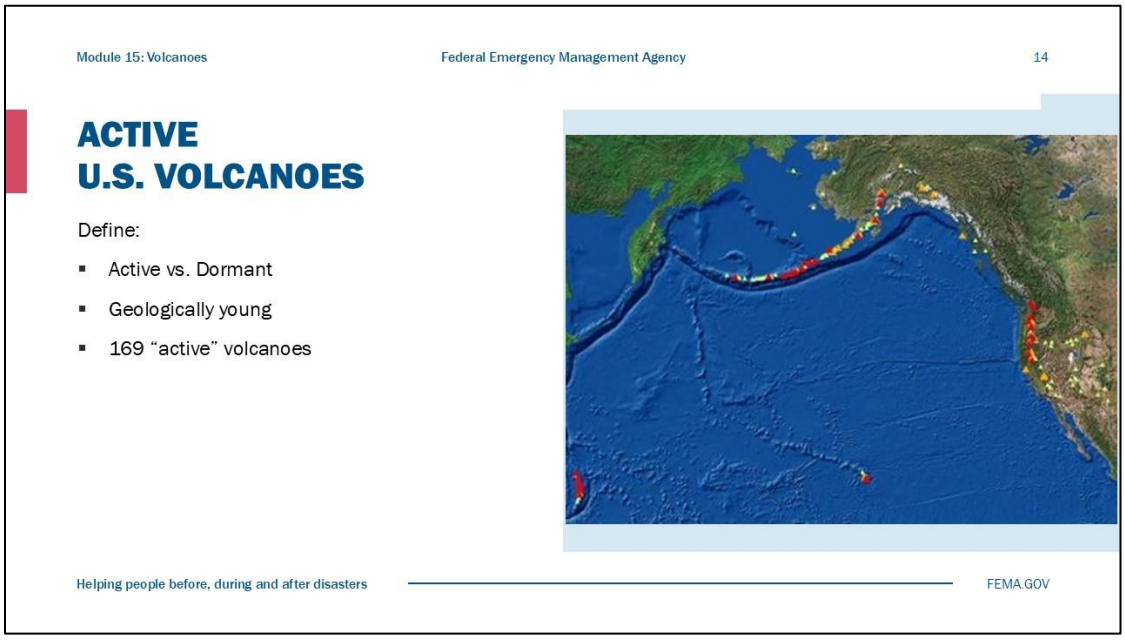
Volcanoes pose a threat to many places in the world, and the largest eruptions have global consequences.

In the last 10,000 years, 1,500 volcanoes have erupted. In recent decades, 50 to 70 different volcanoes have erupted around the world each year. At any one time, about 20 volcanoes are actively erupting. Although the chance is small that any volcano will erupt on a given day, it is essentially guaranteed that a volcano will erupt on any given day.

Even more often, volcanoes show signs that an eruption may be imminent, resulting in volcanic crises where communities and government entities must take action or prepare to take action. Unrest periods can go on for years and may or may not lead to eruptions. A single period of unrest may be punctuated with more than one eruption of varying severities and durations.

Triangles on this map indicate locations of known volcanoes in the world. (Remember that "known" does not necessarily mean active.) Recall that volcanoes occur at certain kinds of plate boundaries (and where there are hot spots). Volcano locations thus tend to delineate plate boundaries; however, volcanoes are hard to count unambiguously.

Volcano Geography (3 of 4)



Slide 15-14, Active U.S. Volcanoes

- Active vs. Dormant
- Geologically young
- 169 “active” volcanoes

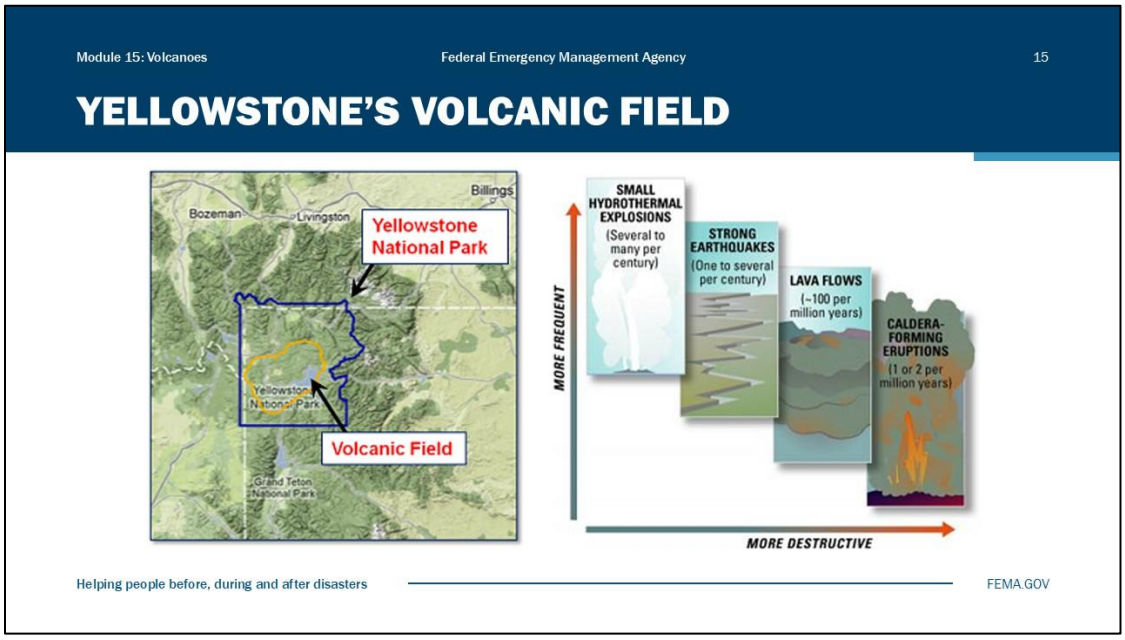
There are 169 active volcanoes in the United States, all of which have the potential to erupt. The colored triangles on the map show their locations. Some volcanoes are significantly more likely to erupt than others, marked in red.

Many scientists, however, are uncomfortable calling a volcano "inactive," as there is no agreed-upon definition of an "active" volcano. Some prefer to identify volcanoes that are geologically young, i.e., those that have been active in the last 10,000 years. (The Smithsonian Institution's Global Volcanism Program database (Institution, n.d.) can be used as a resource for these designations. It is updated by ongoing geologic discoveries and improvements to scientific dating of past eruptions.)

In addition, there are areas called "volcanic fields" where an eruption can occur from many sites rather than from a single distinct structure. Volcanic fields exist in several locations in the United States, including Arizona, New Mexico, and within the city limits of Portland, Oregon.

Pauses between eruptions can be as short as months or as long as thousands of years. Some volcanoes erupt only once; most erupt multiple times, resulting in a large landform.

Volcano Geography (4 of 4)



Slide 15-15, Yellowstone's Volcanic Field

From most frequent and least destructive to least frequent and most destructive are:

- Small Hydrothermal Explosions (Several to many per century)
- Strong Earthquakes (One to several per century)
- Lava Flows (100 per million years)
- Caldera-Forming Eruptions (1 or 2 per million years)

The map on the left shows northwestern Wyoming, with the perimeter of Yellowstone National Park outlined in blue, and the perimeter of the current Yellowstone caldera in orange.

There is no volcanic mountain in Yellowstone, WY. However, there is a volcanic field that produces the largest eruptions in the United States. Yellowstone is a massive hotspot volcano.

Evidence of ancient hot-spot eruptions exists to the southwest of Yellowstone. These hot spots burned a hole through the North American plate, resulting in the volcanic field. If plate motion does not shift direction, eruptions will eventually occur northeast of Yellowstone.

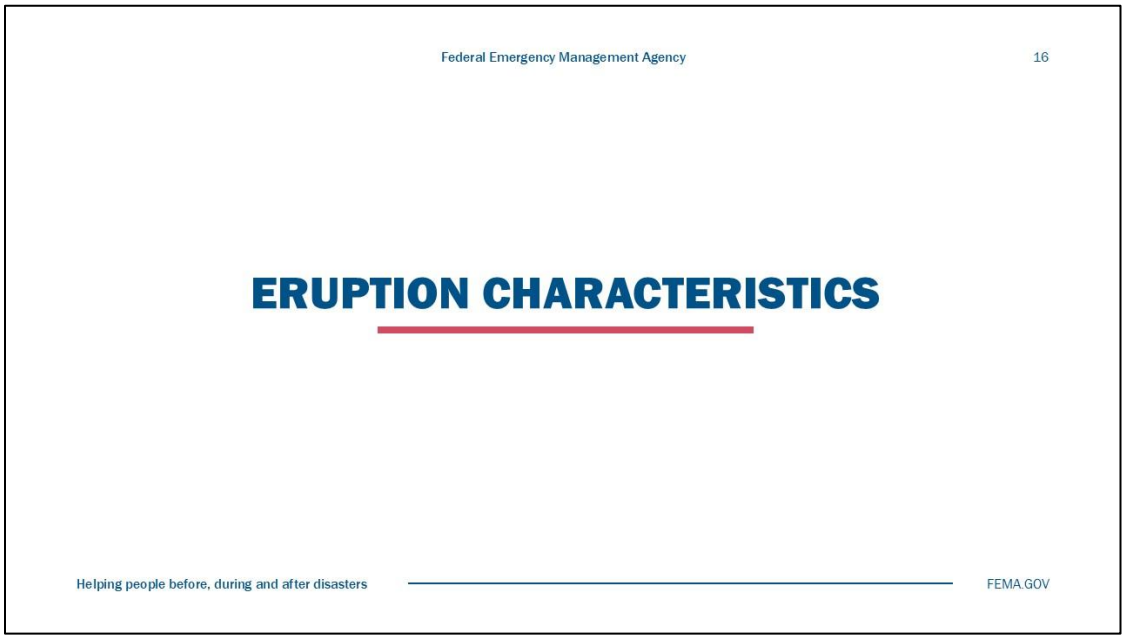
The Yellowstone Caldera measures approximately 30 to 45 miles in width and 55 miles in length, reaching depths of hundreds of meters. It is the largest volcanic vent in North America.

At some point, a volcano stops producing eruptions, but a volcano can erupt after being inactive for millennia. In fact, the biggest eruptions are the rarest. As the chart on the right indicates, a super

volcano like Yellowstone keeps active with small steam eruptions but waits tens of thousands of years between lava flows and a million years between eruptions large enough to form volcanic craters called calderas.

Yellowstone is a good representative of the opposing factors that volcano scientists must juggle in helping society prepare for volcanic eruptions, which are low-probability, high-consequence events. A Yellowstone eruption is a very low likelihood event, but there is no indication that Yellowstone is "done." At some point, an eruption will occur, and when it does, it will affect the health and economy of the entire Nation and the world.

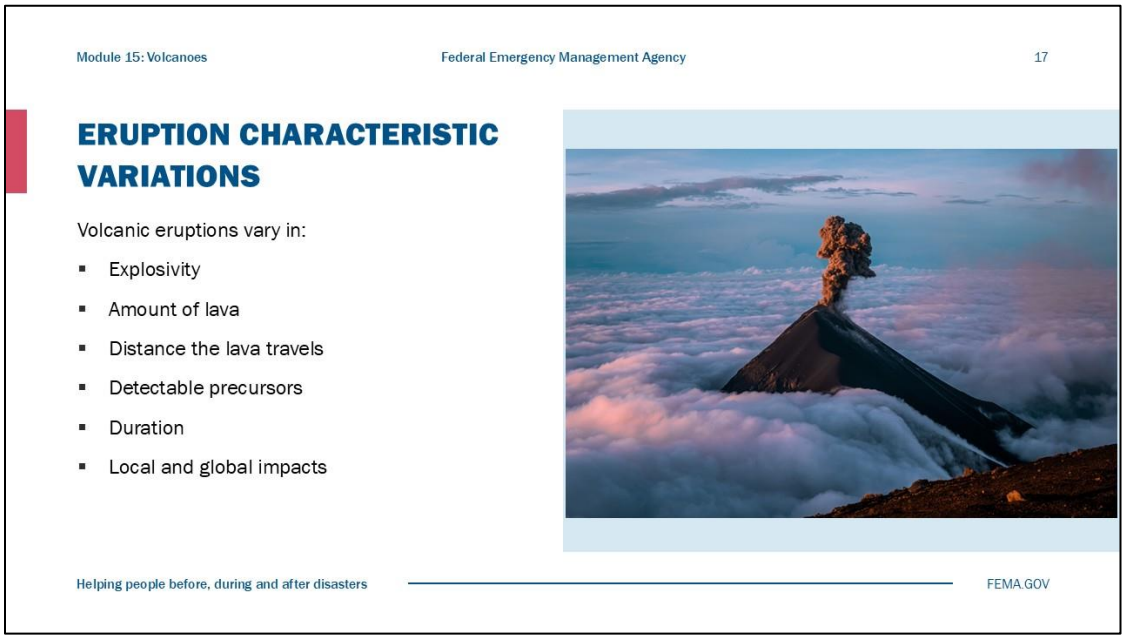
Eruption Characteristics (1 of 3)



Slide 15-16, Eruption Characteristics

Not Applicable.

Eruption Characteristics (2 of 3)

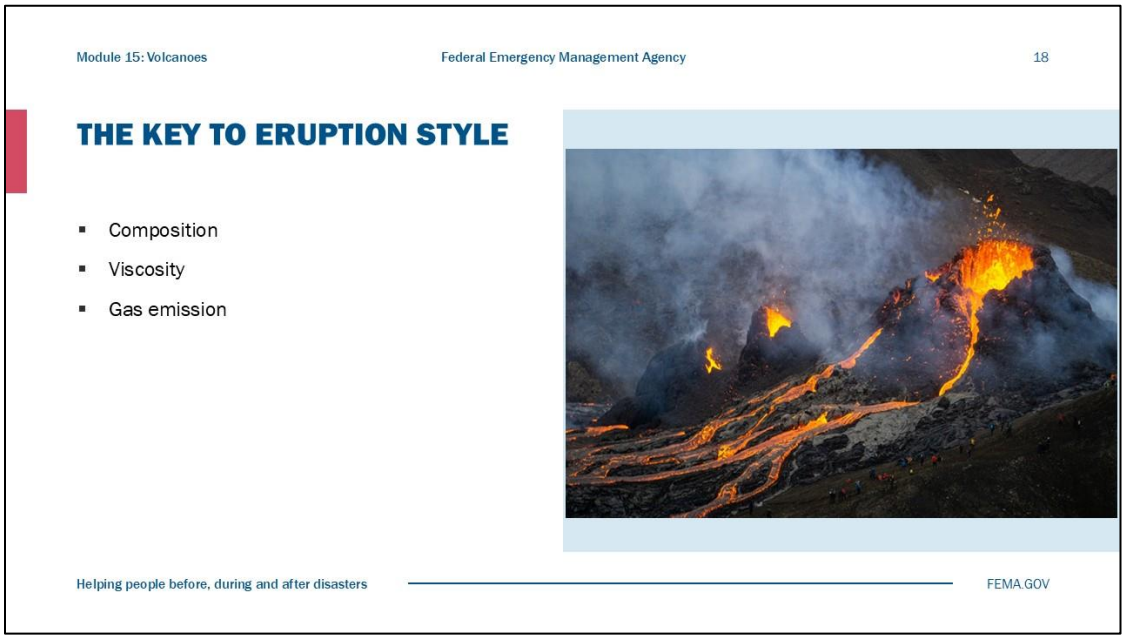


Slide 15-17, Eruption Characteristic Variations

- Volcanic eruptions vary in:
- Explosivity
- Amount of lava
- Distance the lava travels
- Detectable precursors
- Duration
- Local and global impacts

In this part of the module, we will look at how variations in molten rock, or magma, influence volcano formation and behavior.

Eruption Characteristics (3 of 3)

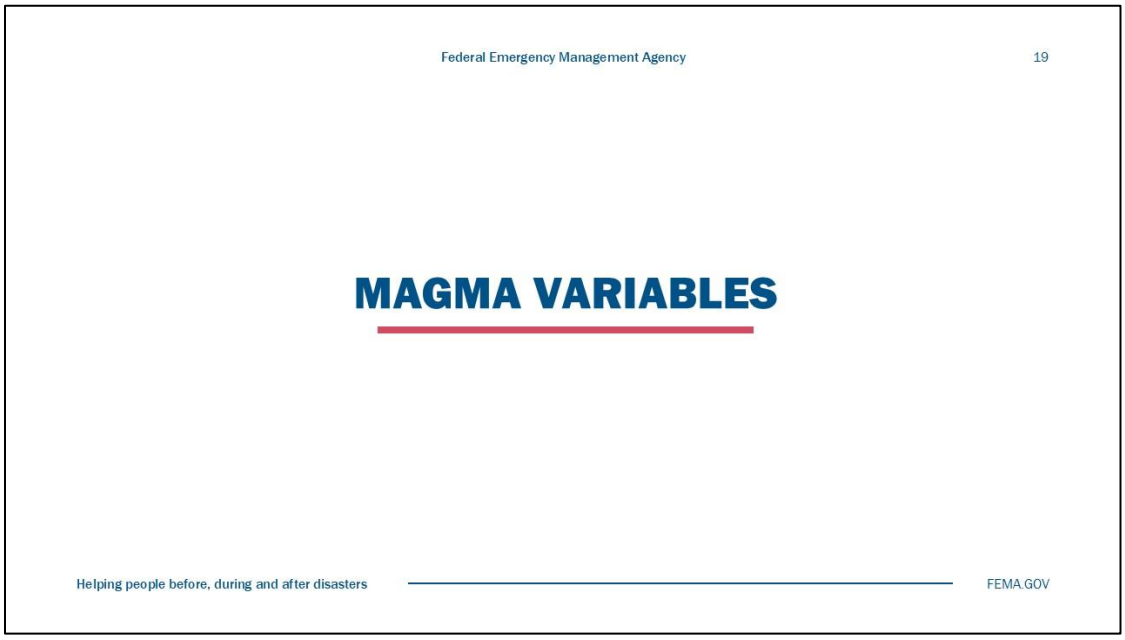


Slide 15-18, The Key to Eruption Style

- Composition
- Viscosity
- Gas emission

Key magma variables that can change an eruption include composition, viscosity, and dissolved gas content (gas emission).

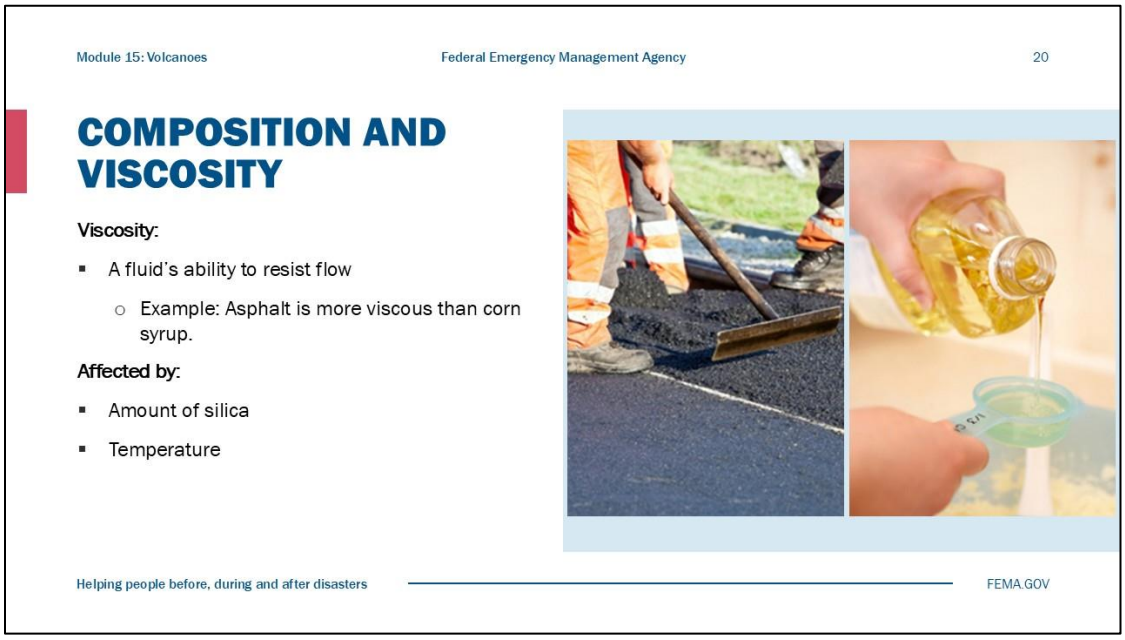
Magma Variables (1 of 4)



Slide 15-19, Magma Variables

Not Applicable.

Magma Variables (2 of 4)



Slide 15-20, Composition and Viscosity

Viscosity:

- A fluid's ability to resist flow
  - Example: Asphalt is more viscous than corn syrup.

Affected by:

- Amount of silica
- Temperature

Viscosity is a measure of the ability of a fluid to resist flow. If you increase a fluid's viscosity, then you decrease the ability of that fluid to flow. For example, at the same temperature, corn syrup is less viscous than asphalt, so it flows more easily. With volcanic fluids, viscosity is affected by the amount of silica and by temperature.

Silica in solid form is the mineral quartz. Different magmas have different amounts of silica. Higher silica occurs in subduction zones, usually because continental rock melts to form the magma, and continental rock is high in silica content.

Different concentrations of silica produce different magma types that, when cooled, form different types of rock:

Silica Content	Magma Type	Volcanic Rock
~50%	Mafic	Basalt
~60%	Intermediate	Andesite
~65%	Felsic (low silicon)	Dacite
~70%	Felsic (high silicon)	Rhyolite

For example, Hawaiian magmas are lower in silica, de-gas more easily, and hence produce more effusive lava flows. Effusive lava is comparatively “runny” and likely to flow longer distances.

Temperature also affects viscosity, as higher temperatures decrease viscosity (making the magma runnier) and increase flow. (For example, Syrup just out of the refrigerator is more viscous than room-temperature syrup.)

Oceanic hot spots such as Hawaii are lower in silica and have a lower viscosity magma. This means that the magma degasses more easily and produces eruptions that are more effusive. An effusive lava is comparatively “runny” and likely to flow longer distances. Oceanic hot spots rarely exhibit cataclysmic eruptions.

Temperature also affects viscosity because higher temperatures decrease viscosity (make the magma runnier) and increase flow. (Example: Syrup just out of the refrigerator is more viscous than syrup at room temperature.) Basaltic magmas like those in Hawaii and Iceland form at higher temperatures than granitic magmas like those at Mount St. Helens. Therefore, not only are the oceanic hot-spot lavas less viscous because of their lower silica content, but they are also less viscous because of their higher temperature.

Magma Variables (3 of 4)



Slide 15-21, Composition and Explosivity

Less silica content - Less explosive

More silica content - More explosive

Why is viscosity important?

Explosivity: More viscous magmas and lavas that cannot flow or de-gas easily are more explosive. Therefore, the less silica content, the less explosive the volcano. The more silica content, the more explosive.

Volcanic eruptions' explosivity varies widely. Some are relatively calm, with nonviolent lava flows extruding. Others are highly explosive and characterized by the violent ejection of fragmented volcanic debris. This variation depends on the composition of the magma, particularly on the amount of silica in the melt.

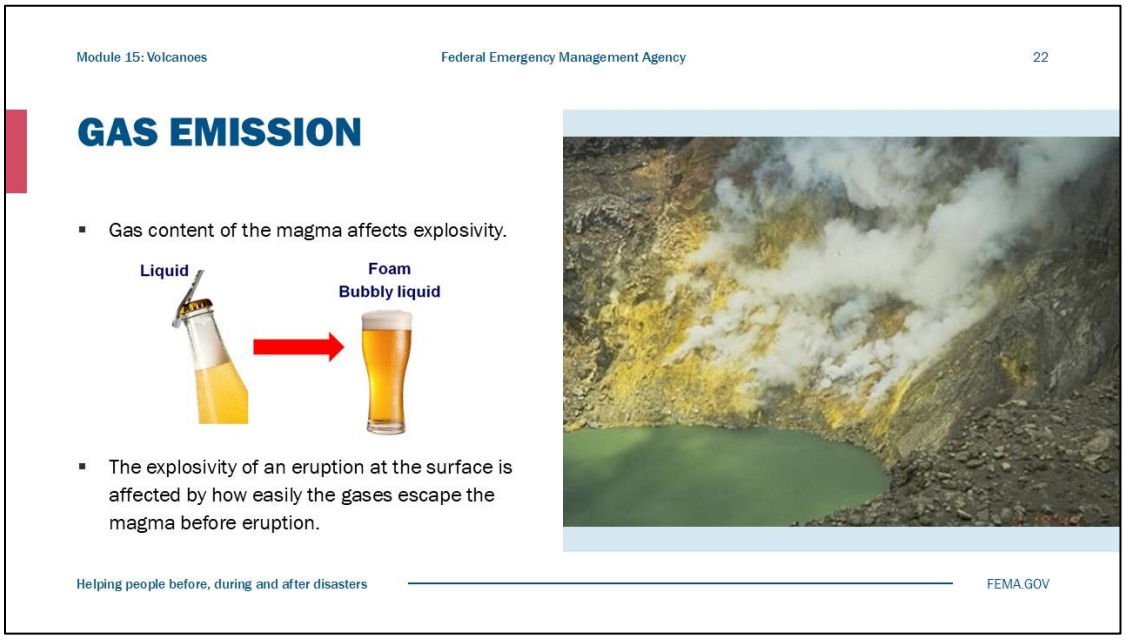
Volcano shape and size: The factors that affect explosivity, how much lava will erupt, and how far lava will travel, also influence the shape and size of a volcano. Most volcanoes have characteristic eruptive styles and thus a characteristic shape. On this visual are three examples of distinctly shaped volcanoes. Moving from left to right goes from least to most explosive, and from less to more silica content.

- At left is Mauna Loa in Hawaii

- In the middle is Mount Shasta and Shastina, California
- On the right is what is left of Mount Aniakchak in Alaska after the volcano blew itself apart in an explosive eruption some 3,700 years ago. (Such an eruption today would affect air traffic worldwide for months.)

Although a volcano's shape tells scientists important information about past eruptions, any volcano can change its eruptive style during the next eruption. A single volcano can (and often does) have mixtures of magma types and thus many styles of eruption.

Magma Variables (4 of 4)



Slide 15-22, Gas Emission

- Gas content of the magma affects explosivity.
- The explosivity of an eruption at the surface is affected by how easily the gases escape the magma before eruption.

Gas emission is another variable that affects volcanic behavior. Magmas include varying degrees of volcanic gases such as water vapor, carbon dioxide, and sulfur dioxide.

Deeper in the Earth, where pressure is higher, gas is contained in the liquid, much like gas is contained in a carbonated liquid within a pressurized container. If the pressure is released on a bottle by opening the cap, the liquid degasses quickly. First, the foamy and gassy contents will be released, and then the liquid will follow.

Similarly, in a volcanic eruption, rapid changes in pressure can occur as the magma ascends, allowing trapped gas to escape explosively. Although the magma is not always shaken in a volcanic eruption, the escape of gas can be explosive depending on the amount of gas present and the buildup of pressure.

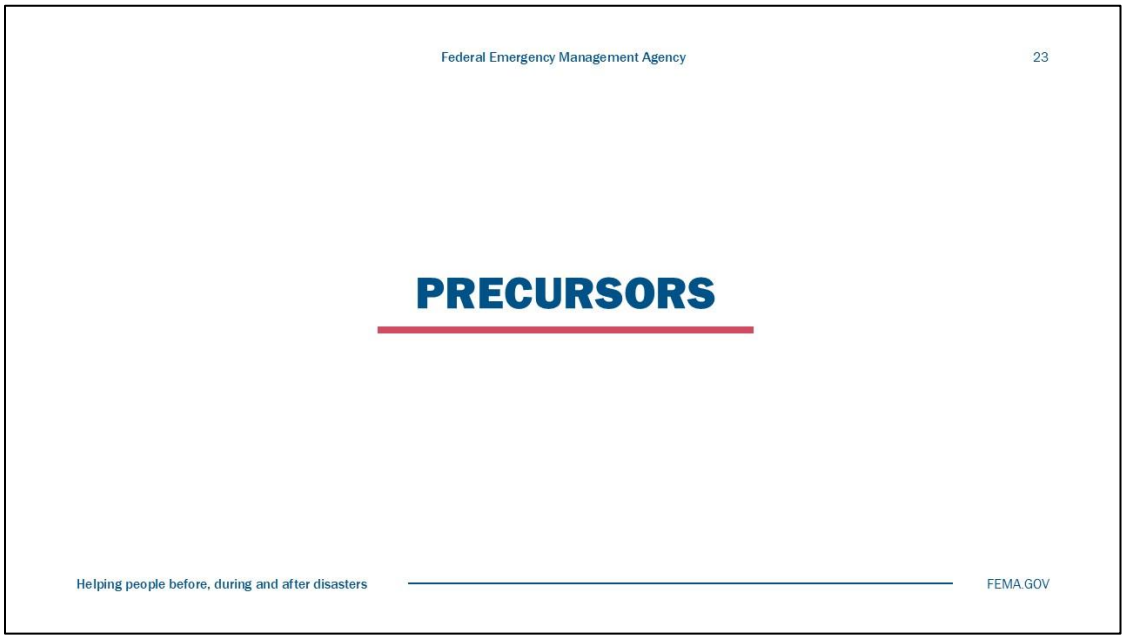
The extent to which the liquid magma and gas can separate before the eruption starts affects eruption behavior. This separation occurs as a result of the following process:

1. As magma rises toward the surface, where pressure is lower, gases begin to form tiny bubbles. These take up more volume than the gas did previously, making the magma less dense and more buoyant and allowing it to continue its upward journey.
2. Closer to the surface, the bubbles increase in size and number. Sometimes, the gas volume exceeds the melt volume, creating a magma foam.
3. During eruptions, dissolved gases in the magma are released into the atmosphere. The most common gases released are water vapor, carbon dioxide, and sulfur dioxide.

It is more difficult for gas to escape a viscous lava, making an explosion more likely when the gas-filled magma reaches the surface.

Although the explanation for why volcanoes stop erupting is complex, the simple answer is that as magma reservoirs become depleted of hot, gassy magma, they lose their driving force, which is excess buoyancy.

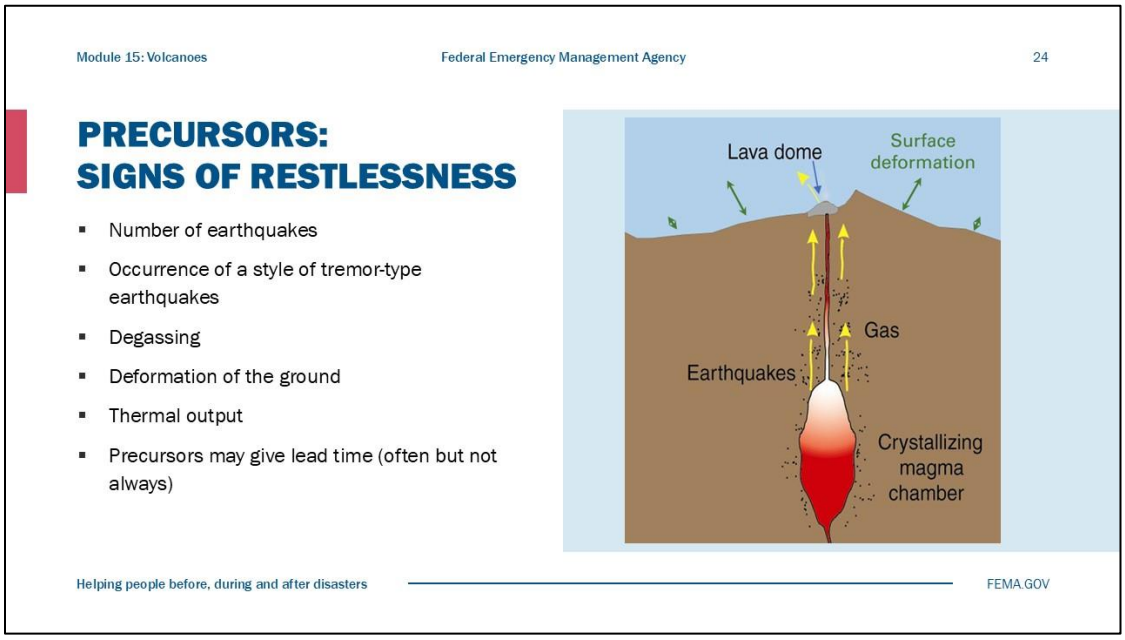
Precursors (1 of 3)



Slide 15-23, Precursors

Not Applicable.

Precursors (2 of 3)



Slide 15-24, Precursors: Signs of Restlessness

Precursors help scientists predict volcanic eruptions. There are several important eruption precursors, including:

- Number of earthquakes
- Occurrence of a style of earthquake called tremor
- Degassing
- Deformation of the ground
- Thermal output

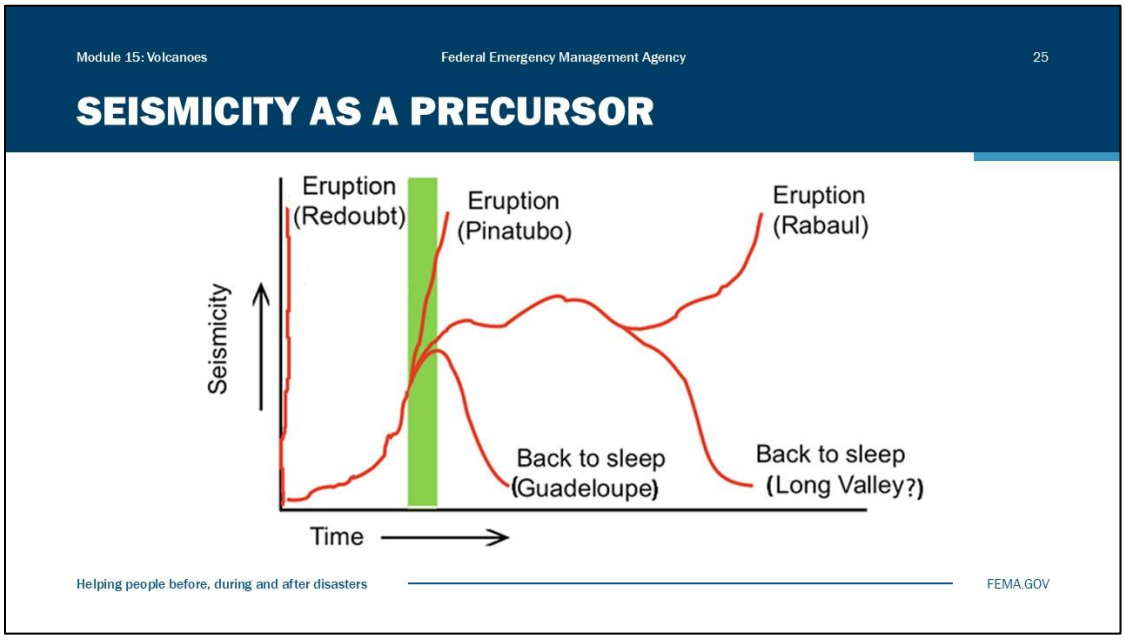
All of these precursory signals are caused by processes associated with magma migration toward the surface.

Magma accumulates a few miles below a volcano. Before an eruption, magma ascends toward the surface through narrow conduits. The magma changes the volume of the rock and breaks rock, which produces earthquakes. Moving magma and escaping gas can also produce distinctive styles of earthquakes together, called volcanic tremors.

As magma migrates, it often deforms the volcano or nearby land because of increases and decreases in volume. An increasing volume of hot material will heat groundwater and can change

spring water chemistry. Then, gases escape from the magma when the magma reaches lower pressures near the surface.

Precursors (3 of 3)



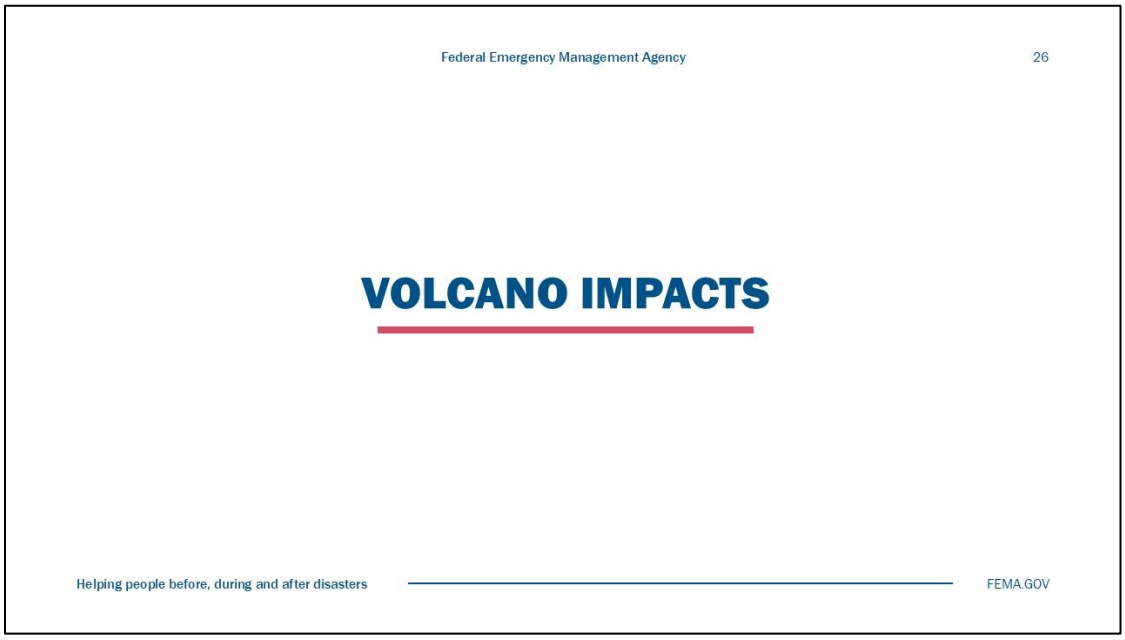
Slide 15-25, Seismicity as a Precursor

Seismicity—the number and characteristics of earthquakes near the volcano—is a key indicator.

As magma rises, it often causes small earthquakes. Sometimes an increase in the seismicity indicates that an eruption is imminent.

What the graphic shows: This plot shows the behavior of five recently restless volcanoes (Redoubt, Pinatubo, Guadeloupe, Rabaul, and Long Valley) vs. the number of earthquakes near the volcano over time. (Similar plots could be made for other indicators of volcanic unrest, such as gas emission.) In this case, the timeframe is months to years, but other examples could be shown in hours, days, or decades.

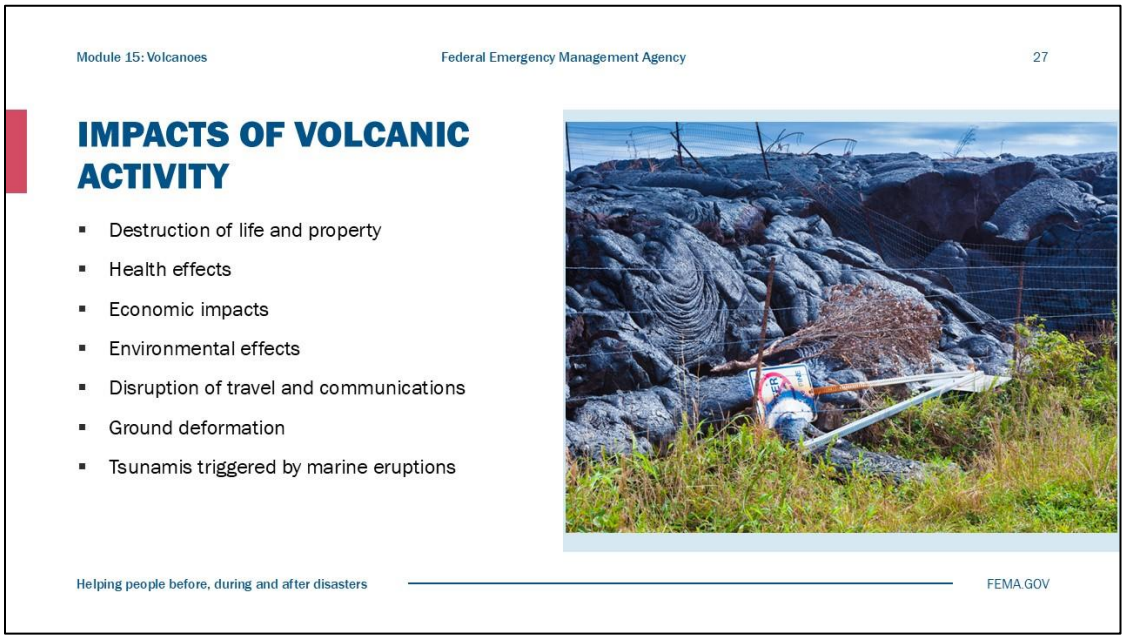
Volcano Impacts (1 of 8)



Slide 15-26, Volcano Impacts

Not Applicable.

Volcano Impacts (2 of 8)



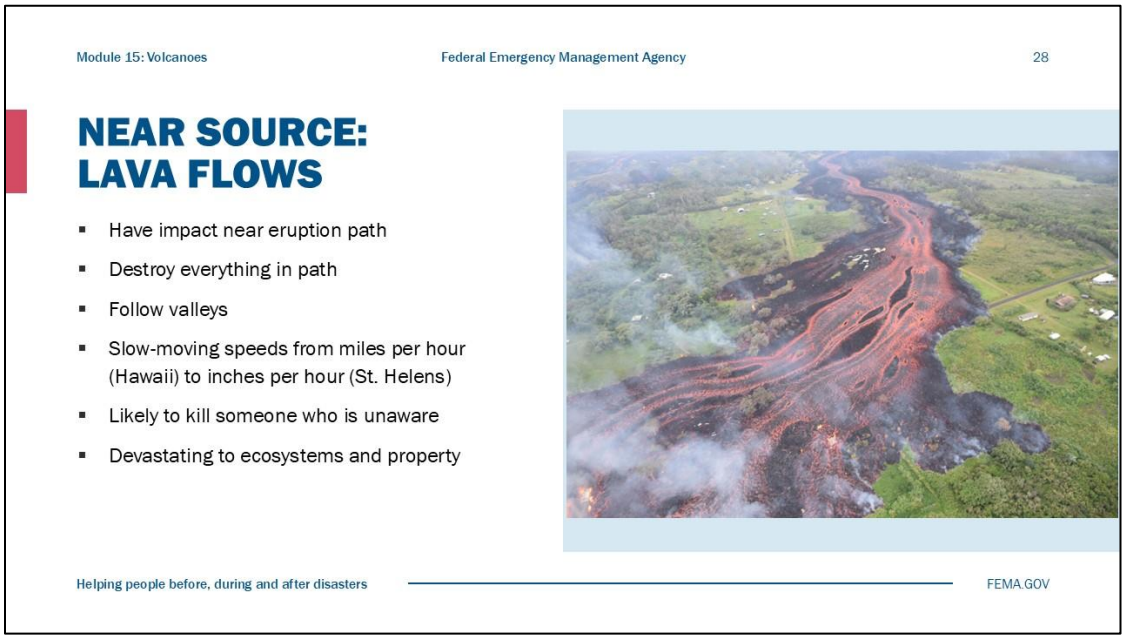
Slide 15-27, Impacts of Volcanic Activity

Although eruption styles and intensities vary, a wide array of impacts can generally be seen, including:

- Destruction of life and property
- Health effects
- Economic impacts
- Environmental effects
- Disruption of travel and communication
- Ground deformation
- Tsunamis triggered by marine eruptions

Long durations of volcanic events (extended eruptions or long periods of unrest) can create significant economic and health impacts. Among the health impacts are mental and physical fatigue, which can impede good decision-making and appropriate action. This impacts animals and plants as well. Plant death can lead to wildfires. In addition, a psychological reaction to extended periods of official alert is to redefine what "normal" is and accept the new conditions as average.

Volcano Impacts (3 of 8)



Slide 15-28, Near Source: Lava Flows

Lava flows:

- Have an impact near the eruption source
- Destroy everything in their path
- Follow paths that can be anticipated, typically through valleys
- Are relatively slow-moving

Less viscous lava flows, such as those on Hawaii, move at speeds of miles per hour. Viscous, high-silica lava travels inches per hour.

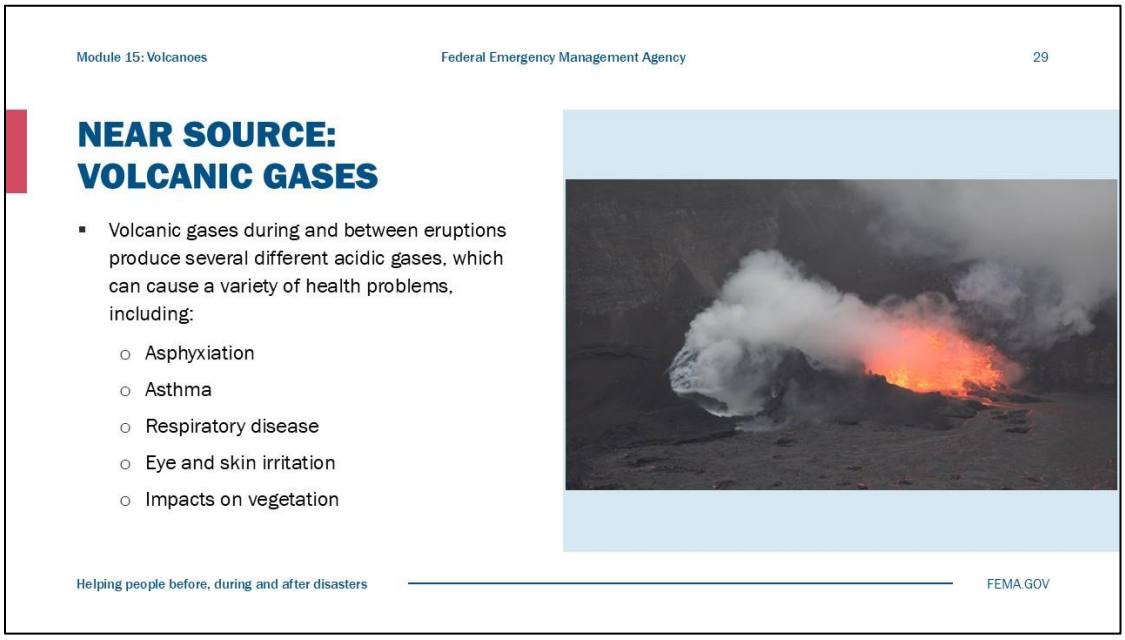
- Are most likely to kill someone who is caught unaware
- Are devastating to ecosystems and property because their high temperatures (often 800°F) destroy everything in their path

Photo Details: Helicopter overflight of Kīlauea Volcano's lower East Rift zone on May 19, 2018, around 8:18 AM, HST. ʻAʻā lava flows emerging from the elongated fissure 16-20 form channels. The flow direction in this picture is from upper center to the lower left.(*Kīlauea Volcano — Channelized Lava Flow | U.S. Geological Survey*, 2018)



For more information about this eruption, read the featured story: January 17, 2025 — Kīlauea summit eruption UAS operations.

Volcano Impacts (4 of 8)



Slide 15-29, Near Source: Volcanic Gases

During and between eruptions, volcanoes produce several different acidic gases, including sulfur dioxide and hydrogen chloride. Volcanic gases occur in the highest levels near volcanoes that are actively degassing, and can cause a variety of health problems, including:

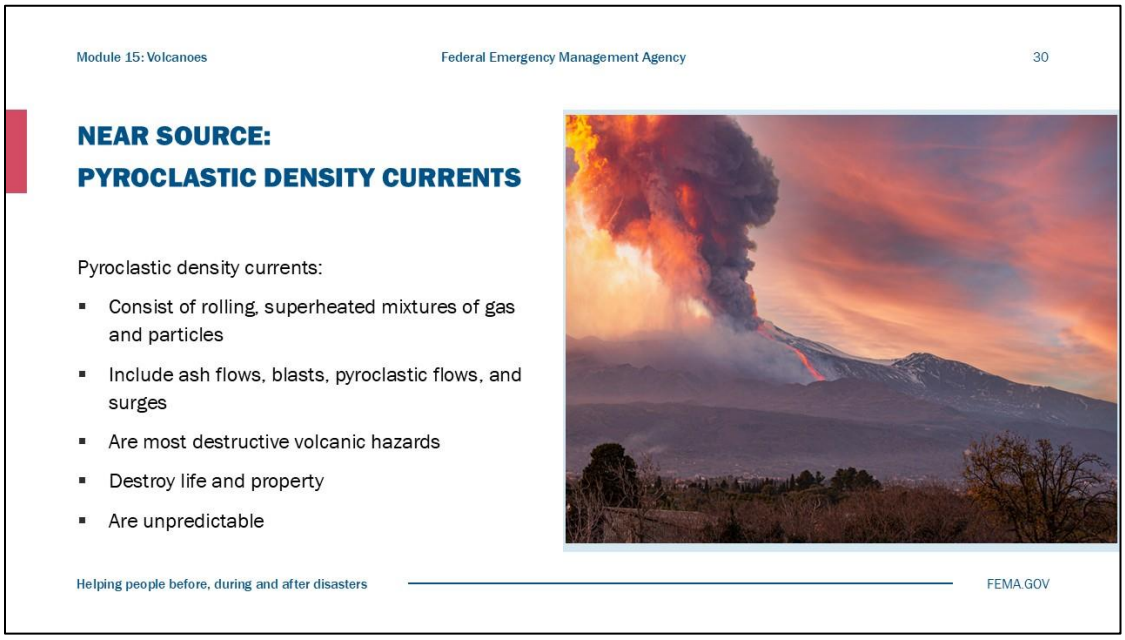
- Asphyxiation
- Asthma
- Respiratory disease
- Eye and skin irritation
- Impacts on vegetation

The only protection from these gases is relocation.



https://www.usgs.gov/media/images/january-22-2025-kilauea-summit-eruption-episode-5-lava-fountain (*January 22, 2025 — Kīlauea Summit Eruption Episode 5 Lava Fountain | U.S. Geological Survey*, 2025)

Volcano Impacts (5 of 8)



Slide 15-30, Near Source: Pyroclastic Density Currents

Pyroclastic density currents (PDCs):

- Consist of rolling, superheated mixtures of gas and particles
- Include ash flows, blasts, pyroclastic flows, and surges
- Are the most destructive volcanic hazards
- Destroy life and property
- Are unpredictable

PDCs, also called pyroclastic flows, are another near-source hazard. PDCs:

- Are roiling, superheated mixtures of gas and particles that move faster than 100 miles per hour and can blanket a landscape, obliterating everything in their path
- Include ash flows, blasts, pyroclastic flows, and surges
- Are the most devastating of all volcanic hazards, with a long history of destruction of life and property
- Are unpredictable in their path and occurrence

Ancient Pompeii was destroyed by a PDC during an eruption of Mount Vesuvius.

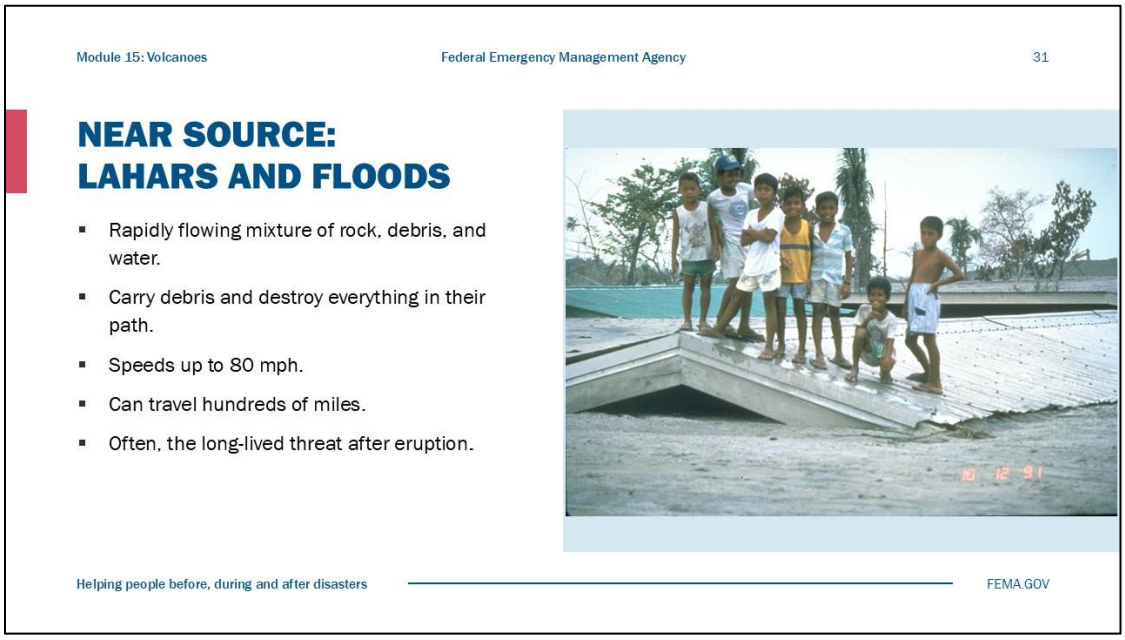
The photo shows a pyroclastic flow during the Mount St. Helens eruption of 1980, which we looked at earlier in this module.



https://www.geological-digressions.com/pyroclastic-surges-and-base-surges/

(brian, 2022)

Volcano Impacts (6 of 8)



Slide 15-31, Near Source: Lahars and Floods

- Rapidly flowing mixture of rock, debris, and water
- Carry debris and destroy everything in their path
- Speeds up to 80 mph
- Can travel hundreds of miles
- Often, the long-lived threat after eruption

A lahar is a rapid volcanic mudflow of up to 80 mph. Lahars:

- Carry a mixture of rock, debris, and water, destroying everything in their path.
- Are the volcanic equivalent of a debris flow; in fact, scientists who study one hazard sometimes collaborate with those who study the other
- Can occur during or between eruptions
- Are the most far-reaching of volcanic hazards that are ground-based (as opposed to air-based) and can travel hundreds of miles
- Are often the long-term threat after an eruption

Lahars can form in a variety of ways, such as:

- When a pyroclastic flow or steam eruption melts snow and ice on a volcano
- By the breakout of a lake dammed by volcanic deposits
- During intense rainfall on loose volcanic deposits

Volcano Impacts (7 of 8)



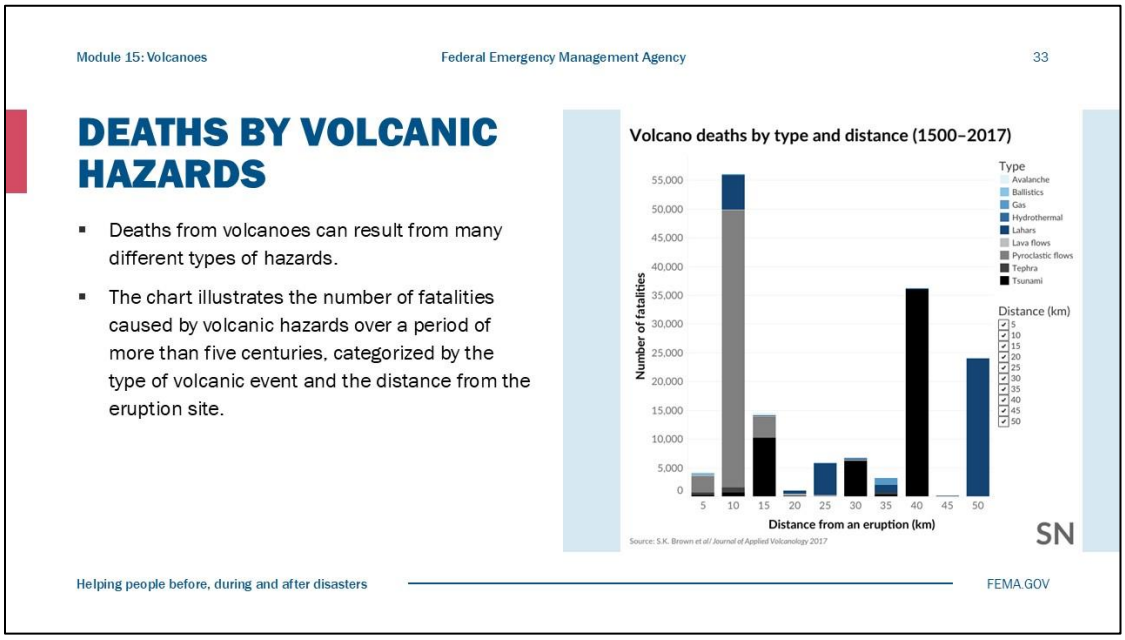
Slide 15-32, Global and Regional Effects: Ash

An effect that reaches beyond the local hazard area is ash, generated by an explosive volcanic eruption. Ash:

- Consists of tiny particles, fractions of an inch in size
- Is typically composed of silica—essentially microscopic glass—and may also contain noxious chemical substances
- Can cause destruction while in the air and when it reaches the ground; even minor amounts cause significant impacts on infrastructure, lifelines, and industry, including aviation, ground transportation, communications, utilities, and farming
- Buries plants, poisons livestock, and contaminates water supplies
- In water, it becomes extremely abrasive; ash inhalation and contact have many health consequences for animals and humans
- Short-term effects include:
  - Asthma, bronchitis, and irritation of airways.
  - Increased risk of stroke or heart attack.
  - Skin and eye irritation.

- Long-term effects include:
  - Chronic obstructive pulmonary disease.
  - Tuberculosis
  - Pneumoconiosis
  - Fluorosis
  - Silicosis and other lung fibrotic diseases

Volcano Impacts (8 of 8)



Slide 15-33, Deaths by Volcanic Hazards

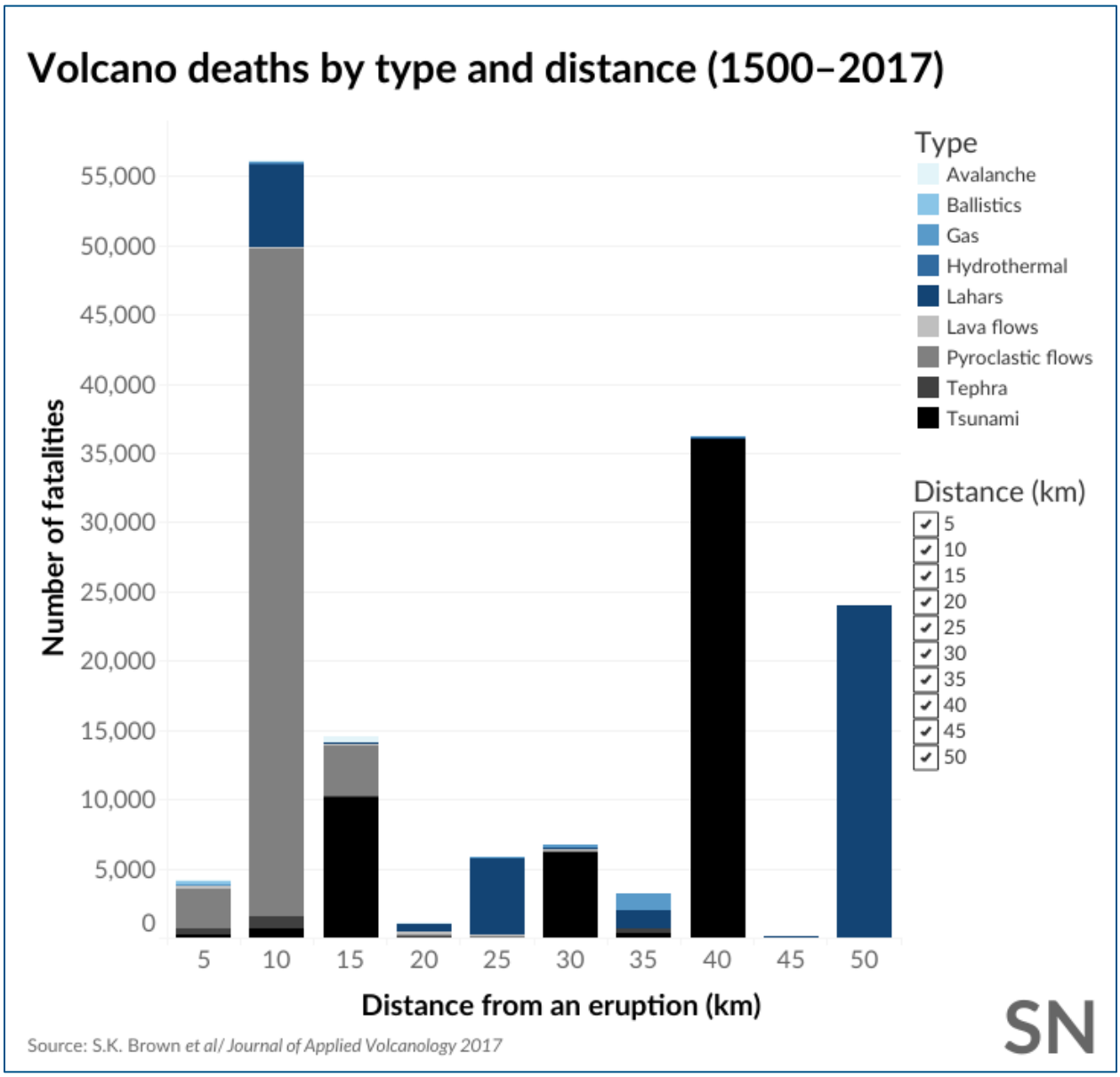
- Deaths from volcanoes can result from many different types of hazards.
- The chart illustrates the number of fatalities caused by volcanic hazards over a period of more than five centuries, categorized by the type of volcanic event and the distance from the eruption site.

The x-axis represents the distance from an eruption, in 5-kilometer intervals, ranging from 5 km to 50 km. The y-axis indicates the number of fatalities, scaling up to 55,000. (*Here's a Look at the World's Deadliest Volcanoes — and the Ways They Kill*, 2018)

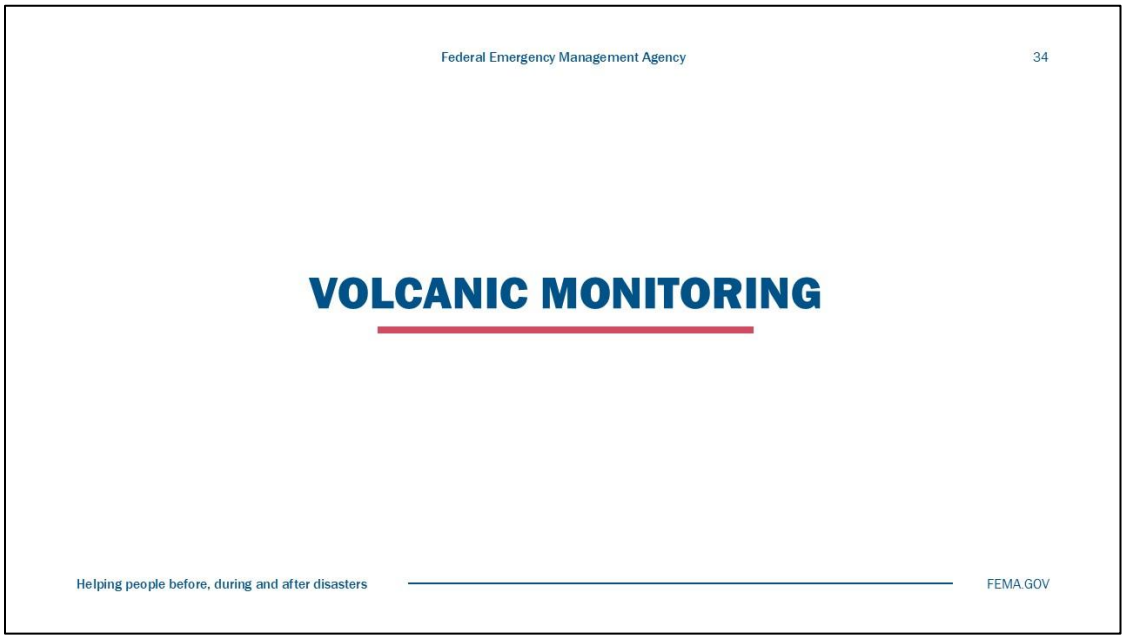
Each vertical bar corresponds to a distance interval and is subdivided into multiple segments that represent the specific type of volcanic hazard contributing to the total fatalities at that distance. The types are distinguished by color, and a legend is provided to the right of the chart:

- **Avalanche** (light gray-blue)
- **Ballistics** (light blue)
- **Gas** (sky blue)
- **Hydrothermal** (medium blue)
- **Lahars** (dark blue)
- **Lava flows** (gray)

- **Pyroclastic flows** (dark gray)
- **Tephra** (black-gray)
- **Tsunami** (black)



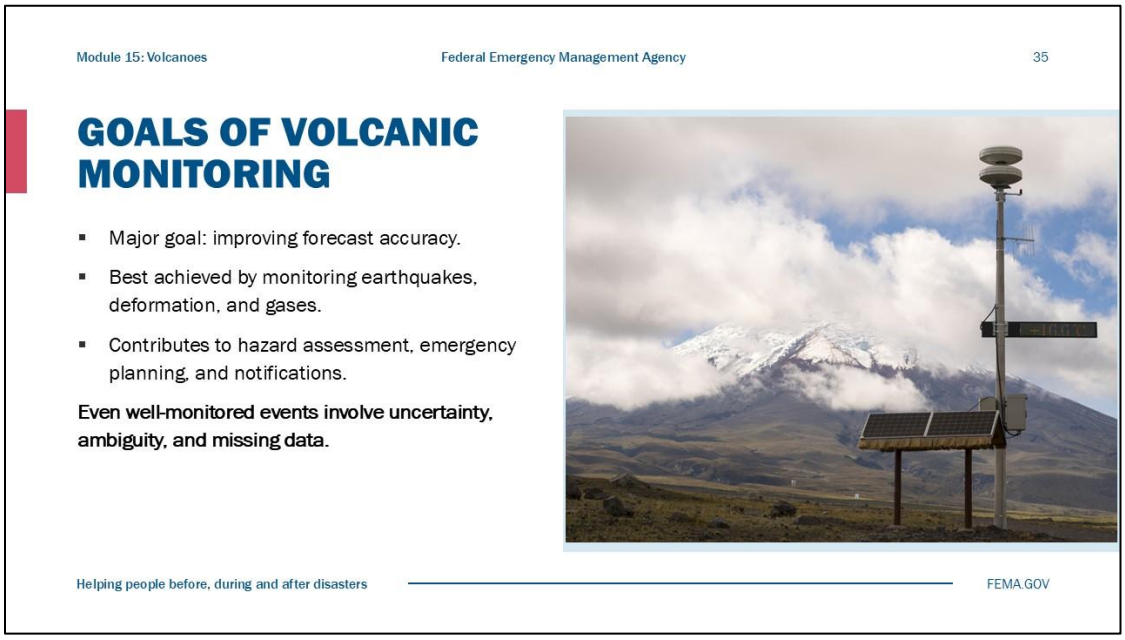
Volcanic Monitoring (1 of 3)



Slide 15-34, Volcanic Monitoring

Not Applicable.

Volcanic Monitoring (2 of 3)



Slide 15-35, Goals of Volcanic Monitoring

- Major goal: improving forecast accuracy
- Best achieved by monitoring earthquakes, deformation, and gases
- Contributes to hazard assessment, emergency planning, and notifications

Even well-monitored events involve uncertainty, ambiguity, and missing data.

How volcanoes are monitored: Volcanology is the study of volcanoes. A major goal of volcanology is to improve the accuracy of forecasting. Because most volcanoes enter periods of unrest before eruption, monitoring volcanoes for signs of activity provides the best chance of reducing eruption impacts. Signs of activity can vary, and monitoring is best achieved by looking at earthquakes, ground deformation, and volcanic gases. Scientists employ an arsenal of skills and methods to observe and detect the great variety and wide scale of changes volcanoes can make to Earth, air, and water.

- **Earthquake** seismometers must detect energy of different wavelengths
- **Ground deformation detection** includes techniques from satellite radar to real-time GPS, to leveling surveys
- Satellite, airborne, and in-person methods are used to sample gas emissions

- During eruptions, volcanoes generate their own weather, so **worldwide lightning detection** is also a method employed for situational awareness

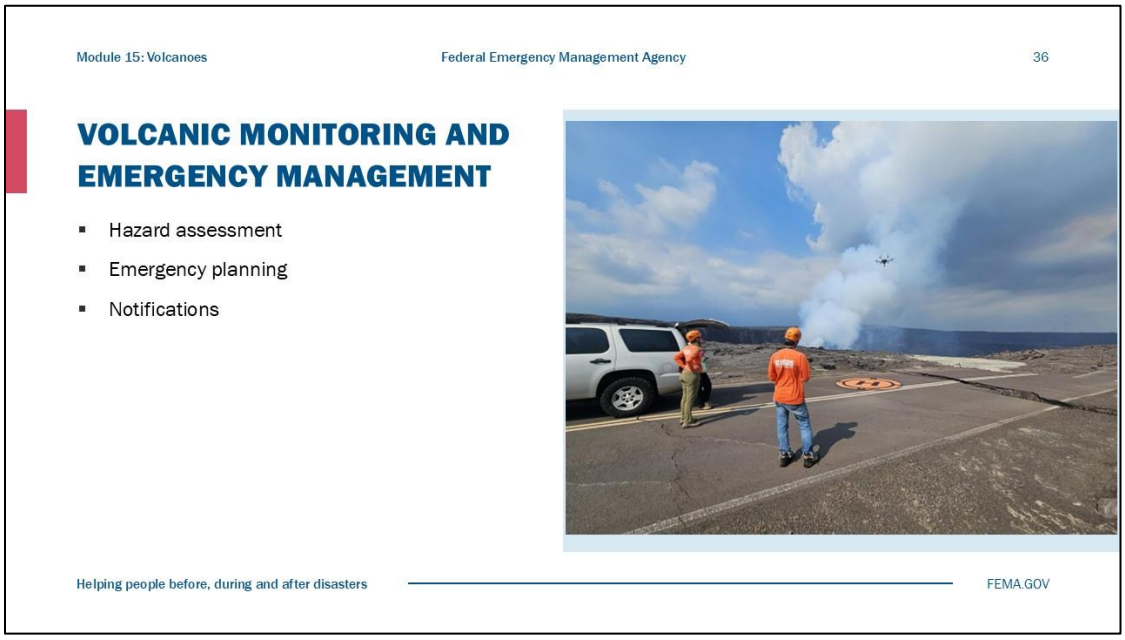
Monitoring in the United States: During an eruption, monitoring remains a critical tool for understanding what will happen next. In the United States, the USGS has a statutory responsibility to monitor U.S. volcanoes and issue alerts and warnings about volcanic unrest and eruptions. It is currently developing a volcano early warning system. However, not all active volcanoes are currently monitored, including some that pose a high risk.

Forecasting: For an eruption forecast to be useful, it needs to identify:

- When the eruption will begin
- How long it will last
- How severe it will be
- Then the eruption is over (although unrest might continue)

However, it is important to remember that even well-monitored events involve uncertainty, ambiguity, and missing data.

Volcanic Monitoring (3 of 3)



Slide 15-36, Volcanic Monitoring and Emergency Management

Contributions to emergency management: Volcanic monitoring contributes to emergency management in several ways:

- **Hazard assessment**: Before unrest, scientists focus on an individual volcano or hazardous process to develop a hazard assessment, which is based on an understanding of volcanic processes in general and on the history and likely behavior of a particular volcano or process. To fully quantify the hazard in space and time, a hazard assessment will include:
  - Geologic mapping of the volcano
  - Accurate topography from a digital elevation model
  - Analyses of past eruptions at that volcano
  - Knowledge of Local wind directions and other weather features

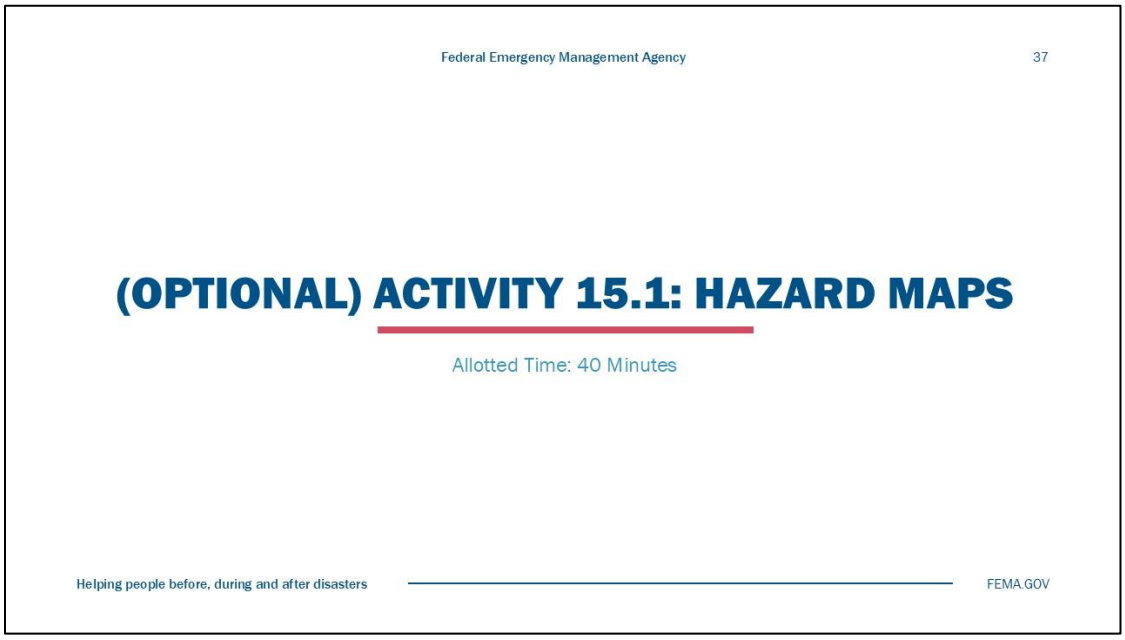
  Hazard assessments will change as conditions change, including landscape changes and increases in understanding.
- **Emergency planning**: Response plans are in place at the national and regional levels to deal with the widespread potential effects of ash eruptions.

Developing such plans requires the combination of scientific and emergency management expertise, and the participation of numerous agencies and organizations to delineate interagency roles and coordination requirements for events that can have Local, regional, and national impacts. There exist scattered Local plans for individual volcanoes, but as is true with other hazards, it is difficult to engage communities in preparations for rare events.

- **Notifications:** When a volcano becomes restless or finally erupts, scientific scrutiny greatly increases. Monitoring that volcano, its hazard assessment, and understanding of volcanic processes are all more generally brought to bear, quickly, to produce Volcano Activity notifications. These notifications are available by subscription and on the web. Weather science is combined with Earth science to produce special weather statements from the National Weather Service.

During an eruption or crisis, the scientists who create these messages and those who receive them must grapple with the difficulty of communicating information and making decisions in a situation with great inherent uncertainty.

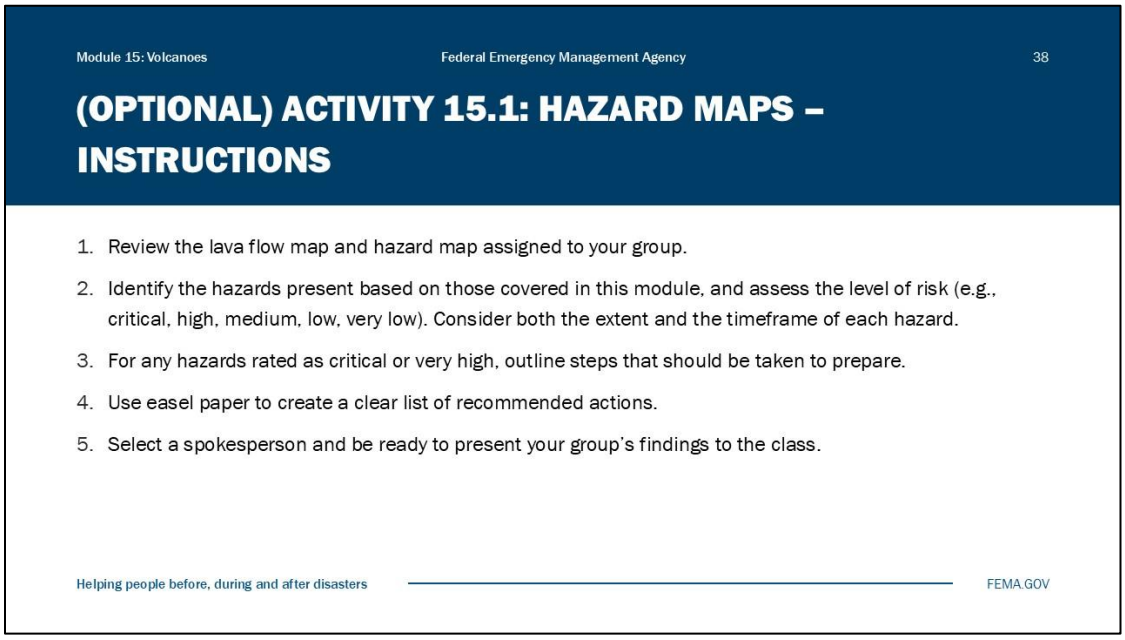
(Optional) Activity 15.1: Hazard Maps (1 of 2)



Slide 15-37, (Optional) Activity 15.1: Hazard Maps

Not Applicable.

(Optional) Activity 15.1: Hazard Maps (2 of 2)



Slide 15-38, (Optional) Activity 15.1: Hazard Maps – Instructions

Activity 15.1: Hazard Maps – Directions to Students

Purpose

The purpose of this activity is to help students analyze and evaluate geological hazards using real-world lava flows and hazard maps. By working collaboratively, students will assess risk levels and propose practical preparedness steps, enhancing their understanding of hazard assessment and disaster planning in different geologic settings.

Directions

1. In your table group, begin by reviewing the Lava Flow Map and your assigned hazard map (Hawaii or Mount Rainier) provided below.
2. Based on the hazards we discussed in this module, identify and evaluate the level of risk using the following criteria: critical, high, medium, low, or very low. Consider both the extent and timeframe of each hazard.

HAWAII – RISK ASSESSMENT

Hazard	Kailua Kona	Ocean View	Pāhoa	Waimea
Ash Fall				
Explosive Eruptions				
Ground Cracks and Settling				
Lava Flows				
Lahars				
Pyroclastic Flows				
Tephra				
Volcanic Gasses				

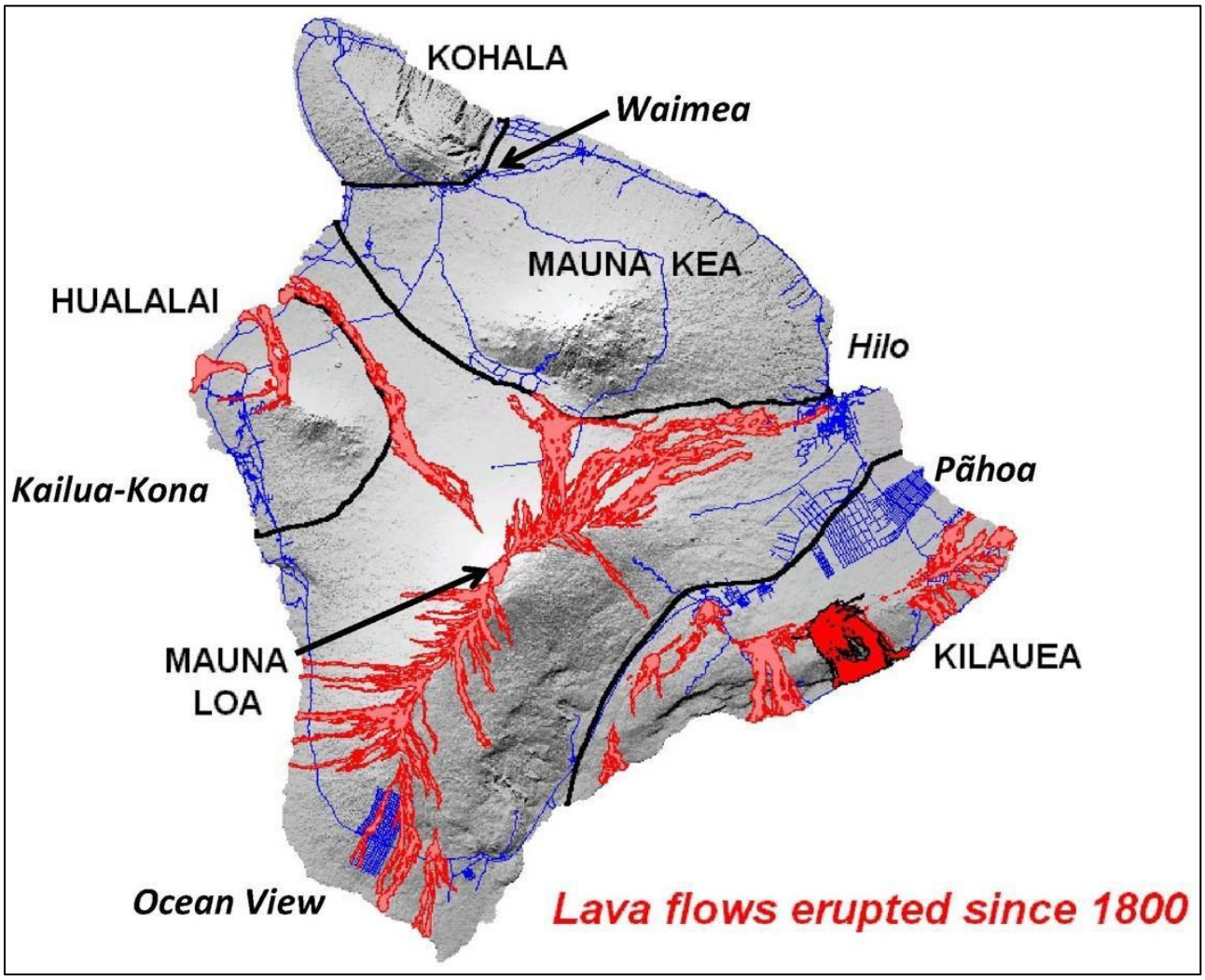
MOUNT RAINIER – RISK ASSESSMENT

Hazard	Ashford	Morton	Paradise	50 miles due east of Rainier
Ash Fall				
Explosive Eruptions				
Ground Cracks and Settling				
Lava Flows				
Lahars				

Hazard	Ashford	Morton	Paradise	50 miles due east of Rainier
Pyroclastic Flows				
Tephra				
Volcanic Gasses				

3. For each hazard rated as critical or very high:
    a. Use easel paper to list the actions that should be taken to prepare for these hazards.
    b. Choose a spokesperson to present your group's recommendations.
    c. Be ready to share your group's findings and action steps with the class during the debrief.
4. After the debrief, be prepared to discuss:
    a. How the hazards in Hawaii differ from those at Mount Rainier.
    b. How those differences relate to each volcano's geologic setting.

Lava Flow Map

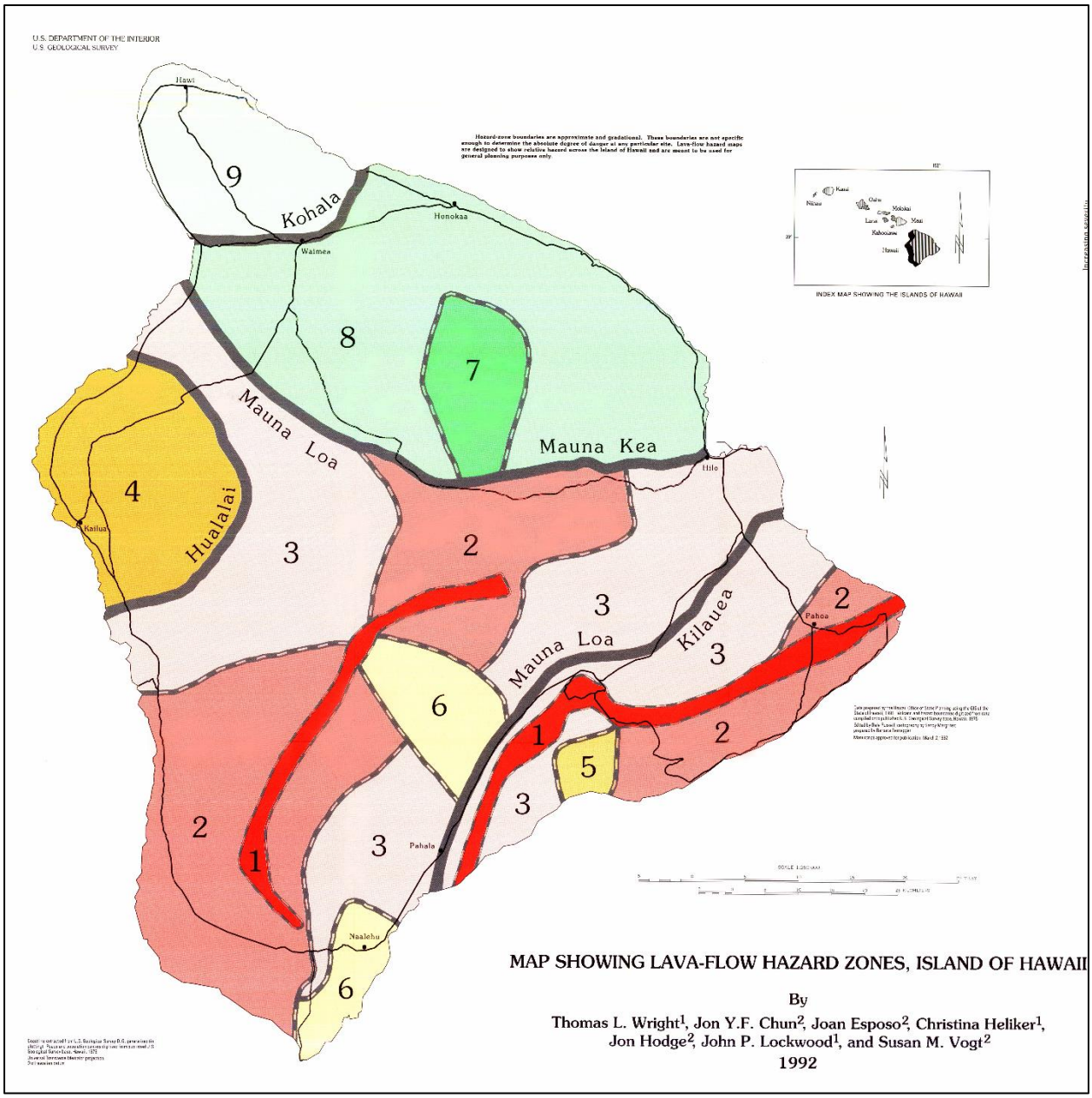


Hawaii Hazard Map

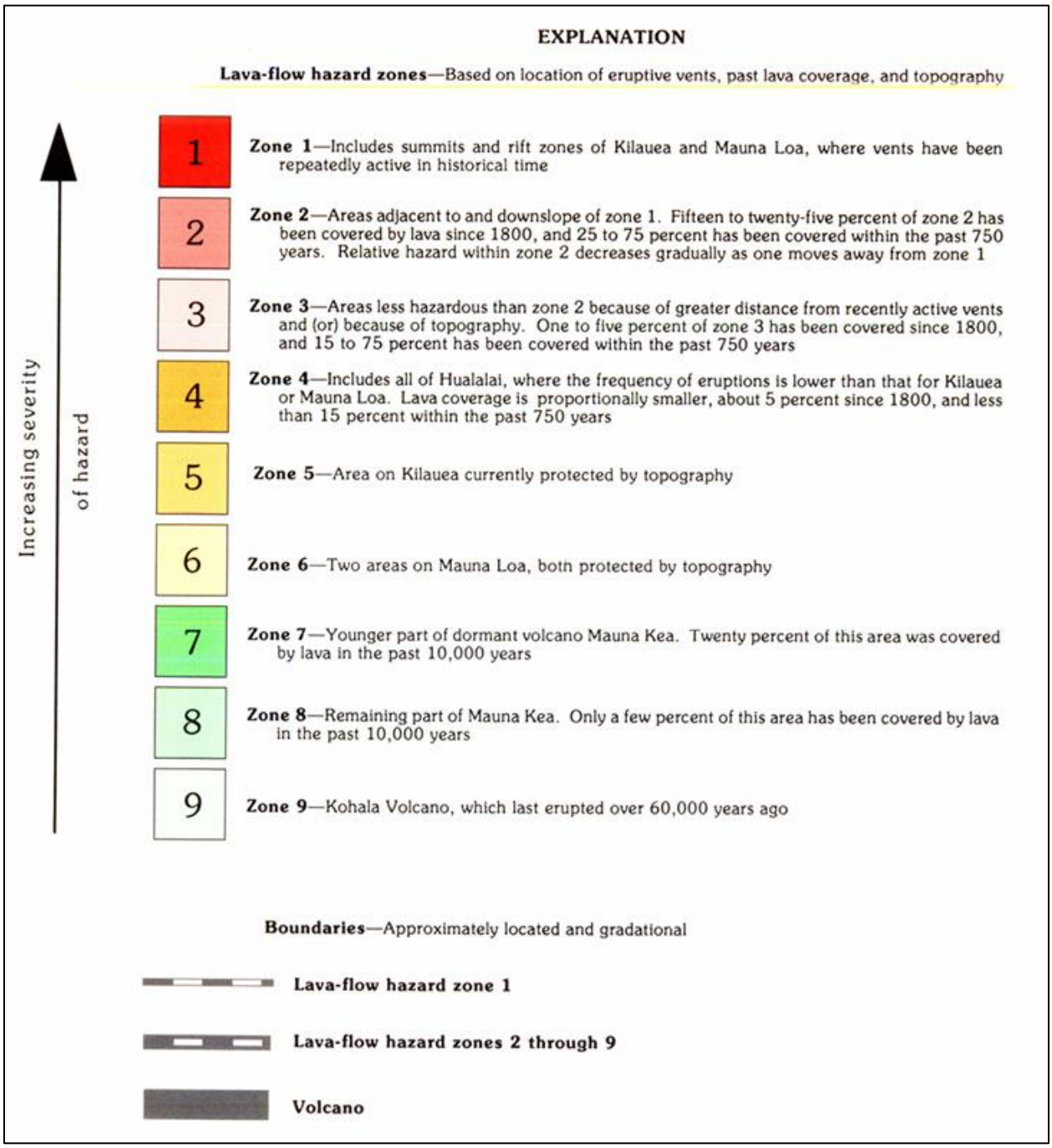
This map shows lava-flow hazard zones for the five volcanoes on the Island of Hawaii. Volcano boundaries are shown as heavy, dark bands, reflecting the overlapping of lava flows from adjacent volcanoes along their common boundary. Hazard-zone boundaries are drawn as double lines because of the geologic uncertainty in their placement. Most boundaries are gradational,

and the change in the degree of hazard can be found over a distance of a mile or more. The general principles used to place hazard-zone boundaries are discussed by Mullineaux and others (1987) and Heliker (1990). The differences between the boundaries presented here and in Heliker (1990) reflect new data used in the compilation of a geologic map for the Island of Hawaii (E.W. Wolfe and Jean Morris, unpub. data, 1989). The primary source of information for volcano boundaries and generalized ages of lava flows for all five volcanoes on the Island of Hawaii is the geologic map of Hawaii (E.W. Wolfe and Jean Morris, unpub. data, 1989). More detailed information is available for the three active volcanoes. For Hualalai, see Moore and others (1987) and Moore and Clague (1991); for Mauna Loa, see Lockwood and Lipman (1987); and for Kilauea, see Holcomb (1987) and Moore and Trusdell (1991).

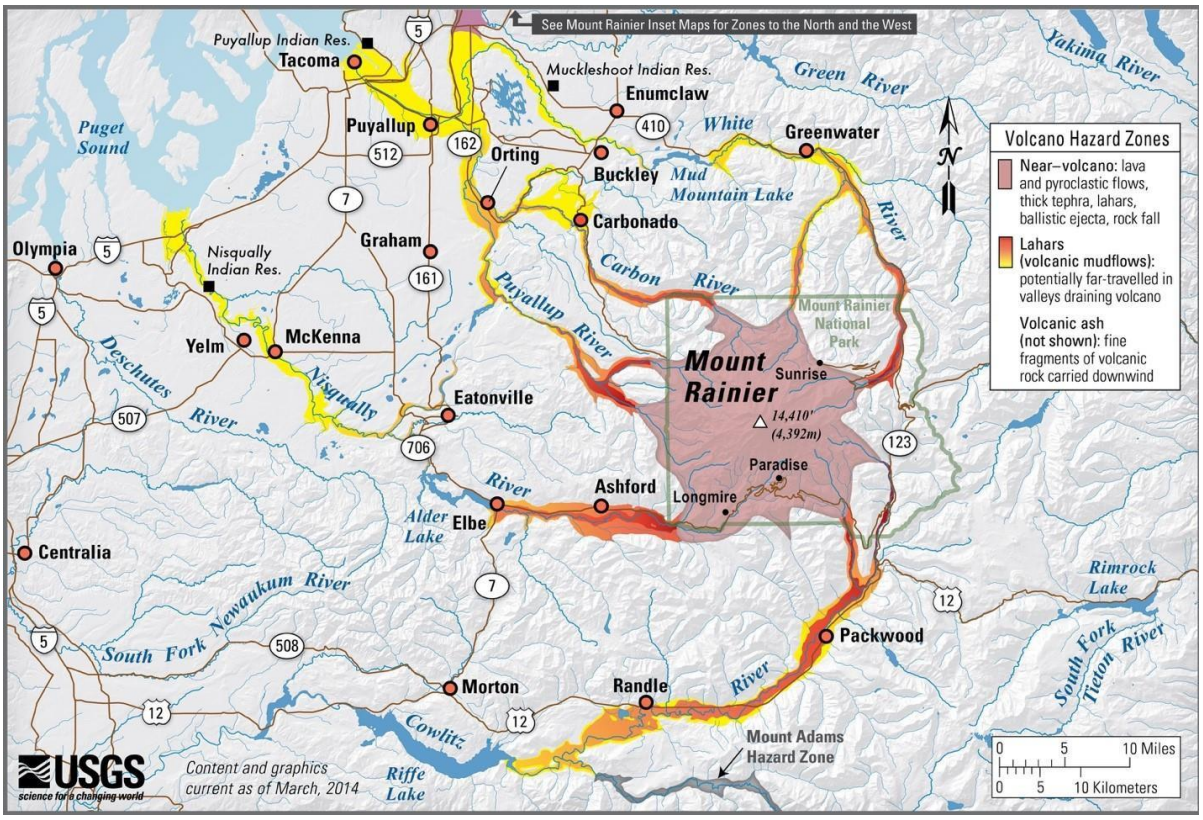
Source: Wright, T.L., Chun, J.Y.F. ,Exposo, Jean, Heliker, Christina, Hodge, Jon, Lockwood, J.P., and Vogt, S.M., 1992, Map showing lava-flow hazard zones, Island of Hawaii: U.S. Geological Survey Miscellaneous Field Studies Map MF-2193, scale 1:250,000.


U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
Hazard-zone boundaries are approximate and gradational. These boundaries are not specific enough to determine the absolute degree of danger at any particular site. Lava-flow hazard maps are designed to show relative hazard across the Island of Hawaii and are meant to be used for general planning purposes only.
INDEX MAP SHOWING THE ISLANDS OF HAWAII
Hawi
Honokaa
Waimea
Hilo
Kailua
Pahoa
Pahala
Naalehu
Kohala
Mauna Loa
Mauna Kea
Hualalai
Kilauea
9
8
7
4
3
2
6
1
5
MAP SHOWING LAVA-FLOW HAZARD ZONES, ISLAND OF HAWAII
By
Thomas L. Wright[1], Jon Y.F. Chun[2], Joan Esposo[2], Christina Heliker[1], Jon Hodge[2], John P. Lockwood[1], and Susan M. Vogt[2]
1992

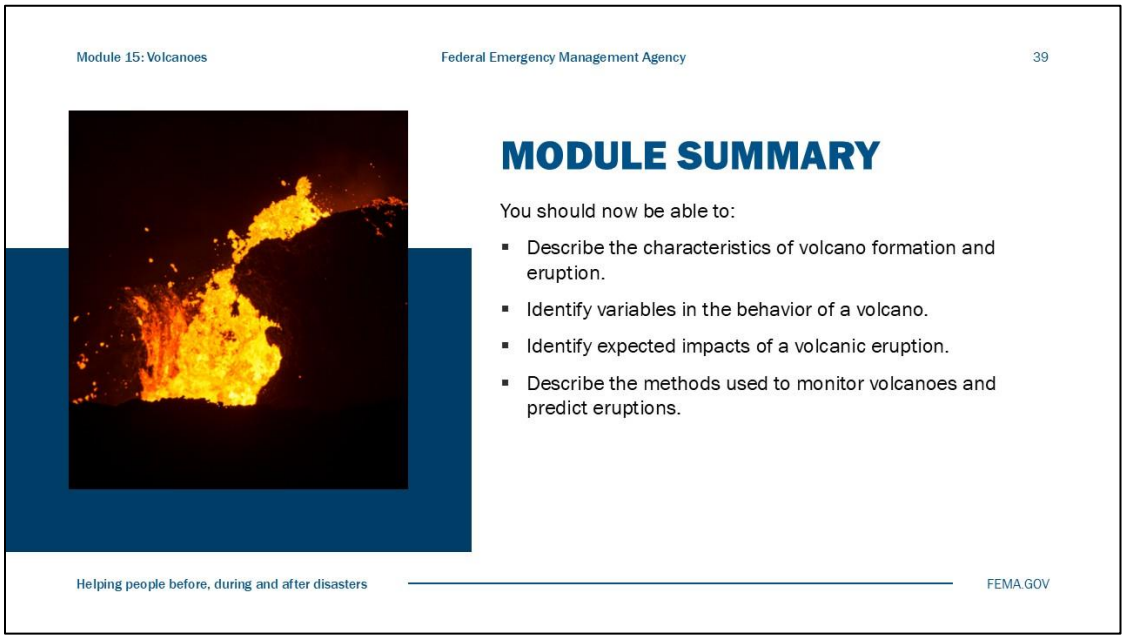
Legend from Lava-Flow Hazard Zones, Island of Hawaii



Mt. Rainier Hazard Map



End of Module (1 of 2)



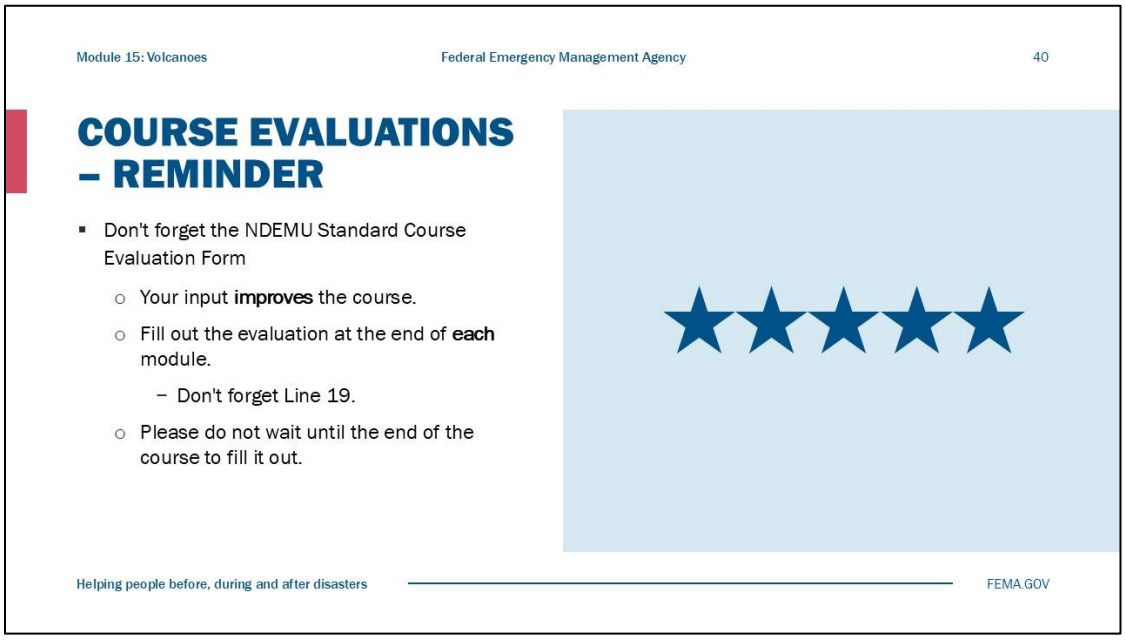
Slide 15-39, Module Summary

MODULE SUMMARY

You should now be able to:

- Describe the characteristics of volcano formation and eruption.
- Identify variables in the behavior of a volcano.
- Identify expected impacts of a volcanic eruption.
- Describe the methods used to monitor volcanoes and predict eruptions.

End of Module (2 of 2)



Slide 15-40, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

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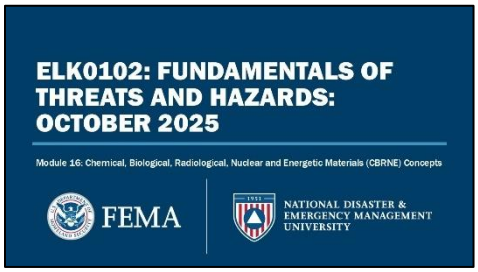
神戸市. (1995). *日本語: ポートアイランドから見た阪神淡路大震災の火災* [Graphic]. 阪神・淡路大震災「1.17の記録」（写真コード:c173、ポートアイランドから望む長田方面の火災（中央区/1995年））. https://commons.wikimedia.org/wiki/File:Fire_of_Great_Hanshin_earthquake_Seen_from_Portisland.jpg

Module

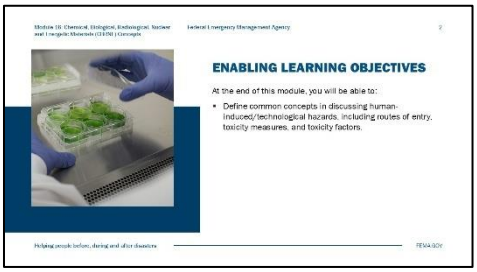
16

Chemical, Biological, Radiological, Nuclear and Energetic Materials (CBRNE) Concepts

Administration



Slide 16-1, Module 16: CBRNE



Slide 16-2, Enabling Learning Objectives

Duration

30 minutes

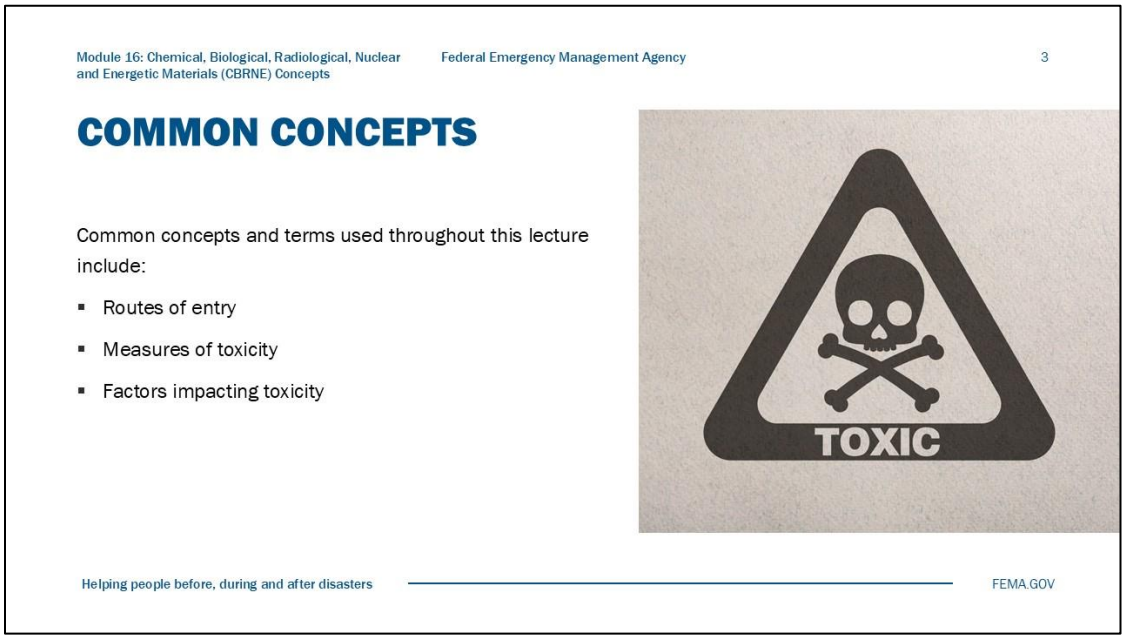
Terminal Learning Objective (TLO)

By the end of this module, participants will be able to define common concepts in discussing human-induced/technological hazards, including routes of entry, toxicity measures, and toxicity factors.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to define common concepts in discussing human-induced/technological hazards, including routes of entry, toxicity measures, and toxicity factors.

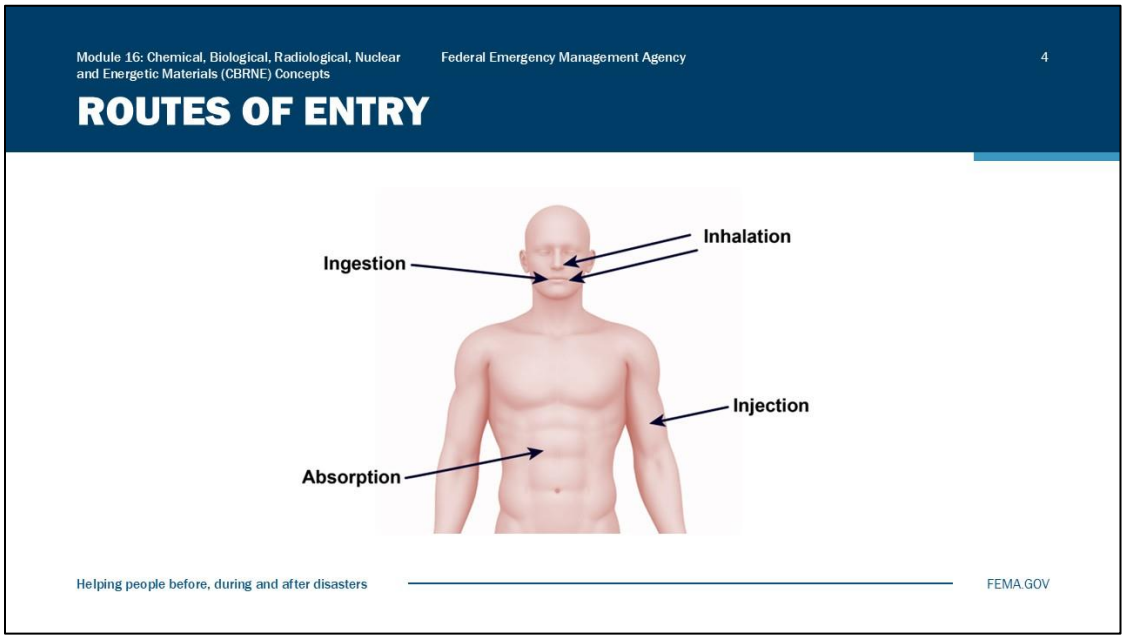
CBRNE (1 of 5)



Slide 16-3Common Concepts

The next section of this module will discuss come common concepts and terms that will be used throughout the remainder of this module.

CBRNE (2 of 5)



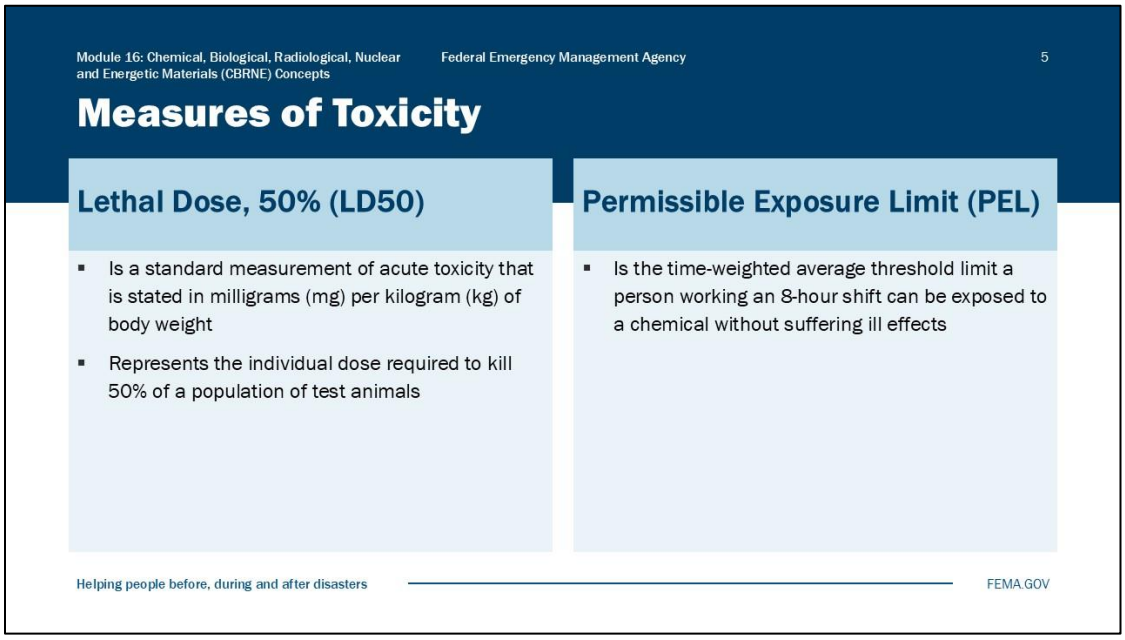
Slide 16-4, Routes of Entry

As we review the chemical classes, we will discuss the various hazards—including health hazards—associated with each. In many cases, the health impacts of exposure to a chemical depend on how an agent gets into the body (the route of entry).

There are several ways a chemical can enter the body:

- **Ingestion:** Some chemicals may enter the body by ingestion of contaminated food or liquid, or the individual may contaminate themselves and then touch food or their mouth.
- **Inhalation:** Chemicals that are in a gas phase, that form vapors, or that are dispersed in aerosol form can enter the body through the respiratory tract and enter the lungs.
- **Injection:** Chemicals may enter the skin through puncture and penetration wounds.
- **Absorption:** Liquid chemicals may enter via skin contact. Chemicals in gas or vapor form, if the concentration is high enough or the exposure long enough, can also penetrate the skin and cause the same effects as skin contact with a liquid agent.

CBRNE (3 of 5)



Slide 16-5, Measures of Toxicity

Toxicity can be measured by its effects on the target (organism, organ, tissue, or cell). Because individuals typically have different levels of response to the same dose of a toxin, a population- level measure of toxicity is often used, which relates the probabilities of an outcome for a given individual in a population. One such measure is the LD50.

LD50 description: An LD50 is a standard measurement of acute toxicity that is stated in milligrams (mg) of product per kilogram (kg) of body weight. An LD50 represents the individual dose required to kill 50 percent of a population of test animals (e.g., rats, fish, mice, cockroaches)—i.e., a lethal dose.

Because LD50 values are standard measurements, it is possible to compare relative toxicities among chemicals. The lower the LD50 dose, the more toxic the substance. (For example, a substance with an LD50 value of 10 mg/kg is 10 times more toxic than a substance with an LD50 of 100 mg/kg).

Toxicity in relation to route of entry: The toxicity of a chemical is related to the route of entry of the chemical into an organism.

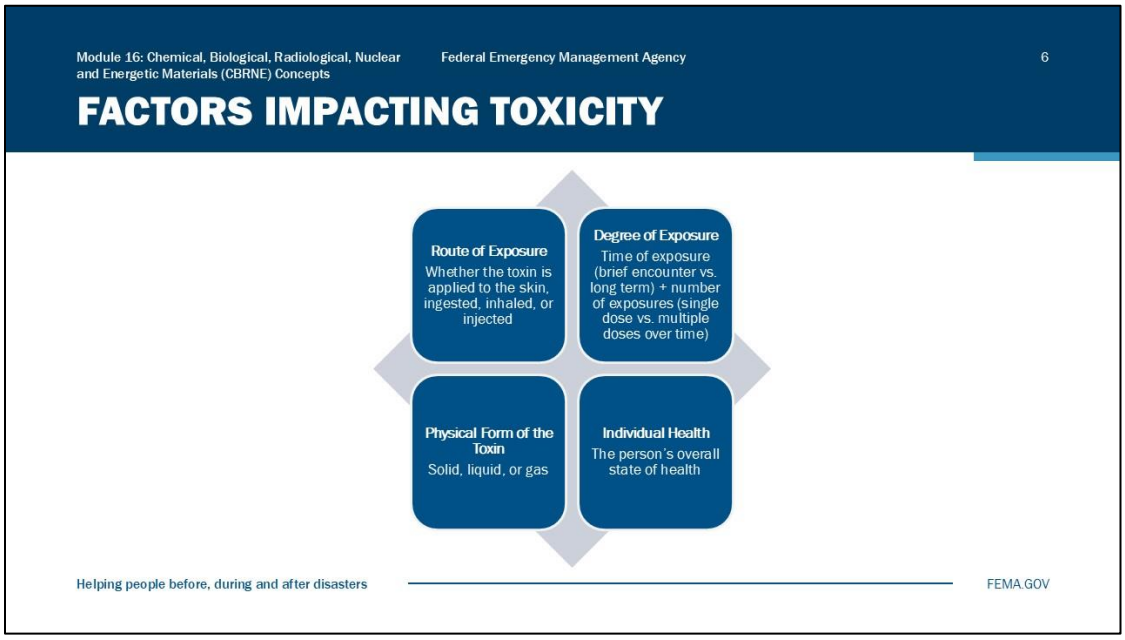
- **Oral toxicity** refers to a liquid with a lethal dose (LD50) for acute oral toxicity of not more than 500 mg/kg, or A solid with an LD50 for acute oral toxicity of not more than 200 mg/kg, which, when administered by mouth, is likely to cause death within 14 days in half of the test animals.

- **Dermal toxicity** refers to a material with an LD50 for acute dermal toxicity of not more than 1,000 mg/kg which, when administered by continuous contact with bare skin, is likely to cause death within 14 days in half of the test animals.
- **Inhalation toxicity** applies to a dust or mist with a lethal concentration (LC50) for acute inhalation toxicity of not more than 10 mg/L.
- **A saturated vapor concentration** in air at 68 °F (20 °C) of more than one-fifth of the LC50 for acute toxicity on inhalation of vapors and with an LC50 for acute inhalation toxicity of vapors of not more than 5,000 ml/m3 which, when administered by continuous inhalation for 1 hour, is likely to cause death within 14 days in half of the test animals.
- **Irritating material** is any liquid or solid substance (such as tear gas) that gives off intense fumes and causes extreme, but reversible, localized irritant effects on the eyes, nose, and throat, temporarily impairing a person's ability to function.

Often the inhalation LD50 is lower (more toxic) than the oral LD50, which is, in turn, lower (more toxic) than the dermal LD50.

Permissible exposure limits: OSHA sets enforceable permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation. OSHA PELs are based on an 8-hour, time-weighted, average (TWA) exposure. TWA is the employee's average airborne exposure in any 8-hour work shift of a 40- hour work week which shall not be exceeded.

Toxicity Factors

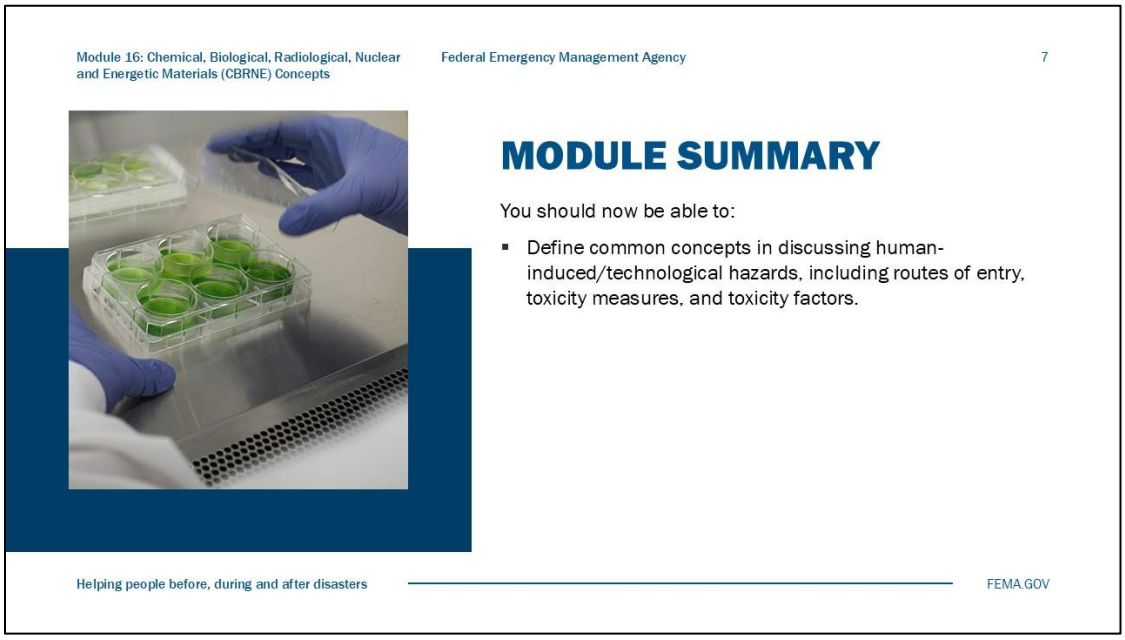


Slide 16-6, Factors Impacting Toxicity

The toxicity of a chemical can be affected by many different factors, such as:

- **Route of exposure:** whether the toxin is applied to the skin, ingested, inhaled, or injected
- **Degree of exposure:** including:
  - **Time of exposure:** a brief encounter vs. long term
  - **Number of exposures:** a single dose vs. multiple doses over time
  - **Concentration:** amount of toxic component in relation to total volume
- **Physical form of the toxin:** solid, liquid, or gas phase.
- **Individual health:** the genetic makeup of an individual, an individual's overall health, and other health factors.
- It is more difficult to determine the toxicity of a chemical mixture than a pure chemical because each component displays its own toxicity, and components may interact to produce enhanced or diminished effects.
- Common mixtures include gasoline, cigarette smoke, and industrial waste; even more complex are situations with more than one type of toxic entity, such as the discharge from a malfunctioning sewage treatment plant, with both chemical and biological agents.

End of Module (1 of 2)

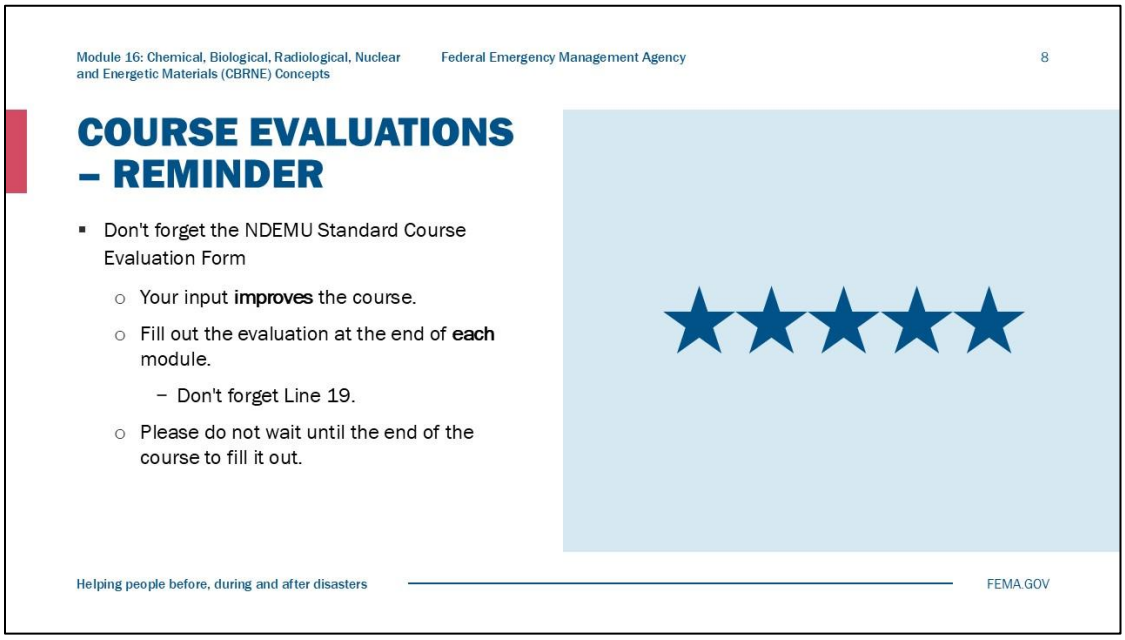


Slide 16-7, Module Summary

You should now be able to:

- Define what is meant by biology.
- Identify the importance of cells.
- Differentiate between pathogens and toxins.
- Identify the characteristics and significance of bacteria, viruses, and fungi.

End of Module (2 of 2)



Slide 16-8, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

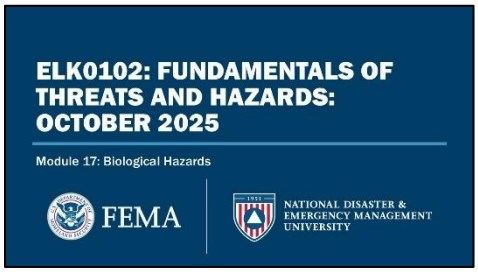
Reference List

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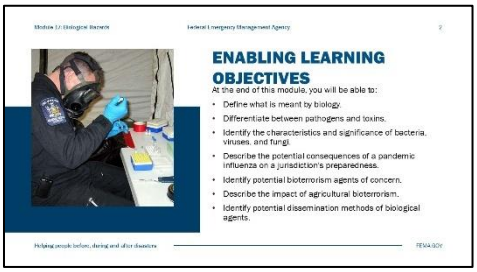
Module 17

Biological Hazards

Administration



Slide 17-1, Module 17: Biological Hazards



Slide 17-2, Enabling Learning Objectives

Duration

1 hour, 50 minutes

Terminal Learning Objective (TLO)

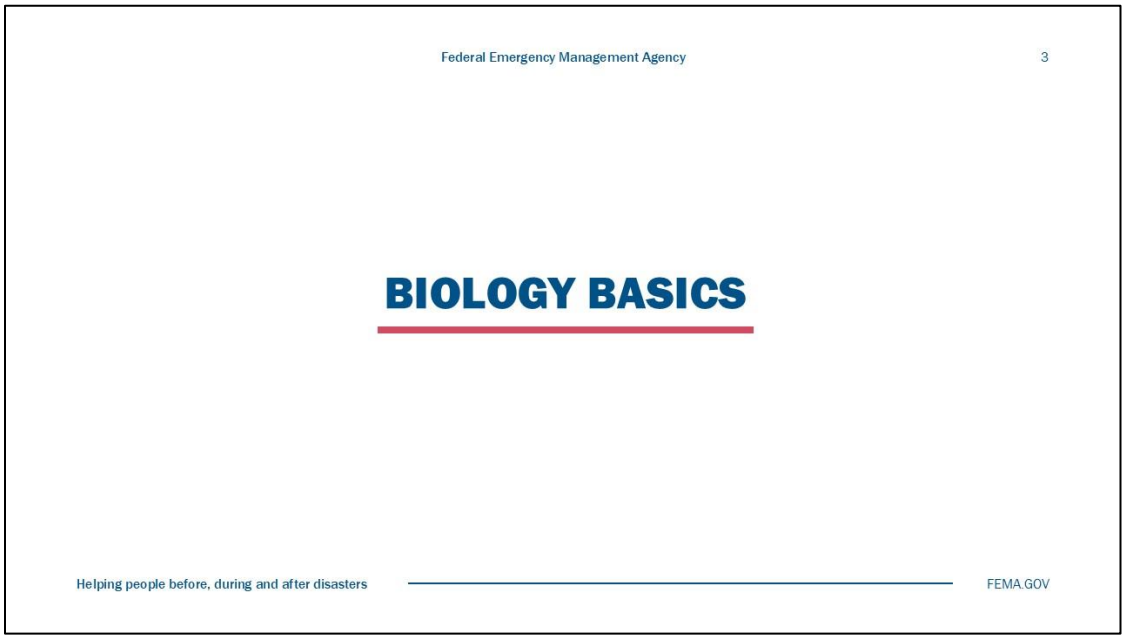
By the end of this module, participants will be able to identify and explain biological hazards.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Define what is meant by biology.
- Differentiate between pathogens and toxins.
- Identify the characteristics and significance of bacteria, viruses, and fungi.
- Describe the potential consequences of a pandemic influenza on a jurisdiction's preparedness.
- Identify potential bioterrorism agents of concern.
- Describe the impact of agricultural bioterrorism.
- Identify potential dissemination methods of biological agents.

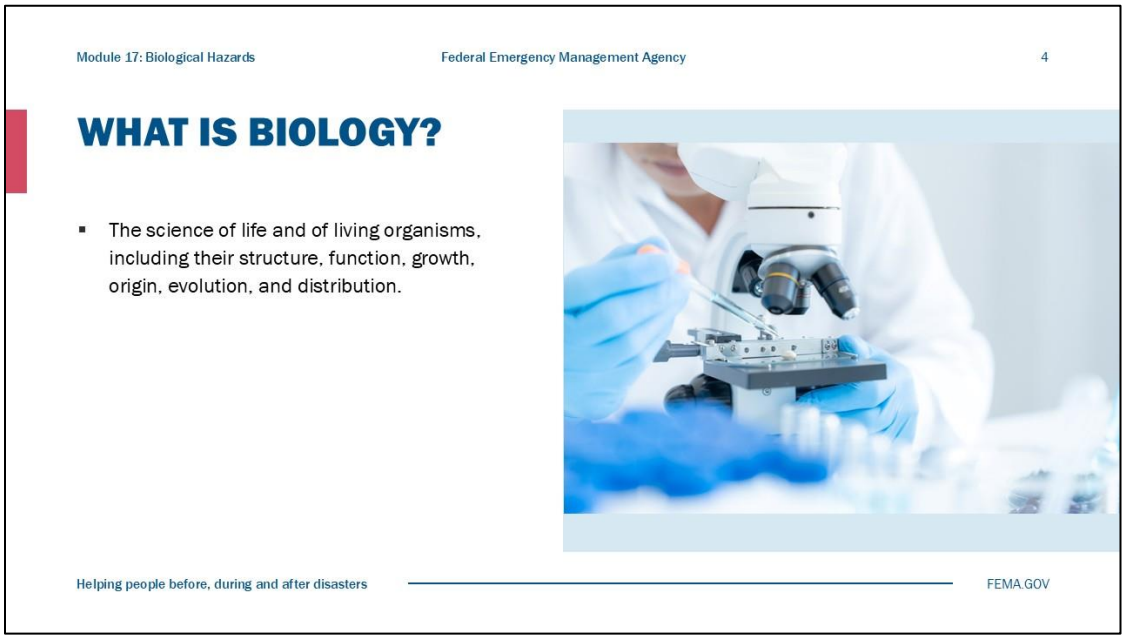
Biology Basics (1 of 5)



Slide 17-3, Biology Basics

Not Applicable.

Biology Basics (2 of 5)



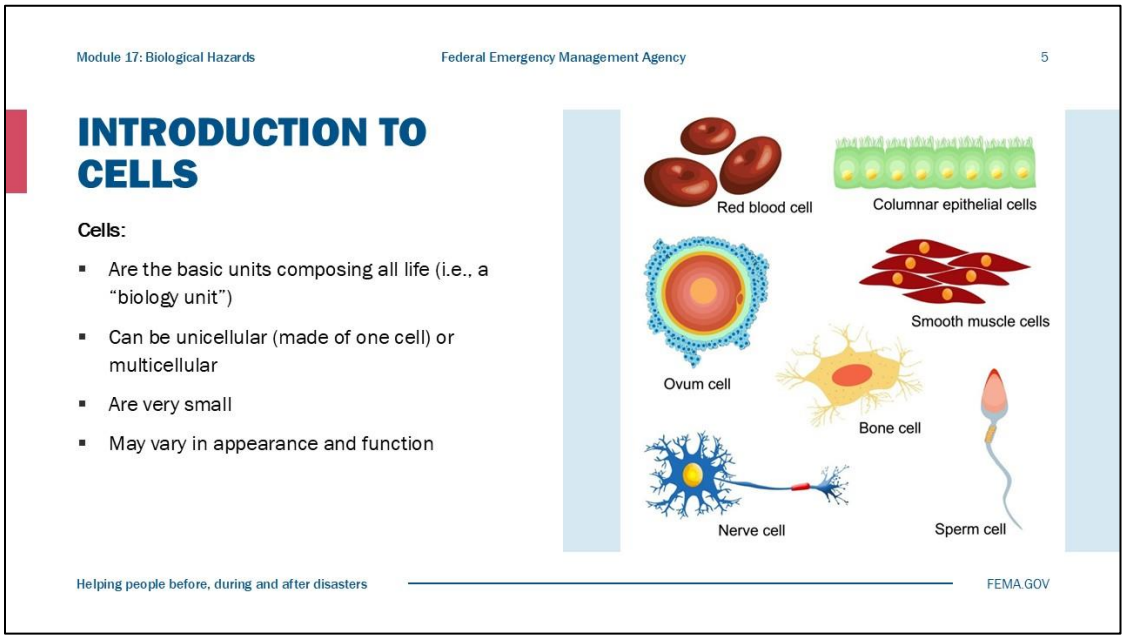
Slide 17-4, What Is Biology?

Biology is defined as "the science of life and of living organisms, including their structure, function, growth, origin, evolution, and distribution."

There are numerous subdisciplines of biology. For example:

- Cellular biology examines the basic building block of all cells.
- Biochemistry examines the rudimentary chemistry of life.
- Molecular biology studies the complex interactions of systems of biological molecules.

Biology Basics (3 of 5)



Slide 17-5, Introduction to Cells

Discussion: Characteristics of Cells

What are some key characteristics of cells?

Cellular Organisms:

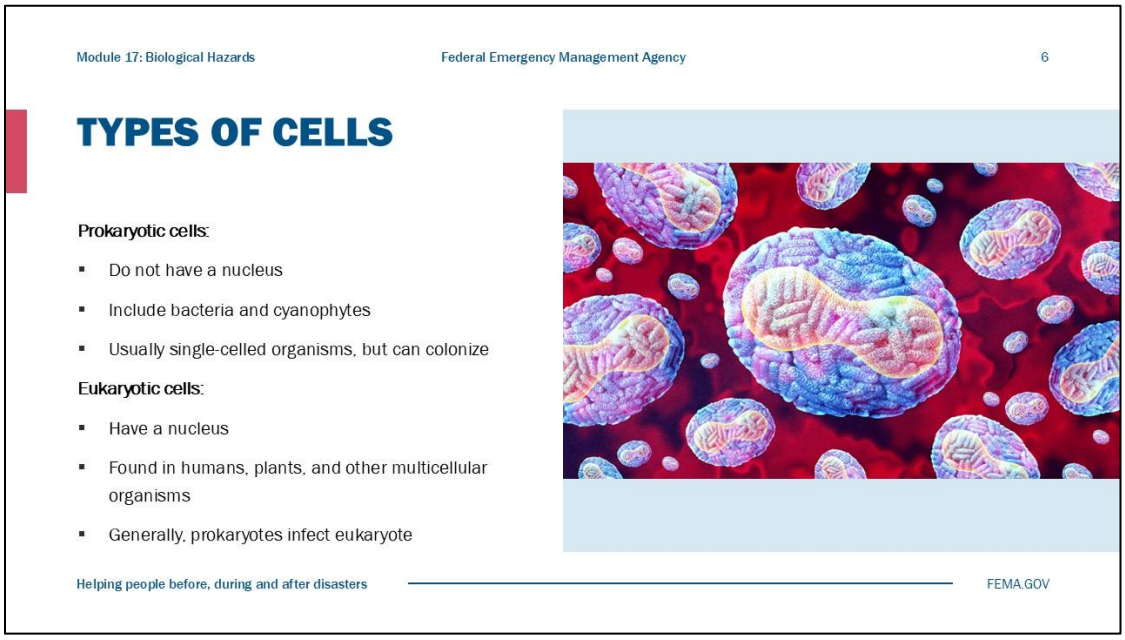
- Are the basic units composing all life (i.e., a "biology module"), such as:
  - Bacteria;
  - Fungi;
  - Plants; and
  - Animals (including humans).

Viruses and prions are not cellular organisms:

- Can be unicellular (made of one cell) or multicellular (billions of cells organized at different levels);
- Are very small and the size range is approximately from 1 to 100 micrometers (1 millionth of a meter) – a human hair is approximately 50 times wider than a cell; and

- May vary in appearance and function, and many conduct specialized functions (e.g., reproductive (sperm and ova); red and white blood cells; epithelial (skin), connective, muscle, and nervous tissue).

Biology Basics (4 of 5)



Slide 17-6, Types of Cells

Prokaryotic cells:

- Do not have a nucleus
- Include bacteria and cyanophytes
- Usually single-celled organisms, but can colonize

Eukaryotic cells:

- Have a nucleus
- Found in humans, plants, and other multicellular organisms
- Generally, prokaryotic cells infect eukaryotic cells

It is useful to distinguish between cell types to understand biological hazards and threats. There are two types of cells: prokaryotes and eukaryotes. The following table highlights their differences.

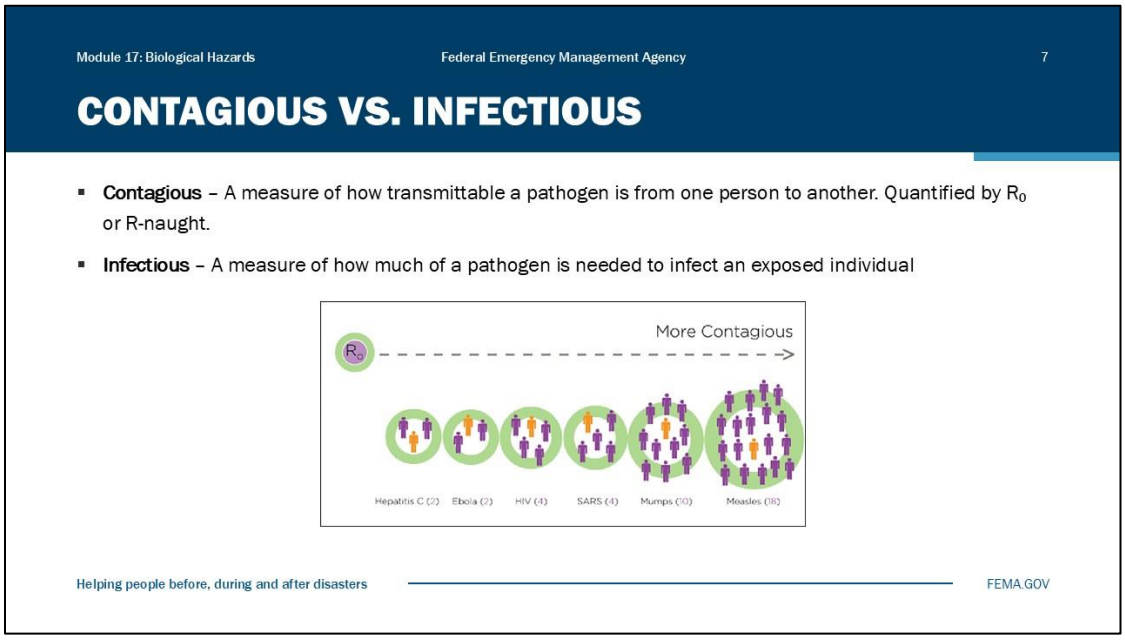
Prokaryotic Cells	Eukaryotic Cells
Are cells without a nucleus	Are cells with a nucleus
Have genetic material but are not enclosed in a membrane.	Have both a cellular membrane and a nuclear membrane
Include bacteria and cyanophytes	Are found in humans, plants, and other multicellular organisms
Genetic material is a single DNA strand contained in the cytoplasm, because there is no nucleus. This DNA works in just the same way as it does in other organisms but is not gathered together into chromosomes visible through a microscope.	Genetic material forms multiple chromosomes.

Additional Information

You can learn more about cells in the science education booklet Inside the Cell, which explores the interior design of cells and vividly describes the processes that take place within.

Inside the Cell is available online (This link can also be accessed at the following URL: https://www.wiredhealthresources.net/presentations/701-2/story_content/external_files/Booklet-Inside-the-Cell.pdf) and is published by the U.S. Department of Health and Human Services, NIH Publication No. 07-2778, National Institutes of Health.

Biology Basics (5 of 5)



Slide 17-7 Contagious vs. Infectious

It is important to understand the distinction between the two.

- **Infectious** refers to how many bacteria, virions, or other pathogen particles are needed to infect an exposed individual.
- **Contagious** means the bacteria or virus can be transmitted from person to person (a communicable disease), and is quantified by R-naught.

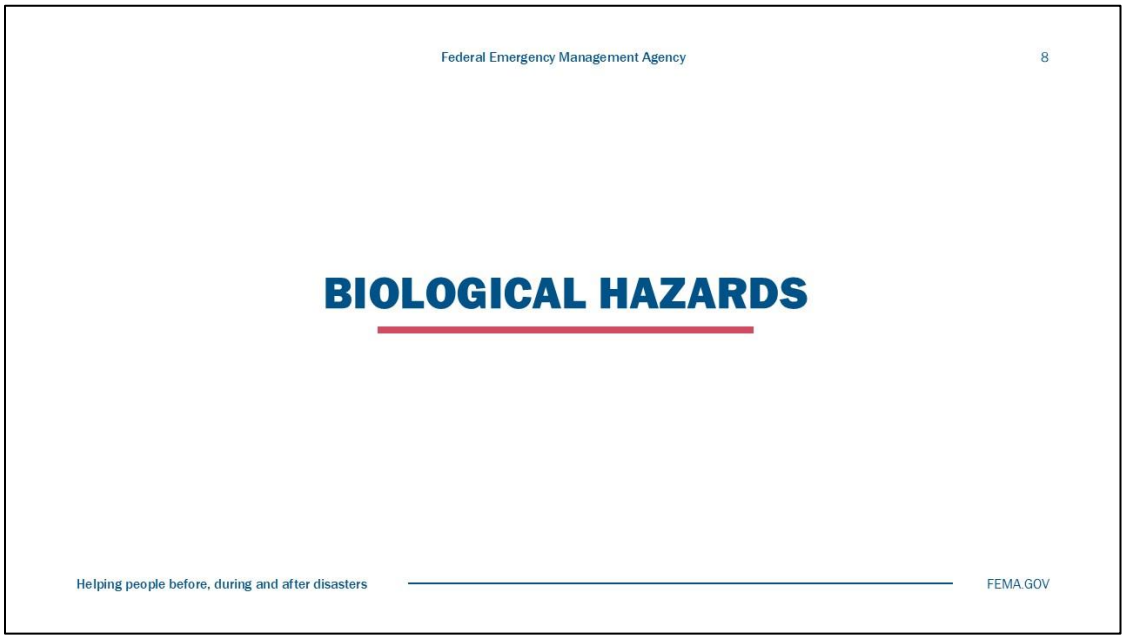
The basic reproduction number, R_0, represents, on average, how many other people a single infected person can be expected to infect. It is simply a calculation of the average "spreadability" of an infectious disease. For example, an R_0 of 3.0 means that one person can infect 3 others on average. Those 3 new people can infect 3 more each, and the disease can spread rapidly, especially with higher R_0 numbers.

Determining the R_0 for a disease can provide valuable insight into the potential spread of the disease, and scientists use models to estimate the likelihood of spread, drawing from different sources of information and past outbreaks. How quickly a new pathogen can spread among the population is an essential piece of information scientists use to make recommendations to officials on how best to mitigate the spread of the disease. Local, state, territorial, tribal, and federal governments, in concert with public health authorities, can factor this into their decision-making to best control the spread.

The three main factors used to calculate R_0 are the infectious period of the disease, the mode of transmission, and the contact rate. The R_0 can change over time as more information and data are gathered, and as the new disease becomes better understood. Also, as protective measures such as hand hygiene, wearing a mask, and social distancing are implemented, the spread of the disease is typically reduced (thus reducing the R_0) since the mode of disease transmission has been interrupted. R_0 has been successfully calculated for diseases in the past, such as SARS, MERS, Ebola, AIDS, seasonal flu, and the 2009 H1N1 flu pandemic.

For more information, check out this Harvard Global Health article - Understanding Predictions: What is R-Naught? (https://globalhealth.harvard.edu/understanding-predictions-what-is-r-naught/#:~:text=R%2Dnaught%20(R0),to%20transmit%20that%20disease%20to.)

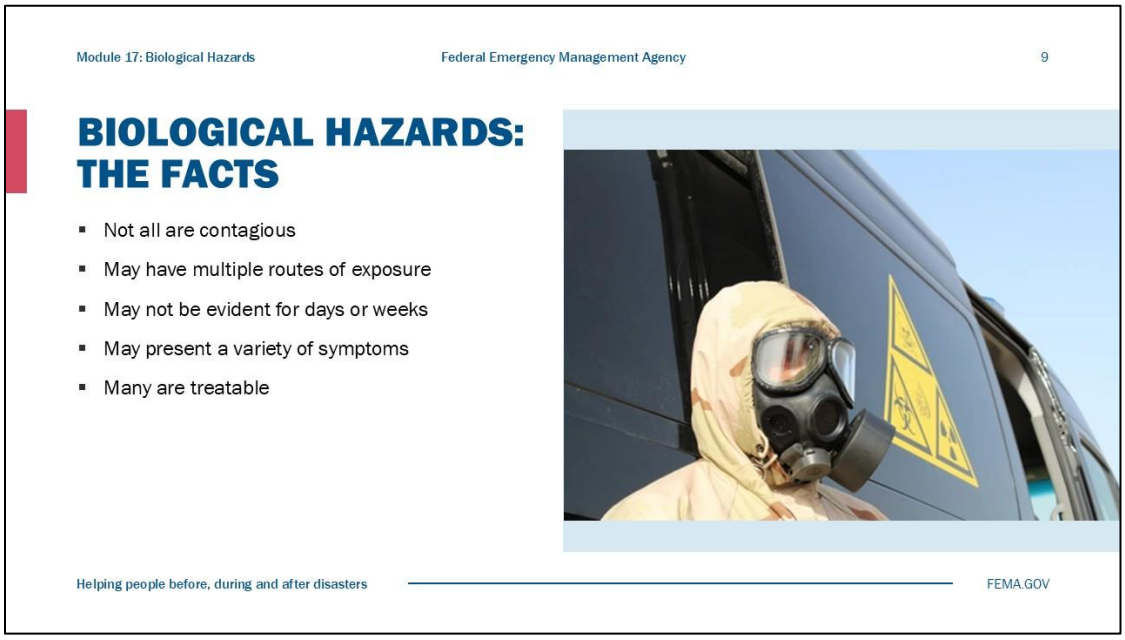
Biological Hazards (1 of 22)



Slide 17-8, Biological Hazards

Not Applicable.

Biological Hazards (2 of 22)



Slide 17-9, Biological Hazards: The Facts

The basic cell concepts just discussed provide a basis for understanding biological hazards and threats that can attack the cells.

What do we know about biological hazards? There are various types of biological hazards, and they vary widely from one to the next in their characteristics. However, there are a few general facts that are important to keep in mind:

- Contagion: Not all hazards are contagious. Some are, but others cannot be transmitted from one person to another.
- Exposure: Biological hazards may have multiple routes of exposure. The routes of entry for pathogens and toxins are the same as chemicals—ingestion, eyes, inhalation, and absorption. Common means for spreading pathogens and toxins include:
  - Airborne: Coughing and/or sneezing;
  - Contact: Touching another person or object;
  - Ingestion: Eating food touched by someone with dirty hands;
  - Bloodborne: Coming in contact with body fluids, such as blood, saliva, etc.
- Incubation: A hazard may not be evident for days or weeks.

- Symptoms: Different hazards may present a variety of symptoms.
- Treatment: Many hazards are treatable.

Isolation vs. Quarantine

- Isolation - separates sick people with a contagious disease from people who are not sick.
- Quarantine - separates and restricts the movement of people who were exposed to a contagious disease to see if they become sick.

"Twenty U.S. Quarantine Stations, located at ports of entry and land border crossings, use these public health practices as part of a comprehensive Quarantine System that serves to limit the introduction of infectious diseases into the United States and to prevent their spread." – CDC

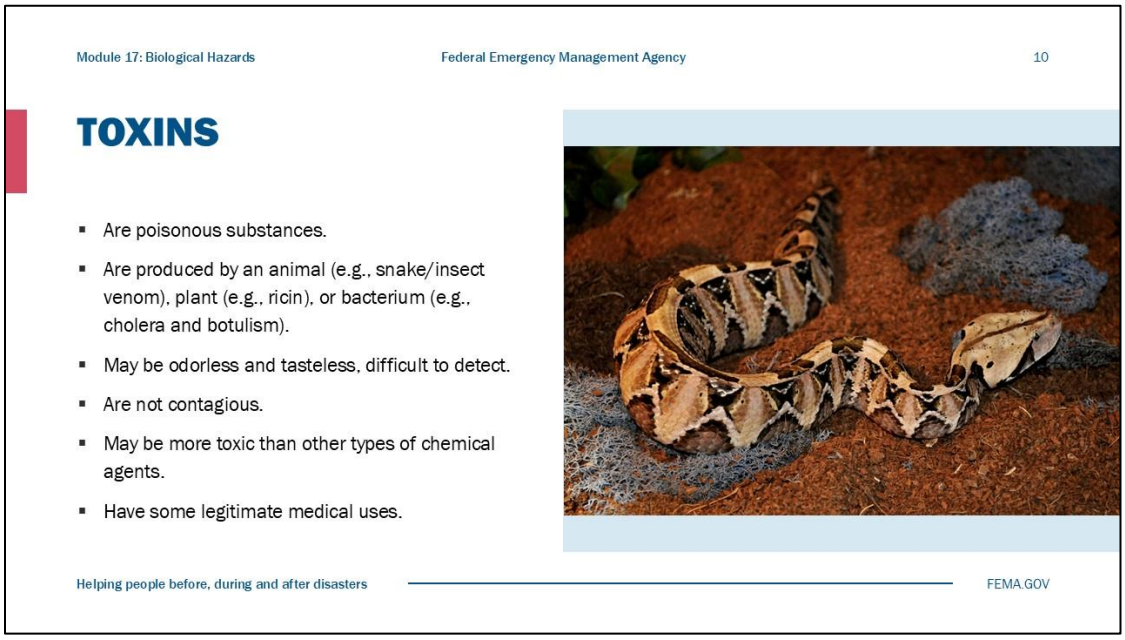
The media also often confuses the terms isolation and quarantine. Especially given recent events regarding Ebola, as well as challenges to the powers of public health officials, it is important to understand what each term means.

"Under section 361 of the Public Health Service Act (42 U.S. Code § 264), the U.S. Secretary of Health and Human Services is authorized to take measures to prevent the entry and spread of communicable diseases from foreign countries into the United States and between states."

"States have police power functions to protect the health, safety, and welfare of persons within their borders. To control the spread of disease within their borders, states have laws to enforce the use of isolation and quarantine. These laws can vary from state to state and can be specific or broad. In some states, local health authorities implement state law. In most states, breaking a quarantine order is a criminal misdemeanor. Tribes also have police power authority to take actions that promote the health, safety, and welfare of their own tribal members. Tribal health authorities may enforce their own isolation and quarantine laws within tribal lands, if such laws exist."

Source: Centers for Disease Control and Prevention (This link can also be accessed at the following URL: https://www.cdc.gov/quarantine/)

Biological Hazards (3 of 22)



Slide 17-10, Toxins

Description: Toxins are substances produced within living organisms that are poisonous to humans. (Notice that their origin differentiates toxins from chemical or manmade "toxics" or "toxicants.")

Production: Toxins are produced by:

- Animals—e.g., snake or insect venom
- Plants—e.g., ricin from castor beans
- Bacteria—e.g., cholera and botulism

Bacteria release most of the toxins that are harmful to humans. In fact, the bacterial toxin Clostridium botulinum is the most poisonous substance known to scientists. It causes severe food poisoning (botulism) that can lead to death by suffocation in just a few days. We will examine botulism in greater detail later in this module.

Marine organisms produce many toxins. One example is saxitoxin, which is synthesized by a type of blue-green algae (cyanobacteria). These algae provide food for different shellfish, including mussels. The poison does not affect the mussels themselves, but human beings who later eat them may become seriously ill.

Characteristics: Toxins:

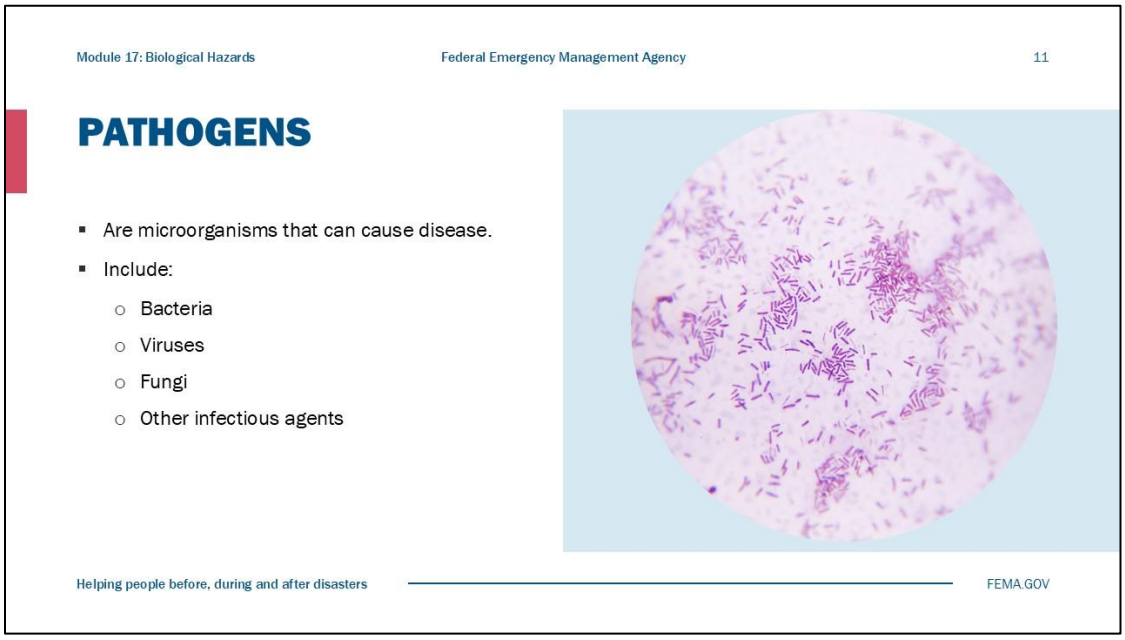
- May be odorless and tasteless, and therefore difficult to detect.

- Are made unstable by heat or other environmental factors.
- Are not contagious like viruses.
- May be more toxic than other types of chemical agents.

Legitimate uses: Although toxins are extremely dangerous (and often fatal), many toxins have legitimate medical uses in smaller doses.

For example, botulinum toxin is used to treat muscular disorders, and forms of ricin (the plant-generated toxin) are studied to treat leukemia and liver cancer.

Biological Hazards (4 of 22)



Slide 17-11, Pathogens

Pathogens are microorganisms that can cause disease in a host (another living thing). There are human pathogens and animal pathogens. Pathogens include:

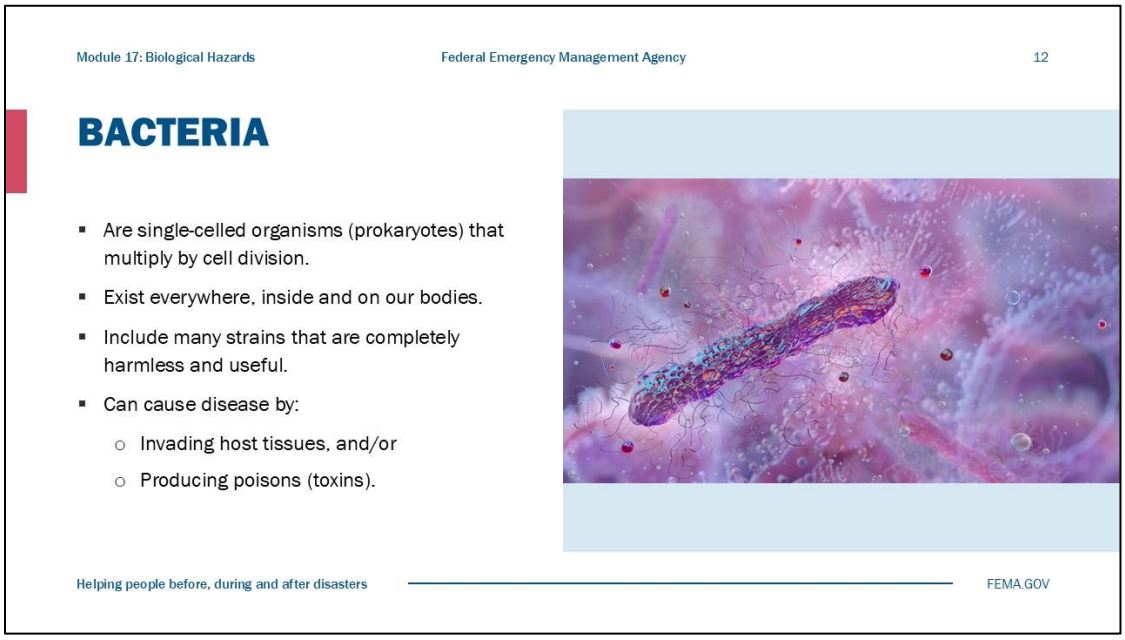
- Bacteria
- Viruses
- Fungi
- Other infectious agents, such as parasites and prions.

A parasite is an organism that lives in or on another organism without benefiting the host organism.

The CDC describes prions as "abnormal, pathogenic agents that are transmissible and can induce abnormal folding of specific normal cellular proteins called prion proteins that are found most abundantly in the brain."

In this section, you will take a closer look at bacteria, viruses, and fungi.

Biological Hazards (5 of 22)



Slide 17-12, Bacteria

Description: Bacteria:

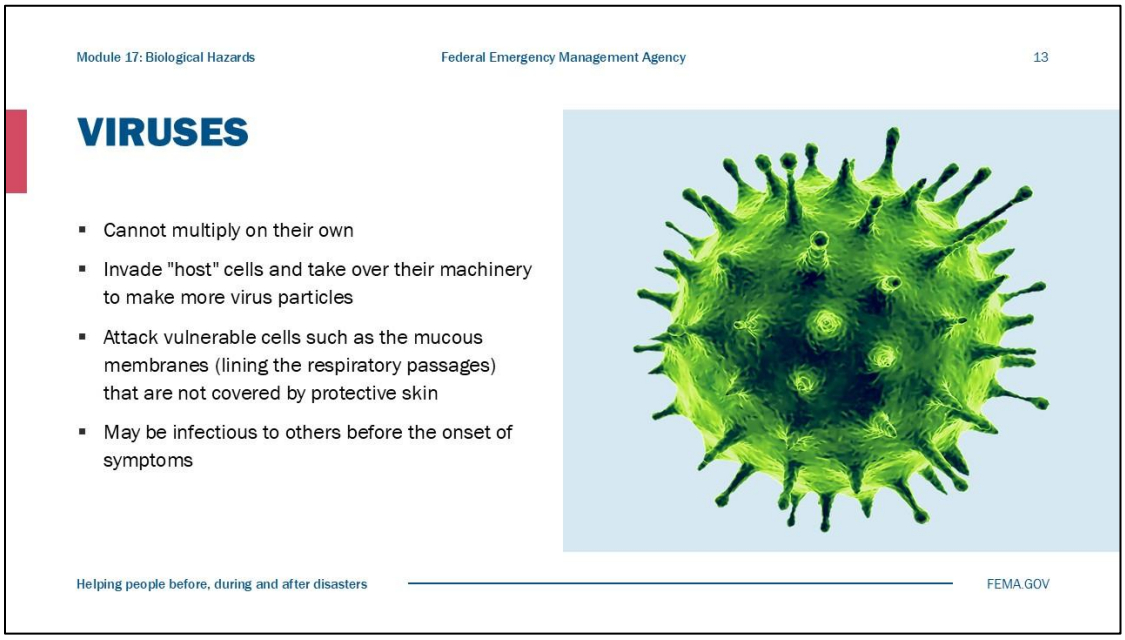
- Are one-celled organisms that multiply by cell division;
- Are visible only with a microscope; Bacteria are so small that if you lined up a thousand of them end to end, they could fit across the end of a pencil eraser;
- Are shaped like short rods, spheres, or spirals; and
- Exist everywhere, including inside and on our bodies.

Useful bacteria: Not all bacteria are harmful. In fact, less than 1 percent cause disease, and some bacteria that live in your body are useful. For instance, Lactobacillus acidophilus – a harmless bacterium that resides in the intestines– helps digest food, destroys some disease-causing organisms, and provides nutrients to your body.

Disease: Some bacteria cause disease, either by invading host tissues (infection) or by producing toxin-powerful chemicals that damage cells and make you ill. Bacteria cause diseases such as:

- Strep throat
- Tuberculosis
- Urinary tract infections

Biological Hazards (6 of 22)



Slide 17-13, Viruses

Viruses are another type of pathogen.

Description: Viruses are basically just capsules—a protein coat and a core of genetic material, either RNA or DNA. They are much smaller than cells and may be shaped like rods, spheres, or tiny tadpoles.

Survival and reproduction: Unlike bacteria, viruses can't survive without a host. They can only reproduce by attaching themselves to cells and hijacking the cells' cellular machinery. In most cases, they reprogram the cells to make new viruses until the cells burst and die. In other cases, they turn normal cells into malignant or cancerous cells.

Disease: Unlike bacteria, most viruses do cause disease, and they are quite specific about the cells they attack. For example, certain viruses are programmed to attack cells in the liver, respiratory system, or blood. In some cases, viruses called bacteriophages target bacteria. Viruses are responsible for causing a wide range of diseases, including:

- AIDS
- Common cold
- Ebola hemorrhagic fever
- Herpes (including chickenpox and later shingles)

- Influenza
- Measles
- Smallpox

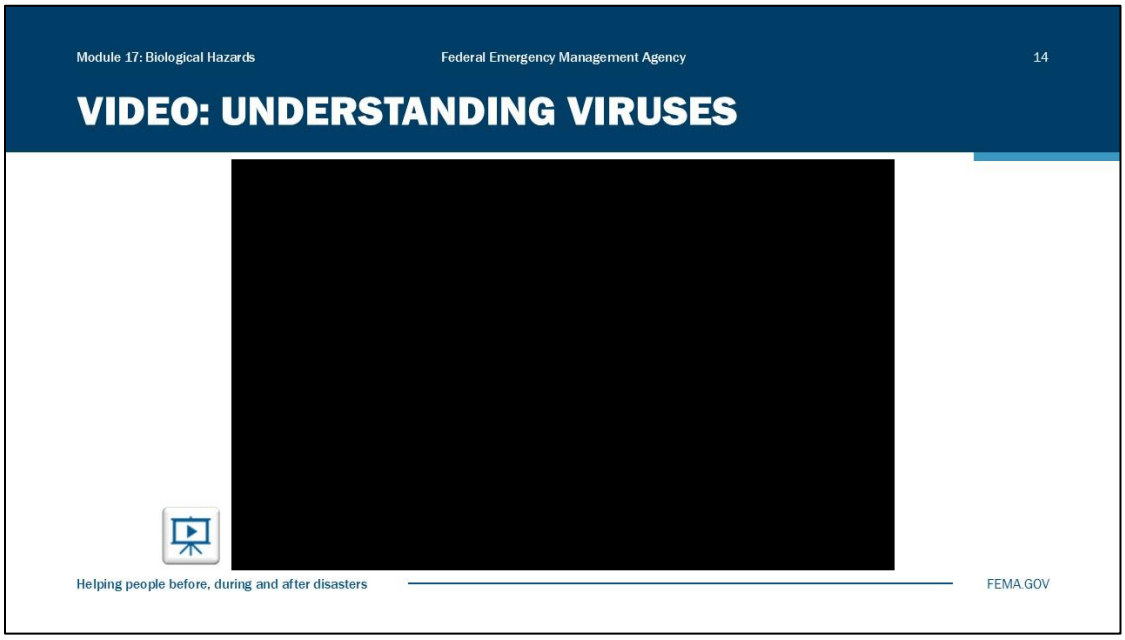
Incubation and transmission: Viruses may be transmitted infectiously before any symptoms appear, as is the case with chickenpox; this is because they have an incubation period (the time between infection and symptoms) after access into your body, during which the virus multiplies "silently."

The following are examples of the incubation periods for some common viral infections:

Infection	Incubation Period
Chickenpox	10 to 21 days
Diphtheria	2 to 5 days
Influenza	Up to 7 days, most likely to be 2 to 3 days
Measles	About 10 days, with a further 2 to 4 days before the rash appears
Mumps	Around 17 days, with a range of 12 to 25 days
Rubella (German measles)	14 to 21 days, and the time you can infect someone else is from 1 week until 4 days before the rash appears
Slapped cheek syndrome (also known as parvovirus B19 or fifth disease)	Usually 13 to 18 days, but can be as long as 20 days
Tetanus	Between 4 and 21 days, most commonly about 10 days
Whooping cough (pertussis)	Between 7 and 10 days

Treatment: Antibiotics have no effect on viruses.

Biological Hazards (7 of 22)



Slide 17-14, Video: Understanding Viruses

(Video used with permission of Zirus, Inc., the Anti-Virus Company, and XVIVO Scientific Animation. Originally broadcast on NPR.org on October 2009. Used with the permission of NPR.)

Introduction: This video examines how viruses infect cells and replicate themselves.

Video Transcript:

(Man sneezing)

Robert Krulwich (RK): So, let's say that this guy has the flu, could be any flu, and here's a droplet from his sneeze containing—if we move in and take a really close look, you see each one of those little purple things is a virus, and there are a lot of viruses floating through the air, some of which go inevitably up this unfortunate man's nose.

RK: How did that guy feel when you ripped off half of his face?

David Bolinsky (DB): It was interesting because we did it while he was sleeping. (Laughing)

RK: Okay, I am talking with medical illustrator David Bolinsky who designed this video for Zirus, a research company. So here comes the virus, and it's going to land on one of this guy's throat cells. So notice it's covered with little yellow knobby things—you call these keys, right?

DB: Those are the keys this is a key, this is a key, this is a key.

RK: Okay, if the keys on this virus happen to fit the locks, which are those little purple-y stick- up-y things on the surface of the cell. If there is a match, the cell-watch this-welcomes the virus in and what's this?

DB: This is the welcoming committee. They all interlock with each other and they pull this membrane down into the cell.

RK: And down it goes, deeper and deeper, and that welcoming structure disperses and the virus capsule bursts and out comes the secret recipe for how to make more viruses, those little noodle- y things. So this unsuspecting cell has been tricked into guiding these virus recipes right into its own command center, the nucleus. So in they go.

DB: And they are immediately recognized by this big pink molecule, which is a mini-factory.

RK: Yeah, what is it doing?

DB: It threads the nuclear material; the instruction code of the virus, through one hole-and out another hole comes a brand new instruction set.

RK: So it's a copying machine, making copy after copy after copy of virus recipes which then go out of the nucleus to the little chefs—those blue peanut-y things. They cook up proteins that go back into the nucleus where they are reassembled into baby viruses and then out they go. They get covered up and head to the surface, where they get new keys and then boom, here they come. This is an eruption of virus after virus after virus after only one virus entered the cell, but how many came out? Well, millions, millions. So if one virus can produce a million babies and do it again and again and again how come this guy doesn't just drop dead, I don't know, in like 10 minutes?

DB: Well, because you have about a hundred trillion cells.

RK: I see, so a million viruses is just a drop in the bucket when you have a hundred trillion cells. And anyway, remember you do have your own immune system, which when it sees a virus usually kills it. So, while the virus does multiply fast, with any luck your immune system will work just a little faster. So, yes, viruses, all viruses want to spread, that's what they do. But most of the time we do keep them in check most of the time.

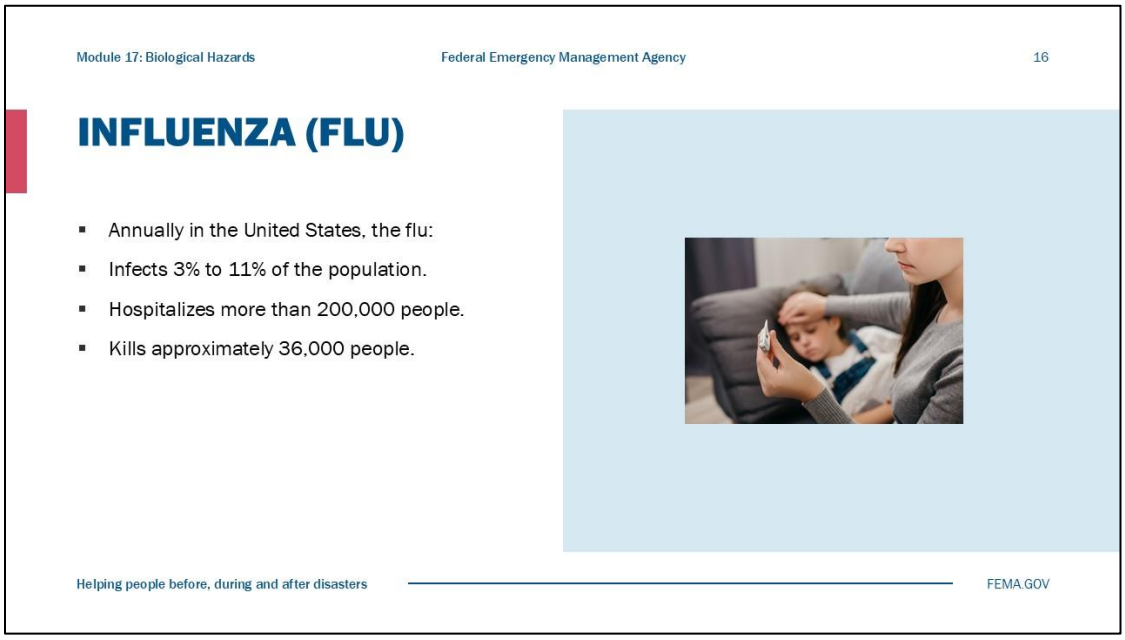
Biological Hazards (8 of 22)



Slide 17-15, Video: Immunology

Watch this video on the immune system and vaccines.

Biological Hazards (9 of 22)



Slide 17-16, Influenza (Flu)

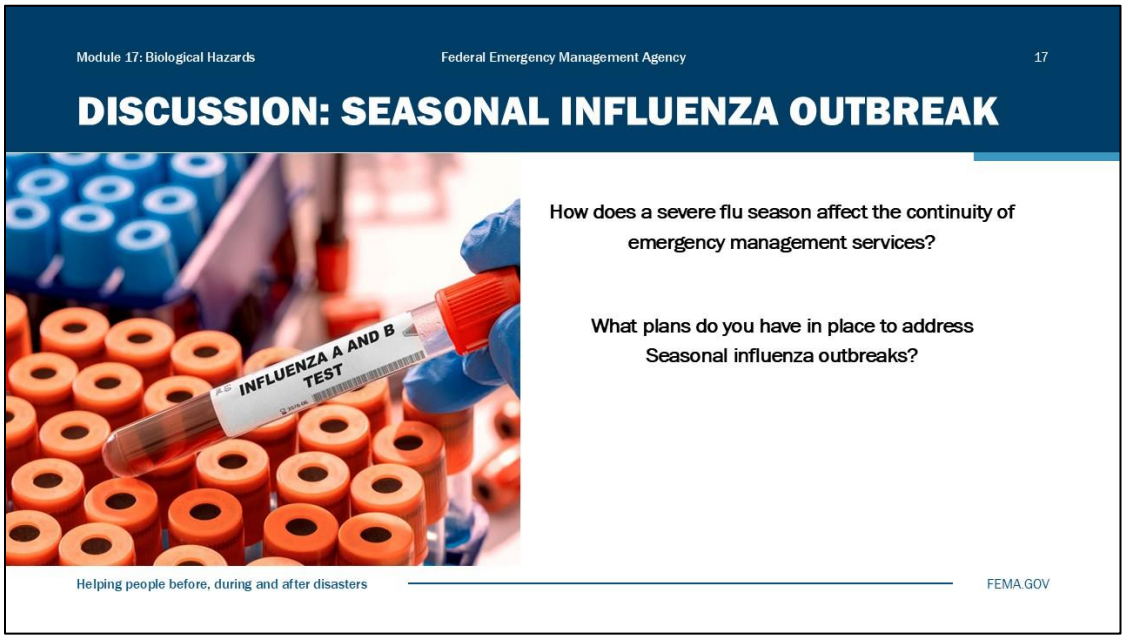
Influenza, or flu, is an example of a virus most of us are familiar with. Every year in the United States, the flu:

- Infects 3 percent to 11 percent of the population
- Hospitalizes more than 200,000 people with flu-related complications
- Kills approximately 36,000 people

People with a high risk for serious complications as a result of the flu include:

- The elderly
- Young children
- People with certain health conditions

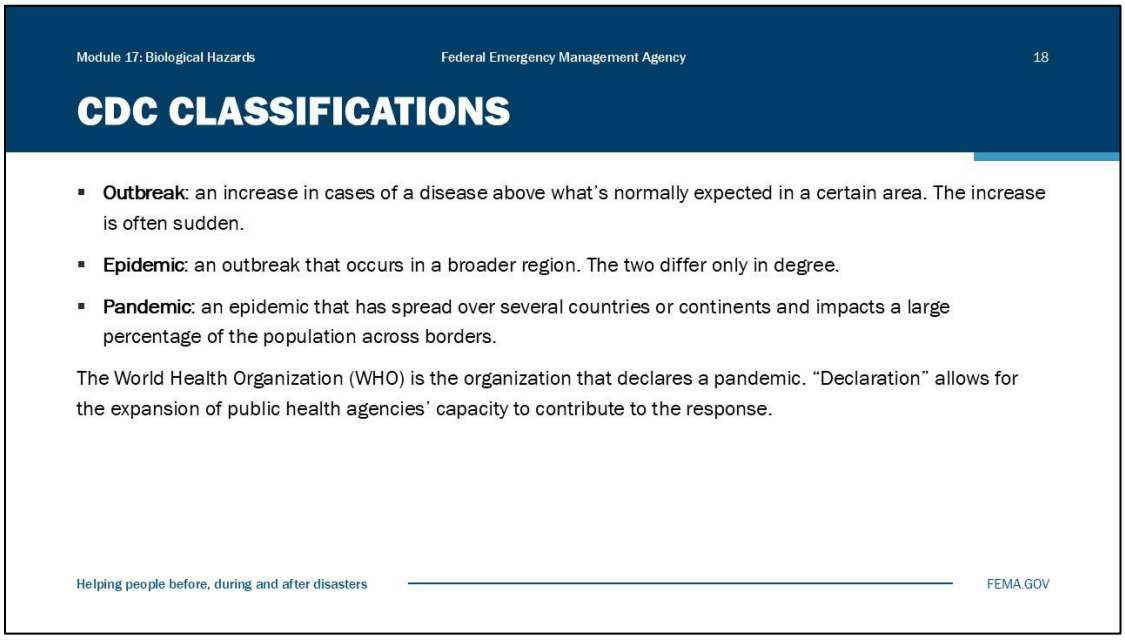
Biological Hazards (10 of 22)



Slide 17-17, Discussion: Seasonal Influenza Outbreak

1. How does a severe flu season affect the continuity of emergency management services?
2. What plans are in place to address seasonal influenza outbreaks?

Biological Hazards (11 of 22)



Slide 17-18, CDC Classifications

CDC classifications

- **Outbreak:** an increase in cases of a disease above what's normally expected in a certain area. The increase is often sudden.
- **Epidemic:** an outbreak that occurs in a broader region. The two differ only in degree.
- **Pandemic:** an epidemic that has spread over several countries or continents and impacts a large percentage of the population across borders.

The World Health Organization (WHO) is the organization that declares a pandemic. "Declaration" allows for the expansion of public health agencies' capacity to contribute to the response.

Examples of Pandemics

- 1918–1920: Spanish Flu
- 1981-Present: AIDS
- 2009-2010: H1N1 Swine Flu
- 2020–present: COVID-19

Definitions

- **Infectious:** Rate at which virus/bacteria or other microorganisms spread within a host, causing disease.
- **Contagious:** Rate at which an infectious disease-causing organism is passed from one host to another.
- **Virulence:** Severity and harmfulness of a disease on its host

Ebola, Marburg, and malaria are highly infectious and virulent but not highly contagious. They cause a lot of infection inside a host, but transmitting it to another host isn't readily possible. Additionally, hosts are not alive long enough to spread the disease widely beyond a village or area.

COVID-19 is not as infectious or widely virulent as Ebola, but it is very contagious. Infected individuals include asymptomatic (i.e., not showing symptoms) hosts, who can easily spread the disease without knowing they have it.

Average Death Rates:

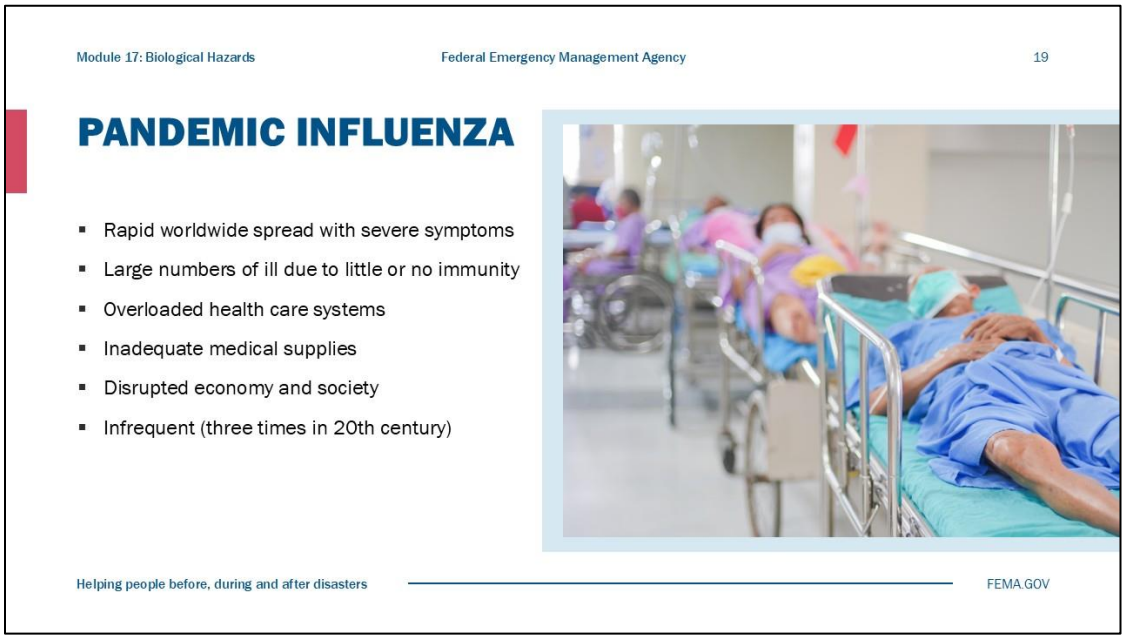
- Ebola, Marburg: up to 90%
- Malaria: 80-90%
- COVID-19: 2-4% (still gathering data)
- Seasonal Flu: 0.1%

Visit the World Health Organization website for information on world statistics, and the CDC website for information on U.S. statistics.

Required for a Pandemic:

- Contagion must be highly contagious, like SARS-CoV-2, to allow for spread globally. SARS-CoV-2 can spread asymptomatically, which increases its rate of spread.
- Contagion must have a lower virulence than Ebola, so it doesn't kill those infected both widely and rapidly, preventing global spread.
- COVID-19 has the perfect ratio of infection rate, contagious rate, and virulence to become a pandemic.

Biological Hazards (12 of 22)



Slide 17-19, Pandemic Influenza

- Rapid worldwide spread with severe symptoms
- Large numbers of ill due to little or no immunity
- Overloaded health care systems
- Inadequate medical supplies
- Disrupted economy and society
- Infrequent (three times in the 20th century)

Description: A pandemic is a global disease outbreak. It is determined by how the disease spreads, not how many deaths it causes.

When a new influenza A virus emerges, a flu pandemic can occur. Because the virus is new, the human population has little to no immunity against it. The virus spreads quickly from person to person worldwide.

Characteristics: According to the Centers for Disease Control and Prevention (CDC), the characteristics of a flu pandemic include:

- **Rapid worldwide spread**. A flu pandemic will spread quickly around the world, from country to country, even if governments attempt to close their borders, restrict travel, or otherwise protect their populations.
- **Overloaded health care systems**. As infection and illness rates soar, large populations require medical care, and death rates increase, medical staff and resources will become overloaded and overwhelmed. There may be a shortage of beds and treatment locations, in which case alternative sites like schools may be used as facilities.
- **Inadequate medical supplies**. Just as medical staff will be overwhelmed by a pandemic, the need for vaccines will outrun the supply. High-risk patients will more than likely receive the vaccine (or antiviral medication) first.
- **Disrupted economy and society**. Communities and citizens will be greatly impacted by disruptions to the economy and society, including banning travel, canceling events, and closing schools and businesses. The economy will be affected as employees remain absent to care for sick family members.

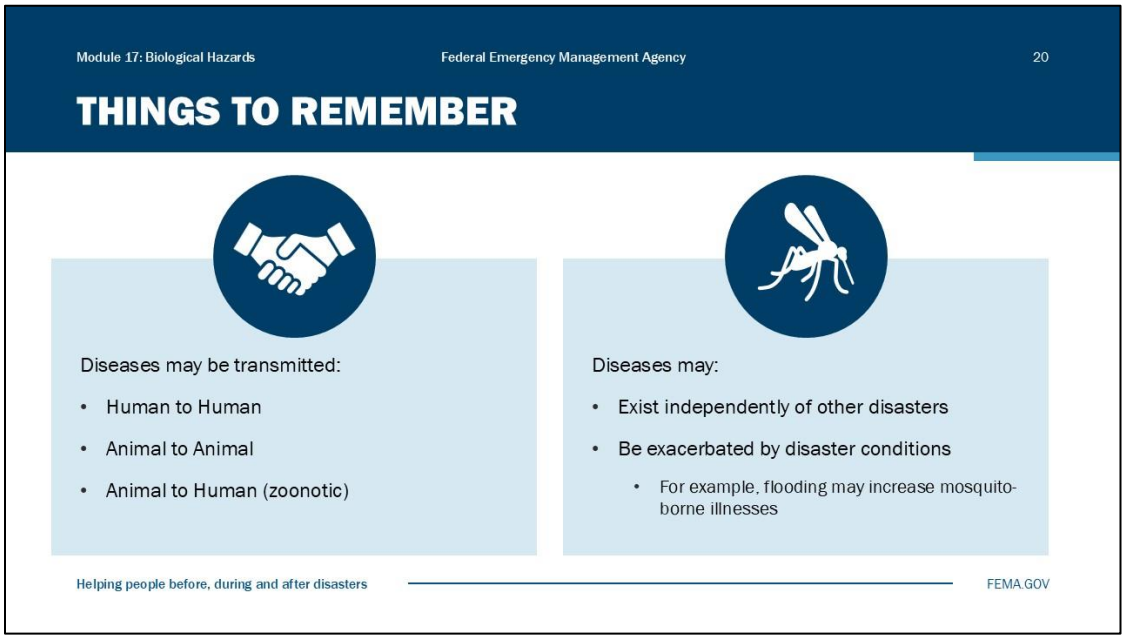
Although flu pandemics have happened throughout history, they are infrequent and have occurred just three times in the 20th century. The table below presents the basic facts of the four flu pandemics that have occurred since 1918.

History of Pandemic Influenza in the United States

Pandemic	Description
1918 - 1919 Pandemic	Called "The Spanish Flu." Often resulted in deaths from secondary effects such as pneumonia. Made 20 percent to 40 percent of the worldwide population ill. Resulted in about 50 million fatalities, 675,000 of which were in the United States. Noted for high mortality rates among healthy adults rather than the elderly or children; in fact, the highest rates were seen among adults 20 to 50 years old.
1957 - 1958 Pandemic	Started in February of 1957 with the identification of a new virus in the Far East. Officials predicted a pandemic, monitored outbreaks, and produced a limited supply of vaccine. Came to the United States through small outbreaks and the spread of the disease in classrooms. October 1957 was the peak of infection rates for the "first wave." Resurged in "second wave" in January and February 1958. Resulted in about 69,800 fatalities in the United States, with the highest rates of death occurring among the elderly.
1968 - 1969 Pandemic	Started in early 1968 with the identification of a new virus in Hong Kong. Became widespread in the United States in September 1968 and peaked that winter. Resulted in 33,800 deaths between September 1968 and March 1969-the mildest pandemic of the 20th century. Was similar to 1957 virus, leading researchers to conclude that U.S. citizens had built some immunity. The virus also hit during school vacation (December), which may have slowed the spread among children. Was treated with improved medical care and antibiotics for secondary infections from bacteria.

Pandemic	Description
2009 - 2010 Pandemic	Started in the spring of 2009 with the rapid spread of new virus (H1N1 - "swine flu") across the United States and the world. CDC worked to develop a vaccine, and in April, the U.S. Government declared a public health emergency. Affected 74 countries, with 18,000 cases reported in the United States by June. By November, 48 States had reported cases. Patients with the highest risk of complications related to the flu received the vaccine first. Minimized by the vaccination of 80 million people against the virus. Resulted in 43 to 89 million infections between April 2009 and April 2010 (CDC estimate) and 8,870 to 18,300 H1N1-related deaths.

Biological Hazards (13 of 22)



Slide 17-20, Things to Remember

Diseases may be transmitted:

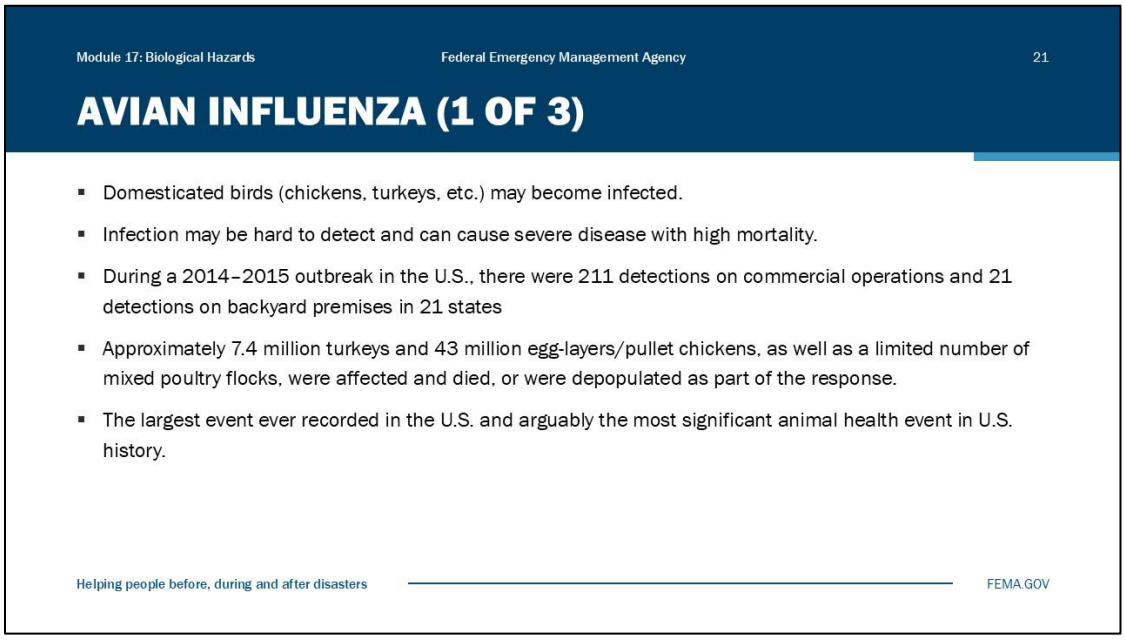
- Human to Human
- Animal to Animal
- Animal to Human (zoonotic)

Diseases may:

- Exist independently of other disasters
- Be exacerbated by disaster conditions

For example, flooding may increase mosquito-borne illnesses

Biological Hazards (14 of 22)



Slide 17-21, Avian Influenza (1 of 3)

- Domesticated birds (chickens, turkeys, etc.) may become infected.
- Infection may be hard to detect and can cause severe disease with high mortality.
- During a 2014–2015 outbreak in the U.S., there were 211 detections on commercial operations and 21 detections on backyard premises in 21 States.
- Approximately 7.4 million turkeys and 43 million egg-layers/pullet chickens, as well as a limited number of mixed poultry flocks, were affected and died, or were depopulated as part of the response.
- The largest animal event ever recorded in the U.S. and arguably the most significant animal health event in U.S. history.
- Another avian flu outbreak began in 2024 and is still occurring at the time of this update.

Avian Influenza in Poultry (Domesticated Birds)

Domesticated birds (chickens, turkeys, etc.) may become infected with avian influenza A viruses through direct contact with infected waterfowl or other infected poultry, or through contact with surfaces that have been contaminated with the viruses.

Infection of poultry with LPAI viruses may cause no disease or mild illness, only mild signs (such as ruffled feathers and a drop in egg production), and may not be detected.

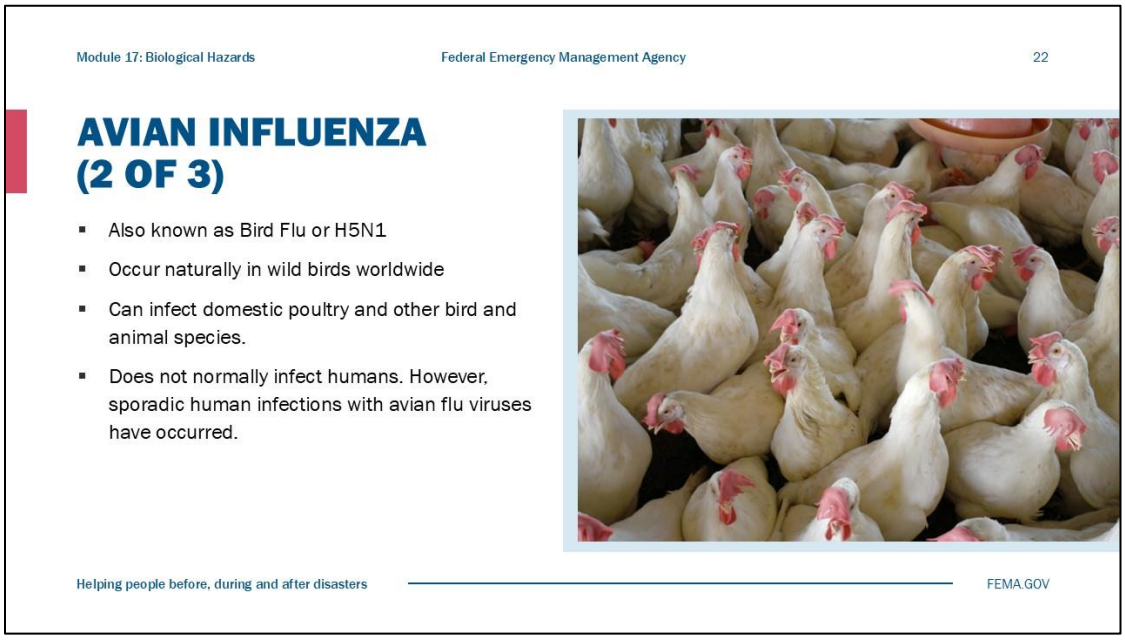
Infection of poultry with HPAI viruses can cause severe disease with high mortality. Both HPAI and LPAI viruses can spread rapidly through flocks of poultry. HPAI virus infection in poultry (such as with HPAI H5 or HPAI H7 viruses) can cause disease that affects multiple internal organs, with mortality up to 90% to 100%, often within 48 hours. Some ducks can be infected without any signs of illness.

Avian influenza outbreaks are of concern in domesticated birds for several reasons:

- Potential for low pathogenic H5 and H7 viruses to evolve into highly pathogenic viruses;
- Potential for rapid spread and significant illness and death among poultry during outbreaks of highly pathogenic avian influenza;
- Economic impact and trade restrictions from a highly pathogenic avian influenza outbreak; and
- Possibility that avian influenza A viruses could be transmitted to humans.

When H5 or H7 avian influenza outbreaks occur in poultry, depopulation (or culling, also called "stamping out") of infected flocks is usually carried out. In addition, surveillance of flocks that are nearby or linked to the infected flock(s), and quarantine of exposed flocks with culling if disease is detected, are the preferred control and eradication methods.

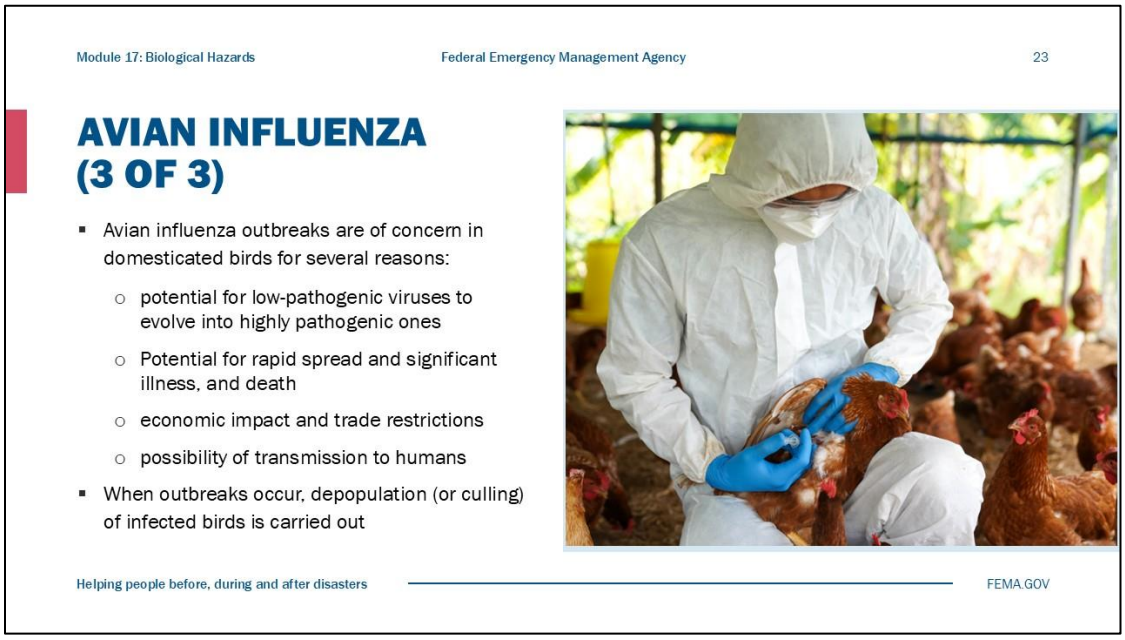
Biological Hazards (15 of 22)



Slide 17-22, Avian Influenza (2 of 3)

- Also known as Bird Flu or H5N1;
- Occurs naturally in wild birds worldwide;
- Can infect domestic poultry and other bird and animal species; and
- Does not normally infect humans (However, sporadic human infections with avian flu viruses have occurred).

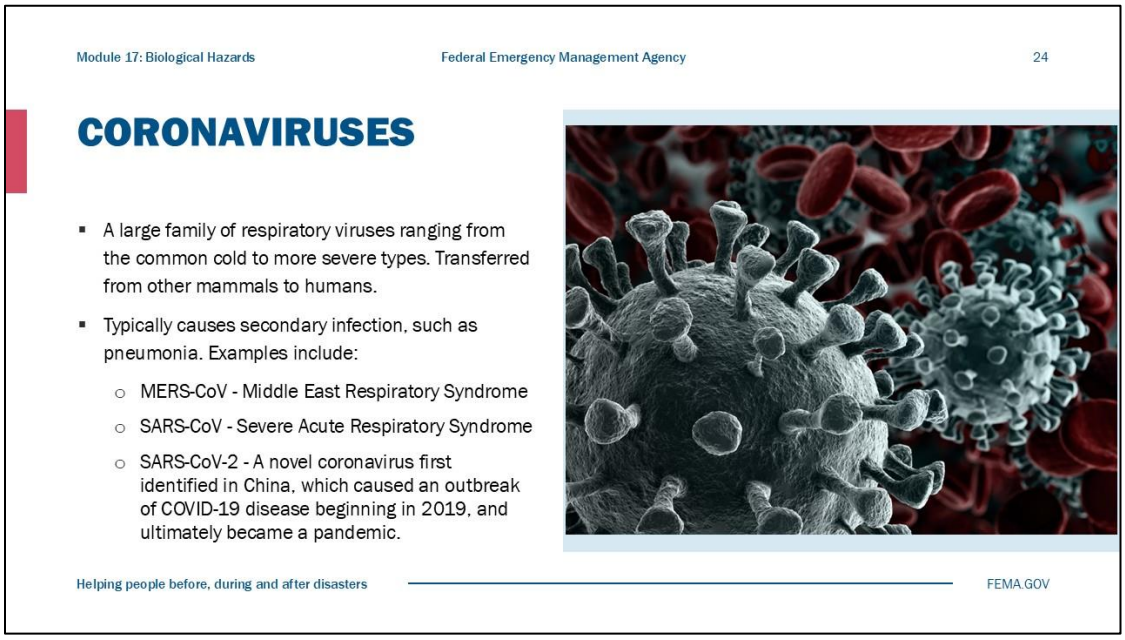
Biological Hazards (16 of 22)



Slide 17-23, Avian Influenza (3 of 3)

- Avian influenza outbreaks are of concern in domesticated birds for several reasons:
  - potential for low-pathogenic viruses to evolve into highly pathogenic ones;
  - potential for rapid spread and significant illness, and death;
  - economic impact and trade restrictions; and
  - possibility of transmission to humans.
- When outbreaks occur, depopulation (or culling) of infected birds is carried out.

Biological Hazards (17 of 22)



Slide 17-24, Coronaviruses

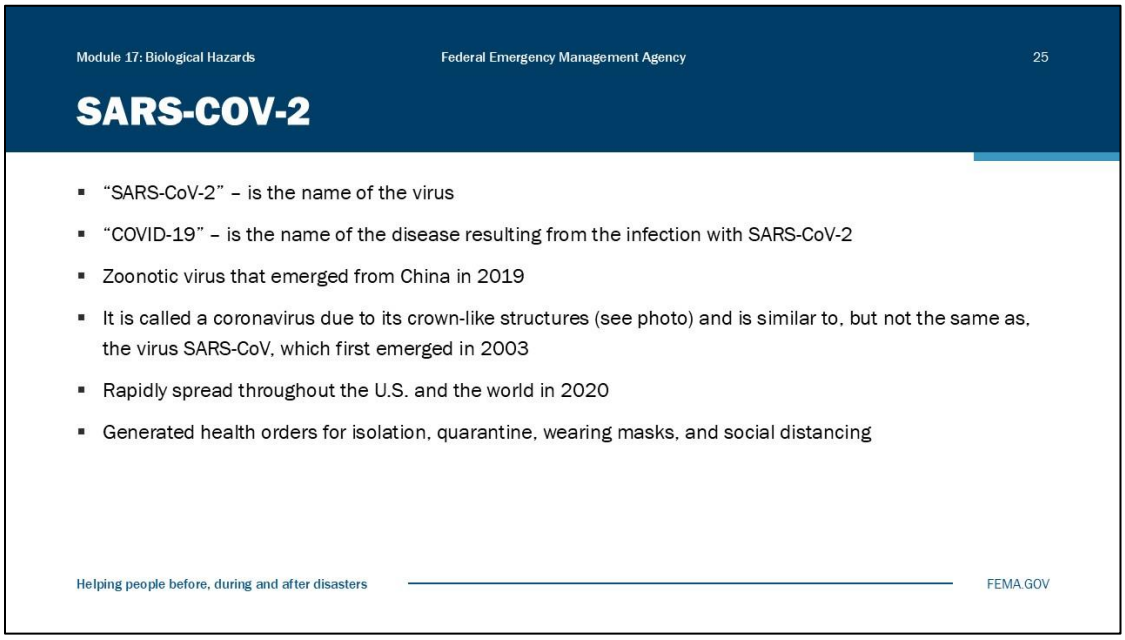
- A large family of respiratory viruses ranging from the common cold to more severe types. Transferred from other mammals to humans.
- Typically causes secondary infection, such as pneumonia. Examples include:
  - MERS-CoV - Middle East Respiratory Syndrome
  - SARS-CoV - Severe Acute Respiratory Syndrome
  - SARS-CoV-2 - A novel coronavirus first identified in China, which caused an outbreak of COVID-19 disease beginning in 2019, and ultimately became a pandemic.

Coronaviruses are zoonotic, meaning they are transmitted between animals and people. Detailed investigations found that SARS-CoV was transmitted from civet cats to humans and MERS-CoV from dromedary camels to humans. Several known coronaviruses are circulating in animals that have not yet infected humans.

Common signs of infection include respiratory symptoms, fever, cough, shortness of breath, and breathing difficulties. In more severe cases, infection can cause pneumonia, severe acute respiratory syndrome, kidney failure, and even death. Standard recommendations to prevent infection spread include regular hand washing, covering mouth and nose when coughing and sneezing, thoroughly

cooking meat and eggs. Avoid close contact with anyone showing symptoms of respiratory illness, such as coughing and sneezing.

Biological Hazards (18 of 22)

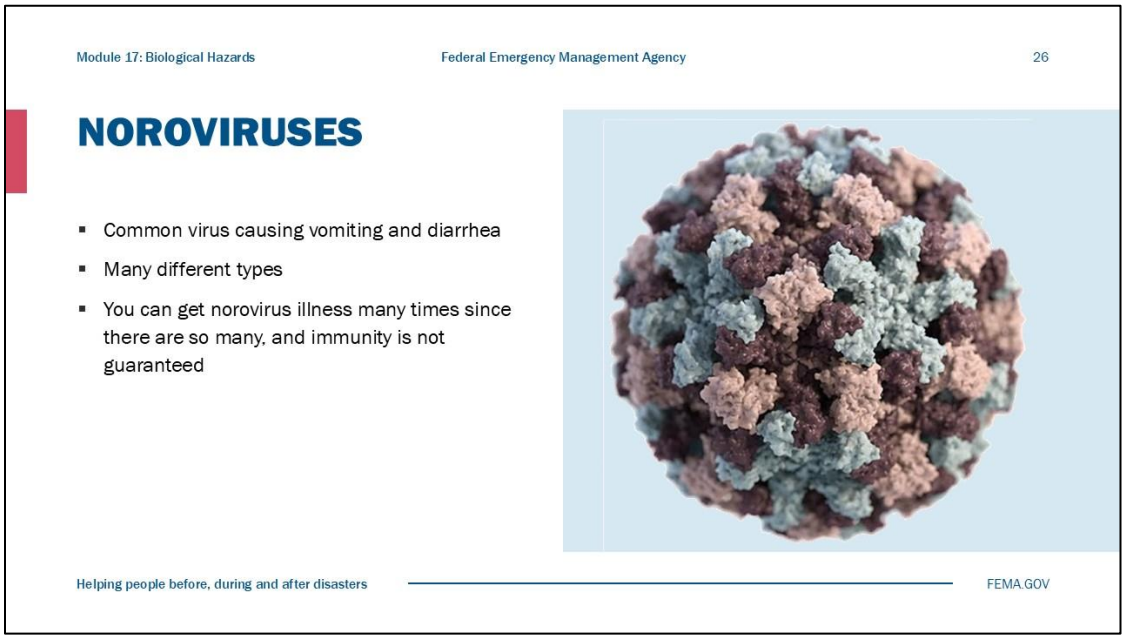


Slide 17-25, SARS-COV-2

- "SARS-CoV-2"- is the name of the virus
- "COVID-19" - is the name of the disease resulting from the infection with SARS-CoV-2
- Zoonotic virus that emerged from China in 2019
- It is called a coronavirus due to its crown-like structures (see photo) and is similar to, but not the same as, the virus SARS-CoV, which first emerged in 2003
- Rapidly spread throughout the U.S. and the world in 2020
- Generated health orders for isolation, quarantine, wearing masks, and social distancing

Severe acute respiratory syndrome (SARS) is a viral respiratory illness caused by a coronavirus called SARS-CoV. SARS was first reported in Asia in February 2003. The illness spread to more than two dozen countries in North America, South America, Europe, and Asia before the 2003 global outbreak was contained.

Biological Hazards (19 of 22)

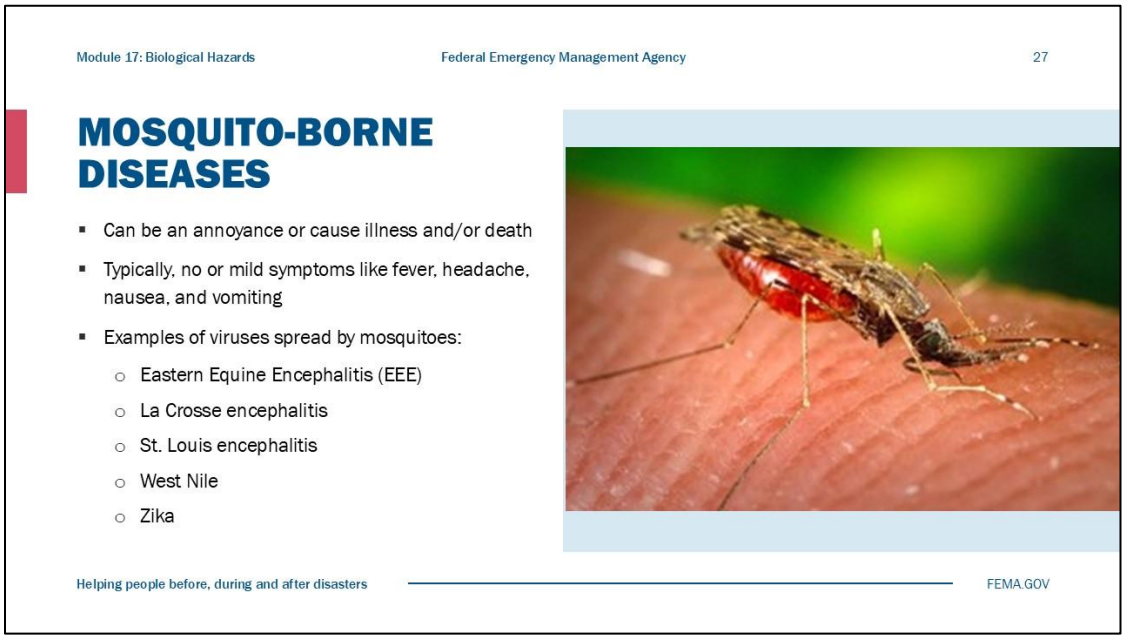


Slide 17-26, Noroviruses

- Common virus causing vomiting and diarrhea
- Many different types
- You can get norovirus illness many times since there are so many, and immunity is not guaranteed

Infection with one type of norovirus may not protect you against other types. It is possible to develop immunity to (protection against) specific types. But it is not known exactly how long immunity lasts. This may explain why many people of all ages get infected during norovirus outbreaks. Also, whether you are susceptible to norovirus infection is also determined in part by your genes.

Biological Hazards (20 of 22)



Slide 17-27, Mosquito-Borne Diseases

- Can be an annoyance or cause illness and/or death
- Typically, no or mild symptoms like fever, headache, nausea, and vomiting
- Examples of viruses spread by mosquitoes:
  - Eastern Equine Encephalitis (EEE)
  - La Crosse encephalitis
  - St. Louis encephalitis
  - West Nile
  - Zika.

The most effective way to avoid getting sick from viruses spread by mosquitoes when at home and during travel is to prevent mosquito bites. Mosquito bites can be more than just annoying and itchy. They can spread viruses that make you sick or, in rare cases, cause death. Although most kinds of mosquitoes are just nuisance mosquitoes, some kinds of mosquitoes in the United States and around the world spread viruses that can cause disease.

Mosquitoes bite during the day and night, live indoors and outdoors, and search for warm places as temperatures begin to drop. Some will hibernate in enclosed spaces, like garages, sheds, and under

(or inside) homes, to survive cold temperatures. Except for the southernmost states in North America, mosquito season starts in the summer and continues into fall. Examples of viruses spread by mosquitoes:

- Chikungunya
- Dengue
- Eastern equine encephalitis
- Japanese encephalitis
- La Crosse encephalitis
- St. Louis encephalitis
- West Nile
- Yellow fever
- Zika

When used as directed, insect repellents are the BEST way to protect yourself and family members from getting sick from mosquito bites.

Prevention

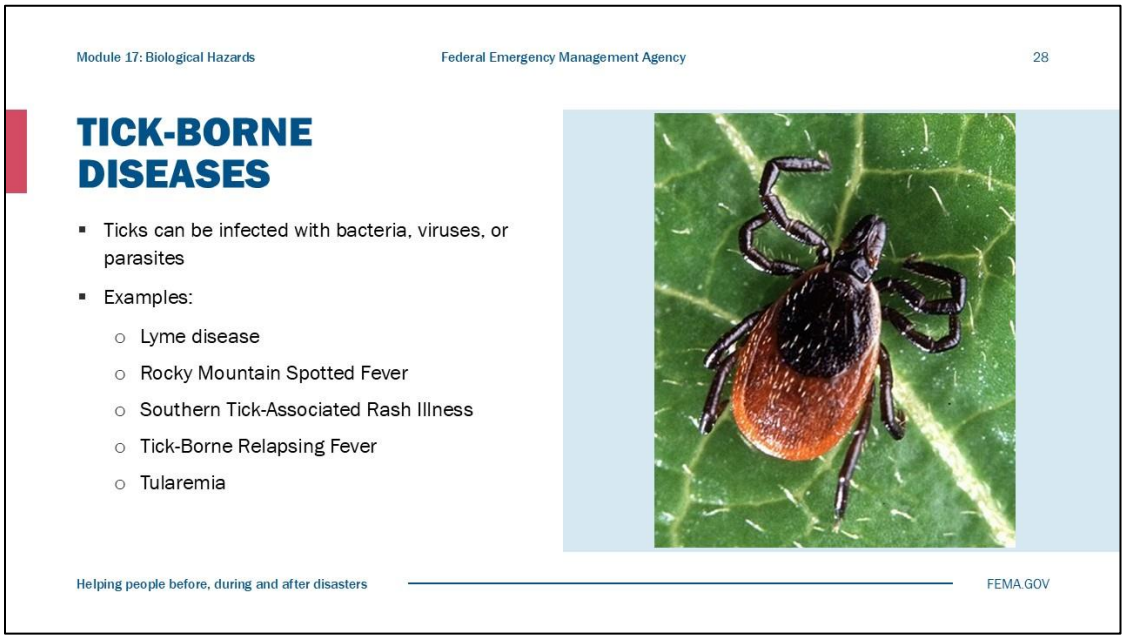
Use insect repellent: When used as directed, Environmental Protection Agency (EPA)-registered insect repellents (www.epa.gov/insect-repellents) are proven safe and effective, even for pregnant and breastfeeding women. Use an EPA-registered insect repellent with one of the following active ingredients:

- DEET
- Picaridin
- IR3535
- Oil of lemon eucalyptus (OLE)
- Para-menthane-diol (PMD)
- 2-undecanone

Cover up: Wear long-sleeved shirts and long pants.

Keep mosquitoes outside: Use air conditioning, or window and door screens. If you are not able to protect yourself from mosquitoes inside your home or hotel, sleep under a mosquito bed net.

Biological Hazards (21 of 22)



Slide 17-28, Tick-Borne Diseases

- Ticks can be infected with bacteria, viruses, or parasites.
- Examples:
  - Lyme disease
  - Rocky Mountain Spotted Fever
  - Southern Tick-Associated Rash Illness
  - Tick-Borne Relapsing Fever
  - Tularemia

According to the CDC, Lyme disease is the most commonly reported tick-borne disease in the United States. In 2010, more than 22,500 confirmed and 7,500 probable cases of Lyme disease were reported to the Centers for Disease Control and Prevention (CDC). Take the following steps to protect yourself from tick bites:

- Wear a hat and light-colored clothing, including long-sleeved shirts and long pants tucked into boots or socks.

- Use Environmental Protection Agency (EPA)-registered insect repellents containing DEET, picaridin, IR3535, Oil of Lemon Eucalyptus (OLE), para-menthane-diol (PMD), or 2-undecanone.

EPA's search tool (www.epa.gov/insect-repellents/find-repellent-right-you) can help you find the product that best suits your needs.

Always follow product instructions.

- Treat clothing and gear with products containing 0.5% permethrin.
- Permethrin kills ticks on contact.
- Permethrin can be used to treat shoes, clothing, and gear, but should not be used on skin.
- One application of permethrin to pants, socks, and shoes remains protective through several washings.
- Alternatively, permethrin-treated clothing is available.
- Check your skin and clothes for ticks every day. The immature forms of these ticks are very small and may be hard to see.

Shower or bathe as soon as possible after working outdoors to wash off and check for ticks. Remember to check your hair, underarms, and groin for ticks.

Immediately from your tick's body using fine-tipped tweezers.

Grasp the tick firmly and as close to your skin as possible.

Pull the tick's body away from your skin with a steady motion. Clean the area with soap and water.

Removing infected ticks within 24 hours reduces your risk of being infected with the Lyme disease bacterium.

Wash and dry work clothes in a hot dryer to kill any ticks present.

Learn about tick-borne diseases from the CDC (https://www.cdc.gov/ticks/about/)

If you develop symptoms of a tick-borne disease, seek medical attention promptly. Be sure to tell your health care provider that you work outdoors in an area where ticks may be present.

Biological Hazards (22 of 22)



Slide 17-29, Public Health

- Local Health Departments (LHD) and Emergency Management are partners in the community health response.
- Examples of response: 2019 H1N1 pandemic; Ebola (2014); SARS-CoV-2.
- Public Health Emergency Preparedness (PHEP) cooperative agreement funds state and LHD efforts.
- Technical expertise may be found at the following:
  - Centers for Disease Control (CDC) (https://www.cdc.gov/)
  - Health and Human Services (HHS) (https://www.hhs.gov/)
  - Assistant Secretary for Preparedness and Response/Technical Resources Assistance Center and Information Exchange (ASPR/TRACIE) (https://asprtracie.hhs.gov/)

Funding Streams

Here's some information on recent public health funding streams.

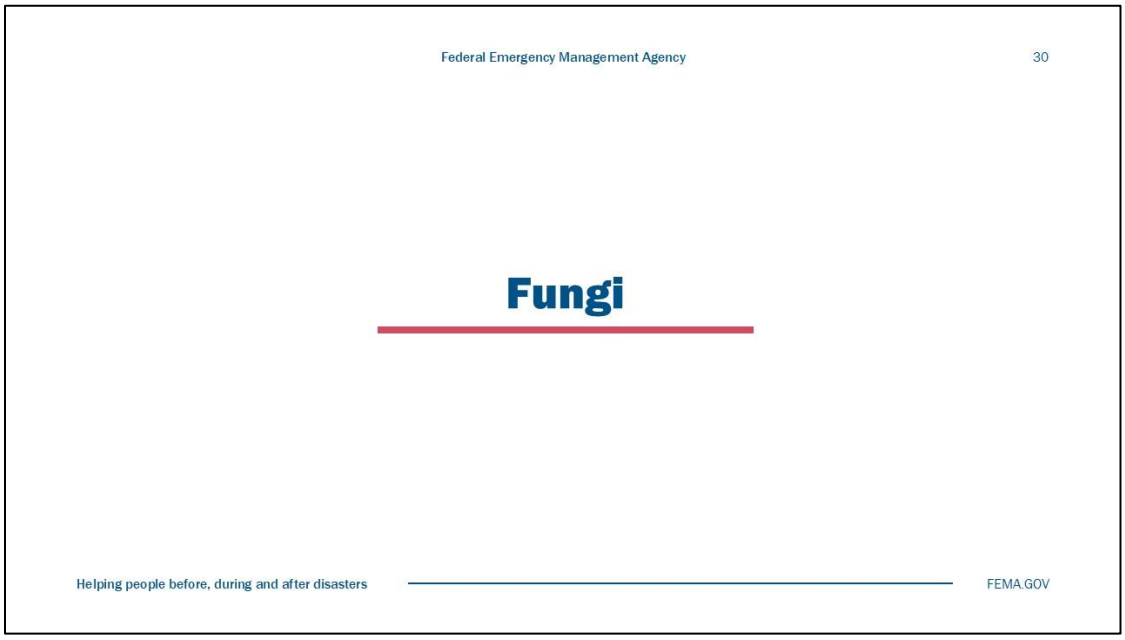
	Programs	President's Budget FY2019 ($ in millions)	NAC CHO Request ($ in millions)
HHS	*Prevention and Public Health Fund (PPHF)*	$0	$1,000
Emergency Preparedness			
CDC	Public Health Emergency Preparedness Cooperative Agreements	$660	$824
ASPR	Hospital Preparedness Program	$265	$474
ASPR	Medical Reserve Corps	$6	$11
Infectious Disease Prevention			
CDC	Section 317 Immunization Program (Prevention and Public Health Fund (PPHF))	$611 ($324)	$711
CDC	Core Infectious Disease [Antibiotic Resistance]	$425 [$168]	$457 [$200]
CDC	Epidemiology and Lab Capacity Grants (PPHF)	$195 ($40)	$195 ($40)
CDC	New Initiative for Infectious Diseases Related to IV Drug Use	-	$58
Environmental Health			
CDC	Childhood Lead Poisoning Prevention (PPHF)		

	Programs	President's Budget FY2019 ($ in millions)	NAC CHO Request ($ in millions)
HHS	*Prevention and Public Health Fund (PPHF)*	$0	$1,000
CDC	Vector Control	$39	$129
CDC	Food Safety	$60	$66
Public Health Capacity			
CDC	Public Health Workforce Development	$51	$57
CDC	Preventive Health & Health Services Block Grant (PPHF)	$160 ($160)	$170
Injury Prevention			
CDC	Opioid Overdose Prevention & Surveillance	$476	$650
Chronic Disease Prevention			
CDC	Racial & Ethnic Approaches to Community Health	$56	$77*
CDC	Tobacco (PPHF)	$80 ($130)	$310

*Includes $21 million for tribal communities

Source: Briggs, E. (2018). *Updated Appendix C - Local Health Departments Rely on Federal Funding Streams*. NACCHO. https://www.naccho.org/uploads/downloadable-resources/Updated-Appendix-C-LHDs-Rely-on-Fed-Funding-Streams.pdf

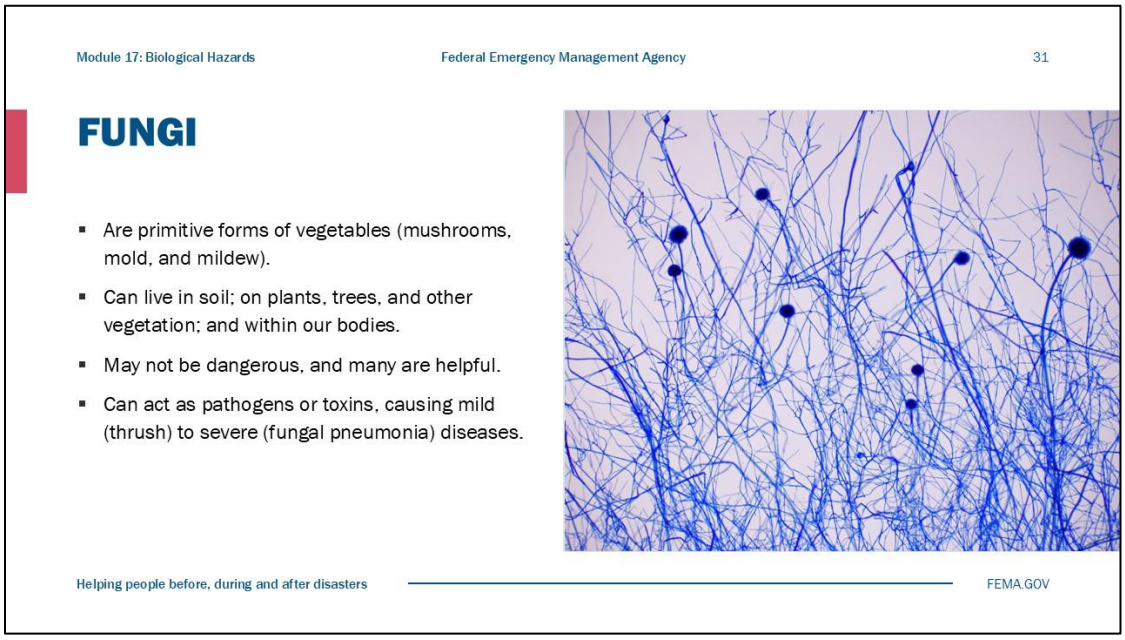
Fungi (1 of 2)



Slide 17-30, Fungi

Not applicable.

Fungi (2 of 2)



Slide 17-31, Fungi

- Are primitive forms of vegetables (mushrooms, mold, and mildew);
- Can live in soil; on plants, trees, and other vegetation; and within our bodies;
- May not be dangerous, and many are helpful; and
- Can act as pathogens or toxins, causing mild (thrush) to severe (fungal pneumonia) diseases.

Description: A fungus is actually a primitive plant. Mushrooms, mold, and mildew are examples. Fungi can be found in soil; on plants, trees, and other vegetation; and on our skin, mucous membranes, and intestinal tracts.

Reproduction: Some fungi reproduce through tiny spores in the air. Spores can be inhaled or land on the body. As a result, fungal infections often start in the lungs or on the skin. A fungal infection is more likely to occur in individuals with a weakened immune system or those who have taken antibiotics.

Useful fungi: Most fungi are not dangerous, and some can even be helpful, for example, penicillin, bread, wine, and beer all use ingredients made from fungi.

Health impacts: Some types of fungi can be harmful to health, and like bacteria and viruses, can act as pathogens or toxins. Only about half of all types of fungi are harmful. Fungal diseases are often caused by fungi that are common in the locality.

- Fungal infections can be mild, such as a rash or a mild respiratory illness. More common fungal infections include athlete's foot or thrush (a yeast infection).
- Other fungal infections can be severe, such as fungal pneumonia or bloodstream infection, and can lead to serious complications such as meningitis or death.
- The symptoms of fungal diseases depend on the type of infection and location within the body. Mycotic (fungal) infections pose an increasing threat to public health for several reasons.

Categories of fungal infections being studied include:

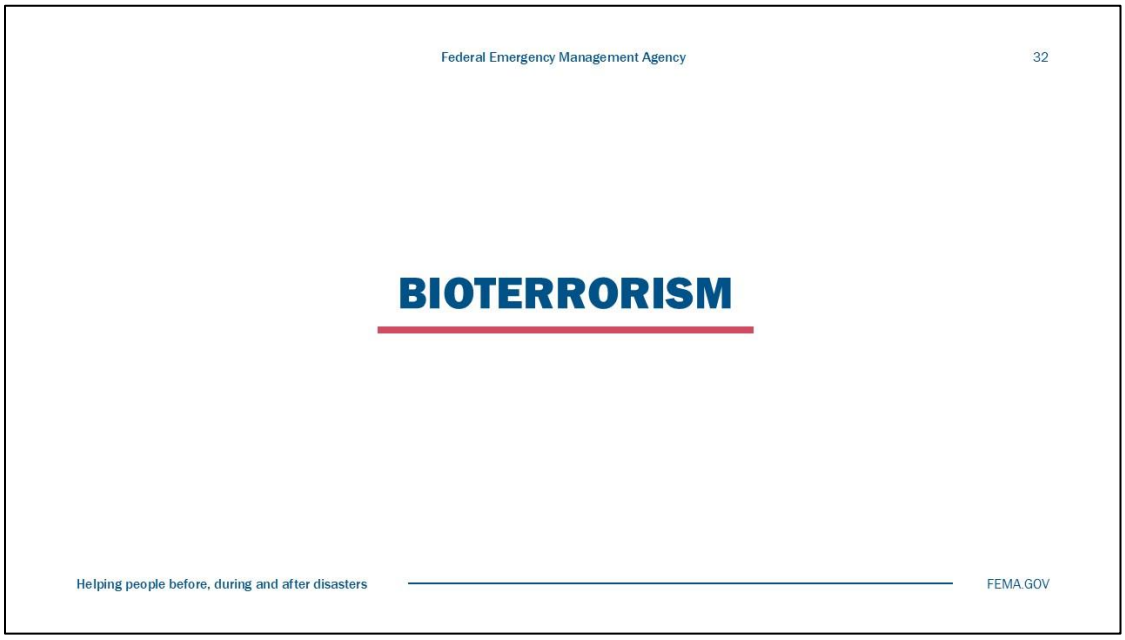
Opportunistic infections such as cryptococcosis and aspergillosis. These infections are becoming increasingly problematic as the number of people with weakened immune systems rises, including cancer patients, transplant recipients, and people with HIV/AIDS.

Hospital-associated infections, such as candidemia, are a leading cause of bloodstream infections in the United States.

Community-acquired infections such as coccidioidomycosis (valley fever), blastomycosis, and histoplasmosis. Fungi that cause these infections live in the soil, on plants, or in compost heaps, and are endemic (native and common) throughout much of the United States.

Treatment: Fungi can be difficult to kill. For skin and nail infections, medicine can be applied directly to the infected area. Oral antifungal medicines are also available for serious infections.

Bioterrorism (1 of 3)



Slide 17-32, Bioterrorism

Not applicable.

Bioterrorism (2 of 3)



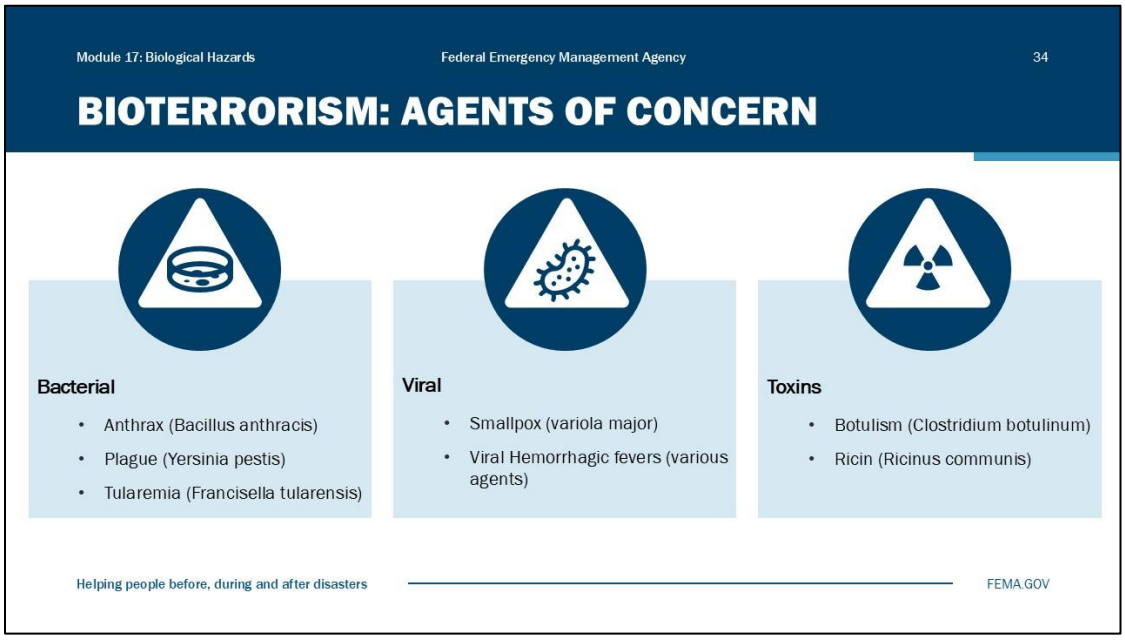
Slide 17-33, Bioterrorism Defined

Now that we have reviewed the various types of biological agents, next we will consider how they have been—or could be—used as weapons of terror.

Bioterrorism is the deliberate release of viruses, bacteria, or other germs (agents) used to cause illness or death in people, animals, or plants.

- These agents are typically found in nature, but it is possible that they could be changed to:
  - Increase their ability to cause disease;
  - Make them resistant to current medicines; and
  - Increase their ability to spread into the surroundings
- Biological agents can be spread through the air, through water, or in food.
- Terrorists may use biological agents because they can be extremely difficult to detect and do not cause illness for several hours to several days.
- Some bioterrorism agents, like the smallpox virus, can be spread from person to person, and some cannot be spread, like anthrax.

Bioterrorism (3 of 3)



Slide 17-34, Bioterrorism: Agents of Concern

Bacterial:

- Anthrax (Bacillus anthracis)
- Plague (Yersinia pestis)
- Tularemia (Francisella tularensis)

Viral:

- Smallpox (variola major)
- Viral Hemorrhagic fevers (various agents)

Toxins:

- Botulism (Clostridium botulinum)
- Ricin (Ricinus communis)

Agents of concern fall into three categories: bacterial, viral, and toxic. Here are examples of each. We will discuss some of these examples in more detail.

Categories: Biological agents fall into one of three categories based on the level of risk (i.e., how easily they can spread, the severity of illness caused, etc.). Category A agents have the highest risk, and Category C agents are emerging threats.

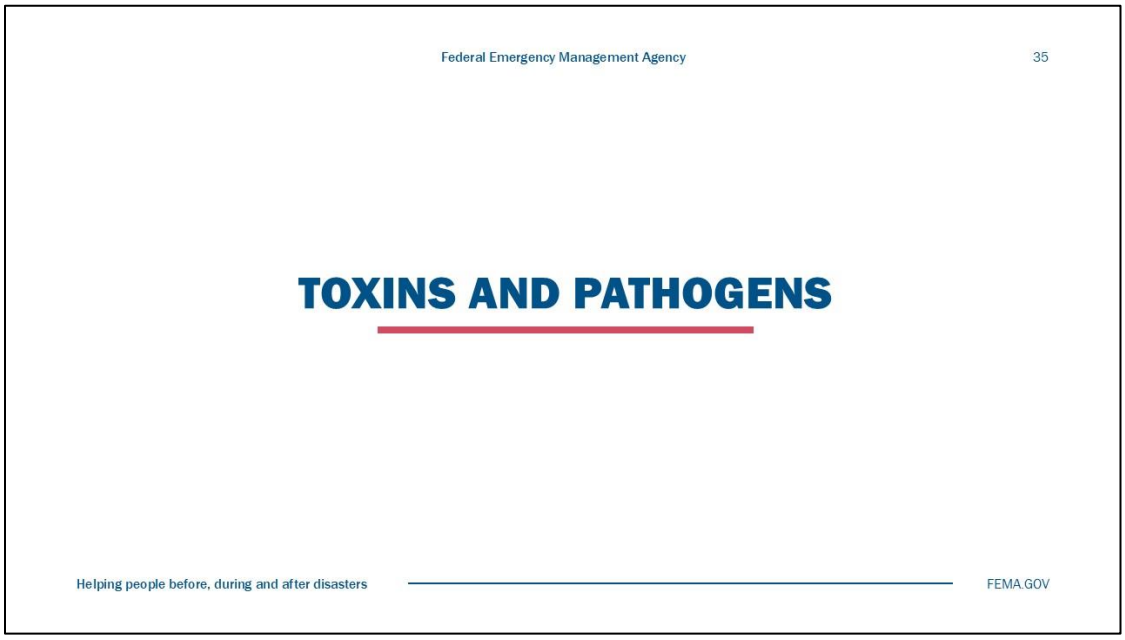
The following table summarizes these categories.

Biological Agent Categories

Category	CDC Definition	Agents/Diseases
A	The U.S. public health system and primary healthcare providers must be prepared to address various biological agents, including pathogens that are rarely seen in the United States. High-priority agents include organisms that pose a risk to national security because they: Can be easily disseminated or transmitted from person to person. Result in high mortality rates and have the potential for major public health impact. Might cause public panic and social disruption; and require special action for public health preparedness.	Anthrax (Bacillus anthracis) Botulism (Clostridium botulinum toxin) Plague (Yersinia pestis) Smallpox (variola major) Tularemia (Francisella tularensis) Viral hemorrhagic fevers: Filoviruses (e.g., Ebola, Marburg) Arenaviruses (e.g., Lassa, Machupo)
B	Second highest priority agents include those that: • Are moderately easy to disseminate; • Result in moderate morbidity rates and low mortality rates; and • Require specific enhancements of CDC's diagnostic capacity and enhanced disease surveillance.	Brucellosis (Brucella species) Epsilon toxin of Clostridium perfringens Food safety threats (e.g., Salmonella species, Escherichia coli O157:H7, Shigella) Glanders (Burkholderia mallei) Melioidosis (Burkholderia pseudomallei) Psittacosis (Chlamydia psittaci) Q fever (Coxiella burnetii) Ricin toxin from Ricinus communis (castor beans) Staphylococcal enterotoxin B

Category	CDC Definition	Agents/Diseases
		Typhus fever (Rickettsia prowazekii) Viral encephalitis (alphaviruses (e.g., Venezuelan equine encephalitis, eastern equine encephalitis, western equine encephalitis)) Water safety threats (e.g., Vibrio cholerae, Cryptosporidium parvum)
C	Third highest priority agents include emerging pathogens that could be engineered for mass dissemination in the future because of: Availability Ease of production and dissemination; and Potential for high morbidity and mortality rates and major health impact.	Emerging infectious diseases such as Nipah virus and hantavirus

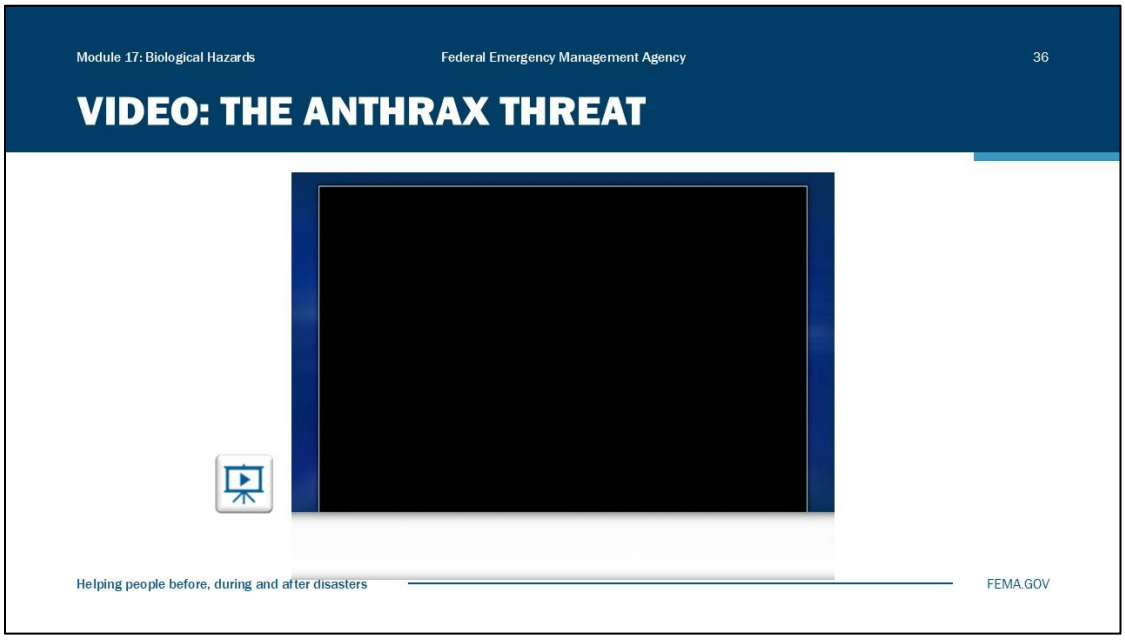
Toxins and Pathogens (1 of 14)



Slide 17-35, Toxins and Pathogens

Not Applicable.

Toxins and Pathogens (2 of 14)



Slide 17-36, Video: The Anthrax Threat

Introduction: This video provides a brief overview of the history of the threat posed by anthrax.

Video Transcript:

Joanne Cono, MD, ScM, Centers for Disease Control and Prevention: The idea of using disease as a weapon gained a new level of sophistication in the early 1930s as nationally funded research programs on biological warfare were developed. The Japanese had a very active offensive biowarfare research program, which included a battalion known as 731. In their program, the Japanese conducted experiments on humans, using 15 to 20 different disease- causing agents, with anthrax being one of their favorites. Allied prisoners of war and innocent Manchurian civilians in nearby villages provided an almost endless supply of experimental subjects. When word of module 731 leaked to the West, allied forces began their own programs, concerned that Japan and possibly Germany would gain a military advantage in biowarfare research.

Narrator: On the third day after exposure, the casualties begin. Dead sheep can be seen further down the line. It is, of course, necessary to confirm that they have died of anthrax.

Dr. Cono: In 1942, on Gruinard Island off the coast of Scotland, the British conducted their first scientifically controlled biowarfare field trials. Scientists exploded anthrax bombs near immobilized sheep to determine if the spores would survive an explosion and retain the ability to infect anyone

nearby. Test results showed that anthrax could in fact be effectively disbursed by explosive devices and could also remain viable in the soil for decades. This brought home the realization that if an anthrax bomb were dropped on a city like London, the results could have been catastrophic. Gruinard Island was declared off limits until it was decontaminated in the 1980s. It's now safe for both humans and animals.

Like our allies, the United States responded to the perceived threats from Germany and Japan. In 1943, we began an offensive biological program with a modest research and development facility at Camp Detrick, which is now Fort Detrick, Maryland. By the end of the program, we had weaponized a total of seven incapacitating or lethal human agents, including anthrax. In 1969, Richard Nixon renounced the use of biological weapons for the United States.

Richard Nixon: I have decided that the United States of America will renounce the use of any form of deadly biological weapons that either kill or incapacitate.

William C. Patrick III, Biological Warfare Consultant: President Nixon visited Fort Detrick on the 25th of November, 1969. I remember that date quite well because following his announcement of taking munitions and beating them into plowshares, we all lost our job and that was a very traumatic experience. But following his presidential announcement on this date, the entire United States offensive program on biological warfare came to a close within two years.

We destroyed all of our seed stocks; we destroyed all of our production material at Pine Bluff, Arkansas; and we completely got out of the biological warfare business.

Dr. Cono: Even at its peak, the U.S. offensive program paled compared to the Soviet Union's. The Soviets had a massive, extensive, sophisticated, top-secret program which employed tens of thousands of scientists and engineers in numerous research and production facilities. The Soviets signed the biological warfare convention in the 1970s and yet their program continued uninterrupted, and, in fact, intensified. Our worst fears were confirmed in 1979 when an accidental release of anthrax occurred at a biological research facility in the town of Sverdlovsk. Much of our recent knowledge about their joint military and civilian program comes from a Soviet defector, Dr. Ken Alibek, formerly known as Dr. Kanatjian Alibekov. He was the deputy director of Biopreparat, a cover organization for their civilian bioweapon and production facilities. Although we had suspected for years that they had continued their offensive program, some of the information he provided was a real wake-up call for the United States.

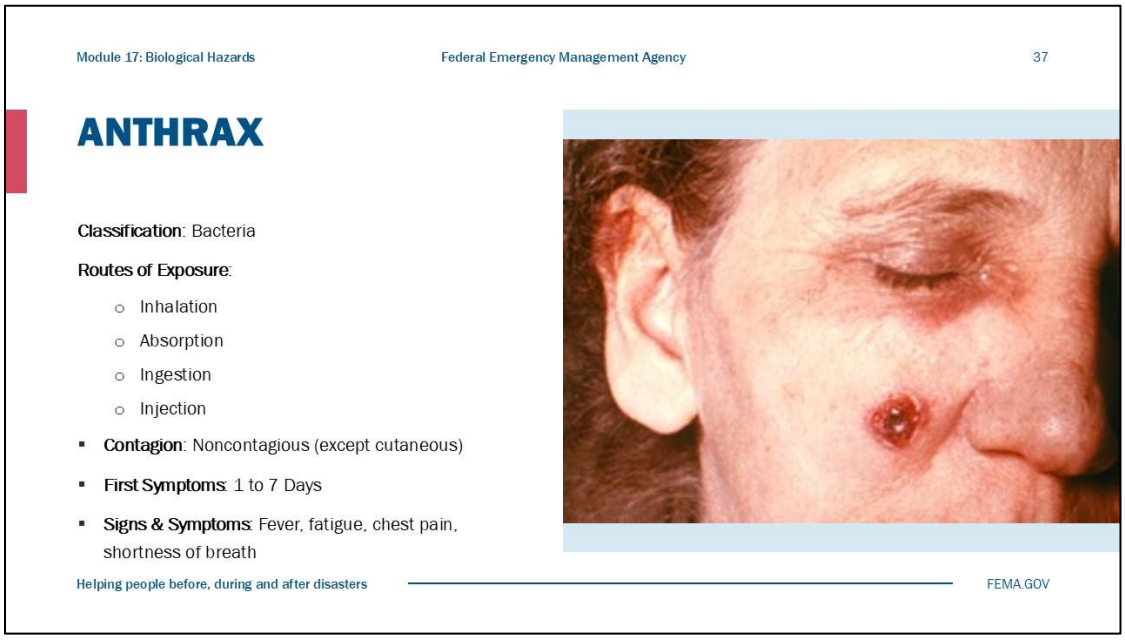
Prior to the Gulf War, the intelligence community suspected that the Iraqis had done research on anthrax, but they didn't know just how extensive their program was. So as a precautionary measure during the war, about 150,000 U.S. service members were vaccinated against anthrax. And more would have been immunized if the war hadn't ended so quickly. After the war, the Iraqis admitted to producing and weaponizing anthrax, although the weapons were never used.

Dr. Cono: This past decade, anthrax moved from being an agent of concern for biological warfare to the top of the threat list for terrorism. The Aum Shinrikyo cult in Japan, which released the nerve agent sarin from the Tokyo subway in 1995, allegedly made multiple unsuccessful attempts to infect

people with anthrax. In October of 2001, the United States experienced anthrax attacks using powder sent through the United States postal service. Twenty-two people got sick and five people died from this attack. We learned just how dangerous anthrax could be.

But there are things we can do. The best defense against a bioterrorism attack is knowledge and preparation. The Web page ready.gov is a good resource for preparedness information. It can be found at www.ready.gov. Visit this Web page for detailed guidelines, facts, and what you can do to be ready in the event of an emergency. A small amount of time spent becoming informed, developing a plan, and preparing yourself against terrorist threats now can prove to be invaluable, should the need arise. Don't be afraid, be ready.

Toxins and Pathogens (3 of 14)



Slide 17-37, Anthrax

Classification: Bacteria

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Noncontagious (except cutaneous)

First Symptoms: 1 to 7 Days

Signs & Symptoms: Fever, fatigue, chest pain, shortness of breath

We have seen the history of anthrax as a weapon of terror. What, exactly, is anthrax? Below is a brief summary:

Classification—bacteria: Anthrax is a serious disease caused by Bacillus anthracis, a bacterium that forms spores. There are four types of anthrax: cutaneous, inhalation, gastrointestinal, and injection.

Routes of exposure: There are four routes of exposure, correlating with the types of anthrax:

- Absorption-cutaneous anthrax is absorbed through the skin.
- Inhalation anthrax is contracted by breathing it into the lungs (the most hazardous route).
- Ingestion-gastrointestinal anthrax is contracted by eating contaminated food.
- Injection-injected anthrax is usually injected by needle through tainted illicit drugs.

Contagion: Anthrax is not known to spread from one person to another. Humans can become infected with anthrax by handling products from infected animals or by breathing in anthrax spores from infected animal products (e.g., wool). People also can become infected with gastrointestinal anthrax by eating undercooked meat from infected animals.

First symptoms: For all three types of anthrax, symptoms can appear within 7 days of coming in contact with the bacterium. However, for inhalation anthrax, symptoms can appear within a week or can take up to 42 days to appear.

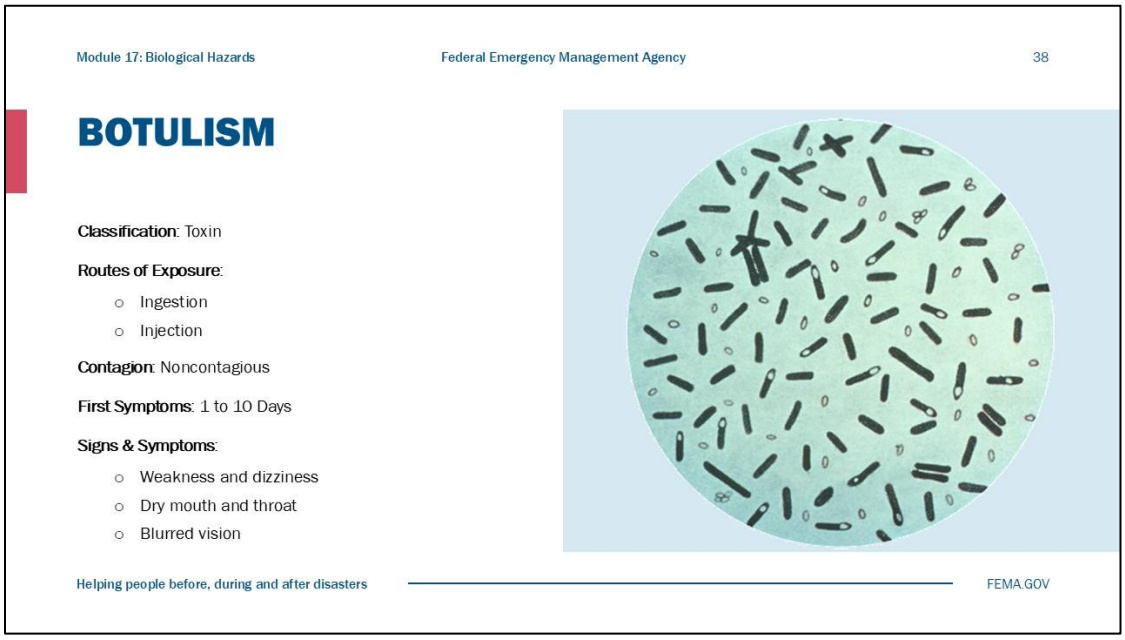
Signs and symptoms: The symptoms (warning signs) of anthrax are different depending on the type of the disease:

- Cutaneous: The first symptom is a small sore that develops into a blister. The blister then develops into a skin ulcer with a black area in the center. The sore, blister, and ulcer do not hurt.
- Gastrointestinal: The first symptoms are nausea, loss of appetite, bloody diarrhea, and fever, followed by bad stomach pain.
- Inhalation: The first symptoms of inhalation anthrax are cold or flu symptoms and can include a sore throat, mild fever, and muscle aches. Later symptoms include cough, chest discomfort, shortness of breath, tiredness, and muscle aches. Because the symptoms are generic and flu-like, victims may miss the window of opportunity for effective treatment.
- Injection: Injection anthrax symptoms are similar to those of cutaneous anthrax, but injection anthrax can spread throughout the body faster and be harder to recognize and treat than cutaneous anthrax.

Treatment and prevention: In most cases, early treatment with antibiotics can cure cutaneous anthrax. Even if untreated, 80 percent of people who become infected with cutaneous anthrax do not die. Gastrointestinal anthrax is more serious: between one-fourth and more than half of cases lead to death. Inhalation anthrax is much more severe. In 2001, about half of the cases of inhalation anthrax ended in death.

There is a vaccine to prevent anthrax, but it is not yet available for the general public. (Source: CDC)

Toxins and Pathogens (4 of 14)



Slide 17-38, Botulism

Classification: Toxin

Routes of Exposure:

- Ingestion
- Injection

Contagion: Noncontagious

First Symptoms: 1 to 10 Days

Signs & Symptoms:

- Weakness and dizziness
- Dry mouth and throat
- Blurred vision

Classification—toxin: Botulism is a muscle-paralyzing disease caused by a toxin made by a bacterium called Clostridium botulinum. There are five main kinds of botulism.

- Foodborne botulism is caused by eating foods that contain the botulinum toxin. It is a public health emergency because the contaminated food may still be available to others besides the patient.

- Infant botulism is caused by consuming the spores of the botulinum bacteria, which then grow in the intestines and release toxin.
- Wound botulism is caused by toxin produced by a wound infected with C. botulinum.
- Adult intestinal toxemia botulism is a very rare kind of botulism that occurs among adults by the same route as infant botulism.
- Iatrogenic botulism can occur from accidental overdose of botulinum toxin.

Routes of exposure: The main routes of exposure are ingestion (from food) and injection (through wounds).

Contagion: Botulism is not spread from one person to another. Foodborne botulism can occur in all age groups.

First symptoms: With foodborne botulism, symptoms begin within 6 hours to 10 days (most commonly between 12 and 36 hours) after eating food that contains the toxin.

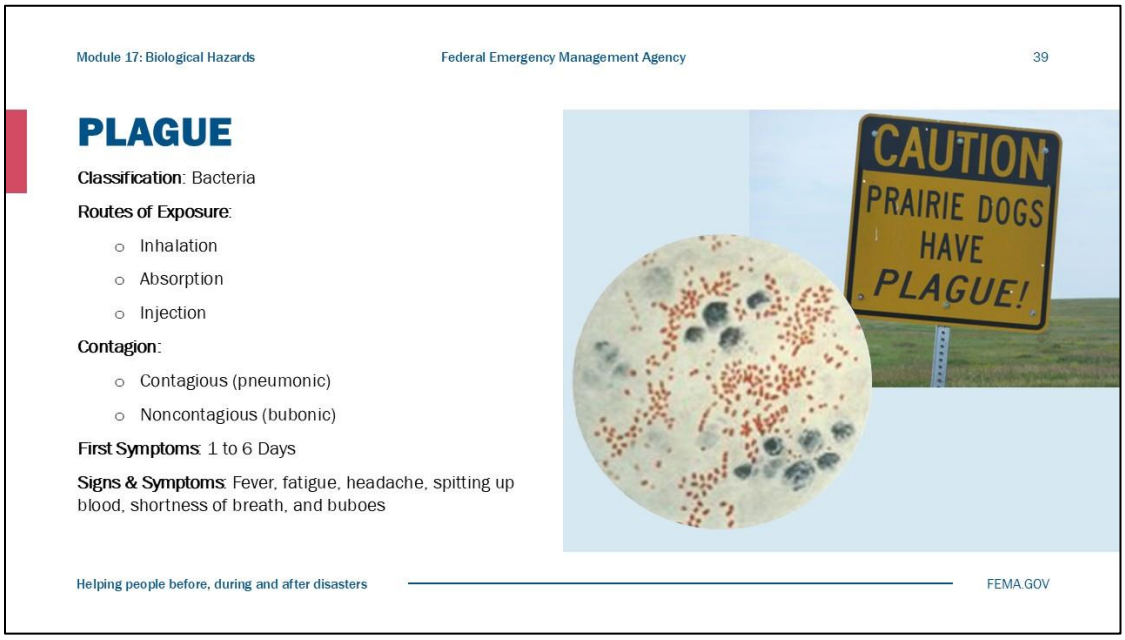
Signs and symptoms: Symptoms of botulism include:

- Double or blurred vision
- Drooping eyelids
- Slurred speech
- Difficulty swallowing
- Dry mouth
- Muscle weakness that moves down the body, usually affecting the shoulders first, then the upper arms, lower arms, thighs, calves, etc.; Paralysis of breathing muscles can cause a person to stop breathing and die, unless assistance with breathing (mechanical ventilation) is provided.

Treatment: Antitoxins are used to reduce the severity of symptoms. Most patients eventually recover after weeks to months of supportive care.

(Source: CDC)

Toxins and Pathogens (5 of 14)



Slide 17-39, Plague

Classification: Bacteria

Routes of Exposure:

- Inhalation
- Absorption
- Injection

Contagion:

- Contagious (pneumonic)
- Noncontagious (bubonic)

First Symptoms: 1 to 6 Days

Signs & Symptoms: Fever, fatigue, headache, spitting up blood, shortness of breath, and buboes

Classification—bacteria: Plague is a disease caused by Yersinia pestis (Y. pestis), a bacterium found in rodents and their fleas in many areas around the world. Two types of plague are pneumonic plague and bubonic plague.

Routes of exposure:

- Pneumonic plague: Exposure occurs through inhalation. This could happen in an aerosol release during a bioterrorism attack or by breathing in respiratory droplets from a person (or animal) with pneumonic plague, usually from coughing or sneezing within 6 feet.
- Bubonic plague: Exposure occurs through absorption or injection through the bite of an infected flea or exposure to infected material through a break in the skin.

Contagion: Pneumonic plague can be transmitted from person to person; bubonic plague cannot.

First symptoms: A person usually becomes ill with bubonic plague 2 to 6 days after being infected. Someone exposed to Yersinia pestis through the air would become ill within 1 to 3 days.

Signs and symptoms:

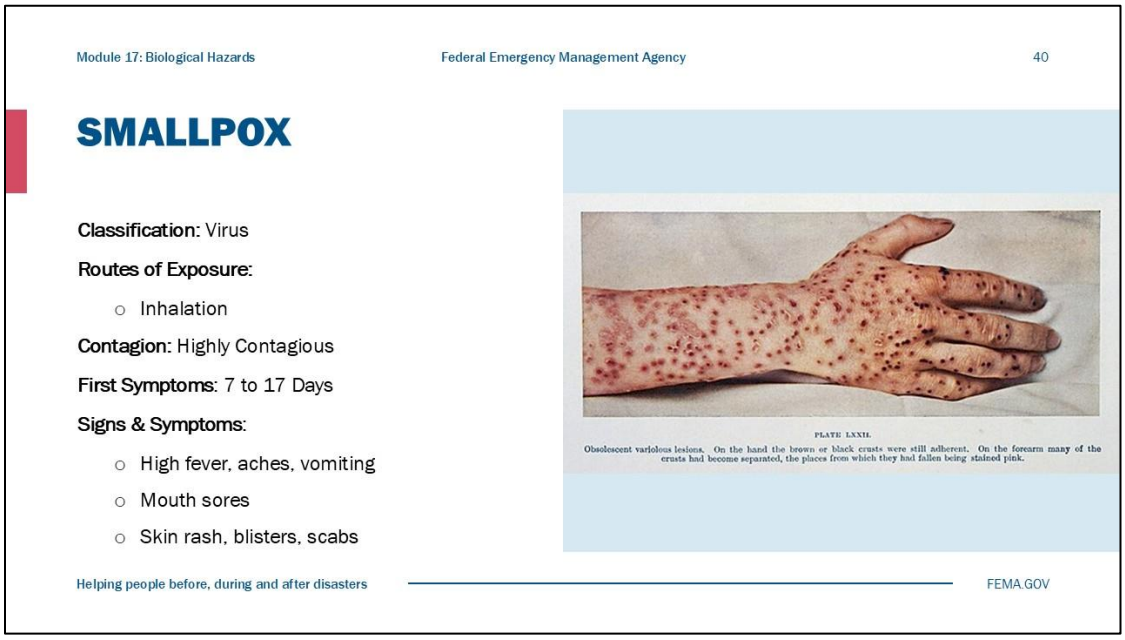
- Pneumonic plague: Patients usually have fever, weakness, and rapidly developing pneumonia with shortness of breath, chest pain, cough, and sometimes bloody or watery sputum. Nausea, vomiting, and abdominal pain may also occur. Without early treatment, pneumonic plague usually leads to respiratory failure, shock, and rapid death.
- Bubonic plague: Symptoms include swollen, tender lymph glands called buboes. If bubonic plague is not treated, however, the bacteria can spread through the bloodstream and infect the lungs, causing a secondary case of pneumonic plague.

Treatment: People who have had close contact with an infected person can greatly reduce the chance of becoming sick if they begin treatment within 7 days of their exposure. Treatment consists of taking antibiotics for at least 7 days. Currently, no plague vaccine is available in the United States.

Bioterrorism concern: Yersinia pestis used in an aerosol attack could cause cases of the pneumonic form of plague. Because of the delay between being exposed to the bacteria and becoming sick, people could travel over a large area before becoming contagious and possibly infecting others. Controlling the disease would then be more difficult.

(Source: CDC)

Toxins and Pathogens (6 of 14)



Slide 17-40, Smallpox

Classification: Virus

Routes of Exposure:

- Inhalation

Contagion: Highly Contagious

First Symptoms: 7 to 17 Days

Signs & Symptoms:

- High fever, aches, vomiting
- Mouth sores
- Skin rash, blisters, scabs

Classification—virus: Smallpox is a serious and sometimes fatal infectious disease caused by the variola virus. The pox part of smallpox is derived from the Latin word for "spotted" and refers to the raised bumps on an infected person's face and body. There are two clinical forms of smallpox: variola major and variola minor. Variola major, the severe and most common form of smallpox-includes four types:

- Ordinary (the most frequent type, accounting for 90 percent or more of cases);

- Modified (mild and occurring in previously vaccinated persons);
- Flat; and
- Hemorrhagic (both rare and very severe).

Historically, variola major has an overall fatality rate of about 30 percent; however, flat and hemorrhagic smallpox are usually fatal. Variola minor is a less common and much less severe disease, with death rates historically of 1 percent or less.

Routes of exposure: Smallpox is transmitted by inhalation.

- Generally, direct and fairly prolonged face-to-face contact is required to spread smallpox from one person to another.
- Smallpox can also be spread through direct contact with infected bodily fluids or contaminated objects such as bedding or clothing.
- Rarely, smallpox has been spread by virus carried in the air in enclosed settings such as buildings, buses, and trains.
- Humans are the only natural hosts of variola. Smallpox is not known to be transmitted by insects or animals.

Contagion: Smallpox is highly contagious. A person with smallpox is sometimes contagious with the onset of fever but becomes most contagious with the onset of rash. At this stage, the infected person is usually very sick and unable to move around in the community. The infected person is contagious until the last smallpox scab falls off.

First symptoms: The incubation period is 7 to 17 days (average 12 to 14 days), during which the person is not contagious.

Signs and symptoms: The signs and symptoms of smallpox come in phases.

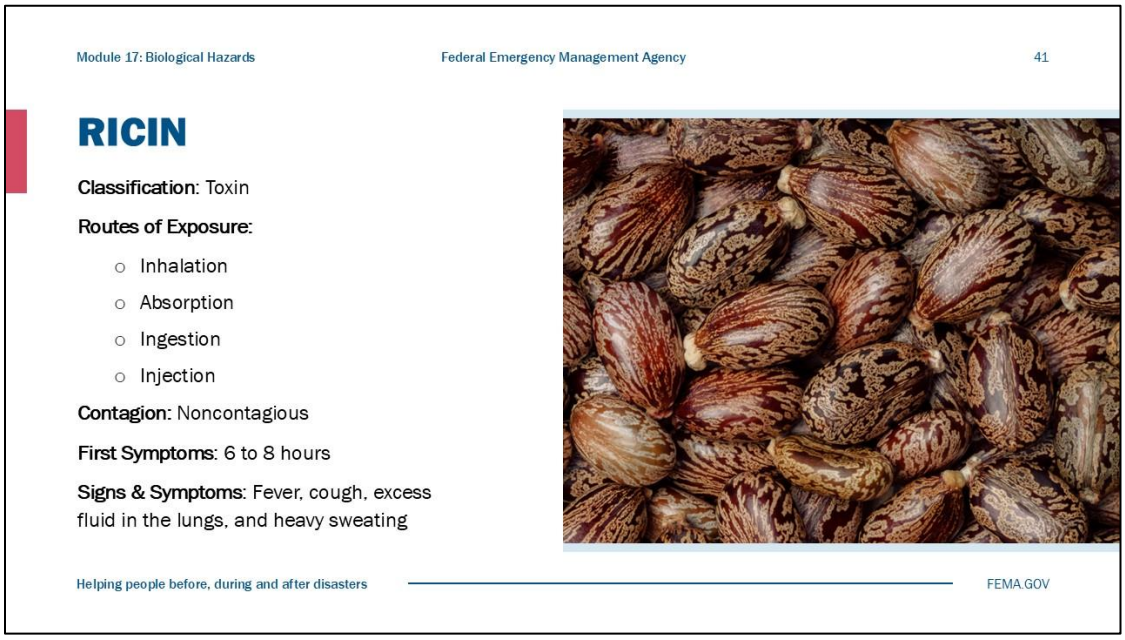
- The first symptoms of smallpox include fever, malaise, head and body aches, and sometimes vomiting. The fever is usually high (2 to 4 days duration).
- This stage is followed by a rash sequence (about 21 days, during which the person is quite contagious) that includes the emergence of mouth sores, skin rash, formation of blisters, crusting, scabbing, and scabs falling off, leaving scars.

Treatment: There is no specific treatment for smallpox disease; vaccination is the only prevention.

Bioterrorism concern: The variola virus has been eliminated except for laboratory stockpiles. The last case of smallpox in the United States was in 1949, and the last naturally occurring case in the world was in Somalia in 1977. However, the deliberate release of smallpox as an epidemic disease is a remote possibility.

(Source: CDC)

Toxins and Pathogens (7 of 14)



Slide 17-41, Ricin

Classification: Toxin

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Noncontagious

First Symptoms: 6 to 8 hours

Signs & Symptoms: Fever, cough, excess fluid in the lungs, and heavy sweating

Classification—toxin: Ricin is a poison that can be made from the waste left over from processing castor beans. Depending on the route of exposure, as little as 500 micrograms of ricin could be enough to kill an adult. A 500-microgram dose of ricin would be about the size of the head of a pin. A greater amount would likely be needed to kill people if the ricin were swallowed.

Routes of exposure: Ricin poisoning can occur through:

- Inhalation;

- Absorption;
- Ingestion; and
- Injection.

Contagion: Ricin poisoning is not contagious. It cannot be spread from person to person through casual contact.

First symptoms: Initial symptoms of ricin poisoning by inhalation (breathing in the ricin) may occur within 8 hours of exposure. Following ingestion (swallowing) of ricin, initial symptoms typically occur in less than 6 hours.

Signs and symptoms: The major symptoms of ricin poisoning depend on the route of exposure and the dose received, though many organs may be affected in severe cases.

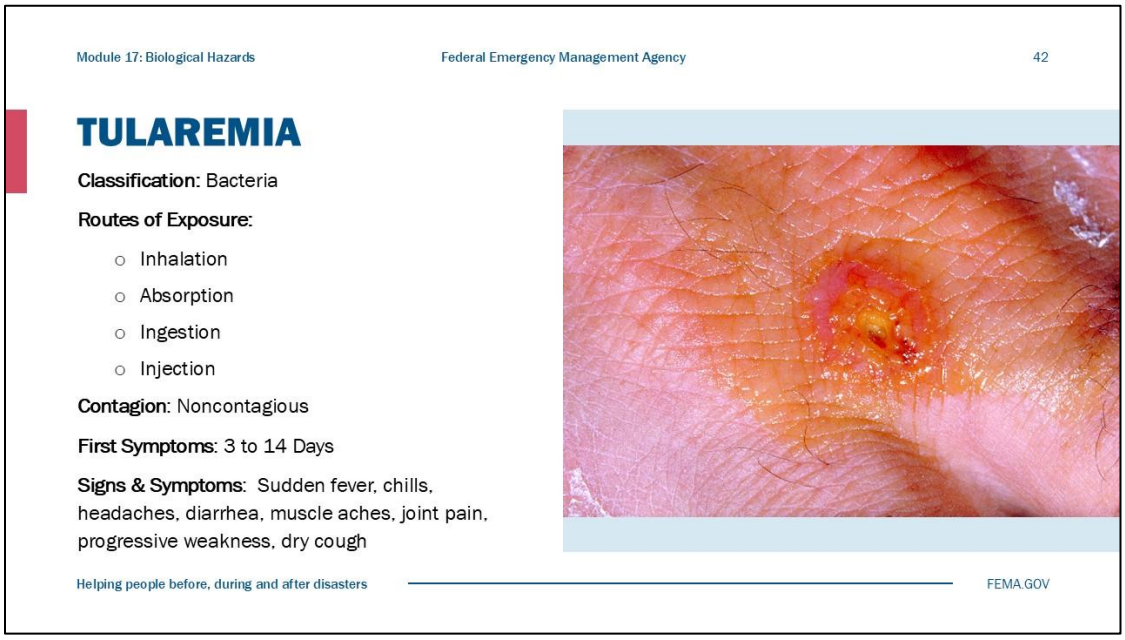
- Inhalation: Within a few hours of inhaling significant amounts of ricin, the likely symptoms would be:
  - Respiratory distress (fluid buildup in the lungs, difficulty breathing)
  - Fever, heavy sweating
  - Cough
  - Nausea
  - Tightness in the chest

Low blood pressure and respiratory failure, leading to death

- Ingestion: A person who swallowed a significant amount of ricin would develop vomiting and diarrhea that may become bloody, resulting in severe dehydration and low blood pressure. Other signs or symptoms may include hallucinations, seizures, and blood in the urine. Within several days, the person's liver, spleen, and kidneys might stop working, and the person could die.
- Absorption: Ricin in powder or mist form can cause redness and pain in the skin and eyes.

Death from ricin poisoning could take place within 36 to 72 hours of exposure, depending on the route of exposure and the dose received. If death has not occurred in 3 to 5 days, the victim usually recovers.

Toxins and Pathogens (8 of 14)



Slide 17-42, Tularemia

Classification: Bacteria

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Noncontagious

First Symptoms: 3 to 14 Days

Signs & Symptoms: Sudden fever, chills, headaches, diarrhea, muscle aches, joint pain, progressive weakness, dry cough.

Classification—bacteria: Tularemia is a potentially serious illness that occurs naturally in the United States. It is caused by the bacterium Francisella tularensis found in animals (especially rodents, rabbits, and hares).

Routes of exposure: People can get tularemia in many different ways:

- Inhalation: Breathing in contaminated dusts or aerosols
- Absorption-skin or eye: Handling infected animal carcasses
- Ingestion: Eating or drinking contaminated food or water
- Injection: Being bitten by an infected tick, deerfly, or other insect

First symptoms: Symptoms usually appear 3 to 5 days after exposure to the bacteria, but can take as long as 14 days.

Contagion: Although the bacterium that causes tularemia is highly infectious, tularemia is not known to be spread from person to person. People who have tularemia do not need to be isolated.

Signs and symptoms: Symptoms of tularemia vary with the route of exposure and can include:

- Sudden fever, chills, and headaches
- Diarrhea
- Muscle aches, joint pain
- Dry cough
- Progressive weakness

People can also catch pneumonia and develop chest pain, bloody sputum, and difficulty breathing.

Other symptoms of tularemia depend on how a person was exposed to the tularemia bacteria. These symptoms can include ulcers on the skin or mouth, swollen and painful lymph glands, swollen and painful eyes, and a sore throat.

Treatment: Tularemia is treated with antibiotics. People who have been exposed to the tularemia bacteria should be treated as soon as possible. The disease can be fatal if it is not treated with the right antibiotics.

Bioterrorism concern: The bacteria that cause tularemia occur widely in nature and could be isolated and grown in quantity in a laboratory, although manufacturing an effective aerosol weapon would require considerable sophistication. Because Francisella tularensis is infectious, a small number (10-50 organisms) can cause disease. If Francisella tularensis were used as a weapon, the bacteria would likely be made airborne for exposure by inhalation.

(Source: CDC)

Toxins and Pathogens (9 of 14)



Slide 17-43, Viral Hemorrhagic Fevers

Classification: Virus

Routes of Exposure:

- Inhalation
- Absorption
- Ingestion
- Injection

Contagion: Contagious

First Symptoms: 3 to 21 Days

Signs & Symptoms: Fever, fatigue, dizziness, muscle aches, loss of strength, exhaustion, bleeding under skin and within organs, shock, nervous system malfunction, coma, delirium, and seizures

Classification—virus: Viral hemorrhagic fevers (VHFs) refer to a group of illnesses that several distinct families of viruses cause. In general, the term "viral hemorrhagic fever" is used to describe a severe multisystem syndrome (multisystem in that multiple organ systems in the body are affected).

Examples of VHFs include:

- Ebola
- Marburg
- Hantavirus
- Lassa fever
- Crimean-Congo hemorrhagic fever
- Tick-borne encephalitis

Viruses associated with most VHFs are zoonotic, meaning they naturally reside in an animal host or arthropod (e.g., flea, tick, or mosquito) vector and can cross over to humans.

Routes of exposure: Routes of exposure for VHFs include:

- Inhalation: Breathing air contaminated with the virus (e.g., when rodent urine, droppings, or nesting materials are stirred up)
- Absorption: For example, contact with infected rodent urine, feces, saliva, or other body excretions, or close contact with infected people or their body fluids.
- Ingestion: Eating food contaminated by urine, droppings, or saliva from an infected host.
- Injection: From mosquitoes, tick bites, or contaminated syringes and needles. Vectors may also spread the virus to animals (e.g., livestock). Humans then become infected when they care for or slaughter the animals.

Contagion: Some viruses that cause hemorrhagic fever, such as Ebola, Marburg, Lassa, and Crimean-Congo hemorrhagic fever, can spread from one person to another once an initial person has become infected.

First symptoms: The Onset of symptoms varies with the disease. For example, the incubation period for Ebola is 3-21 days; for Marburg, 5-10 days; for hantavirus, symptoms may appear in 1-5 weeks.

Signs and symptoms: Specific signs and symptoms vary by the type of VHF, but initial signs and symptoms often include:

- Marked fever
- Fatigue
- Dizziness
- Muscle aches
- Loss of strength
- Exhaustion

Patients with severe cases of VHF often show signs of bleeding under the skin, in internal organs, or from body orifices like the mouth, eyes, or ears. However, patients rarely die because of blood loss. Severely ill patients may also show shock, nervous system malfunction, coma, delirium, seizures, and kidney failure. Lassa fever can cause deafness.

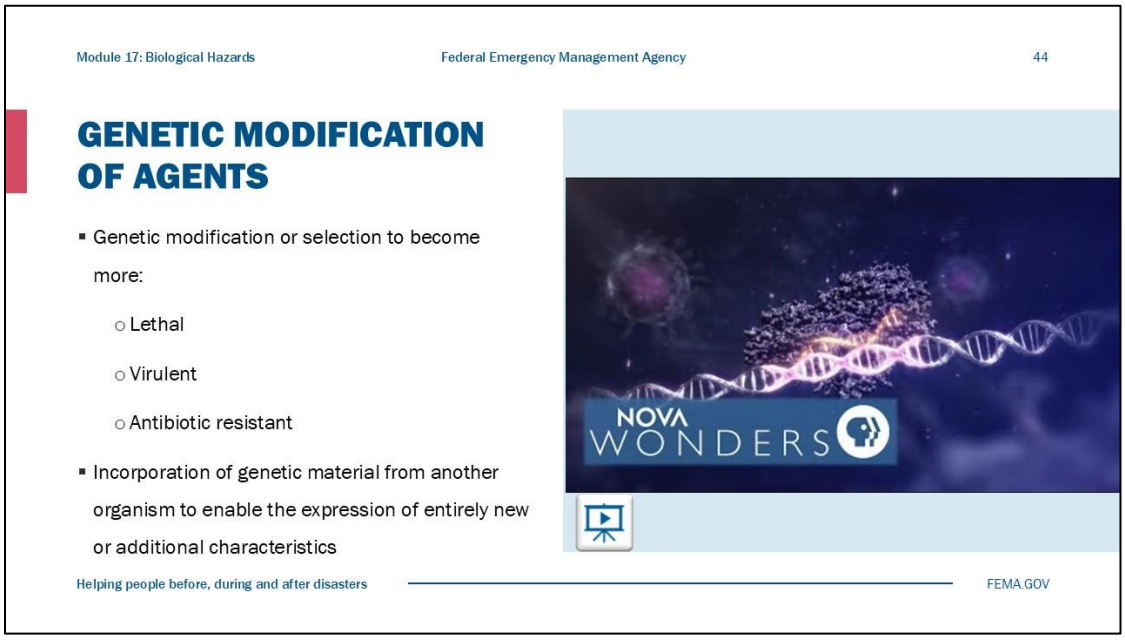
Ebola Vaccine

The U.S. Food and Drug Administration (FDA) approved the Ebola vaccine rVSV-ZEBOV (tradename "Ervebo") on December 19, 2019. The rVSV-ZEBOV vaccine is a single-dose vaccine regimen that has been found to be safe and protective against only the Zaire ebolavirus species of ebolavirus. This is the first FDA approval of a vaccine for Ebola.

Another investigational vaccine was developed and introduced under a research protocol in 2019 to combat an Ebola outbreak in the Democratic Republic of Congo. This vaccine leverages two different vaccine components (Ad26.ZEBOV and MVA-BN-Filo) and requires two doses with an initial dose followed by a second "booster" dose 56 days later. The second vaccine is also designed to protect against only the Zaire ebolavirus species of Ebola.

(Source: CDC)

Toxins and Pathogens (10 of 14)



Slide 17-44, Genetic Modification of Agents

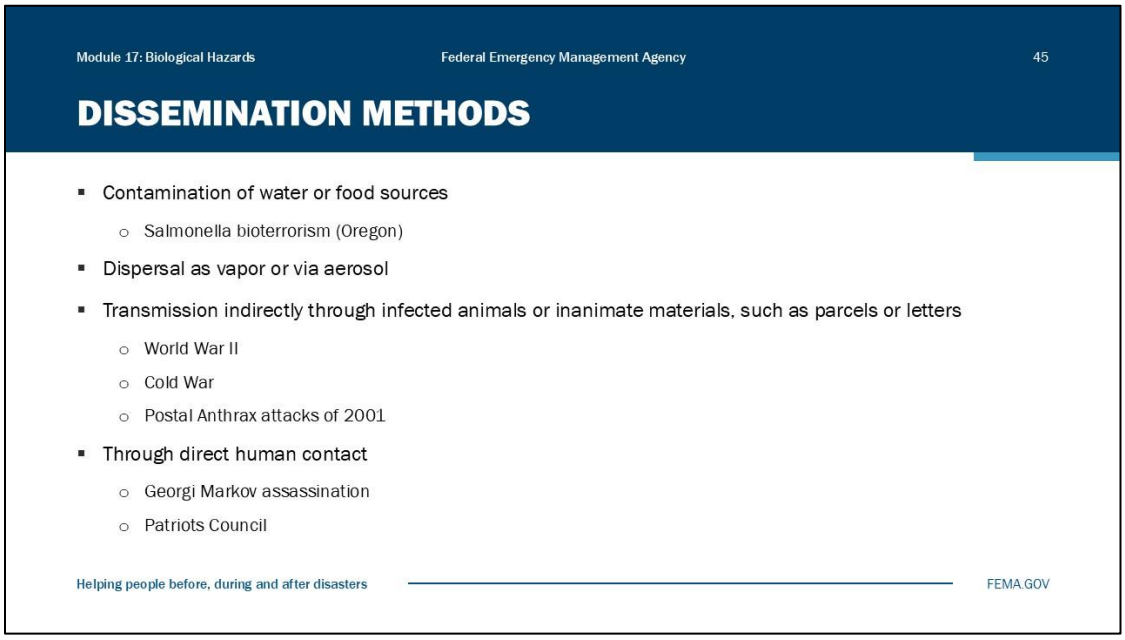
- Genetic modification or selection to become more:
  - Lethal
  - Virulent
  - Antibiotic resistant
- Incorporation of genetic material from another organism to enable the expression of entirely new or additional characteristics.

Biological agents can be altered genetically to make them more effective weapons. A terrorist's goals for genetic modification of organisms may include:

- Making them more lethal or virulent
- Making diagnosis difficult by altering the clinical signs or symptoms
- Making the pathogen resistant to vaccine protection or treatment

Genetically modified organisms are also of concern because, due to their hardiness and rapid reproductive rates, genetically modified crops released into agricultural systems could invade natural ecosystems.

Toxins and Pathogens (11 of 14)



Slide 17-45, Dissemination Methods

- Contamination of water or food sources
  - Salmonella bioterrorism (Oregon)
- Dispersal as vapor or via aerosol
- Transmission indirectly through infected animals or inanimate materials, such as parcels or letters
  - World War II
  - Cold War
  - Postal Anthrax attacks of 2001
- Through direct human contact
  - Georgi Markov assassination
  - Patriots Council

Specialists agree that for mass destruction purposes, effective delivery of a biological agent is more problematic than its production. Means of dissemination may include the following:

- **Contamination of water supply**: Poisoning a large water supply is virtually impossible. Most lethal biological agents become less viable when transmitted in water and would be further debilitated by the purification system.
- **Contamination of food sources**: Foods are at risk of contamination. According to the CDC, unintentional foodborne diseases cause about 5,000 deaths and 325,000 hospitalizations each year.

In 1984, members of an Oregon religious commune–followers of Bhagwan Shree Rajneesh–tried to influence a local election by poisoning salad bars with Salmonella bacteria to sicken voters.

Although no one died, 751 people became ill. The Oregon attack occurred at local restaurants, but an attack could occur at any point between farm and table. Imported food could be tainted with biological or chemical agents before entering the United States, or toxins could be introduced at a domestic food-processing plant.

- **Aerosolization**: The aerosol dissemination of a biological agent is difficult. To work, the agent in suspension would need to be small (< 5m) particles or droplets in the air, and the agent must survive long enough to infect the intended target. Factors such as mechanical stresses in the aerosolization process, moisture, sunlight, temperature changes, and others may reduce the amount or strength of the agent. The most successful aerosolization transmission occurs naturally through coughing, sneezing, talking, or breathing. Spreading a chemical agent in a vapor or aerosol is more feasible.
- **Infected animals and insects**: The release of infected rats, insects, etc., could spread certain diseases to a target location. The animals and insects act as a vector, infecting any person or animal they might bite. The Japanese experimented with plague-infected fleas and cholera-coated flies during World War II. During the Cold War, the United States conducted research on the use of yellow fever-infected mosquitoes.
- **Inanimate materials:** Some pathogens and toxins are able to survive on inanimate objects. For example, the smallpox virus lives longer in scabs than in the droplets spread from person to person. According to Dr. Inger Damon, a researcher and epidemiologist at the CDC, viruses stored in a smallpox scab in a humidity-controlled location can survive for a year or longer. The postal anthrax attacks of 2001-the worst biological attacks in

U.S. history is another example of inanimate objects being used to transmit a biological threat.

Human contact: Ricin was used in the assassination of Bulgarian dissenter Georgi Markov, who died several days after being jabbed by a poison-tipped umbrella injector designed by the Soviet intelligence agency KGB. In Minnesota, four members of the Patriots Council planned to mix the ricin with the solvent dimethyl sulfoxide and then smear it on the door handles of a U.S. Marshal's vehicle. The plan was discovered and averted, and the men were convicted.

Toxins and Pathogens (12 of 14)



Slide 17-46, Agricultural Bioterrorism

- Intentional use of biologicals (toxins, pathogens, or pests) against some component of the agriculture industry
- Include natural resources, crops, livestock, and wildlife

An intentional release of foot and mouth disease (FMD) could result in $30 billion in lost trade, and a simple fungus called "soybean rust" could result in an $8 billion loss.

The U.S. Department of Agriculture defines **agricultural bioterrorism** as "the intentional use of biologicals (toxins, pathogens, or pests) against some component of agriculture in such a way as to adversely impact the agriculture industry or any component thereof, the economy, or the consuming public."

- An act of agricultural terrorism causing billions of dollars in damage could be produced by a limited infection of pathogens delivered by simple methods.
- There are fewer controls monitoring the possession of microorganisms that infect only plants or livestock, compared to those that infect humans.
- Terrorist attacks on agriculture are difficult to distinguish from naturally occurring outbreaks.

History: The United States has not experienced a major agricultural disaster in recent memory. However, history is full of examples of intentional introductions of pests and diseases.

- During World War I, Germany used anthrax and glanders to target horses, mules, cattle, sheep, and reindeer in the United States, Romania, Spain, France, Norway, and Argentina. By World War II, Japan, Russia, Great Britain, France, and the United States had active biological weapons programs. The United States began its weapons program in response to the threat posed by other countries.
- In more recent times, Rhodesian and South African forces used anthrax to target cattle. In addition to thousands of cattle dying, there were more than 10,000 human cases with 334 known deaths.
- In 1997, New Zealand farmers, dissatisfied with the Government's lack of action in controlling the exploding rabbit population, developed simple methods for extracting and concentrating particles of viral hemorrhagic fever, which they used to contaminate carrots and other food sources for rabbits. The plan experienced limited effectiveness.

Potential impact: The impact of an intentional introduction of foot and mouth disease (FMD) would be staggering. The sheer numbers of livestock and wildlife at risk are enormous: 100 million cattle, 70 million swine, 10 million sheep, and 40 million wildlife.

Consumers would feel the consequences of a major attack on the livestock industry almost immediately. No major city has more than a 7-day supply of food. Such an attack could easily cause widespread fear and panic and undermine public confidence in the government. The economic costs could potentially be devastating, resulting in a loss of billions in trade, and costs for diagnostics, surveillance, slaughter, cleaning, disinfection, and indemnities.

An attack on crops would have a similar impact. Plant targets include:

- Food crops:
  - Corn
  - Wheat
  - Soybeans
  - Citrus
  - Sugarcane

- Fiber:
  - Cotton
- Timber:
  - Northwest United States

The threat posed by soybean rust (one of the select agents) alone is estimated at $8 billion if it enters the mainland United States. Soybean rust causes huge production losses in Asia and South America. It is present in Hawaii and Puerto Rico.

Toxins and Pathogens (13 of 14)

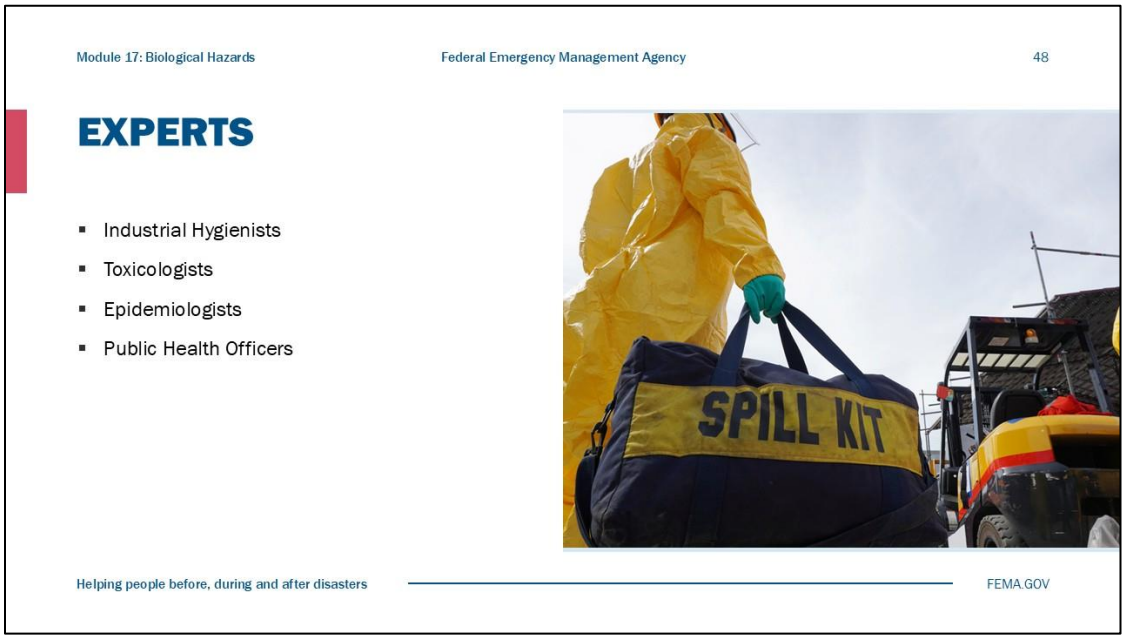


Slide 17-47, Agricultural Vulnerabilities

The following factors make U.S. agriculture susceptible to bioterrorism:

- **Concentrated targets**. Livestock and crops are found in concentrated areas throughout the United States.
- **Business practices**. Large agribusiness companies control production, processing, and distribution, making the spread of pathogens easier.
- **Security challenges**. Farm biosecurity measures must cover a vast area (considering 6,000 miles of national borders and almost a billion acres of farmland).
- **Reduced genetic variety**. As crops and animals become more similar in their genetic makeup, they become more susceptible to a single pathogen.
- **Lack of immunity**. The absence of foreign animal diseases means that our livestock have no natural immunity to many diseases.
- **Resistant pathogens**. Widespread use of antibiotics can make livestock susceptible to resistant strains of pathogens. Pesticide use may create resistant strains of exotic plant pests.

Toxins and Pathogens (14 of 14)



Slide 17-48, Experts

- Industrial Hygienists
- Toxicologists
- Epidemiologists
- Public Health Officers

A variety of experts are working to better understand biological threats and develop strategies for controlling them. The following are some of them:

- **Industrial hygienists** use environmental monitoring and analytical methods to anticipate, recognize, evaluate, and control workplace conditions that may cause worker injury or illness.
- **Toxicologists** plan and carry out laboratory and field studies to identify, monitor, and evaluate the impact of toxic materials and radiation on human and animal health, the surroundings, and the impact of future technology.
  - In general, toxicologists:
    - Conduct laboratory studies on substances (e.g., drugs, food additives, solvents, herbicides) or on energy (e.g., radiation) to determine their effects on laboratory animals, plants, and human tissue.

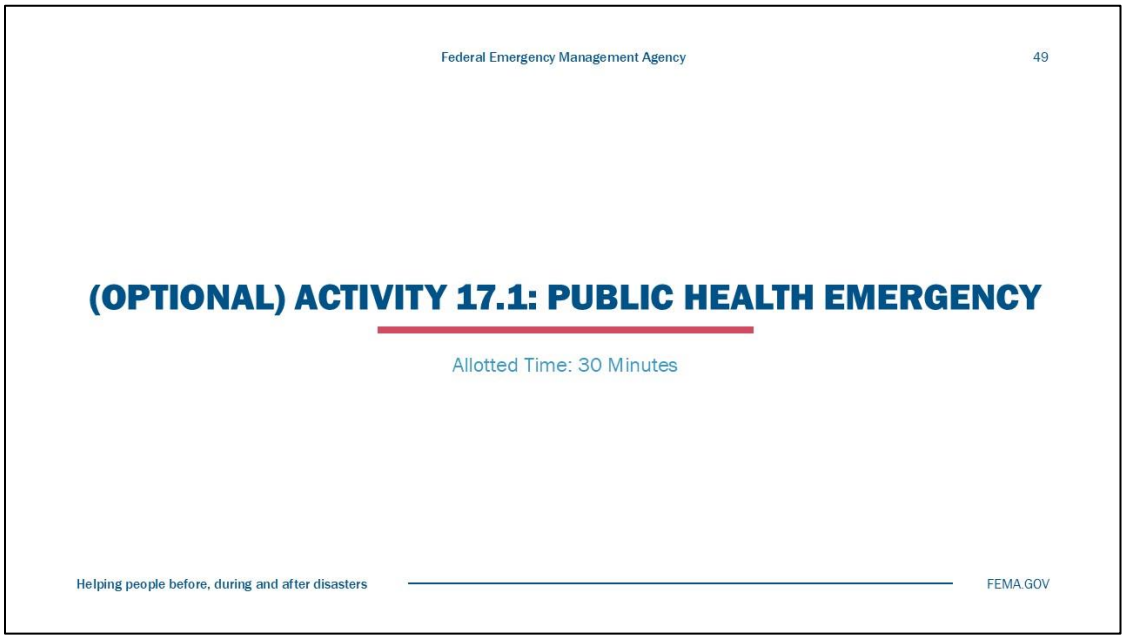
- Conduct research to develop new tests for use in toxicological studies.
- Evaluate potential risks based on levels and periods of exposure.
- Analyze and evaluate data gathered from studies and reliable scientific publications to determine appropriate controls for various chemical and physical hazards.
- Develop standards or guidelines for safe levels of chemical and physical agents in workplaces, air, food, or drinking water.
- Provide advice and scientific information to policy and program developers concerning the health and legal aspects of chemical use.

- **Epidemiologists** investigate and describe the determinants and distribution of disease, disability, or health outcomes. Epidemiologists may:
  - Develop or refine methods of measuring and evaluating disease occurrences.
  - Develop and recommend public health policy.
  - Study chronic diseases, infectious diseases, disease outbreaks, injuries, occupations, and environments.
  - Develop the means for prevention and control.
- **Public Health Officers** protect and improve the health of families and communities by promoting healthy lifestyles, conducting research for disease and injury prevention, and detecting and controlling infectious diseases. Overall, public health is concerned with protecting the health of entire populations using methods such as implementing educational programs, recommending policies, administering services, and conducting research. Public health officials also work to limit health disparities by promoting healthcare parity, quality, and availability.

Local public health officers may:

- Make periodic sanitary inspections of school buildings, restaurants, dairies, grocery stores, meat markets, and public gathering places.
- Disseminate information on the causes, nature, and prevention of prevalent diseases and on preserving and improving health.
- Enforce the health laws, rules, and regulations of the State Board of Health, the State, and the city, including the laws relating to contagious diseases.
- Take steps to secure prompt and full physician reports of communicable diseases and prompt and full registration of births and deaths.

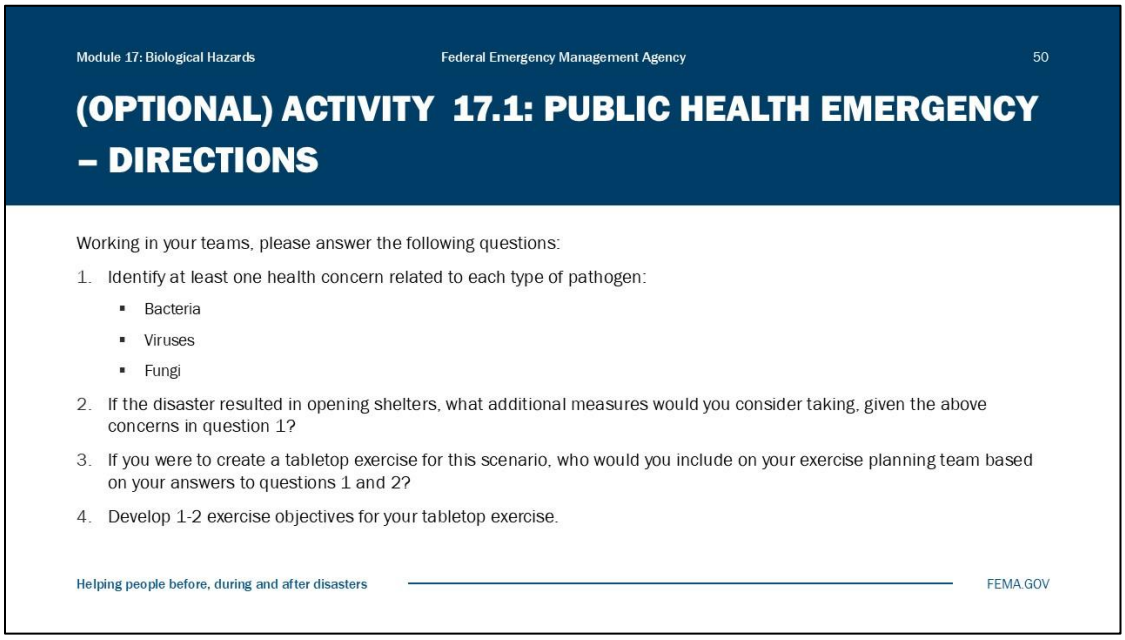
(Optional) Activity 17.1: Public Health Emergency (1 of 2)



Slide 17-49, (Optional) Activity 17.1: Public Health Emergency

Not Applicable.

(Optional) Activity 17.1: Public Health Emergency (2 of 2)



Slide 17-50, (Optional) Activity 17.1: Public Health Emergency - Directions

Activity 17.1: Public Health Emergency – Directions to Students

Scenario

In October 2012, Hurricane Sandy struck the Northeast, causing major flooding, disruption, structural damage, and power outages.

Instructions

Working in your teams, please answer the following questions:

1. Identify at least one health concern related to each type of pathogen:
    a. Bacteria:

    b. Viruses:

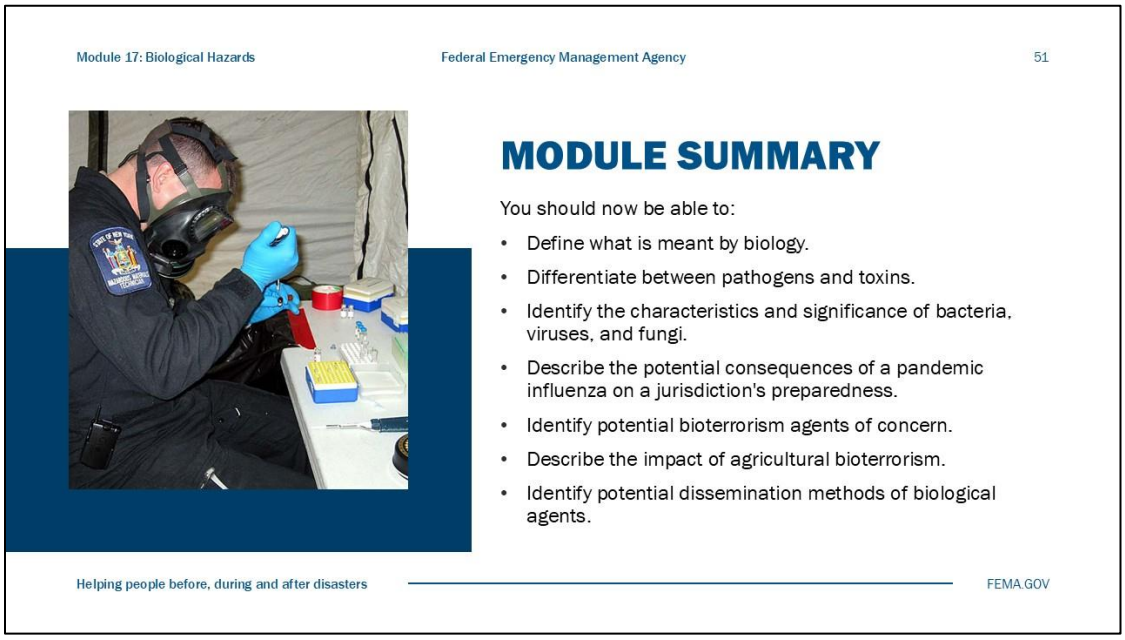
c. Fungi:

2. If the disaster resulted in opening shelters, what additional measures would you consider taking, given the above concerns in question 1?

3. If you were to create a tabletop exercise for this scenario, who would you include on your exercise planning team based on your answers to questions 1 and 2?

4. Develop 1-2 exercise objectives for your tabletop exercise.

End of Module (1 of 2)



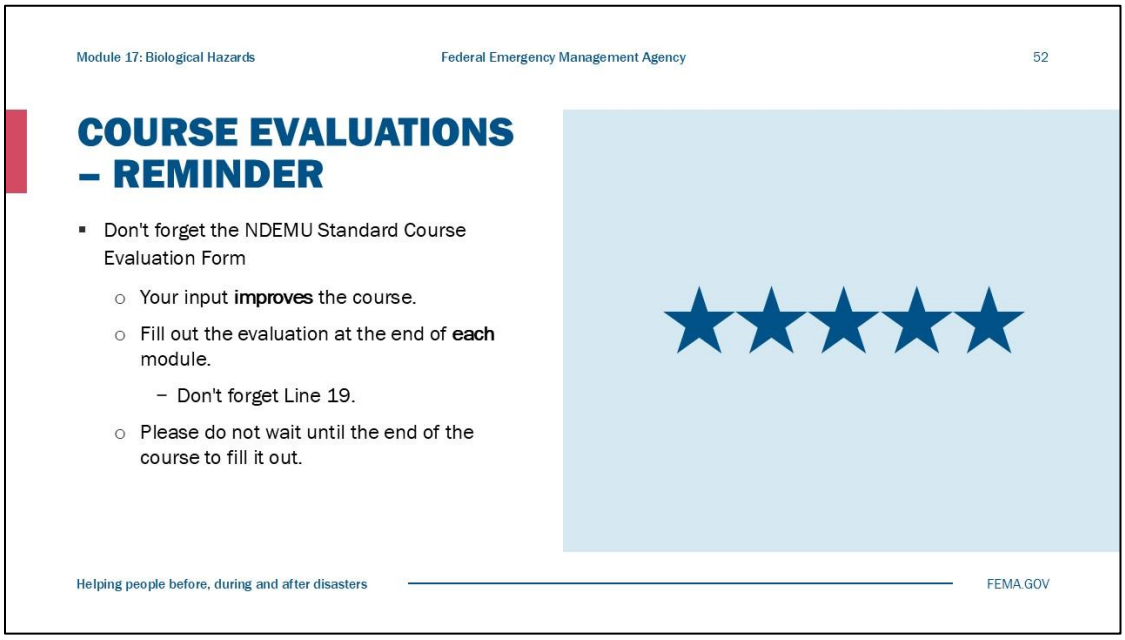
Slide 17-51, Module Summary

MODULE SUMMARY

You should now be able to:

- Define what is meant by biology.
- Differentiate between pathogens and toxins.
- Identify the characteristics and significance of bacteria, viruses, and fungi.
- Describe the potential consequences of a pandemic influenza on a jurisdiction's preparedness.
- Identify potential bioterrorism agents of concern.
- Describe the impact of agricultural bioterrorism.
- Identify potential dissemination methods of biological agents.

End of Module (2 of 2)



Slide 17-52, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

Past Outbreaks of Avian Influenza in North America (https://www.cdc.gov/flu/avianflu/past-outbreaks.htm)

United States Department of Agriculture's Animal and Plant Health Inspection (www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease- information/avian)

CDC. (2025, September 5). *H5N1 Bird Flu Surveillance and Human Monitoring*. Avian Influenza (Bird Flu). https://www.cdc.gov/bird-flu/h5-monitoring/index.html

World Health Organization (WHO) (https://www.who.int/teams/global-influenza-programme/surveillance-and- monitoring)

World Organization for Animal Health (OIE) (https://www.oie.int/en/disease/avian-influenza/)

H5 Bird Flu: Current Situation (https://www.cdc.gov/bird-flu/situation-summary/index.html)

Final Report for the 2014–2015 Outbreak of Highly Pathogenic Avian Influenza (HPAI) in the United States (https://www.aphis.usda.gov/animal_health/emergency_management/downloads/hpai/2015-hpai- final-report.pdf).

World Health Organization (https://www.who.int/health-topics/coronavirus)

https://www.cdc.gov/sars/index.html or at Johns Hopkins University and Medicine: https://coronavirus.jhu.edu/.

CDC (https://www.cdc.gov/norovirus/about/index.html

CDC Prevent Mosquito Bites (https://www.cdc.gov/mosquitoes/mosquito-bites/prevent- mosquito-bites.html)

EPA search tool (http://www.epa.gov/insect-repellents/find-repellent-right-you)

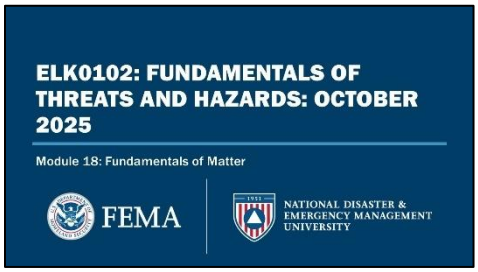
Technical expertise may be found at the following: Centers for Disease Control (CDC) (https://www.cdc.gov/)

Health and Human Services (HHS) (https://www.hhs.gov/)

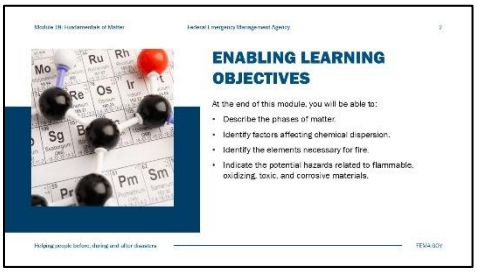
Assistant Secretary for Preparedness and Response/Technical Resources Assistance Center and Information Exchange (ASPR/TRACIE) (https://asprtracie.hhs.gov/)

Module
18
Fundamentals of Matter

Administration



Slide 18-1, Module 18: Fundamentals of Matter



Slide 18-2, Enabling Learning Objectives

Duration

1 hour

Terminal Learning Objective (TLO)

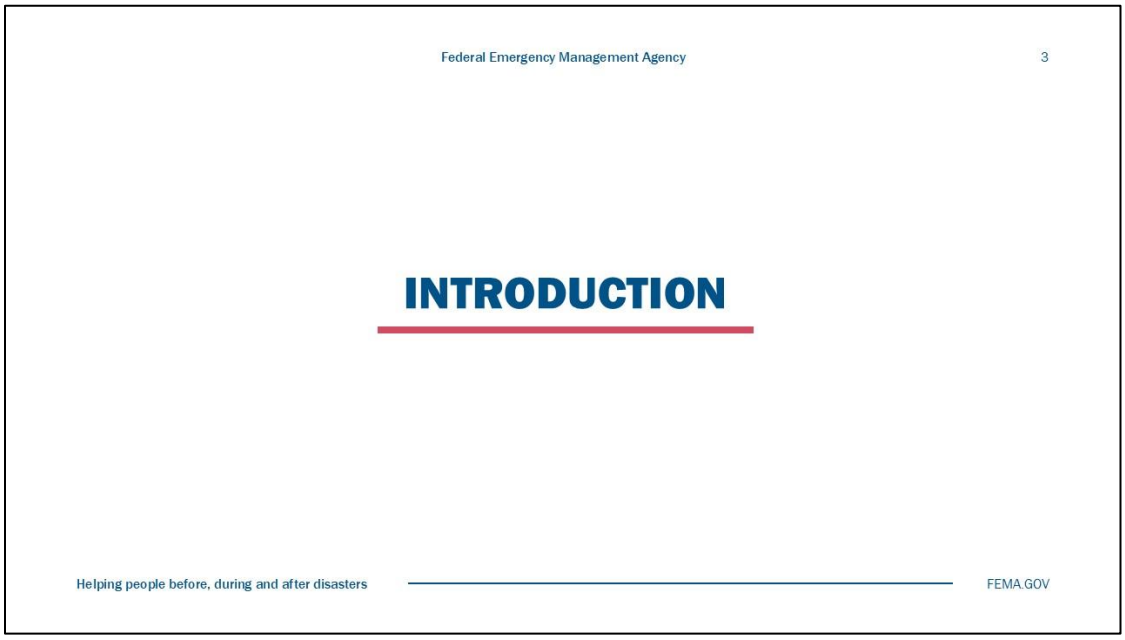
By the end of this module, participants will be able to demonstrate an understanding of basic chemical principles, including atomic structure, isotopes, and chemical reactions, and apply this knowledge to assess the potential hazards and threats associated with chemical, radiological, and explosive materials.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Describe the phases of matter.
- Identify factors affecting chemical dispersion.
- Identify the elements necessary for fire.
- Indicate the potential hazards related to flammable, oxidizing, toxic, and corrosive materials.

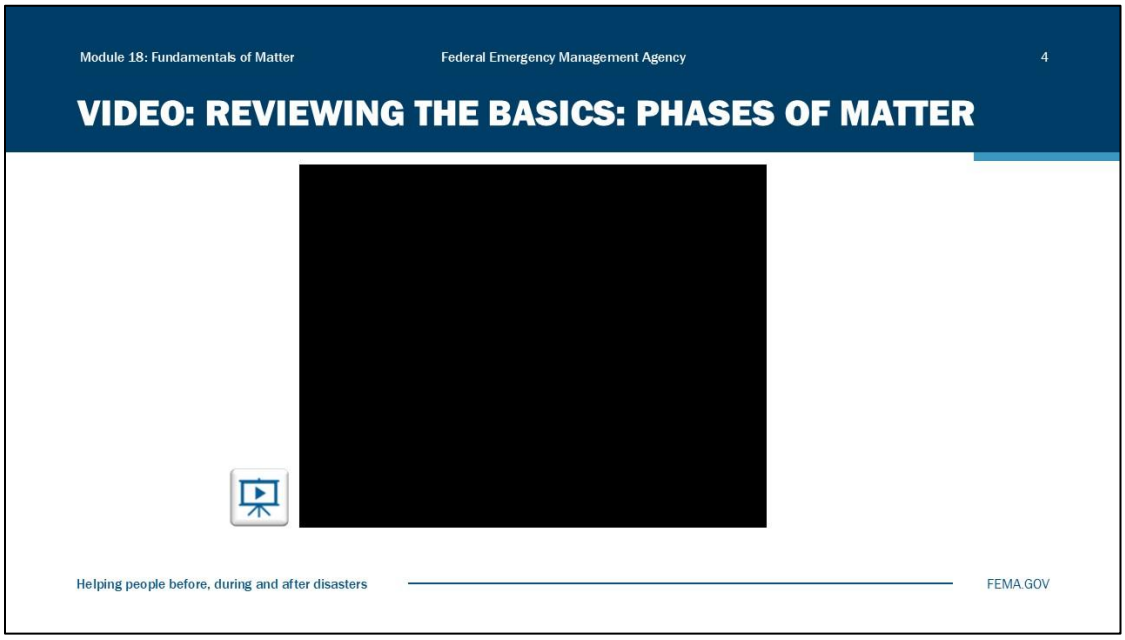
Introduction (1 of 2)



Slide 18-3, Introduction

Not Applicable.

Introduction (2 of 2)

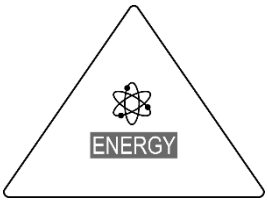


Slide 18-4, Video: Reviewing the Basics: Phases of Matter

Watch this video about the physical and chemical changes that matter can undergo.

Video: Reviewing the Basics: Phases of Matter

This is energy.



Introduction: Matter can exist in different phases (also known as states): solid, liquid, or gas. Most substances can transition between these phases depending on the amount of heat the material absorbs (or loses). This video will discuss the phases of matter and how they can change.

Video Transcript:

Phases of Matter

The phases of matter are:

- Solid—which has a definite shape and volume;
- Liquid—which has a definite volume, but it can change shape; and
- Gas— shape and volume of a gas can change.

Phase Changes of Matter

There are several ways in which phases of matter can change from one to another:

- **Melting** occurs when a substance changes from a solid to a liquid.
- **Boiling** is when a substance changes from a liquid to a gas.
- **Condensing** is when a gas changes to a liquid.
- **Freezing** is when a liquid changes to a solid.

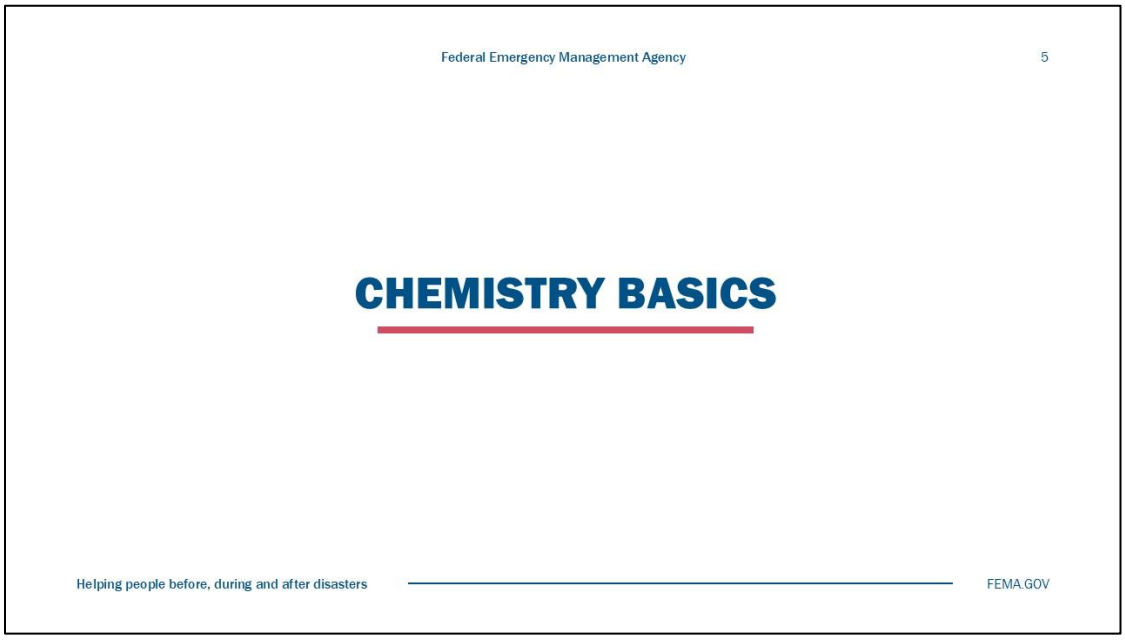
Classes of Changes in Matter

- The changes that take place in substances may be categorized into two classes:
  - Physical Change—a new substance is not produced, and only the physical properties are changed (for example, phase changes or crushing a can).
  - Chemical Change—a new substance is produced with different chemical properties (for example, burning, rusting, and photosynthesis).

Solutions

Sometimes, when two or more substances are combined, they form a solution. Making a solution can produce either a physical or chemical change. When there's a physical change in a solution, the original substances can be separated from one another. If a chemical change takes place while creating a solution, the original substances cannot be separated from one another.

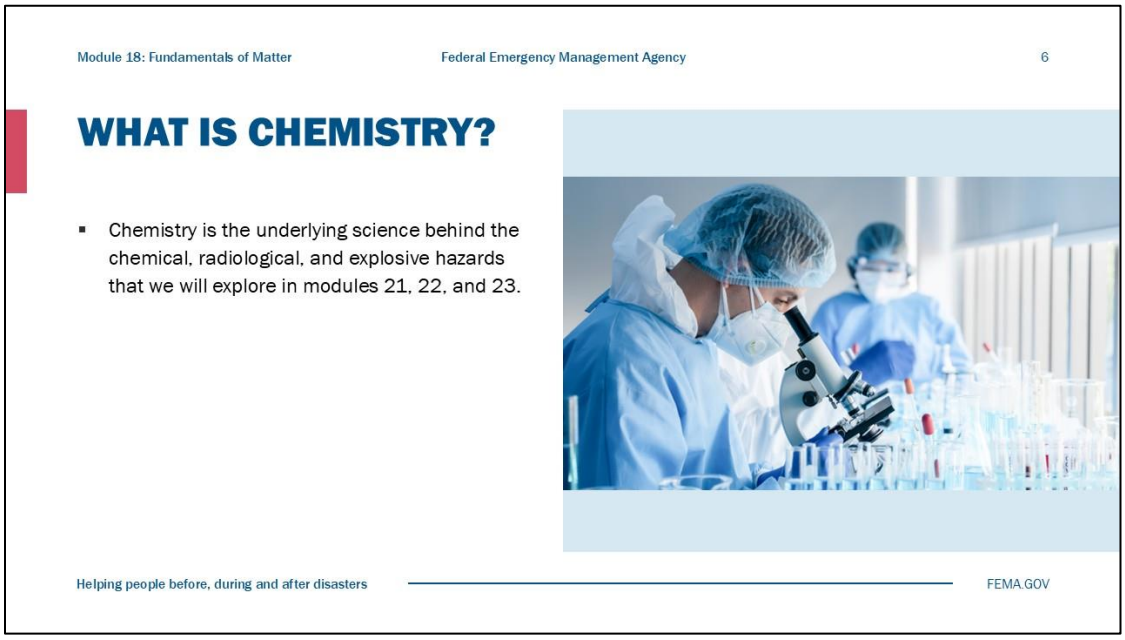
Chemistry Basics (1 of 5)



Slide 18-5, Chemistry Basics

Not Applicable.

Chemistry Basics (2 of 5)



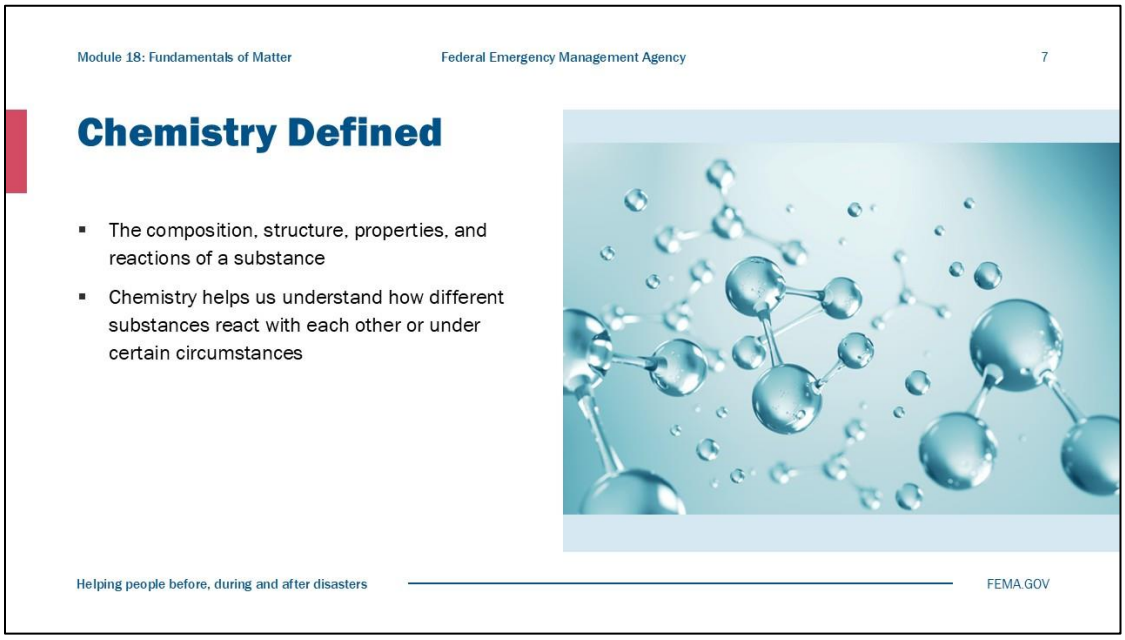
Slide 18-6, What is Chemistry?

Chemistry is the underlying science behind the chemical, radiological, and explosive hazards that we will explore in units 21, 22, and 23.

Chemistry, a branch of the physical sciences, studies the composition, structure, properties, and reactions of matter, or substances.

Understanding some basic chemical principles and processes will help you understand the potential hazards and threats associated with chemicals.

Chemistry Basics (3 of 5)

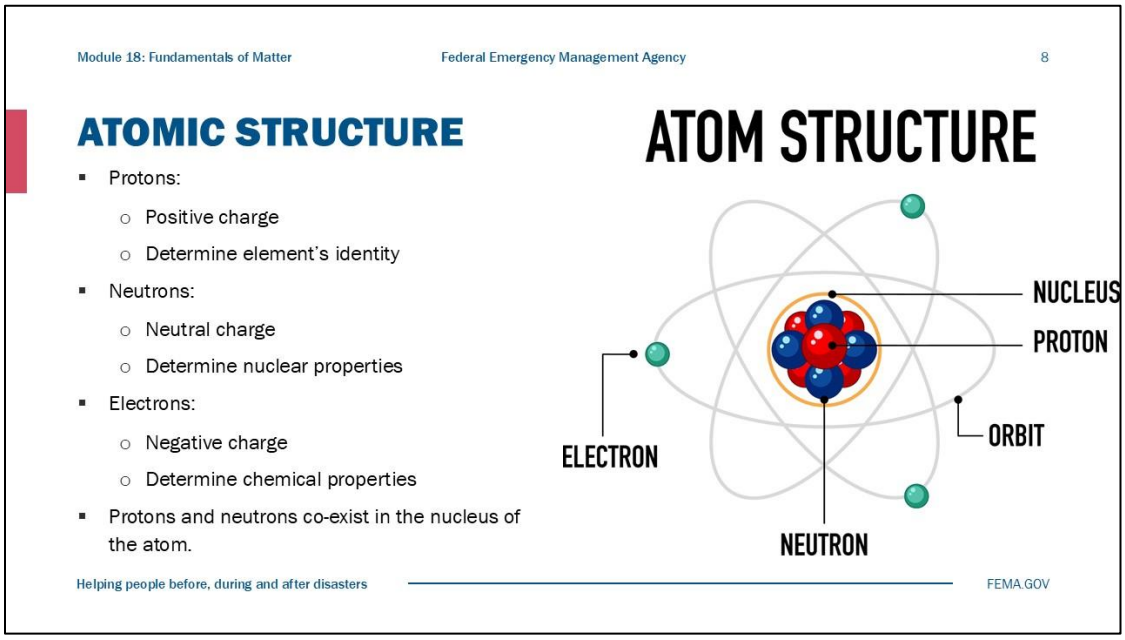


Slide 18-7, Chemistry Defined

Chemistry, a branch of the physical sciences, studies the composition, structure, properties, and reactions of matter, or substances.

Understanding some basic chemical principles and processes will help you understand the potential hazards and threats associated with chemicals.

Chemistry Basics (4 of 5)



Slide 18-8, Atomic Structure

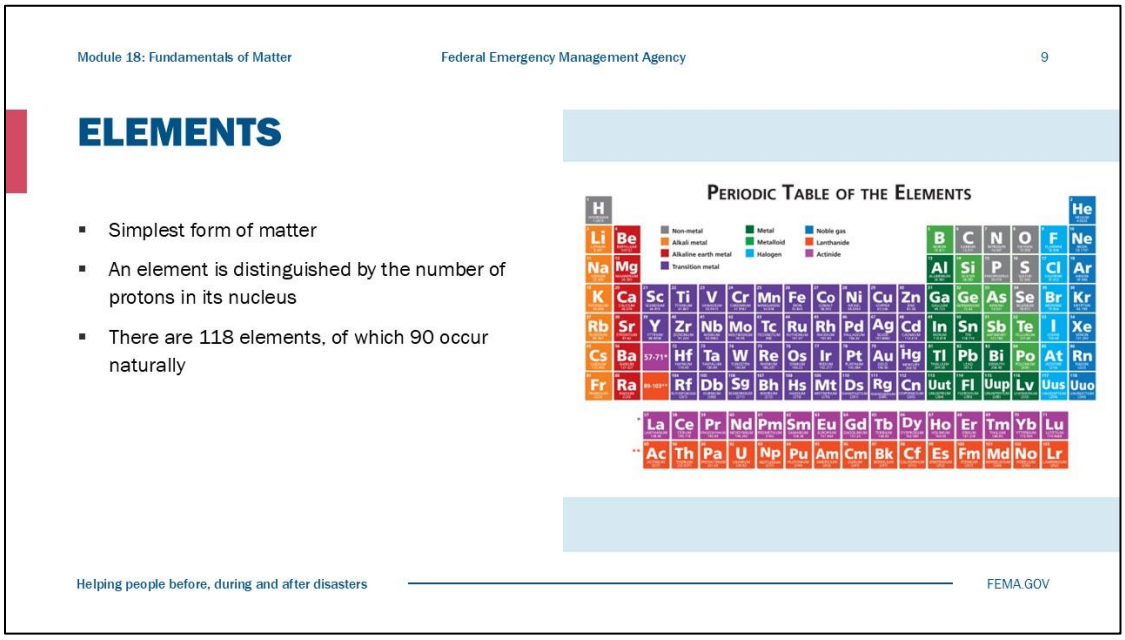
- Protons:
  - Positive charge
  - Determine the element's identity and nuclear stability
- Neutrons:
  - Neutral charge
  - Determine nuclear properties and help keep protons in the nucleus
- Electrons:
  - Negative charge
  - Determine chemical properties

The atom is made up of three fundamental parts: protons, neutrons, and electrons. Protons and neutrons are located in the center part or nucleus of the atom. Electrons revolve around the nucleus, similar to the way the planets orbit the sun.

- **Protons** have a positive electrical charge and determine the element's identity, but repel one another due to their same electrical charge.
- **Neutrons** have a neutral electrical charge and help keep the nucleus stable.

- **Electrons** have a negative electrical charge and determine the chemical properties of an atom.

Chemistry Basics (5 of 5)



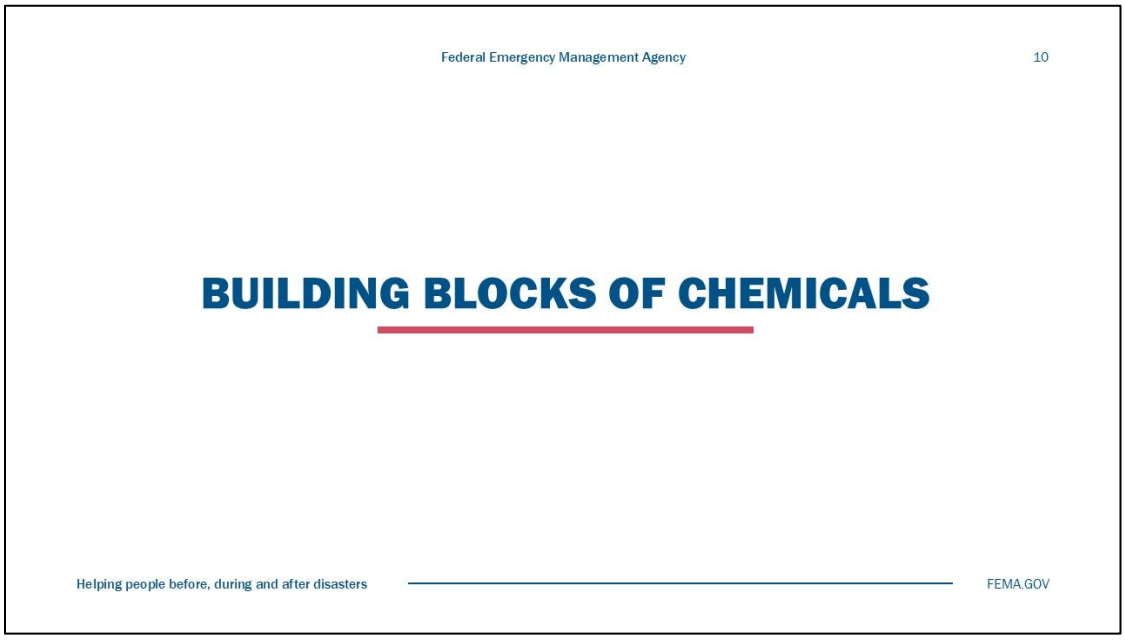
Slide 18-9, Elements

Elements are distinguished by their atomic number; that is, by the number of protons in their nucleus. The term is also used to refer to a pure chemical substance composed of atoms with the same number of protons.

The following are common examples of elements:

- Iron
- Copper
- Silver
- Gold
- Hydrogen
- Carbon
- Nitrogen
- Oxygen

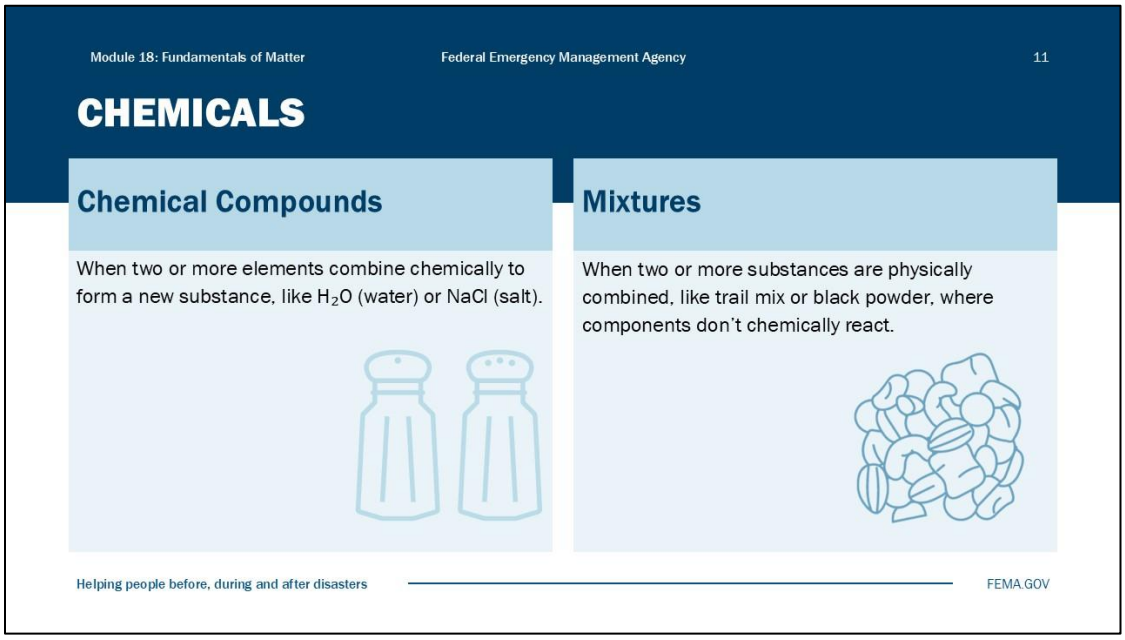
Building Blocks of Chemicals (1 of 5)



Slide 18-10, Building Block of Chemicals

Not Applicable.

Building Blocks of Chemicals (2 of 5)

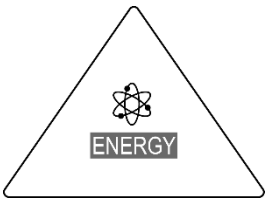


Slide 18-11, Chemicals

Next, we'll consider the building blocks of chemical substances.

- An **element**—the simplest form of matter- is a pure chemical substance consisting of one type of atom. Examples of elements are aluminum, carbon, chlorine, hydrogen, mercury, and oxygen.
- A **chemical compound** is a substance consisting of two or more elements combined or bonded together so that its constituent elements are always present in the same proportions.

This is energy.

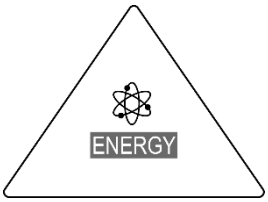


Chemical reactions combine elements into compounds. Chemical compounds are combinations of elements held together by attractive electrical forces known as chemical bonds. Molecules are chemical compounds that have two or more different elements. Common examples of molecules are

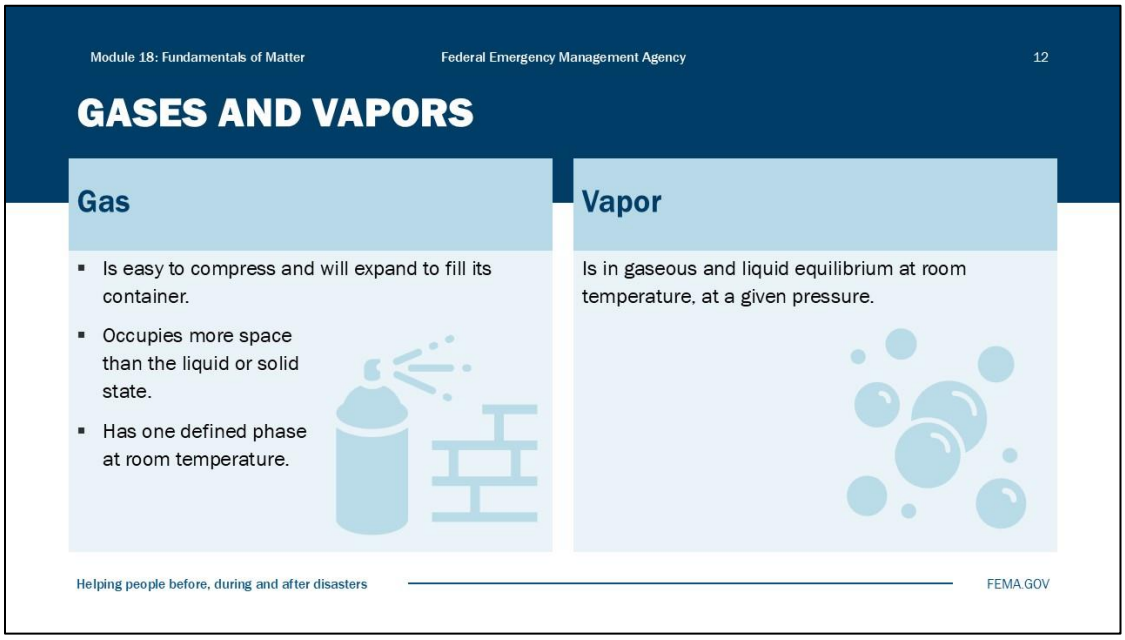
water (H_2O) and carbon dioxide (CO_2). Energy is stored in these bonds and can be released in chemical reactions.

- A compound can only be created by a chemical reaction, and the components of a compound can only be separated by a chemical reaction.
- A **mixture** is two or more chemicals added together. The combination is NOT, in whole or in part, the result of a chemical reaction. Mixtures can be created by mechanical means alone, and the constituents of a mixture can usually be separated by simple mechanical means, such as filtering, evaporation, or magnetic force.

This is energy.



Building Blocks of Chemicals (3 of 5)



Slide 18-12, Gases and Vapors

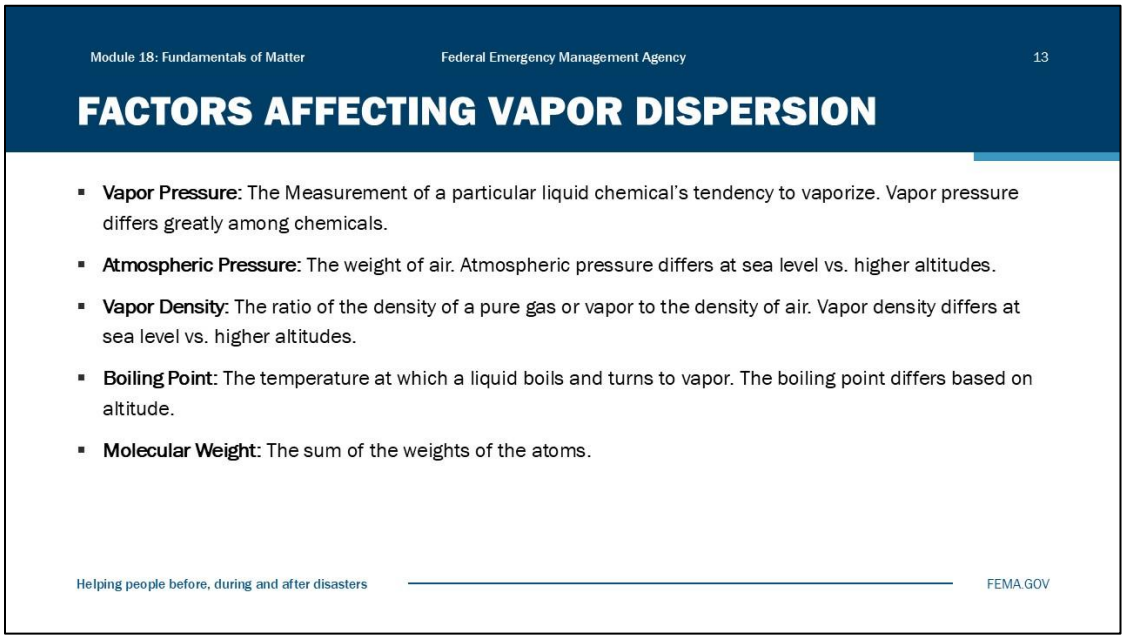
Gas: A gas has a single defined thermodynamic phase at room temperature. The molecules of a gas are in constant free motion past each other and can be compressed (also referred to as a compressible fluid). When no liquid or solid can form at the temperature of the gas, it is called a fixed gas.

Recall that in the phases of matter discussed earlier, there is a "gas phase" that does not necessarily refer to a gas as a distinct element. Rather, it represents differences in the interrelationships of molecules. A gas has its single gas particles vastly separated, making a gas invisible to the eye.

Vapor: A vapor is a mixture of two phases, gaseous and liquid, at room temperature. Vapor results from the two types of vaporization of a liquid: boiling and evaporation, causing the transition from the liquid phase to the gas phase. Evaporation occurs at the surface of the liquid when its temperature is below the boiling temperature at a given pressure. Boiling occurs below the surface of the liquid.

When a substance is at a temperature below its critical temperature, it is in a gas phase and therefore will be a vapor. A vapor can co-exist with its liquid or solid phase when they are in the equilibrium state.

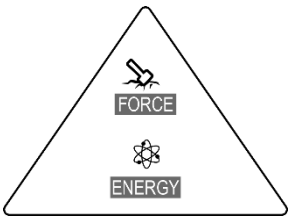
Building Blocks of Chemicals (4 of 5)



Slide 18-13, Factors Affecting Vapor Dispersion

- Vapor Pressure
- Atmospheric Pressure
- Vapor Density
- Boiling Point
- Molecular Weight

This is force and energy.



Dispersion of vapors is affected by several factors, summarized in the following table.

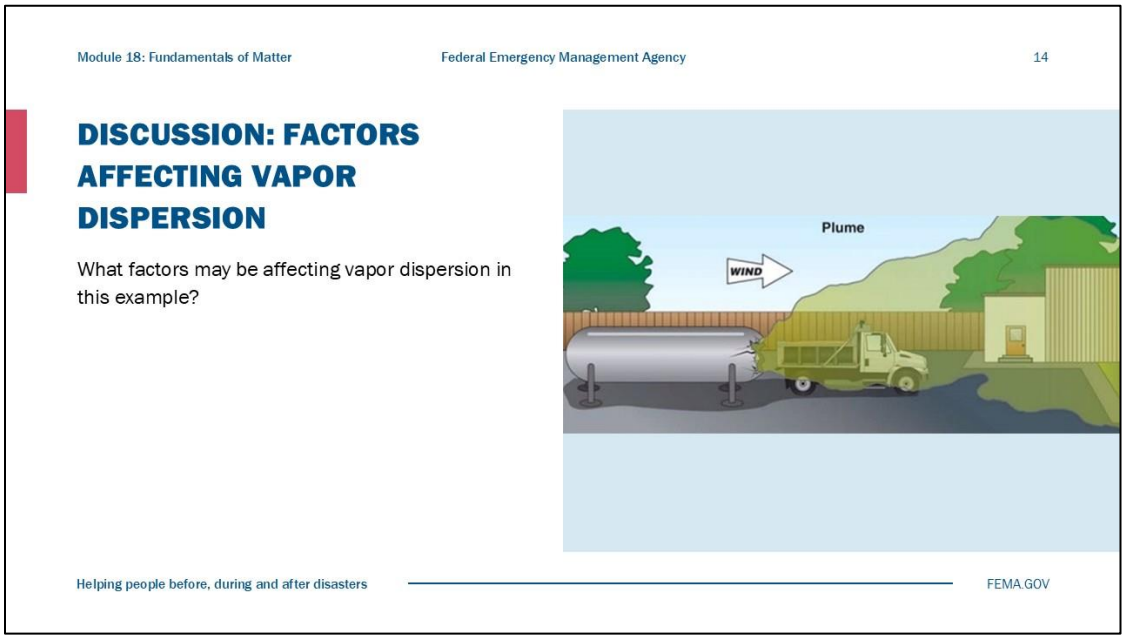
Example: Ammonia boils at -28.17 °F. If it spills, there may be a second-phase reaction, which can cause a cloud of ammonia to expand and move very quickly. Ammonia is lighter than air, and once it warms up, it tends to move up and into the atmosphere.

Factors That Affect Vapor Dispersion

Factor	Implications
Vapor pressure—The measurement of a particular liquid chemical's tendency to vaporize. Vapor pressure differs greatly among chemicals.	• Higher vapor pressure may disperse the chemical further. • Temperatures affect vaporization rate. • Amount of exposed surface affects vaporization rates.
Atmospheric pressure—The weight of air. Atmospheric pressure differs at sea level vs. higher altitudes.	• Atmospheric pressure, if high enough, may prevent a substance from going from liquid to vapor. If low enough, atmospheric pressure. • Vapors at higher elevations travel farther than at sea level. • Gas or vapor entering the atmosphere will quickly adjust its volume; upon release, a tank of liquefied gas will expand.
Vapor density—The ratio of the density of a pure gas or vapor to the density of air. Vapor density differs at sea level vs. higher altitudes.	• Lighter density vapors float away. • Higher-density vapors tend to sink.
Boiling point—The temperature at which a liquid boils and turns to vapor. The boiling point differs based on altitude.	• Heating liquids above their normal boiling points in sealed containers causes vapor pressures that may become very dangerously high; If pressure is not relieved, the container may burst or rupture. • If a spilled liquid is in a setting above its boiling point, it will rapidly boil and expand, and sometimes explode. • The lower the boiling point, the more likely the liquid will vaporize.

Factor	Implications
Molecular weight—The sum of the weights of the atoms.	• Chemicals with heavier molecular weights will evaporate and float away more slowly. • Chemicals with heavier molecular weights are more likely to move along the ground rather than upward.

Building Blocks of Chemicals (5 of 5)

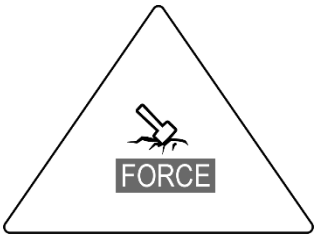


Slide 18-14, Discussion: Factors Affecting Vapor Dispersion

What factors may be affecting vapor dispersion in this example?

- Normal physical state – The physical state or form of a material at normal temperature (68°F)
- Atmospheric pressure
- Vapor pressure
- Vapor density
- The substance's molecular weight and boiling point

This is force.

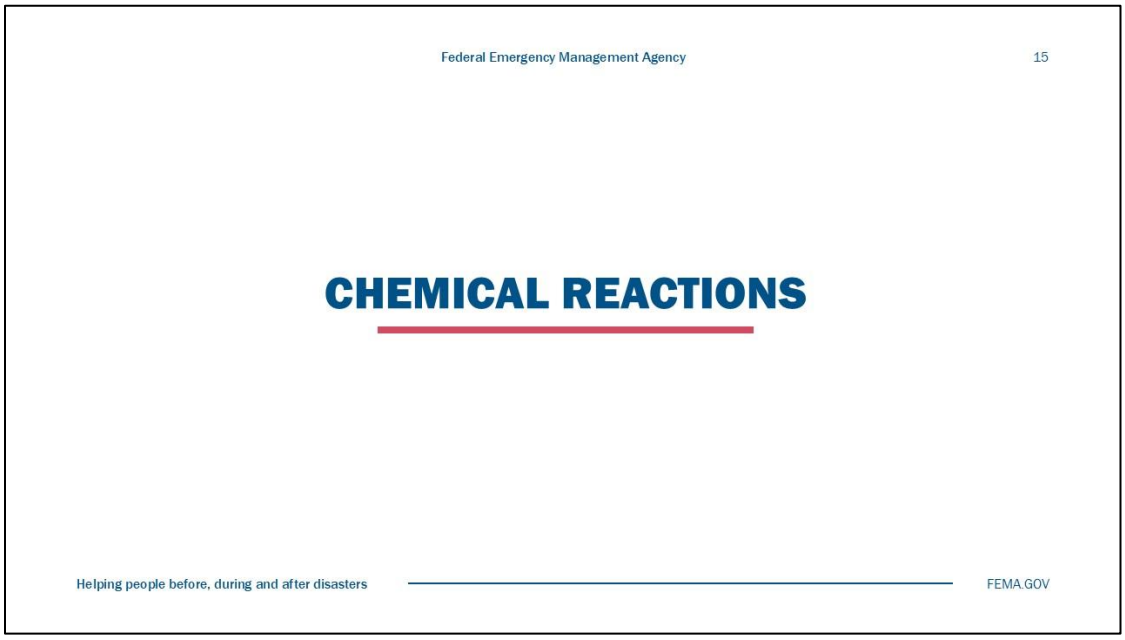


Other factors impacting vapor dispersion include:

- Wind direction – direction of the wind
- Possible temperature inversion: “An inversion occurs when a section of the atmosphere becomes warmer as the elevation increases. Inversion layers are a significant factor in the formation of smog in Los Angeles because they create stable atmospheric conditions. Inversions act to prevent mixing in the lower regions of the troposphere, so pollutants become trapped quite easily and contribute to the formation of smog.” An inversion layer can trap gases and vapors near the surface.

These concepts will impact you as an emergency manager. Understanding the above may impact your community and the response actions you may take.

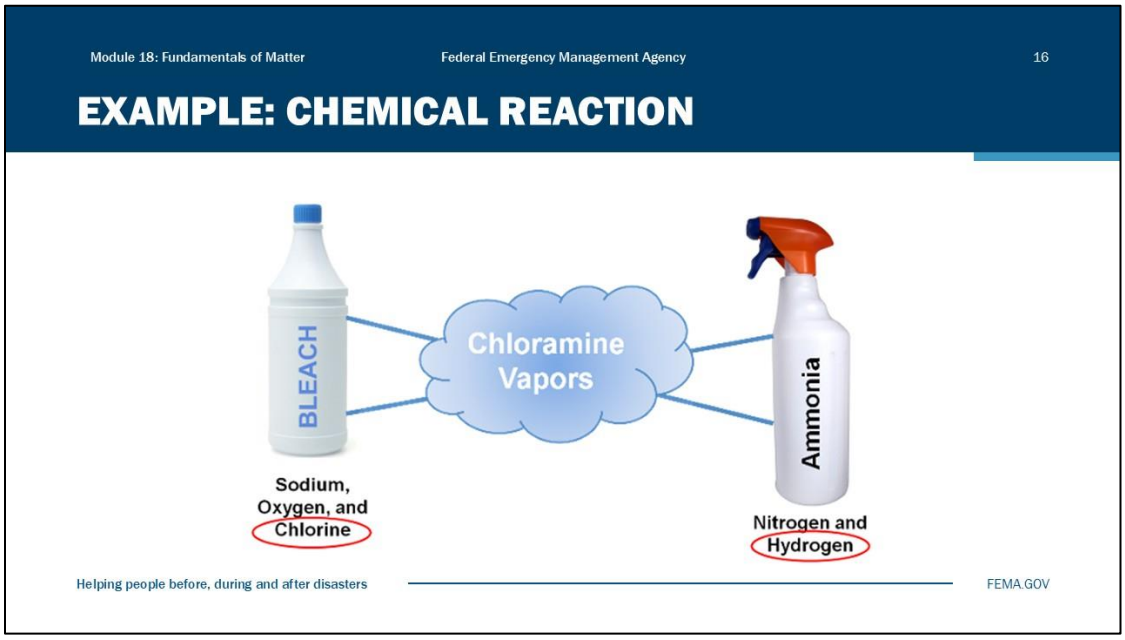
Chemical Reactions (1 of 11)



Slide 18-15, Chemical Reactions

Not Applicable.

Chemical Reactions (2 of 11)

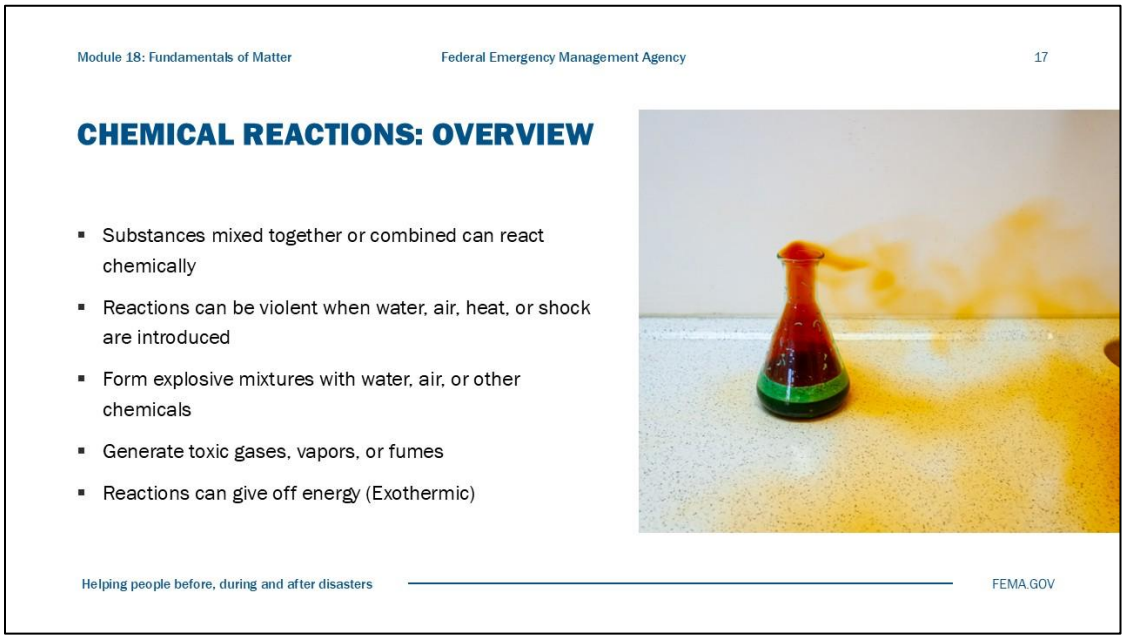


Slide 18-16, Example: Chemical Reaction

Chemical Reaction: When two substances combine and react to form new compounds, such as mixing bleach and ammonia.

Hazard: This combination produces chlorine gas, which is toxic, and hydrochloric acid, which can cause burns.

Chemical Reactions (3 of 11)



Slide 18-17, Chemical Reactions: Overview

Chemistry helps us understand how different substances react. Chemicals can react when exposed to other chemicals or certain physical conditions. Their reactive properties vary widely, and they play a vital role in the production of many chemical, material, pharmaceutical, and food products we use daily.

Some chemicals change phases or react violently when exposed to water, air, heat, or shock.

When chemical reactions are not properly managed, they can have harmful or even catastrophic consequences, such as fires, explosions, or the generation of toxic gases, vapors, and fumes.

These reactions may result in death and injury to people, damage to physical property, and severe effects on the surroundings.

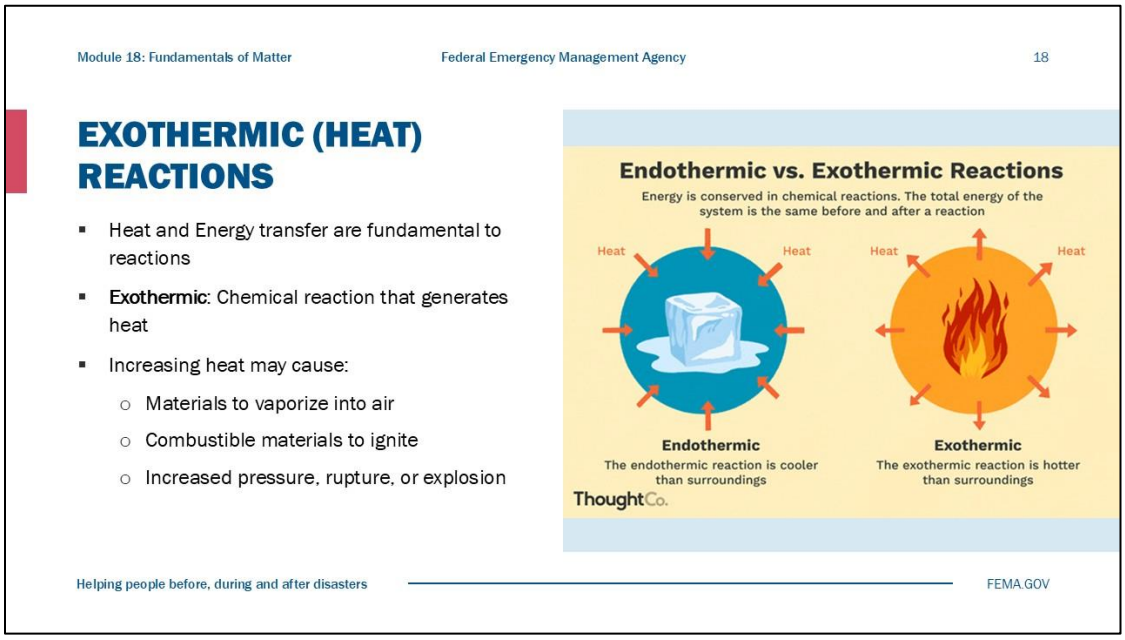
Some **incompatible groups** of chemicals include:

- Acids and bases.
- Flammables and toxics.
- Flammables and oxidizers.
- Oxidizers and reducers. (Source: OSHA)

Chemical reactions are either exothermic or endothermic. Typically, as emergency management professionals, exothermic chemical reactions are the ones of particular concern for us.

Simple examples – Alka-Seltzer/water – baking soda/vinegar – turn penny green/vinegar – clean penny with lemon juice – Chemical changes can be color changes, gas bubbles, formation of a precipitate, or temperature changes (although physical changes may also involve temperature change.)

Chemical Reactions (4 of 11)



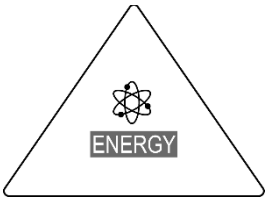
Slide 18-18, Exothermic (Heat) Reactions

- Heat and Energy transfer are fundamental to reactions
- Exothermic: Chemical reaction that generates heat

Increasing heat may cause:

- Materials to vaporize
- Combustible materials to ignite
- Increased pressure, rupture, or explosion

This is energy.



Definition: When one substance is combined with another and the resulting interaction absorbs heat, the process is referred to as an endothermic reaction (endo- is a prefix meaning “within” or “inner”).

Definition: When one substance is combined with another and the resulting interaction generates heat, the process is referred to as an exothermic reaction (exo- is a prefix meaning “out of”). An

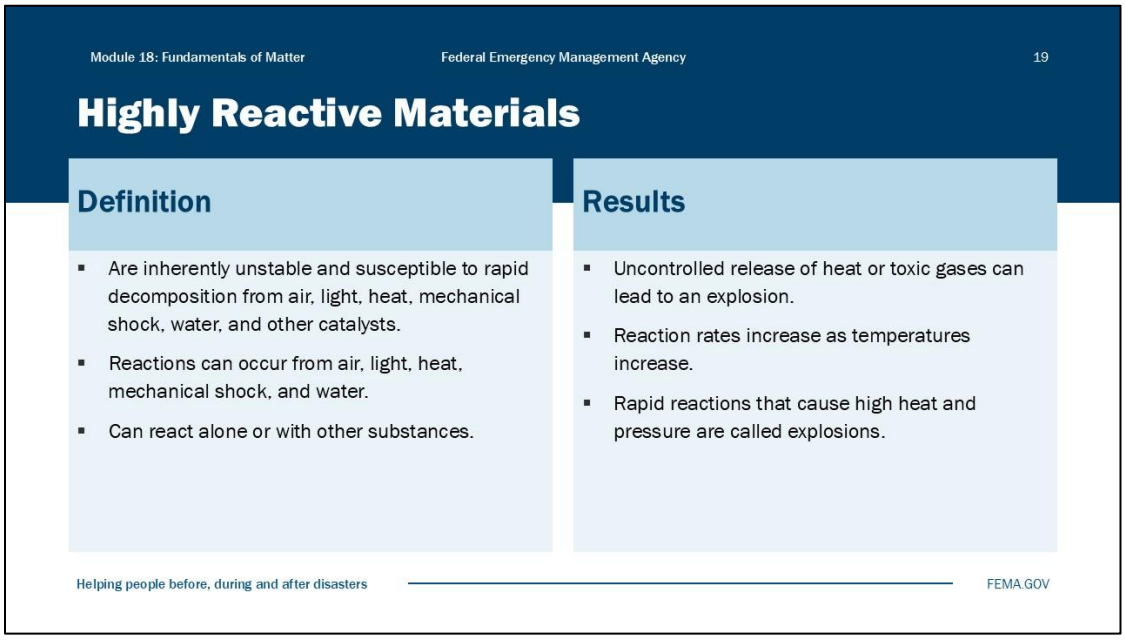
exothermic reaction is one where the energy flows out of the system into the surroundings. When heat is generated, it increases the volume of a gas and creates pressure.

Combustion reactions are exothermic. Some exothermic reactions may require heating just to get started and will then proceed on their own.

Results: Exothermic reactions pose special hazards whether they occur in the open surroundings or within a closed container.

- **Reactions in the open**: In the open, the heat that is produced will raise the temperature of the reactants, of any products of the reaction, and of surrounding materials. The resulting higher temperatures may affect how the materials involved behave in the surroundings.
  - Heat will increase the vapor pressures of hazardous materials and the rate at which they vaporize.
  - If very high temperatures are reached, nearby combustible materials may ignite.
  - Explosive materials, whether they are the reactants of the reaction or just nearby, may explode upon ignition or excessive heating.
- **Reactions in closed containers:** Exothermic reactions taking place in closed containers pose additional hazards. The increased internal temperatures, plus the production of gases from the reaction, may increase internal pressures to the point that the container explodes. The explosion suddenly releases large amounts of possibly flammable and/or toxic gases or vapors into the atmosphere.

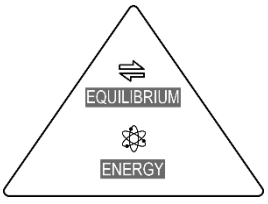
Chemical Reactions (5 of 11)



Slide 18-19, Highly Reactive Materials

Chemical reactions are generally considered safe because the reaction rate is relatively slow or can be easily controlled. However, certain reactions proceed at such a fast rate and generate so much heat that they may result in an explosion.

This is equilibrium and energy.



Definition: Highly reactive or unstable materials are those that have the potential to vigorously polymerize, decompose, condense, or become self-reactive when exposed to shock, pressure, temperature, light, or contact with another material. Major types of highly reactive chemicals are:

- **Pyrophorics**—These substances will ignite spontaneously in air.
- **Water-reactives**—These substances react vigorously to water or moisture.

- **Peroxides**—Peroxides are shock-sensitive. Organic peroxides are even more shock-sensitive than explosives such as TNT or picric acid.
- **Polymers**—Many polymers generate large amounts of heat upon polymerization (a chemical process of combining single molecules into groups called polymers).

Explosives—Explosives can release extremely large amounts of thermal or physical energy and can cause a true detonation (a shock wave traveling at supersonic speed). You will learn more about explosives later in this course.

Results: When triggering conditions are present, the reaction can occur in a violent, uncontrolled manner, liberating heat and/or toxic gases, or leading to an explosion.

Reaction rates almost always increase dramatically as the temperature increases. Therefore, if heat from a reaction is not dissipated, the reaction can accelerate out of control and possibly result in injuries or costly accidents.

Highly Reactive Chemicals

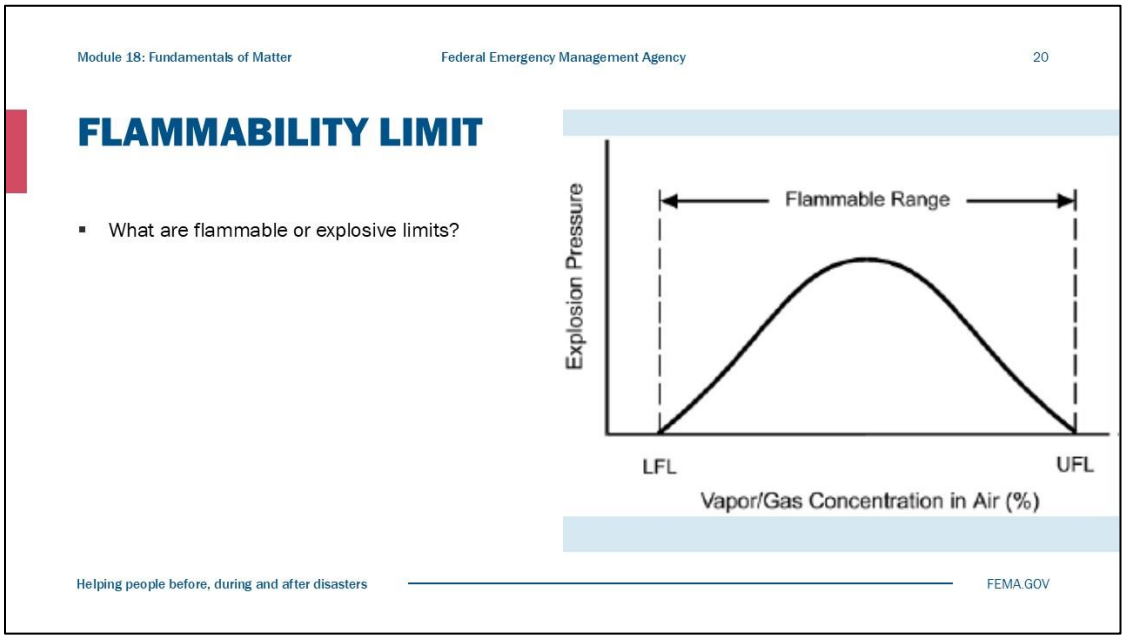
The table below provides additional information about chemicals that react with air, water, heat, or other substances.

Type of Chemical	Description	Examples
Air Reactives (Pyrophorics)	React violently in contact with air or oxygen or with compounds containing oxygen. It does not need an ignition source to begin combustion or to burn. May be found in gas cylinders or packaged under nitrogen or some other inert atmosphere. May produce a flame that is clear and not readily visible.	Alkali metals (potassium, cesium) Finely divided metal dusts (nickel, zinc, titanium) Hydrides

Type of Chemical	Description	Examples
Water Reactives	It can react violently or vigorously when exposed to water, wet surfaces, or even moisture in the air. May give off a flammable gas (such as hydrogen) or a toxic gas (such as phosgene), or spontaneously burn or explode. Cannot be extinguished with water; requires a class D fire extinguisher.	Alkali metals Anhydrides Carbides Halides Hydrides Organometallics Oxides Peroxides Phosphides
Peroxide Formers	It can form peroxide either upon aging or upon contact with air or other substances. May be shock sensitive and explode if handled roughly or upon heating. May exist without problem in a solvent until the solvent is evaporated (during distillation, for example) and the peroxides concentrate.	Ethers 1,4-dioxane
Polymers	May generate large amounts of heat upon polymerization. Some may cause a runaway polymerization reaction that can explode. It may generate heat buildup that can cause bumping, overbooking (too much pressure), or rupture of the container, which can also cause explosive-like damage.	Acrylic acid Butadiene Cyclopentadiene Ethylene Styrene Vinyl chloride

Type of Chemical	Description	Examples
	Bumping - When a liquid is heated in a smooth container, it can become "superheated," meaning its temperature rises above its boiling point without forming vapor bubbles. This happens when there are no nucleation sites (e.g., small scratches or impurities) for bubbles to form. When a bubble finally forms, it does so with explosive force, causing the liquid to "bump" or violently splash out of the container. This is a serious hazard in a laboratory setting and can also occur in larger industrial vessels. Overbooking- In a sealed container, the heat from an uncontrolled reaction causes the vapor pressure of the contents to increase dramatically. Overbooking refers to this excessive pressure buildup, which can exceed the container's structural limits.	

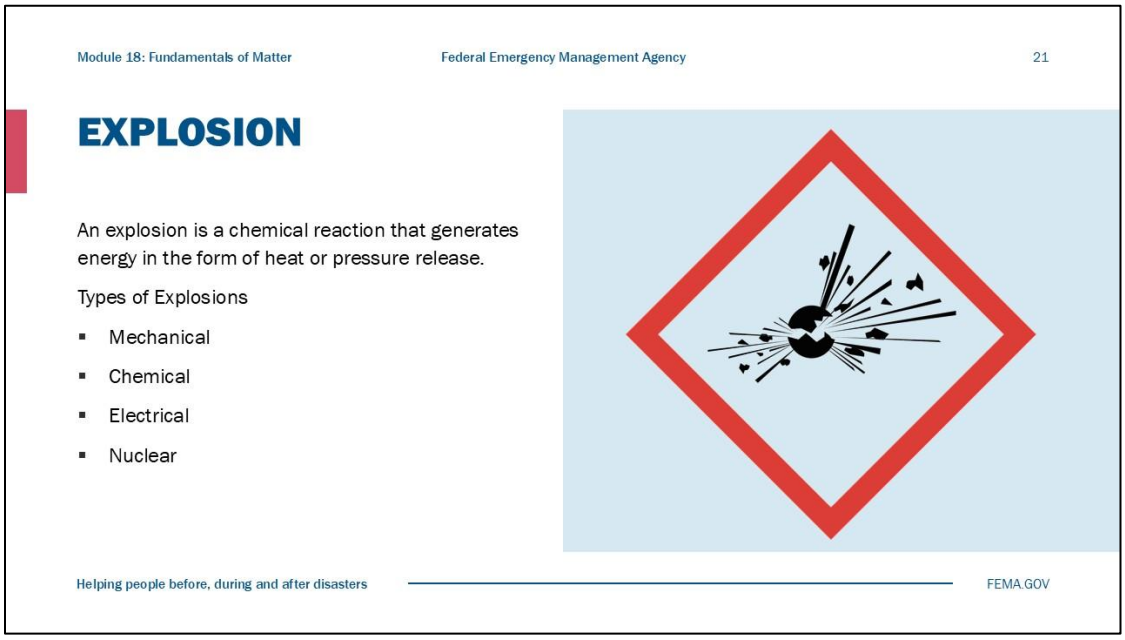
Chemical Reactions (6 of 11)



Slide 18-20, Flammability Limit

Discussion Question: What are flammable or explosive limits?

Chemical Reactions (7 of 11)



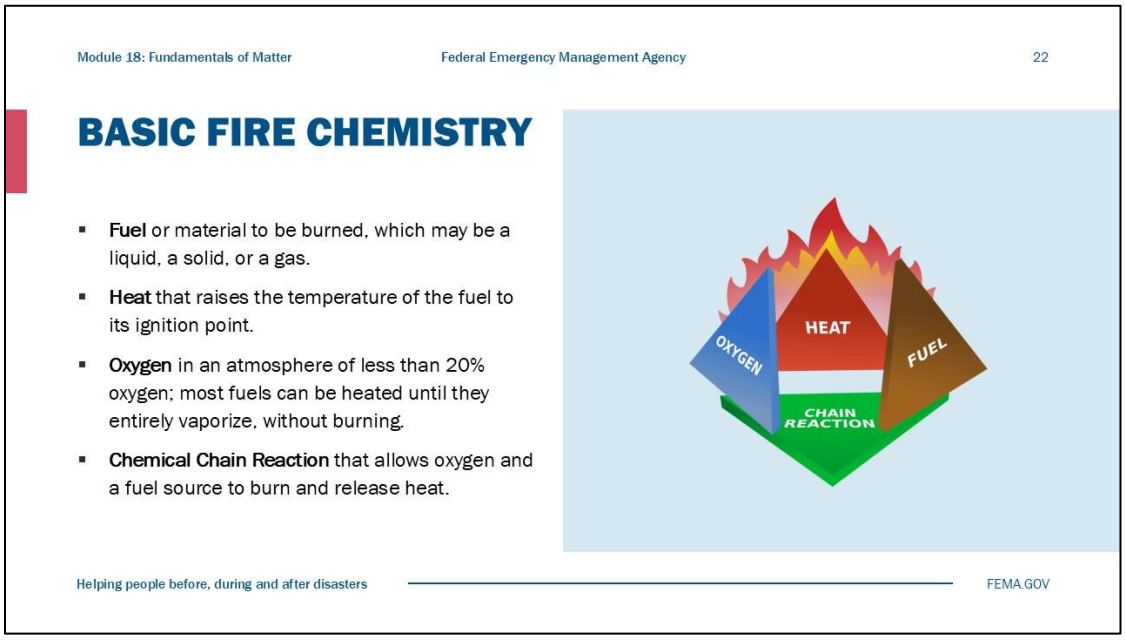
Slide 18-21, Explosion

An explosion is a chemical reaction that generates energy in the form of heat or pressure release.

Types of Explosions include, mechanical, chemical, electrical, and nuclear.

You just saw an example of a mechanical explosion (overpressurizing a cylinder of gas) Lightning is an example of an electrical explosion. We'll spend the rest of our time in chemical and then nuclear explosions.

Chemical Reactions (10 of 11)



Slide 18-22, Basic Fire Chemistry

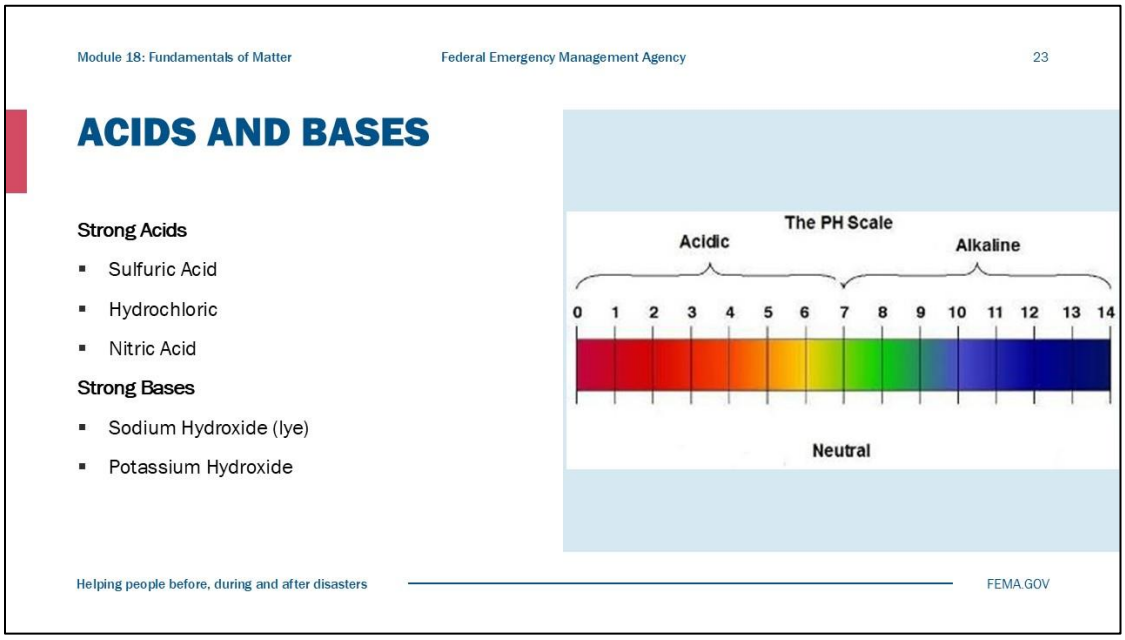
Image: Fire Tetrahedron

Three elements are required to create a chemical exothermic reaction (fire): fuel, heat, and an oxidizing agent (usually oxygen). A fire naturally occurs when the elements are present and combined in the right mixture. If you take any one of these elements away and permanently interrupt the reaction, the fire goes out because the chemical chain reaction is interrupted. Together, these four components are called the fire tetrahedron or combustion tetrahedron.

- **Fuel**: Without fuel, a fire will stop. Fuel can be removed naturally (as when the fire has consumed all the burnable fuel) or manually, by mechanically or chemically removing the fuel from the fire. When fuel is removed, the fire stops because a lower concentration of fuel vapor in the flame leads to a decrease in energy release and a lower temperature. Removing the fuel thereby decreases the heat.
- **Heat:** Without sufficient heat, a fire cannot begin, and it cannot continue. Heat can be removed by the application of a substance that reduces the amount of heat available to the fire reaction. The heat produced by the fire can also cause the reaction to increase
- **Oxygen: Without** sufficient oxygen, a fire cannot begin, and it cannot continue. With decreased oxygen concentration, the combustion process slows.

- **Chemical Chain Reaction**: Fire is a process of combustion in which a chemical reaction is sustained to allow oxygen and a fuel source to burn and release heat. Removing one element from the tetrahedron will prevent the chemical chain reaction from continuing, and interrupting it can also prevent the fire from continuing.

Chemical Reactions (11 of 11)



Slide 18-23, Acids and Bases

Strong Acids:

- Sulfuric Acid
- Hydrochloric
- Nitric Acid

Strong Bases:

- Sodium Hydroxide (lye)
- Potassium Hydroxide

Acids and bases: Most corrosives are either acids or bases (alkaline). The relative acidity or alkalinity of a substance is measured on the pH scale.

- An **acid** is a substance that donates hydrogen ions. When an acid is dissolved in water, the balance between hydrogen ions and hydroxyl ions is shifted, resulting in more hydrogen ions than hydroxyl ions in the solution. This kind of solution is acidic. Examples of strong acids include hydrochloric acid (HCL), hydrofluoric acid (HF), nitric acid (HNO_3), and sulfuric acid (H_2SO_4).

- A **base** is a substance that accepts hydrogen ions. When a base is dissolved in water, the balance between hydrogen ions and hydroxyl ions shifts the opposite way. Because the base "soaks up" hydrogen ions, the result is a solution with more hydroxyl ions than hydrogen ions. This kind of solution is alkaline. Examples of strong bases include sodium hydroxide (NaOH) and potassium hydroxide (KOH).

Corrosiveness: The corrosiveness of an acid or base refers to how severely it damages surfaces upon contact, specifically living tissue. Strong acids and bases such as hydrofluoric acid and sodium hydroxide have a very high or very low pH and are highly corrosive, requiring extensive precautions when handling because they eat through tissue and even bone. While acids and bases damage tissues in somewhat different ways (burning vs. emulsifying), the end result is often irreversible damage at the site of the injury.

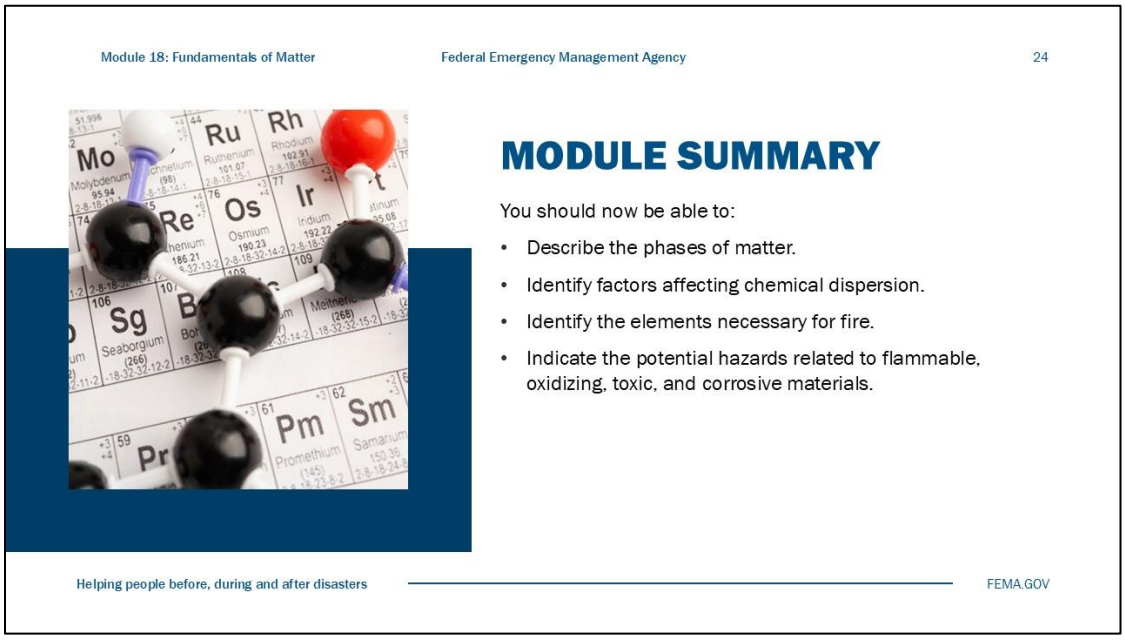
pH scale: The pH scale ranges from 0 to 14 and is logarithmic, meaning that each numerical increase on the pH scale represents a tenfold increase in acid or base concentration relative to pure water measured at 7.0 pH. (For example, a 6.0 pH is 10 times more acidic than a 7.0 pH; a 5.0 is 100 times more acidic than a 7.0 pH.)

Distilled water is 7.0 (right in the middle of the scale). Acids are found between 0 and 7. Bases are from 7 to 14. Most of the liquids you find every day have a pH near 7. However, the pH of chemicals can reach both extremes.

Health effects of acids: Different corrosives can have different health effects on the human body.

- **Localized damage**: If splashed with a hydrochloric acid solution on skin, an immediate sensation of burning will take place, and the tissue that was exposed will burn and decompose until the acid is flushed away or neutralized. While the exposed tissues will be damaged, there is no danger of the exposure going "systemic" (body-wide) and killing the person—although infection could be a problem later.
- **Systemic damage:** With systemic damage, the poison causes damage beyond the initial exposed area—for example, by contaminating the blood or targeting one or more vital organs. If splashed with a 2% solution of hydrofluoric acid on \skin, the skin will not burn away as with other acids. Rather, the chemical will move to the bone and cause the bone to decompose. The effect will be systemic as the acid lowers the body's calcium level, causing confusion, dizziness, and fainting. Besides the extreme pain of the bone being eaten away, without immediate medical attention, the victim will die.

End of Module (1 of 2)

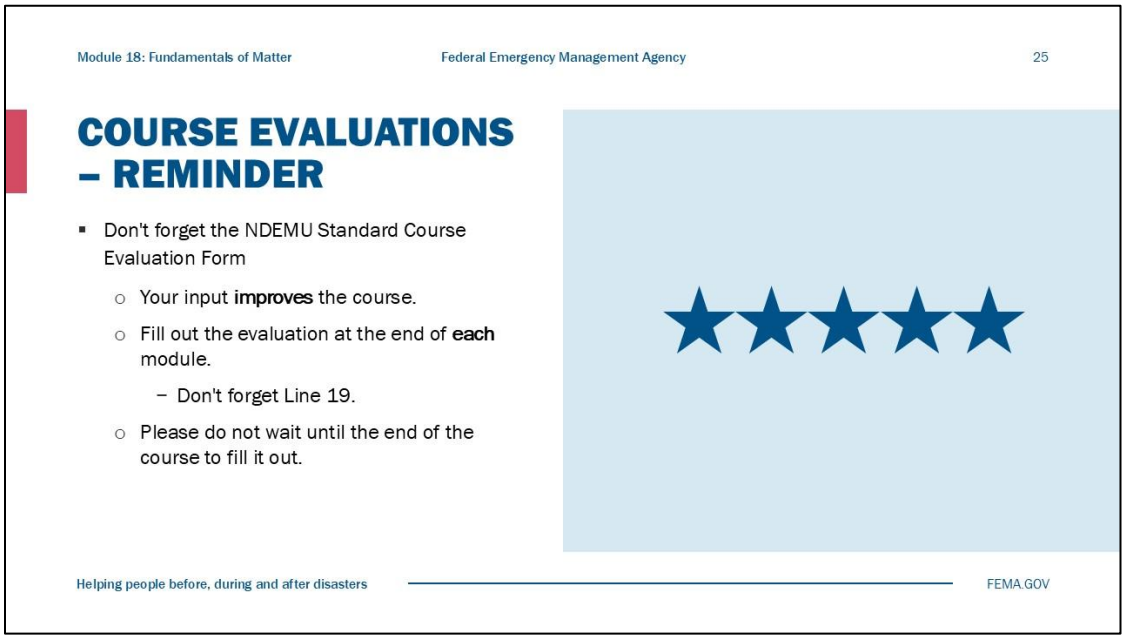


Slide 18-24, Module Summary

You should now be able to:

- Describe the phases of matter;
- Identify factors affecting chemical dispersion;
- Identify the elements necessary for fire; and
- Indicate the potential hazards related to flammable, oxidizing, toxic, and corrosive materials.

End of Module (2 of 2)



Slide 18-25, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

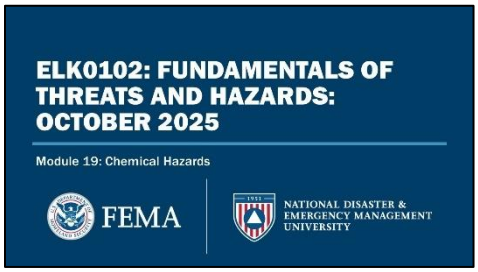
Reference List

OSHA (https://www.osha.gov/)
Public Broadcasting System (PBS) NOVA, "Einstein's Big Idea" (https://www.pbs.org/wgbh/nova/video/einsteins-big-idea/)

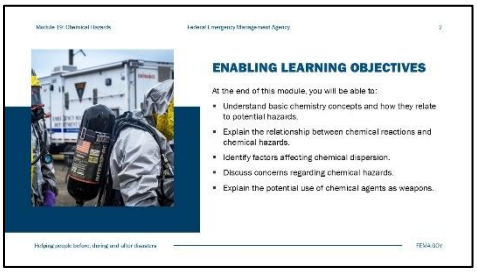
Module 19

Chemical Hazards

Administration



Slide 19-1, Module 19: Chemical Hazards



Slide 19-2, Enabling Learning Objectives

Duration

1 hour, 30 minutes

Terminal Learning Objective (TLO)

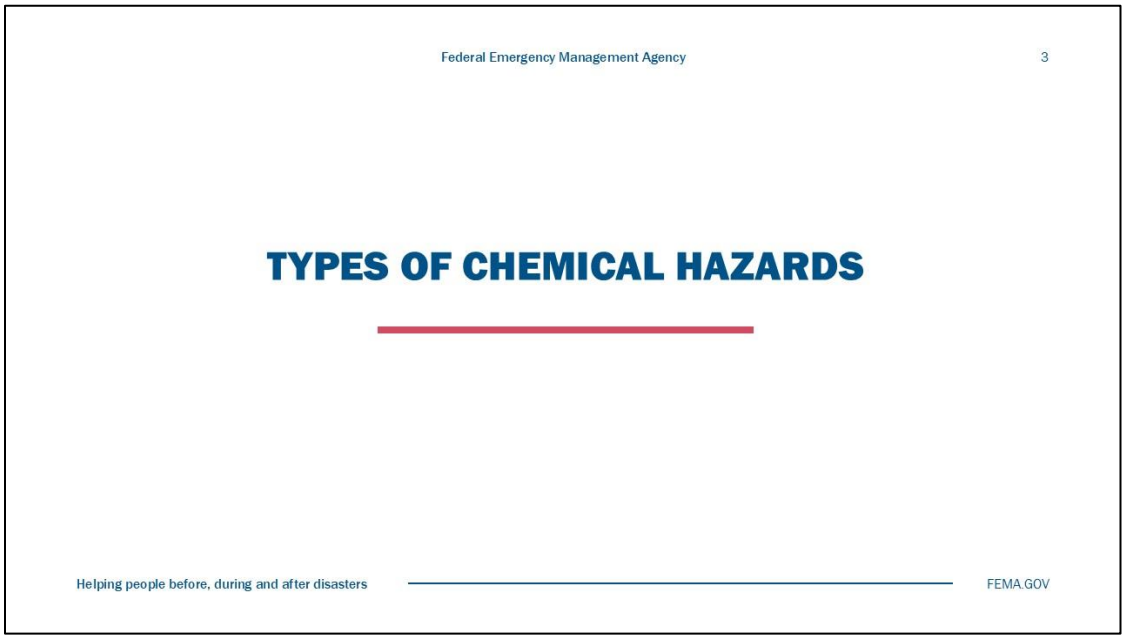
By the end of this module, participants will be able to analyze and evaluate chemical hazards, including their basic concepts, reactions, dispersion factors, and potential use as weapons, to effectively manage and mitigate associated risks.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Understand basic chemistry concepts and how they relate to potential hazards.
- Explain the relationship between chemical reactions and chemical hazards.
- Identify factors affecting chemical dispersion.
- Discuss concerns regarding chemical hazards.
- Explain the potential use of chemical agents as weapons.

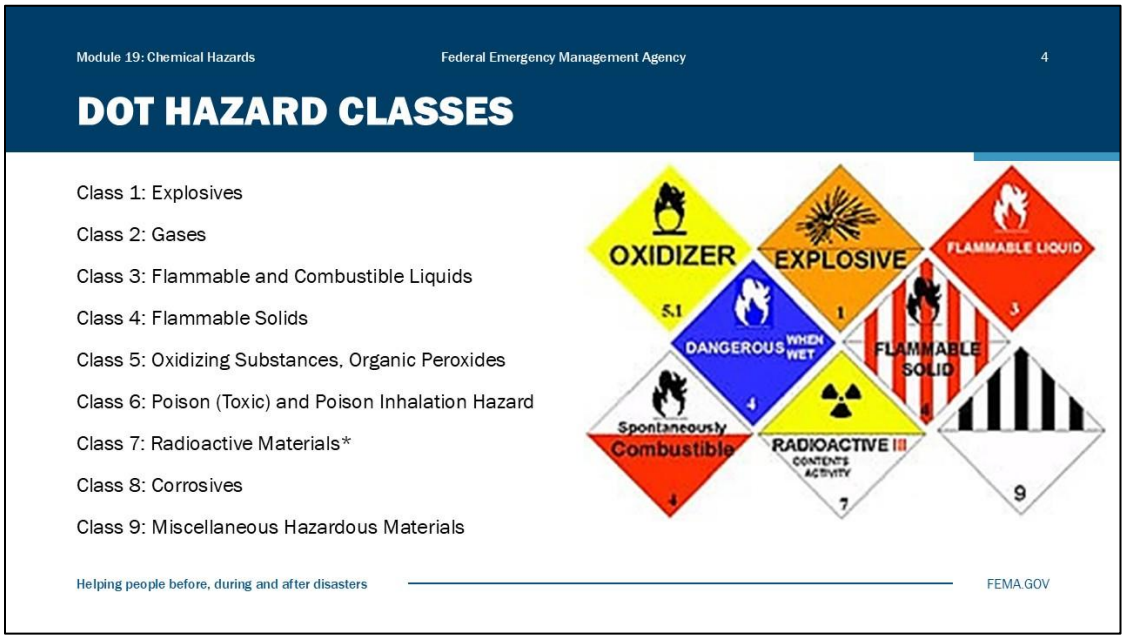
Types of Chemical Hazards (1 of 5)



Slide 19-3, Types of Chemical Hazards

Not Applicable.

Types of Chemical Hazards (2 of 5)



Slide 19-4, DOT Hazard Classes

The U.S. Department of Transportation organizes hazardous materials into nine classes. Other classification systems, such as the one used by the Occupational Safety and Health Administration (OSHA), vary slightly. The nine DOT groups are the standard classifications used by responders during a hazardous materials incident.

The classes are:

- Class 1: Explosives*
- Class 2: Gases
- Class 3: Flammable and Combustible Liquids
- Class 4: Flammable Solids
- Class 5: Oxidizing Substances, Organic Peroxides
- Class 6: Poison (Toxic) and Poison Inhalation Hazard
- Class 7: Radioactive Materials*
- Class 8: Corrosives

- Class 9: Miscellaneous Hazardous Materials

*We will cover explosives and radiation in other units.

DOT Hazard Type	Examples
Class 1: Explosives	• 1.1 Mass Explosion Hazard - a small ignition source will cause any of these substances to react instantaneously with violent and terrible force. Examples include gunpowder, some fireworks, rocket fuel, trinitrotoluene (TNT). • 1.2 Projection Hazard - these explosives emit dangerous projectiles and include some kind of ammunition and grenades. • 1.3 Fire Hazard - these explosives have a fire hazard in addition to projection or explosive properties. Examples include the flash powder used in pyrotechnics and fireworks. • 1.4 Package Confined - these substances cause minor explosions that are mostly contained to their own packaging. Examples include signal flares, tracers for ammunition, some fireworks and weapon cartridges, and distress signals. • 1.5 Insensitive Substances - these can cause mass explosions but are inert in most conditions. An example is an ammonium nitrate-fuel oil (ANFO) mixture that contains only ammonium nitrate in pellet form and fuel oil. • 1.6 Extremely Insensitive Substances - carry both minimal sensitivity to ignition and will not produce a mass explosion.

DOT Hazard Type	Examples
Class 2: Gases	• Compressed Gases: Become rockets, burst, or cause runaway reactions, • Flammable Gases: Burn or explode, • Oxidizing Gases: React rapidly and violently with other materials, • Inert Gases: Replace oxygen, • Corrosive Gases: Destroy body tissues, • Reactive Gases: Produce violent reactions from slight temperature/pressure changes or mechanical shock, • Toxic Gases: Create health concerns,
Class 3: Flammable and Combustible Liquids and Class 4: Flammable Solids	• Combustible materials include anything that can burn Flammable substances are those that readily catch fire and burn in air, • Flammable substances are those that readily catch fire and burn in air, • Flammable solids are any solid, other than an explosive or a blasting agent, that can be ignited easily and burn so vigorously or persistently as to create a serious fire hazard, • Liquids can be flammable or combustible depending on their flash point,
Class 5: Oxidizing Substances, Organic Peroxides	• Are liquids or solids that readily give off oxygen or other oxidizing substances (such as bromine, chlorine, or fluorine). • Increase the chance of a fire or explosion,
Class 6: Poison (Toxic) and Poison Inhalation Hazard	• A toxic substance is a poisonous material, other than a gas, that is known to be so toxic to humans as to cause death, injury, or harm to human health, • An infectious substance is a material known or reasonably expected to contain a pathogen (this will be covered in the next module).

DOT Hazard Type	Examples
Class 8: Corrosives	• Chemical reaction that gradually erodes or dissolves another material is often referred to as corrosion. • May cause damage to the skin, eyes, or other bodily tissues upon contact.

Hazard Class 2, Compressed Gases, includes three divisions:

- Division 2.1: Flammable gas
- Division 2.2: Non-Flammable/Non-Poisonous Compressed Gas
- Division 2.3: Gas Poisonous by Inhalation
- **Compressed gases:** Thousands of products are available that contain gases and mixtures of gases stored under pressure in cylinders. Three major groups of compressed gases are stored in cylinders:
  - **Liquefied gases:** These gases exist inside the cylinder in a liquid-vapor equilibrium. They can become liquids at normal temperatures under pressure when inside cylinders.
  - **Non-liquefied gases:** These gases do not become liquid when compressed at normal temperatures, even at very high pressures.
  - **Dissolved gases:** These gases are chemically volatile and can explode even at atmospheric pressure. They become stable in solutions with an inert solvent (e.g., acetylene in acetone).

Gas pressure basics: It is helpful to understand a few basics about gas under pressure:

- Pressure units: The pressure of the gas in a cylinder is commonly given in units of kilopascals (kPa) or pounds per square inch gauge (psig).
- Atmospheric pressure is normally about 101.4 kPa (14.7 psi).
- Gauge **pressure** = Total gas pressure inside the cylinder minus atmospheric pressure.

Before discussing the next hazard class (flammable and combustible liquids), let's consider a few concepts related to flammability, combustibility, and fire chemistry.

Flammable substances are materials that can easily catch fire under normal circumstances and with the help of minimal ignition source. Just a spark is sufficient. A good example of a flammable substance is propane. (What is considered "flammable" differs among organizations.)

Combustible materials include anything that can burn. They require more vigorous conditions for combustion; a simple spark is not enough. Paper and wood are good examples of combustible materials.

Hazard Class 4 consists of three divisions. U.S. DOT defines these divisions as follows:

- **Division 8.2, Flammable Solids**—Any solid material other than one classed as an explosive that, under conditions normally incident to transportation, is likely to cause fires through friction or retained heat from manufacturing or processing, or that can be ignited readily and, when ignited, burns so vigorously and persistently as to create a serious transportation hazard.
- **Division 4.2**, **Spontaneously Combustible**—A liquid or solid pyrophoric material that, even in small amounts and without an external ignition source, can ignite within 5 minutes after coming in contact with air, or a self-heating material that, when in contact with air and without an energy supply, is liable to self-heat.
- **Division 4.3, Dangerous When Wet**—A material that, by contact with water, is likely to become spontaneously flammable or to give off flammable or toxic gas at a rate greater than 1 liter per kilogram of the material per hour.

Examples of flammable solids include certain metallic hydrides, metallic sodium and potassium, oily fabrics, processed metals, matches, and nitrocellulose products.

Description: Hazard Class 5 includes two divisions: oxidizers and organic peroxides.

Oxidizing materials are liquids or solids that readily give off oxygen or other oxidizing substances. They also include materials that react chemically to oxidize combustible materials. This means that oxygen combines chemically with the other material in a way that increases the chance of a fire or explosion. This reaction may be spontaneous at room temperature or may occur under slight heating.

Example: Ammonium perchlorate is an oxidizing material with many uses in industry, construction, agriculture, and life support systems. Ammonium perchlorate:

- Can decompose at high temperatures, forming toxic gases, such as chlorine, hydrogen chloride, and nitrogen oxides. Closed containers or tanks may rupture and explode if heated.
- Does not burn, but is a powerful oxidizer and explosive when mixed with combustible materials.
- Is highly reactive, and impact or high temperatures can cause violent decomposition or explosion.
- Can form shock-sensitive mixtures with finely powdered metals, metal oxides, strong reducing agents, sulfur, and phosphorus.
- May cause eye irritation

Examples: Common oxidizers are:

- Concentrated nitric acid
- Compressed oxygen
- Hydrogen peroxide

There are other chemicals that are oxidizing materials. For example, liquid air has been involved in many explosions because of its oxidizing properties. Liquid air itself has about 30% oxygen, which makes it a powerful oxidant. However, when liquid air evaporates, it becomes richer in oxygen content as more volatile components evaporate slightly faster.

Impact of oxidizing materials: Oxidizing materials can:

- Speed up the development of a fire and make it more intense;
- Cause substances that do not normally burn readily in air to burn rapidly; and
- Cause combustible materials to burn spontaneously without the presence of an obvious ignition source such as a spark or flame.

What happens when an oxidizing material comes in contact with a combustible substance largely depends on the chemical stability of the oxidizing material. The less stable an oxidizing material is, the greater the chance that it will react in a dangerous way.

Hazard Class 6 includes:

- Division 6.1: Poisonous or Toxic Substances.
- Division 6.2: Infectious Substances.

A **toxic substance** is a poisonous material, other than a gas, that is known to be so toxic to humans as to cause death, injury, or harm to human health if swallowed, inhaled, or brought into contact with skin.

An **infectious substance** is a material known or reasonably expected to contain a pathogen.

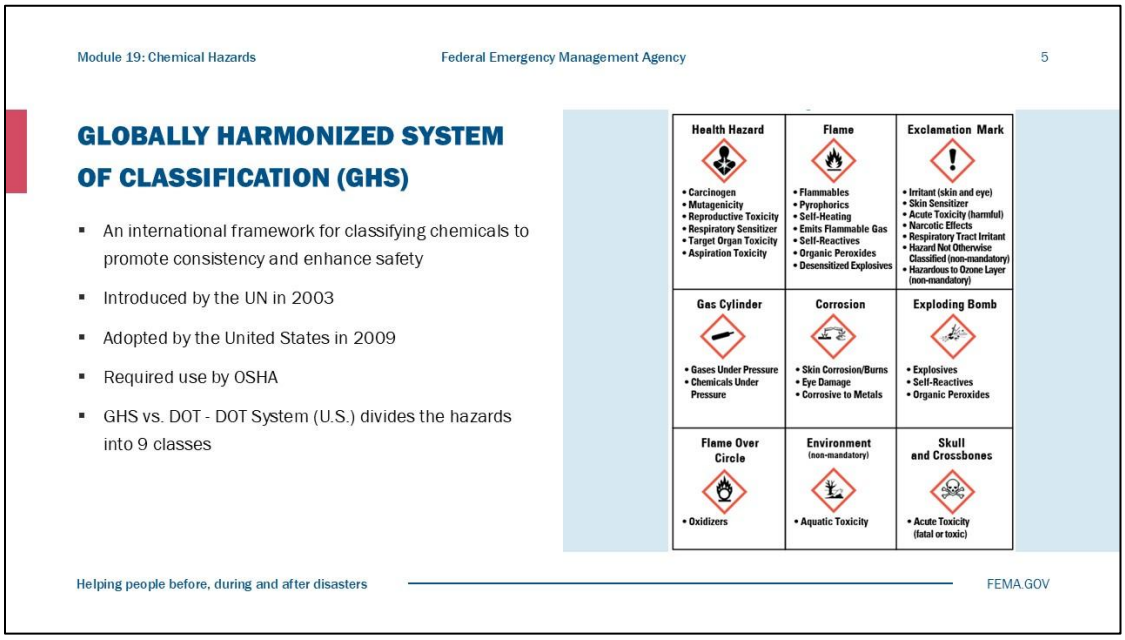
Hazard Class 8 is Corrosives.

Corrosives are materials that can attack and chemically destroy another material, such as exposed body tissues or even metal.

They begin to cause damage as soon as they touch the skin, eyes, respiratory tract, digestive tract, or metal.

Corrosives might be hazardous in other ways, too, depending on the corrosive material.

Types of Chemical Hazards (3 of 5)



Slide 19-5, Globally Harmonized System of Classification (GHS)

- An international framework for classifying chemicals to promote consistency and enhance safety
- Introduced by the UN in 2003
- Adopted by the United States in 2009
- Required use by OSHA
- GHS vs. DOT - DOT System (U.S.) divides the hazards into 9 classes

GHS Pictograms & Hazards
(https://www.osha.gov/Publications/HazComm_QuickCard_Pictogram.html)

After years of research on hazard communications and multiple incidents involving injuries or death where hazard communication was ineffective, the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) was developed by the United Nations. The UN has identified the GHS as a multinational strategy and communication system to avoid future incidents.

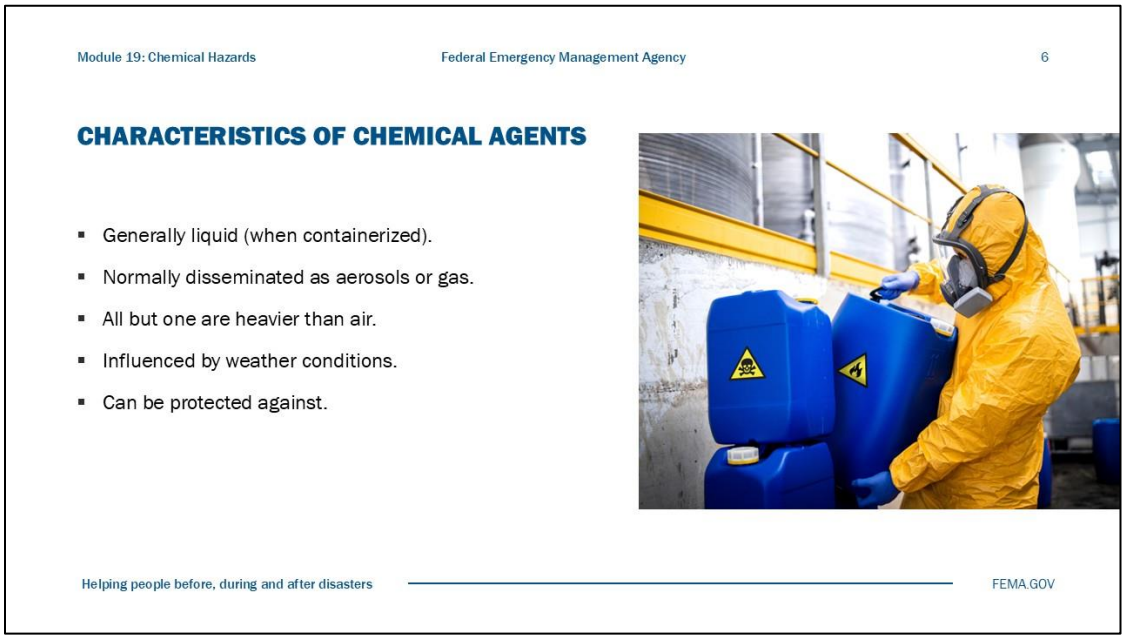
The GHS includes criteria for classifying health, physical, and environmental hazards, as well as specifying what information should be included on labels of hazardous chemicals safety data sheets.

Major changes to the DOT Hazard Communication Standard:

- **Hazard classification:** Chemical manufacturers and importers are required to determine the hazards of the chemicals they produce or import. Hazard classification under the updated standard provides specific criteria to address health and physical hazards, as well as classification of chemical mixtures.
- **Labels:** Chemical manufacturers and importers must provide labels that include a signal word, pictogram, hazard statement, and precautionary statement for each hazard class and category.
- **Safety Data Sheets:** The format requires 16 specific sections, ensuring consistency in the presentation of important protection information.
- **Information and training:** To facilitate understanding of the system, the standard requires that workers be trained by December 1, 2013, on the label elements and safety data sheet format, in addition to the current training requirements.

Ever since OSHA implemented chemical labeling requirements in June of 2015, there has been some confusion among chemical manufacturers in the U.S. They want to know if they should use the Global Harmonized System (GHS) of classification or the U.S. Department of Transportation's (DOT) labeling system. OSHA agreed that there is no reason GHS labels cannot be included on containers that feature a DOT pictogram. Manufacturers wait for the official change; they are allowed to include both DOT and GHS pictograms on the same label of hazardous containers.

Types of Chemical Hazards (4 of 5)



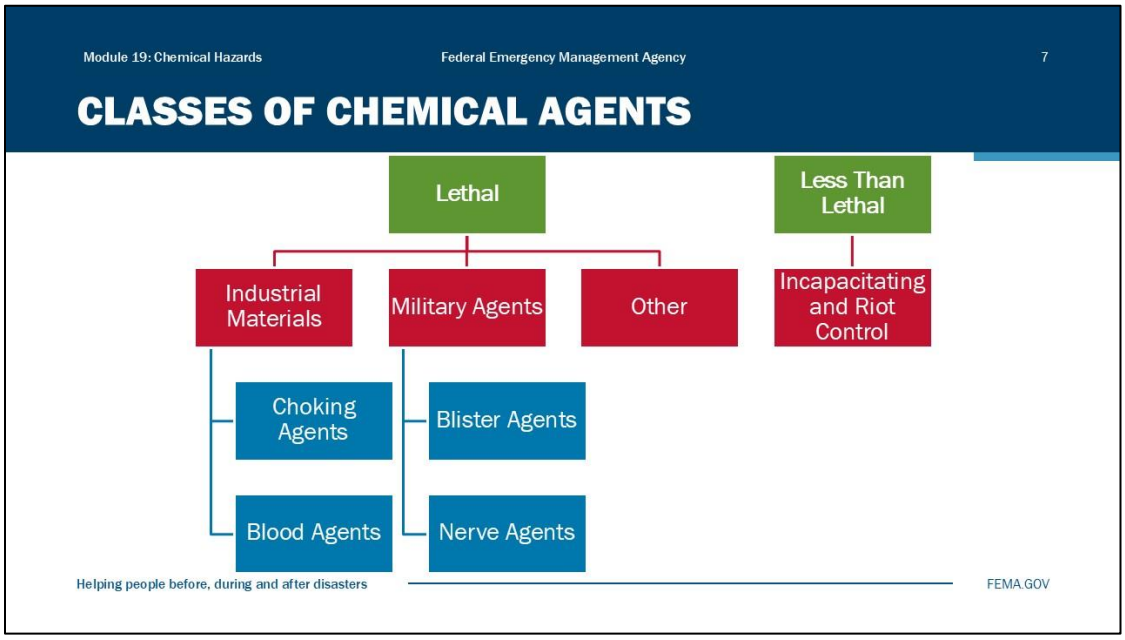
Slide 19-6, Characteristics of Chemical Agents

- Generally liquid (when containerized);
- Normally disseminated as aerosols or gas;
- All but one is heavier than air;
- Influenced by weather conditions and
- Can be protected against.

In general, chemical agents:

- Are liquid when containerized (even though they are often referred to as gases). Some boil at low temperatures and become gases when exposed to the atmosphere.
- Are normally disseminated as aerosols or as gases and thus will dissipate with time.
- Are influenced by weather conditions (temperature, wind speed, wind direction, humidity, and air stability).
- Can be protected against, treated, and decontaminated.

Types of Chemical Hazards (5 of 5)



Slide 19-7, Classes of Chemical Agents

Lethal

- Industrial Materials
  - Choking Agents
    - Phosgene (CG): A colorless, highly toxic gas that smells like freshly cut hay or grass. It can be deadly because symptoms, including fluid in the lungs, can be delayed for up to 24 hours after exposure. Phosgene was a major cause of death from chemical weapons in World War I.
    - Chlorine (Cl): A yellowish-green gas with a distinctive, pungent odor. It was one of the first chemical weapons used in World War I. At high concentrations, chlorine reacts with water in the lungs to form hydrochloric acid, which can cause severe burns and damage.
    - Diphosgene (DP): A colorless liquid that becomes a gas when released. It has similar effects to phosgene and was also used as a choking agent in World War I.
    - Chloropicrin (PS): An oily, colorless liquid with a strong, irritating odor. In addition to being a choking agent, it is also a riot control agent and was historically used in World War I.

- Ammonia: A colorless gas with a strong, sharp odor. Exposure can cause severe irritation to the respiratory system and other serious health problems.
- Hydrogen chloride (HCl): This agent can damage the upper airways and respiratory tract.

– Blood Agents

- Hydrogen Cyanide (HCN): Also known as "prussic acid," was first used by French forces in July 1916 and shortly after by other Allied powers. It was considered an "instant onset" blood agent.
- Cyanogen Chloride (CNCl): Along with hydrogen cyanide, was a blood agent with a rapid onset, used during World War I.

- Military Agents

– Blister Agents

- Sulfur Mustard, and Nitrogen Mustard, also known as mustard gas, were introduced during WWI.
- Lewisite, a blister agent containing arsenic, was also employed in warfare.

– Nerve Agents (developed after WWI)

- Tabun (GA): The first nerve agent, synthesized in 1936.
- Sarin (GB): A highly volatile nerve agent that evaporates at a rate similar to water.
- Soman (GD): A nerve agent with a slight camphor-like odor.
- VX: An oily liquid with a very slow evaporation rate, often described as having the consistency of motor oil.

Less Than Lethal

- Incapacitating and Riot Control
  - Pepper Spray (OC - Oleoresin Capsicum):
    (1) Derived from chili peppers, its active ingredient irritates pain-sensing nerves.
  - Tear Gas (Lacrymators):
    (1) CS Gas: (o-chlorobenzylidene malononitrile): A common chemical irritant in tear gas.
    (2) CN Gas: (chloroacetophenone): Another chemical, once common in tear gas but now less used due to higher toxicity compared to CS.
    (3) CR Gas: (dibenz[b,f]--oxazepine): Another type of irritant gas.

Source: US EPA, O. (2024, January 9). *Chemical Warfare Agents* [Overviews and Factsheets]. https://www.epa.gov/emergency-response/chemical-warfare-agents

Chemical agents are classified as either (1) lethal agents or (2) incapacitating and riot control agents, according to their intended use.

Our focus is on lethal agents because of their greater potential for terrorist use. Incapacitating and riot control agents are not considered primary terrorist threats, due primarily to their relatively short duration of effects and minimal toxicity.

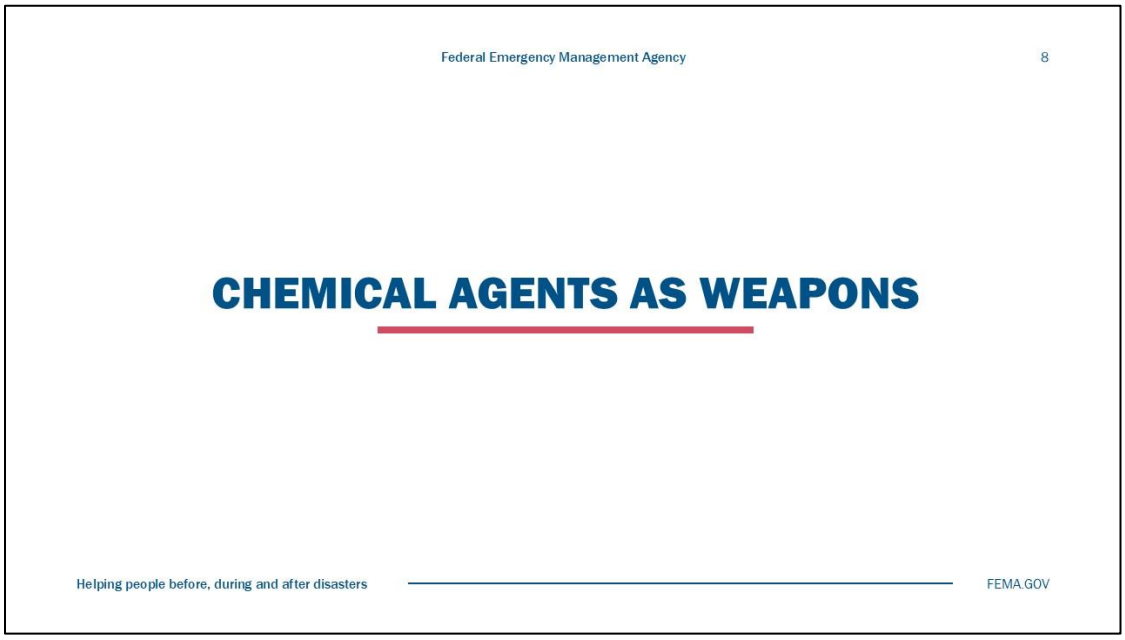
Lethal agents are subdivided into:

- **Industrial materials** (choking agents and blood agents), which have various legitimate applications.
- **Military agents** (blister and nerve agents), which have little or no other purpose beyond their destructive nature.

Other agents include:

- Biotoxins
- Caustics/Acids
- Long-Acting Anticoagulants
- Metals
- Organic Solvents
- Toxic Alcohols
- Vomiting Agents

Chemical Agents as Weapons (1 of 3)



Slide 19-8, Chemical Agents as Weapons

Not Applicable.

Chemical Agents as Weapons (2 of 3)



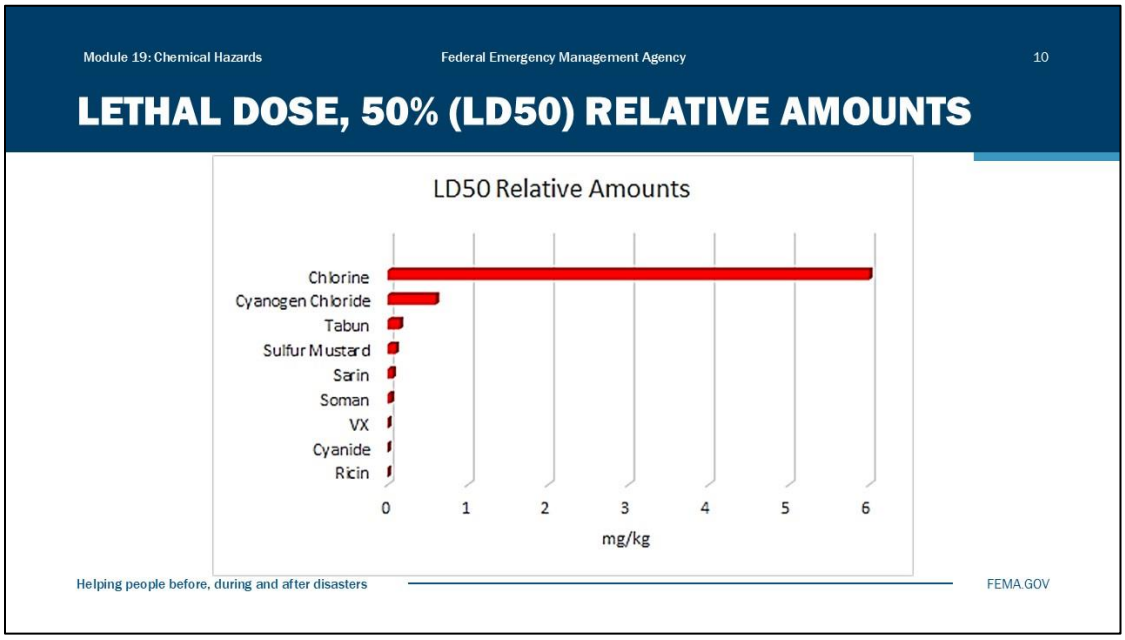
Slide 19-9, Chemical Agents as Weapons

- Can be a liquid or powder
- Survive dissemination
- Can have an immediate or delayed effect on victims

Let's begin with a few basic facts about chemical agents.

- Chemical agents can be a liquid or a powder;
- They can have an immediate effect on victims (but some have a delayed effect and may not affect victims for 12 hours or more);
- Different chemical agents are used in varied quantities, from a few grams to gallons; and
- The quantities needed vary; For example, nerve agents require only a few grams, whereas blister agents and blood agents require gallons to have a widespread effect.

Chemical Agents as Weapons (3 of 3)



Slide 19-10, Lethal Dose, 50% (LD50) Relative Amounts

The graph on the visual shows the amount needed for LD50 based on the amount of the substance in mg (vertical axis) per the mass of the person in kg (horizontal axis).

A small amount of VX or cyanide can be lethal.

Agent	mg/kg
Ricin	0.00002
Cyanide	0.00002
VX	0.008
Soman	0.04
Sarin	0.06
Sulfur Mustard	0.1

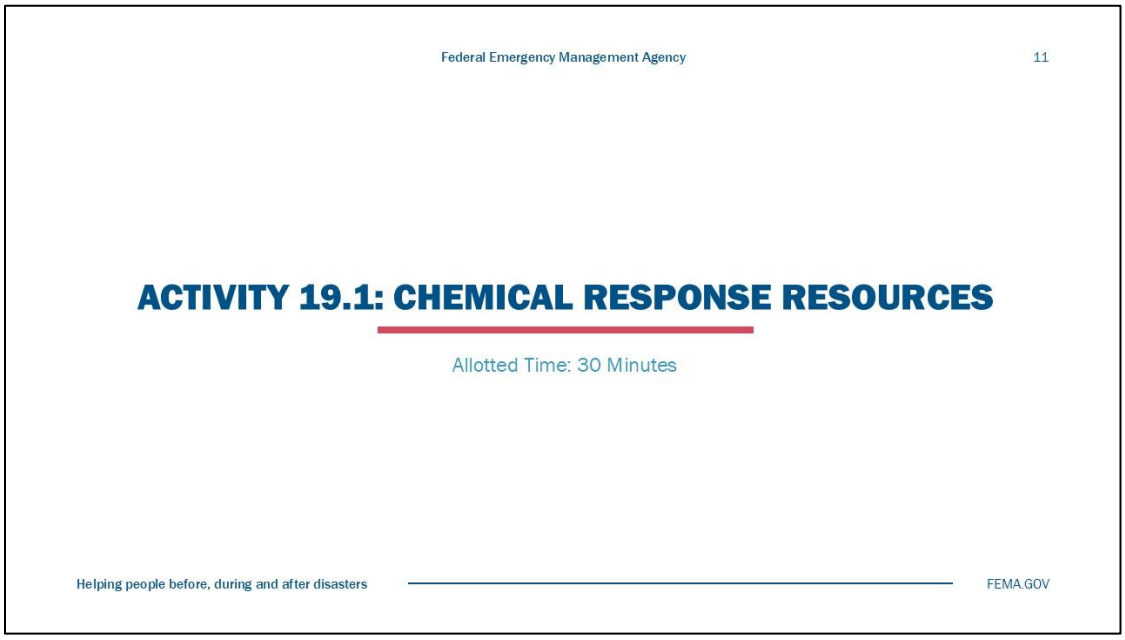
Agent	mg/kg
Tabun	0.15
Cyanogen Chloride	0.6
Chlorine	6

Choking Agents, Blood Agents, Blister Agents, and Nerve Agents

	Choking Agents	Blood Agents	Blister Agents	Nerve Agents
Examples	Chlorine, phosgene, chloropicrin	Cyanide (CN), cyanogen chloride (CNCL)	Mustard, Lewisite, Phosgene	Sarin, Tabun, VX, Soman
Signs/Symptoms	Choking, excessive salivation, bluish tint to skin	Air hunger, tachycardia, seizures	Dermal blisters, photophobia, respiratory distress, GI distress	Seizures, salivation, lacrimation, urination, defecation, GI distress, and emesis (SLUDGE)
Mechanism of Action	Varies by adult, but typically causes a buildup of fluid in the throat and lungs, inhibiting breathing	Prevents oxygen from reaching cells	Varies based on agent. Many cause irritation of exposed tissues, fluid and electrolyte imbalances, edema, and death of white blood cells	Attack the nervous system, causing muscles to contract but not relax, leading to asphyxiation or cardiac arrest

	Choking Agents	Blood Agents	Blister Agents	Nerve Agents
Medical Treatment	Oxygen therapy, steroids, rest	Hyperbaric treatment, cyanide antidote kit (amyl nitrate and sodium nitrate)	No known treatment. Supportive care is indicated	Mark I Kit/ NAAK; Atropine, Pralidoxime (2-Pam)

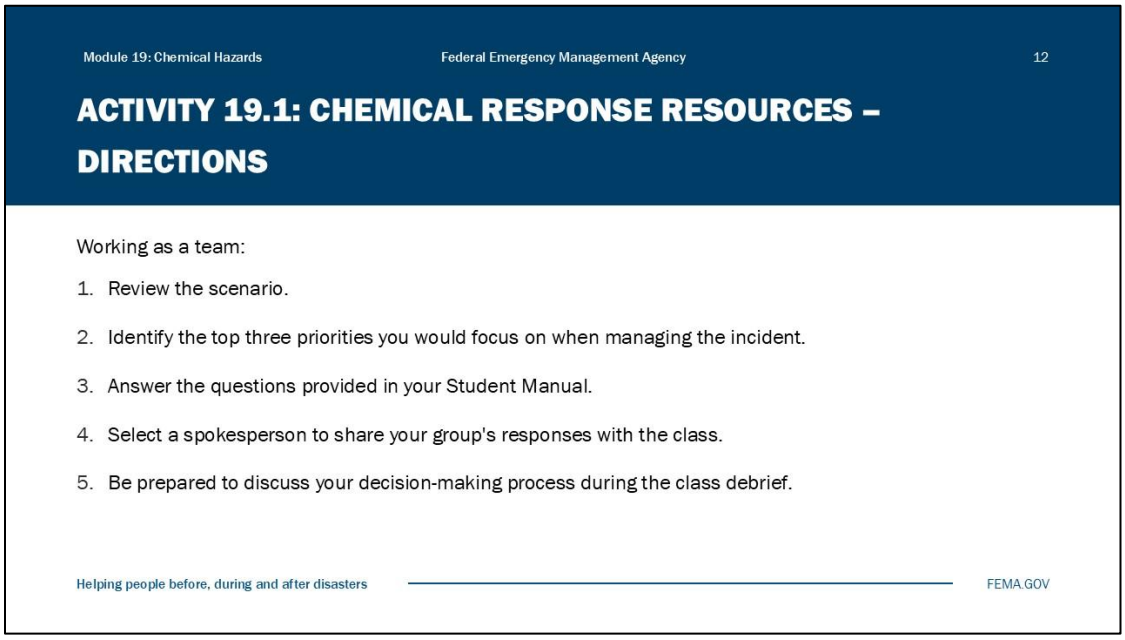
Activity 19.1: Chemical Response Resources (1 of 2)



Slide 19-11, Activity 19.1: Chemical Response Resources

Not Applicable.

Activity 19.1: Chemical Response Resources (2 of 2)



Slide 19-12, Activity 19.1 – Chemical Response Resources – Directions

Activity 19.1: Chemical Response Resources – Directions to Students

Purpose

This activity's purpose is to analyze a chemical incident scenario from an Emergency Management perspective. As an Emergency Management professional, how would you and the EOC support incident response? What issues and concerns would you be considering as the Emergency Manager? Facilitate group discussion about the most appropriate emergency response strategies.

Directions to Students

1. Review the scenario.
2. Identify the top three priorities you would focus on when supporting the incident from the EOC.
3. Answer the questions provided below.
4. Select a spokesperson to share your group's responses with the class.
5. Be prepared to discuss your decision-making process during the class debrief.

Scenario

At around 3 a.m., two freight trains collided in your community. One train was transporting chlorine gas, sodium hydroxide, and cresol. One of the rail cars ruptured, releasing approximately 60 tons of chlorine gas. The surrounding area is a blend of industrial facilities and residential neighborhoods.

Activity 19.1 Worksheet

1. As an emergency management professional, identify your top three priorities when attempting to manage this incident from the EOC.

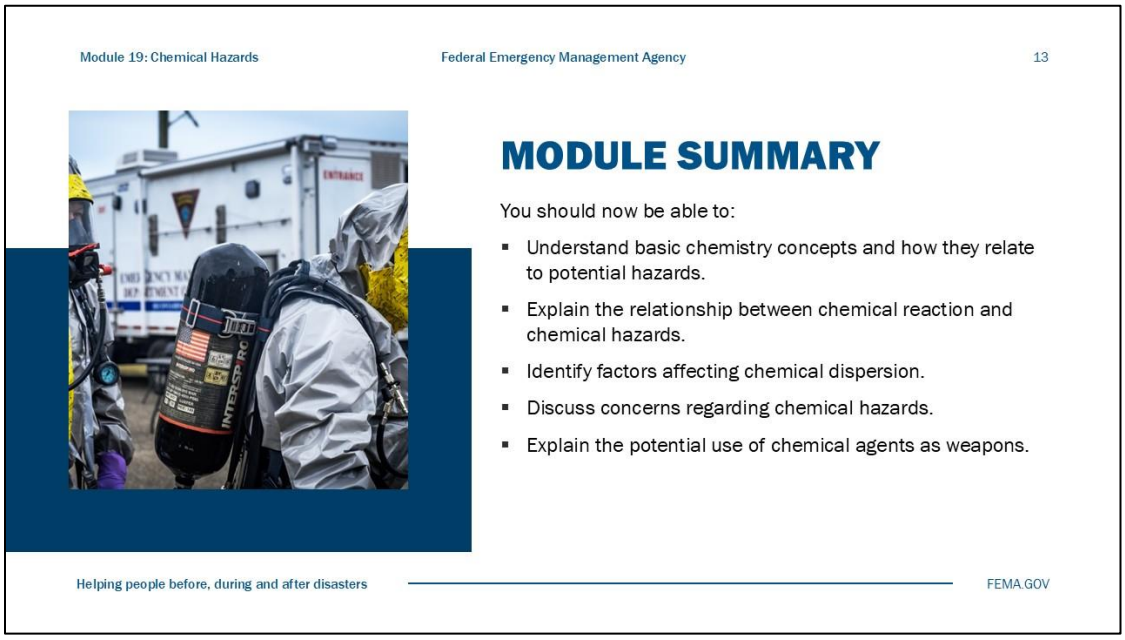
2. What are the impacts of chlorine gas on the surrounding community? What emergency management decisions are influenced by these impacts?

3. What are the health impacts to the public and first responders? What emergency management decisions are influenced by these impacts?

4. What other decisions would you be considering as the emergency manager?

5. Who are some of the partners that may be available to help you in this incident?

End of Module (1 of 2)



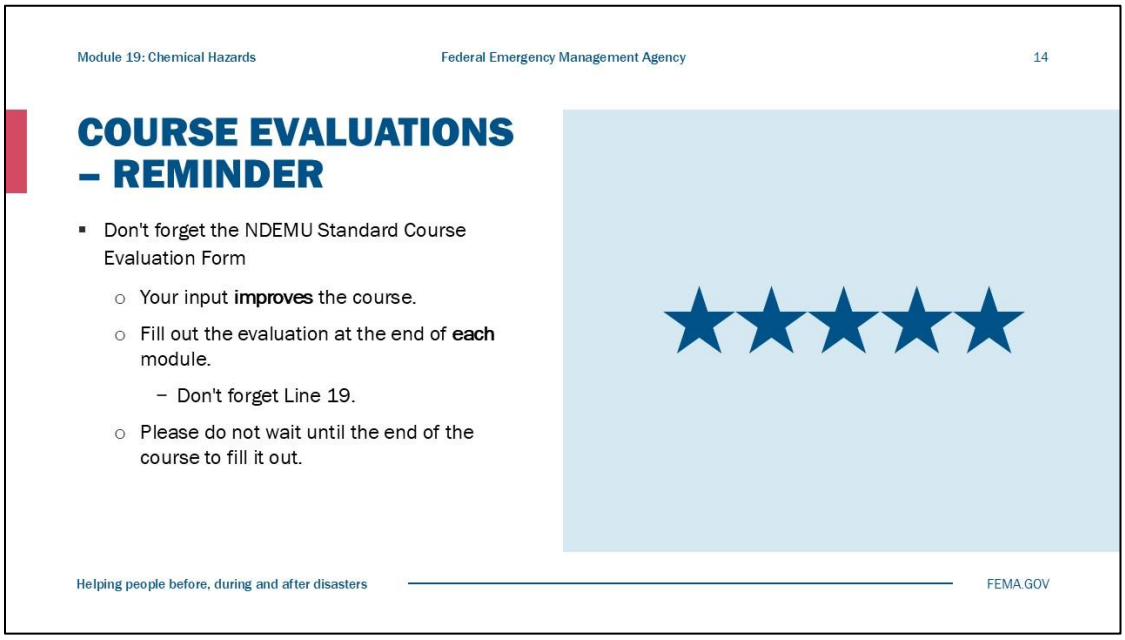
Slide 19-13, Module Summary

You should now be able to:

- Understand basic chemistry concepts and how they relate to potential hazards.
- Explain the relationship between chemical reactions and chemical hazards.
- Identify factors affecting chemical dispersion.
- Discuss concerns regarding chemical hazards.
- Explain the potential use of chemical agents as weapons.

Do you have any questions about the material covered in this module?

End of Module (2 of 2)



Slide 19-14, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

Chemical Warfare Agents https://www.epa.gov/emergency-response/chemical-warfare-agents

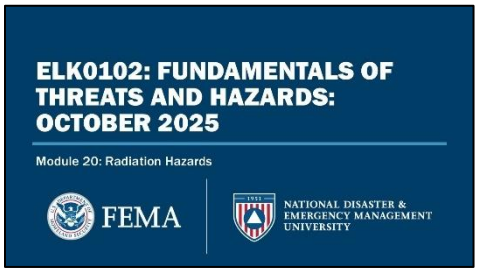
GHS Pictograms & Hazards
(https://www.osha.gov/Publications/HazComm_QuickCard_Pictogram.html)

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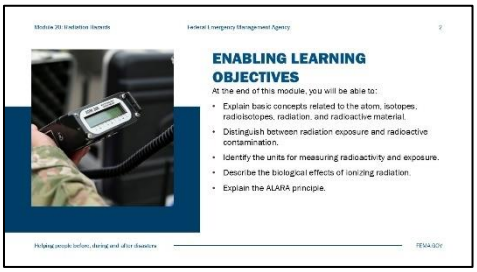
Module 20

Radiation Hazards

Administration



Slide 20-1, Module 20: Radiation Hazards



Slide 20-2, Enabling Learning Objectives

Duration

1 hour, 40 minutes

Terminal Learning Objective (TLO)

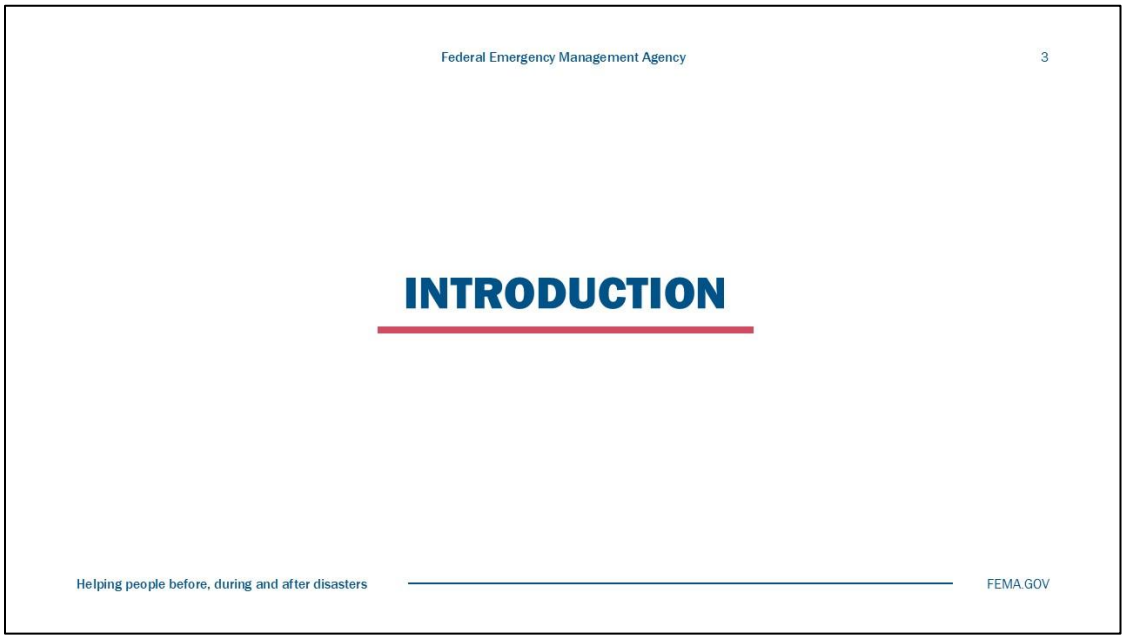
By the end of this module, participants will be able to explain key radiation safety concepts by describing atomic structure, types of radiation, exposure vs. contamination, measurement units, biological effects, and how to apply the ALARA principle.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Explain fundamental concepts about atoms, isotopes, radioisotopes, radiation, and radioactive material.
- Distinguish between radiation exposure and radioactive contamination.
- Identify the units used to measure radioactivity and exposure.
- Describe the biological effects caused by ionizing radiation.
- Explain the ALARA principle.

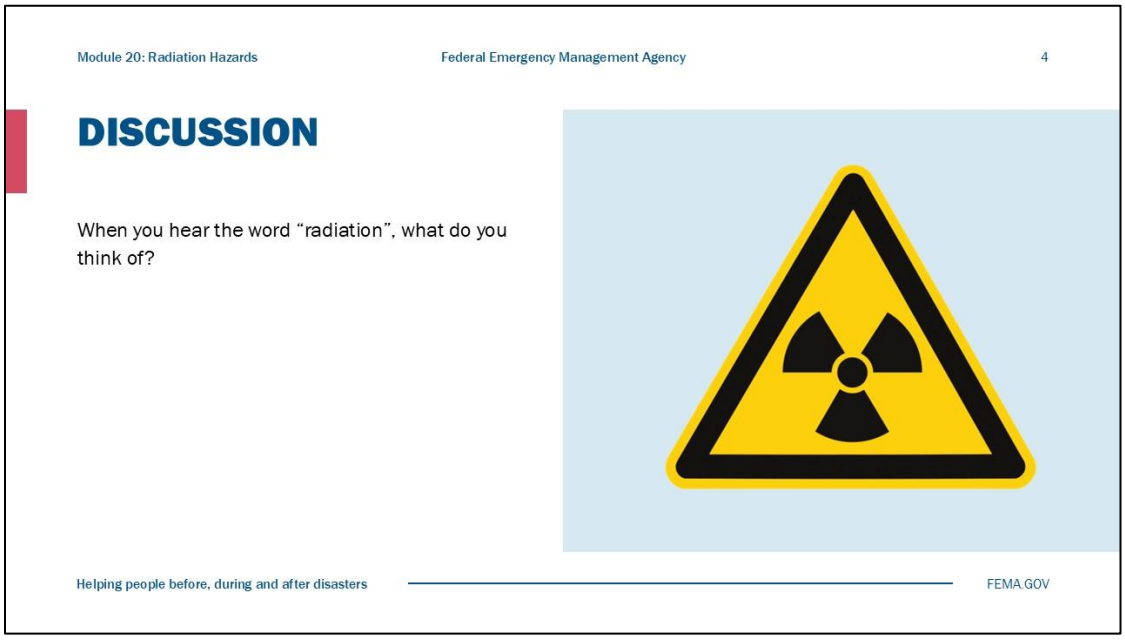
Introduction (1 of 4)



Slide 20-3, Introduction

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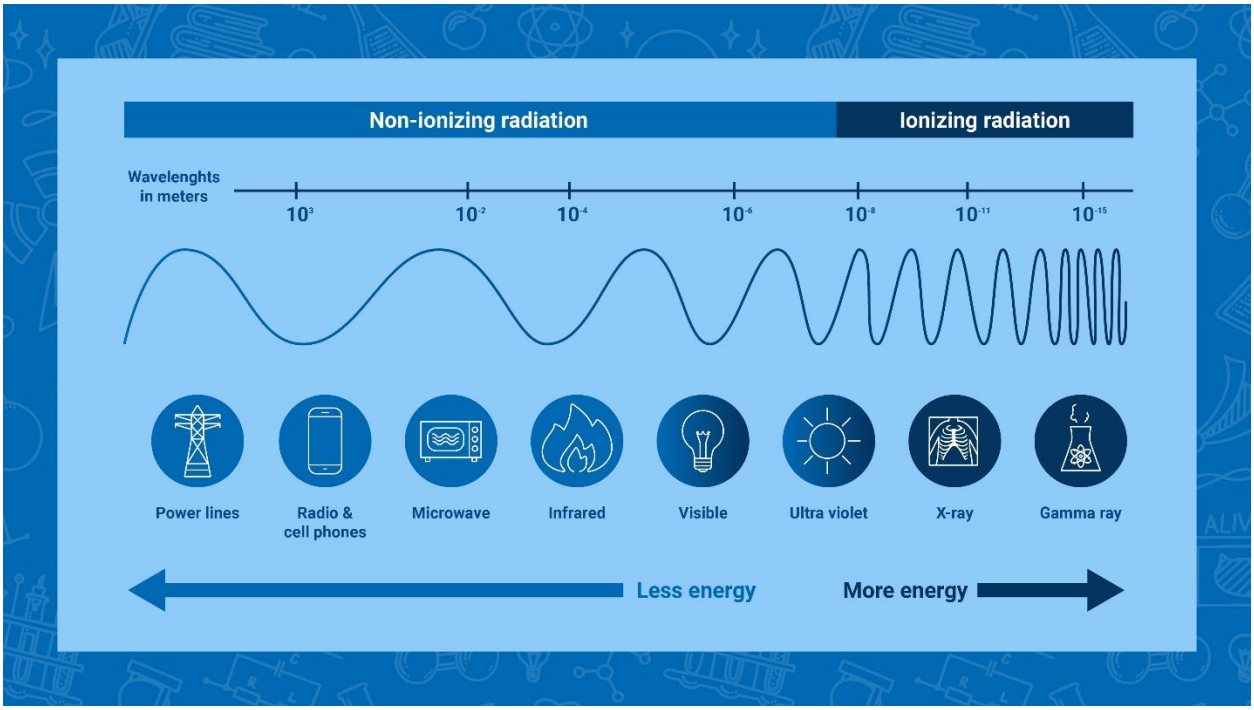
Introduction (3 of 4)



Slide 20-4, Discussion

Discussion Question: When you hear the word "radiation," what do you think of?

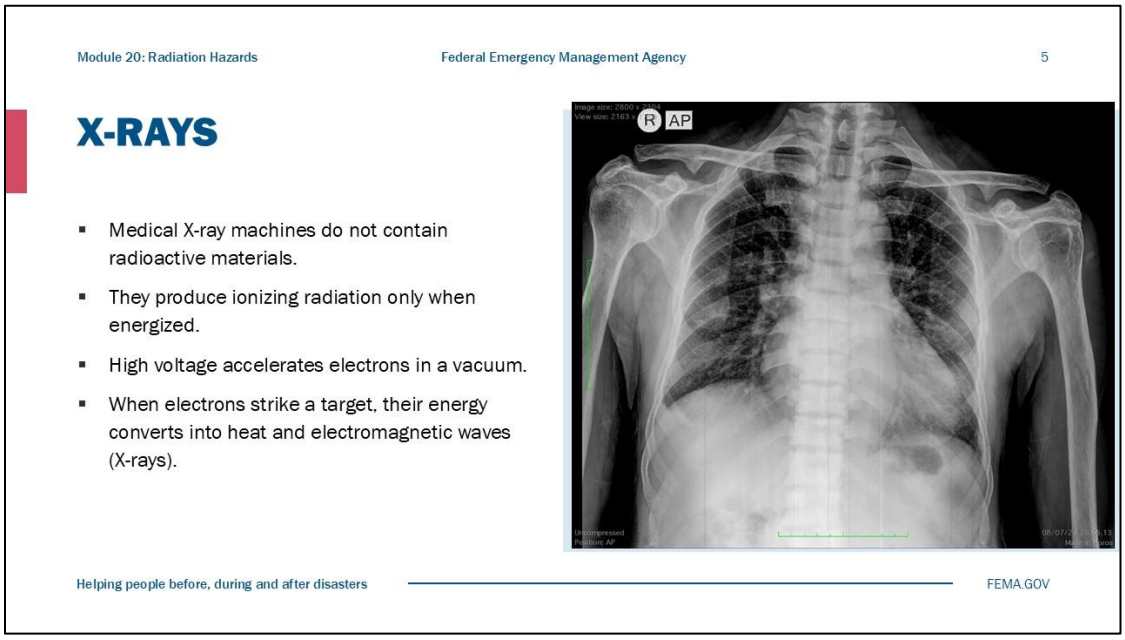
For instructor only



Source:

What is Radiation? (2023, January 25). [Text]. IAEA. https://www.iaea.org/newscenter/news/what-is-radiation

Introduction (4 of 4)

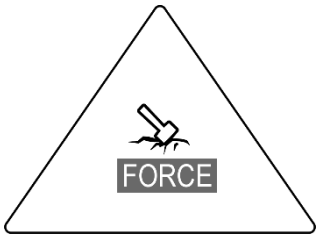


Slide 20-5, X-rays

Ionizing radiation plays a crucial role in various medical applications, particularly in the use of X-rays. Here are several key points to understand about the operation and safety aspects of medical X-ray machines:

- Medical X-ray machines do not contain radioactive materials.
- They produce ionizing radiation only when energized.
- High voltage accelerates electrons in a vacuum.
- When electrons strike a target, their energy converts into heat and electromagnetic waves (X-rays).

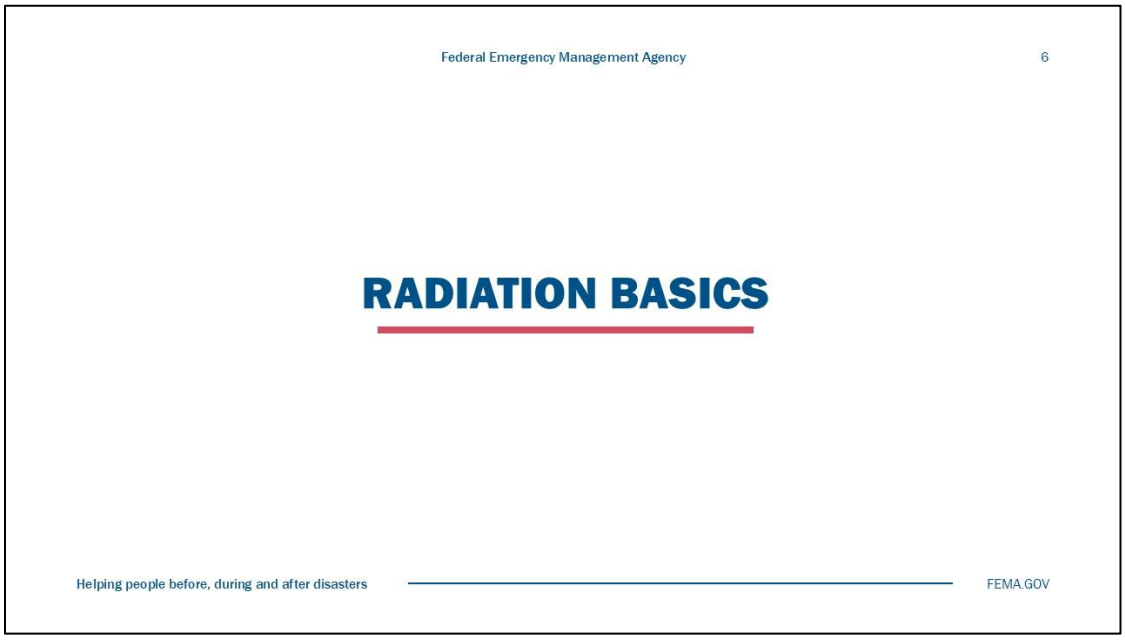
This is force.



Medical X-rays are a good example of exposure without contamination.

- X-rays are generated by using high voltage to accelerate electrons in a vacuum and then stopping them at a target. Electrons possess mass, and as they are accelerated, they gain kinetic energy—energy resulting from their motion.
- When an electron strikes the target, it relinquishes its kinetic energy. Most of that energy generates heat in the target, but a portion of it produces X-rays. The higher the voltage, the greater the kinetic energy of the electron, resulting in more energetic X-rays being generated.
- Medical X-ray machines do not have a radioactive source, so you will not become contaminated from X-ray exposure.
- Without high voltage, X-rays cannot be created. Removing the energy source eliminates the hazard.

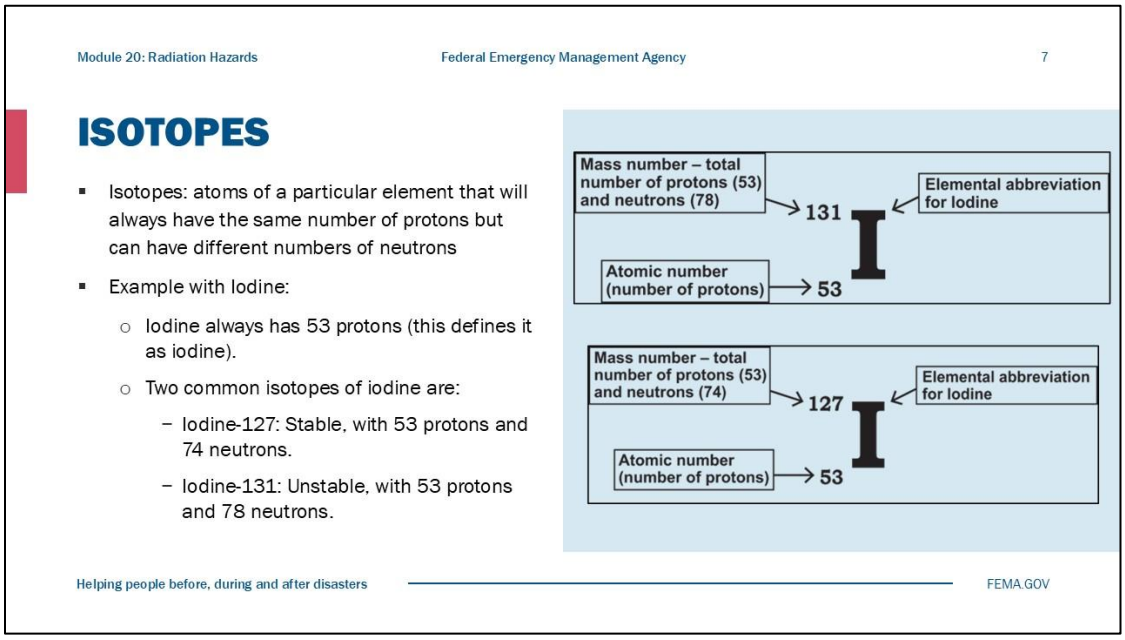
Radiation Basics (1 of 16)



Slide 20-6, Radiation Basics

Not Applicable.

Radiation Basics (2 of 16)



Slide 18-7, Isotopes

Isotopes: Atoms of the same element have the same number of protons but can have different numbers of neutrons. The number of protons plus the number of neutrons is the isotope number.

Example with Iodine:

- Iodine always has 53 protons (this defines it as iodine).
- Two common isotopes of iodine are:
  - Iodine-127: Stable, with 53 protons and 74 neutrons.
  - Iodine-131: Unstable, with 53 protons and 78 neutrons.

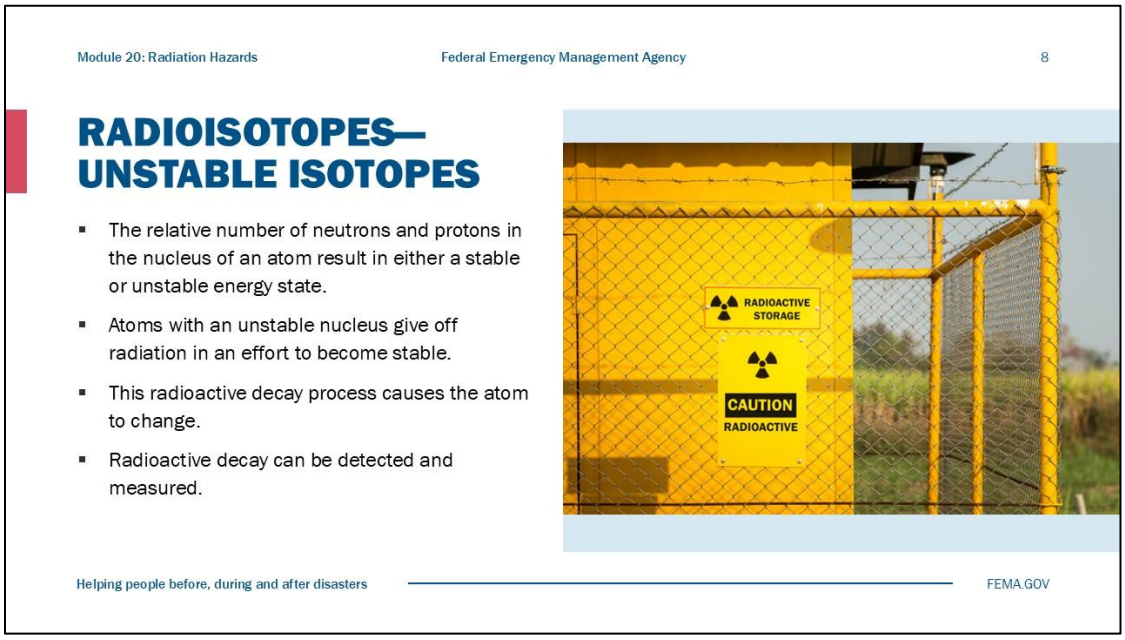
Key Insight: Unstable isotopes, such as Iodine-131, release energy through radioactive decay, transitioning to a more stable element (Xenon).

An isotope is an atomic species characterized by the number of protons and neutrons, as well as the energy state of the nucleus. The notation for a nuclide includes:

- Element (X)
- Atomic Number (Z): Number of protons in the nucleus
- Mass Number (A): Total number of protons + neutrons in the nucleus

The number of protons defines what an element is (Hydrogen, Oxygen, Carbon, etc.). The number of neutrons can be different, which makes them isotopes of that element. Elements with larger numbers of protons, like uranium, require many more neutrons to prevent the protons from repelling each other too strongly and thus keep the nucleus together.

Radiation Basics (3 of 16)



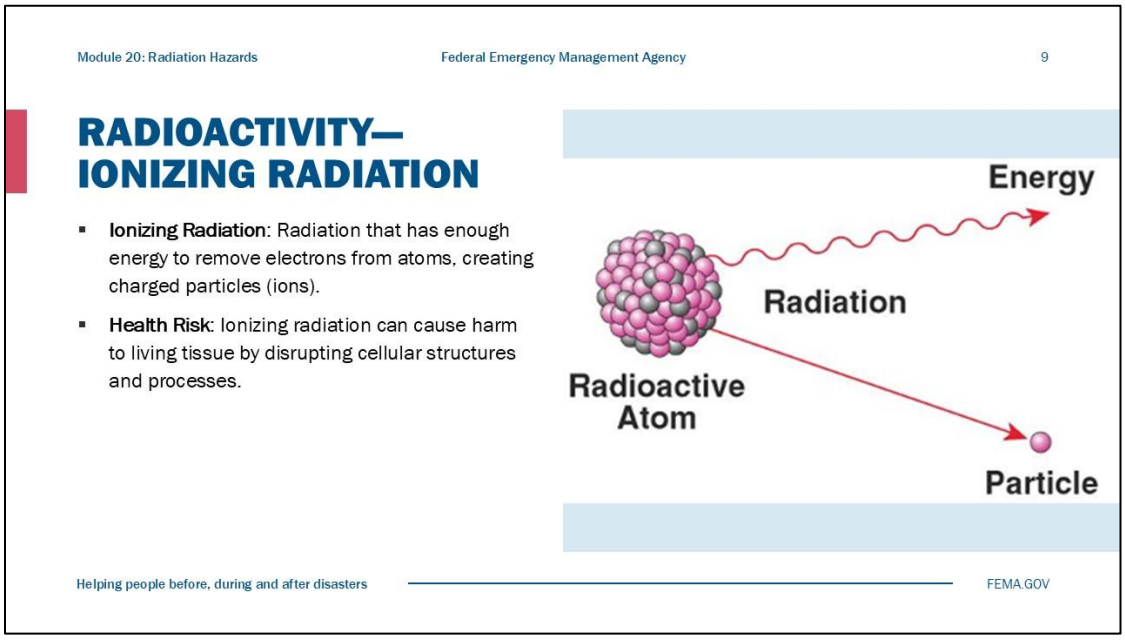
Slide 18-8, Radioisotopes—Unstable Isotopes

Radioisotopes (also known as radionuclides) are atoms that decay radioactively and give off ionizing radiation. Ionizing radiation (energy) causes other elements and molecules to become ionized (i.e., electrically charged). Radioisotopes are the radioactive isotope of an element: they give off radiation in an effort to become stable. The decay process (ionizing radiation, or radioactivity) causes the atom to change. Not all isotopes are radioactive.

Some elements, like uranium, have different isotopes with different numbers of neutrons. Depending on the number of neutrons in the isotope, some are more unstable than others, resulting in radioactive decay. Uranium in the form of U-234, U-235, and U-238 is found in nature.

This concept will be revisited when we discuss radiation in Module 22.

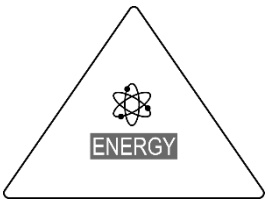
Radiation Basics (4 of 16)



Slide 18-9, Radioactivity—Ionizing Radiation

Ionizing radiation can be in the form of energy, waves, or particles.

This is energy.

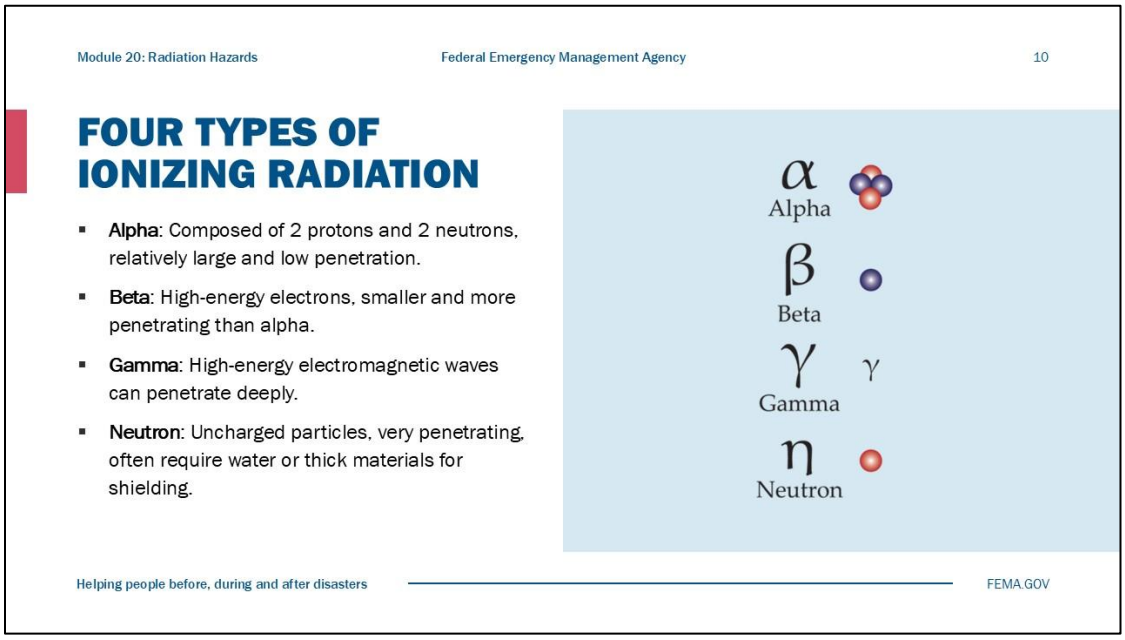


In this course, when we speak of radiation, we are referring to the energy released in radioactive decay, which is more energetic than other types of radiation. It has enough energy to remove electrons from atoms as it passes through matter. (The process of removing electrons from atoms is called **ionization**.)

Ionizing radiation can be in the form of energy, waves, or particles.

The ability to remove electrons from atoms is what makes ionizing radiation potentially hazardous. Non-ionizing radiation, like visible light or radio waves, is generally harmless.

Radiation Basics (5 of 16)



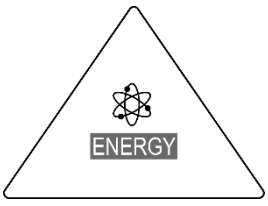
Slide 18-10, Four Types of Ionizing Radiation

Interaction of Ionizing Radiation with Matter:

- Charged particles interact strongly and ionize directly.
- Neutral particles interact less, ionize indirectly, and penetrate farther.

Ionizing radiation carries enough energy to remove electrons from atoms or molecules, causing them to become ionized (electrically charged).

This is energy.



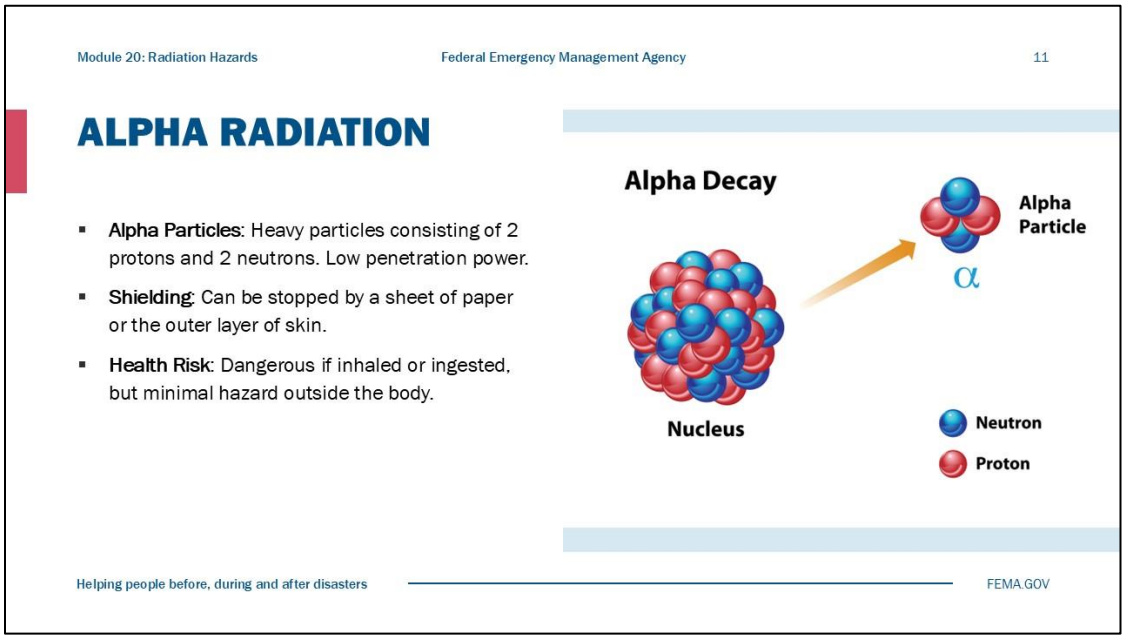
The **four basic types** of ionizing radiation are:

- Alpha radiation
- Beta radiation
- Gamma radiation

- Neutron radiation

These types differ in their penetrating power and the way they affect human tissue. Next, you will take a closer look at each kind of ionizing radiation and its penetrating ability.

Radiation Basics (6 of 16)



Slide 18-11, Alpha Radiation

Alpha radiation: Alpha radiation consists of particles with two protons and two neutrons (but no electrons) that are ejected from the nucleus of a radioactive atom. Alpha particles are essentially a helium nucleus without its electrons.

Alpha particles:

- Are high-energy particles that are relatively large, heavy, and only travel a short distance (a few inches in air)
- Lose their energy very rapidly
- Have a low penetrating ability
- The greatest hazard from alpha-emitting material is when it is inhaled or ingested

PPE with Self-Contained Breathing Apparatus (SCBA) will enhance safety when dealing with alpha radiation.

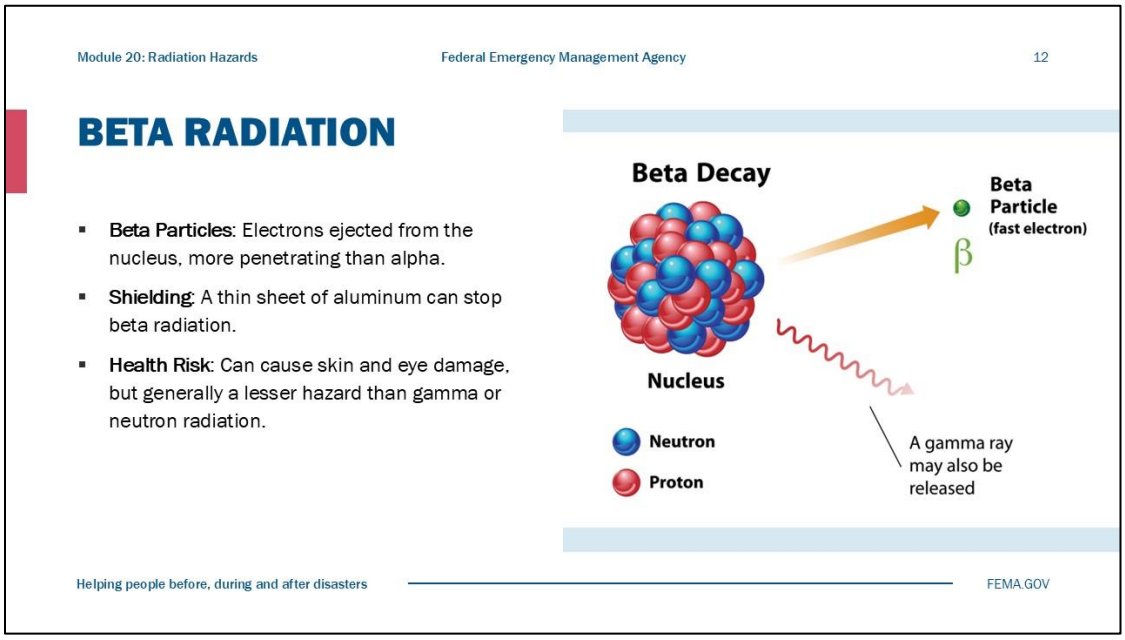
Hazard: Alpha particles pose a minimal biological hazard outside the body. The greatest hazard occurs when the material is inhaled or ingested. Once inside the body, alpha radiation can cause harm to individual cells or organs.

Note that the original element is not what poses the internal hazard; it is the alpha particle that poses the internal hazard. Once an alpha particle is emitted from the nucleus of an atom, it travels a

short distance until it interacts with other atoms and stops. When the alpha particle stops, it takes electrons from another substance, ionizing it, and the alpha then becomes a harmless helium atom. Therefore, it is not possible to inhale or ingest alpha particles; rather, it is the material emitting the alpha particles that is inhaled.

Shielding: The characteristics of alpha radiation make it easy to shield, and something as thin as a sheet of paper can block the passage of alpha radiation.

Radiation Basics (7 of 16)



Slide 18-12, Beta Radiation

Beta radiation: Beta radiation consists of particles, electrons, ejected from the nucleus of a radioactive atom.

Beta particles:

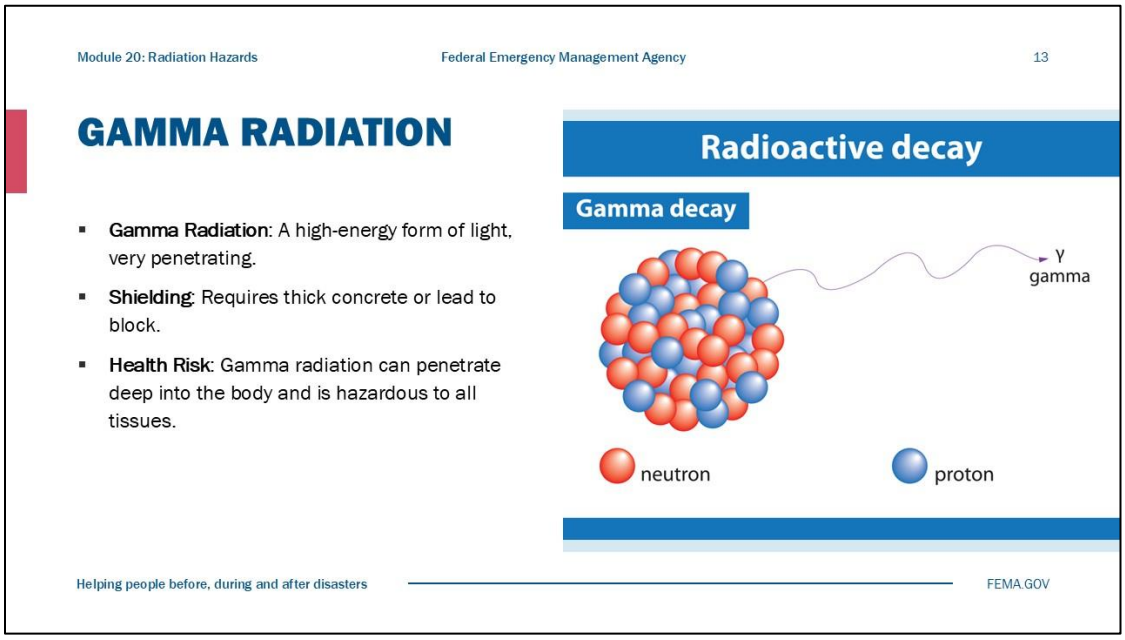
- They are smaller and lighter than alpha particles because they are simply electrons.
- Travel farther than alpha particles. In the air, beta radiation can travel several feet.
- Outside the body, beta radiation is only a slight hazard.

PPE with Self-Contained Breathing Apparatus (SCBA) will enhance safety when dealing with beta radiation.

Hazard: Beta radiation is more penetrating than alpha radiation; however, outside the body, it poses only a slight hazard. The range of penetration in human tissue is less than an inch.

Shielding: The characteristics of beta radiation make it easy to shield with moderately dense materials like aluminum

Radiation Basics (8 of 16)



Slide 18-13, Gamma Radiation

Gamma radiation: Gamma radiation is an electromagnetic wave of energy (not particles) emitted from the nucleus of a radioactive atom.

Gamma waves:

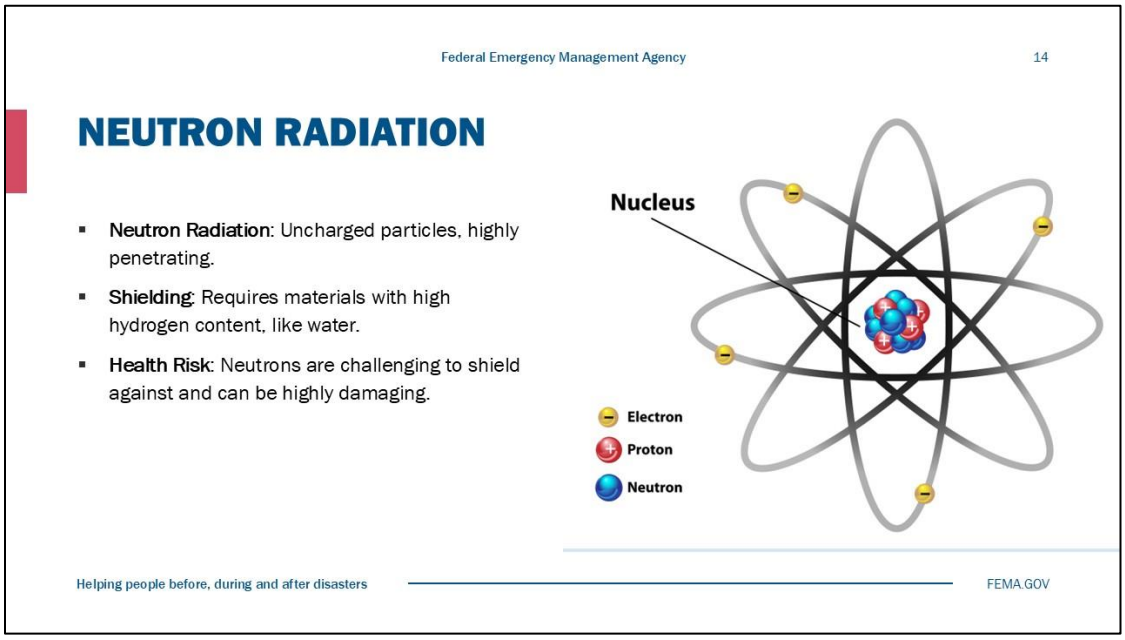
- Have no mass and no electrical charge
- Are commonly referred to as "photons"
- Can travel great distances because they are pure energy

PPE cannot protect against exposure from high-energy, highly penetrating forms of ionizing radiation, like Gamma radiation.

Hazard: Gamma radiation poses a hazard to the entire body because it can easily penetrate human tissue.

Shielding: The characteristics of gamma radiation make it very difficult to shield because of its high penetrating ability. Very dense materials, such as concrete, are required to shield gamma radiation.

Radiation Basics (9 of 16)



Slide 18-14, Neutron Radiation

Neutron radiation: Neutron radiation, like alpha and beta radiation, consists of particles ejected from the nucleus of a radioactive atom.

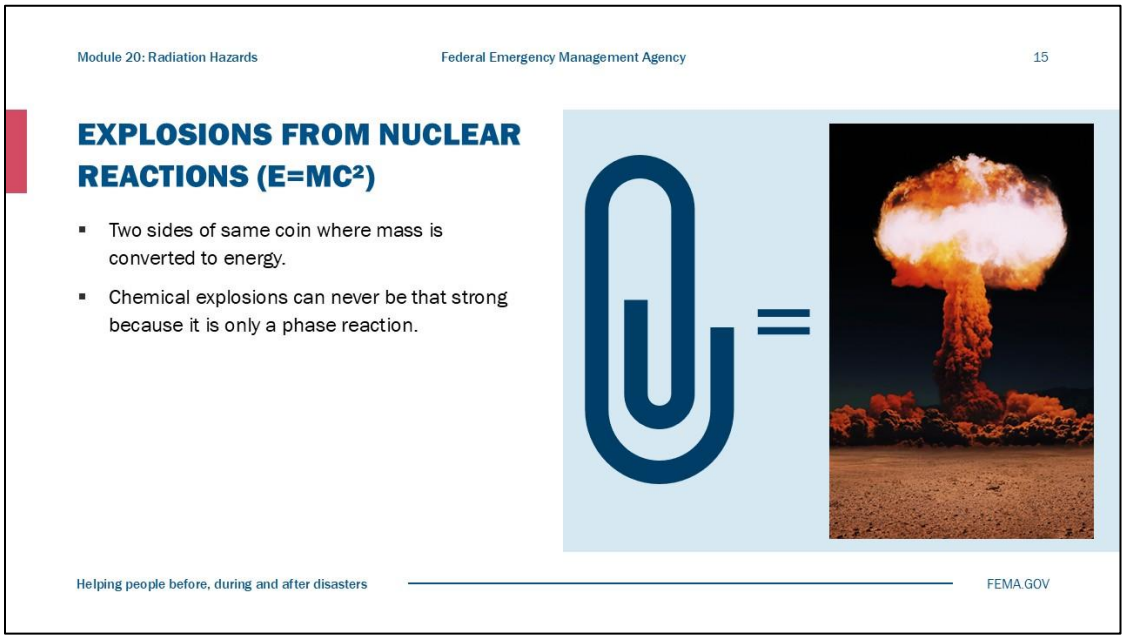
Neutrons:

- No electrical charge
- Can travel great distances and are highly penetrating
- Best shielded by dense materials with high hydrogen content (e.g., water)

Hazard: Neutron radiation, like gamma radiation, is highly penetrating.

Shielding: The characteristics of neutron radiation make it difficult to shield. Typically, materials with high hydrogen content (e.g., water) are required to shield neutron radiation. In transportation situations, neutron radiation is not commonly encountered.

Radiation Basics (10 of 16)



Slide 18-15, Explosions from Nuclear Reactions (E=MC²)

- Two sides of the same coin, where mass is converted to energy
- Chemical explosions can never be that strong because they are only a phase reaction

If you could turn the amount of mass in a paper clip into pure energy, it would yield an equivalent of about 18 kilotons of TNT. That is roughly the size of the bomb that destroyed Hiroshima in 1945. In the Hiroshima explosion, countless atoms of uranium were split apart in a nuclear chain reaction. Each time an atom splits, the total mass of the fragments speeding apart is less than that of the original atom. The bomb, in essence, transformed three-hundredths of an ounce of mass into a cataclysmic burst of heat and light.

Source: Public Broadcasting System (PBS) NOVA, "Einstein's Big Idea" (https://www.pbs.org/wgbh/nova/video/einsteins-big-idea/)

Energy in The Nucleus:

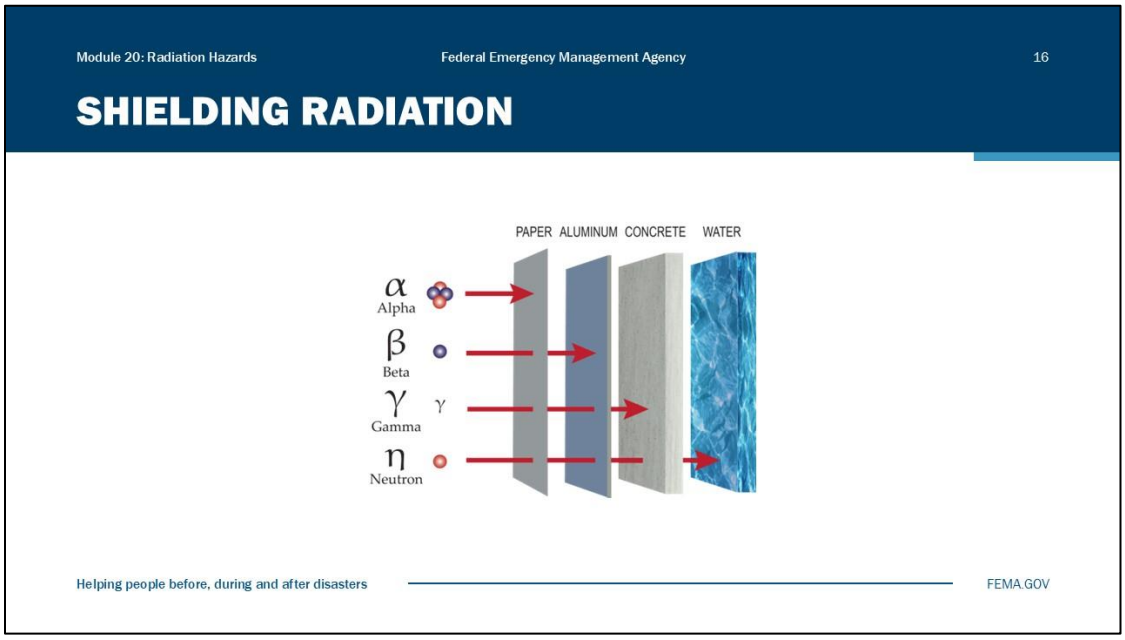
- A nuclear force of attraction between protons and neutrons helps keep the protons together in the nucleus even though their like positive charge causes them to repel.
- There is a certain amount of energy locked up in that nucleus due to these forces at play.
- Without enough neutrons to mitigate the negative repulsive force, the nucleus can radioactively decay, releasing energy.

- This can happen naturally; We can cause it to happen by shooting neutrons at the nucleus.
- The decay process is called FISSION when the nucleus splits, forming two lighter elements. One neutron can cause U-235 to decay into Ba-141 and Kr-92, plus three new neutrons.
- We can cause it to happen by shooting neutrons at the nucleus like a slow bowling ball at bowling pins, causing some to fly out.
- Those three new neutrons, if they hit more U-235, can cause even more to split, creating three more neutrons each, plus energy.
- This is the process by which nuclear reactors work. The energy from fission heats water into steam to drive turbines and create electricity.
- This reaction can "run away" if left unchecked.

Fusion

- The opposite of fission.
- Fusion combines two nuclei to create a heavier element.
- This is the process by which the Sun creates its energy.
- The Sun's gravity is strong enough to combine hydrogen nuclei into helium, releasing energy.
- The helium is lighter than the sum of its parts. The "missing" mass was converted to energy

Radiation Basics (11 of 16)

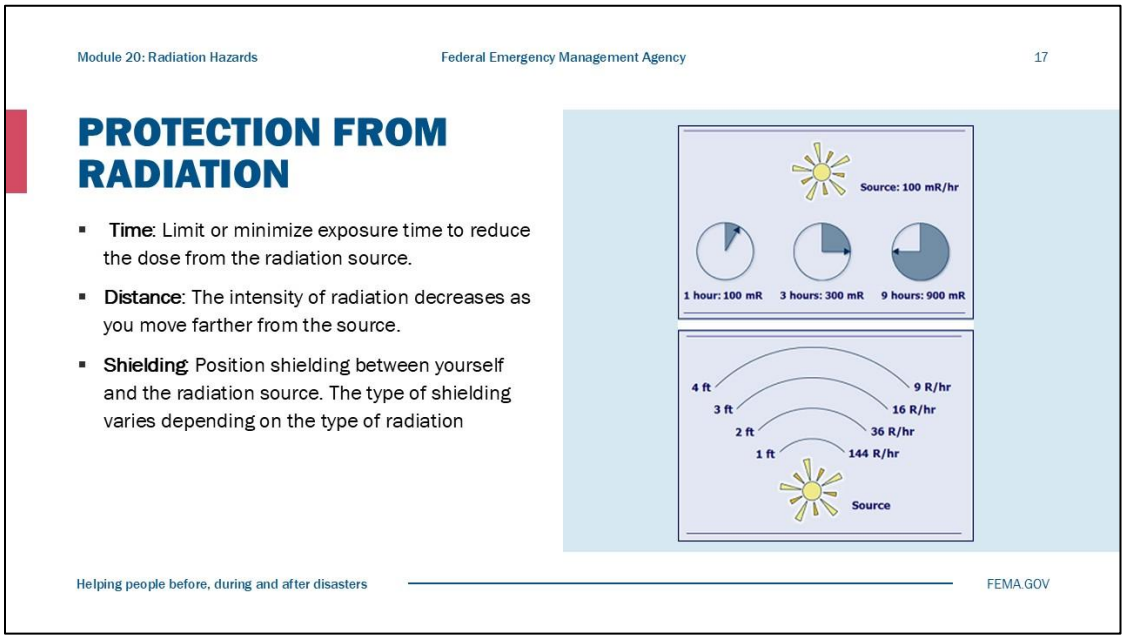


Slide 20-16, Shielding Radiation

The shielding required for the four types of ionizing radiation is as follows:

- **Alpha radiation**: A thin sheet of paper can block alpha radiation, as it is essentially a helium nucleus.
- **Beta radiation**: Moderately dense materials like aluminum can block beta radiation, as it is composed of electrons.
- **Gamma radiation**: Because of its high penetration ability, very dense materials like concrete are necessary to shield against gamma radiation, as it consists of pure energy.
- **Neutron radiation**: The characteristics of neutron radiation make it challenging to shield, as it is a very small subatomic particle that moves through most materials without obstruction. Generally, materials with a high hydrogen content, such as water, are necessary to shield against neutron radiation. The cooling pools in a nuclear reactor serve as an excellent example.

Radiation Basics (12 of 16)

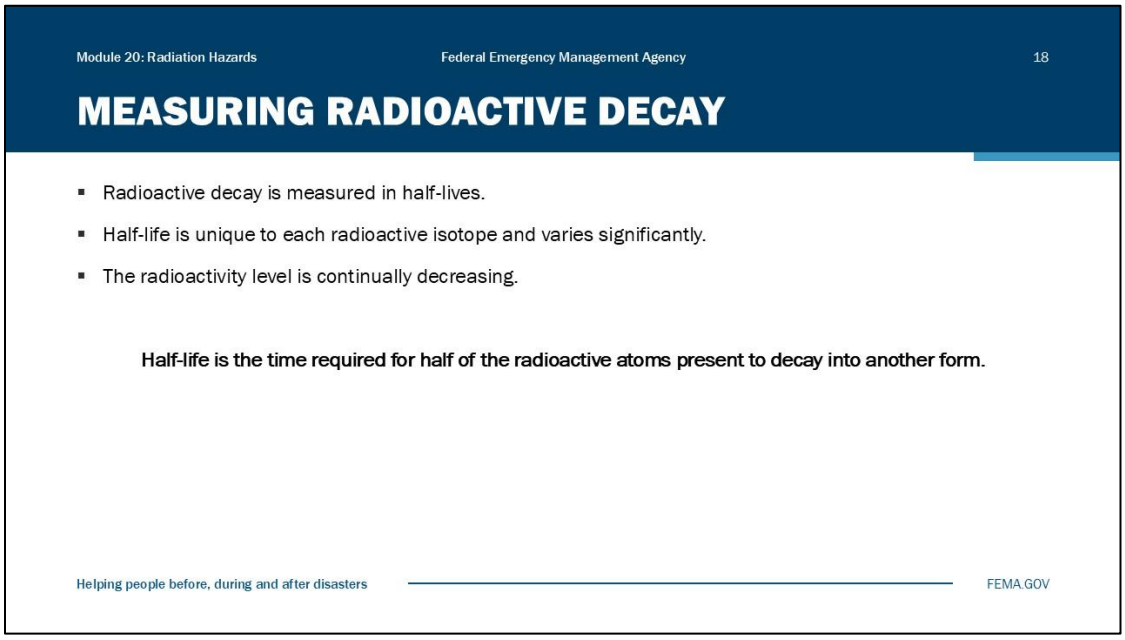


Slide 20-17, Protection from Radiation

Understanding radiation protection principles is essential for minimizing exposure risks. By concentrating on time, distance, and shielding, individuals can effectively reduce the hazards associated with ionizing radiation. Let's explore these key strategies for protection against radiation.

- **Time:** Limit or minimize exposure time to reduce the dose from the radiation source.
- **Distance:** The intensity of radiation decreases as you move farther from the source.
- **Shielding:** Position shielding between yourself and the radiation source. The type of shielding varies depending on the type of radiation.

Radiation Basics (13 of 16)



Slide 20-18, Measuring Radioactive Decay

Measuring radioactive decay is a fundamental aspect of understanding radiation and its effects. It involves tracking the reduction in the number of radioactive atoms over time using the concept of half-life. This measurement helps scientists determine the rate at which a radioactive substance transforms into another form, enabling effective management of radiation exposure and safety protocols.

- Radioactive decay is measured in half-lives.
- Half-life is unique to each radioactive isotope and varies significantly.
- The radioactivity level is continually decreasing.

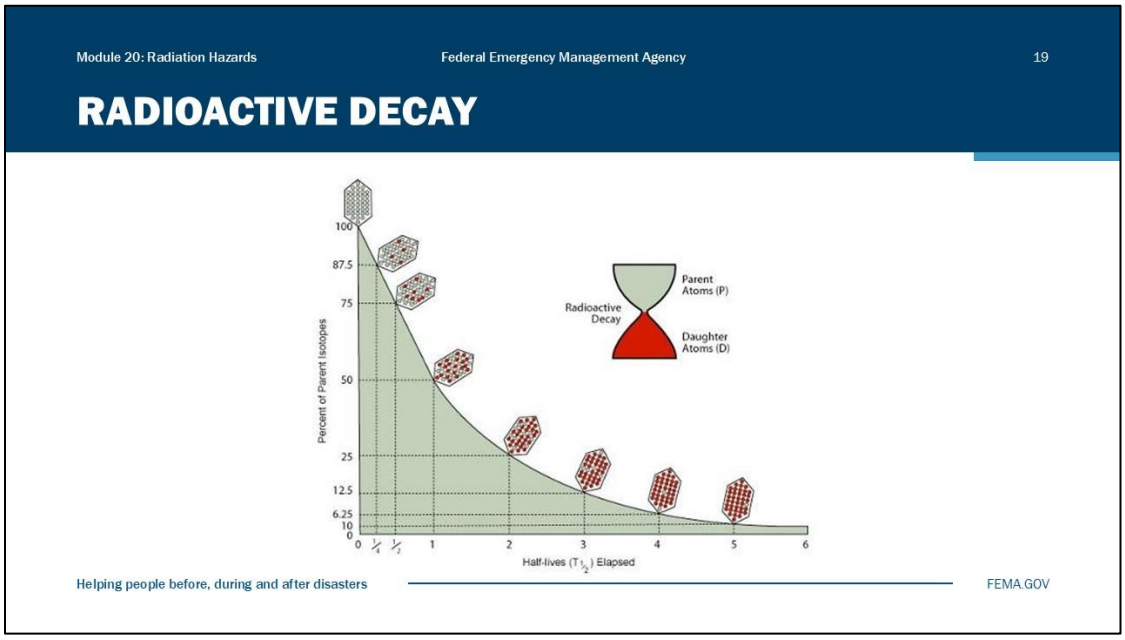
Half-life is the time required for half of the radioactive atoms present to decay into another form.

Radioactive decay is measured in half-lives.

- After a transformation, the nucleus is usually more stable than before, but it may not be completely stable. In such cases, another transformation occurs, in which the nucleus emits radiation again to achieve greater stability.
- Each step in the series of transformations results in a distinct reduction in the total mass-energy of the nucleus. As the energy of the nucleus decreases, it is said to disintegrate or decay. Half-life is the time it takes for half of the present radioactive atoms to decay into another form.

- Half-life is unique to each radioactive isotope and can vary significantly among different radioactive materials. Radioactive pharmaceutical products, also known as radiopharmaceuticals, typically have half-lives ranging from a few hours to several days.
- Regardless of the half-life, the radioactivity level of any given amount of radioactive material consistently decreases by half during each "half-life."

Radiation Basics (14 of 16)



Slide 20-19, Radioactive Decay

Due to the ongoing decrease in radioactivity, after seven half-lives, the activity of the material will fall to less than 1 percent of its original level. While the radiation emitted is still present, the amount of material has diminished.

The curve shown in the graphic represents the same shape common to the radioactive decay of all isotopes through the first several half-lives.

The table below shows several common radioactive materials and their respective half-lives. More information about each of these materials and their uses is provided in the chart that follows.

Radioactive Isotope	Half Life
Nitrogen-16	7 seconds
Technetium-99m	6 hours
Thallium-201	73 hours
Cobalt-60	5 years

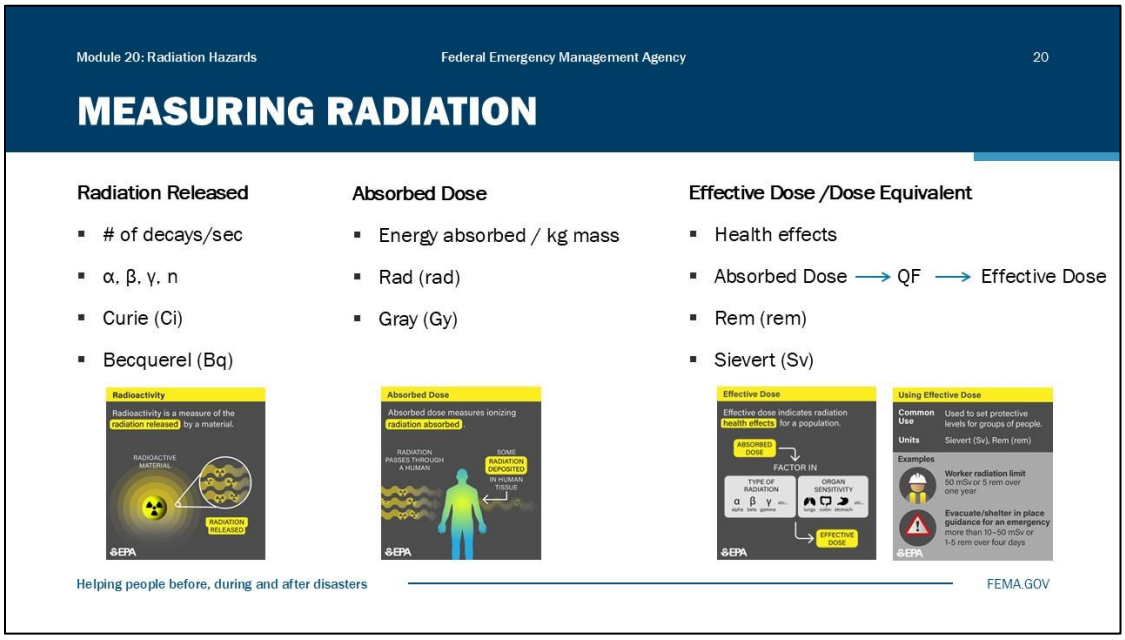
Radioactive Isotope	Half Life
Cesium-137	30 years
Americium-241	432 years
Uranium-238	4.5 billion years

Information About Selected Radioactive Isotopes

Isotope	Descriptive
Nitrogen-16	• A radionuclide associated with nuclear powerplant operations. • Produced in a process called activation when oxygen in the reactor coolant is exposed to neutron radiation. • Formed when Oxygen-16 captures a neutron and emits a proton to form Nitrogen-16.
Technetium-99m	• The most widely used radiopharmaceutical for diagnosing diseased organs. (A small amount of the radioactive isotope is placed in the patient's body, usually injected into the bloodstream, for the purpose of imaging some part of the body.) • One of the things that makes technetium-99m so popular for this purpose is its short half-life, which leads to very fast clearing from the body after an imaging process.
Thallium-201	• Widely used as a radiopharmaceutical for diagnosis of coronary artery disease, other heart conditions such as heart muscle death, and for the location of low-grade lymphomas.
Cobalt-60	• Produced in a process called activation, when materials (such as steel) are exposed to neutron radiation in reactors. It can also be produced in a particle accelerator. • In medicine, it is used for cancer radiotherapy. • Industrial uses include testing of welds and castings, and various measurement and test instruments (e.g., leveling devices and thickness gauges).

Isotope	Descriptive
Cesium-137	• A common radionuclide produced when nuclear fission of uranium and plutonium occurs in a reactor or atomic bomb. • Commonly used in hospitals for diagnosis and treatment, as a calibration source, and to sterilize medical equipment. • In industry, it is used to irradiate food and in industrial instruments.
Americium-241	• A human-made radioactive metal that exists as a solid under normal conditions and is produced when plutonium absorbs neutrons in nuclear reactors and nuclear weapons tests. • Blended with beryllium, it is used in various types of test gauges. • Used as a radiation source in medical diagnostic devices and in research. • Commonly used in minute amounts in smoke detectors as an ionization source.
Uranium	• A naturally occurring radioactive metal present in low amounts in rocks, soil, water, plants, and animals that contributes to low levels of natural background radiation in the surroundings. • Occurs in three forms or isotopes: uranium-234, uranium-235, and uranium-238. About 99 percent of uranium in rock is uranium-238, which decays to form other radioisotopes, including radium-226 and radon-222. • Significant concentrations of uranium occur naturally in some substances such as phosphate deposits and uranium-enriched ores.

Radiation Basics (15 of 16)



Slide 20-20, Measuring Radioactive

The strength of a radioactive source is measured in:

- The traditional unit of curies (Ci) or
- The international system (SI) unit of becquerels (Bq).

Both units measure activity. The Ci is a large amount of activity, while the Bq is a small amount.

Radioactive material is not typically measured by its mass, weight, or volume. Rather, radioactivity is measured in terms of the number of nuclear decays or disintegrations that occur in a sample over a specific period. This is known as the activity of the sample.

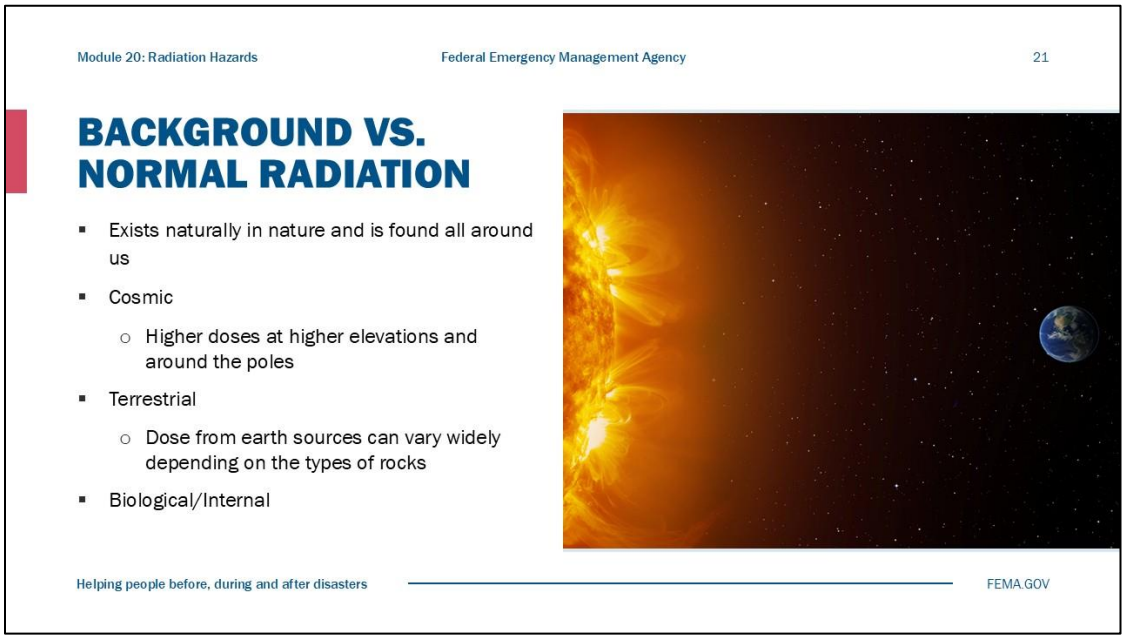
The curie (Ci) is defined as 3.7 x 1010 or 37 billion (37,000,000,000) disintegrations per second (dps). The becquerel (Bq) is defined as 1 dps.

- The traditional unit of activity is the **curie (Ci),** named after Marie and Pierre Curie, physicists who were pioneers in the study of radioactivity.
- The international system (SI) unit of activity is the **becquerel (Bq),** after Henri Becquerel, who shared a Nobel Prize for Physics with the Curies in 1903.

Both the curie and becquerel measure the same thing—activity. One curie represents a large amount of activity, whereas one becquerel represents a very small amount of activity.

Because the base unit for measuring activity may be either very large (Ci) or very small (Bq), prefixes (e.g., nano, micro, milli, kilo, mega, giga) are often used to change the size of the unit.

Radiation Basics (16 of 16)



Slide 20-21, Background Vs. Normal Radiation

- Exists naturally in nature and is found all around us
- Cosmic
- Higher doses at higher elevations and around the poles
- Terrestrial
  - Doses from earth sources can vary widely depending on the types of rocks

Background radiation encompasses all-natural radiation that is present in the environment. This includes cosmic radiation from the sun and stars, terrestrial radiation from the soil and the Earth, and internal radiation that is present in all living things. According to the National Council on Radiation Protection and Measurements (NCRP), the average annual radiation dose per person in the United States is 620 mrem.

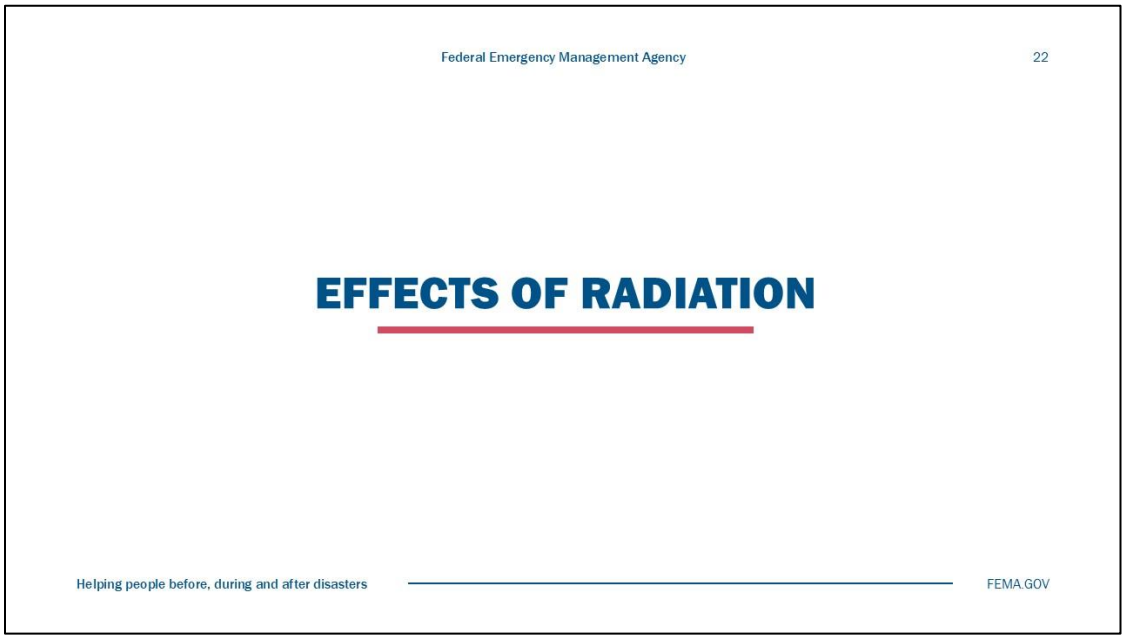
You can estimate your yearly radiation dose (https://www.epa.gov/radiation/calculate-your-radiation-dose) [1] from the EPA webs*ite by answering a few questions.*

When taking radiation readings, HAZMAT technicians and scientists must account for background radiation by taking sample/control readings without the materials to be tested:

[1] US EPA, "Calculate Your Radiation Dose."

- Source Radiation = Radiation Sampled by Meter – Background Radiation

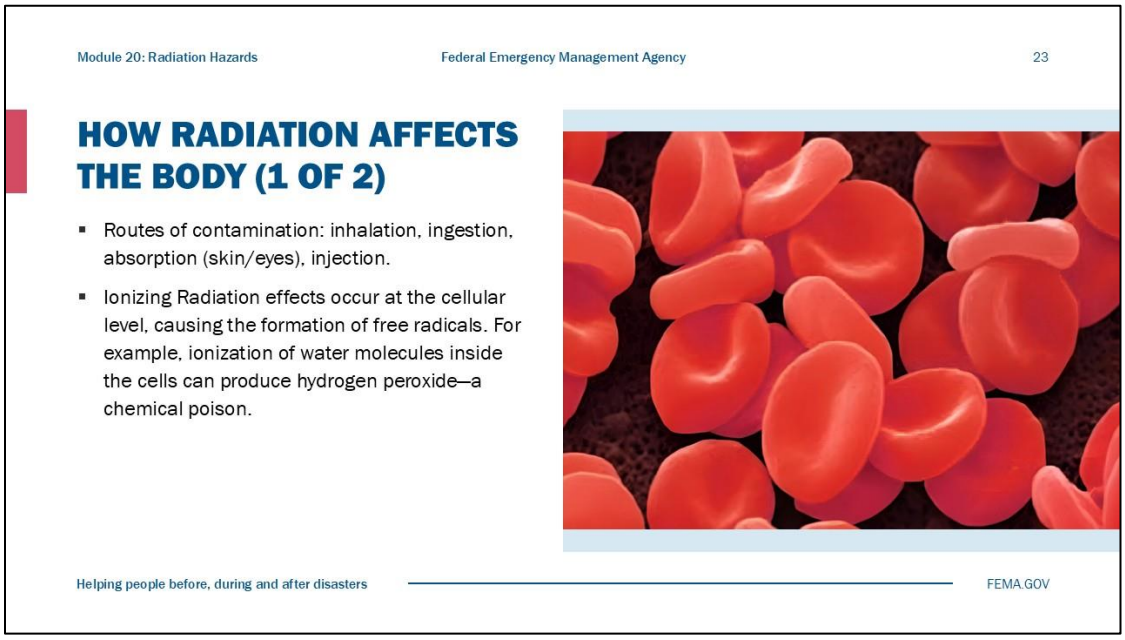
Effects of Radiation (1 of 8)



Slide 20-22, Effects of Radiation

Not Applicable.

Effects of Radiation (2 of 8)



Slide 20-23, How Radiation Affects the Body (1 Of 2)

- Recall the routes of contamination: inhalation, ingestion, absorption (skin/eyes), injection
- Ionizing Radiation effects occur at the cellular level, causing the formation of free radicals. For example, the ionization of water molecules inside cells can produce hydrogen peroxide—a toxic chemical.

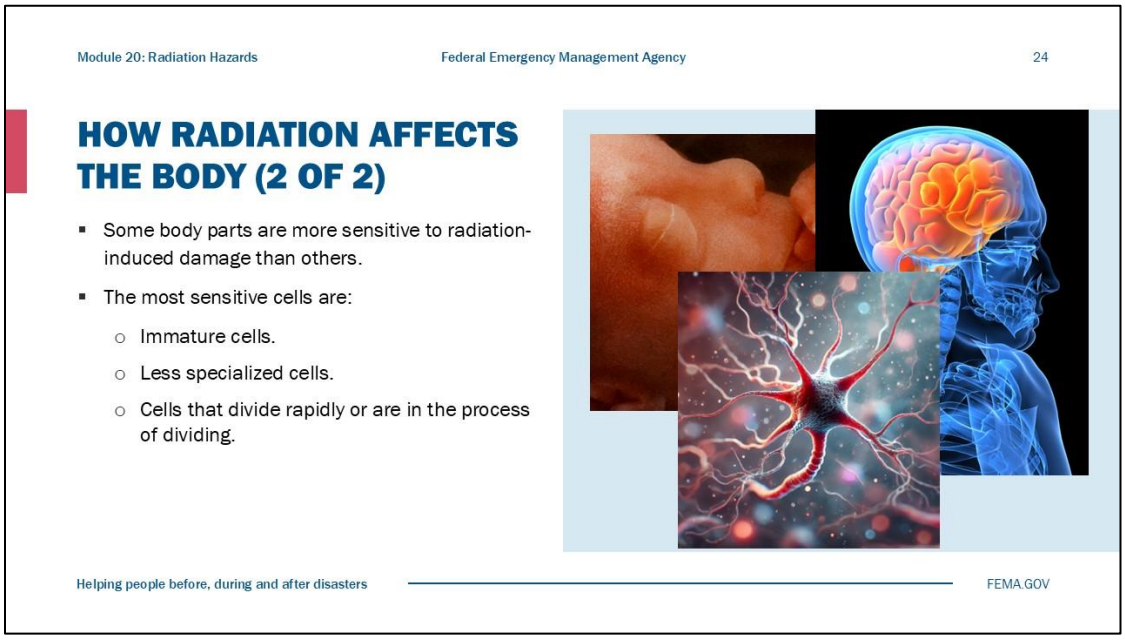
Routes of exposure: Radiation exposure can occur through the same primary routes as we have discussed for other hazards: inhalation, ingestion, absorption (through the skin or eyes), and injection.

- Gamma radiation can penetrate your body, delivering a deep dose. Radiation affects the blood and internal organs. Gamma radiation is a significant external and internal health hazard.
- All types of radiation cause health effects through internal contamination, when people swallow or breathe in radioactive materials, or when radioactive materials enter the body through an open wound or are absorbed through the skin. Some types of radioactive materials stay in the body and are deposited in different body organs. Other types are eliminated from the body in blood, sweat, urine, and feces.

Cellular damage: Scientists have determined that the effects of ionizing radiation occur at the cellular level. Each organ in the body is composed of specialized cells, and ionizing radiation can disrupt the normal functioning of these cells.

How damage occurs: Radiation causes damage to any material by ionizing the atoms within that material. When atoms are ionized, their chemical properties are altered. If a person receives a sufficiently high dose of radiation and many cells are damaged, observable health effects may occur.

Effects of Radiation (3 of 8)



Slide 20-24, How Radiation Affects the Body (2 of 2)

- Some body parts are more sensitive to radiation-induced damage than others.
- The most sensitive cells to ionizing radiation are:
  - Immature cells (e.g., hematopoietic stem cells, lymphoblasts, myeloblasts, and osteoblasts);
  - Less specialized cells (e.g., stem cells); and
  - Cells that divide rapidly or are in the process of dividing (e.g., skin, blood, gastrointestinal).

Sensitivity: It is important to note that radiation does not affect all cells equally. Certain types of cells are more susceptible to radiation-induced damage due to their unique characteristics and functions. The sensitivity of cells to radiation is primarily determined by their level of maturity, specialization, and rate of division.

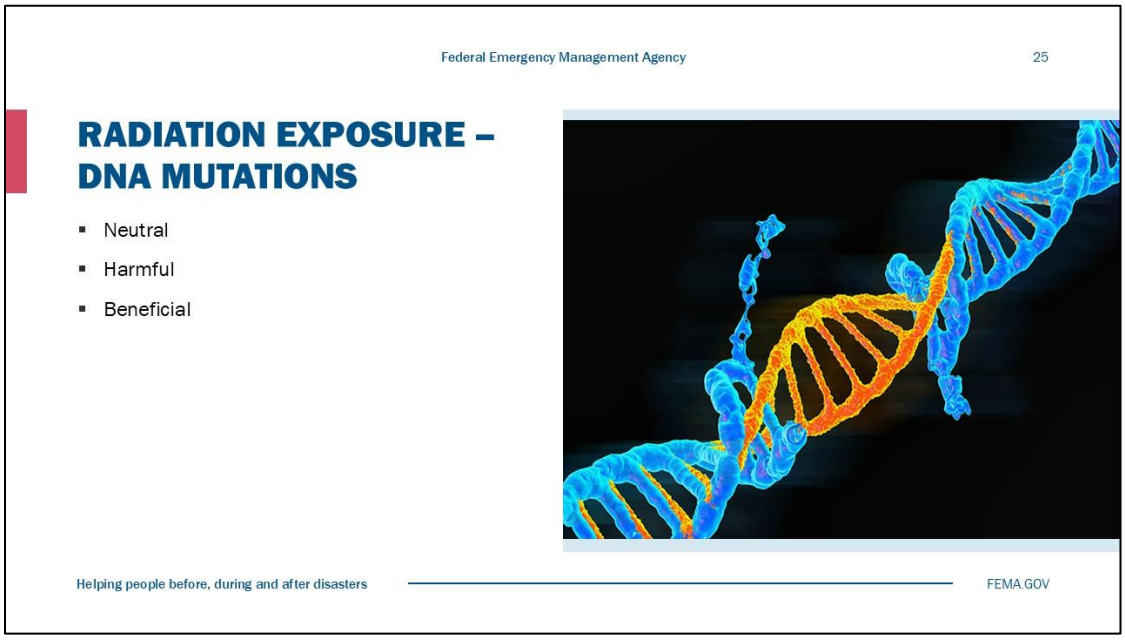
Most sensitive cells: In general, the most sensitive cells are those that are immature and less specialized, those that divide rapidly, or those that are in the process of dividing. These cells are most vulnerable because it is **difficult or impossible for them to repair damage that occurs during cell division**. Examples of rapidly dividing immature cells include:

- Blood-forming cells (e.g., bone marrow). The more primitive stem cells are more sensitive than the more mature ones.
- Cells lining the intestinal tract. Again, the more primitive crypt cells are more sensitive than the more mature epithelial cells lining the gut.
- Cells in an embryo or fetus.

Cells that divide more slowly and cells that are more specialized are not as easily damaged by ionizing radiation. Examples include:

- Nerve cells
- Brain cells
- Muscle cells

Effects of Radiation (4 of 8)



Slide 20-25, Radiation Exposure – DNA Mutations

Radiation exposure may be:

- Neutral
- Harmful
- Beneficial

Radiation directly interacts with the atoms of the DNA molecule or other critical components essential for cell survival, potentially affecting the cell's ability to reproduce and survive, or destroying the cell by interfering with its life-sustaining systems.

Mutations are permanent changes in DNA. Most mutations are neutral; they either make no change in gene expression, or the changes made do not affect the function of any gene product. Of those mutations that do make a difference, most have a negative effect.

- **Neutral**—Most mutations to DNA are neutral and have no negative or beneficial impact on the host organism.

Not all portions of the DNA are equally important.

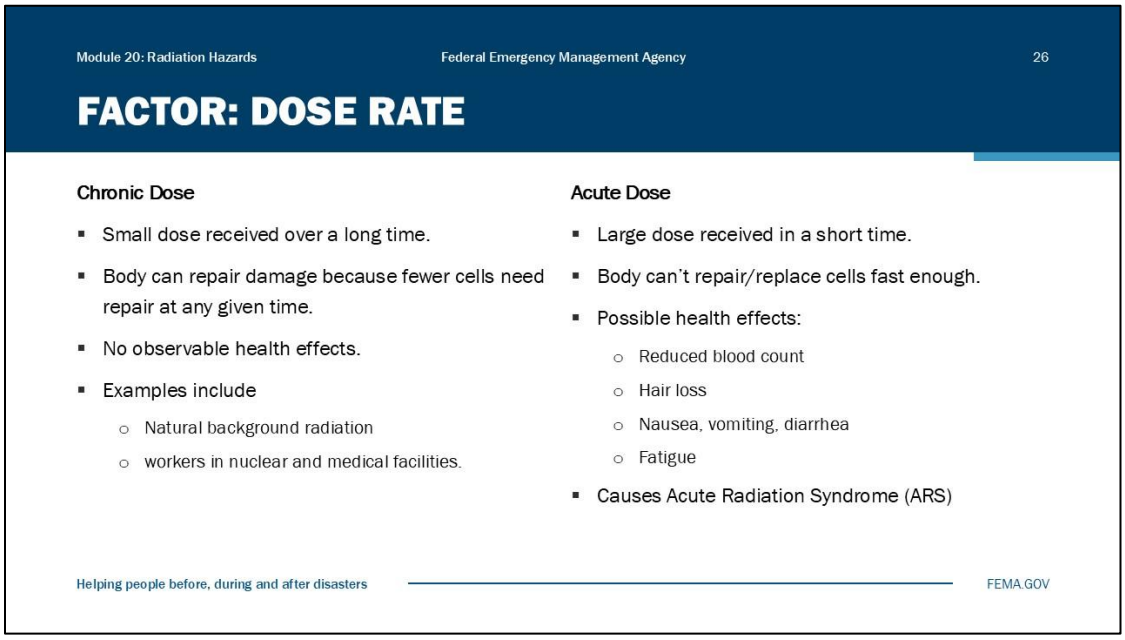
- **Harmful**—Can modify DNA to a point where protein structures are rendered ineffective, dead, or cancerous

- **Beneficial**—While extremely rare, it is possible for DNA mutations to lead to overall positive impacts.



Image Credit: https://hms.harvard.edu/news/origins-mutation

Effects of Radiation (5 of 8)



Slide 20-26, Factor: Dose Rate

Chronic Dose

- Small dose received over a long time.
- The body can repair damage because fewer cells need repair at any given time.
- No observable health effects.
- Examples: Natural background radiation; workers in nuclear and medical facilities.

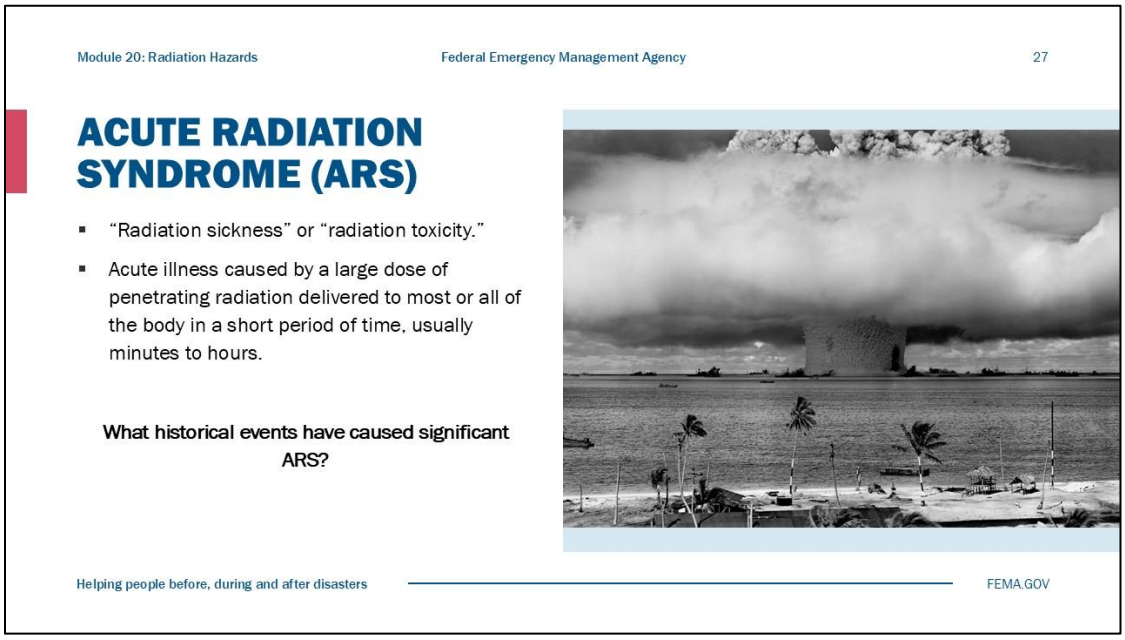
Acute Dose

- Large dose received in a short time.
- The body can't repair/replace cells fast enough.
- Possible health effects:
  - Reduced blood count;
  - Hair loss;
  - Nausea, vomiting, diarrhea;
  - Fatigue
- Causes Acute Radiation Syndrome (ARS)

Often, the biological effects of ionizing radiation depend not only on the amount of radiation received but also on the dose rate, or the **rate at which a radiation dose is administered**. There are two categories of radiation doses: chronic radiation doses and acute radiation doses.

- **Chronic Dose: A small amount of radiation received over a long period of time**. Examples of chronic radiation doses include the everyday doses we receive from natural background radiation and the doses received by workers in nuclear and medical facilities. The body can repair the damage from chronic doses because fewer cells require repair at any given time, and it has sufficient time to replace dead or nonfunctional cells with healthy ones. Chronic doses do not result in detectable health effects.
- **Acute Dose: A large dose of radiation received in a short period of time**. The body cannot repair or replace cells fast enough after a large acute dose of radiation, so physical effects may be seen. It takes a large acute dose of radiation before people experience any observable physical effects. The physical reaction to an acute dose of radiation is the result of extensive cell damage over a short period of time.

Effects of Radiation (6 of 8)



Slide 20-27, Acute Radiation Syndrome (ARS)

Acute Radiation Syndrome (ARS):

- Also known as "radiation sickness" or "radiation toxicity"
- Acute illness results from a large dose of penetrating radiation received in a short period of time.

What historical events have caused significant ARS?

An extreme example of the effects of ionizing radiation is ARS.

What is ARS? Acute Radiation Syndrome (ARS) is an acute illness caused by a large dose of penetrating radiation delivered to most or all of the body in a short period of time-usually within a matter of minutes to hours. The major cause of this syndrome is depletion of immature stem cells in specific tissues.

Necessary conditions. The following are required conditions for ARS:

- **Large:** The radiation dose must be large (i.e., greater than 70 rem).
- **External**: The dose is usually external (i.e., the source of radiation is outside of the person's body).

- **Penetrating:** The radiation must be able to penetrate (i.e., reach) the major organs.
- **Entire body:** The entire body (or a significant portion of it) must have received the dose. Most radiation injuries are local, frequently involving just the hands, and these local injuries seldom cause classical signs of ARS.
- **Short timeframe**: The dose must have been delivered in a short time (usually a matter of minutes). Fractionated doses are often used in radiation therapy. These large total doses are administered in small daily amounts over a specified period. Fractionated doses are less likely to induce ARS than a single dose of the same magnitude.

Acute Effects. Symptoms of acute radiation sickness include:

- Changes in blood cells and blood vessels
- Skin irritation (similar to sunburn but lasting 3 weeks)
- Gastrointestinal system effects
- Nausea and vomiting
- Diarrhea
- High fever
- Hair loss
- Dermal burns
- Severe injury to internal organs
- Long-term physiological effects

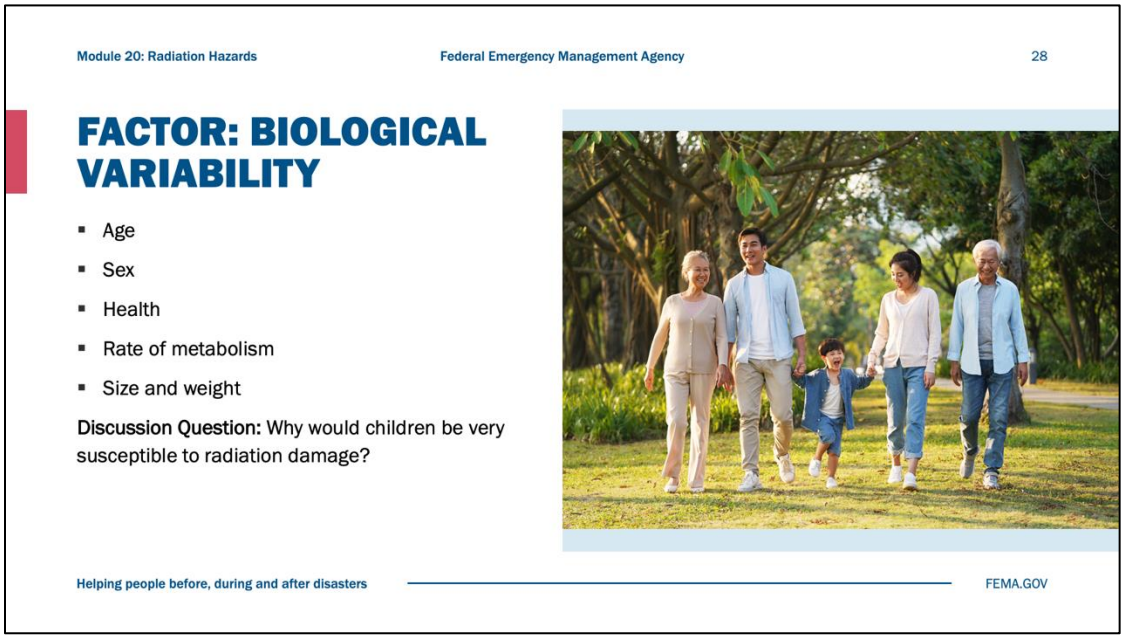
Symptoms may appear shortly after exposure, then disappear for a few days, and reappear in a much more serious form a week or so later. Later symptoms may include:

- Malaise, fatigue, and drowsiness
- Weight loss
- Fever
- Abdominal pain
- Insomnia and restlessness
- Blisters

Long-Term Effects: The likelihood of experiencing long-term effects increases with increasing exposure levels. Long-term effects may include various forms of cancer (e.g., leukemia, bone cancer, thyroid cancer, lung cancer), cataracts, and a shortened life span.

The severity and course of acute radiation sickness depend on the total dose received, the extent of body exposure, and the individual's radiosensitivity.

Effects of Radiation (7 of 8)



Slide 20-28, Factor: Biological Variability

Biological factors include:

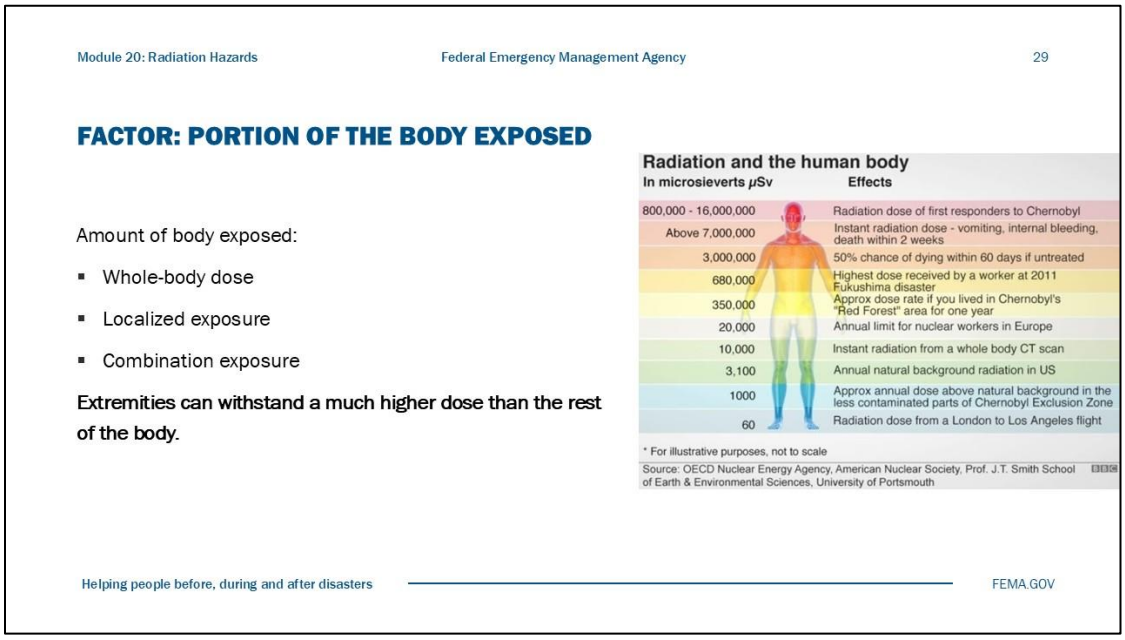
- Age
- Sex
- Health
- Rate of metabolism
- Size and weight

Discussion Question: Why would children be very susceptible to radiation damage?

Individuals also have biological variability factors that impact how they are affected by radiation.

These factors include the age, sex, health, metabolic rate, size, and weight of the exposed person. Children are very susceptible to the damage caused by ionizing radiation.

Effects of Radiation (8 of 8)



Slide 20-29, Factor: Portion of the Body Exposed

Amount of body exposed:

- Whole-body dose
- Localized exposure
- Combination exposure

Extremities can withstand a much higher dose than the rest of the body.

The extremities of the body can withstand a significantly higher dose of radiation than the whole body, including the head, trunk, arms above the elbow, and legs above the knee. This is because the major blood-forming organs are located in the whole-body area.

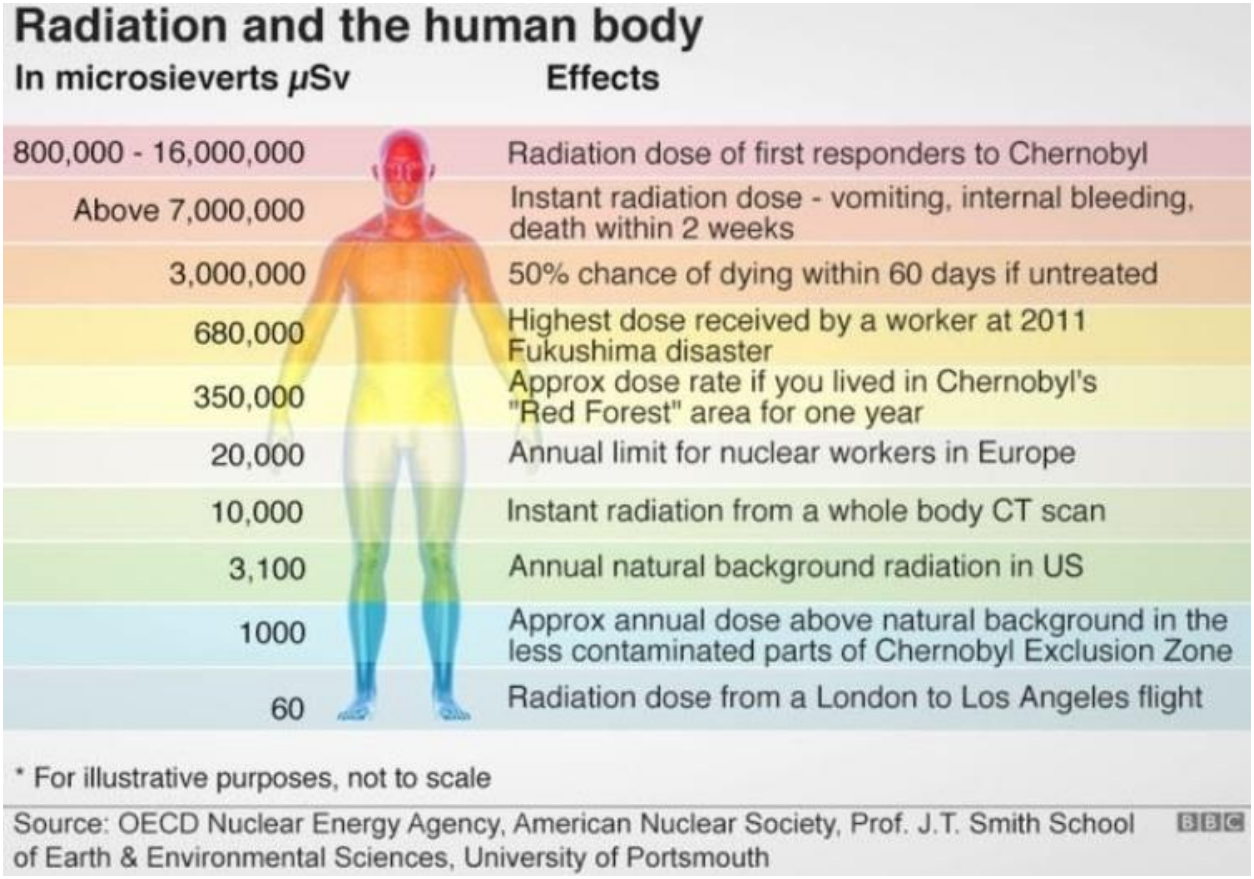
Whole-body dose: When a whole-body dose is administered, the radiation is delivered uniformly to the entire body. For example, a person may enter a radiation field (e.g., a sterilizer that uses a radioactive source, or an industrial radiography area) where the entire body is exposed to radiation.

Localized exposure: In the case of localized radiation exposure, the dose is delivered only to a portion of the body, as would occur if a person placed their hand in the path of a radiation beam or picked up a radioactive rod.

Combination exposure: In some cases, the dose may occur as a combination of whole-body and localized exposure. For example, in one case a janitor placed an industrial radiography source in his

back pocket and sustained severe local injury to his buttock; he also received a whole-body dose sufficient to cause ARS.

Amount of body exposed: The amount of the body that is exposed to radiation is a factor in determining the biological effect. While many cancer patients receive large doses of radiation to destroy tumors, this radiation is concentrated on a specific portion of the body. Exposing the whole body poses a greater risk because the radiation-induced damage affects a larger area.

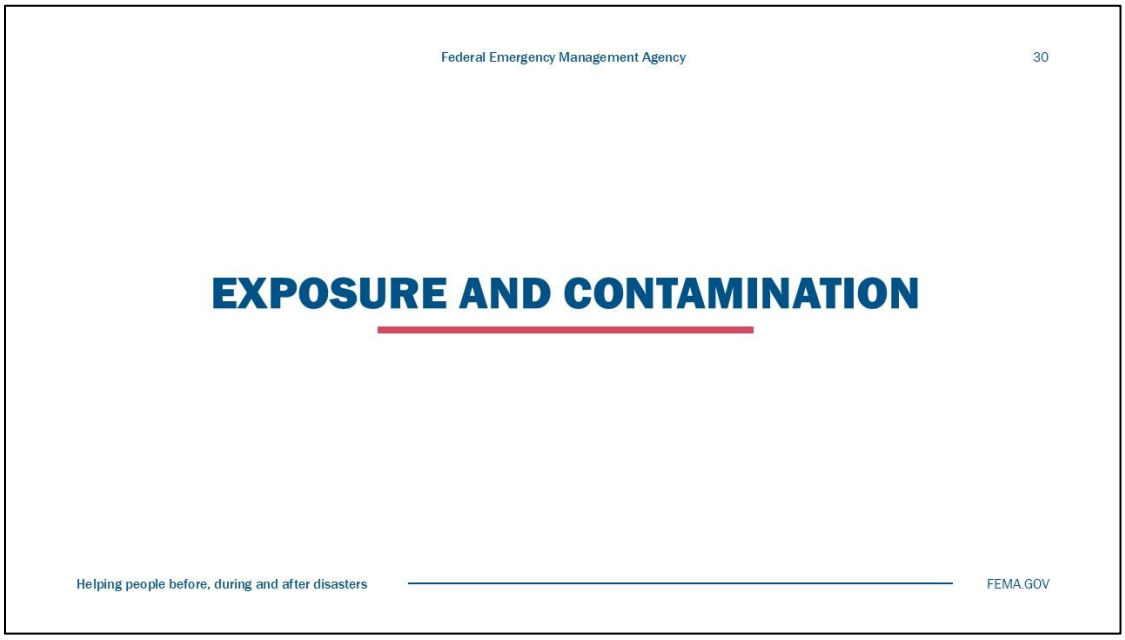


This image illustrates the effects of various radiation doses on the human body, measured in microsieverts (μSv).

- 800,000 - 16,000,000 μSv: Represents the radiation dose experienced by first responders to the Chernobyl disaster.
- Above 7,000,000 μSv: An instant radiation dose causing vomiting, internal bleeding, and death within 2 weeks, with a 50% chance of dying within 60 days if untreated.

- 680,000 µSv: The highest dose received by a worker during the 2011 Fukushima disaster.
- 350,000 µSv: The approximate dose rate if someone lived in Chernobyl's "Red Forest" area for one year.
- 20,000 µSv: The annual limit for nuclear workers in Europe.
- 10,000 µSv: The instant radiation dose from a whole-body CT scan.
- 3,100 µSv: Represents the annual natural background radiation in the US.
- 1,000 µSv: The approximate annual dose above natural background in the less contaminated parts of the Chernobyl Exclusion Zone.
- 60 µSv: The radiation dose received from a London to Los Angeles flight.

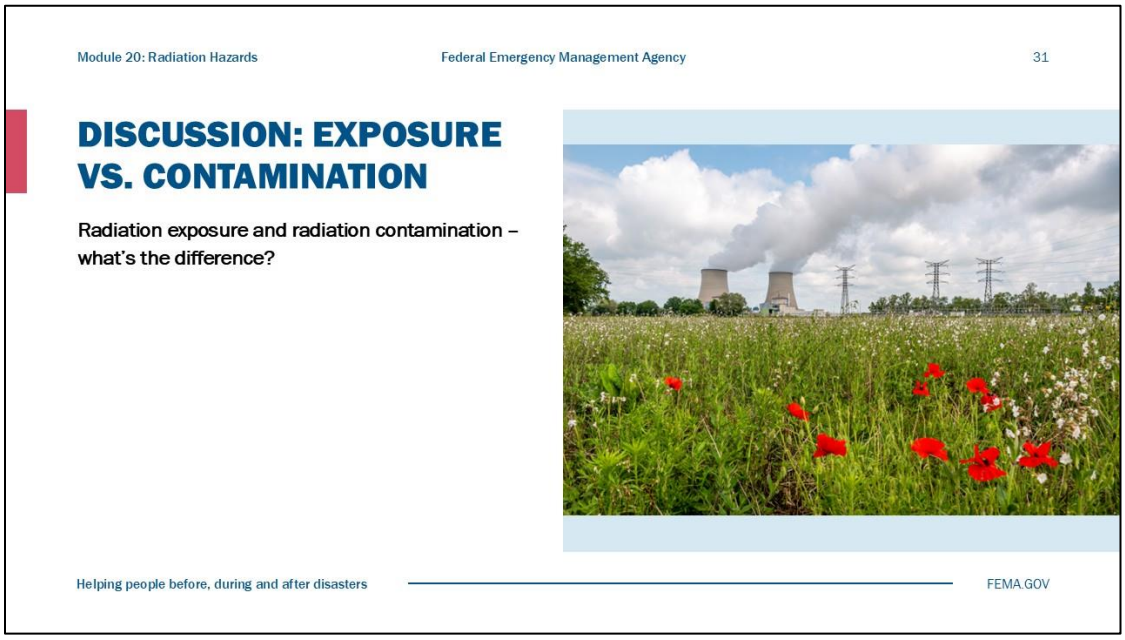
Exposure and Contamination (1 of 7)



Slide 20-30, Exposure and Contamination

Not Applicable.

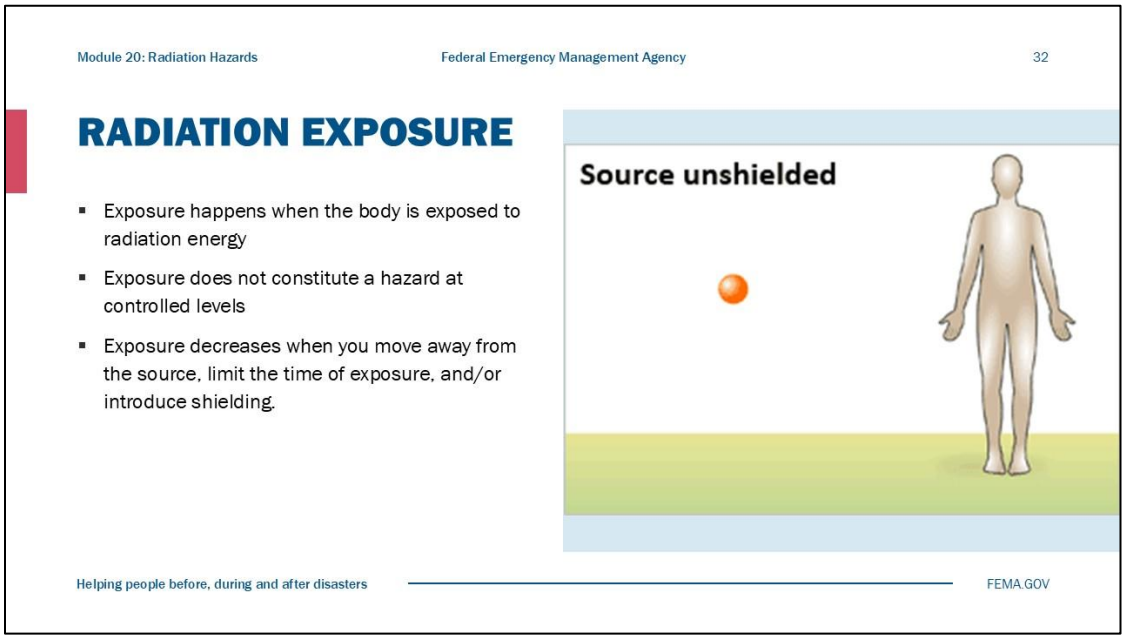
Exposure and Contamination (2 of 7)



Slide 20-31, Discussion: Exposure Vs. Contamination

Discussion Question: Radiation exposure and radiation contamination – what's the difference?

Exposure and Contamination (3 of 7)



Slide 20-32, Radiation Exposure

- Exposure happens when the body is exposed to radiation energy.
- Exposure does not constitute a hazard at controlled levels.
- Exposure decreases when you move away from the source, limit the time of exposure, and/or introduce shielding.

Animation description:

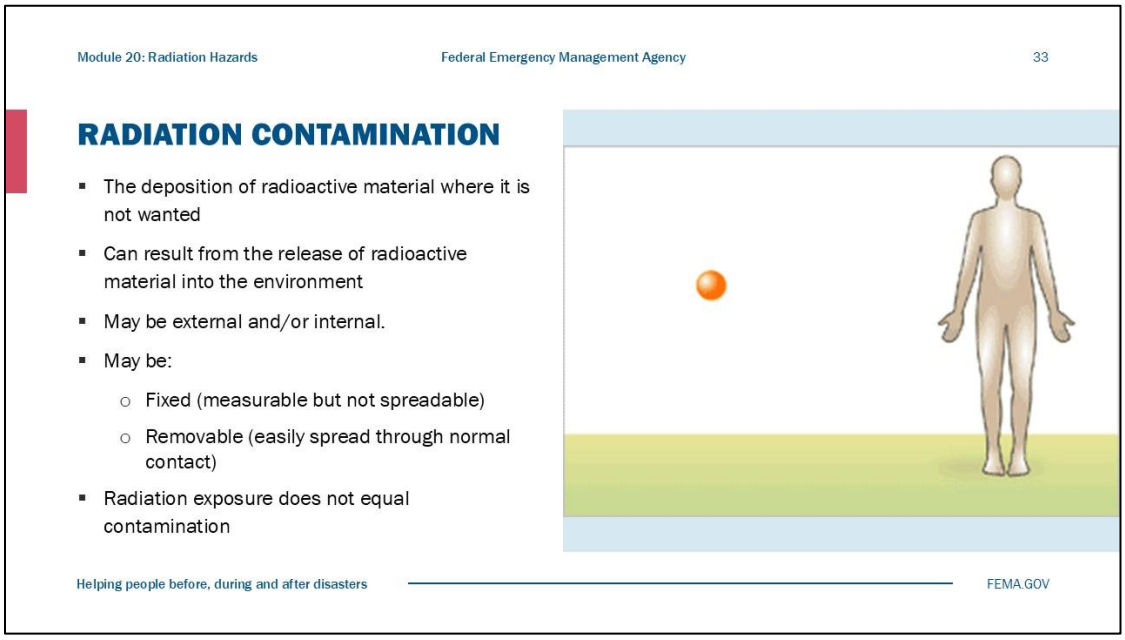
Illustrating exposure from an unshielded source and lack of exposure when the source is shielded.

Radiation exposure and radioactive contamination are distinct concepts.

We are exposed to low levels of radiation in the natural environment every day. Exposure does not, in and of itself, constitute a hazard at controlled levels. For example, there are numerous medical applications involving radiation exposure.

Exposure decreases as soon as the person is moved away from the radiation source. The animation on this visual illustrates the difference between what happens when the source is unshielded and what happens when it is shielded.

Exposure and Contamination (4 of 7)



Slide 20-33, Radioactive Contamination

- The deposition of radioactive material where it is not wanted.
- Can result from the release of radioactive material into the environment.
- May be external and/or internal.
- May be:
  - Fixed (measurable but not spreadable)
  - Removable (easily spread through normal contact)
- Radiation exposure does not equal contamination.
  - However, contamination also includes exposure because of the proximity of the material on the body or clothing.

Radioactive Contamination animation Description

Illustrating the deposition of radioactive particles on the body.

Radioactive contamination, in short, means the deposition of radioactive material where you don't want it, such as on surfaces, on people, or ingested by living things.

For a person to be contaminated, radioactive material must be on or inside their body. A contaminated person is also exposed to radiation released by radioactive material.

Radioactive contamination can be categorized as either fixed or removable.

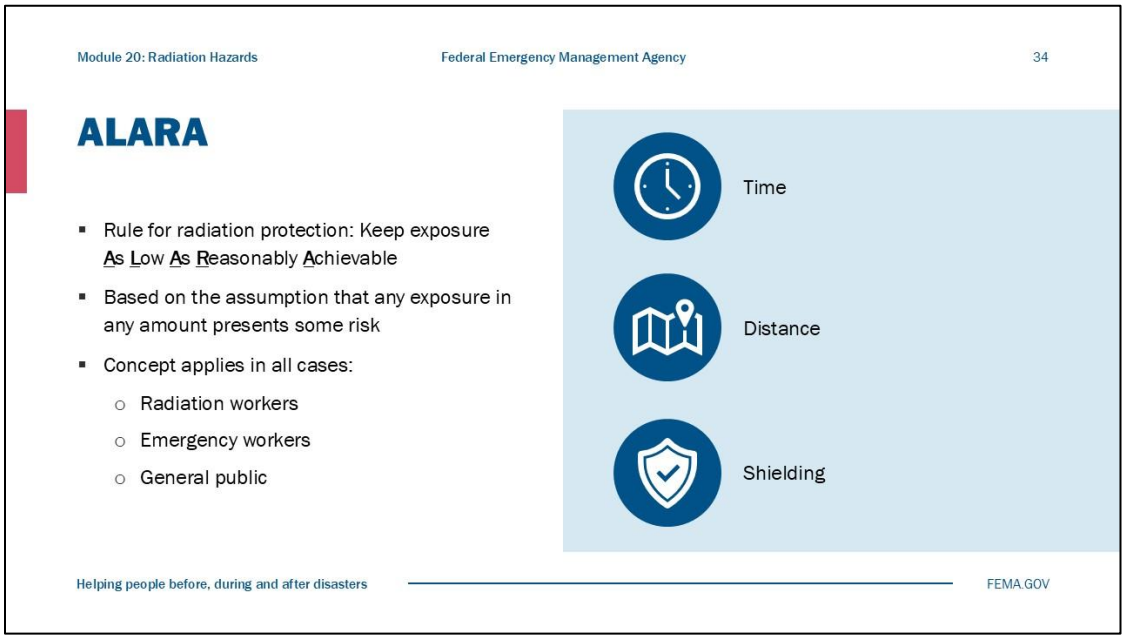
- **Fixed contamination** is radioactive material that is not easily transferred to other people or equipment through normal contact.
- **Removable contamination** is radioactive material that is easily transferred to other people or equipment through normal contact. Removable contamination poses an additional hazard because it can be spread.

When contamination is discovered at an incident scene or on a person, it will likely be a combination of both fixed and removable.

	Fact Sheet: Exposure and Contamination
Exposure vs. Contamination	Radiation exposure does not equal contamination. We are exposed to low levels of radiation every day from common sources, such as cosmic rays and the bricks used in building construction. Exposure to radiation at controlled levels does not constitute a hazard. Exposure stops when one moves away from the radiation source. Radioactive contamination, on the other hand, must be removed to prevent continued harm,
Contamination	Radioactive contamination is, simply stated, radioactive material in a place where it is not wanted. Should radioactive material be released during an incident, anyone or anything present could become contaminated if they come into contact with the material. Radioactive contamination can be external, internal, or a combination of the two.

	Fact Sheet: Exposure and Contamination
External Contamination	External contamination refers to radioactive material that is present on an object where it is not intended to be. As long as the material is on you or your clothing, you remain exposed to radiation from the material. Individuals who are contaminated may contaminate others, either directly or indirectly through secondary contamination. Secondary contamination occurs when a contaminated person or object comes into contact with or is contaminated by another person, thereby transferring the radioactive material.
Internal Contamination	Internal contamination refers to radioactive material that is present in a location where it is not intended to be. Internal contamination occurs when people swallow or inhale radioactive material, typically in liquid or powder form, or when radioactive material is absorbed through the skin. Once inside the body, radioactive material may be difficult to remove. Radioactive material that might not be very dangerous outside the body may be dangerous if allowed to enter the body.
Avoiding Contamination	In the presence of radioactive material, it is essential to avoid eating, drinking, smoking, and chewing to prevent the possibility of internal contamination. It is also important to use personal protective equipment (PPE) to prevent external contamination.

Exposure and Contamination (5 of 7)



Slide 20-34, Alara

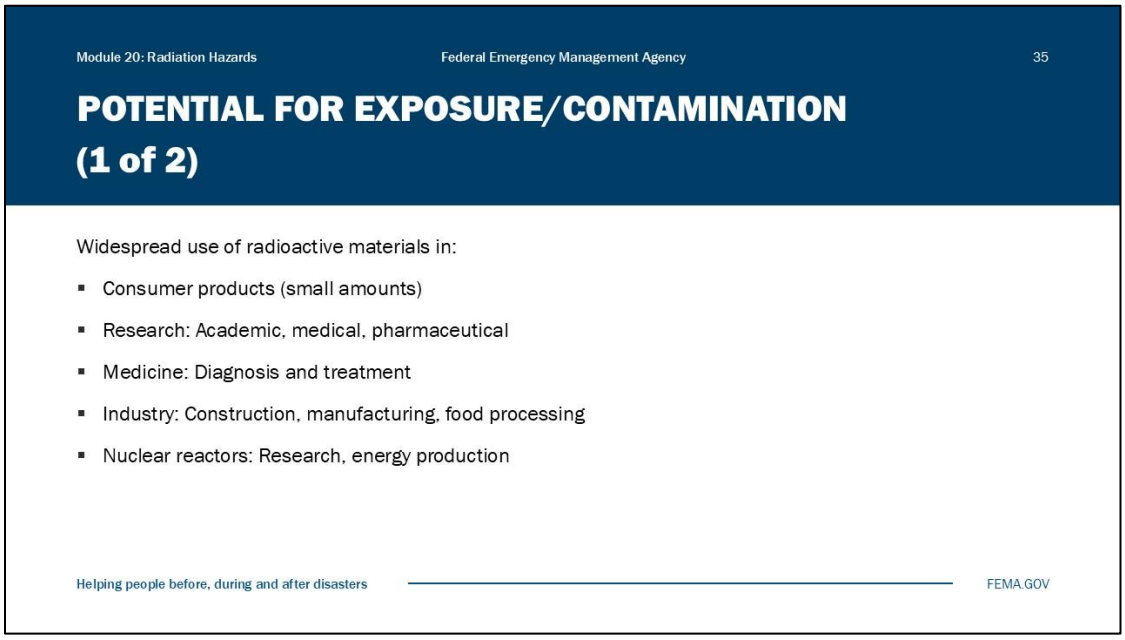
- Rule for radiation protection: Keep exposure As Low As Reasonably Achievable.
- Based on the assumption that any exposure in any amount presents some risk.
- Concept applies in all cases:
  - Radiation workers
  - Emergency workers
  - General public.

Use:

- Time
- Distance
- Shielding

The rule for radiation protection is to keep exposure "As Low As Reasonably Achievable" (ALARA), based on the assumption that any radiation exposure, no matter how small, presents some risk. The ALARA concept applies to all individuals, including radiation workers, emergency responders, and the general public.

Exposure and Contamination (6 of 7)



Slide 20-35, Potential for Exposure/Contamination (1 of 2)

Widespread use of radioactive materials in:

- Consumer products (small amounts);
- Research: Academic, medical, pharmaceutical;
- Medicine: Diagnosis and treatment;
- Industry: Construction, manufacturing, food processing; and
- Nuclear reactors: Research, energy production.

Radioactive material is a natural component of our surroundings and is widely utilized in industrial and commercial applications. It has specialized uses in consumer products, building materials, research, medicine, industry, nuclear reactors, irradiators, and transportation.

Due to regulations governing the use of radioactive material and the enhanced safety precautions implemented, the risk of exposure to the general public is low.

Common uses of radioactive materials are summarized in the following table.

Uses/Sources of Radioactive Material

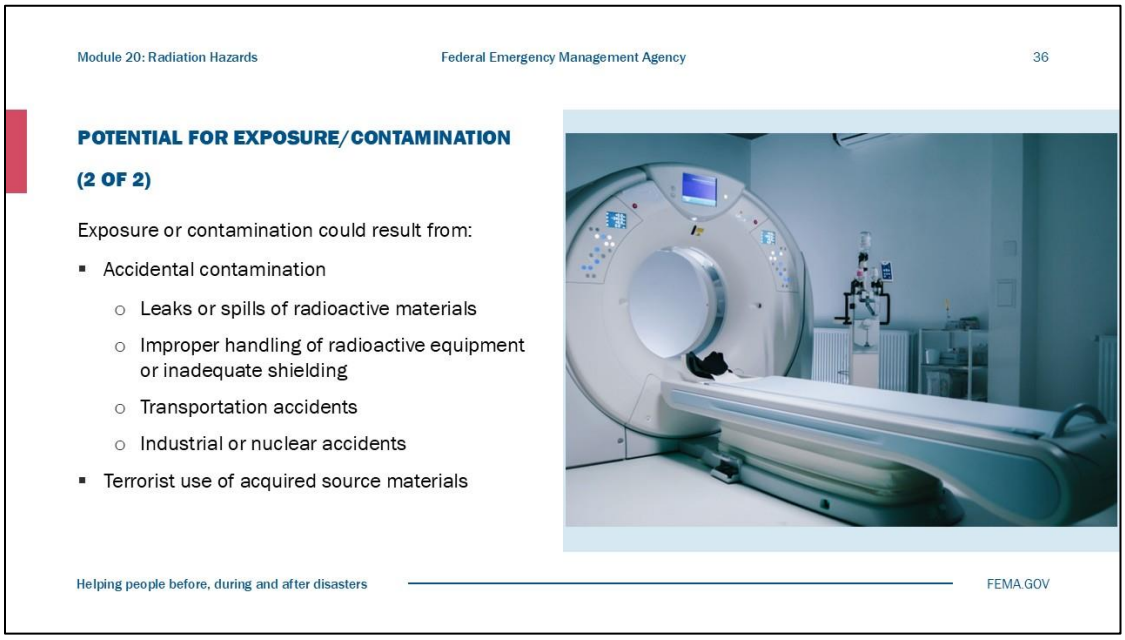
Area of Use	Description
Consumer Products	The following are examples of consumer products that may contain radioactive materials: • Antique items including ceramic-glaze products in orange, red, or yellow (e.g., antique cups and plates, decorative floor tiles, jewelry, pottery) (uranium salts); • "Vaseline" glass (emerald-green glass used in some antique tableware) (uranium); • Older camera lenses and gas lantern mantels (thorium-232); • Radio-luminescent products (using radium paint), including older watches, clocks, and instrument gauges; • Low-sodium salt substitutes (potassium-40); • Propane tanker trucks (from radioactive deposits on the tanker's interior walls); • Smoke detectors (Am-241); • Thoriated aluminum (an alloy containing Th-233); • Thoriated tungsten arc-welding electrodes (often labeled thoriated welding rods); and • Uranium ore samples. Other materials that contain naturally occurring radioactive material include marble, monazite sand, sandstone, slate, concrete, feldspar, fertilizers, and granite.
Research	Radioactive material is commonly used for research by academic and medical institutions, pharmaceutical companies, and small research and development companies. Radioactive isotopes can be chemically incorporated into the molecules that make up DNA. When processed appropriately, the materials can create an image showing where the radioactively labeled genetic material has concentrated. This technique is used in forensic analyses of biological specimens to provide physical evidence in legal proceedings. Research facilities may use a wide variety of isotopes. The activity levels used may be very high or low.

Area of Use	Description
Medicine	Radioactive materials are used for diagnosing and treating various illnesses, including cancer. Diagnostic imaging with radiopharmaceuticals involves binding a radioactive isotope to a chemical or drug that is administered to a patient via injection, ingestion, or inhalation. The type of isotope and the chemical form vary depending on the type and purpose of the medical procedure being performed. Therapeutic treatments such as brachytherapy and teletherapy use radioactive material to treat cancer and other illnesses. In brachytherapy, radioactive sources are placed in close proximity to a tumor to kill cancer cells. The radioactive material is sealed in specially formed capsules ("seeds") that are implanted into the body. In teletherapy, intense and focused beams of radiation are used to treat cancerous tumor growths.

Area of Use	Description
Industry	Radioactive material is used in a variety of industrial applications, including: • **Density gauges** are used to measure thickness, compaction, density, or moisture content. • **Industrial radiography equipment** is used for nondestructive testing and internal inspection of an object, such as checking welds and metal for flaws. • **Irradiators** are used to calibrate instrumentation, sterilize blood, and treat food products to kill harmful bacteria. Sources commonly used in industry that may be of concern if misused include: • American (Am-241) • Cobalt (Co-60) • Barium (Ba-133) • Iridium (Ir-192) • Cesium (Cs-137) • Radium (Ra-226) • Cobalt (Co-57) • Thorium (Th-232) As of April 30, 2024, there were 54 nuclear power plants in the United States that were in commercial operation. These plants have 94 nuclear reactors that power homes and businesses in 28 states. As of June 2021, there were 223 operational research reactors, with many more under construction, planned, or undergoing decommissioning. Research reactors are used for academic research, medical and industrial isotope production, and radiographic services. The U.S. Nuclear Regulatory Commission regulates 31 operating research and test reactors.

Area of Use	Description
Reactors	They are located at universities and national labs. Many research reactors are used for international collaboration. The products of research reactors used for isotope production are traded internationally. Isotopes of major concern for accidental or terrorism-related contamination include: • Plutonium (Pu-239). • Enriched Uranium (U-235). • Uranium (U-233). • Neptunium (Np-237).
Transportation	Approximately 3 million packages of radioactive materials are shipped annually in the United States by highway, rail, air, and water, thereby increasing the risk of transportation accidents. However, as with other hazardous materials, the transportation of radioactive material is strictly regulated. Many governmental agencies have jurisdiction over the transfer and shipment of radioactive material from nuclear facilities. The regulatory requirements become more restrictive as the quantity, concentration, and potential hazard of the radioactive material increase. Most of the regulatory restrictions apply to the packaging and the methods of shipment used to transport the package.

Exposure and Contamination (7 of 7)



Slide 20-36, Potential for Exposure/Contamination (2 of 2)

Exposure or contamination could result from:

- Accidental contamination
  - Leaks or spills of radioactive materials
  - Improper handling of radioactive equipment or inadequate shielding
  - Transportation accidents
  - Industrial or nuclear accidents
- Terrorist use of acquired source materials

With the wide range of radioactive materials in use today, radiation exposure or contamination could result from accidental contamination or from malicious use of acquired source materials.

Accidental contamination can result from leaks or spills of radioactive materials, improper handling of radioactive equipment, inadequate shielding, transportation accidents, or industrial or nuclear accidents. The risks vary with the type of radioactive material, the quantities involved, and whether the material is sealed or unsealed.

- **Unsealed radioactive material** is a potential internal radiation hazard because it can be inhaled, ingested, or absorbed through the skin, leading to dangerous exposure to internal organs. Some isotopes (e.g., P-32, Cs-137) also pose an external radiation

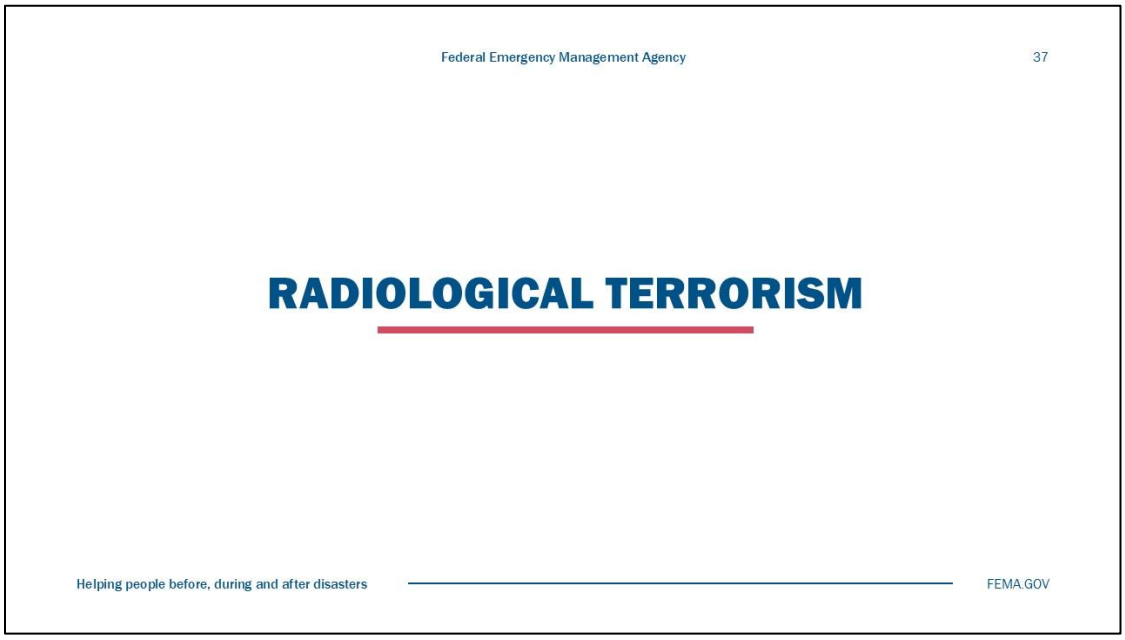
hazard, so shielding is required to protect against exposure to the radiation field. Isotopes such as C-14 and H-3 emit such low-energy beta radiation that they can be safely handled without concern for external radiation exposure.

- **Sealed source** means radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions. An example is the Gamma Knife® unit, which uses cobalt-60. A small, pea-sized source is sealed in a small, welded capsule, and the capsule is encased in a shield, typically made of lead, with a small, shuttered opening that controls the gamma beam.

In medical facilities, radioactive material may be sealed or unsealed. Research facilities may use a wide variety of isotopes, typically in unsealed or dispersible forms, which increases the potential for radiological contamination. The activity levels used may be very high or low.

Incidents that occur at such facilities, therefore, may require a hazardous materials response.

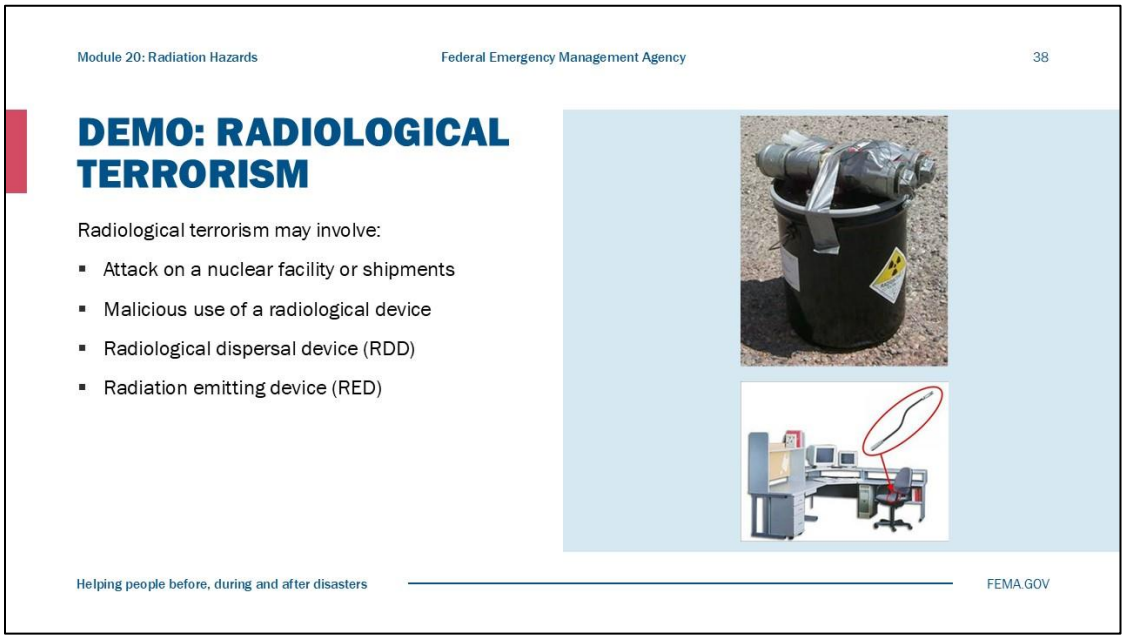
Radiological Terrorism (1 of 4)



Slide 20-37, Radiological Terrorism

Not applicable.

Radiological Terrorism (2 of 4)



Slide 20-38, Demo: Radiological Terrorism

Radiological terrorism may involve:

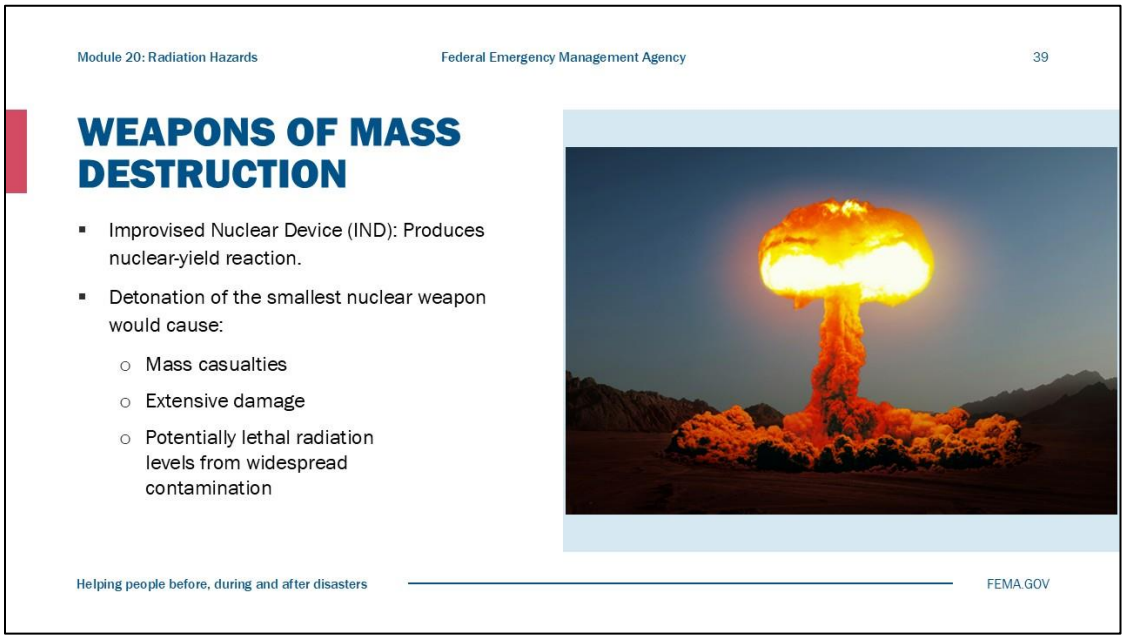
- Attack on a nuclear facility or shipments
- Malicious use of a radiological device
- Radiological dispersal device (RDD)
- Radiation emitting device (RED)

Background: Not long after their development, nuclear weapons became a symbol of both military and national power, and nuclear testing became a useful tool for sending political messages. Many nations have evaluated the use of nuclear or radiological weapons, but in the aftermath of atomic attacks on Hiroshima and Nagasaki, they have so far concluded that the consequences of using such weapons would outweigh any military gains they might make. These consequences include high civilian casualties, destroyed land and property, and a fierce international backlash, which could include retaliation with nuclear weapons.

Methods: There are two primary ways to implement radiological terror, and the motives for either action are the same: to cause injury and damage property, escalate public fears of radiation, harm the economy, and prompt political changes.

- **Attacks on nuclear facilities and transport**: Attacks on nuclear facilities could be in populated or rural areas. Potential facility targets include nuclear power plants, cooling pools for spent nuclear fuel rods, nuclear reactors used for research or other non-electricity purposes, nuclear reprocessing facilities, calibration laboratories, and nuclear waste sites. Trucks or railcars carrying nuclear weapons, spent nuclear fuel, and high-level radioactive waste are also potential terrorist targets.
- Because of the **robust safeguards** in place for nuclear facilities and nuclear shipments in the United States, the likelihood of a successful attack on a nuclear installation or nuclear shipment is considered remote.
- **Malicious use of a radiological device**: While terrorists would face significant obstacles in the development and deployment of a radiological device, an attack is possible; consequently, responders need to plan and train for a response to a radiological terrorism incident. Radiological devices would most likely be used in large cities.

Radiological Terrorism (3 of 4)



Slide 20-39, Weapons of Mass Destruction

- Improvised Nuclear Device (IND): Produces nuclear-yield reaction.
- Detonation of the smallest nuclear weapon would cause:
  - Mass casualties;
  - Extensive damage; and
  - Potentially lethal radiation levels from widespread contamination.

Definition: Nuclear weapons are defined as "a weapon in which enormous energy is released by nuclear fission (splitting the nuclei of a heavy element like uranium 235 or plutonium 239)."

Nuclear weapons are the world's most powerful and destructive weapons. A nuclear weapon contains enough fissile material to form several critical masses, but before detonation, it is kept in a "sub-critical" state (that is, the fissile material is arranged so that spontaneous neutrons cannot start chain reactions, or only very short ones, which quickly die out).

Method: Unlike an RDD that disperses radioactive material using conventional explosives, a nuclear attack is the use of a device that **produces a nuclear explosion**. The effect of detonating even the smallest nuclear weapons in any city would be devastating. Responders would encounter mass casualties, extensive damage, and potentially lethal radiation levels from widespread contamination.

Existing Weapons: According to the Federation of American Scientists, there are more than 17,000 nuclear warheads, with the largest stockpiles in the United States and Russia. Many safeguards are in place to protect nuclear weapons controlled by the United States. While many nuclear weapons in Russia are adequately protected from theft, it is believed that others are not. Many Soviet-era tactical nuclear devices are susceptible, and given the smaller size of such weapons, would be particularly useful to terrorist groups. Some reports have estimated that several hundred weapons are susceptible to theft by terrorists or criminals who might sell them to terrorist organizations. While it may be unlikely, it is at least conceivable that a terrorist group could purchase and smuggle a nuclear weapon into the United States or explode one off its coasts, either by constructing a weapon on its own or by obtaining a weapon from a rogue nation.

Improvised Weapons: There is little doubt among experts that technically competent terrorists could make a device given sufficient quantities of the right radioactive material. Such a device would be referred to as an Improvised Nuclear Device, or IND (sometimes referred to as "dirty bombs").

According to the Department of Defense (DOD), an IND is a:

> "device incorporating radioactive materials designed to result in the dispersal of radioactive material or in the formation of a nuclear-yield reaction. Such devices may be fabricated in a completely improvised manner or may be an improvised modification to a U.S. or foreign nuclear weapon."

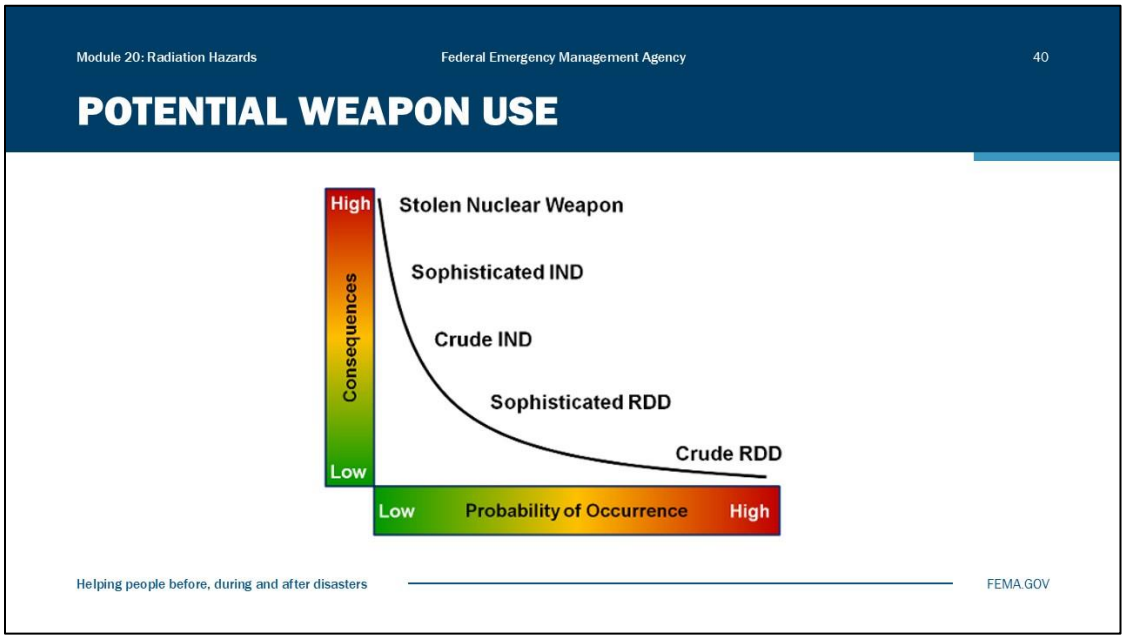
Purpose: Like RDDs, one of the primary intents of INDs is to scatter radiological contamination. A key difference between an IND and an RDD is that an IND results in a nuclear yield that can cause widespread destruction, whereas an RDD does not.

Impact of a Nuclear Explosion:

- The energy of the initial explosion creates a fireball, roughly spherical in shape. It can reach tens of millions of degrees.
- A shockwave races away from the explosion and can cause significant damage to structures and injuries to humans.
- The ionization of the atmosphere around the blast can result in an electromagnetic radiation pulse (EMP) that, for ground detonations, can drive an electric current through underground wires, causing local damage. For high-altitude nuclear detonations, EMP can cause widespread disruption to electronic equipment and networks.
- A mushroom cloud typically forms as everything inside the fireball vaporizes and is carried upwards. Radioactive material from the nuclear device mixes with the vaporized material in the mushroom cloud.
- Fallout results when the vaporized radioactive material in the mushroom cloud cools, condenses to form solid particles, and falls back to the Earth. As a plume, fallout can be

carried long distances on wind currents and contaminate surfaces miles from the explosion, including food and water supplies.

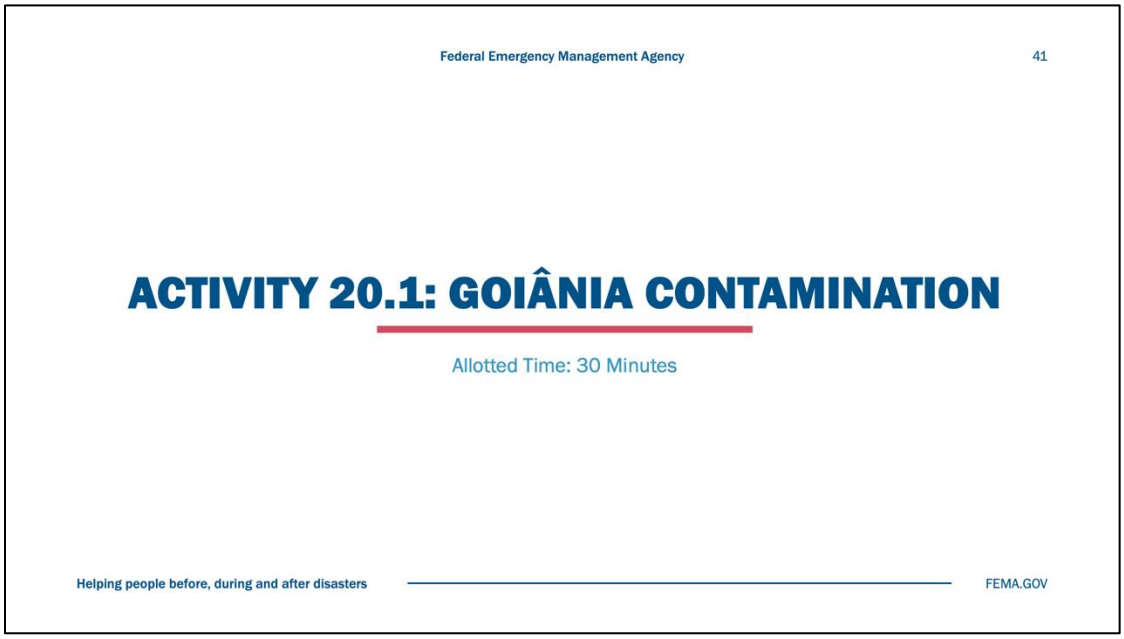
Radiological Terrorism (4 of 4)



Slide 20-40, Potential Weapon Use

The chart on the visual illustrates that radiological weapons, which have the greatest consequences, are the least likely to be used, while weapons with lower consequences have a higher probability of occurrence.

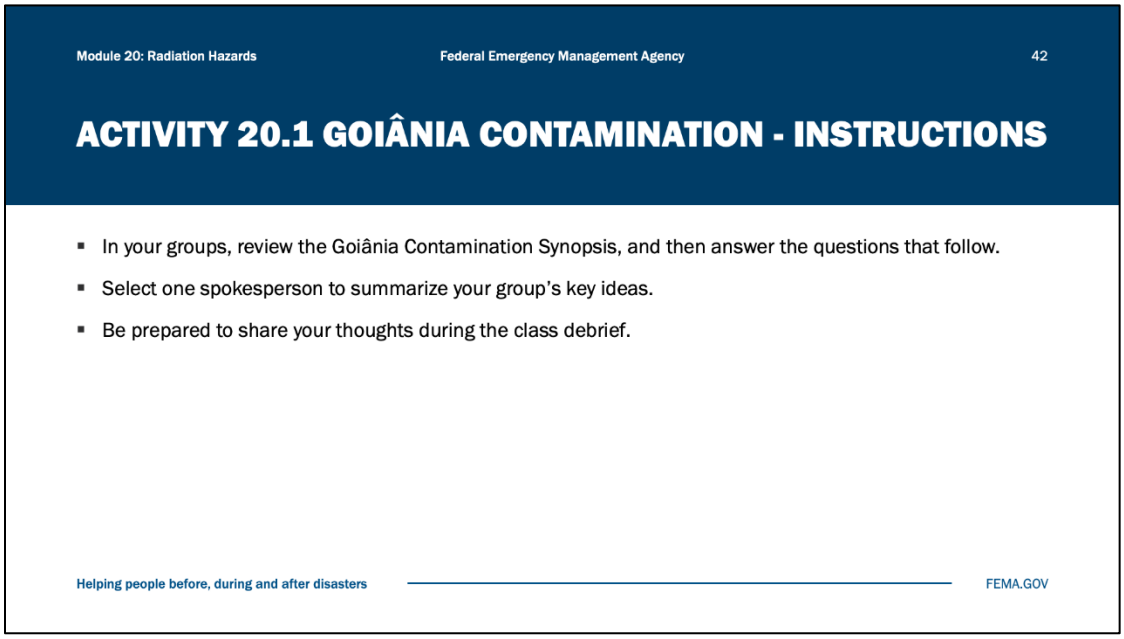
Activity 20.1: Goiânia Contamination (1 of 3)



Slide 20-41, Activity 20.1: Goiânia Contamination

Not Applicable.

Activity 20.1: Goiânia Contamination (2 of 3)



Slide 20-42, Activity 20.1: Goiânia Contamination - Instructions

Activity 20.1: Goiânia Contamination – Directions to Students

Group Activity

30 minutes (15 minutes: Group work and discussion, 15 minutes: Class debrief)

Purpose

The purpose of this activity is to help students understand the **social and psychological impacts of uncontrolled radiological contamination events**, by analyzing the **Goiânia, Brazil incident** as a case study. Through the video and subsequent discussion, students will reflect on the human, community, and communication aspects of such events and consider how these lessons apply to modern preparedness and response.

Instructions

1. **Watch the video** about the Goiânia, Brazil, radiological incident.
2. As you watch, think about the discussion questions in your Student Guide.

3. Focus on how the community responded, what challenges emerged, and how communication and preparedness affected outcomes.
4. After the video, **review the Goiânia Contamination Synopsis** in your Student Guide to reinforce key details.
5. **Discuss the scenario questions** as a group, drawing on both what you saw in the video and what you read in the synopsis.
6. **Select one spokesperson** to summarize your group's key ideas.
7. **Be ready to share** your group's main points during the class debrief.

Goiânia Contamination Synopsis

The Goiânia accident was a radioactive contamination incident that occurred on September 13, 1987, in Goiânia, Brazil, after an old radiotherapy (https://en.wikipedia.org/wiki/Radiation_therapy) source was stolen from an abandoned hospital site in the city. It was subsequently handled by many people, resulting in four deaths. About 112,000 people were examined for radioactive contamination, and 249 were found to have significant levels of radioactive material in or on their bodies.

Health outcomes: News of the radiation incident was broadcast on local, national, and international media. Within days, nearly 130,000 people swarmed local hospitals concerned that they might have been exposed. Of those, 250 were indeed found to be contaminated—some with radioactive residue still on their skin—through the use of Geiger counters. Eventually, 20 people showed signs of radiation sickness and required treatment.

Fatalities: (Ages in years are given, with dosages listed in Greys (Gy)

- Leide das Neves Ferreira, age 6 (6.0 Gy), was the daughter of Ivo Ferreira. When an international team arrived to treat her, she was discovered confined to an isolated room in the hospital because the hospital staff were afraid to go near her.
- She was buried in a common cemetery in Goiânia, in a special fiberglass coffin lined with lead to prevent the spread of radiation. Despite these measures, news of her impending burial caused a riot of more than 2,000 people in the cemetery on the day of her burial, all fearing that her corpse would poison the surrounding land. Rioters tried to prevent her burial by using stones and bricks to block the cemetery roadway.

Other affected individuals: Following the incident, approximately 112,000 people were examined for radioactive contamination, and 249 were found to have significant levels of radioactive material in or on their bodies. Of this group, 129 people had internal contamination. The majority of the internally contaminated people only suffered small doses (< 50 mSv), less than a 1 in 400 risk of getting cancer as a result.

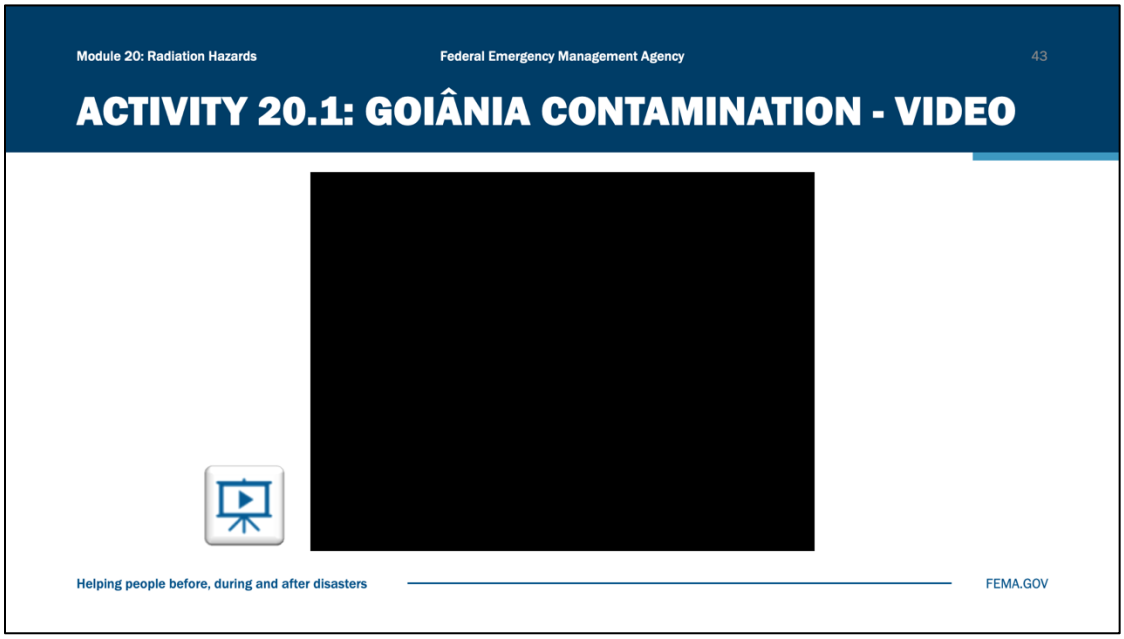
Cleanup: Topsoil had to be removed from several sites, and several houses were demolished. All the objects from within those houses were removed and examined. Those that were found to be free of radioactivity were wrapped in plastic bags, while those that were contaminated were either decontaminated or disposed of as waste. In industry, the choice between decontaminating or disposing of objects is based on only the economic value of the object and the ease of decontamination. In this case, the IAEA recognized that to reduce the psychological impact of the event, greater effort should have been taken to clean up items of personal value, such as jewelry and photographs. It is unclear from the IAEA report to what extent this was practiced.

For more information, see Goiânia accident - Wikipedia (https://en.wikipedia.org/wiki/Goi%C3%A2nia_accident).

Goiânia Contamination Worksheet

1. What would you do if this occurred in your community? (Response)
2. What resources/partners would be available to help your community? (Preparedness-Planning)
3. What are the long-term impacts of an incident such as this? (Recovery)

Activity 20.1: Goiânia Contamination (3 of 3)



Slide 20-43, Video: Goiânia

Introduction: The 1987 Goiânia radiological incident led to significant changes in worldwide regulations for radiological waste. More than 200 people were exposed to cesium-137, with four deaths. More than 100,000 people were monitored and screened for radiation exposure.

Goiânia Transcript

Speaker: Thank you for staying with CNN. It is a symbol that can save lives. A red triangle with radiation waves and a man running. It was just adopted last year, but there was no such sticker to convey danger when scavengers went routing through debris at a deserted clinic in Brazil over 20 years ago. UN TV has details.

Voiceover speaker: Two families live at this scrapyard at the Brazilian city of Goiania. It is also home to the world's worst accident involving a radiative source. Its lessons still shape actions on nuclear safety and security decades later.

It started in September 1987 when scrap dealers pillaged and then sold a metal canister from an abandoned medical clinic. They had no clue it contained a powerful radioactive source used to treat cancer: Cesium Chloride, a glittering powder that glows blue in the dark.

Dr. Nelson Jose L. Valverde: They took the equipment to his dining room and called the neighbors, relatives, friends to show them that glittering object, and small fragments of the source were taken, were robbed on the scene, were given to other people as souvenirs, and that's the way contamination came to spread.

Voiceover: The powdery cesium spread undetected for over 2 weeks. Almost 250 people were contaminated or died in the first month, including a little girl who lived here. The legacy of a handful of cesium is three thousand cubic meters of contaminated waste. It's buried here.

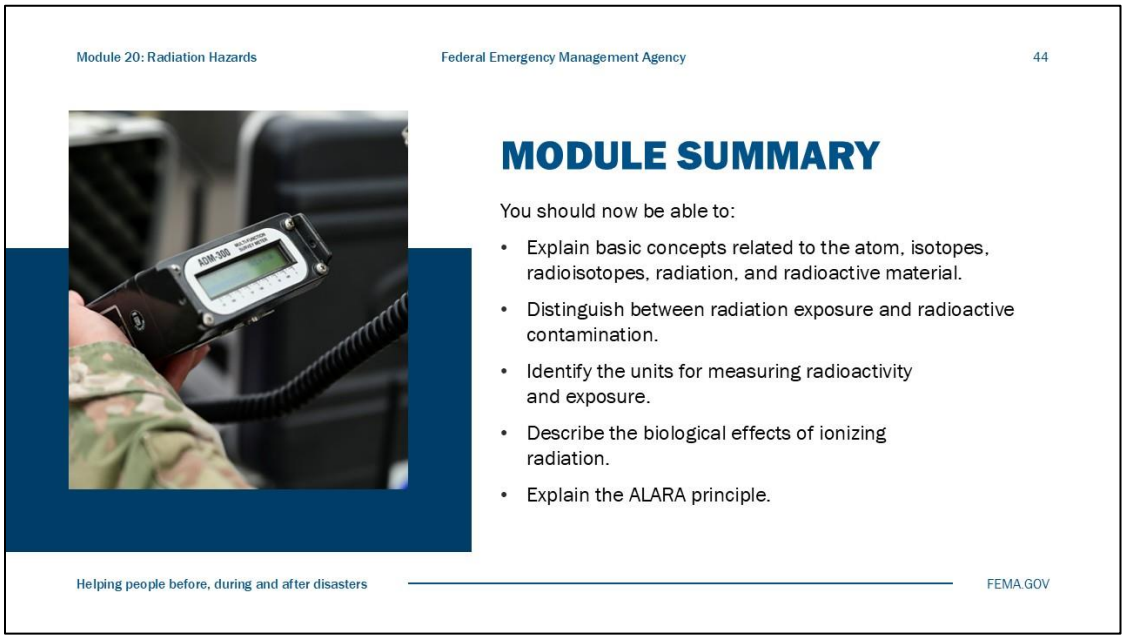
Goiania's plight brought global change. The international atomic energy agency introduced rigorous safety standards for sources. Brazil now requires that each and every source is licensed for lifetime tracking to final disposal.

Didier Louvat: Certainly the public and the environment are better protected now than thirty years ago.

Voiceover: Lessons were learned in Goiania, but worldwide radioactive sources are still dumped and lost. Efforts are underway to assist countries to search and secure abandoned sources, train body guards to detect them, as part of a cradle to grave approach needed to keep radioactive materials secure so that what happened in Goiania is never repeated.

From UN Television, this is Kirsty Hansen, with CNN World Report.

End of Module (1 of 2)

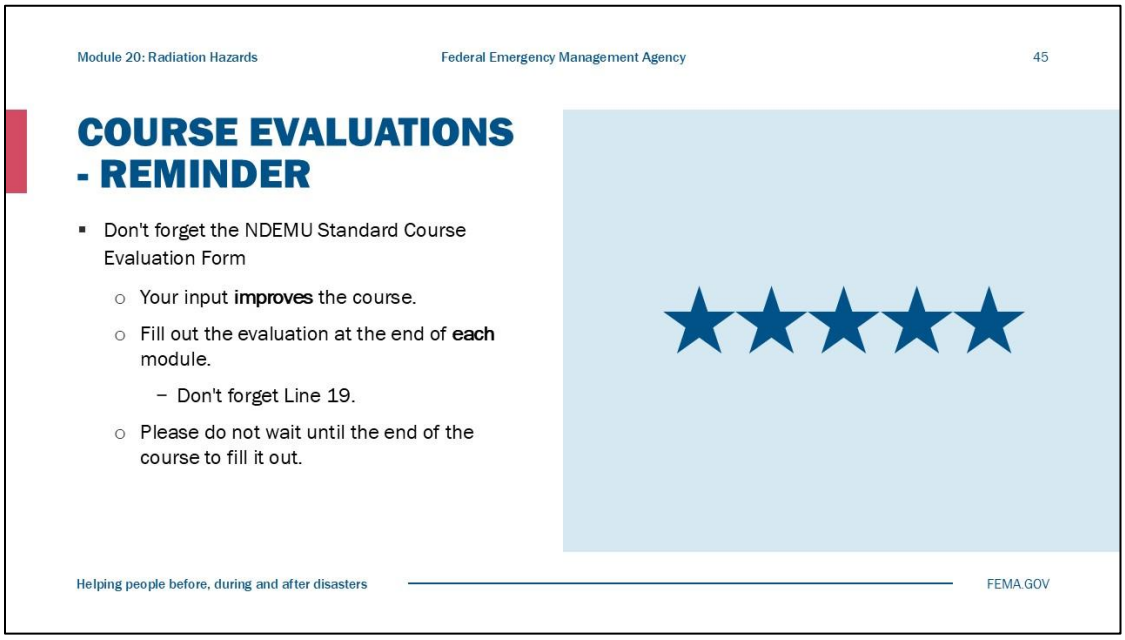


Slide 20-44, Module Summary

You should now be able to:

- Explain basic concepts related to the atom, isotopes, radioisotopes, radiation, and radioactive material.
- Distinguish between radiation exposure and radioactive contamination.
- Identify the units for measuring radioactivity and exposure.
- Describe the biological effects of ionizing radiation.
- Explain the ALARA principle.

End of Module (2 of 2)



Slide 20-45, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

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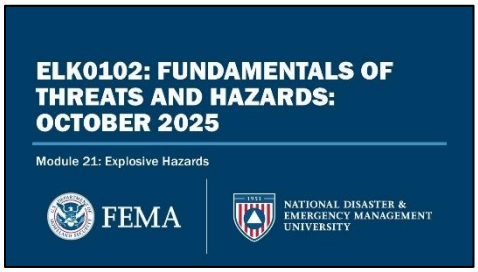
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Module

21

Explosive Hazards

Administration



Slide 21-1, Module 21: Explosive Hazards



Slide 21-2, Enabling Learning Objectives

Duration

1 hour, 30 minutes

Terminal Learning Objective (TLO)

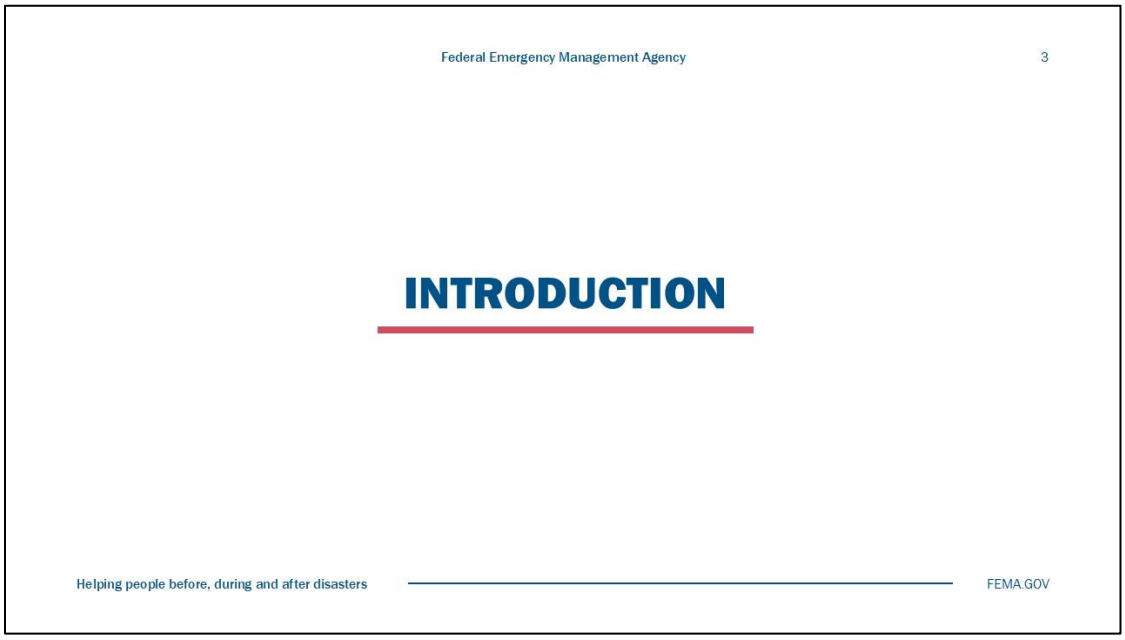
By the end of this module, participants will be able to apply knowledge of blast effects, mitigation strategies, and emergency management considerations to respond effectively to explosive incidents.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to…

- Describe the formation and movement of an explosive shock wave and factors that affect it.
- Describe how different categories of materials work together in an explosive train.
- Describe blast effects on structures and people.

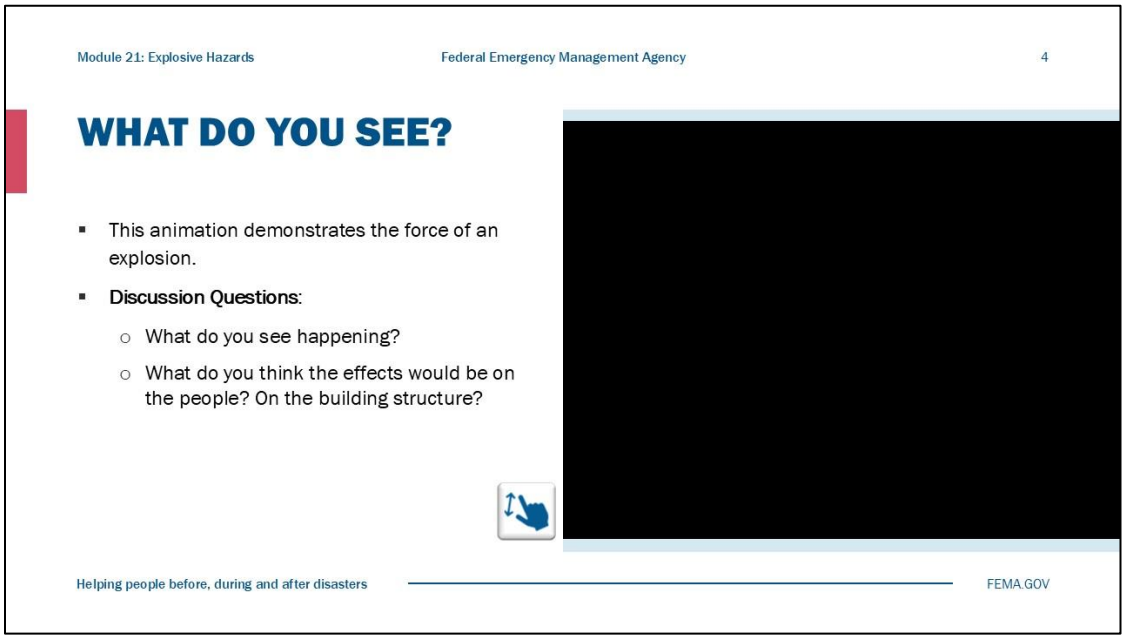
Introduction (1 of 3)



Slide 21-3, Introduction

Not Applicable.

Introduction (2 of 3)



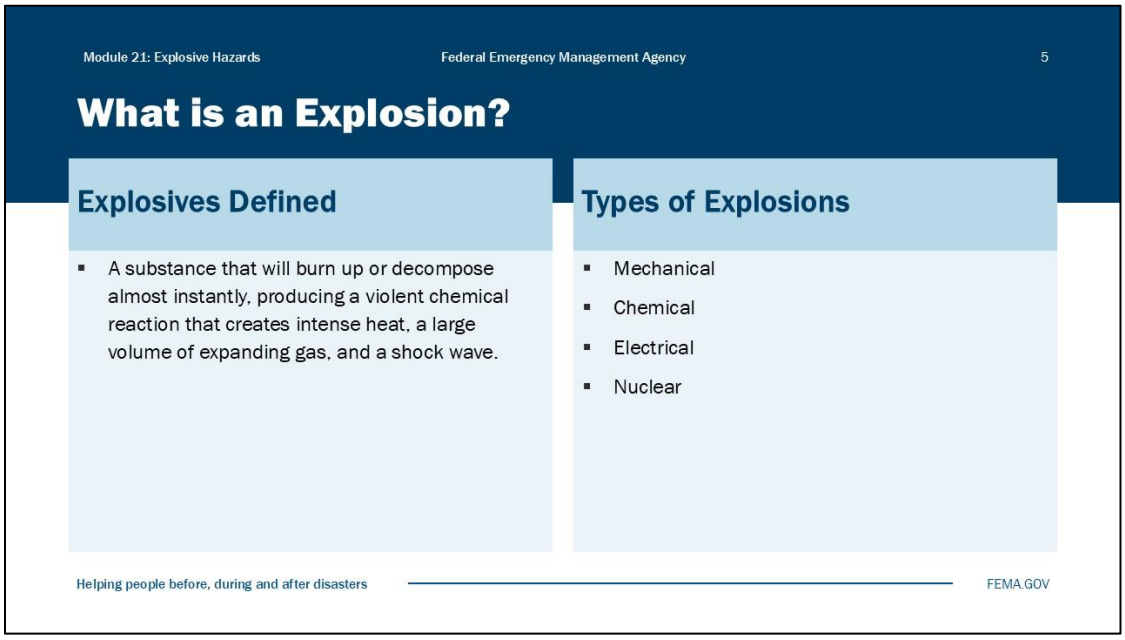
Slide 21-4, What do you see?

The animation demonstrates the force of an explosion and its impact on the structure, interior of the building, and personnel within.

Discussion Questions:

- What do you see happening?
- What do you think the effects would be on the people? On the building structure?

Introduction (3 of 3)



Slide 21-5, What is an Explosion?

A substance that will burn up or decompose almost instantly, producing a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.

An explosive is anything that, once ignited, burns extremely rapidly and produces a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.

An explosion is an oxidation or decay reaction that generates an increase in temperature (**exothermic change**), pressure **(positive entropy change),** or both simultaneously.

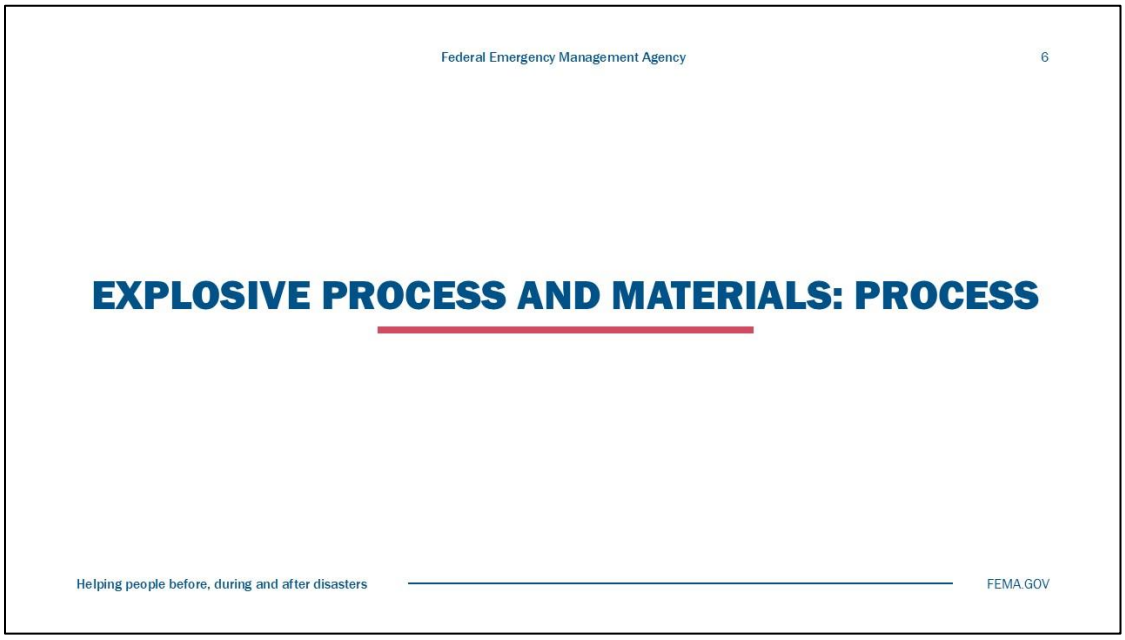
Put more simply, an explosion is a sudden escape of gases from a confined space accompanied by high temperatures, a violent shock, and a loud noise.

There are four types of explosion:

- **Mechanical:** Caused by gas expanding inside a closed space until it exceeds the strength of the container (typically accidental). There is no chemical reaction. The explosion may be followed by fire. An exploding oxygen cylinder is an example. An exploding oxygen cylinder or a Boiling Liquid Expanding Vapor Explosion (BLEVE) are examples.
- **Chemical:** Caused by an uncontrolled chemical reaction between two or more materials that release energy.

- **Electrical:** Caused by the weakening of air resistance around a high-voltage source, allowing electricity to escape and travel to a nearby conductor or ground.
- **Nuclear:** Caused by the splitting of nuclei of atoms by fission or the joining of nuclei of atoms by fusion (discussed in a later module.)

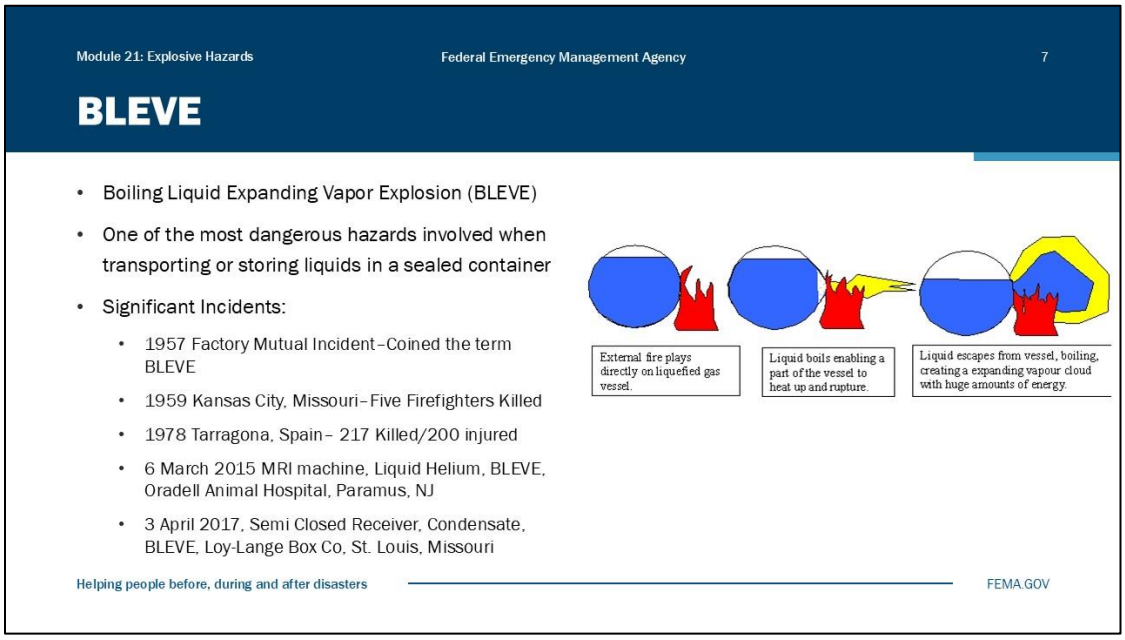
Explosive Process and Materials: Process (1 of 4)



Slide 21-6, Explosive Process and Materials: Process

Not Applicable.

Explosive Process and Materials: Process (2 of 4)



Slide 21-7, BLEVE

- One of the most dangerous hazards involved when transporting or storing liquids in a sealed container.
- Significant Incidents:
  - 1957 Factory Mutual Incident–Coined the term BLEVE
  - 1959 Kansas City, Missouri–Five Firefighters Killed
  - 1978 Tarragona, Spain– 217 Killed/200 injured
  - 6 March 2015 MRI machine, Liquid Helium, BLEVE, Oradell Animal Hospital, Paramus, NJ
  - 3 April 2017, Semi Closed Receiver, Condensate, BLEVE, Loy-Lange Box Co, St Louis, Missouri

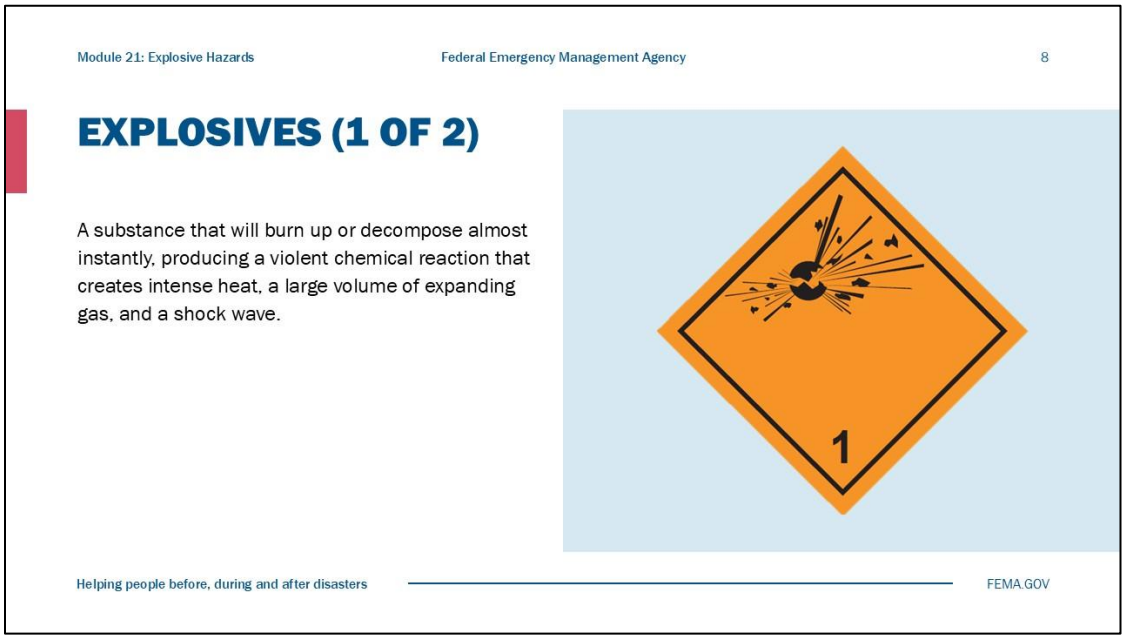
BLEVE is an acronym that was first coined by three Factory Mutual (FM) researchers. There are three characteristics of liquids that are relevant to the discussion of a BLEVE:

- If a liquid in a sealed container is heated to a boil, the pressure inside the container increases. As the liquid changes to a gas, it expands. This expansion in a vented container would cause the gas and liquid to occupy more space. In a sealed container, the gas and liquid are not able to take up more space, and so the pressure rises.

Pressurized vessels containing liquids can reach an equilibrium where the liquid stops boiling and the pressure stops rising. This occurs when no more heat is being added to the system, either because it has reached ambient temperature or a heat source has been removed.

- The boiling temperature of a liquid is dependent on pressure—high pressures will yield high boiling temperatures, and low pressures will yield low boiling temperatures. A common simple experiment is to place a cup of water in a vacuum chamber and then reduce the pressure in the chamber until the water boils. By reducing the pressure, the water will boil even at a temperature as low as room temperature. This works both ways—if the pressure is increased beyond normal atmospheric pressures, the boiling of hot water could be suppressed far beyond normal temperatures. The cooling system of a modern internal combustion engine is a real-world example.
- When a liquid boils, it turns into a gas. The resulting gas takes up far more space than the liquid did.

Explosive Process and Materials: Process (3 of 4)

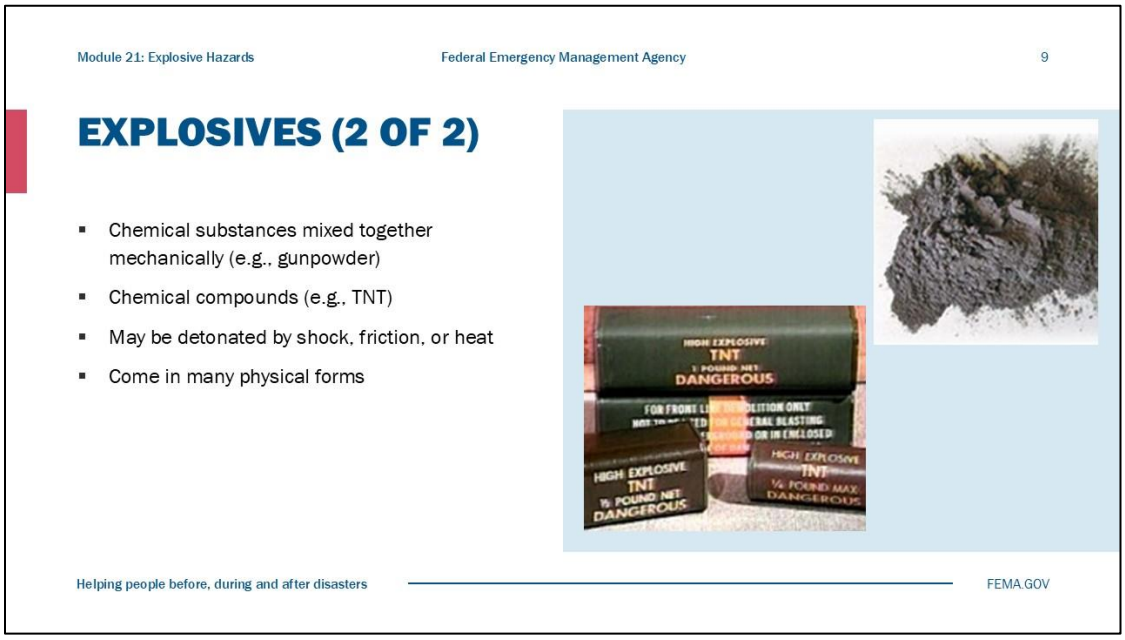


Slide 21-8, Explosives (1 of 2)

An explosive is a substance that will burn up or decompose almost instantly, producing a violent chemical reaction that creates intense heat, a large volume of expanding gas, and a shock wave.

Once ignited, it burns extremely rapidly and produces a violent chemical reaction, creating intense heat, a large volume of expanding gas, and a shock wave.

Explosive Process and Materials: Process (4 of 4)



Slide 21-9, Explosives (2 of 2)

- Chemical substances mixed together mechanically (e.g., gunpowder)
- Chemical compounds (e.g., TNT)
- May be detonated by shock, friction, or heat
- Come in many physical forms

In the context of chemical hazards, we spoke of the differences between chemical mixtures and chemical compounds. The same holds true for explosives. Explosives may be:

- **Chemical mixtures** (composed of distinct substances that are mechanically conglomerated in varying proportions), such as black powder
- **Chemical compounds** (homogeneous substances whose molecules contain within themselves the oxygen, carbon, and hydrogen necessary for combustion)

Explosives may be detonated by shock (hitting, shaking), friction (rubbing surfaces together to produce a spark), or heat.

Explosive materials come in many physical forms. Many are known by their commercial names. Examples are described in the following table.

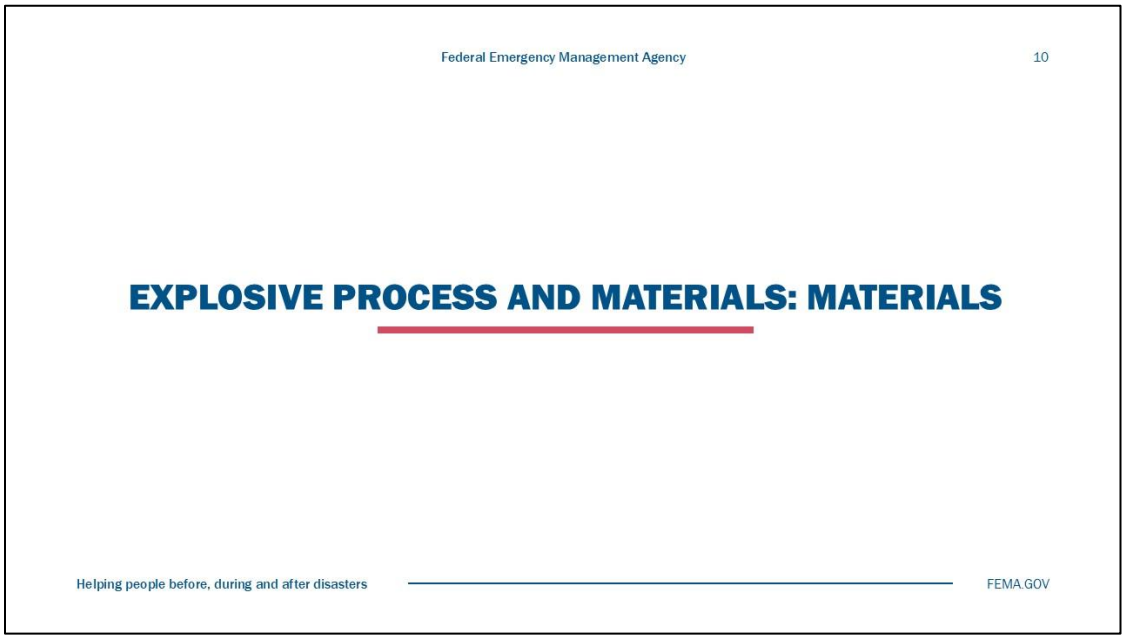
Physical Forms of Explosive Materials

Additional Information

Form	Description
Binary Explosives	Two-part mixtures based on ammonium nitrate plus a volatile fuel that are shipped separately and combined onsite into a slurry or a liquid containing solids. Unlike Ammonium Nitrate Fuel Oil (ANFO), they can be detonated by blasting caps. Examples include Kinestik and Marine Pac.
Blasting Agents	Explosive materials or mixtures that are not detonable by standard #8 blasting caps. They may be prepackaged, like ANFO, or made onsite from fertilizer-grade ammonium nitrate and fuel oil. Other examples include Carbomite and Dynatex.
Castable Explosives	Contain at least one component (typically TNT) that can be melted at a temperature at which it is safe to handle the other components. Produced by casting or pouring the molten mixture or material into a form or a used container.
Dynamites	An absorbent mixture soaked in nitroglycerin and compressed into cylinders and wrapped in paper. Dynamites, which have a limited shelf life, are used in mining, quarrying, construction, and demolition.
Extrudable Explosives	Viscous liquids similar to caulk. They can be extruded out of a nozzle into thin cracks, holes, or along surfaces. Some will remain viscous; others can be hardened using a heat-curing process. Examples include Demex-400 and LX-13.
Polymer Bonded Explosives (PBX)	A relatively solid and inflexible explosive form containing a powdered explosive material and a polymer (plastic) binder. Often, a very thin coating of the polymer is placed onto the powder grains of the explosive material and then hot pressed to form dense solid blocks of PBX material. Most are based on Research Department Explosives (RDX), High Melting Explosive (HMX), or Triammine Benzene (TATB) explosives. There are many different kinds, most used in nuclear weapons.
Putties (Plastic Explosives)	Thick, flexible, moldable, clay-like solid material that can be shaped and will retain that shape after forming. Putties normally contain mostly RDX explosive but may include some PETN. Examples include C-4, Semtex, and PE-4.

Form	Description
Rubberized Explosives	Flat sheets of solid but flexible material made from a mixture of a powdered explosive such as RDX or PETN and a synthetic or natural rubber compound. Rubberized explosives can be cut to shape, bent around objects, affixed in place, or simply laid on relatively flat surfaces. They are commonly used for explosive welding and for other industrial and military applications. Examples include Primasheet and Detasheet
Slurries and Gels	Fuel-sensitized explosive mixtures contain an aqueous ammonium nitrate solution that acts as the oxidizer and a thickener. They may be pourable or solid. An example is Tovex.

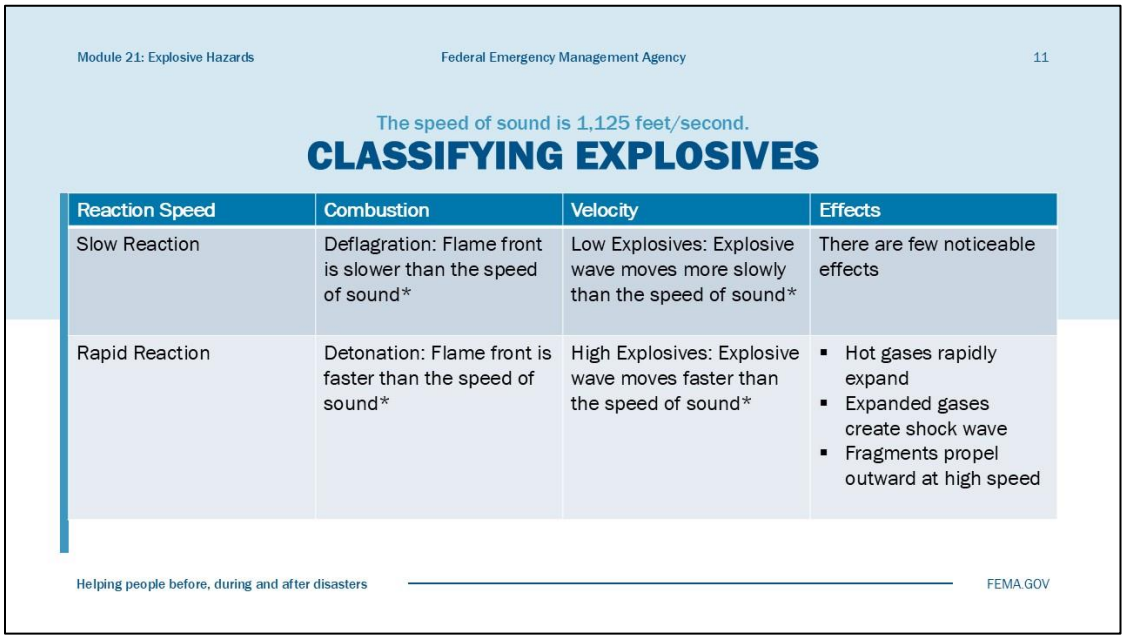
Explosive Process and Materials: Materials (1 of 9)



Slide 21-10, Explosive Process and Materials: Materials

Not Applicable.

Explosive Process and Materials: Materials (2 of 9)

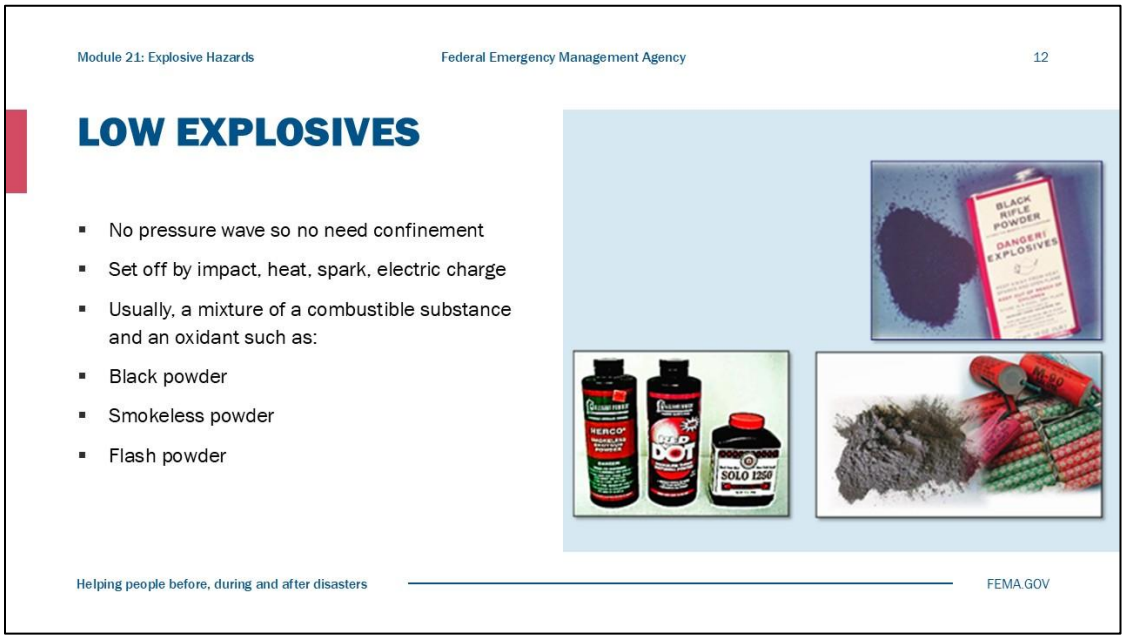


Slide 21-11, Classifying Explosives

Reaction Speed	Combustion	Velocity	Effects
Slow Reaction	Deflagration: Flame front is slower than the speed of sound*	Low Explosives: The Explosive wave moves more slowly than the speed of sound*	There are a few noticeable effects
Rapid Reaction	Detonation: Flame front is faster than the speed of sound*	High Explosives: Explosive wave moves faster than the speed of sound*	• Hot gases rapidly expand • Expanded gases create a shock wave • Fragments propel outward at high speed

*The speed of sound is 1,125 feet/second.

Explosive Process and Materials: Materials (3 of 9)



Slide 21-12, Low Explosives

- No pressure wave, so no need for confinement
- Set off by impact, heat, spark, electric charge
- Usually, a mixture of a combustible substance and an oxidant such as:
  - Black powder
  - Smokeless powder
  - Flash powder

Low explosives are usually a mixture of a combustible substance and an oxidant. Examples include black powder, smokeless powder, and flash powder.

Explosive Process and Materials: Materials (4 of 9)



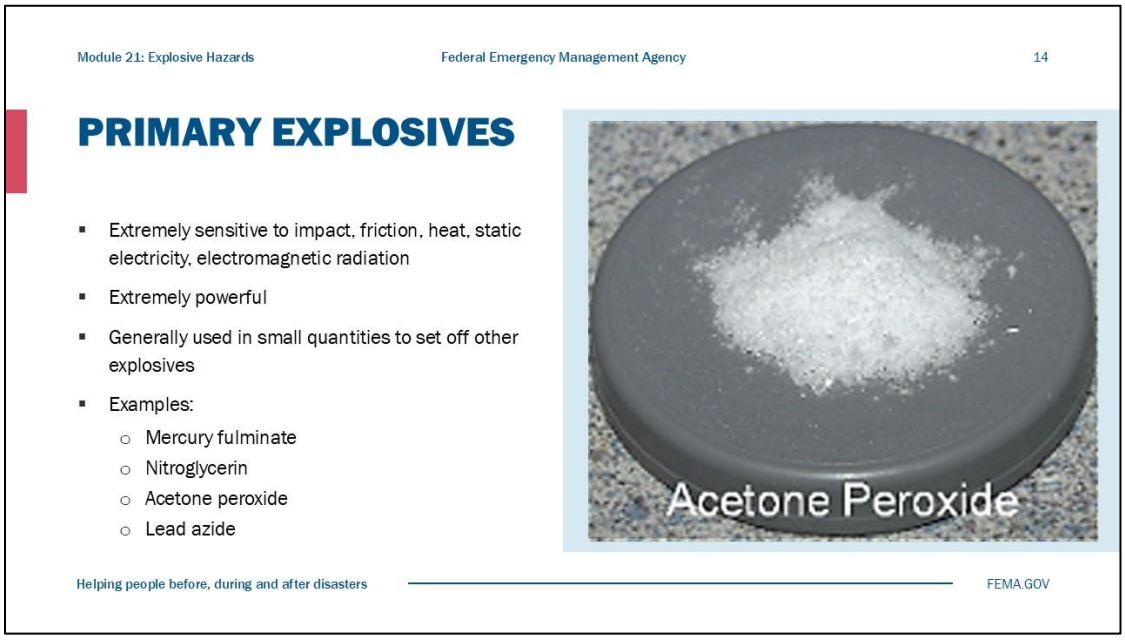
Slide 21-13, High Explosives

- High explosives are set off by detonator shock and may be classified by sensitivity—the ease with which they may be detonated by impact, heat, or friction.
- Three classes:
  - Primary explosives
  - Secondary explosives
  - Tertiary explosives

Explosives Classified by Sensitivity

- High explosives may be classified by sensitivity, that is, the ease with which they may be detonated by impact, heat, or friction.
- Three classes:
  - Primary explosives
  - Secondary explosives
  - Tertiary explosives

Explosive Process and Materials: Materials (5 of 9)



Slide 21-14, Primary Explosives

- Extremely sensitive to impact, friction, heat, static electricity, and electromagnetic radiation
- Extremely powerful
- Generally used in small quantities to set off other explosives
- Examples:
  - Mercury fulminate
  - Nitroglycerin
  - Acetone peroxide
  - Lead azide

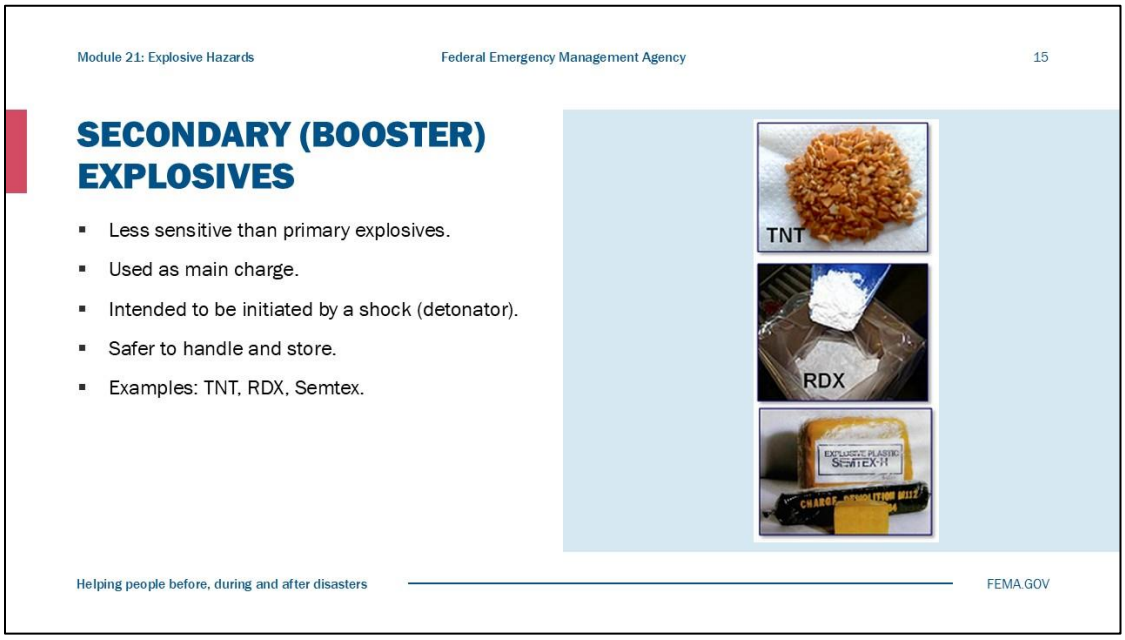
Examples of Primary Explosives

Explosive	Description
Acetone Peroxide (TATP)	• Triacetone triperoxide (TATP); peroxyacetone (TCAP). • White crystalline powder with a distinctive bleach-like odor. • Improvised primary explosive that is relatively easy to synthesize. • Made of a mixture of hydrogen peroxide and acetone with the addition of an acid, such as sulfuric, nitric, or hydrochloric acid. • Very unstable and sensitive to heat, shock, and friction. • Not easily soluble in water. It is more stable and less sensitive when wet.
DDNP	• Diazodinitrophenol (DDNP). • Yellowish brown powder. • Soluble in acetic acid, acetone, strong hydrochloric acid, and most solvents. Insoluble in water. It may be desensitized by immersing it in water. • Less sensitive to impact and friction but more powerful than mercury fulminate. • Used with other materials to form priming mixtures, particularly where a high sensitivity to flame or heat is desired.
HMTD	• Hexamethlene Triperoxide Diamine (HMTD). • Improvised primary explosive prepared from hexamine, a weak acid, and hydrogen peroxide. • Highly sensitive to friction, impact, and electrostatic discharge. • Corrosive in contact with metals. • It can degrade quickly if improperly synthesized or stored.

Explosive	Description
Lead Azide	• Crystalline, cream-colored compound. • High temperature of ignition. Sensitive to both flame and impact, but less so than mercury fulminate. • Practically insoluble in water. • Must not be exposed to copper, zinc, or metal alloys because of the possible formation of other, more sensitive azides. • Used in detonating fuses and in priming mixtures.
Lead Styphnate	• Orange or brown crystals. • Easily ignited by heat and static discharge but cannot be used to initiate secondary high explosives reliably. • May be mixed with other materials and then pressed into a metallic container (detonators and primers). • Stored under water (or if there is danger of freezing, under a mixture of water and alcohol). • Used as an igniting charge for lead azide and as an ingredient in priming mixtures for small arms ammunition.
Mercury Fulminate	• White or gray crystals. • Extremely sensitive to initiation by heat, friction, spark or flame, and impact. • Stored under water (or if there is danger of freezing, under a mixture of water and alcohol). • Gradually becomes inert when stored continuously above 100°F. • Can be pressed into containers, usually at 3,000 psi, for use in detonators and blasting caps. When “dead pressed” (compressed at greater and greater pressure (up to 30,000 psi)), it can only be exploded by another initial detonating agent.

Explosive	Description
Nitroglycerin	• Heavy, colorless, oily, explosive liquid. Most commonly produced by treating glycerol with nitric acid under conditions appropriate to the formation of the nitric acid ester. • In undiluted form, it is one of the world's more powerful explosives. Detonates at 30 times the speed of sound. • Sensitive to physical shock, heat, and flame (so sensitive that a slight jolt, friction, or impact may cause it to detonate). • Degrades over time to even more unstable forms. • Used as an active ingredient in the manufacture of explosives (mostly dynamite) used in the construction, demolition, and mining industries. Also used as a propellant in firearms.

Explosive Process and Materials: Materials (6 of 9)



Slide 21-15, Secondary (Booster) Explosives

- Less sensitive than primary explosives
- Used as the main charge
- Intended to be initiated by a shock (detonator)
- Safer to handle and store
- Examples: TNT, RDX, Semtex

Secondary explosives are less sensitive than primary explosives. As such, they are safer to handle and store. These explosives are used as the main charge and require a detonator to initiate their detonation.

Examples of secondary explosives are listed in the following table.

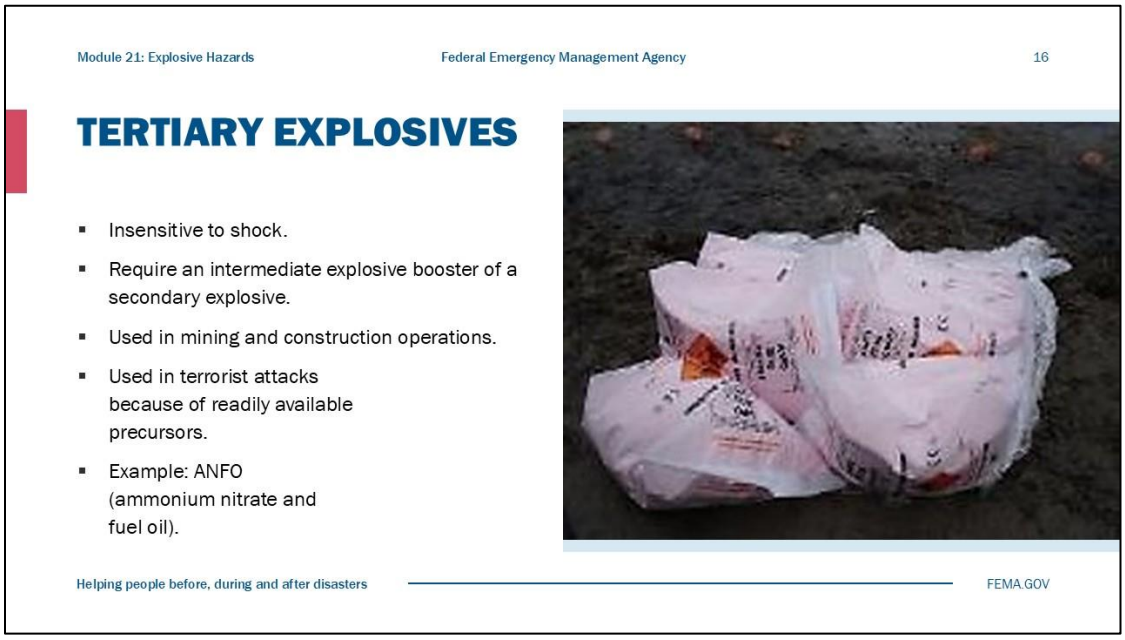
Examples of Secondary Explosives

Explosive	Description
TNT	• Trinitrotoluene (TNT). • Light yellow, brown, or light gray. • A constituent of many explosives, such as amatol, pentolite, tetrytol, torpex, tritonal, picratol, ednatol, and composition B. It has been used under such names as Triton, Trotyl, Trilite, Trinol, and Tritolo. • Relatively insensitive to blows or friction. In a refined form, it is one of the most stable of high explosives and can be stored over long periods of time. • Non-water soluble; neither absorbs nor dissolves in water. • Does not form sensitive compounds with metals, but it is readily acted upon by alkalies to form unstable compounds that are very sensitive to heat and impact. • May exude a flammable oily brown liquid. • Can be used as a booster or as a bursting charge for high-explosive shells and bombs.

Explosive	Description
RDX	• The name RDX stands for Research Department Explosive. Also known as cyclonite, hexogen, and T4. • Obtained by reacting white fuming nitric acid (WFNA) with hexamine. • The pure, synthesized state is a white, crystalline solid. • It is one of the most powerful and brisant (shattering) military high explosives. When exploding in the air, it has about 1.5 times the explosive power of TNT per unit weight. • Often used in mixtures with other explosives, plasticizers, or desensitizers. • Very stable when stored at room temperature. It burns rather than explodes and detonates only with a detonator. • Widely used in military and industrial applications. • Also used by terrorists—e.g., 1993 Bombay bombings, 2006 Mumbai train bombings, 2010 Moscow Metro bombings.
Semtex	• General-purpose plastic explosive. • Contains RDX, PETN (Pentaerythritoltetranitrate), plasticizer, binder, and antioxidant. • Used in commercial blasting, demolition, and in certain military applications. • Also used by terrorists—e.g., Pan Am Flight 103.
C-4	• A common variety of Composition C, a plastic explosive. • Off-white solid with a texture similar to modeling clay. • Composed of RDX, plastic binder, plasticizer, and a small amount of motor oil. May contain a chemical tag to help detect the explosive and identify its source. • Very stable and insensitive to most physical shocks. Detonation can only be initiated by a combination of extreme heat and a shockwave, such as when a detonator inserted into it is fired. • Can be molded into any desired shape, pressed into gaps, and used in shaped charges.

Explosive	Description
PETN	• Pentaerythritoltetranitrate (PETN). • One of the strongest known high explosives. • More sensitive to shock or friction than TNT. • Never used alone as a booster. It is primarily used in booster and bursting charges of small caliber ammunition, in upper charges of detonators in some land mines and shells, and as the explosive core of primacord.

Explosive Process and Materials: Materials (7 of 9)



Slide 21-16, Tertiary Explosives

- Insensitive to shock
- Require an intermediate explosive booster of a secondary explosive
- Used in mining and construction operations
- Used in terrorist attacks because of readily available precursors
- Example: ANFO (ammonium nitrate and fuel oil)

Tertiary explosives, also called blasting agents, are very insensitive to shock. They can't be reliably detonated by practical quantities of primary explosive, so they require an intermediate explosive booster of secondary explosive.

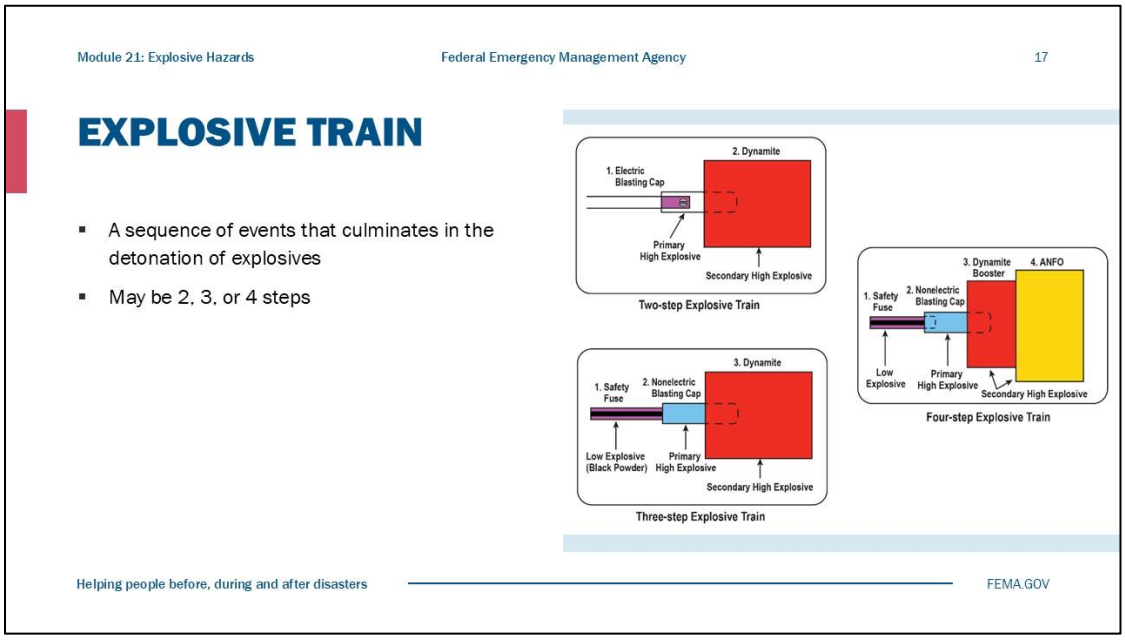
The main users are large-scale mining and construction operations. These materials have also been used for terrorist attacks (e.g., the first attempt on the World Trade Center in 1993 and the 1995 Oklahoma City bombing) because of the availability of large quantities of precursors (e.g., nitrate fertilizers).

ANFO is an example of a tertiary explosive. (Image source: Halen on Wikimedia Commons)

ANFO

- Ammonium Nitrate/Fuel Oil (ANFO).
  - A widely used bulk blasting agent because it is readily available and cheap.
  - Contains 94 percent porous prilled (pelletized) ammonium nitrate that acts as the oxidizing agent and absorbent for the fuel oil.
  - It is highly stable and insensitive. Under most conditions, it cannot be detonated with a #8 blasting cap. It generally requires a booster to ensure the detonation continues.
  - Decomposes through detonation rather than deflagration with a moderate velocity of about 3,200 meters per second in a 5-inch diameter, unconfined, at ambient temperature.
  - Requires confinement for efficient detonation and brisance. The optimum blend for ANFO, if properly prepared, could yield greater explosive power than TNT.
  - Readily absorbs water from air and is dangerous when stored in humid environments, as any absorbed water interferes with its explosive function.
  - It is water soluble.

Explosive Process and Materials: Materials (8 of 9)



Slide 21-17 Explosive Train

What is an explosive train?

- It is a sequence of events that culminates in the detonation of explosives.
- It may be 2, 3, or 4 steps.

Two-step explosive train:

- Electric blasting cap (primary high explosive)
- Dynamite (secondary high explosive)

Three-step explosive train:

- Safety fuse (low explosive [black powder])
- Non-electric blasting cap (primary high explosive)
- Dynamite (secondary high explosive)

Four-step explosive train:

- Safety fuse (low explosive)
- Non-electric blasting cap (primary high explosive
- Dynamite booster (secondary high explosive)

- ANFO (secondary high explosive)

An explosive train, also known as a triggering sequence or firing train, is a sequence of events that begins with low-level energy and culminates in a chain reaction to initiate the final explosive material or main charge. **All explosives need a firing train to work. Explosive train = firing train.**

Because most widely used high explosives are difficult to detonate, a primary explosive of higher sensitivity is used to trigger a uniform and predictable detonation of the main body of the explosive. Although the primary explosive itself is generally a more sensitive and expensive compound, it is only used in small quantities and in relatively safe packaged forms.

High-explosive trains can be either two-step (e.g., detonator and dynamite) or three-step (e.g., detonator, booster of primary explosive, and main charge of secondary or tertiary explosive).

Explosive Process and Materials: Materials (9 of 9)



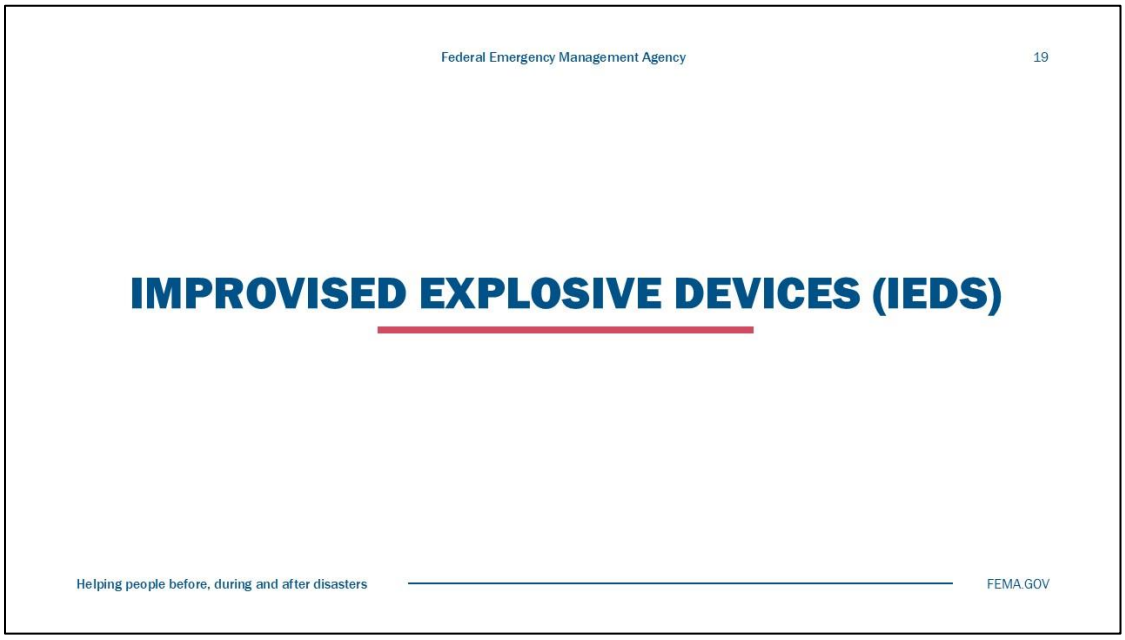
Slide 21-18, Other Important Properties of Explosives

- Brisance
- Density
- Hygroscopicity
- Power, performance, and strength
- Stability
- Toxicity
- Volatility

We have discussed two important properties of explosives: velocity and sensitivity. The table below describes other important properties of explosive materials.

Property	Description
Brisance	Shattering effect. The rapidity with which an explosive reaches its peak pressure (power) is a measure of its brisance.
Density of load	The mass of an explosive per unit volume. High load density can reduce sensitivity by making the mass more resistant to internal friction. Increased load density also permits the use of more explosive, thereby increasing the available power.
Hygroscopicity	Material moisture-absorbing tendencies. Moisture promotes decomposition and can cause corrosion. It can also reduce the sensitivity, strength, and velocity of detonation of the explosive.
Power, performance, and strength	The ability to do the work intended (i.e., deliver the energy needed).
Stability	The ability of an explosive to be stored without deterioration. Stability may be affected by chemical constitution, rate of decomposition, storage temperature, exposure to ultraviolet light, and electrical discharge.
Toxicity	The decomposition of products of an explosion may be hazardous (e.g., carcinogens). Examples of harmful byproducts are lead, mercury, and nitric oxides.
Volatility	The readiness with which a substance vaporizes. Too much volatility may affect chemical composition and reduce stability.

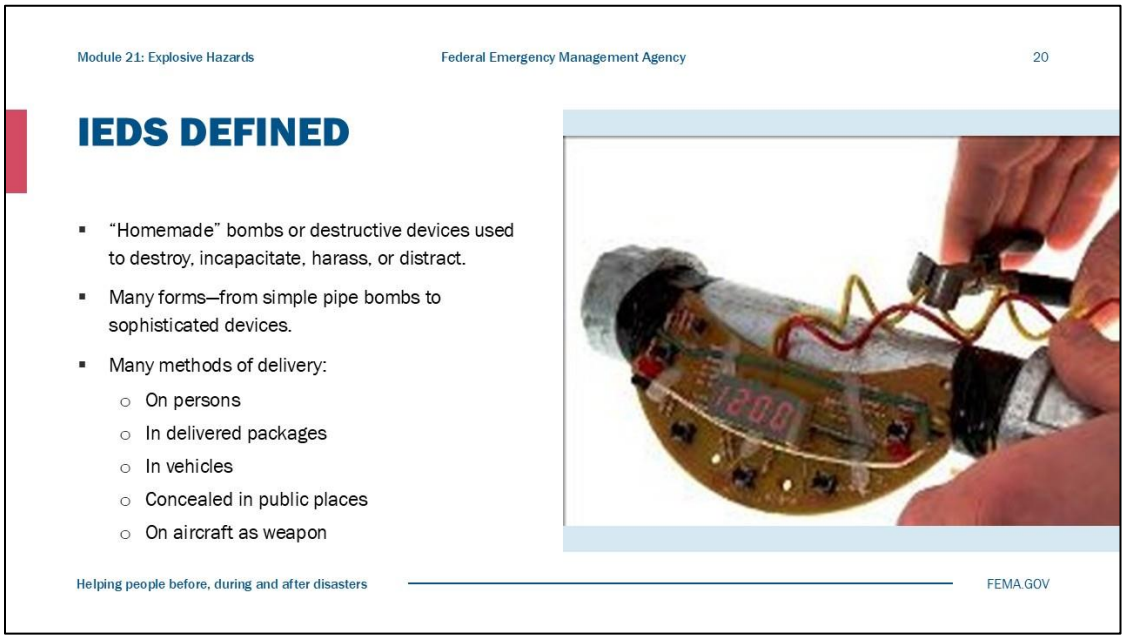
Improvised Explosive Devices (IEDs) (1 of 2)



Slide 21-19, Improvised Explosive Devices (IEDs)

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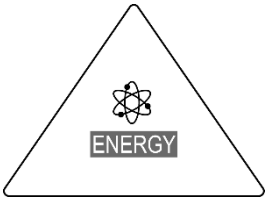
Improvised Explosive Devices (IEDs) (2 of 2)



Slide 21-20, IEDs Defined

- "Homemade" bombs or destructive devices used to destroy, incapacitate, harass, or distract
- Many forms—from simple pipe bombs to sophisticated devices
- Many methods of delivery:
  - On persons
  - In delivered packages
  - In vehicles
  - Concealed in public places
  - On aircraft as a weapon

This is energy.



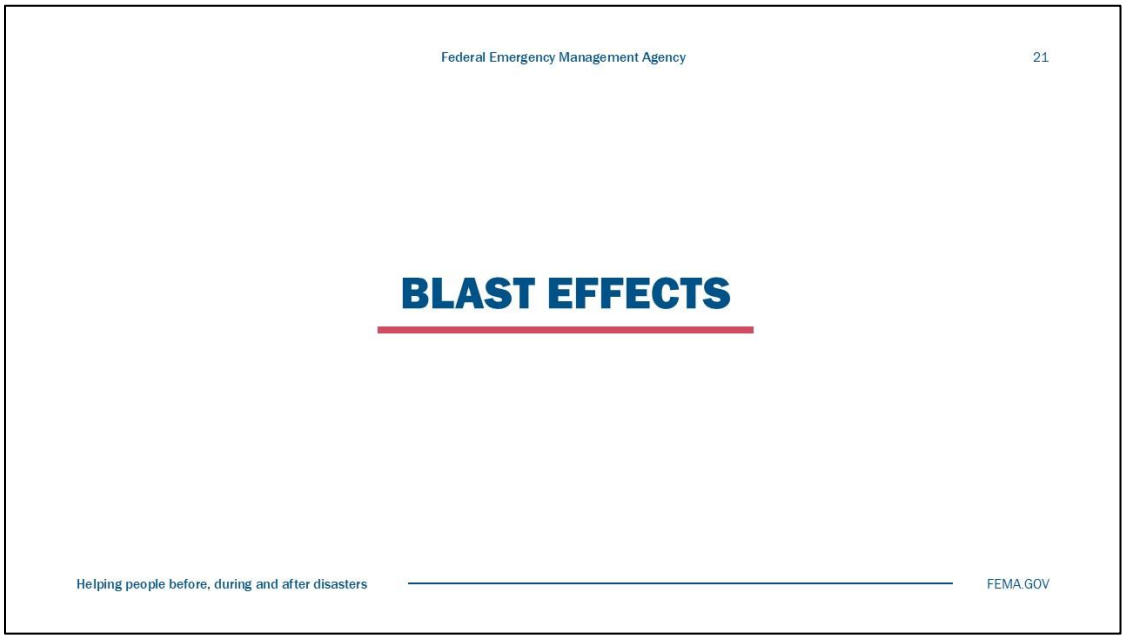
An improvised explosive device (IED) attack is the use of a "homemade" bomb and/or destructive device to destroy, incapacitate, harass, or distract. The term IED came into common usage during the Iraq War that began in 2003. IEDs are used by criminals, vandals, terrorists, suicide bombers, and insurgents.

Forms: Because they are improvised, IEDs can come in many forms, ranging from a small pipe bomb to a sophisticated device capable of causing massive damage and loss of life.

Delivery: There are many methods of delivery-for example:

- Carried, placed, or thrown by a person (briefcase, book bag, suicide vest, parcel, luggage, etc.)
- Delivered in a package (by mail, delivery service, messenger)
- Carried or delivered in a vehicle (bicycle, street cart, automobile, van, large truck, airplane)
- Concealed in public places (transit systems, public gathering places, public events, on the roadside)

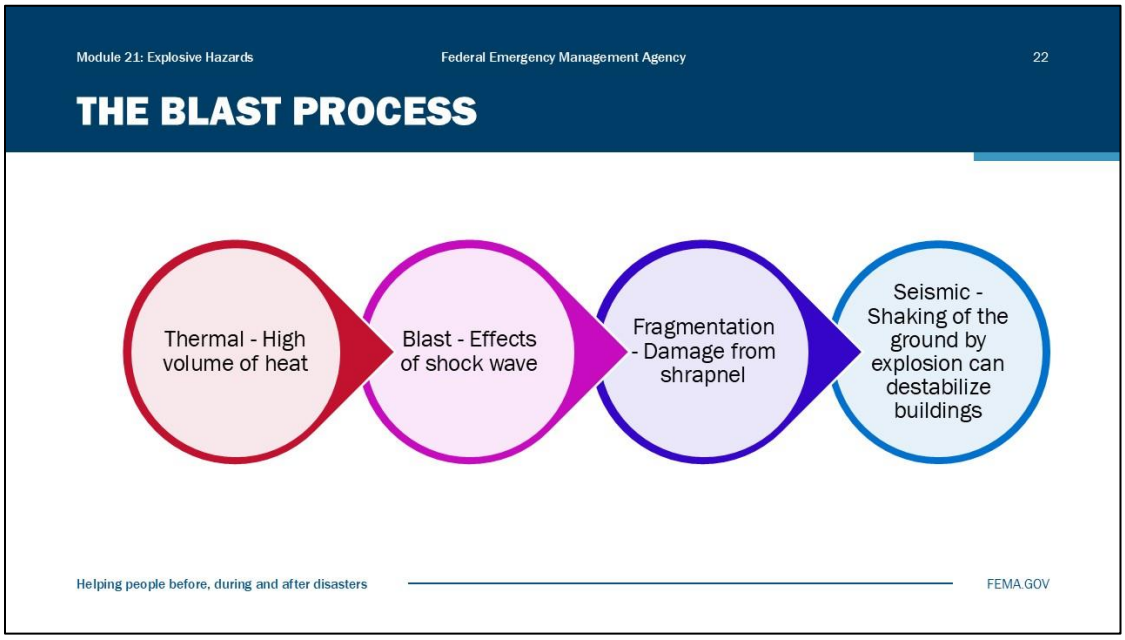
Blast Effects (1 of 11)



Slide 21-21, Blast Effects

Not Applicable.

Blast Effects (2 of 11)

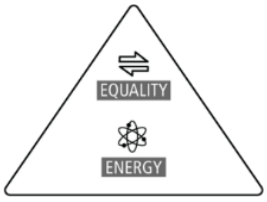


Slide 21-22, The Blast Process

This section will discuss the blast effects of explosives on structures and people. Here's what happens during the blast process:

- **Thermal:** High volume of heat
- **Blast:** Effects of shock wave
- **Fragmentation:** Damage from shrapnel
- **Seismic:** Shaking of the ground by an explosion can destabilize buildings

This is equality and energy.



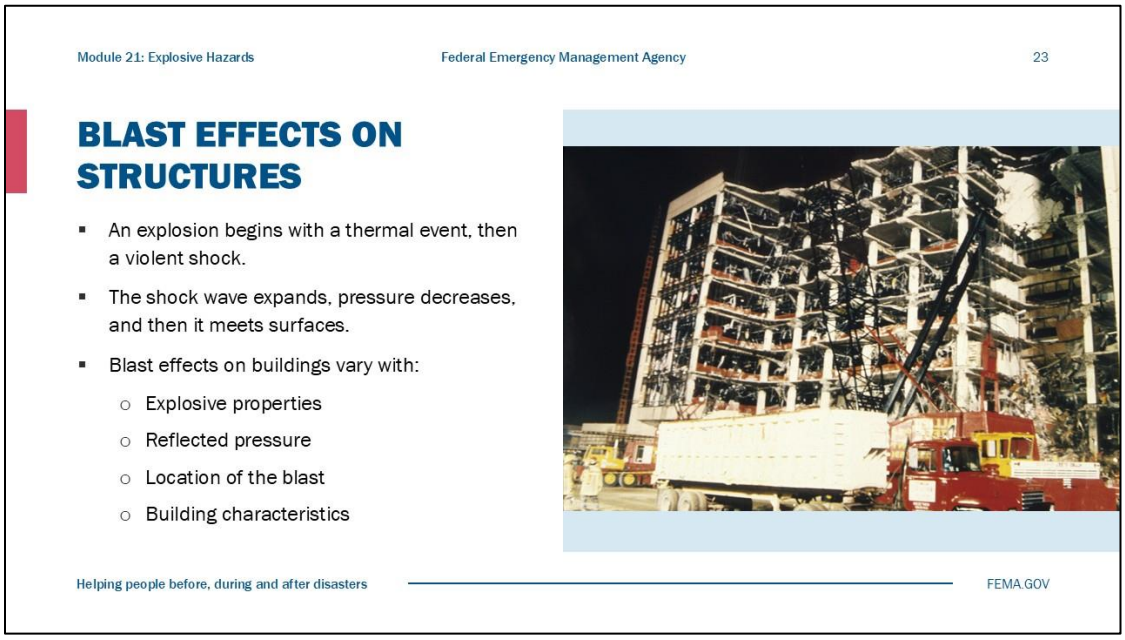
Now that we have seen what happens during the blast process, let's look at the effects. There are four main types of effects from an explosion:

- **Thermal:** First, a high volume of heat is generated by the combustion in the chemical reaction.

- **Blast:** Second, there is overpressure, the effects of the shockwave.
- **Fragmentation:** Next, the explosive device itself and objects in the path of the pressure wave fragment, which can cause damage from shrapnel (flying pieces of material). Due to the force of the explosion, shrapnel can fly a great distance.
- **Seismic:** Large explosions can also have a seismic effect. The downward pressure of the air bubble can cause the ground to shake, and if the blast is large enough, this shaking can destabilize buildings.

Because of the supersonic speed of an explosion, all of these effects may appear to happen at once.

Blast Effects (3 of 11)



Slide 21-23, Blast Effects on Structures

- An explosion begins with a thermal event, then a violent shock.
- The shock wave expands, pressure decreases, and then it meets surfaces.
- Blast effects on buildings vary with:
  - Explosive properties;
  - Reflected pressure;
  - Location of the blast; and
  - Building characteristics.

How do these blast effects impact buildings and other structures in the path of the explosion?

An explosion begins with a thermal event, then a violent shock. The shock wave expands, pressure decreases, and then it meets surfaces. The energy (blast impulse) from an explosion imparted to a building includes both the negative and positive phases of the pressure-time waveform.

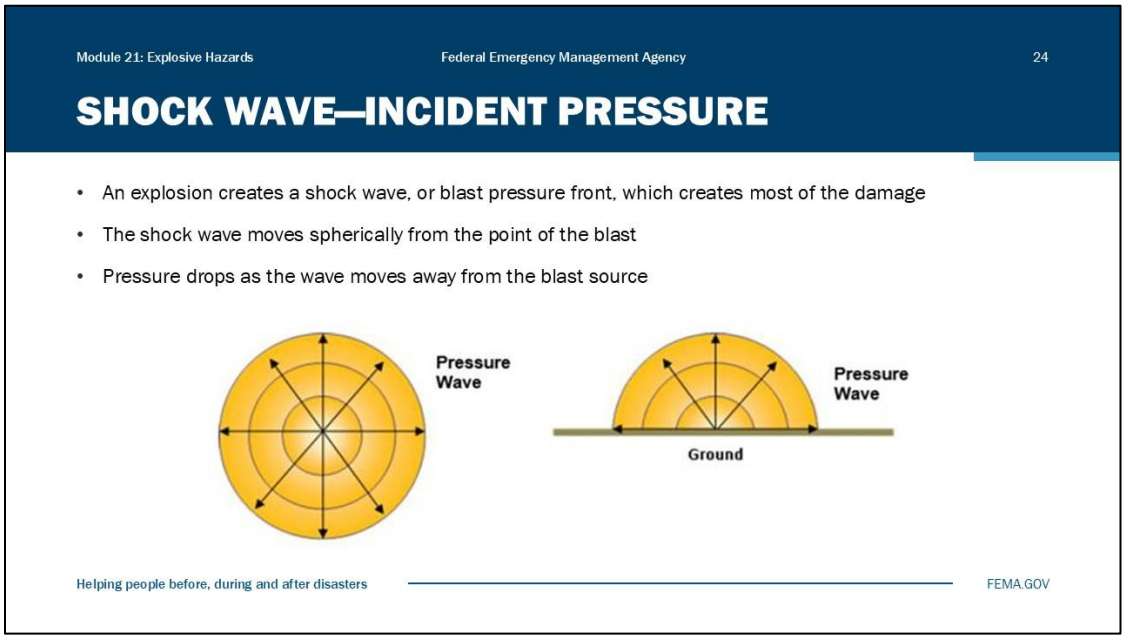
The magnitude and distribution of blast loads on a structure vary greatly with several factors:

- **Explosive properties**: Depending on the type of material, energy output, and quantity of explosive. The amount of explosive is usually expressed as TNT equivalent weight.

- **Reflected pressure**: Reinforcement of the pressure pulse through its interaction with the ground or structure (reflections).
- **Location** of the detonation relative to the structure—the stand-off distance between the explosive and the building.
- **Building characteristics**: The exterior envelope construction (walls and windows) and the framing or load-bearing system used.

The building ultimately responds to the reflected pressure and impulse. These forces vary in time and space over the exposed surface of the building, depending on the location of the detonation in relation to the building.

Blast Effects (4 of 11)

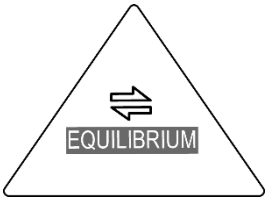


Slide 21-24, Shock Wave—Incident Pressure

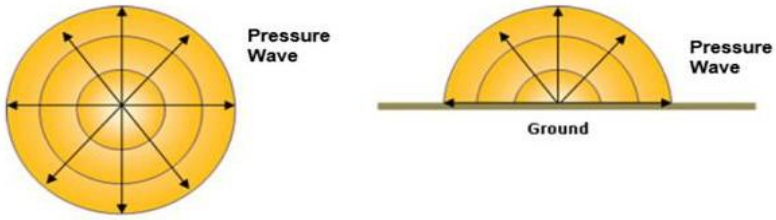
In an explosion, about one-third of the explosive material contributes to the detonation. At this point, several things happen:

- **Creation of a pressure wave**: Hot, expanding gases from the explosion compress the surrounding air to form a constant-velocity bubble of air, or a shock wave. Heat generated by chemical reactions supports the shock wave.

This is equilibrium.

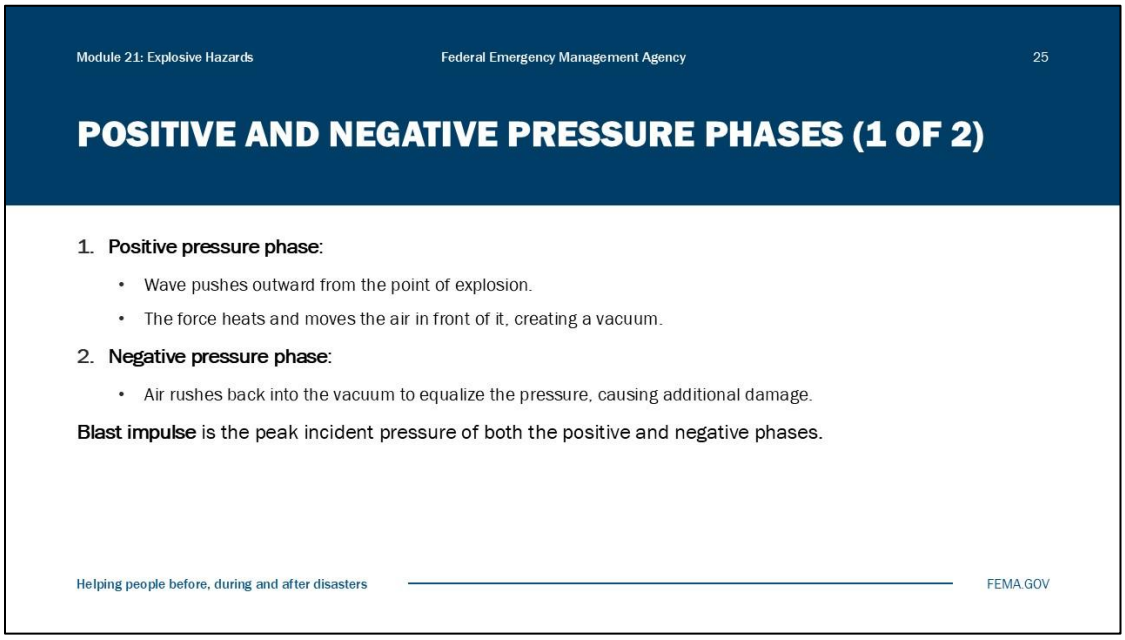


- **Movement of the pressure wave**: The shock wave, or blast pressure wave, moves spherically away from the source of the explosion at supersonic speed at peak pressure. Objects, such as the ground, may alter the shape of the wave.



- **Pressure drop**: As it reaches a point in space, such as a person or building, the wave's pressure rapidly goes from atmospheric to peak pressure in very little time. The pressure at this point decays rapidly as the supersonic bubble moves on, its pressure reducing exponentially as the bubble's surface area increases, expending energy over an ever-increasing area.
- The pressure also drops off due to the completion of the chemical reaction of the explosive mixture (burning of the remaining two-thirds of the material). If the explosion occurs within a **confined space,** the gases generated by the burning of the explosive are contained, keeping the pressure elevated over a longer period.

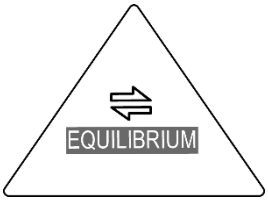
Blast Effects (5 of 11)



Slide 21-25, Positive and Negative Pressure Phases (1 of 2)

Blast impulse is the peak incident pressure of both the positive and negative phases.

This is equilibrium.

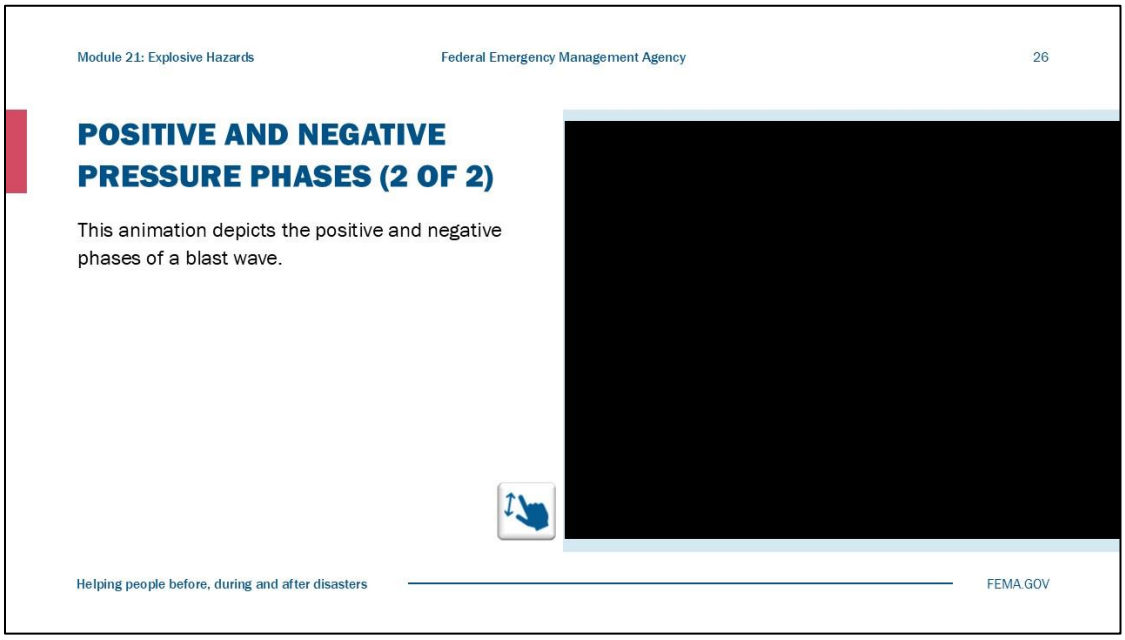


There are two phases in the movement of the pressure wave:

- **Positive pressure phase**: The positive phase is the process just described- the shock wave pushing outward from the point of explosion. The force heats and moves the air in front of it, creating a vacuum.
- **Negative pressure phase:** The negative phase of the blast wave is the ambient air rushing in behind it to return to a stable pressure. Although the negative phase has much less energy than the positive phase, it can hit structures at the most inopportune moment in their vibration, resulting in unexpected consequences, such as increased damage or windows blowing out of the building rather than into it.

Blast impulse is a measure of energy from an explosion imparted to a building. Both the negative and positive phases of the pressure-time waveform contribute to the impulse.

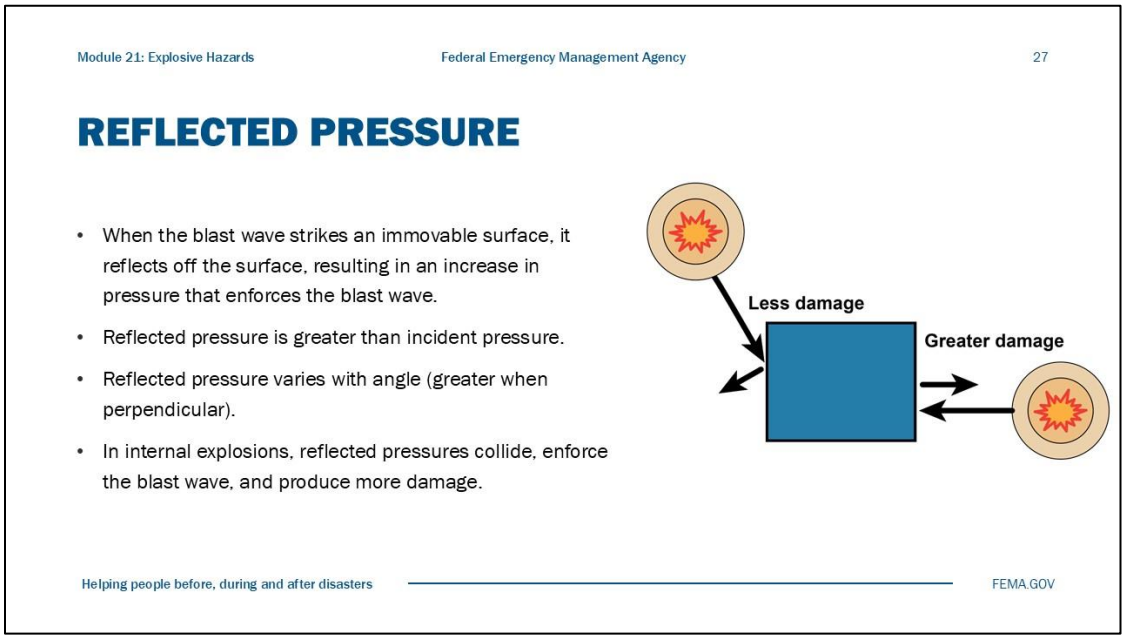
Blast Effects (6 of 11)



Slide 21-26, Positive and Negative Pressure Phases (2 of 2)

This animation depicts the positive and negative phases of a blast wave.

Blast Effects (7 of 11)



Slide 21-27, Reflected Pressure

When the incident pressure wave hits an immovable surface that is not parallel to the direction of the wave's travel, the wave reflects off the surface and is reinforced, resulting in an increase in pressure.

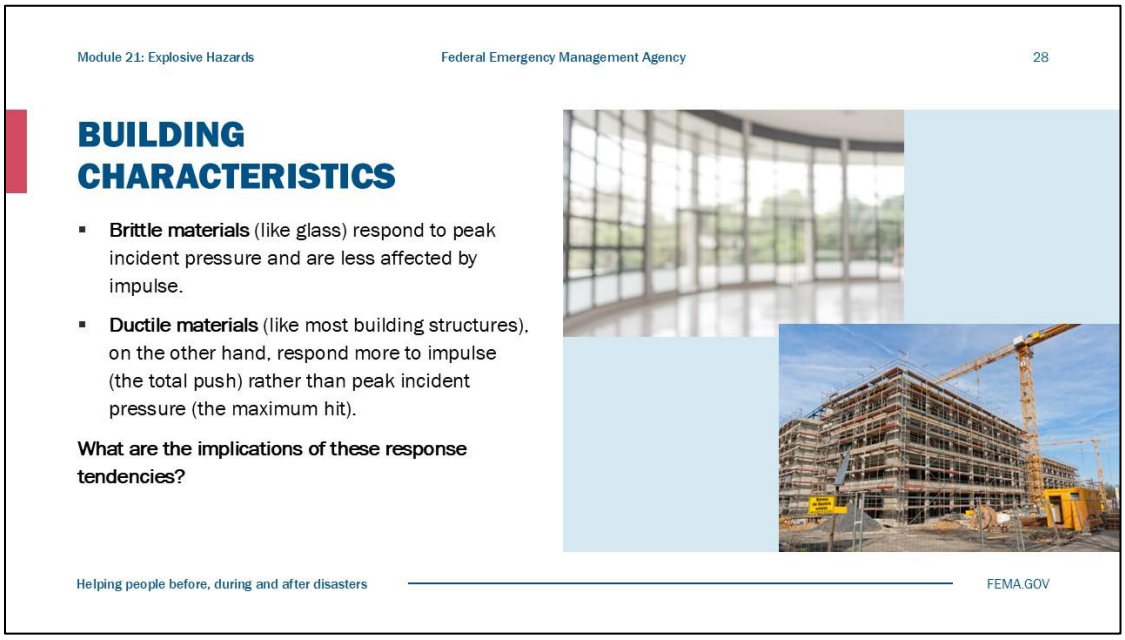
This reflected pressure damages the building. A very high reflected pressure may punch a hole in a wall or cause a column to fail, while a low reflected pressure will try to push over the whole building.

The reflected pressure is always greater than the incident pressure at the same distance from the explosion and varies with the incident angle.

The worst-case scenario occurs when the direction of travel for the blast wave is perpendicular to the surface of the structure and the incident pressure is extremely high.

In internal explosions, reflected pressures inside the structure collide, enforcing the blast wave and greatly increasing the pressure, which produces even more damage.

Blast Effects (8 of 11)

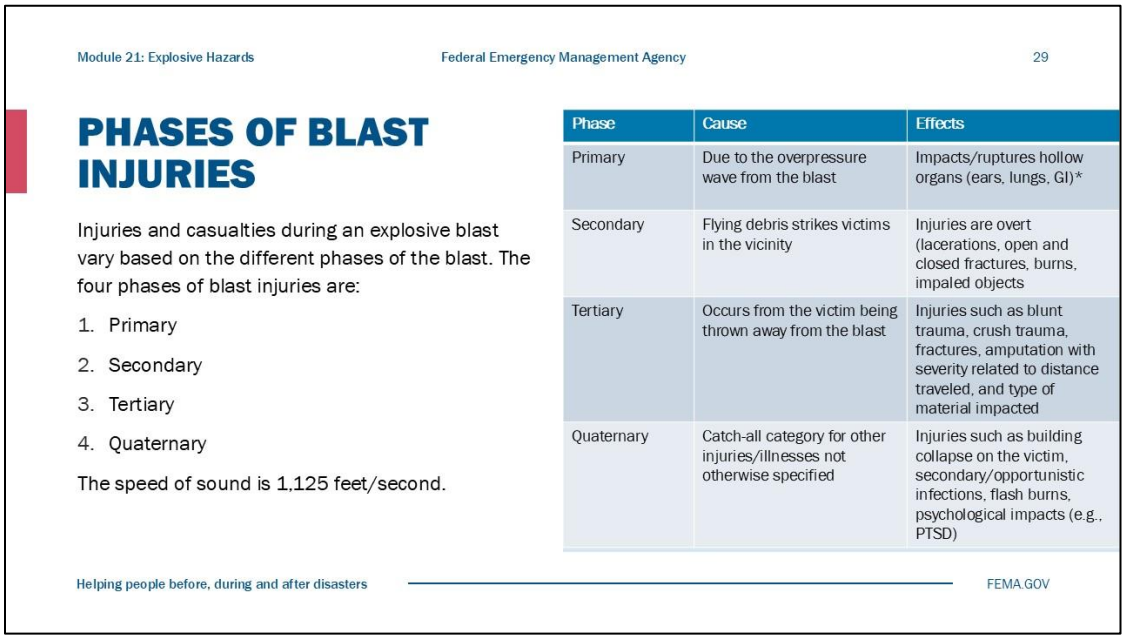


Slide 21-28, Building Characteristics

Building characteristics relate to the exterior envelope construction (walls and windows) and the framing or load-bearing system used.

- **Brittle materials** (like glass) respond to peak incident pressure and are less affected by impulse.
- **Ductile materials** (like most building structures), on the other hand, respond more to impulse (the total push) rather than peak incident pressure (the maximum hit).

Blast Effects (9 of 11)



Slide 21-29, Phases of Blast Injuries

A blast injury is a complex type of physical trauma resulting from direct or indirect exposure to an explosion. Blast injuries occur with the detonation of high-order explosives as well as the deflagration of low-order explosives. These injuries are compounded when the explosion occurs in a confined space.

Injuries and casualties during an explosive blast vary based on the different phases of the blast. The four phases of blast injuries are:

1. Primary
2. Secondary
3. Tertiary
4. Quaternary

The speed of sound is 1,125 feet/second.

The distance from the detonation affects the type of injuries likely to be sustained.

Primary injuries are caused by blast overpressure waves, or shock waves. These are especially likely when a person is close to an exploding munition, such as a land mine.

Overpressure causes eardrum rupture first, which is normally not lethal. Overpressure can also overdrive the lungs, causing injury or death. The relationship between pressure and impulse is very evident in lung response, where the threshold of lethality for incident pressure is:

- 102 psi for 3 milliseconds
- 23 psi for 18.5 milliseconds

Thermal and blast injuries include burns and injuries sustained when the blast wave picks up and throws a person against a surface or object (translation). The result may be blunt trauma, lacerations, and impalement from the impact.

Secondary injuries are caused by fragmentation and other objects propelled by the explosion. These injuries may affect any part of the body and sometimes result in penetrating trauma with visible bleeding. At times, the propelled object may become embedded in the body, obstructing the loss of blood to the outside. However, there may be extensive blood loss within the body cavities.

Fragmentation from any source can result in blunt trauma, impact, penetration, or laceration injuries.

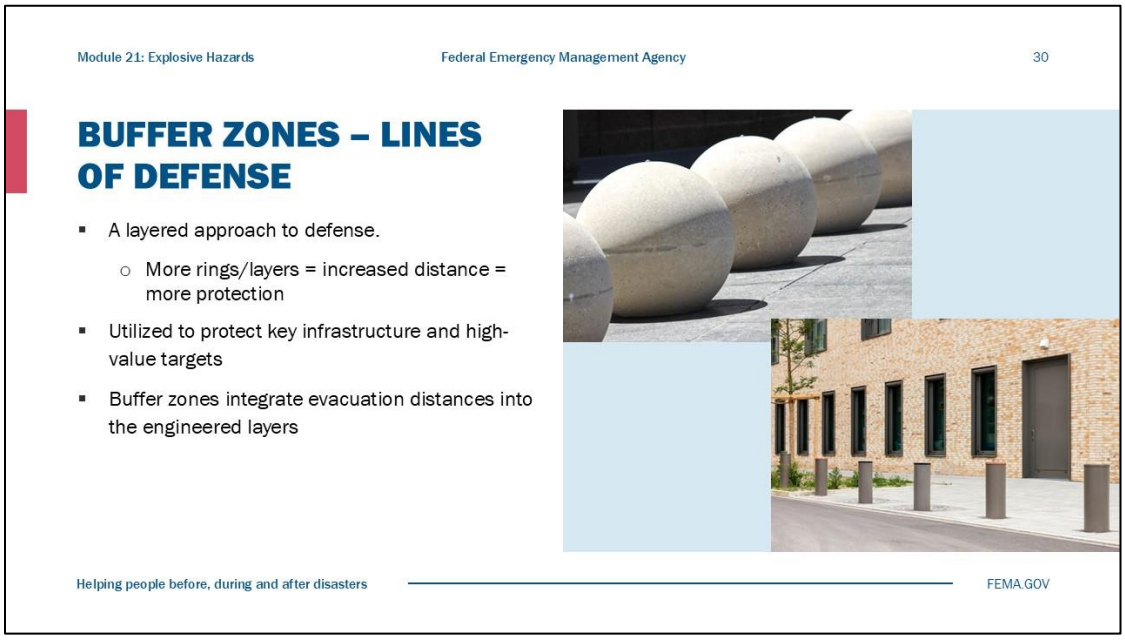
- More than 80 percent of all injuries from explosive blasts can be attributed to lacerations caused by broken glass. The fragments can come from around the bomb or from the bomb container (e.g., parts of the vehicle used in a car bomb, or shrapnel incorporated into the bomb).
- Objects can be picked up either intact or damaged by the blast wave as they travel along (e.g., street furniture or jersey barriers).
- Building component failure also causes material fragments with sufficient velocity to injure or kill. When portions of a building collapse, people commonly suffer crushing or falling injuries.

Displacement of air by the explosion creates a blast wind that can throw victims against solid objects. Injuries resulting from this type of traumatic impact are referred to as tertiary blast injuries. Tertiary injuries may present as some combination of blunt and penetrating trauma, including bone fractures and coup-contrecoup injuries. Children are at a particularly higher risk of tertiary injury due to their relatively smaller body weight.

- The quaternary phase is a catch-all category for other injuries/illnesses not otherwise specified:
  - Building collapse on the victim
  - Secondary/opportunistic infections
  - Flash burns
  - Psychological impacts (e.g., neurological damage or PTSD)


Damage Radii
Fragment Injuries
Blast Injuries
Thermal Injuries
Fragments can travel for several kms
INJURY MECHANISM DEPENDS ON RANGE FROM DETONATION

Blast Effects (10 of 11)



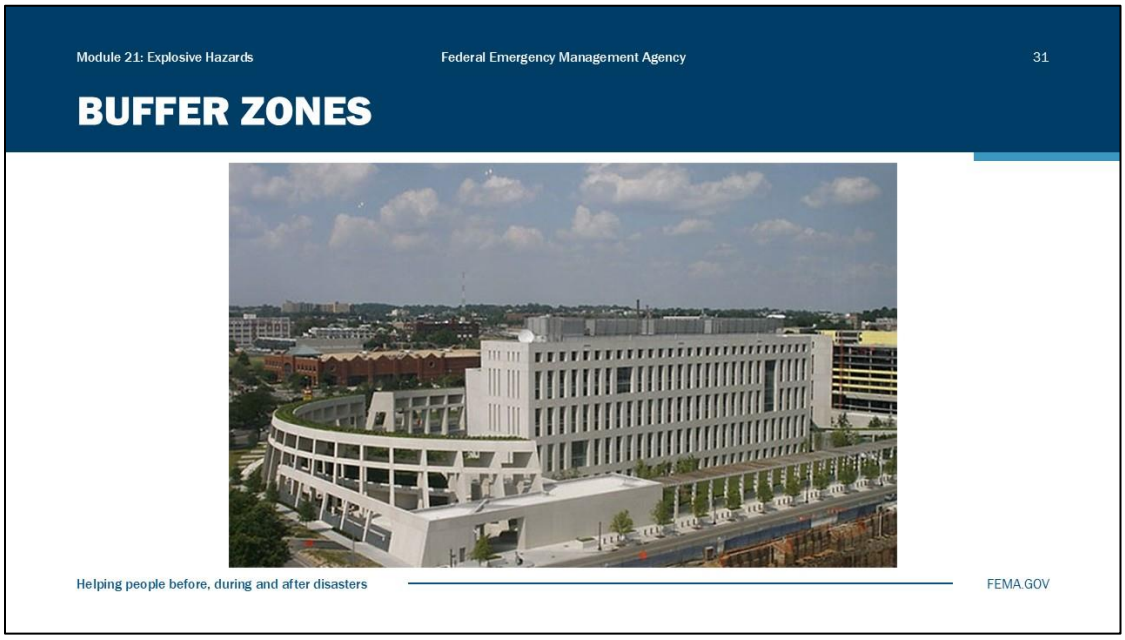
Slide 21-30, Buffer Zones – Lines of Defense

- A layered approach to defense.
  - More rings/layers = increased distance = more protection
- Utilized to protect key infrastructure and high-value targets
- Buffer zones integrate evacuation distances into the engineered layers

Buffer zones are engineered protective rings that aid in the prevention of successful bombings. In theory, buffer zones incorporate a ring of engineered protection, often bollards, to force explosive materials away from the primary target at a distance that minimizes the impact.

(*DHS-DOJ Bomb Threat Stand-Off Card* | *CISA*, n.d.) (https://www.cisa.gov/resources-tools/resources/dhs-doj-bomb-threat-stand-card)

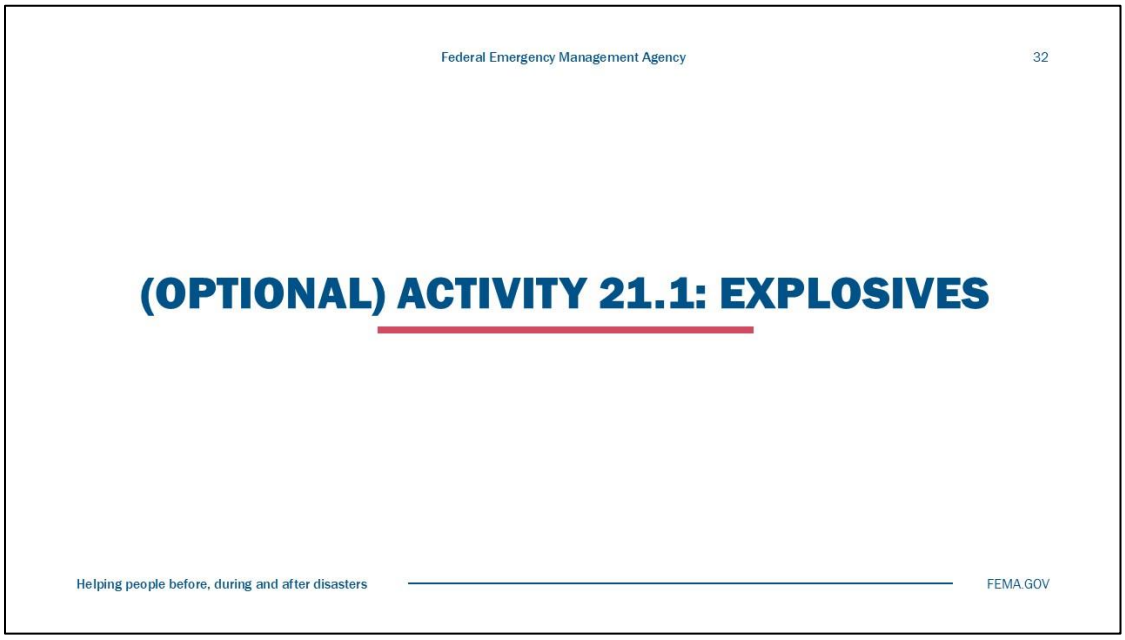
Blast Effects (11 of 11)



Slide 21-31, Buffer Zones

The visual shows a photograph of the Bureau of Alcohol, Tobacco, Firearms, and Explosives' headquarters. Identify the multiple buffer zones, both overt and disguised, in engineering.

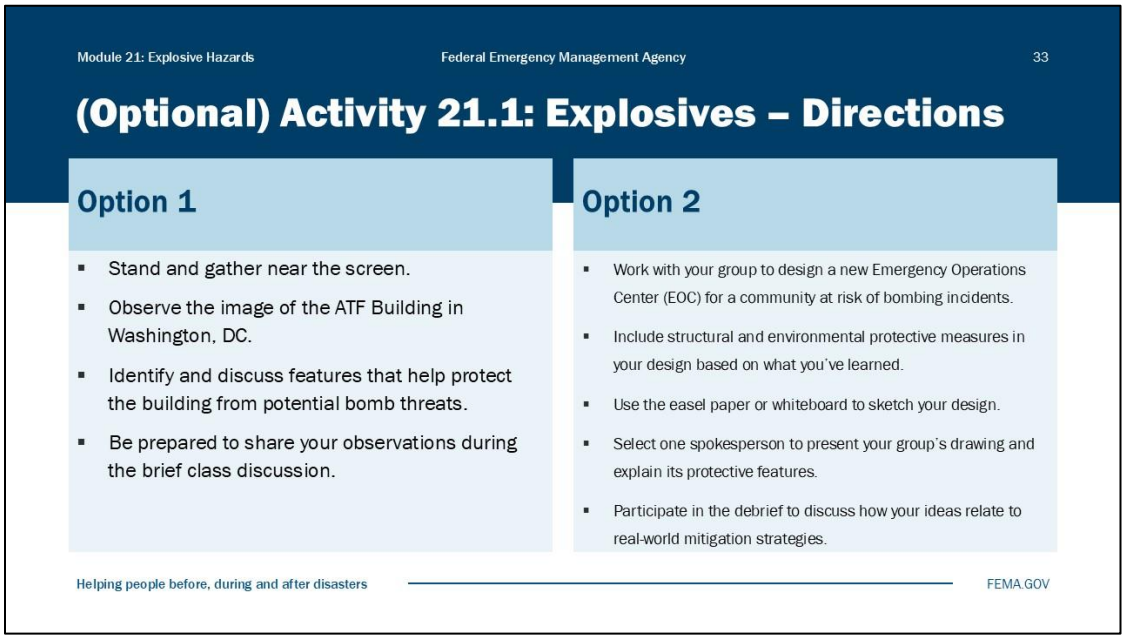
(Optional) Activity 21.1: Explosives (1 of 2)



Slide 20-32, (Optional) Activity 21.1: Explosives

Not Applicable.

(Optional) Activity 21.1: Explosives (2 of 2)



Slide 20-33, (Optional) Activity 21.1: Explosives – Directions

(Optional) Activity 21.1: Explosives – Directions to Students

Purpose

The purpose of this activity is to reinforce awareness of structural and environmental protective measures used to mitigate the impacts of explosive incidents. It provides an opportunity for participants to apply key concepts in a relaxed, interactive setting near the end of the course.

Directions to Student

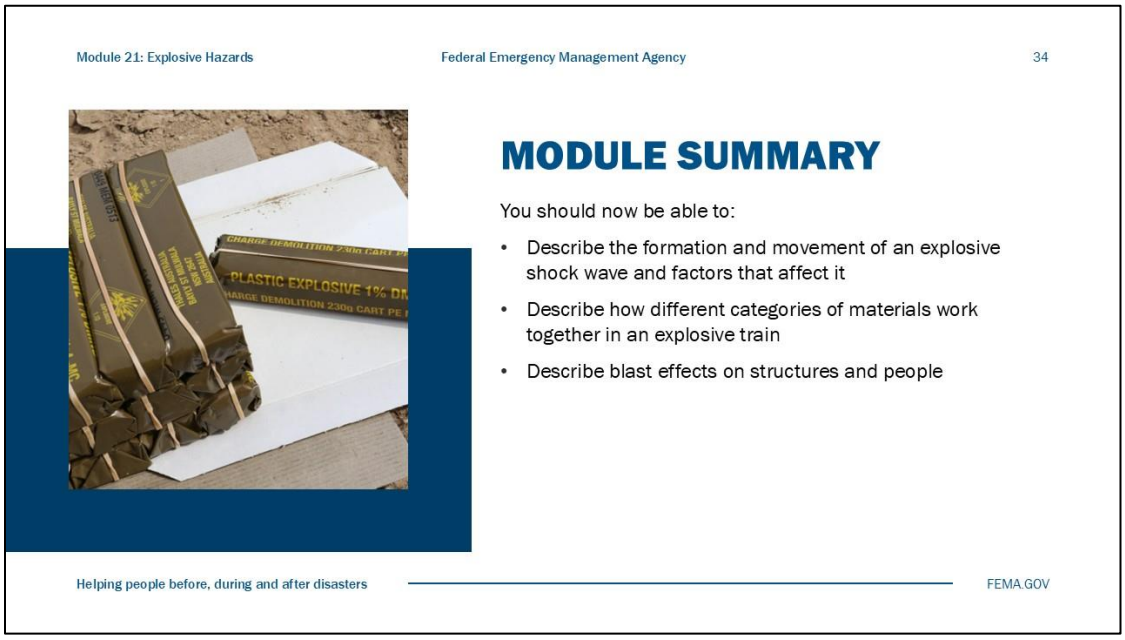
Option 1 – Short Exercise

1. Stand and gather near the screen.
2. Observe the image of the ATF Building in Washington, DC.
3. Identify and discuss features that help protect the building from potential bomb threats.
4. Be prepared to share your observations during the brief class discussion.

Option 2 – Longer Exercise

1. Work with your group to design a new Emergency Operations Center (EOC) for a community at risk of bombing incidents.
2. Include structural and environmental protective measures in your design based on what you've learned.
3. Use the easel paper or whiteboard to sketch your design.
4. Select one spokesperson to present your group's drawing and explain its protective features.
5. Participate in the debrief to discuss how your ideas relate to real-world mitigation strategies.

End of Module (1 of 2)



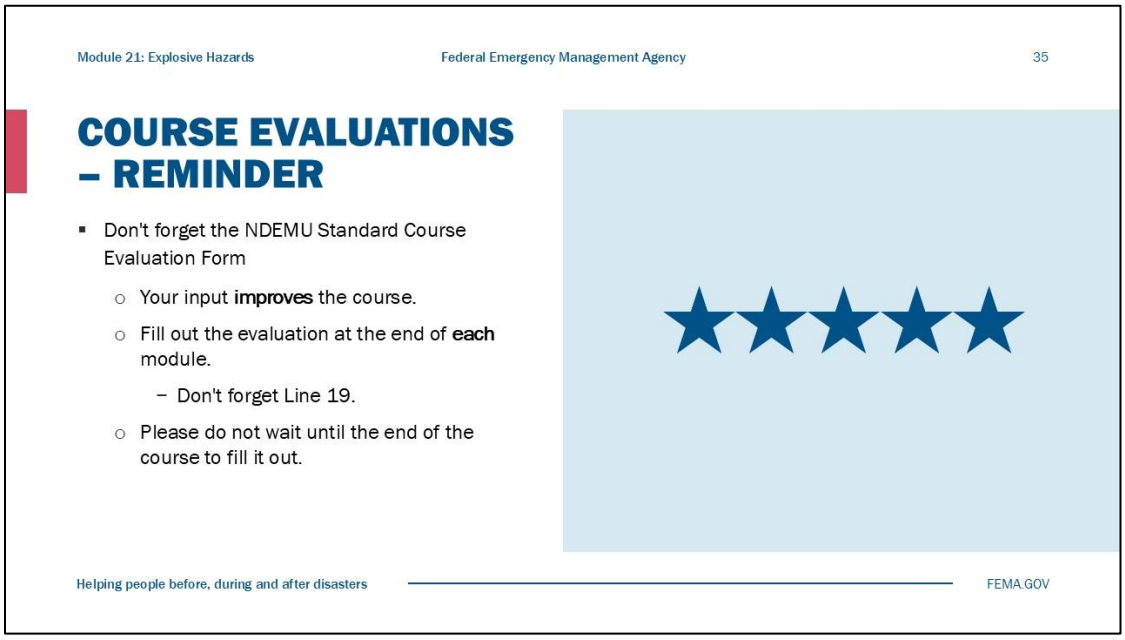
Slide 21-34, Module Summary

You should now be able to:

- Describe the formation and movement of an explosive shock wave and factors that affect it.
- Describe how different categories of materials work together in an explosive train.
- Describe blast effects on structures and people.

Do you have any questions about the content covered in this module?

End of Module (2 of 2)



Slide 21-35, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

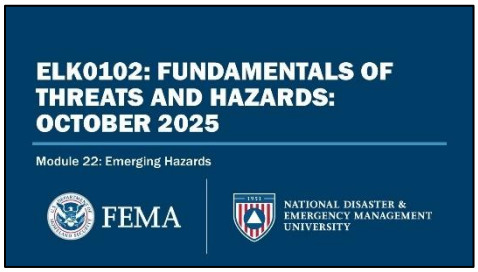
Reference List

DHS-DOJ Bomb Threat Stand-Off Card | *CISA*. (n.d.). Retrieved April 8, 2025, from https://www.cisa.gov/resources-tools/resources/dhs-doj-bomb-threat-stand-card

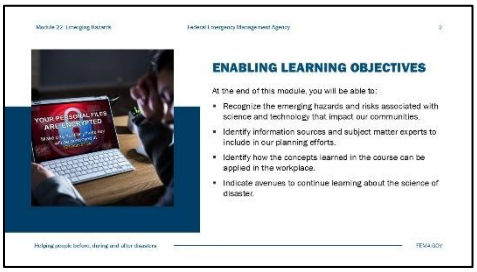
Module 22

Emerging Hazards

Administration



Slide 22-1, Module 22: Emerging Hazards



Slide 22-2, Enabling Learning Objectives

Duration

40 minutes

Terminal Learning Objective (TLO)

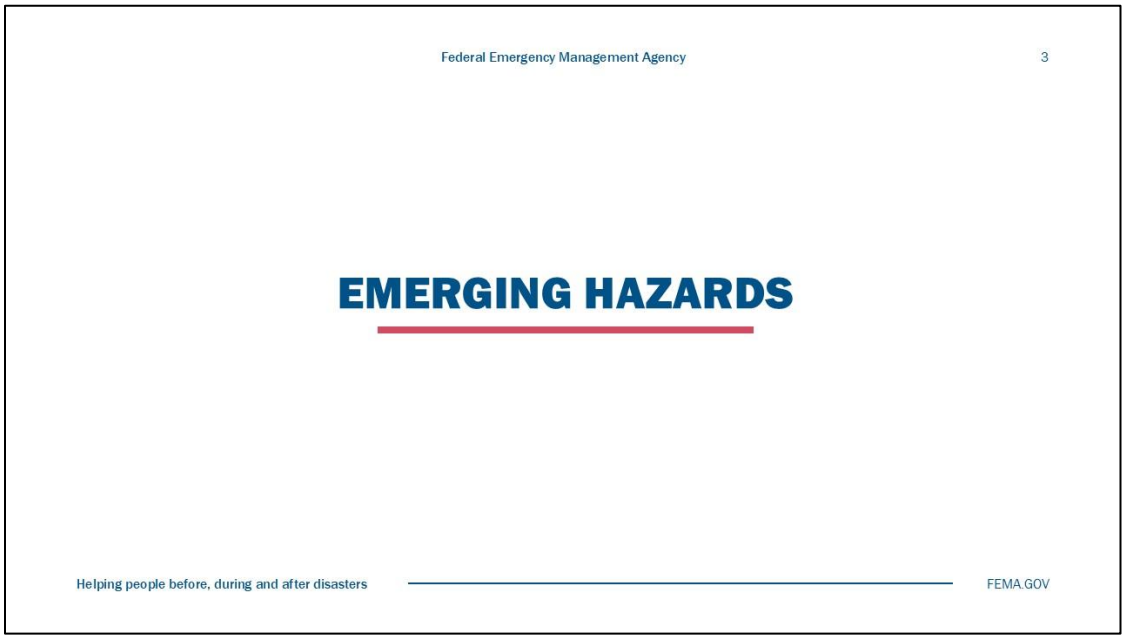
By the end of this module, participants will be able to analyze emerging hazards and threats, including advancements in technology, space weather phenomena, intentional cyber and physical acts, and evolving environmental risks, and integrate this knowledge into emergency management planning and professional development.

Enabling Learning Objectives (ELOs)

By the end of this module, participants will be able to:

- Recognize the emerging hazards and risks associated with science and technology that impact our communities.
- Identify information sources and subject matter experts to include in our planning efforts.
- Identify how the concepts learned in the course can be applied in the workplace.
- Indicate avenues to continue learning about the science of disaster.

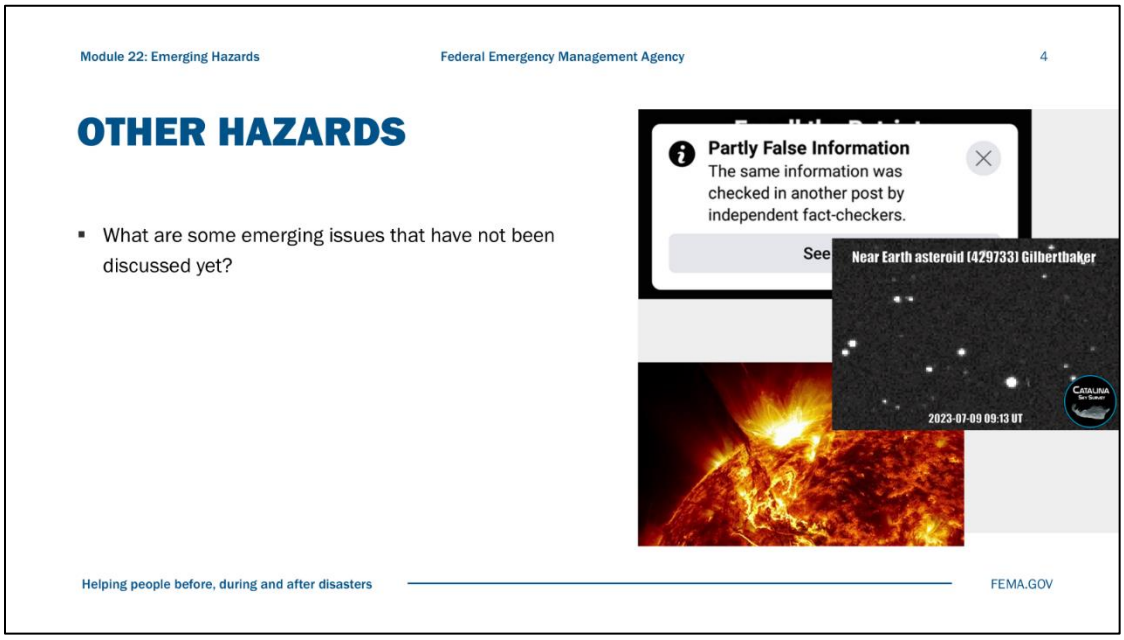
Emerging Hazards (1 of 3)



Slide 22-3, Activity 22.1 – Emerging Hazards

Not Applicable.

Emerging Hazards (2 of 3)



Slide 22-4, Other Hazards

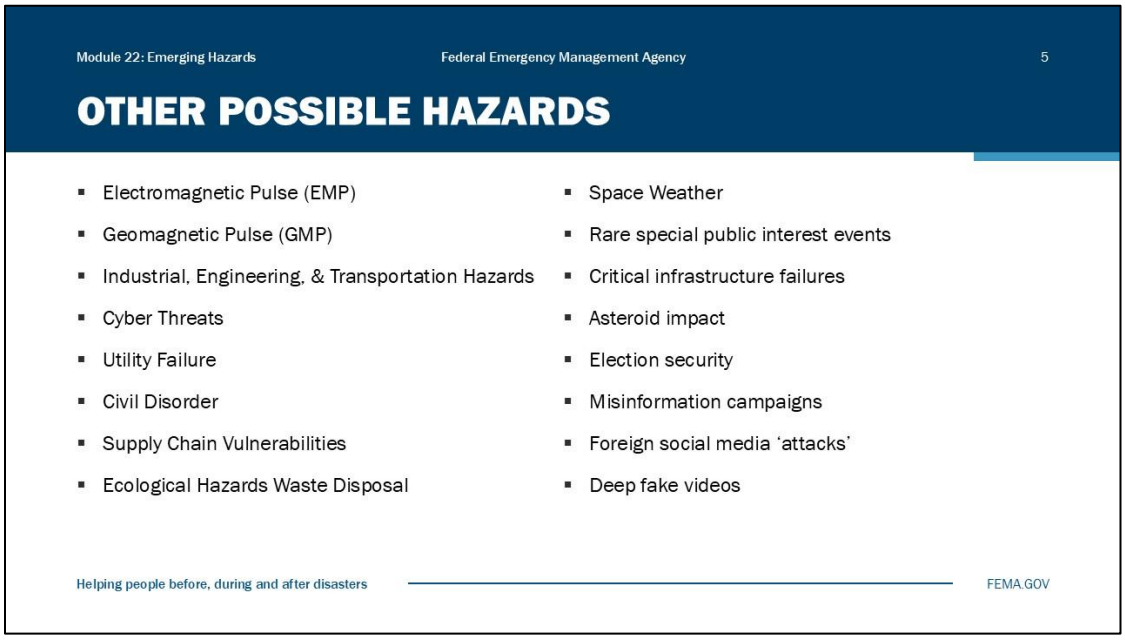
What are some emerging issues that have not been discussed yet?

Beyond class, this is a question for you to consider as you begin your risk analysis at home.

In the 103 course, we will talk about hazard/threat risk analysis in the THIRA format, asking the questions:

- What emerging threats and hazards can affect our community?
- If they occur, what impacts would those threats and hazards have on our community?
- Based on those impacts, what capabilities should our community have?

Emerging Hazards (3 of 3)

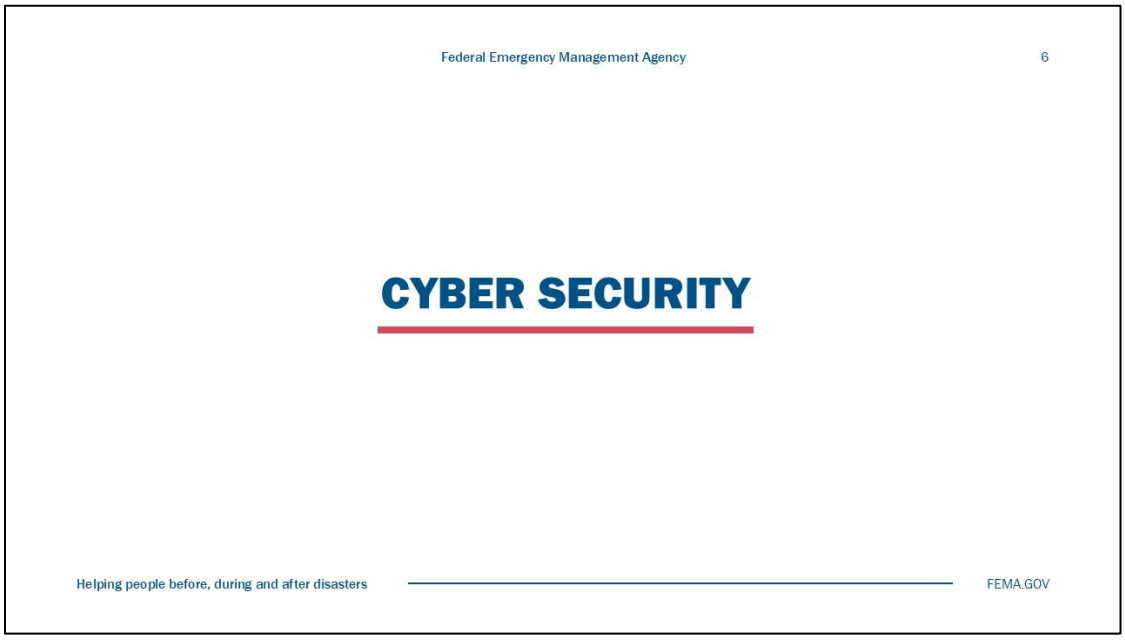


Slide 22-5, Other Possible Hazards

- Electromagnetic Pulse (EMP)
- Geomagnetic Pulse (GMP)
- Industrial, Engineering, & Transportation Hazards
- Cyber Threats
- Utility Failure
- Civil Disorder
- Supply Chain Vulnerabilities
- Ecological Hazards Waste Disposal
- Space Weather
- Rare special public interest events, like the eclipse, Chinese balloon, etc.
- Critical infrastructure failures like the Key Bridge and the East Palestine rail accident
- Asteroid impact
- Election security
- Misinformation campaigns

- Foreign social media ‘attacks,’
- Deep fake videos.

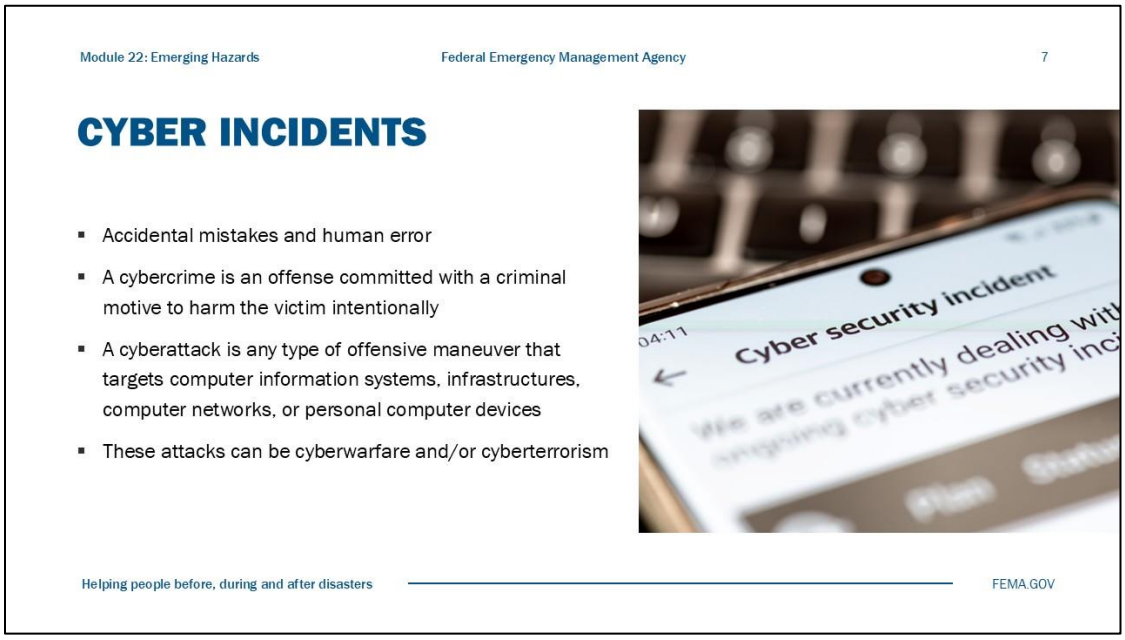
Cyber Security (1 of 3)



Slide 22-6, Cyber Security

Not Applicable.

Cyber Security (2 of 3)



Slide 22-7, Cyber Incidents

Cyber Incidents

- These can be caused by mistakes and human errors.
- A cybercrime is an offense committed with a criminal motive intended to harm the victim.
- A cyberattack refers to any offensive action aimed at computer information systems, infrastructures, computer networks, or personal computer devices. These attacks can involve cyberwarfare and/or cyberterrorism.

Cybercrimes

A cybercrime is an offense committed against individuals or groups with a criminal motive to intentionally harm the reputation of the victim or cause physical or mental harm, or loss, to the victim directly or indirectly, using modern telecommunication networks such as Internet (e.g., chat rooms, emails, notice boards, groups) and mobile phones.

Cybercrime can pose a significant threat to a person's or a nation's security and financial well-being. Includes actions such as:

- Hacking
- Copyright infringement

- Unwarranted mass-surveillance
- Sextortion
- Child pornography
- Child grooming

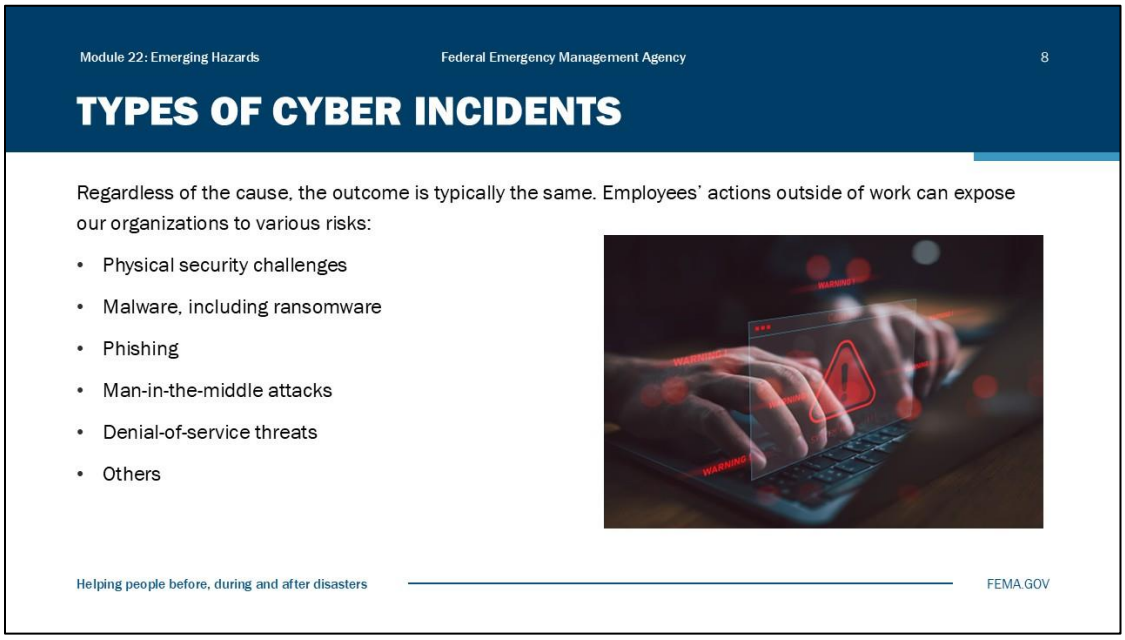
Cyberattacks

A cyberattack can be employed by sovereign states, individuals, groups, society, or organizations and may originate from an anonymous source.

Depending on context, cyberattacks can be:

- **Cyberwarfare**: the use of technology to attack a nation, causing harm comparable to actual warfare.
- **Cyberterrorism**: the use of the internet to conduct violent acts that result in, or threaten, loss of life or significant bodily harm to achieve political or ideological gains through threat or intimidation.

Cyber Security (3 of 3)



Slide 22-8, Types of Cyber Incidents

Regardless of the cause, the outcome is typically the same. Employees' actions outside of work can expose our organizations to various risks:

- Physical security challenges
- Malware, including ransomware
- Phishing
- Man-in-the-middle attacks
- Denial-of-service threats
- Others

Common types of cyberattacks:

Malware

Malware refers to malicious software such as spyware, ransomware, viruses, and worms. It breaches a network through vulnerabilities, typically when a user clicks a harmful link or opens a dangerous email attachment, which installs risky software. Once inside the system, malware can perform the following actions:

- Block access to key components of the network (ransomware).

- Install additional harmful software or malware.
- Covertly obtain information by transmitting data from the hard drive (spyware).
- Disrupt certain components and render the system inoperable.

Phishing

Phishing is the practice of sending fraudulent communications that appear to originate from a legitimate and reputable source, typically via email and text messaging. The attacker's goal is to steal money, gain access to sensitive data and login information, or to install malware on the victim's device. Phishing is a dangerous, damaging, and increasingly common type of cyberattack.

Man-in-the-middle attack

Man-in-the-middle (MitM) attacks, also known as eavesdropping attacks, occur when attackers insert themselves into a two-party communication. Once the attackers intercept the traffic, they can filter and steal data. Two common points of entry for MitM attacks are:

1. On insecure public Wi-Fi, attackers can insert themselves between a visitor’s device and the network. Without knowing, the visitor passes all information through the attacker.
2. Once malware has breached a device, an attacker can install software to process all of the victim’s information.

Denial-of-service attack

A denial-of-service attack floods systems, servers, or networks with traffic to exhaust resources and bandwidth. As a result, the system is unable to fulfill legitimate requests. Attackers can also use multiple compromised devices to launch this attack. This is known as a distributed denial-of-service (DDoS) attack.

SQL injection

A Structured Query Language (SQL) injection occurs when an attacker inserts malicious code into a server using SQL, compelling the server to disclose information it would not typically reveal. An attacker can execute an SQL injection by entering and submitting malicious code into a vulnerable website's search box.

Learn how to defend against SQL injection attacks. Source: Cisco - SQL injection attacks (https://tools.cisco.com/security/center/resources/sql_injection.html).

Zero-day exploit

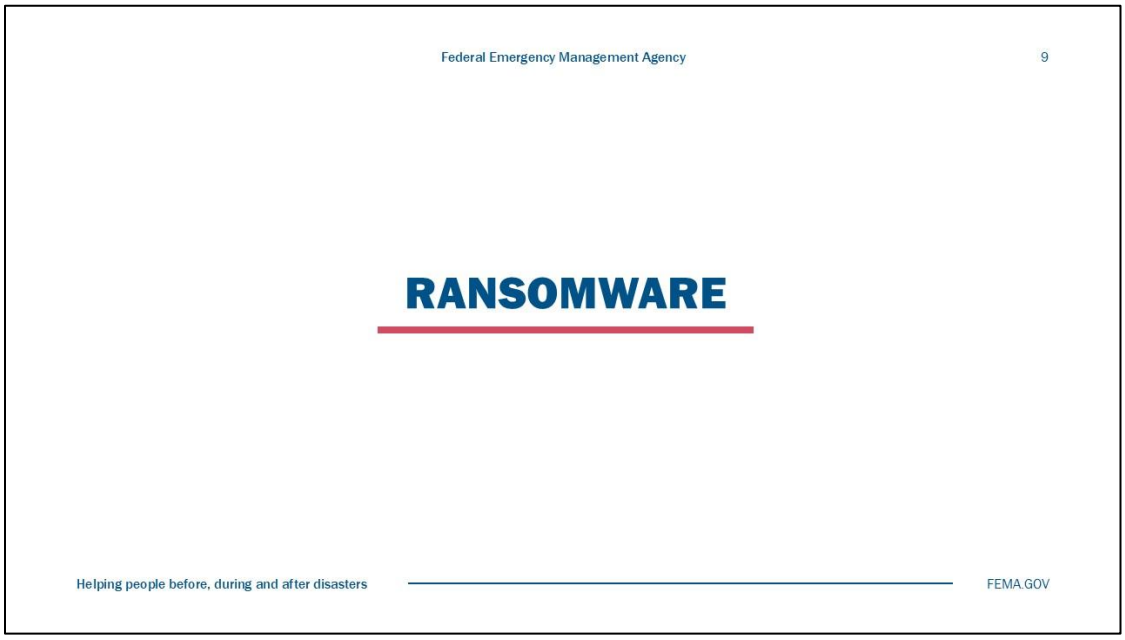
A zero-day exploit hits after a network vulnerability is announced but before a patch or solution is implemented. Attackers target the disclosed vulnerability during this time frame. Zero-day vulnerability threat detection requires constant awareness. (*Vulnerability Reports - Latest Network Security Threats and Zeroday Discoveries || Cisco Talos Intelligence Group - Comprehensive Threat Intelligence*, n.d.)

DNS Tunneling

DNS tunneling utilizes the DNS protocol to communicate non-DNS traffic over port 53. It sends HTTP and other protocol traffic over DNS. There are various legitimate reasons to utilize DNS tunneling. However, there are also malicious reasons to use DNS Tunneling VPN services. They can be used to disguise outbound traffic as DNS, concealing data that is typically shared through an internet connection. For malicious use, DNS requests are manipulated to exfiltrate data from a compromised system to the attacker's infrastructure. It can also be used for command and control callbacks from the attacker's infrastructure to a compromised system.

To learn more about DNS Tunneling, visit Cisco - DNS Tunneling (https://learn-umbrella.cisco.com/solution-briefs/dns-tunneling)

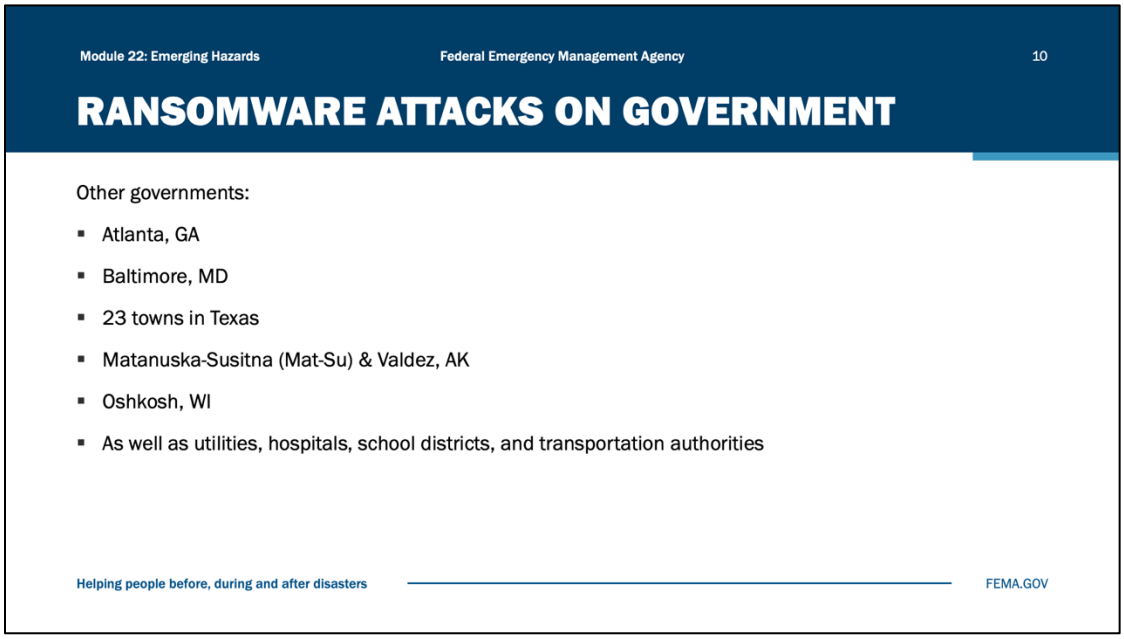
Ransomware (1 of 4)



Slide 22-9, Ransomware

Not Applicable.

Ransomware (2 of 4)



Slide 22-10, Ransomware Attacks on Government

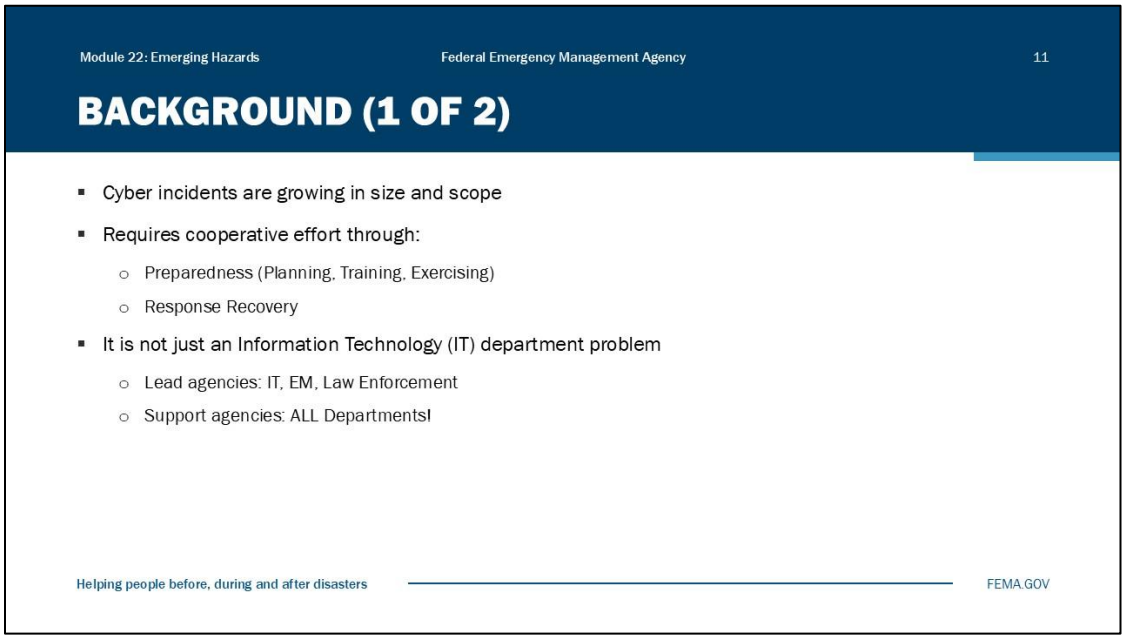
Ransomware Attacks on Government

Other governments:

- Atlanta, GA
- Baltimore, MD
- 23 towns in Texas
- Matanuska-Susitna (Mat-Su) & Valdez, AK
- Oshkosh, WI
- As well as utilities, hospitals, school districts, and transportation authorities

Video: Why ransomware attacks target local governments like Atlanta. (https://www.pbs.org/video/city-held-for-ransom-1522442171).

Ransomware (3 of 4)



Slide 22-11, Background (1 of 2)

How often do cyberattacks occur?

Cyberattacks hit businesses every day. Former Cisco CEO John Chambers once said, "There are two types of companies: those that have been hacked, and those who don't yet know they have been hacked." According to the Wold Economic Forum (WEF) (*What Does the Internet of Everything Mean for Security?*, 2015) (https://www.weforum.org/stories/2015/01/companies-fighting-cyber-crime/), the total volume of events has increased almost fourfold between January 2016 and October 2017.

Why do people launch cyberattacks?

Cybercrime has increased annually as individuals seek to exploit exposed business systems. Attackers often seek ransom: 53 percent of cyberattacks resulted in damages of $500,000 or more.

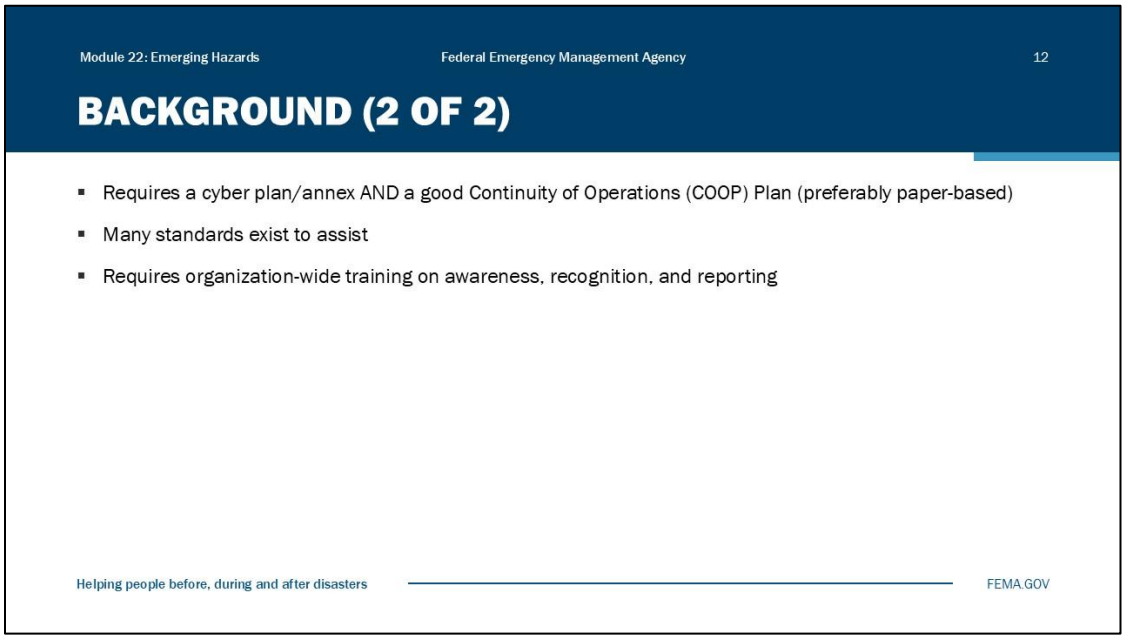
Cyber threats can also be launched with hidden motives. Some attackers aim to destroy systems and data as a form of "hacktivism."

What is a botnet?

A botnet is a network of devices that have been infected with malicious software, such as a virus [Source: Cisco - virus differences (https://tools.cisco.com/security/center/resources/virus_differences). Attackers can control a botnet as a group without the owner's knowledge with the goal of increasing the magnitude of their

attacks. Often, a botnet is used to overwhelm systems in a DDoS attack (www.cisco.com/c/en/us/products/security/what-is-a-ddos-attack.html).

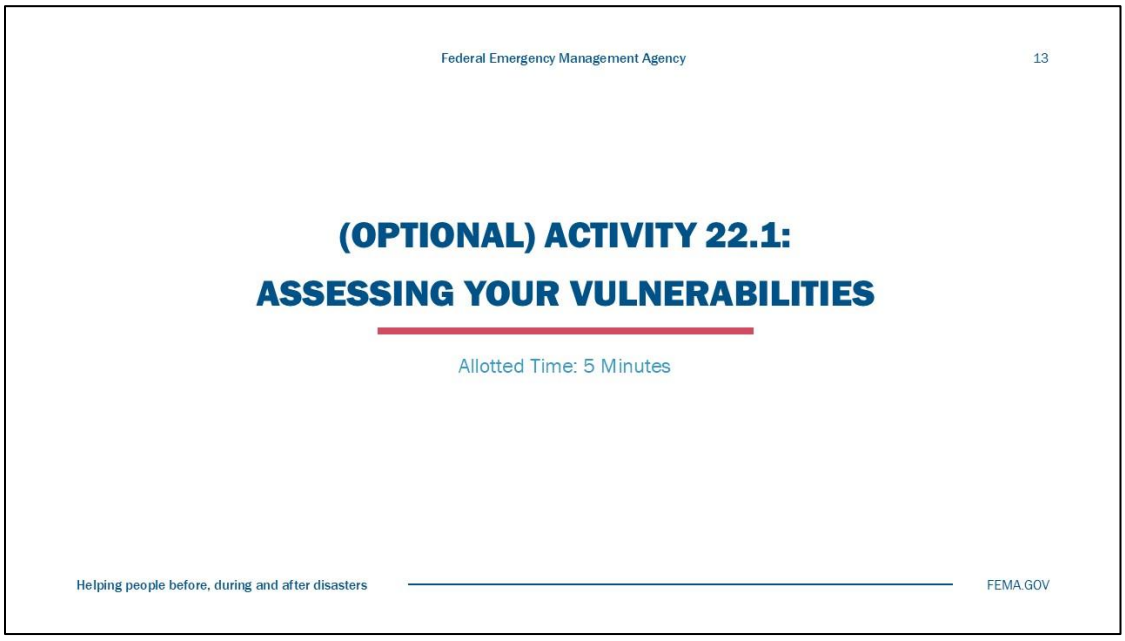
Ransomware (4 of 4)



Slide 22-12, Background (2 of 2)

- Requires a cyber plan or annex **and** a solid Continuity of Operations (COOP) Plan (preferably paper-based).
- Many standards are available to assist.
- Requires organization-wide training on awareness, recognition, and reporting.

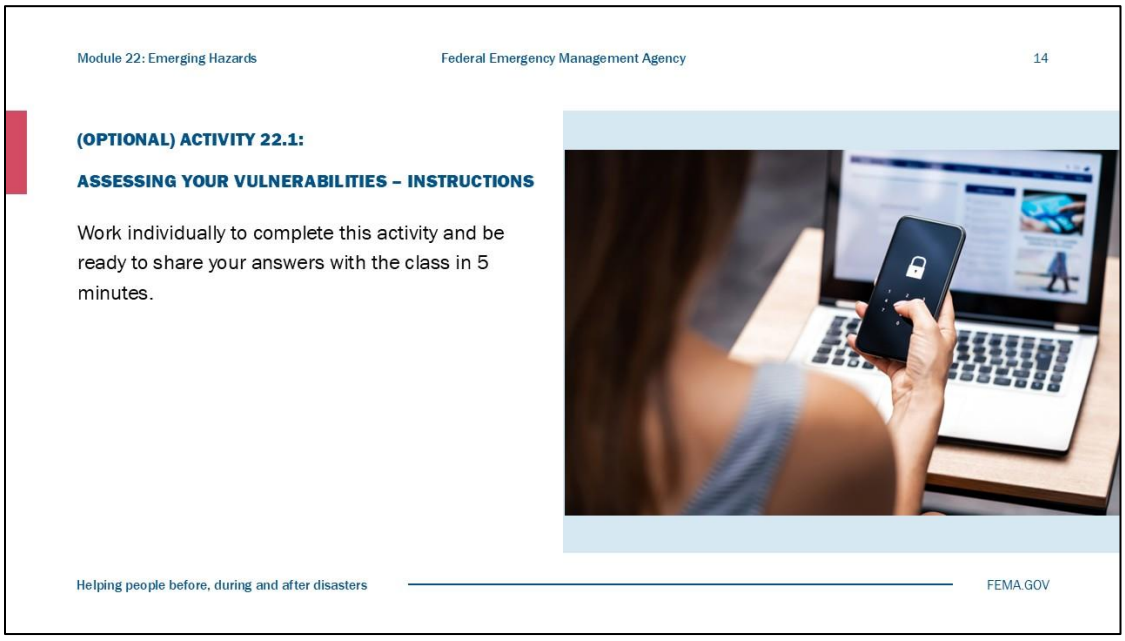
Optional Activity 22.1: Assessing Your Vulnerabilities (1 of 2)



Slide 22-13, (Optional) Activity 22.1: Optional Assessing Your Vulnerabilities (1 of 2)

Not Applicable.

Optional Activity 22.1: Assessing Your Vulnerabilities (2 of 2)



Slide 22-14, Optional Activity 22.1: Assessing Your Vulnerabilities Instructions

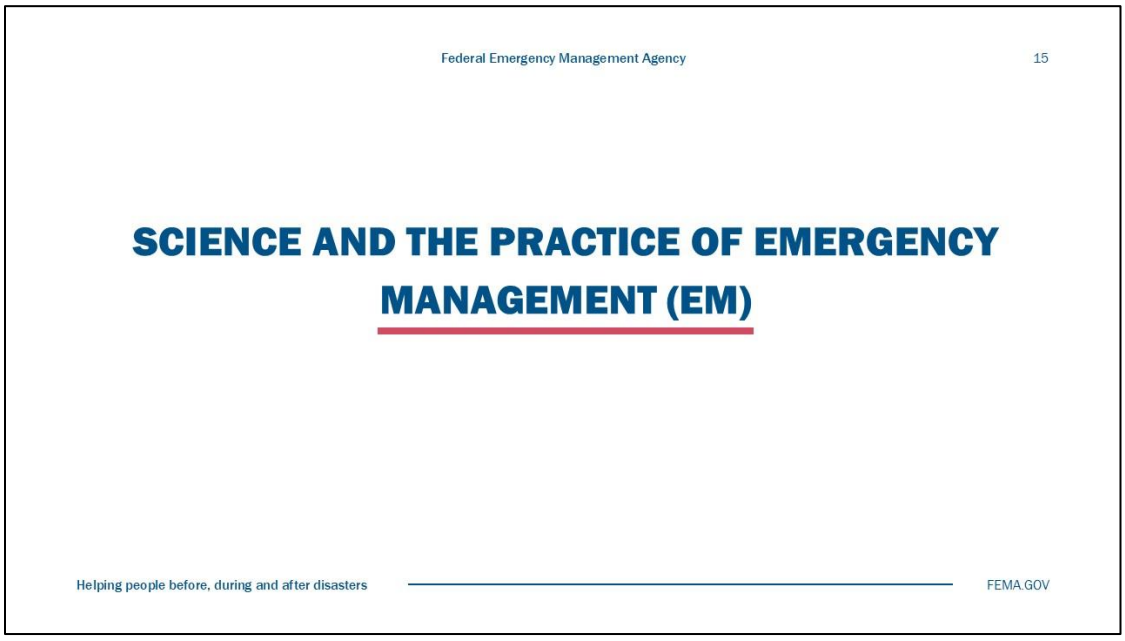
Optional Activity 22.1: Assessing Your Vulnerabilities – Directions to Students

Purpose

The purpose of this activity is to assess personal vulnerabilities online by evaluating your exposure through services such as Have I Been Pwned and Google, as well as identifying any personal or professional information that may be available.

1. Be prepared to share your findings with the class in 5 minutes.
2. Go to Have I Been Pwned and enter one or more of your work or personal email addresses. Review the results and see if any of your email addresses have been compromised. What did you find? Record the results.
3. Google yourself and assess whether there is any public information linking you to your organization. Is there any personal information that could be exposed or misused?

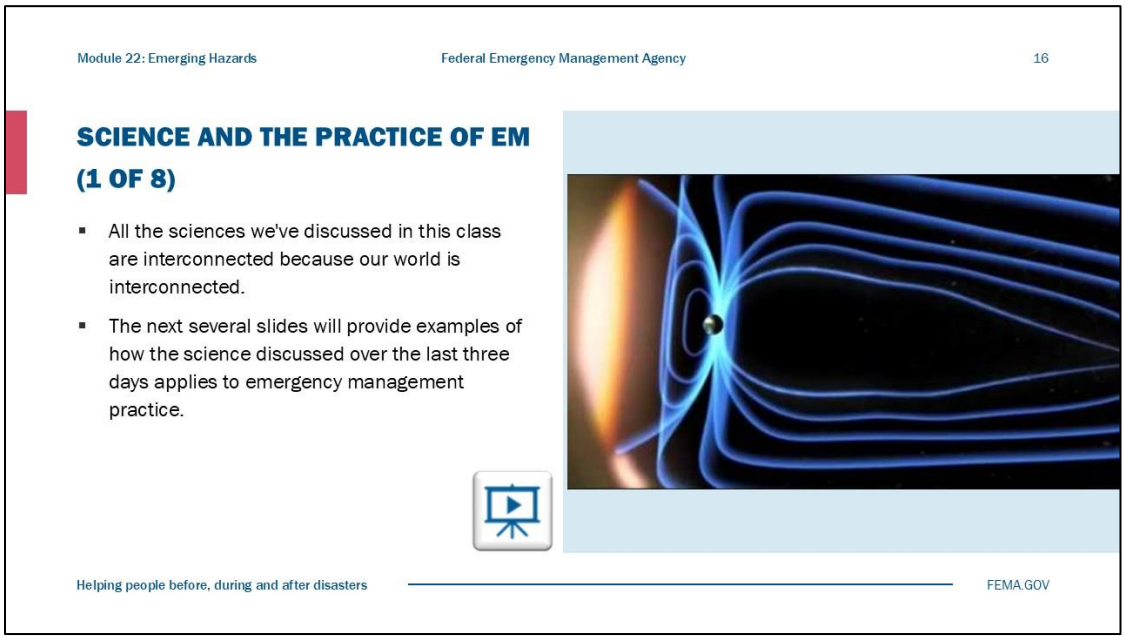
Science and the Practice of Emergency Management (EM) (1 of 9)



Slide 22-15, Science and the Practice of Emergency Management (EM)

Not Applicable.

Science and the Practice of Emergency Management (EM) (2 of 9)



Slide 22-16, Science and the Practice of EM (1 of 8)

- All the sciences we've discussed in this class are interconnected because our world is interconnected.
- The next several slides will provide examples of how the science discussed over the last three days applies to emergency management practice.
  - Electricity and magnetism are interrelated.
  - Moving electric charges generate magnetic fields.
  - Changing magnetic fields induce movement in charges.

Earth's Magnetic Shield Video: Earth's Magnetic Shield (https://www.youtube.com/watch?v=URN-XyZD2vQ)

Earth's Magnetic Shield Video Transcript

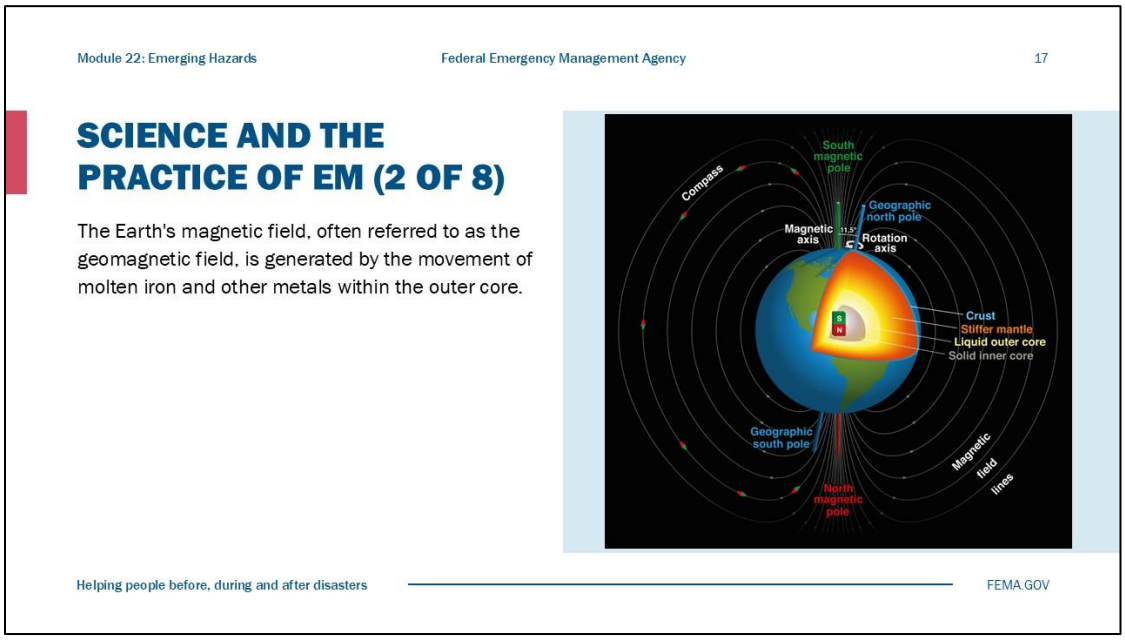
Our sun is constantly blasting huge amounts of hot plasma out into space. All those charged particles have a big effect on everything in their path. So, what's protecting Earth from the solar wind and solar storms? Earth's thick atmosphere provides some defense, scattering and absorbing solar particles before they reach the surface.

But our planet also has a secret weapon: a strong magnetic field it projects into space, mostly generated by molten iron alloys moving in Earth's outer core. The area of space where the magnetic field interacts with the solar wind is called Earth's magnetosphere. Its shape constantly changes as it's bombarded by solar particles. As positively charged protons and negatively charged electrons enter the magnetosphere, most of them are deflected around Earth long before they reach the atmosphere.

The magnetosphere really gets tested when big solar storms, carrying more plasma and traveling at higher speeds, are on a collision course with Earth. While most of the plasma is deflected, some of it gets trapped in the magnetosphere and funnels back toward Earth along field lines emanating from the poles. As charged particles from the Sun collide with nitrogen and oxygen molecules in our atmosphere, they create the cosmic light shows known as auroras.

The bigger the storm, the further from the poles auroras can be seen. Some storms are so big they interfere with satellites, cause planes to alter their routes, and can create other problems. The vast majority of the time, these inconveniences are pretty minor. But the next time the solar version of a perfect storm overwhelms Earth's magnetic shield, we might not be so lucky.

Science and the Practice of Emergency Management (EM) (3 of 9)



Slide 22-17, Science and the Practice of EM (2 of 8)

The Earth's magnetic field and magnetosphere play a crucial role in shielding our planet from harmful solar and cosmic radiation.

How the Earth's Outer Core Creates Its Magnetic Field

The Earth's magnetic field originates from a process called the **geodynamics**, which occurs in the fluid outer core. This layer is primarily composed of molten iron and nickel, and it moves due to heat escaping from the solid inner core. This electrically conductive liquid moves to generate electric currents, which then create magnetic fields. The fields support one another in a continuous feedback loop, helping to maintain the geomagnetic field's stability over long geological periods.

The way the solid inner core and the liquid outer core work together is really important for creating this dynamo effect. The Earth's rotation creates a Coriolis force, which helps organize these flows into spiraling patterns that play a role in the stability and structure of the magnetic field.

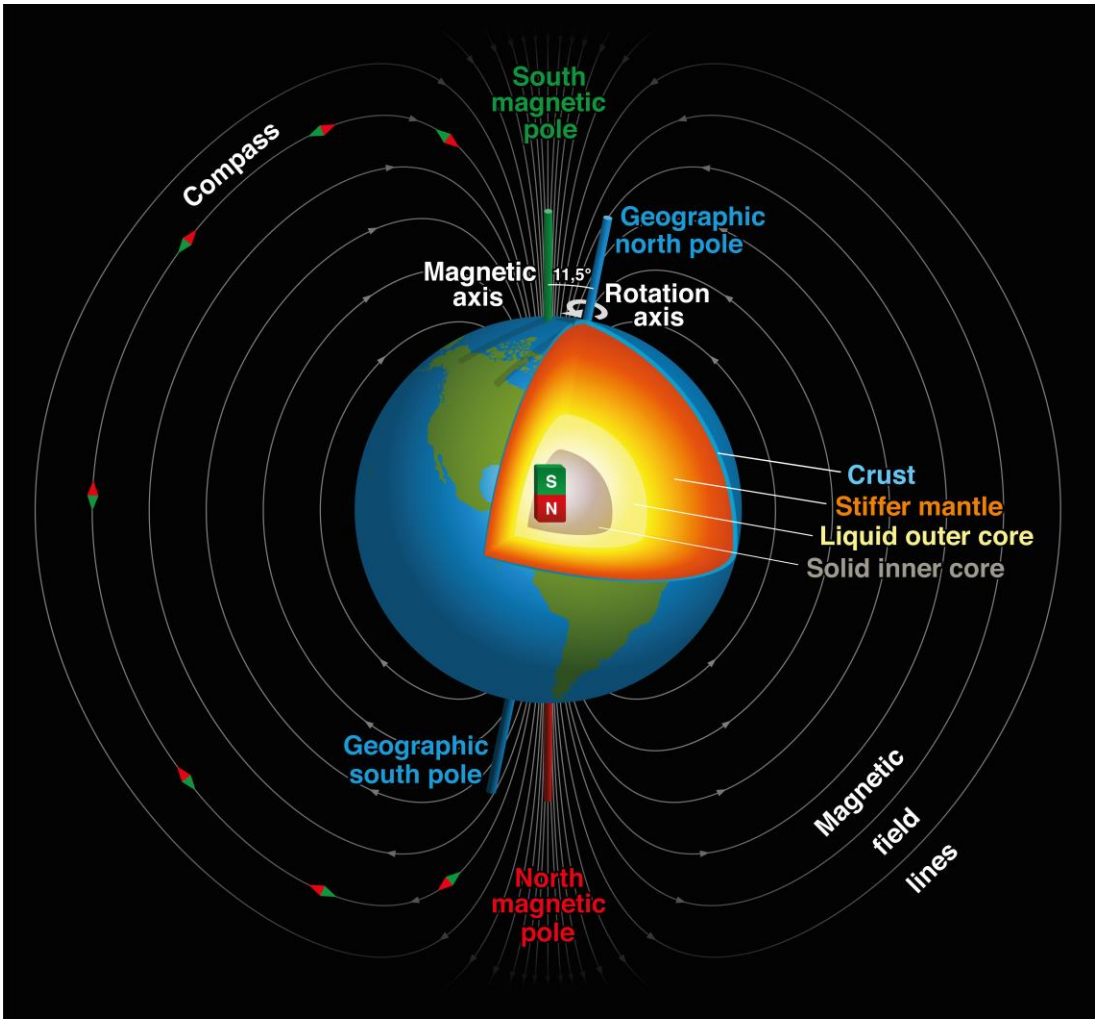


Figure 1: Earth's Magnetic Field

The Magnetosphere: Earth's Friendly Shield

The magnetic field reaches out into space, creating the magnetosphere—a zone where Earth's magnetic power takes charge instead of the magnetic fields from other planets. The magnetosphere interacts with the solar wind, a flow of charged particles emanating from the Sun. This interaction compresses the area facing the Sun (the dayside) and stretches it out into a long tail on the other side (the nightside), resembling a comet.

Protective Functions

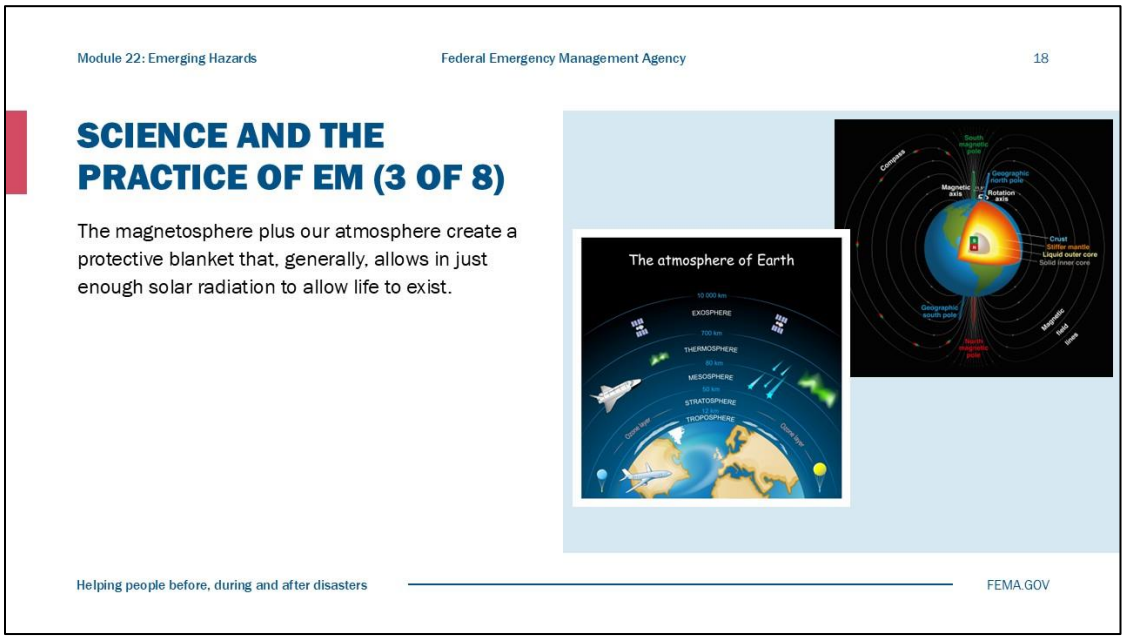
1. **Deflecting Solar Wind**: The magnetosphere serves as a protective shield, redirecting most charged particles from the solar wind. If we didn't have this shield, these particles could gradually wear away Earth's atmosphere, much like what has happened on Mars.
2. **Preventing Radiation Exposure**: It safeguards life on Earth by blocking harmful cosmic rays and solar radiation from reaching the surface.
3. **Maintaining a Stable Atmosphere**: By reducing atmospheric erosion from solar wind, it helps protect important gases such as oxygen and nitrogen.

Response to Solar Activity

When solar storms or flares occur, they emit strong bursts of charged particles and electromagnetic radiation that can impact the magnetosphere. These disturbances can create geomagnetic storms, which can result in beautiful auroras, but they might also interfere with satellites and power grids here on Earth. The magnetosphere plays a crucial role in absorbing and redistributing energy during these events, thereby mitigating their impact.

To summarize, the Earth's magnetic field and magnetosphere originate from the dynamic activities occurring in its outer core. They work together as a vital shield, keeping our planet safe from solar and cosmic dangers while ensuring the conditions we need for life are maintained.

Science and the Practice of Emergency Management (EM) (4 of 9)



Slide 22-18, Science and the Practice of EM (3 of 8)

The Earth's magnetosphere and atmosphere work together to form a protective barrier that keeps out harmful radiation while allowing beneficial light wavelengths to pass through, which are vital for life. Let's take a look at how they work together:

The Magnetosphere: Our Primary Line of Defense

The magnetosphere, created by the Earth's molten outer core, mainly protects us by deflecting charged particles from the solar wind and cosmic radiation. Here are the main functions:

- **Deflecting charged particles**: The magnetic field helps guide about 99% of solar wind particles away from Earth, which keeps our atmosphere safe and protects life on the surface.
- **Trapping radiation**: The Van Allen belts catch high-energy particles, keeping them safely away from the surface.
- **Absorbing solar storm energy**: When events like coronal mass ejections (CMEs) occur, the magnetosphere temporarily changes shape to release energy, leading to geomagnetic storms and beautiful auroras, which helps mitigate any harm to the atmosphere.

If we didn't have this shield, Earth's atmosphere would gradually wear away, just like what happened on Mars.

Atmosphere: Filtering and Blocking

The atmosphere works together with the magnetosphere by:

1. **Blocking harmful electromagnetic radiation**:
    a. The **ozone layer** takes in 97–99% of the Sun's harmful ultraviolet (UV) radiation.
    b. Atmospheric gases such as oxygen and nitrogen can either scatter or absorb X-rays and gamma rays.
2. **Neutralizing leftover particles**: Solar particles that enter the magnetosphere collide with atmospheric molecules, releasing energy as heat or light, such as in auroras.
3. **Allowing beneficial radiation**: Visible light and some infrared radiation come through to aid photosynthesis and help regulate the weather conditions.

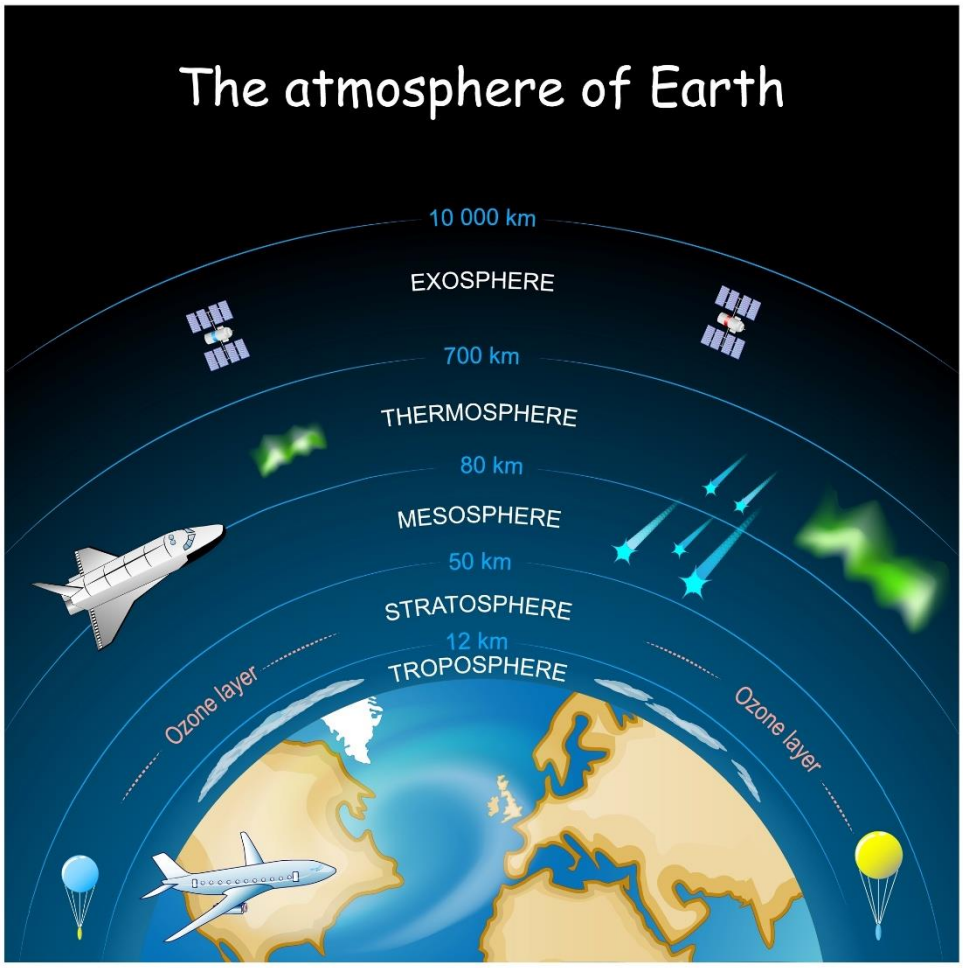


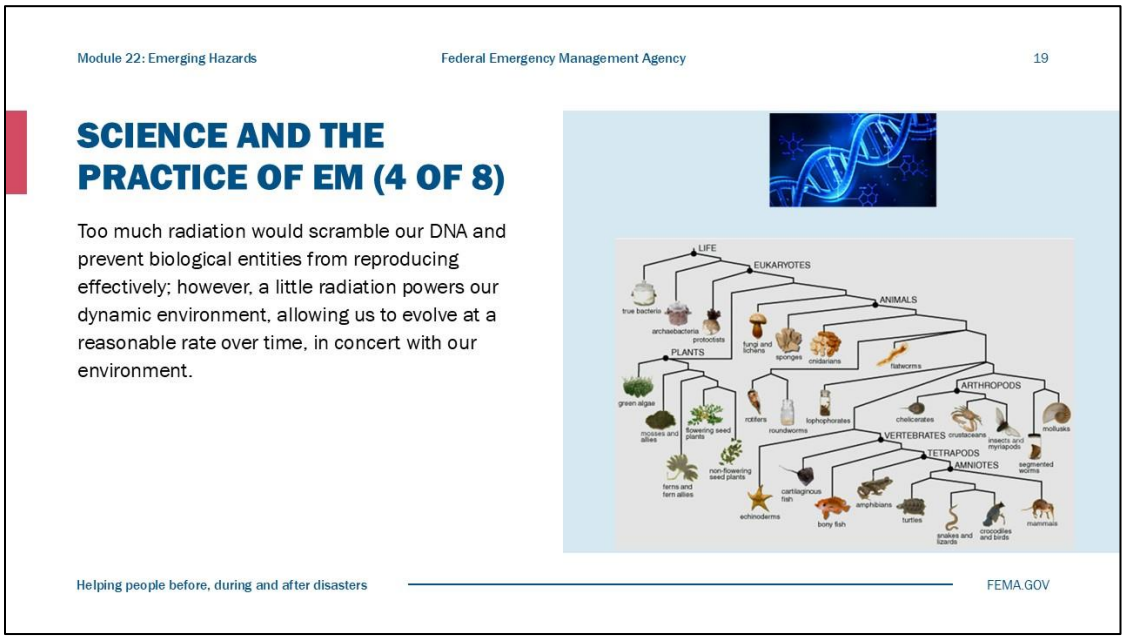
Figure 2: Earth's Atmosphere

Working Together

- **Ionosphere-magnetosphere interaction**: The ionosphere, a component of the upper atmosphere, generates electrical currents that help regulate energy from geomagnetic storms and solar wind interactions.
- **Atmospheric preservation**: The magnetosphere helps keep our atmosphere intact by deflecting solar wind, and in turn, the atmosphere protects us from radiation that the magnetic field can't shield us from, like UV rays.
- **Dynamic balance**: Brief interruptions, like polar cusps, let in a little solar energy, creating beautiful auroras without causing lasting damage.

This dual-layer system helps maintain Earth's atmospheric stability, keeping conditions livable and allowing sunlight to sustain life while protecting us from harmful radiation.

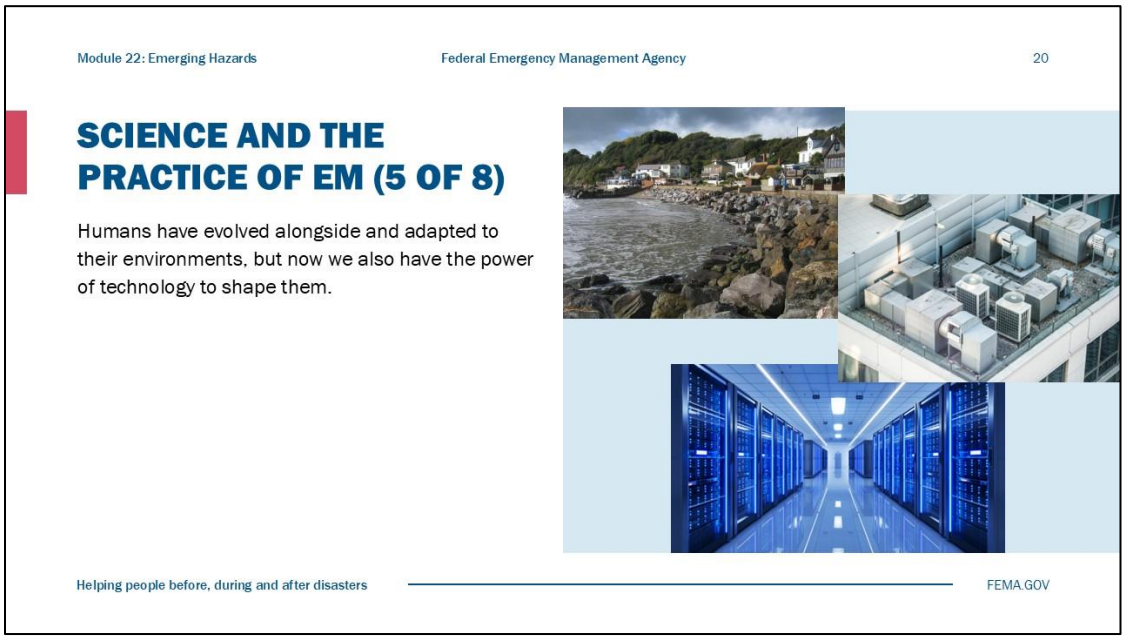
Science and the Practice of Emergency Management (EM) (5 of 9)



Slide 22-19, Science and the Practice of EM (4 of 8)

Too much radiation would scramble our DNA and prevent biological entities from reproducing effectively; however, a little radiation powers our dynamic biosphere, allowing us to evolve at a reasonable rate over time, in concert with our biosphere.

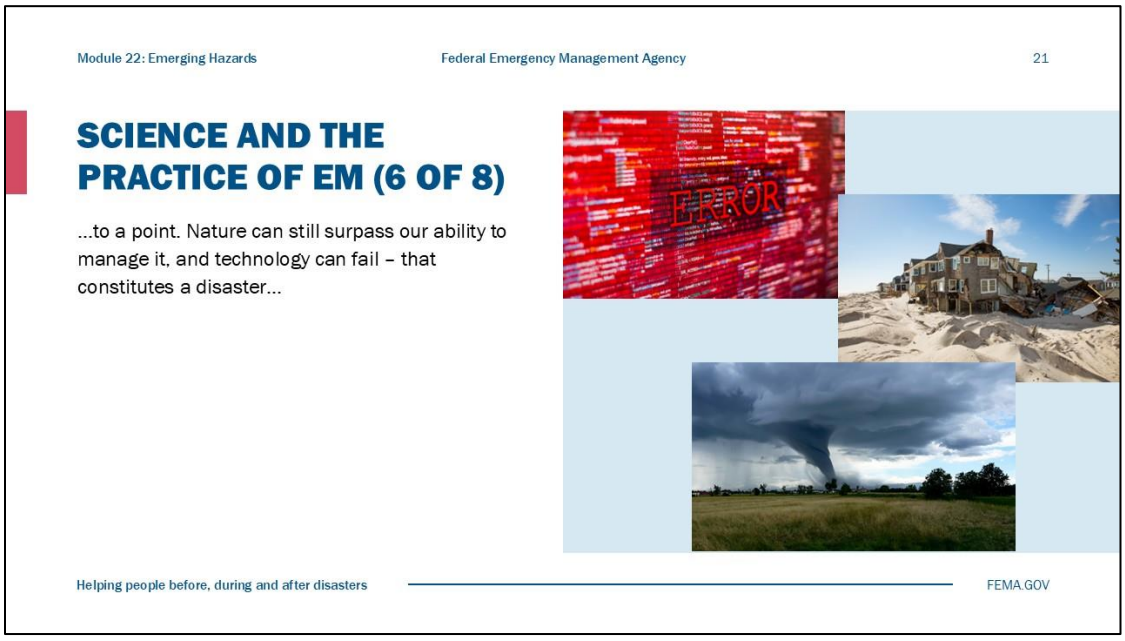
Science and the Practice of Emergency Management (EM) (6 of 9)



Slide 22-20, Science and the Practice of EM (5 of 8)

Humans have evolved alongside and adapted to their environments, but now we also have the power of technology to shape them.

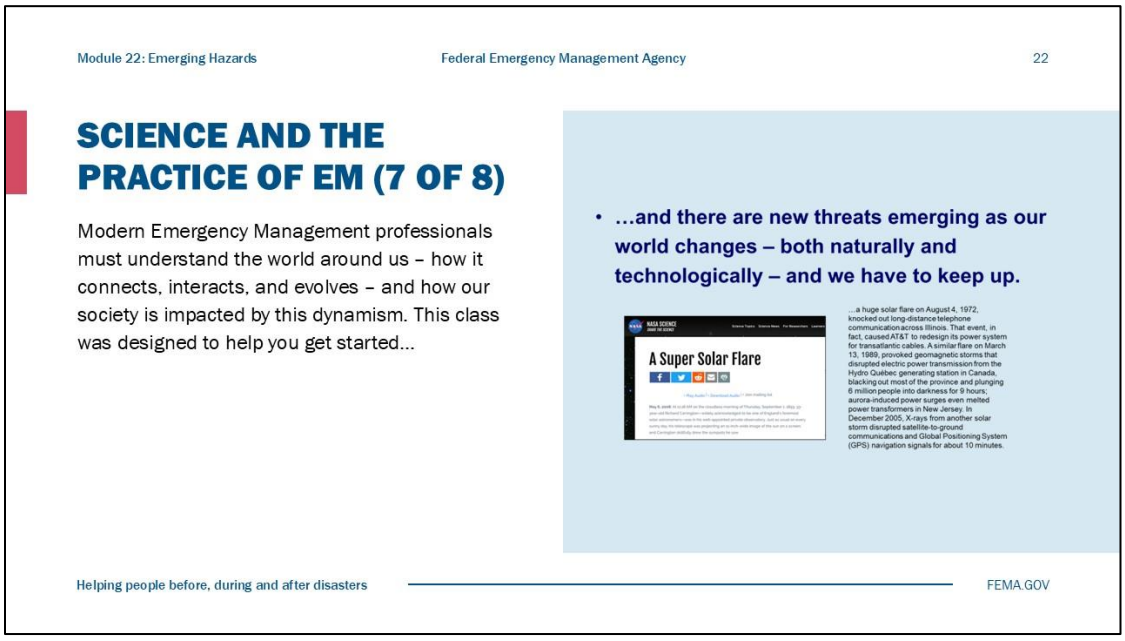
Science and the Practice of Emergency Management (EM) (7 of 9)



Slide 22-21, Science and the Practice of EM (6 of 8)

...to a point. Nature can still surpass our ability to manage it, and technology can fail – that constitutes a disaster...

Science and the Practice of Emergency Management (EM) (8 of 9)



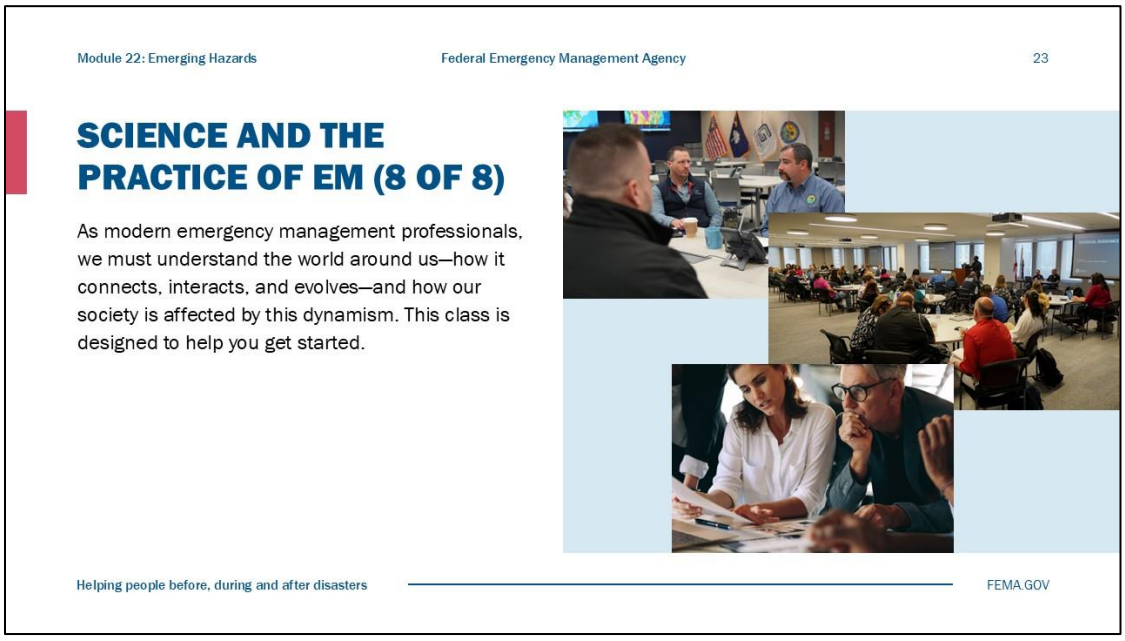
Slide 22-22, Science and the Practice of EM (7 of 8)

“...and there are new threats emerging as our world changes – both naturally and technologically – and we have to keep up.

"...a huge solar flare on August 4, 1972, knocked out long-distance telephone communication across Illinois. That event, in fact, caused AT&T to redesign its power system for transatlantic cables. A similar flare on March 13, 1989, provoked geomagnetic storms that disrupted electric power transmission from the Hydro Québec generating station in Canada, blacking out most of the province and plunging 6 million people into darkness for 9 hours; aurora-induced power surges even melted power transformers in New Jersey. In December 2005, X-rays from another solar storm disrupted satellite-to-ground communications and Global Positioning System (GPS) navigation signals for about 10 minutes. That may not sound like much, but as Lanzerotti noted, "I would not have wanted to be on a commercial airplane being guided in for a landing by GPS or on a ship being docked by GPS during that 10 minutes."

Source: What is a Solar Flare? - NASA Science

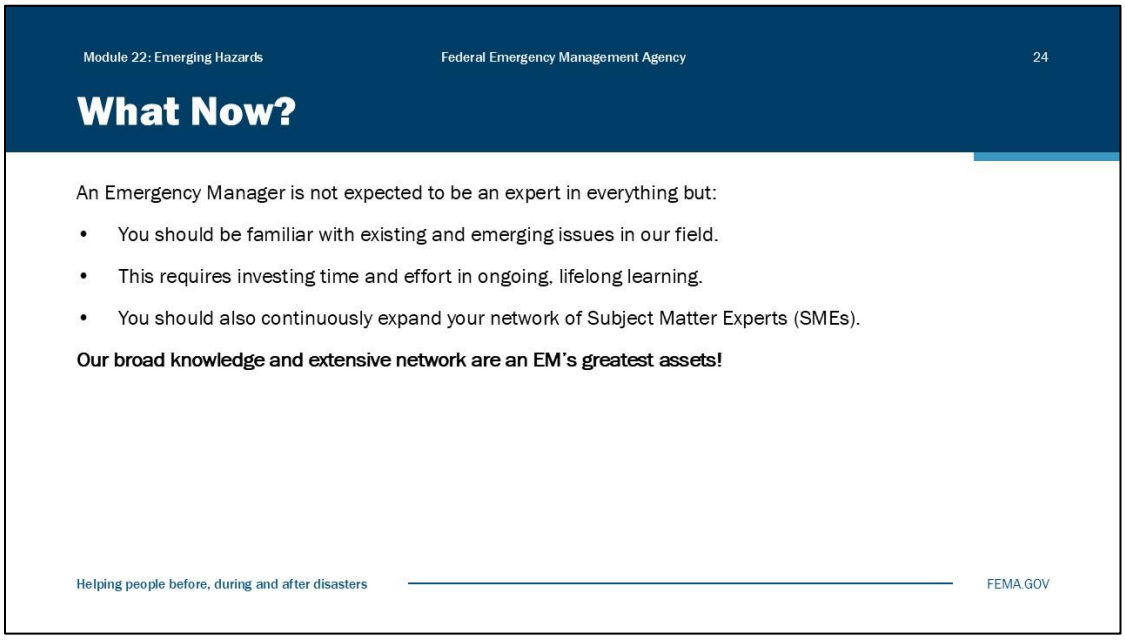
Science and the Practice of Emergency Management (EM) (9 of 9)



Slide 22-23, Science and the Practice of EM (8 of 8)

As modern emergency management professionals, we must understand the world around us—how it connects, interacts, and evolves—and how our society is affected by this dynamism. This class is designed to help you get started.

What Now?



Slide 22-24, What Now?

An Emergency Manager is not expected to be an expert in everything, but:

- You should be familiar with existing and emerging issues in our field.
- This requires investing time and effort in ongoing, lifelong learning.
- You should also continuously expand your network of Subject Matter Experts (SMEs).

Our broad knowledge and extensive network are an EM's greatest assets!

Science Takes Time



Slide 22-25, Science Takes Time

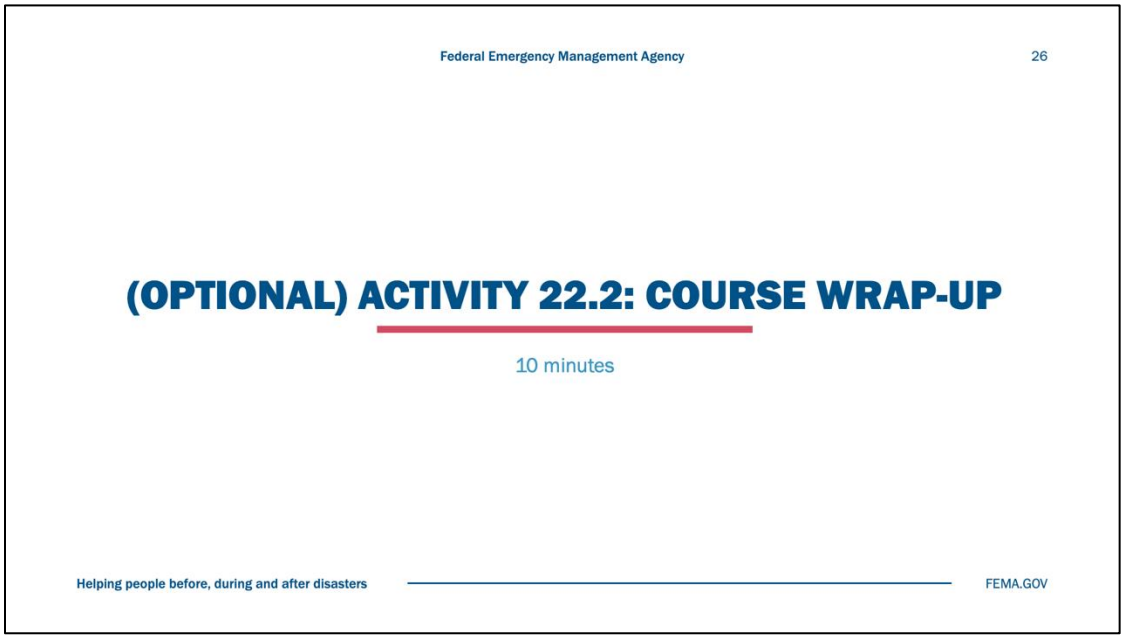
- Remember that as you learn and make connections, you need to ensure that your information is scientifically **credible and valid**.
- It is also important to remember the scientific method takes time – time to make the hypothesis, time to test it, time to peer review the test, and time to have others validate it. This is not a failure of science but a logical and methodical system to ensure that sound science prevails.
- This enhances your value as a professional and ensures that you deliver the best possible service to your community.

The authorized biography by Frank Dyer and T. C. Martin, Edison: His Life and Inventions (the first edition of the book is 1910), quotes Edison's friend and associate Walter S. Mallory about these experiments:

"This [the research on light bulbs] had been going on more than five months, seven days a week, when I was called down to the laboratory to see him [Edison]. I found him at a bench about three feet wide and twelve feet long, on which there were hundreds of little test cells that had been made up by his corps of chemists and experimenters. I then learned that he had thus made over nine thousand experiments in trying to devise this new type of storage battery but had not produced a single thing that promised to solve the question. In view of this immense amount of thought and labor, my sympathy got the better of my judgment, and I said: 'Isn't it a shame that

with the tremendous amount of work you have done, you haven't been able to get any results?' Edison turned on me like a flash, and with a smile replied: **“Results! Why, man, I have gotten lots of results! I know several thousand things that won't work!”**

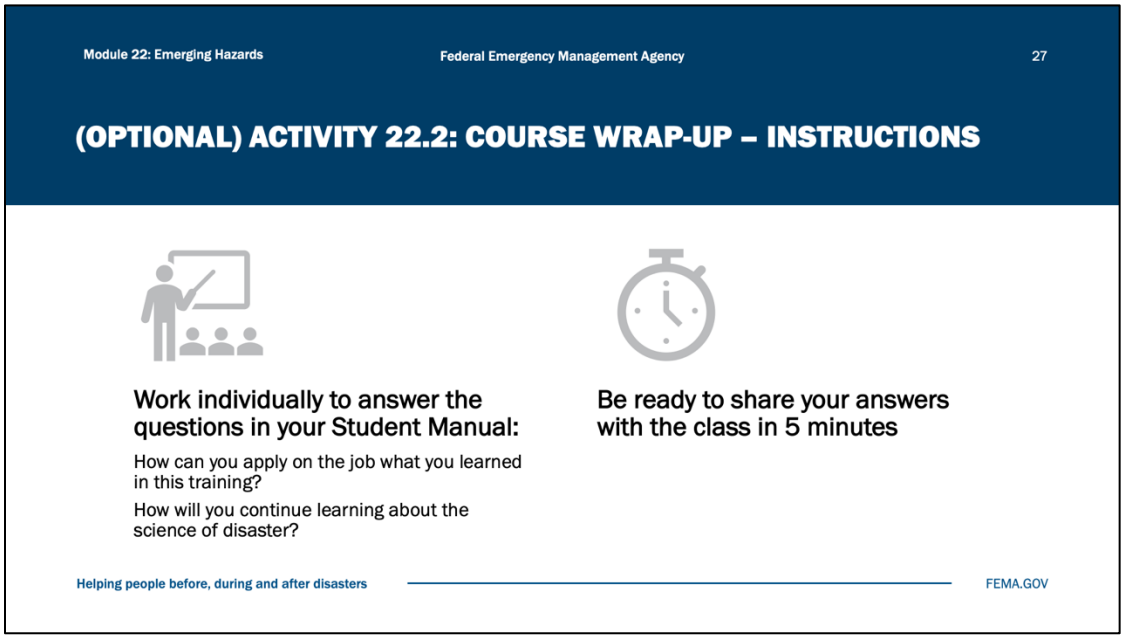
(Optional) Activity 22.2: Course Wrap-Up (1 of 2)



Slide 22-26, (Optional) Activity 22.2: Course Wrap-Up

Not Applicable.

(Optional) Activity 22.2: Course Wrap-Up (2 of 2)



Slide 22-27, (Optional) Activity 22.2: Course Wrap-Up – Instructions

(Optional) Activity 22.2: Course Wrap-Up – Directions to Students

Time: 10 minutes

Purpose

The purpose of this activity is to encourage students to reflect on how they can apply the knowledge gained from the training to their professional roles and continue learning about the science of disaster.

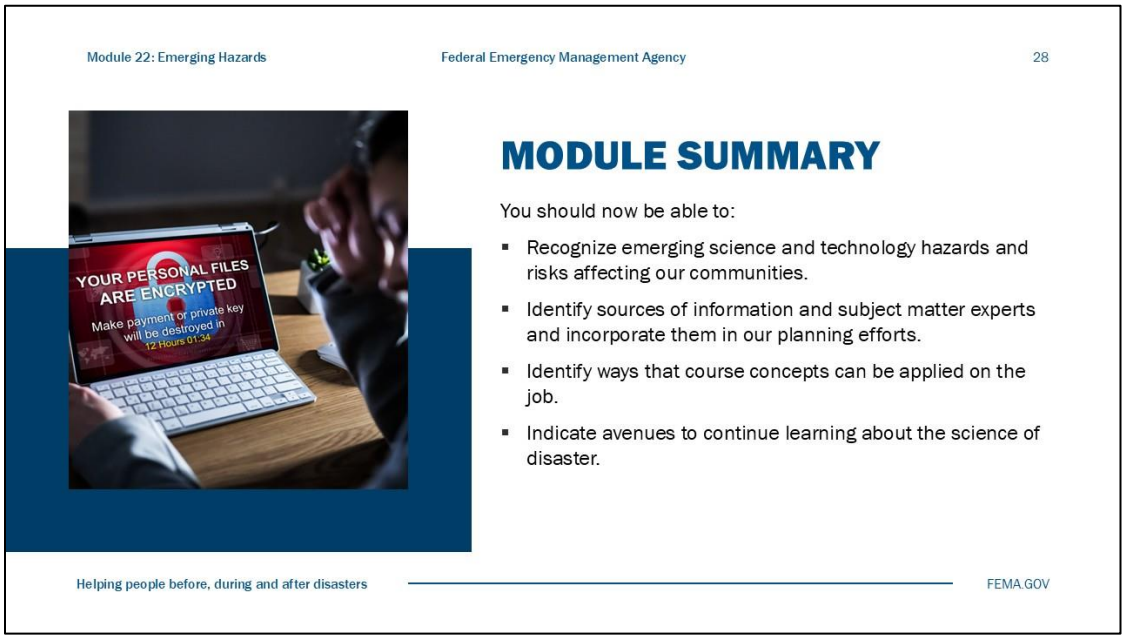
Directions

1. Take 7 minutes to individually answer the following questions.
    a. How can you apply on the job what you learned in this training?

b. How will you continue learning about the science of disaster?

2. After writing your answers, discuss them in your group.
3. Be ready to share one or two ideas with the class that haven't been mentioned by other groups.

End of Module (1 of 2)



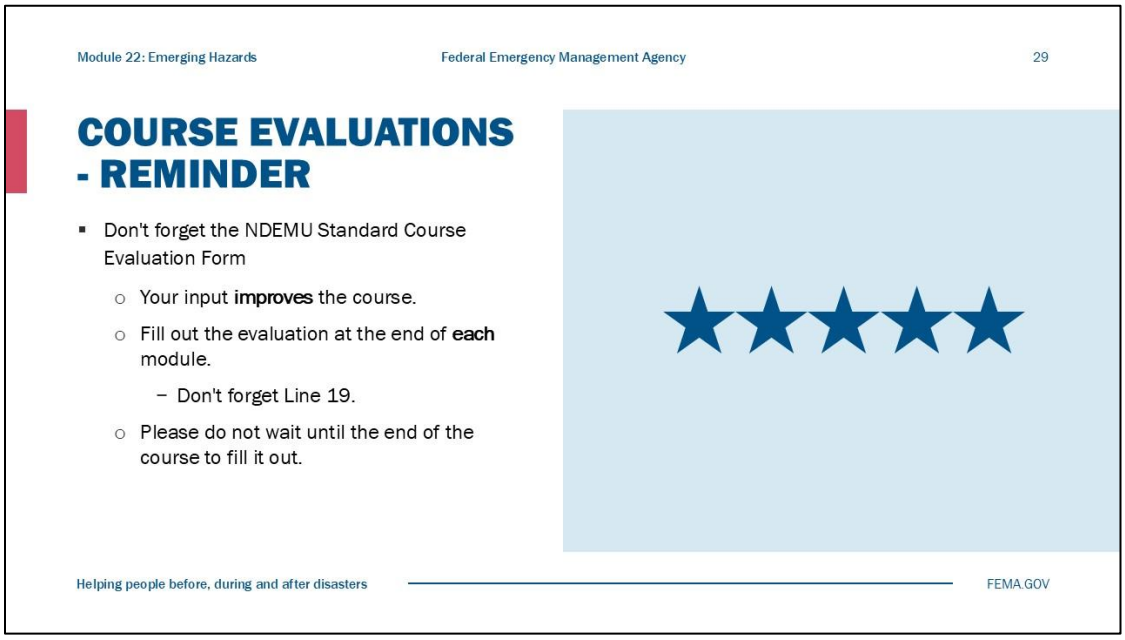
Slide 22-28, Module Summary

You should now be able to:

- Recognize emerging science and technology hazards and risks affecting our communities.
- Identify sources of information and subject matter experts and incorporate them in our planning efforts.
- Identify ways that course concepts can be applied on the job.
- Indicate avenues to continue learning about the science of disaster.

Do you have any questions about the material covered in this module?

End of Module (2 of 2)



Slide 22-29, Course Evaluations - Reminder

- Don't forget the NDEMU Standard Course Evaluation Form
  - Your input **improves** the course.
  - Fill out the evaluation at the end of **each** module.
    - Don't forget Line 19.
  - Please do not wait until the end of the course to fill it out.

Reference List

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Extra reading:

Cyber:

- Cities Speak (https://citiesspeak.org/2019/10/01/how-one-alaskan-borough-stood-up-to-a-cyber- attack/)
- Anchorage Daily News "Price tag for cyberattack on Mat-Su Borough now tops $2 million" (https://www.adn.com/alaska-news/mat-su/2018/10/11/price-tag-for-mat-su-cyberattack-now- tops-2-million/)
- Secure World "Incident Response: The Alaska Cyber Attack, a State of Emergency, and YouTube" (https://www.secureworldexpo.com/industry-news/incident-response-the-alaska-cyberattack-a-state-of-emergency-and-youtube)
- Washington Post "An Alaskan Borough Turns Typewriters and Handwriting After Its Computers Were Hacked" (https://www.washingtonpost.com/technology/2018/08/01/an-alaskan-borough- turns-typewriters-handwriting-after-its-computers-were-hacked/)
- State Scoop "Ransomware attack forces Alaska suburb to revert to typewriters, rebuild email from scratch" (https://statescoop.com/ransomware-attack-forces-alaska-suburb-to-revert-to-typewriters-rebuild-email-from-scratch/)

Valdez (paid the ransom):

- ZDNet "City of Valdez, Alaska admits to paying off ransomware infection" (https://www.zdnet.com/article/city-of-valdez-alaska-admits-to-paying-off-ransomware-infection/)

Baltimore:

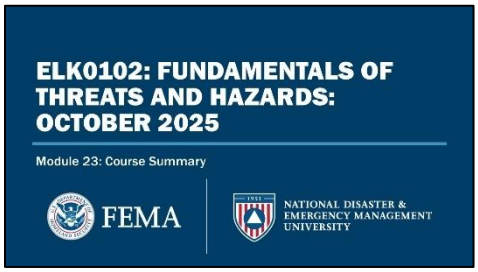
- Baltimore Sun "Baltimore transfers $6 million to pay for ransomware attack; city considers insurance against hacks" (https://www.baltimoresun.com/politics/bs-md-ci-ransomware-expenses-20190828-njgznd7dsfaxbbaglnvnbkgjhe-story.html)
- Secure World "Baltimore, $18 Million Later: 'This Is Why We Didn't Pay the Ransom" (https://www.secureworldexpo.com/industry-news/baltimore-ransomware-attack-2019)
- ISO/IEC 27032 – Information Technology – Security techniques – Guidelines for cybersecurity, International Standards Organization, 2012 (www.iso.org/obp/ui/)
- Cybersecurity and Infrastructure Security Agency (CISA) https://www.cisa.gov/

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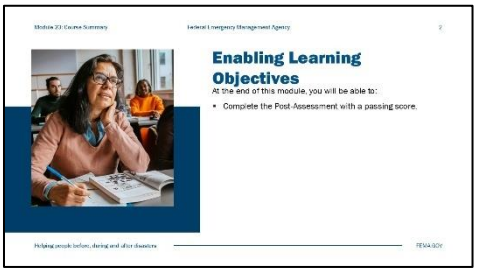
Module 23

Course Summary

Administration



Slide 23-1, Module 23: Course Summary



Slide 23-2, Enabling Learning Objectives

Duration

40 minutes

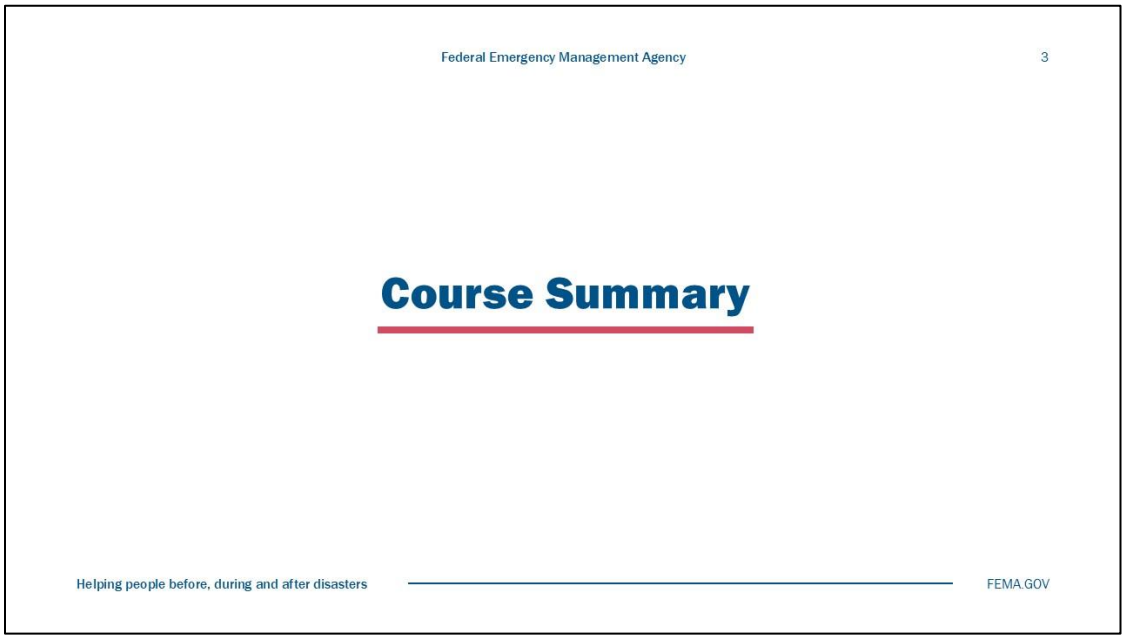
Terminal Learning Objective (TLO)

By the end of this Module, participants will be able to complete the post-assessment and assess the course.

Enabling Learning Objectives (ELOs)

By the end of this Module, participants will be able to complete the Post-Assessment with a passing score.

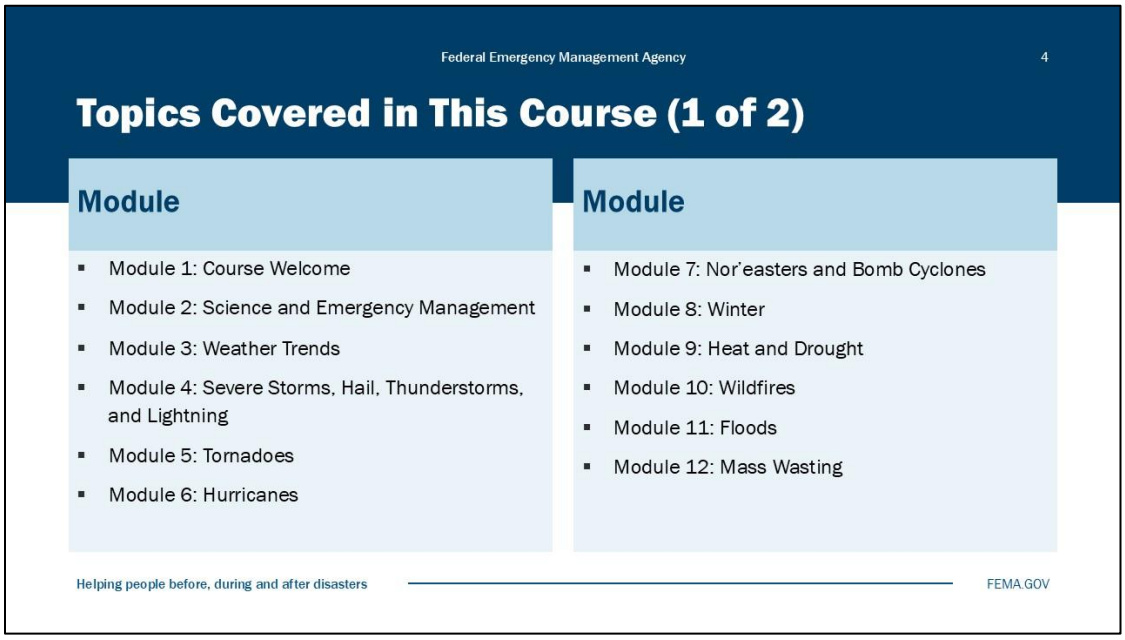
Course Summary (1 of 3)



Slide 23-3, Course Summary

Not Applicable.

Course Summary (2 of 3)



Slide 23-4, Topics Covered in This Course (1 of 2)

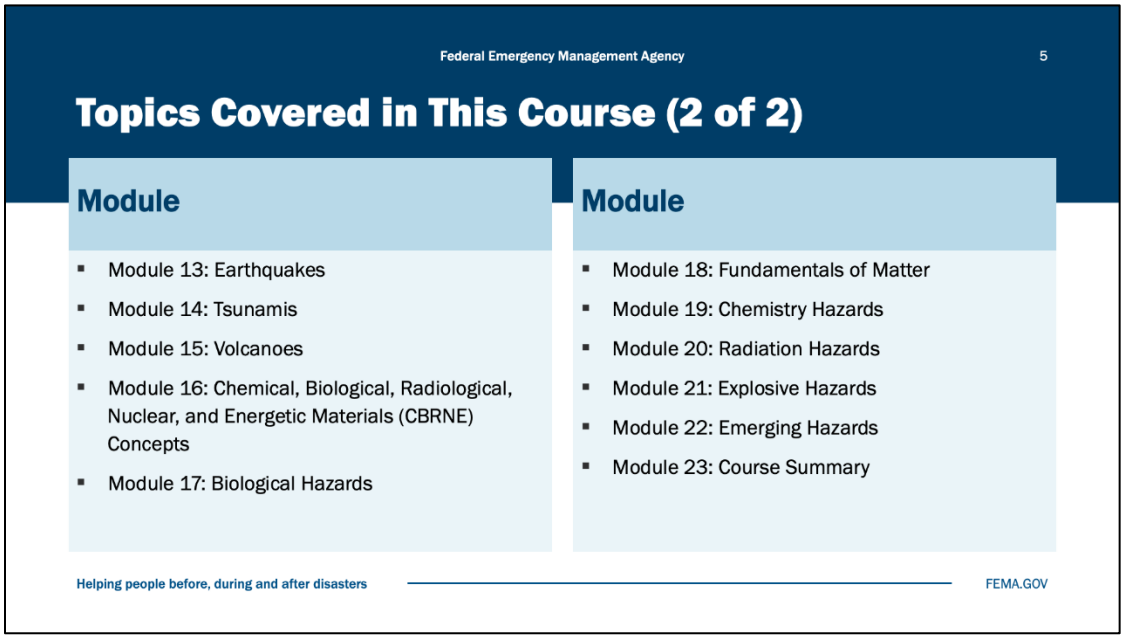
This course introduced you to scientific concepts and principles in several key areas related to natural and human-caused disasters. It focused on common and emerging threats that form a basis for understanding the science of disaster. The course was organized as follows:

- Module 1: Course Welcome
- Module 2: Science and Emergency Management
- Module 3: Weather Trends
- Module 4: Severe Storms, Thunderstorm, Lightning
- Module 5: Tornadoes
- Module 6: Hurricanes
- Module 7: Nor'easters and Bomb Cyclones
- Module 8: Winter

Module 4: Surface Hazards

- Module 9: Heat and Drought
- Module 10: Wildfires
- Module 11: Floods
- Module 12: Mass Wasting

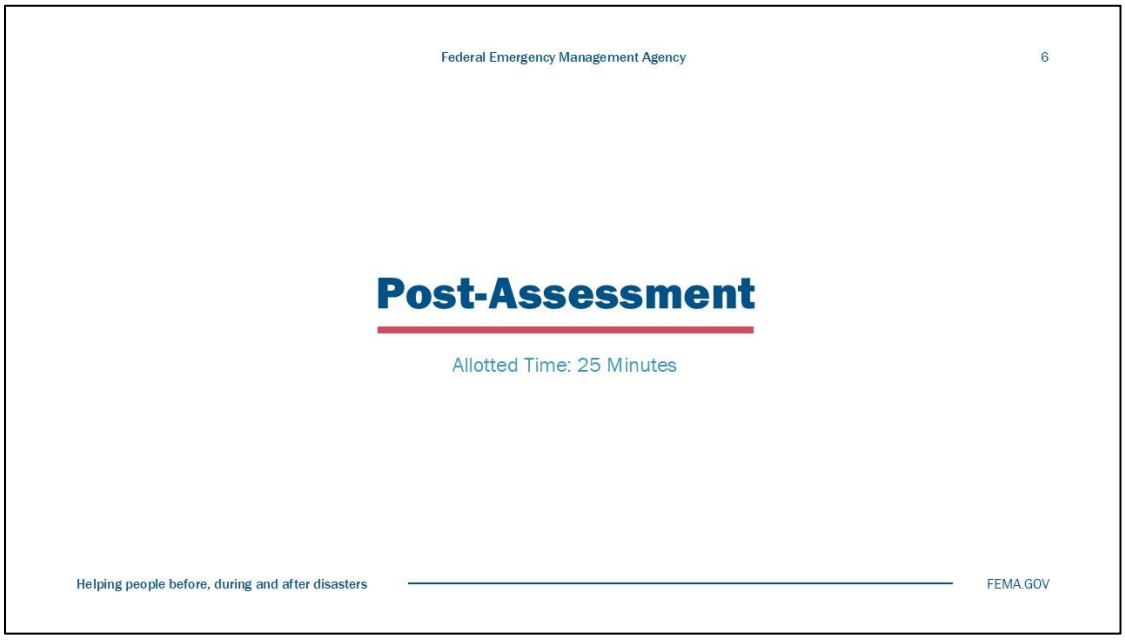
Course Summary (3 of 3)



Slide 23-5, Topics Covered in This Course (2 of 2)

- Module 13: Earthquakes
- Module 14: Tsunamis
- Module 15: Volcanoes
- Module 16: Chemical, Biological, Radiological, Nuclear and Energetic Materials (CBRNE) Concepts
- Module 17: Biological Hazards
- Module 18: Fundamentals of Matter
- Module 19: Chemistry Hazards
- Module 20: Radiation Hazards
- Module 21: Explosive Hazards
- Module 22: Emerging Hazards
- Module 23: Course Summary

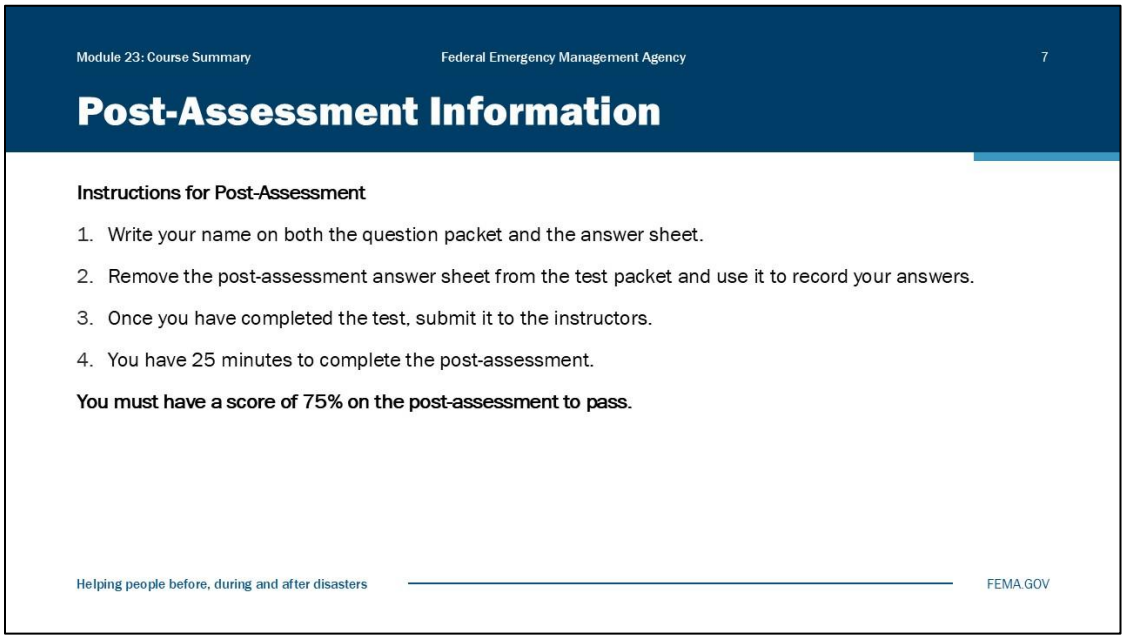
Post-Assessment (1 of 2)



Slide 23-6, Post-Assessment

Not Applicable.

Post-Assessment (2 of 2)



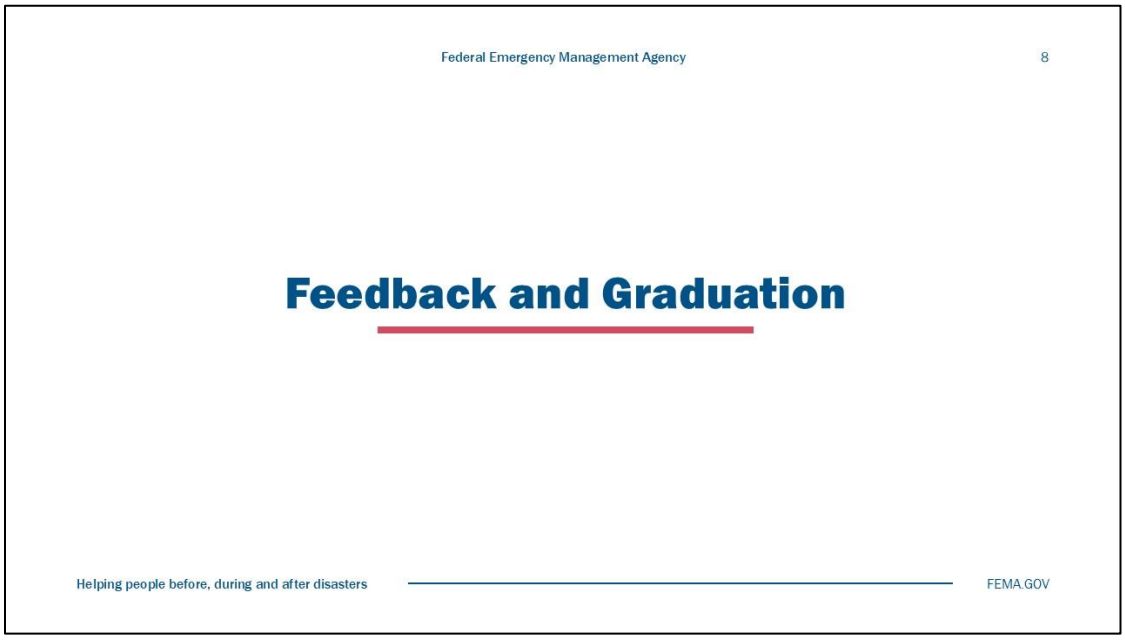
Slide 23-7-, Post-Assessment Information

Instructions for Post-Assessment:

1. Write your name on both the question packet and the answer sheet.
2. Remove the post-assessment answer sheet from the test packet and use it to record your answers.
3. Once you have completed the test, submit it to the instructors.
4. You have 25 minutes to complete the post-assessment.

You must have a score of 75% on the post-assessment to pass.

Feedback and Graduation (1 of 2)



Slide 23-8, Feedback and Graduation

Not Applicable.

Feedback and Graduation (2 of 2)



Slide 23-9, Feedback

Congratulations! You have completed the course, Science of Disaster. Thank you for your participation and your valuable contributions to the discussions.

We appreciate your input. Kindly share your feedback using the course evaluation form.

End of Course (1 of 2)



Slide 23-10, Get in Touch with Us.

Get in touch with us at FEMA-EMPP-Basic-Academy@fema.dhs.gov.

End of Course (2 of 2)



Slide 23-11, The End

Reference List

None