

**Earth's Processes as Hazards, Disasters,
and Catastrophes**

Natural Hazards

Keller | DeVecchio

THIRD EDITION

Lecture Presentation

Chapter 4

Tsunamis

Learning Objectives

- Understand the process of tsunami formation and development
- Understand the effects of tsunamis and the hazards they pose to coastal regions
- Know what geographic regions are at risk for tsunamis
- Recognize the linkages between tsunamis and other natural hazards

Learning Objectives, cont.

- Know what nations, communities, and individuals can do to minimize the tsunami hazard

Introduction

- **Tsunami** is Japanese for “harbor wave”
- Caused by a sudden vertical displacement of ocean water
- Triggered by:
 - Large earthquakes that cause uplift or subsidence of sea floor
 - Underwater landslides
 - Volcano Flank Collapse
 - Submarine volcanic explosion
 - Asteroids
 - Can produce Mega-tsunami

Some Historic Tsunamis

Date	Cause	Damage
1755	Earthquake(M 9) in Lisbon, Portugal	20,000 people killed, wave heights of 23 ft in West Indies
1883	Volcano Collapse	>36,000 people killed, 116 ft high waves
1946	Earthquake (M 8.1) in Aleutians	>160 people killed in Hawaiian Islands
1960	Earthquake (M 9+) in Chile	>61 people killed in Hawaii
1964	Alaskan Earthquake (M 8.3)	130 people killed in Alaska and California
1993	Earthquake (M 7.8) in Sea of Japan	Killed 120 people in Okushiri Island, Japan
1998	Submarine Landslide triggered by earthquake in Papua New Guinea (M 7.1)	Killed >2100 people
2004	Sumatran earthquake (M 9.1+)	Killed > 230,000 people

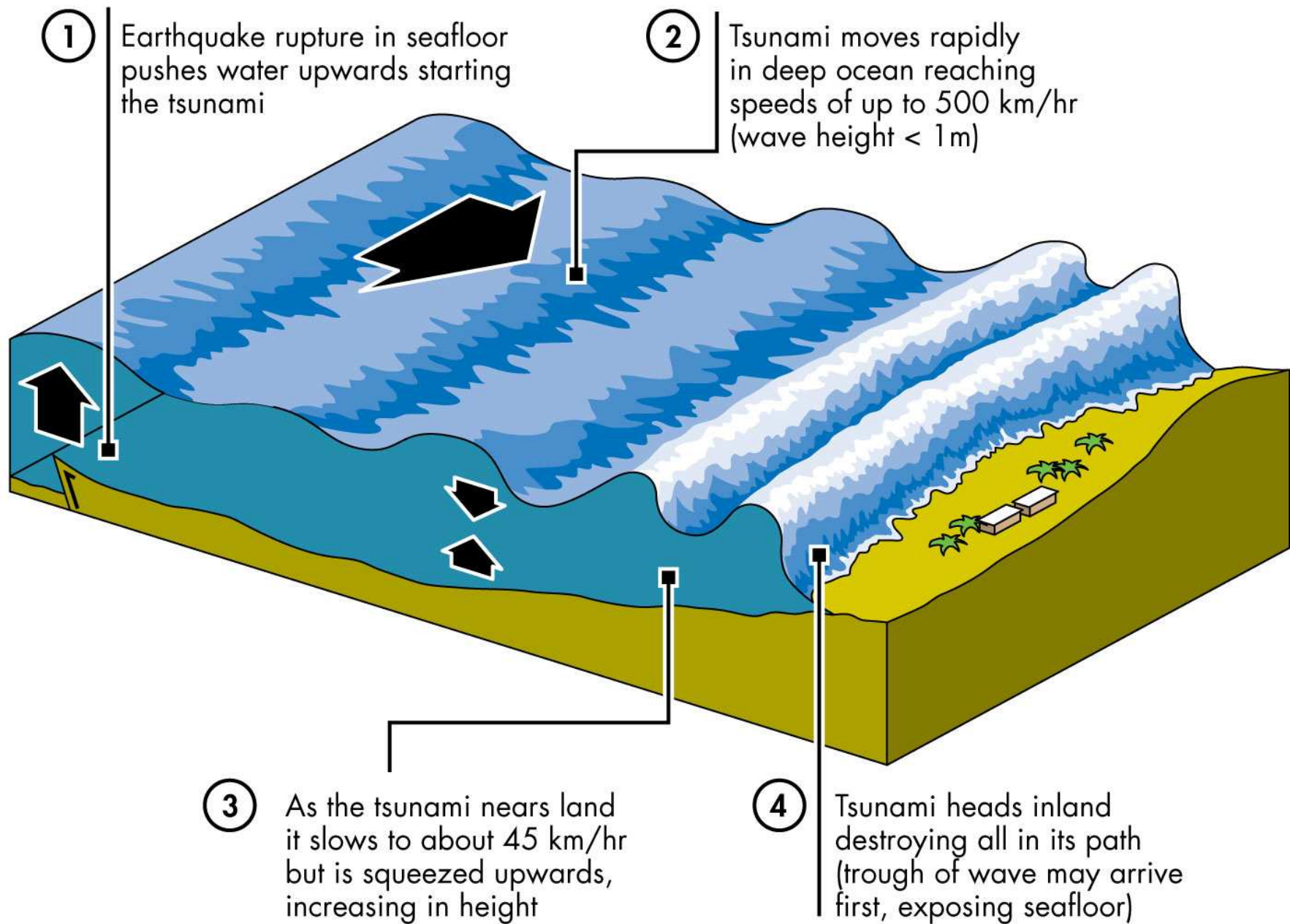
Earthquake Caused Tsunamis

1. Earthquake uplifts or downshifts the seafloor
 - Needs > **M** 7.5 earthquake to create enough displacement
 - Rupture uplifts the seafloor
 - A dome forms on the surface of the water above the fault
 - Dome collapses and generates the tsunami wave
 - Waves radiate outward (like a pebble in a pond)
2. Tsunami moves rapidly in deep ocean
 - Can travel 720 km (450 mi.) per hour
 - Spacing (frequency) of crests is large and small amplitude
 - Boats in open ocean don't notice the tsunami waves

Earthquake Caused Tsunamis, cont. 1

3. Tsunami nears land, loses speed, gains height
 - Depth of ocean decreases, slowing tsunami waves 45 km (28 mi.) per hour
 - More water piles up increasing amplitudes and frequency

4. Tsunami moves inland destroying everything in its path
 - Can be meters to tens of meters high
 - Trough may arrive first, exposing seafloor
 - Often arrives as a quick increase in sea level
 - **Runup**, furthest horizontal and vertical distance of the largest wave
 - Water returns to ocean in a strong, turbulent flow
 - Edge waves may be generated parallel to the shore
 - More waves likely to follow, second and third waves may be amplified



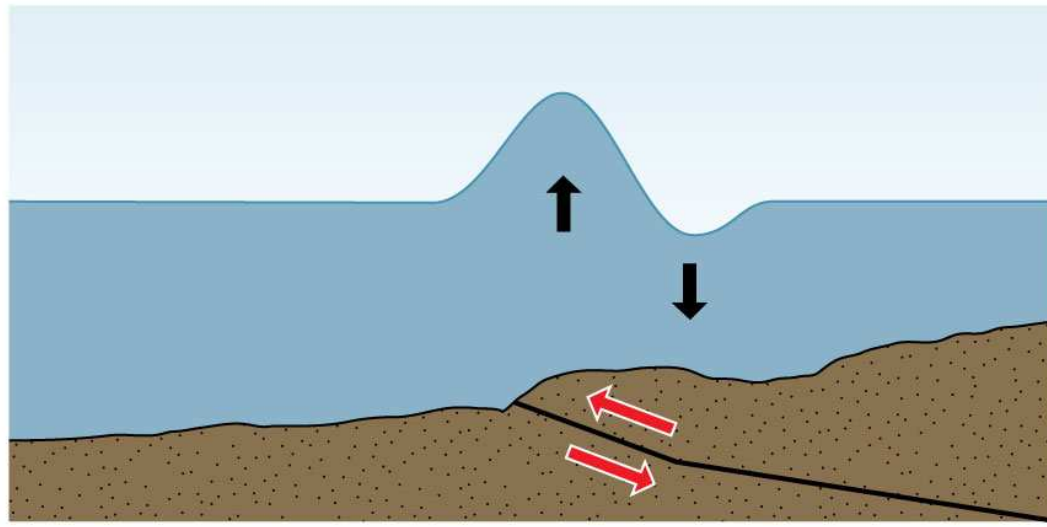
© 2012 Pearson Education, Inc.

Figure 4.7

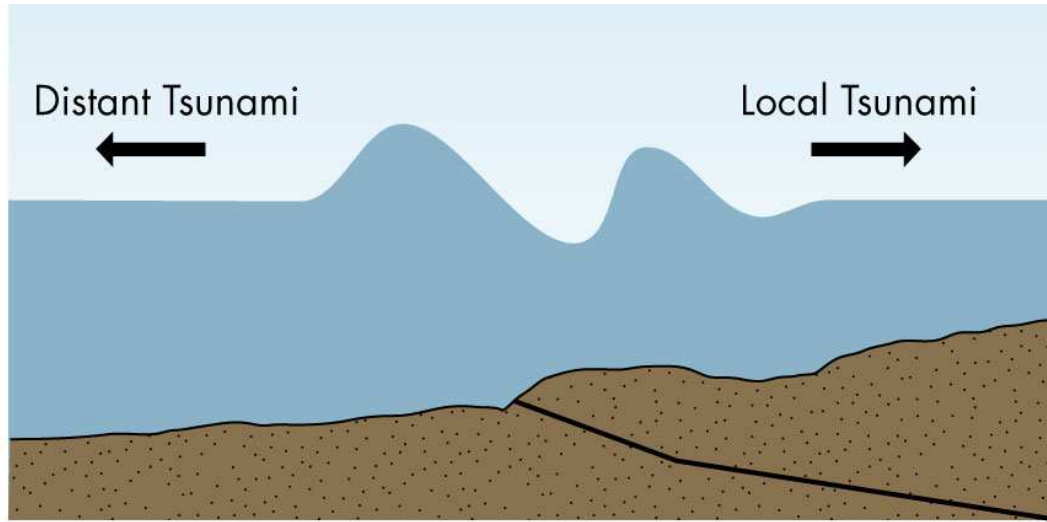
© 2012 Pearson Education, Inc.

Earthquake Caused Tsunamis, cont. 2

- Offshore earthquakes can cause tsunamis to go toward land and out to sea
 - Uplifted dome of water splits in two waves
- Distant tsunami
 - Travels out to sea and can travel long distances with little loss of energy
- Local tsunami
 - Travels towards land very quickly
 - People have very little time to react



(a)



(b)

© 2012 Pearson Education, Inc.

Figure 4.8

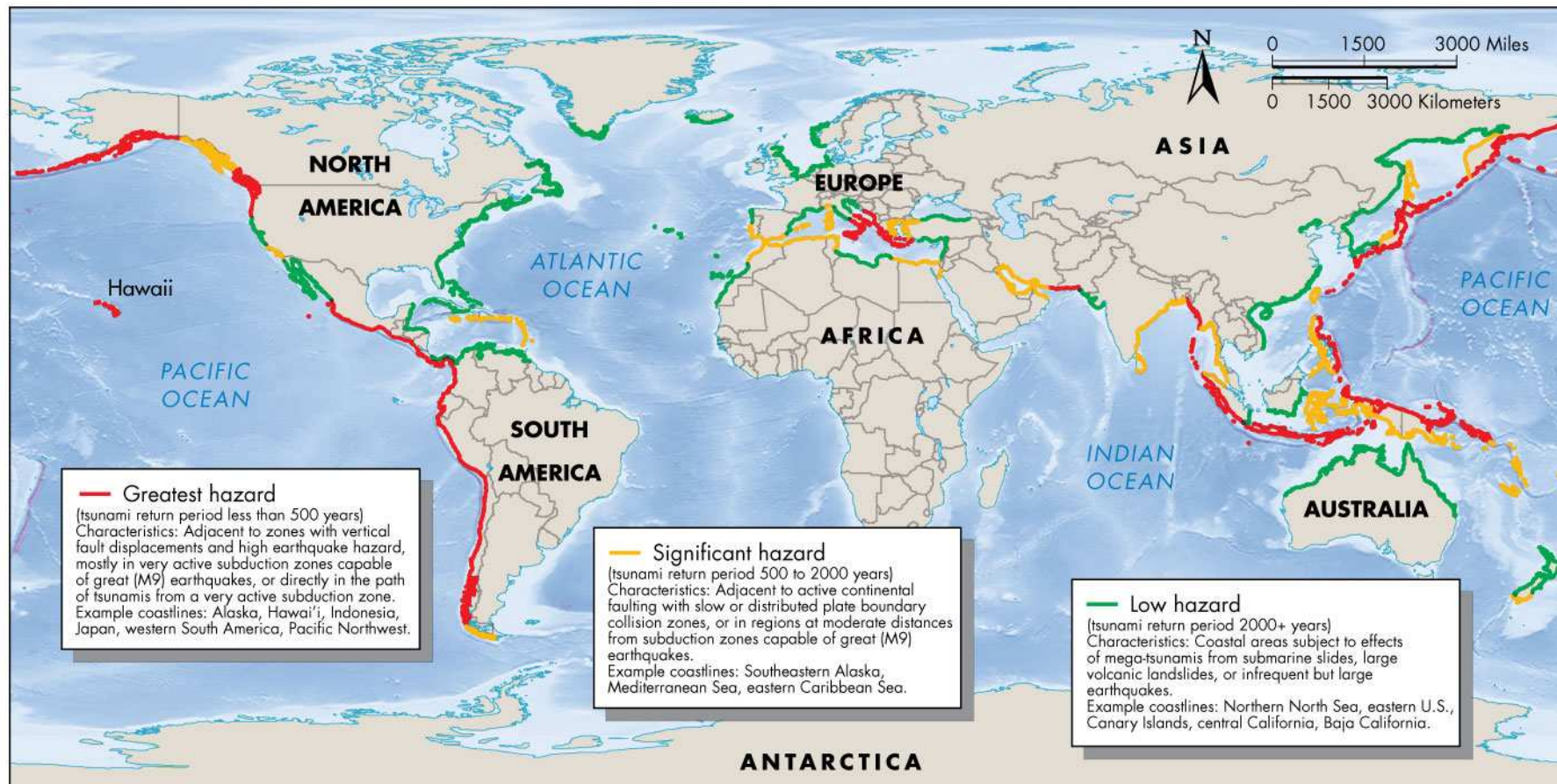
© 2012 Pearson Education, Inc.

Landslide Caused Tsunamis

- Submarine landslides occur when landslides occur underneath the water
 - Displaces water vertically causing tsunamis
- On land, rock avalanches from mountains can cause tsunami
 - Example: Lituya Bay, Alaska
 - 30.5 million cubic meters of rock fell into ocean
 - Bay water surged to 524 m (1790 ft.) above normal

Regions at Risk

- All oceans and some lake shorelines have some risk
- Greater risk is for coasts near sources of tsunami
 - Earthquakes, landslides, volcanoes
- Greatest risk is to areas near or across from subduction zones
 - Example: Cascadia zone, Chilean Trench, off Coast of Japan
- Areas around Pacific Ocean, Mediterranean, northeastern side of Indian Ocean



© 2012 Pearson Education, Inc.

Figure 4.11

© 2012 Pearson Education, Inc.

Effects of Tsunamis

- Primary effects
 - Flooding and erosion
 - Shorten the coastline
 - Debris erodes both landscape and human structures
- Secondary effects
 - Fires
 - From ruptured gas lines
 - Contaminated water supplies
 - Floodwaters, wastewater treatment plants, rotting animal carcasses and plants
 - Disease

Links to Other Natural Hazards

- Causes *of* Tsunami
 - Earthquakes
 - Landslides
 - Volcanic explosions
 - Asteroids
- Caused *by* Tsunami
 - Coastline erosion

Natural Service Functions

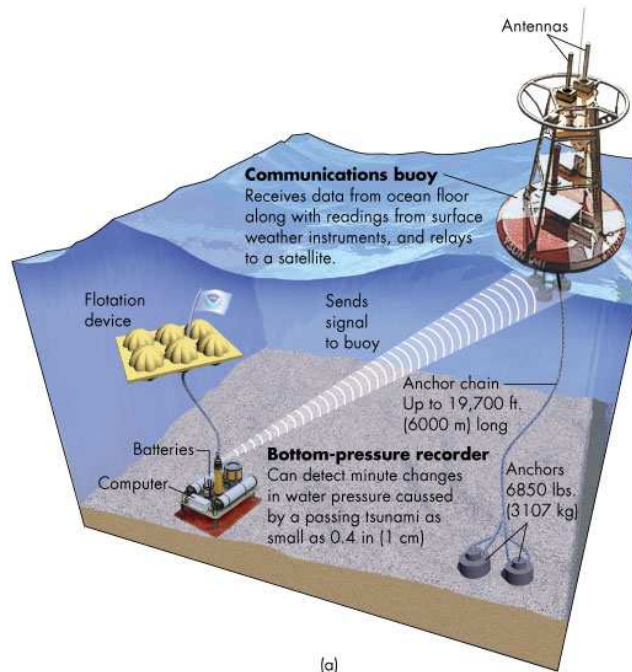
- May bring nutrients and sediments from the ocean that are needed by soil
- May bring in sediment needed to build shoreline

Human Interaction

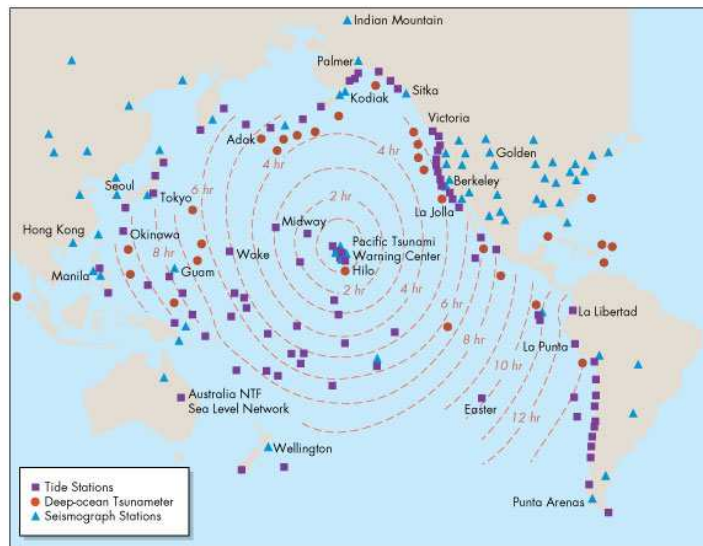
- Humans cannot prevent or control tsunamis
- Human activity does not affect frequency or magnitude
- Increased use of shoreline increases consequences

Minimizing the Tsunami Hazard

- Detection and warning
 - Tsunami warning system
 - Seismographs to detect earthquakes
 - Automated tidal gauges to determine sea level changes
 - Buoy sensors with tsunameter to detect small changes in pressure in ocean
 - Information is relayed by satellite to give arrival time estimates
 - Warning sirens are used to warn public
- Structural Control
 - Building codes for susceptible coastline areas to minimize hazard



(a)



(b)

© 2012 Pearson Education, Inc.

Figure 4.14

© 2012 Pearson Education, Inc.

Minimizing the Tsunami Hazard, cont. 1

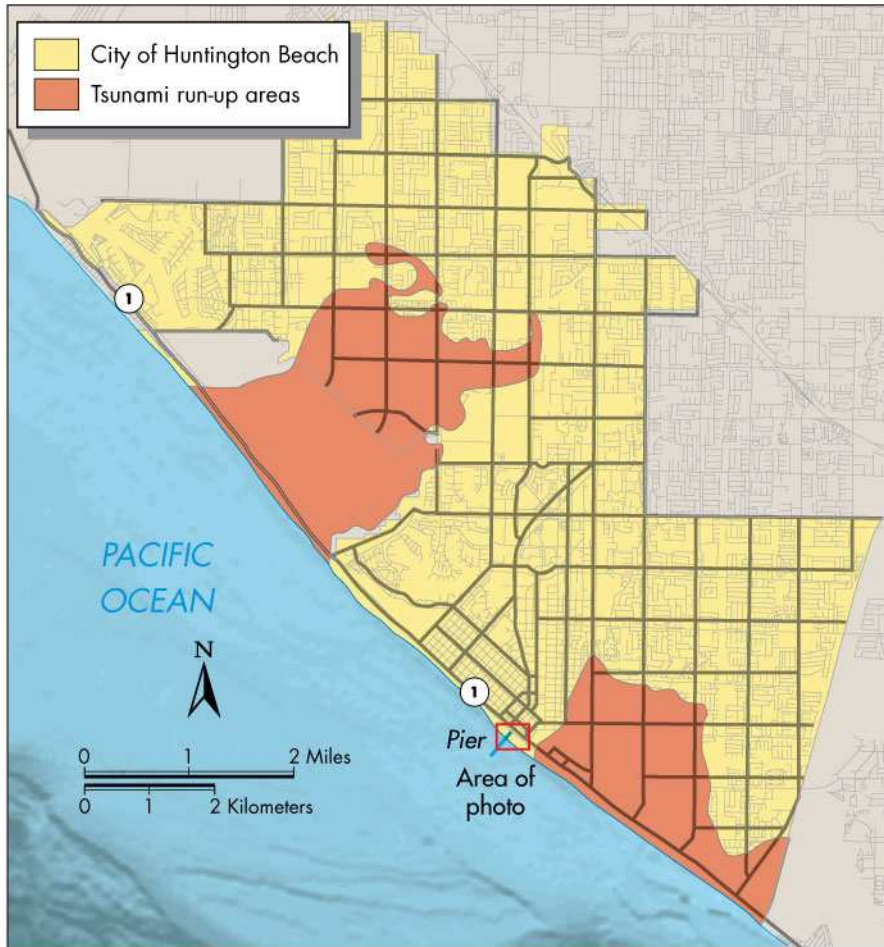
- Construction of tsunami runup maps
 - Show the level to which the water traveled inland
 - A hazard map can show where the Tsunami waves are likely to run up
- Land use
 - Native vegetation may provide defense
 - Development of land must be monitored
- Probability analysis
 - Identify potential earthquake sources
 - Specify relationships that increase or decrease tsunami waves
 - Apply probabilistic analysis to the tsunami



© 2012 Pearson Education, Inc.

Figure 4.15

© 2012 Pearson Education, Inc.



(a)



(b)

Figure 4.16

Minimizing the Tsunami Hazard, cont. 2

- Education
 - Educate people on the signs of tsunami
 - Tsunami watch
 - A possible trigger has occurred for a tsunami
 - Tsunami warning
 - A tsunami has been detected

- Tsunami ready status
 - Establish emergency operation center
 - Be able to receive tsunami warnings
 - Have ways to alert the public
 - Develop a preparedness plan with drills
 - Promote community awareness program

Perception and Personal Adjustment

- If you feel a strong earthquake, leave coastal area immediately
- If the ocean recedes, run from the beach
- Do not assume that all locations are safe because of an absence of dangerous waves elsewhere
- Stay out of dangerous areas until a notice that all is clear is given
- If you hear a siren, move away from the beach to higher ground
- If you are aware that a tsunami watch or warning has been issued, do not go down to the beach to watch the tsunami

End

Tsunamis
Chapter 4