Toxic Waste—Acid Rock Drainage (ARD)

Discharge of Acid Rock Drainage

- Water that collects in mines or drains through them can become acidic and contaminated with toxic metals. Where this water is discharged to the surface, it can degrade nearby surface water quality.
- This happens especially where the ore deposit is rich in sulfide minerals. The sulfide mineral that has the greatest effect on water quality is pyrite (iron sulfide).
- Pyrite (FeS_2) oxidizes (with bacteria) to form Fe oxides + sulfuric acid.

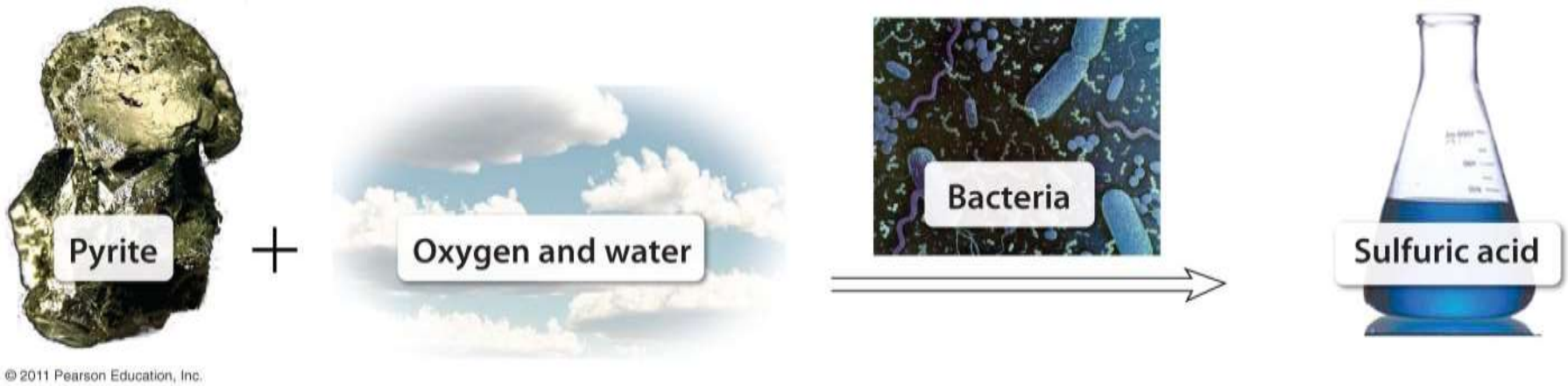


FIGURE 12-28 Generation of Acid Rock Drainage Reaction of oxygen with pyrite, catalyzed by certain bacteria, produces sulfuric acid that can mix with and contaminate surface and groundwater.

Acid Rock Drainage (ARD)

- **Acid rock drainage (ARD)**—acidic water
  - Produced by the oxidation of pyrite (and other sulfide minerals)
  - Dissolves metals such as copper, zinc, and silver
  - Must be properly treated and disposed of
- **Prevention of ARD**, avoiding oxidation of sulfide minerals (e.g., pyrite)
- Disposal of pyrite-bearing wastes in appropriate places
  - With impermeable materials at their base; inhibit water infiltration
- Other prevention techniques include:
  - Flooding underground mine openings
  - Capping pyrite-bearing rock in mines with impermeable coatings
  - Filling unused mine openings with material that neutralizes acid (e.g., limestone or other carbonate)

ARD Being Released from a Mine Adit

FIGURE 12-30 This ARD, flowing from a small underground mine in Colorado, contains high levels of dissolved metals including Cu, Fe, Al, Zn, and As. Looks like Ecto Cooler Hi-C drink but burns your mouth and tastes like copper and acid…GROSS! BAD!!!

Environmental Regulation

- Regulations implement the authority conveyed by laws.
- **Environmental standards**
  - Specific measures of environmental quality
  - Define the acceptable levels of pollution in air, water, and soil
  - Define acceptable pollution discharge levels and establish criteria for responses to contamination, (e.g., cleanup actions and regulatory enforcement proceedings)

Environmental Regulation (cont.)

- **Air quality standards**
  - Six pollutants used to measure air quality: carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, sulfur oxides (Table 15-1)
- **Water quality standards**
  - 126 priority toxic pollutants
    - Heavy metals (copper and silver, for example)
    - VOCs (benzene and chloroform, for example)
  - **TMDL**—Total Maximum Daily Load
  - **MCL**—Maximum Contaminant Level

Remediating Acid Rock Drainage

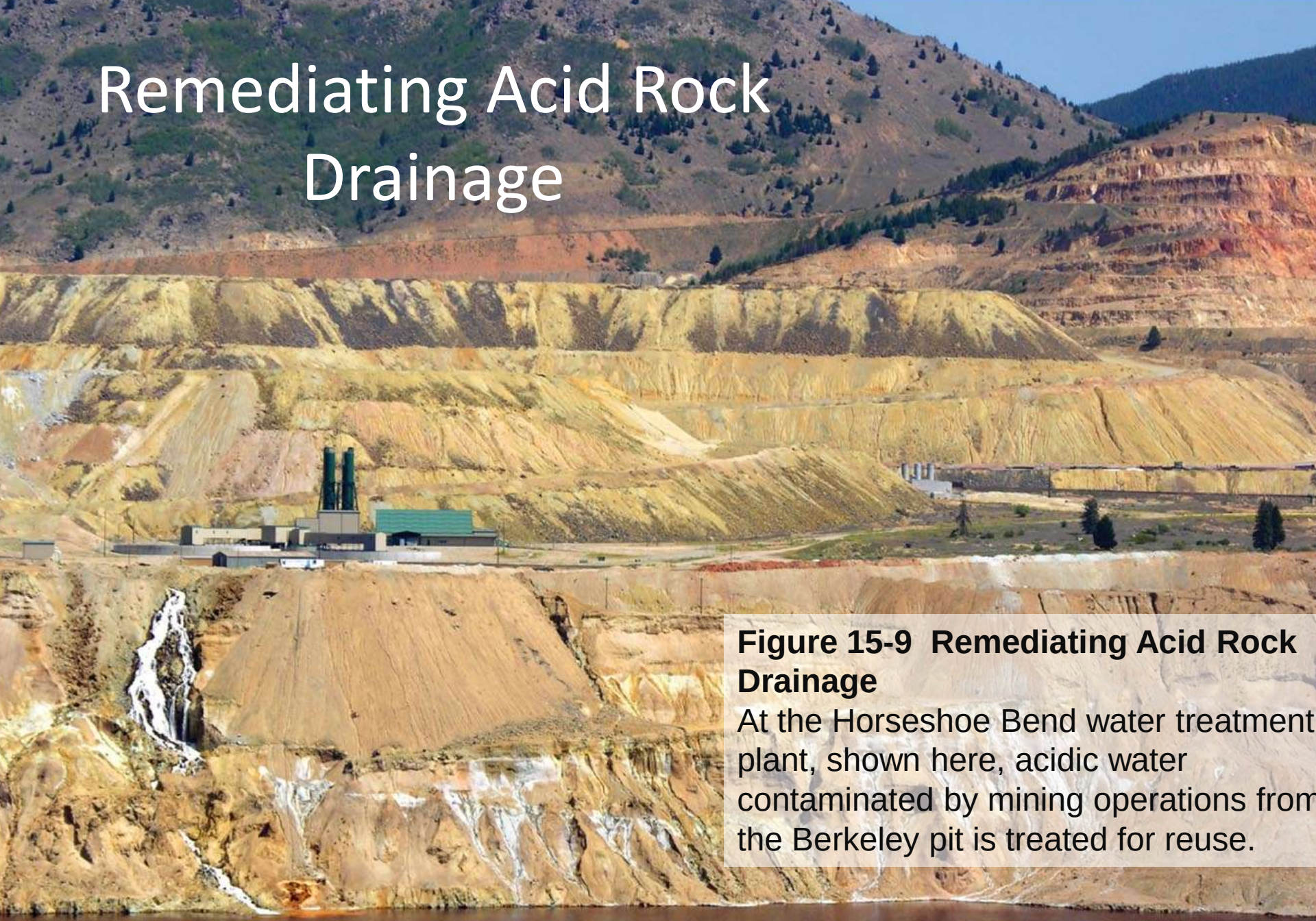


Figure 15-9 Remediating Acid Rock Drainage
At the Horseshoe Bend water treatment plant, shown here, acidic water contaminated by mining operations from the Berkeley pit is treated for reuse.

Water Quality Standards

TABLE 15-2 WATER QUALITY STANDARDS FOR DISCHARGE FROM THE HORSESHOE BEND WATER TREATMENT PLANT, BERKELEY PIT, BUTTE, MONTANA

Metal concentrations are given in micrograms per liter (parts per billion).

Contaminant	Average Pit Concentration	Discharge Standard
Aluminum	270,000	87
Arsenic	700	10
Cadmium	2100	0.8
Copper	180,000	30.5
Iron	900,000	1000
Nickel	1200	100
Uranium	700	30
Zinc	620,000	388
pH	2.7	6.5–9.5

Doe Run Lead, Copper, Zinc, Silver Mine – SE Missouri

Lined dams and special slurry ponds keep mining water Separated from natural streams and groundwater.

Permitting

- Regulatory agencies implement environmental standards through the permitting process. Permits are written permission from an agency to conduct an operation or action—and define how the action:
  - will be undertaken
  - how it will be monitored and reported
  - in many cases how it will be completed

Example: Washington state Environmental Permit Handbook

- 13 categories of permits
- A dozen or more in each category
- 21 different permits for water quality!

TABLE 15-4 THE ENVIRONMENTAL PERMIT CATEGORIES USED IN WASHINGTON STATE

- Air Quality Permits
- Aquatic Resource Permits
- Archaeology and Historic Preservation Permits
- Federal Requirements
- General Requirements
- Land Resource Permits
- Livestock Permits
- Local Permits
- Pesticide Permits
- Waste and Toxic Substance Permits
- Water Quality Permits
- Water Resource Permits
- Wetland Permits

Landfill Permitting in Kentucky

To determine if proposed landfill is consistent with the local county plan

1. Submit a Notice of Intent to the Division of Waste Management
2. Identify required permits (e.g., water discharge to transportation permits)
3. Proposed landfill site is characterized
4. General plan for developing the landfill is submitted to the lead regulatory agency, the Kentucky Division of Waste Management
5. Interested parties can submit comments about plan during 30-day comment period; **stakeholders** can request hearings at this stage
6. Finally, the technical details for the proposed landfill are submitted
7. If accepted by regulatory agency—another 30-day comment period
8. Perhaps—new "adjudicatory" public hearings
9. The proposed landfill finally will be/or not be approved
10. Another permit is required to operate the landfill

On average, the Kentucky landfill permitting process takes 18 to 24 months and $750,000 to $1,200,000 to complete!

Enforcement

- Environmental standards and regulatory permitting implement specific guidance to protect the environment, but it must be enforced.
  - Enforcement starts with the permits
    - **Penalties** for noncompliance and civil and criminal legal remedies
    - Regulatory agencies may **deny permit approval** for undertakings
  - **Permitted operations required to monitor and report performance**
    - Water **discharges are routinely tested** for amount of pollutants
    - Regulatory agencies can impose **financial penalties**
    - **Civil penalties** can also be imposed but these require court approval

Enforcement (cont.)

- Most serious environmental violations can be enforced by **criminal penalties**; individuals can be held accountable and penalties **include jail time and fines**
  - **Violations** include:
    - Filing false statements
    - Knowingly causing pollution that endangers people

How Do We Get People to Be Less Polluting and More Environmentally Conscience?

- Incentives:
  - To Earn Money
    - Business opportunities…
    - Pay people to recycle:
      - Deposits on things like plastic bottles, aluminum cans, or perhaps cardboard boxes…
    - Tax rebates and credits for things like electric vehicles, green power, heating/cooling sources…
    - Credits for not exceeding water quotas or for saving water over prescribed periods…
  - For Better Health…
  - To Follow Laws…
- Disincentives:
  - Losing Money or Opportunities by not participating.
  - Because of Bad Health Consequences.
    - Sickness or Death.
  - Being Penalized for not Following Laws.
    - Fines.
    - Jail time.
  - Peer Pressure.

Economics and Environmental Management

- Economic incentives and disincentives play significant roles in obtaining desired environmental outcomes
  - **Creating business opportunities**
  - **Making undesired actions more expensive**
  - **Using markets to achieve environmental objectives**
  - **Directly funding needed or preferred actions**

Business Opportunities

1. In situ uranium leaching

- 18% of the world's uranium deposits form in permeable sandstone
  - Groundwater with dissolved U encounters chemically reducing conditions.
  - Chemical reactions then cause uranium minerals to precipitate.
  - Mined using open-pit mining techniques
- In situ leaching technology:
  - Pumps oxidizing solutions through the deposit to dissolve the uranium.
  - Production wells recover the uranium-bearing solution
  - Ion-exchange mechanisms separate the uranium from the leach solution.

In Situ Uranium Leaching

- Solutions injected into U-bearing layer
  - dissolve uranium
  - are extracted through recovery wells
  - transferred to plants where the dissolved uranium is recovered
- In situ leaching technology accounts for about 20% of world's uranium production. Benefits include
  - controls underground flow of uranium-bearing solutions
  - restores groundwater conditions when uranium deposit is depleted
  - replaces conventional mining that creates surface disturbances such as open pits and waste rock

Figure 15-13

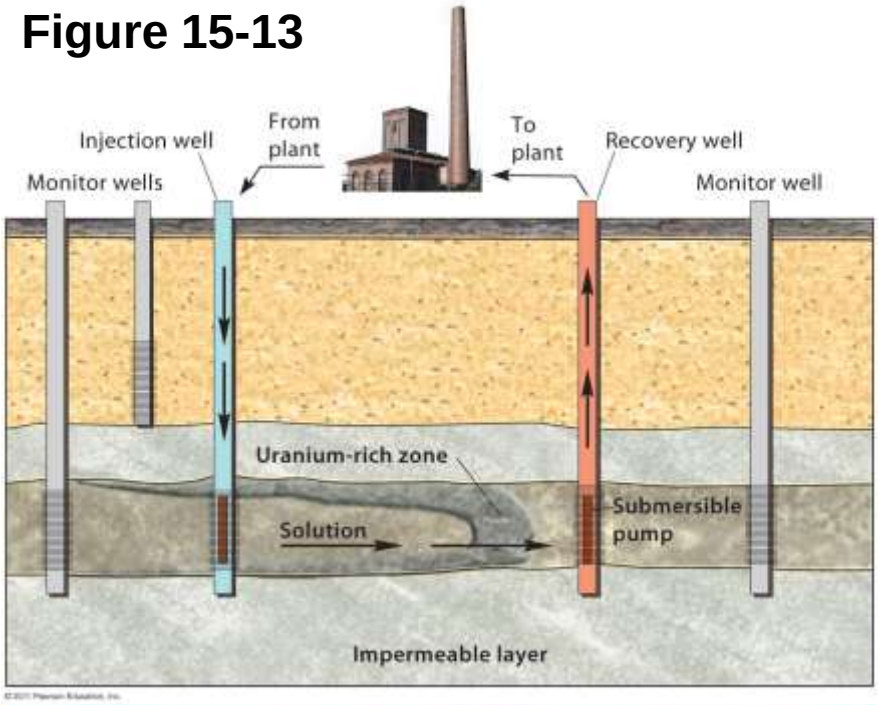


Figure 15-14

Business Opportunities (cont.)

2. Recycling consumer electronics

- A metric tonne (1000 kilograms, or 2205 lb) of cell phones contains:
  - 140 kilograms (309 lb) of copper $2.45/lb.
  - 3.1 kilograms (6.8 lb) of silver $17.35./oz.
  - 310 grams (10.6 oz) of gold $1675./oz.
- At recent metal prices, the gross value of this tonne of cell phones would be over $21,000!

Business Opportunities (cont.)

3. Landfill energy

- Landfills full of municipal solid waste generate significant amounts of methane. Nationwide, 400 landfills are producing energy from methane, like OPPD.
- Using this methane reduces greenhouse gas emissions by the equivalent of 24 million tonnes (26 million tons) of CO_2 annually. This is the amount of CO_2 emitted by 17 million cars in a year.

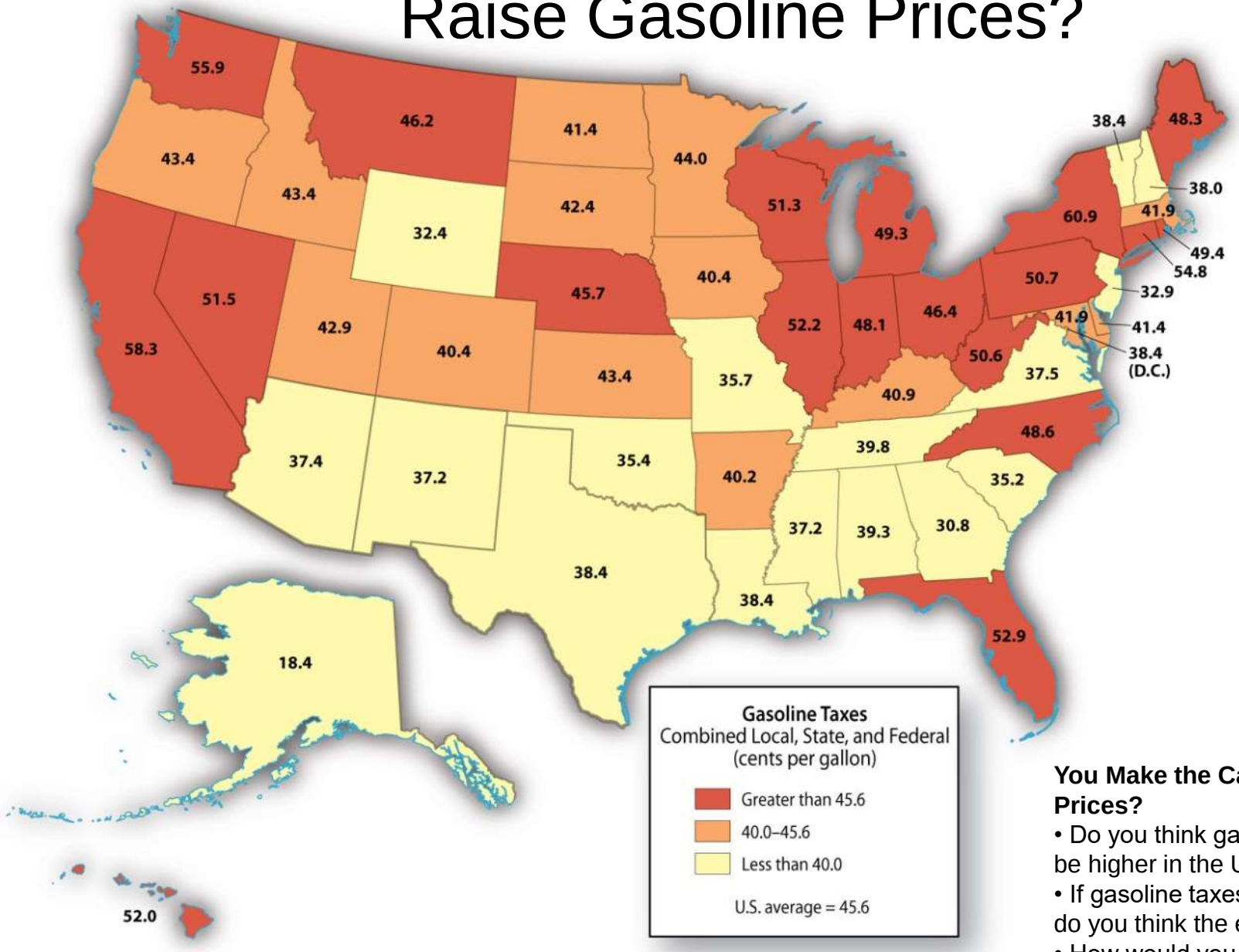
4. Waste water Biofuels – St. Cloud, MN

5. Ecotourism

- Ecosystem tourism can reduce/stop the degradation of natural places by shifting revenues. Example: Madagascar deforestation to ecotourism

Making undesired actions more expensive

Raise Gasoline Prices?



You Make the Call—Raise Gasoline Prices?

- Do you think gasoline taxes should be higher in the United States?
- If gasoline taxes were higher, what do you think the effects would be?
- How would you use the increased revenues from higher gasoline taxes?

Using Markets to Achieve Environmental Objectives

- Using pollution markets to deal with carbon emissions starts with a **cap and trade program**, by:
  - defining the amount of pollution that will be allowed (it sets a ***cap*** on the total amount of pollution)
  - allocating the right to emit specified amounts of pollution (credits or allowances) to individual polluters (such as an industrial manufacturer or a power company)
  - allowing companies to buy and sell (**trade**) the rights to release pollutants
- If a company emits less carbon than its allocation allows, it can sell its rights to the unused allocation to another company
- Conversely, if a company needs to emit more than it is allowed to, it can buy unused allocation from another company
- Thus, the total emissions cannot exceed the cap

Incentivizing Individuals?

- Everyone wants to be healthy and feel good.
  - Having clean water means people are healthier.
- Nobody wants to work harder to have the things they need.
  - Having clean water means less work.
- Everyone wants their children to be better off then they were.
  - Clean water and futures with clean water mean children have a better life and chance at being successful.
- People have to work in concert to achieve these goals.
  - You can't be healthy in an unhealthy environment…
  - Even the richest people have to drink the same water as poor people…
    - Nobody is immune from disease or sickness…

Recycling

- Extend the use of a finite resource
- Diminish environmental consequences of mineral resource development and production
- Note how little the U.S. recycles of these important metals!
- We can do better!
- When we recycle aluminum, we reduce the demand for mining more aluminum. That saves the environment from more mining!

TABLE 12-2 TOP RECYCLED METALS IN THE UNITED STATES, 2006

Commodity	Value	Percent of total annual consumption
Iron (and steel)	$36,100,000,000	55%
Aluminum	$21,800,000,000	40%
Copper	$20,800,000,000	31%
Nickel	$ 6,100,000,000	35%
Lead	$ 2,680,000,000	70%

Some of the oldest tricks are the best tricks…

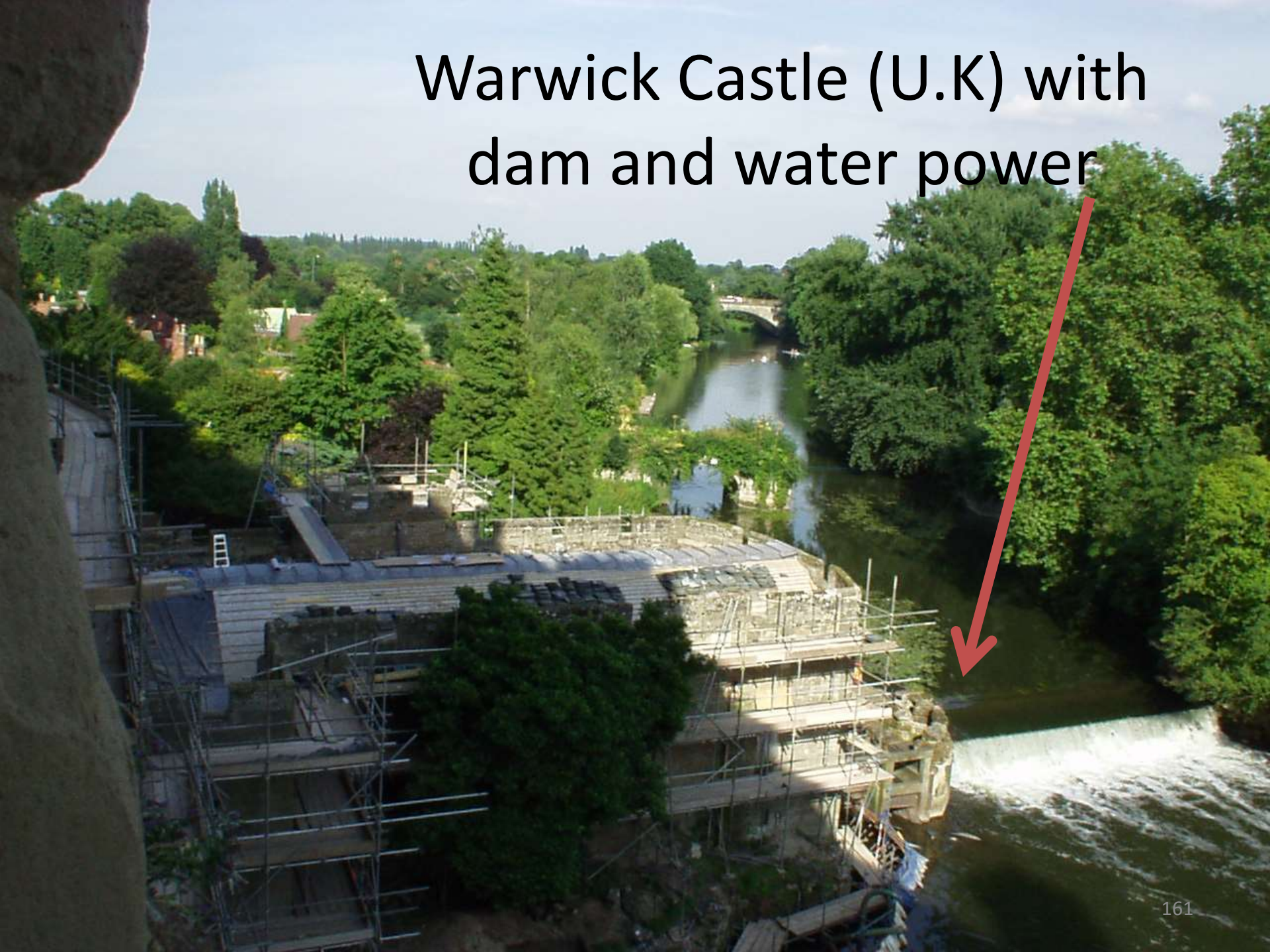
"cave people ~ paleo people" lived underground – Geothermal heat/cooling

Hydropower used to drive mills for grinding grains – now we generate electricity with it.

The wind used to drive windmills that milled grain or pumped water – now we use the wind to generate electricity…

Warwick Castle (U.K)

Warwick Castle (U.K) with dam and water power



Lake Mead and Hoover Dam

Hydroelectric Power

Figure 13-46 Hydroelectric Power
(a) To generate hydroelectricity, water is first trapped by dams, here on Kerr Dam—Flathead River, Montana.
(b) Some water is released, falls, and spins generators that produce electricity. Bonneville Dam—Columbia River near Portland, Oregon.

Figure 13-47 The Three Gorges Dam in China Largest hydropower electricity generator in the world.

Figure 13-48 A Wave Machine Generating Electricity off the Coast of Portugal

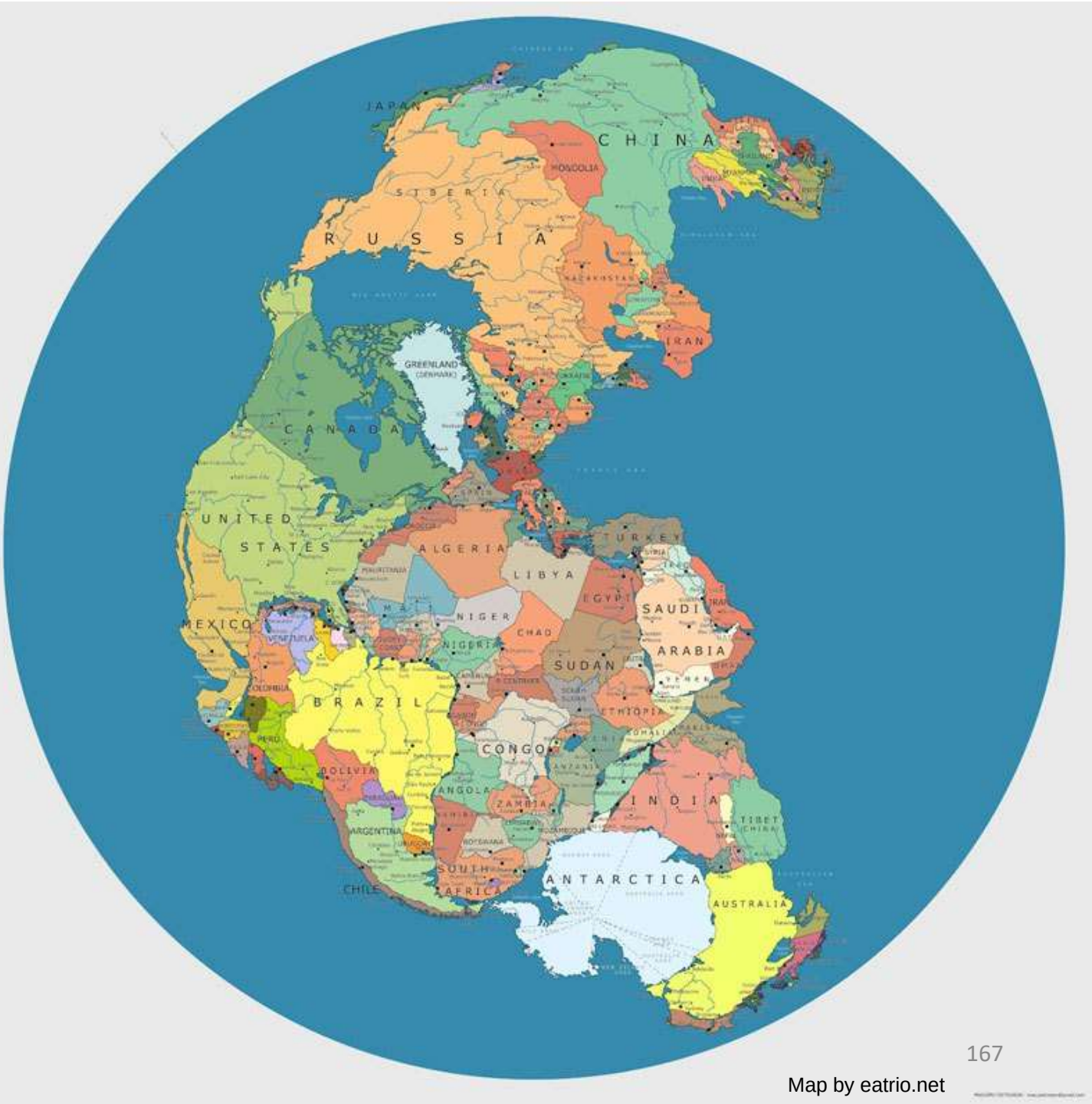
Watch This Film…

Switch

Do not live, buy, rent, or own property in an area prone to FLOODING!

NEVER DRINK UNFILTERED or UNPURIFIED WATER from a STREAM or RIVER!

Pangea redrawn with country borders… We are all neighbors on this island in space!



Map by eatrio.net

If you have questions about this material or anything else, don’t hesitate to write, call, or otherwise communicate with me.

I am here for **you**.

If you need my help in **any way**, tell me and **I will listen and help**.