Environmental Geology, November 8

Revision of the syllabus:

Wednesday, 11/8—Groundwater pollution

Friday, 11/10—Groundwater pollution

Monday, 11/13--Wetlands

Supply of Water Resources

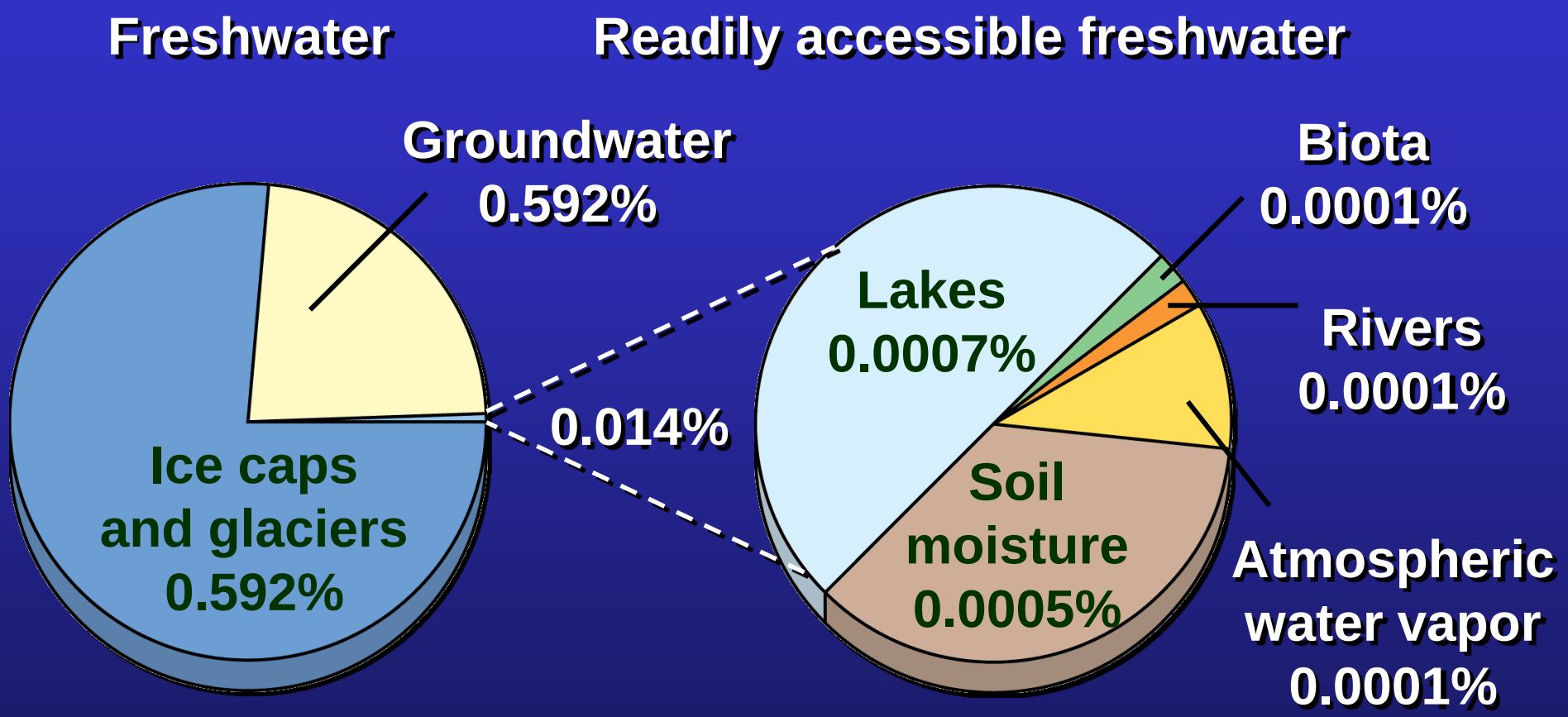


Fig. 15-2 p. 307

Use of Water Resources

- Humans use about 54% of reliable runoff
- Agriculture
- Industry
- Domestic
- Power plants

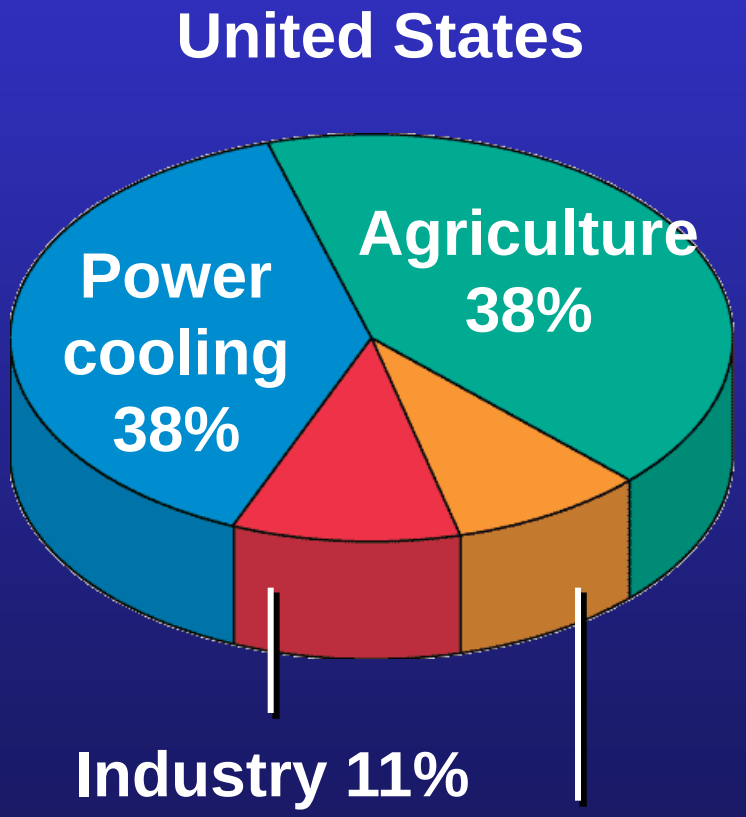


Fig. 15-4 p. 309

Ground Water

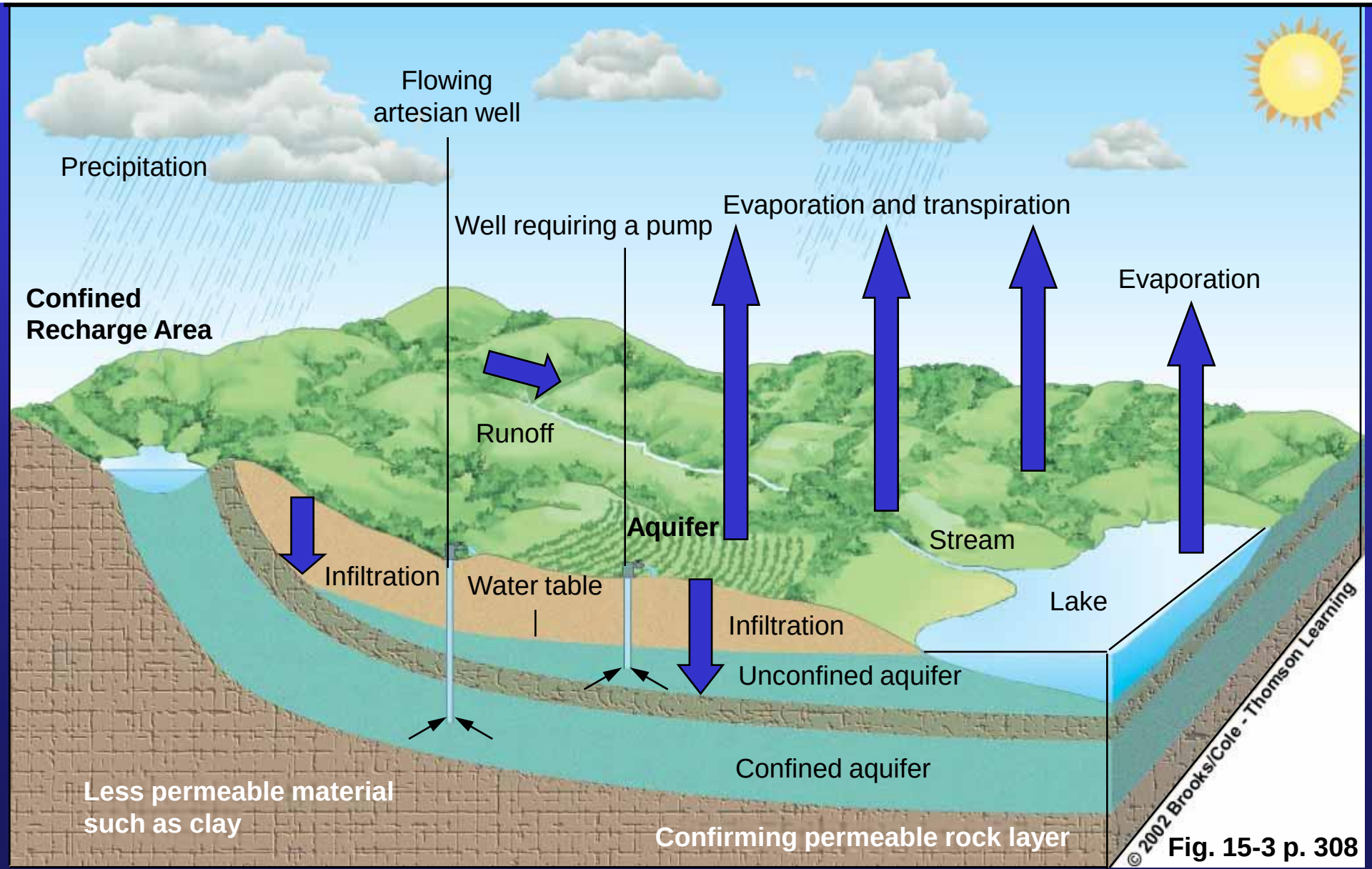


Fig. 15-3 p. 308

Water Resources

- Over the last century
  - Human population has increased 3x
  - Global water withdrawal has increased 7x
  - Per capita water withdrawal has increased 4x

  - About one-sixth of the world's people don't have easy access to safe water
  - Most water resources are owned by governments and are managed as publicly owned resources

Too Little Water

- Dry climate
- Drought
- Desiccation
- Water stress

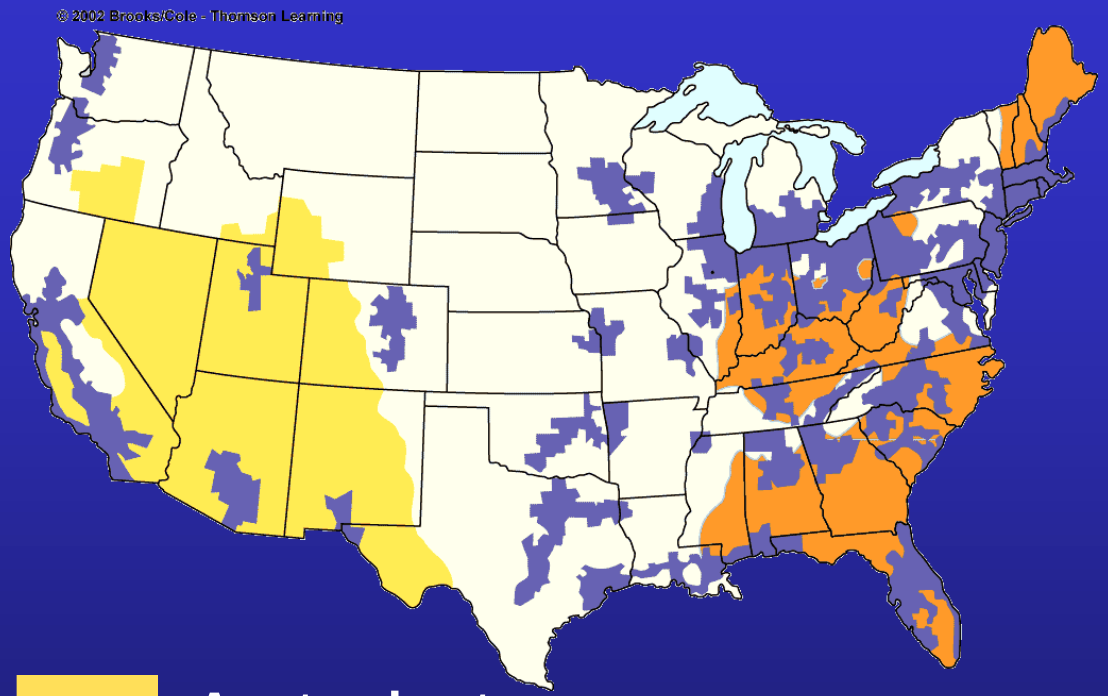


Fig. 15-6 p. 310

Human water needs

- A person needs about 1 gallon water/day for hydration
- In the US each person uses about 188 gallons/day
- An additional 657 gallons/person/day are used for irrigation, industrial use.
- Total per capita use is about 2000 gal/person/day
- If world's water supply were 100 liters, the usable supply would be about 0.5 tsp
- US has highest per capita water withdrawal, followed by Canada, Australia, Russia, Japan

Problems with Using Groundwater

- Water table lowering
- Depletion
- Subsidence
- Saltwater intrusion
- Chemical contamination
- Reduced stream flows

Groundwater Pollution

- >70,000 chemicals are used not; effects of many are not known
- Each year another 700-800 new chemicals are produced
- 55 million tons of hazardous chemical wastes are produced in the US each year
- The 20 most abundant compounds in groundwater at industrial waste disposal sites include TCE, benzene, vinyl chloride…all are carcinogens, and also affect liver, brain, and nervous system

Kinds of Water Pollution

- Inorganic Pollutants
- Organic Pollutants
- Biologic Pollutants

Inorganic Pollutants

- Examples:
  - Pb in gasoline
  - Radionuclides
  - Phosphorus, nitrogen (Great Lakes)
  - Other heavy metals

Inorganic Pollutants

- 3 groups
  - 1) Produce no heavlth effects until a threshold concentration is exceeded—e.g., NO_3 –ook at , 50mg/liter; at higher levels: methaemoglobinaemia
  - 2) No threshold—e.g.—genotoxic substances: some natural and synthetic organic compounds, microorganic compunds, some pesticides, arsenic
  - 3) Essential to diets: F, I, Se—absence causes problems, but too much also causes problems

Inorganic Trace Contaminants

- Mercury—methyl Hg and dimethyl Hg in fish—probably most significant path to humans—Minamata Bay, Japan, 1950's
- Rhine River drains 185,000 sq km—heavily polluted by 1970's
- Lead—toxicity has been known for a long time
  - 1859 book
  - Tetraethyl lead—anti-knowck additive for gas, 1930-1966

Radionuclides

- Bikini Atoll in South Pacific: > 20 tests, 1946-1958
  - Inhabitants evacuated before 1946 tests; their descendents are still exiled
  - Atmospheric testing of nuclear weapons is now banned

National labs…now trying to clean up (Hanford)

Phosphates and Nitrates

- Phosphates—mostly a result of sewage outflow and phosphate detergents
  - Additional phosphate grows excess algae…oxygen depletion, Lake Erie…1972 phosphate management plant…$7.6 billion
- Nitrates—sewage and fertilizers

Case Study: The Great Lakes

How water is used

- In the western US, irrigation makes up 85% of all water use

  --50% to grow food for livestock

  -- 35% to grow crops

Not sustainable…cost of water is heavily subsidized by the federal government

Organic Pollutants

- Three classes of compounds
  - Pesticides and Herbicides
  - Materials for common household and industrial use
  - Materials for industrial use

Scale of Pesticide Use in US

- Since 1959: 50-fold increase in pesticide use
- Most present pesticides are 10-100 x more toxic than those used in 1050's
- About 25% of pesticide use in US is in houses, gardens, lawns, parks, swimming pools, and golf courses
- Average lawn receives 10x more pesticides than equivalent area of cropland

Pesticides--more

- Each year about 250,000 people are admitted to hospitals and/or emergency rooms with pesticide poisoning
- Broad spectrum vs narrow spectrum
- Persistence

Each Year in the US

- About 2.4 million tons of pesticides are used
- 600 active chemicals mixes with 1200 solvents, ‘inactive’ ingredients
- About 25000 commercial pesticide products

Pesticides

- Chlorinated hydrocarbons
  - DDT, heptachlor, etc—2-15 years
- Organophosphates
  - Malathion, methyl parathion—1-2 weeks
- Carbamates
  - Carbaryl, maneb, aldicarb—days to weeks
- Pyrethroids
  - Pemethrin, decamethrin—days to weeks

Herbicides

Contact

Triazines—e.g. atrazine, paraquat

(interfere with photosynthesis)

Systemic—phenoxy compounds, N compounds, Alar, glyphosate

(create excess growth hormones)

Soil sterilants

trifluralin, dalapon

(kill soil microorganisms)

Advantages of Modern Pesticides

- Save human lives (malaria, bubonic plague, typhoid fever)
- Increase food supplies (even now 55% of world's potential food supply is 'lost' to other species)
- Increase profit for farmers ($1investment ➔$4 increased profit
- They work fast

Disadvantages of Modern Pesticides

- They accelerate the development of genetic resistance to pesticides by pest organisms

  Since 1945, ~1000 species of insects and rodents and 550 species of weeds and plant diseases
- They can put farmers on a financial treadmill
- Some kill natural predators and parasites that control 'pests'
  - 300 most destructive insects in US: 100 were once minor
- They don't stay put

  —only 0.1 to 2% of stuff applied reaches target insect, 5% reaches target plant—the rest—into air, water, humans, wildlife

Disadvantages, continued

- Harm wildlife
  - USDA, USFWS: each year pesticides wipe out about 20% of honeybee population, damage another 15%, losing US farmers about $200 million/yr. Kill 6-14 million fish, ~67 million birds/year
- Threaten human health

--Poison 3.5-5 million workers in developing countries, and at least 300,000 in US; cause about 20000-40000 deaths (about 25 in US) per year. Prob greatly underestimated.

--In food causes about 4000-20000 cases of cancer/year in US (Nat'l Academy of Sciences); genetic mutations, birth defects, nervous systems disorders, endocrine disorders.

How they're regulated

- EPA, USDA, FDA
- Federal Insecticide, Fungicide, and Rodenticide Act (1947, 1972)
- Fewer than 10% of active ingredients have been evaluated
- 1996—Food Quality Protection Act—Requires EPA to reduce allowed levels of residues on food by a factor of 10 if inadequate info about effects on children
- Poor enforcement; National Academy study: ~98% of potential cancer risk would be eliminated if EPA standards were as strict for pre-1972 chemicals as they are for later ones.
- Big problem—chemicals banned in US can be manufactured here and shipped to other countries

Roundup (glyphosate)

- Two recent studies: Roundup disrupts hormones and is associated with birth defects in humans

- Farm families that applied pesticides to their crops in Minnesota were studied to see if their elevated exposure to pesticides caused birth defects in their children. Both fungicides and the herbicide Roundup -- were linked to statistically significant increases in birth defects. Roundup was linked to a 3-fold increase in neurodevelopmental (attention deficit) disorders. (Environmental Health Perspecitves, v 110, p. 441-449)

- Roundup interferes with a fundamental protein StAR (steroidogenic acute regulatory protein). The StAR protein is key to the production of testosterone in men (thus controlling male characteristics, including sperm production) but also the production of adrenal hormone (essential for brain development), carbohydrate metabolism (leading to loss or gain of weight), and immune system function. The authors point out that "a disruption of the StAR protein may underlie many of the toxic effects of environmental pollutants." [EHP Vol. 108, No. 8 (August 2000), pgs. 769-776.]

Organic Pollutants

- Three classes of compounds
  - Pesticides and Herbicides
  - Materials for common household and industrial use
  - Materials for industrial use

PCB's

- Polychlorinated biphenyls
- 1940's-1977: GE
- Congress banned production of PCB's in 1979 b/c highly toxic to fish and mammals
- Striped bass in NY, Long Island—PCB's>5 ppm; ban on commercial fishing; Great Lakes

Monitoring water quality

- Number of colonies of fecal coliform bacteria
- Bacterial source tracking (BST)
- Measure biological oxygen demand (BOD)
- Chemical analysis
- Indicator species
- Genetic development of indicator organisms

Biologic Contaminants

- Greater obvious problems than organic and inorganic contaminants in US
- April, 1993, Milwaukee—cryptosporidium (parasite)—source: water plant with a water intake pipe <2mi from a sewage treatment plant; 400,000 ill people, 42 deaths

Scale of Biologic Contaminant Problem

- Major cause of infant deaths in third world
- Diarrhea kills 4-15 million children/year
- Bacteria, viruses, parasites
- Tables 12-9 and 12-10 from Holland and Peterson

Federal Water Legislation

- Refuse Act of 1899

  Refuse only into ‘navigable water’
- Federal Water and Pollution Control Act of 1956
- Fish and Wildlife Coordination Act of 1958

  consider wildlife in water projects
- National Environmental Policy Act of 1969

  require environmental impact statements

Legislation, continued

- Water Quality Improvement Act of 1970

  --control of oil pollution; work to eliminate acid mine drainage, pollution of Great Lakes
- CLEAN WATER ACT OF 1972

  --billions of $ to clean up nation's waters; modern sewage treatment plants—huge affect
- Comprehensive Environmental Response, Compensation, and Liability Act of 1980

  ---superfund!

More legislation

- Hazardous and Solid Waste Amendments to CERCLA of 1984

  --regulates underground storage tanks
- Water Quality Act of 1987

  --national policy for controllling nonpoint sources of water pollution
- Safe Drinking Water Act of 1996

  --risk-based water quality standards, consumer awareness

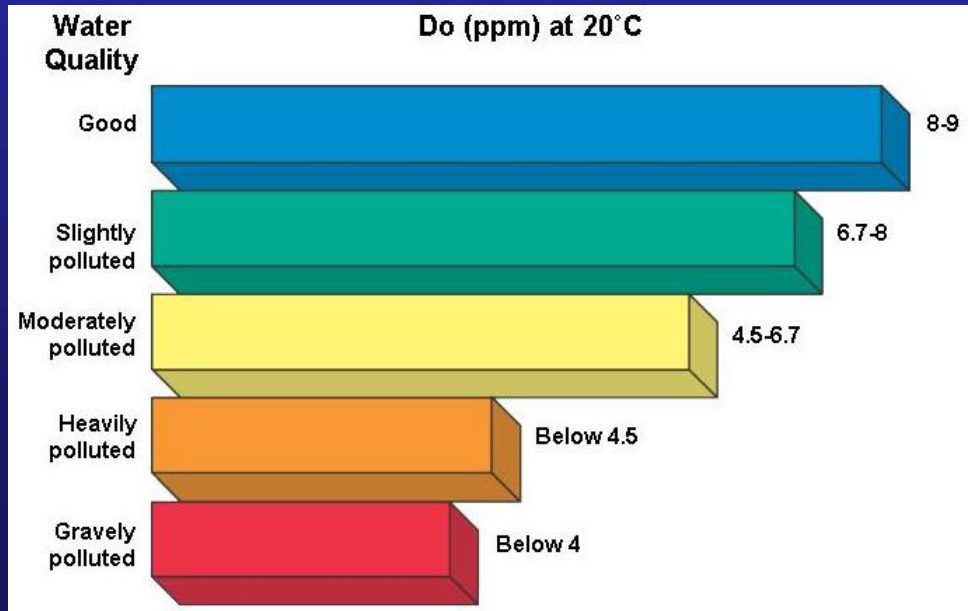
Love Canal

- Landfill near Niagara Falls, NY
- Hooker Chemicals and Plastics Corporation put wastes in abandoned canal, covered it, deeded 16 acres to Niagara Falls Board of Education in 1953.
- Elementary school built on site; houses built around school
- 1976—chemicals leaking into basements
- Env emergency declared in 1978
- State and federal gov’ts bought >500 contaminated houses in 1980; 1989 people began to return

Types, Effects and Sources of Water Pollution

- Point sources
- Nonpoint sources
- Water quality

Fig. 22-3 p. 494



Point and Nonpoint Sources

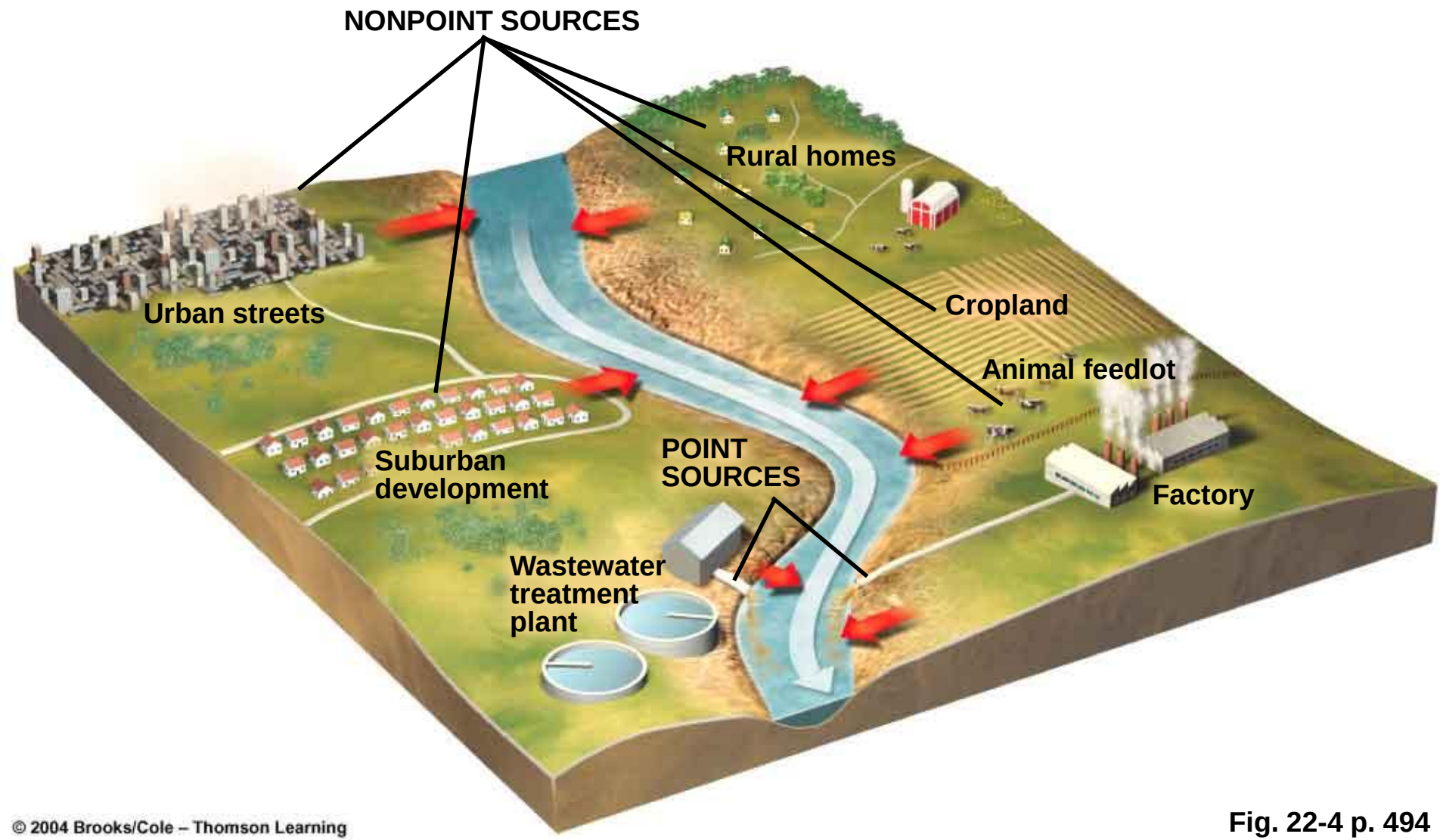


Fig. 22-4 p. 494

$23 billion/year for 8-10 years to bring clean drinking water to those who don't have it

- Consequences of a warmer world
- Pollution of freshwater streams
- Dilution and biodegradatoin
- Breakdown of pollutants by bacteria—oxygen sag curve

Point source vs non-point source pollution; developed vs non-developed

Developing countries: half of world's 500 major rivers are heavily polluted

Solutions: Preventing and Reducing Surface Water Pollution

Nonpoint Sources

- **Reduce runoff**
- **Buffer zone vegetation**
- **Reduce soil erosion**

Point Sources

- **Clean Water Act**
- **Water Quality Act**

Pollution of Lakes

Eutrophication

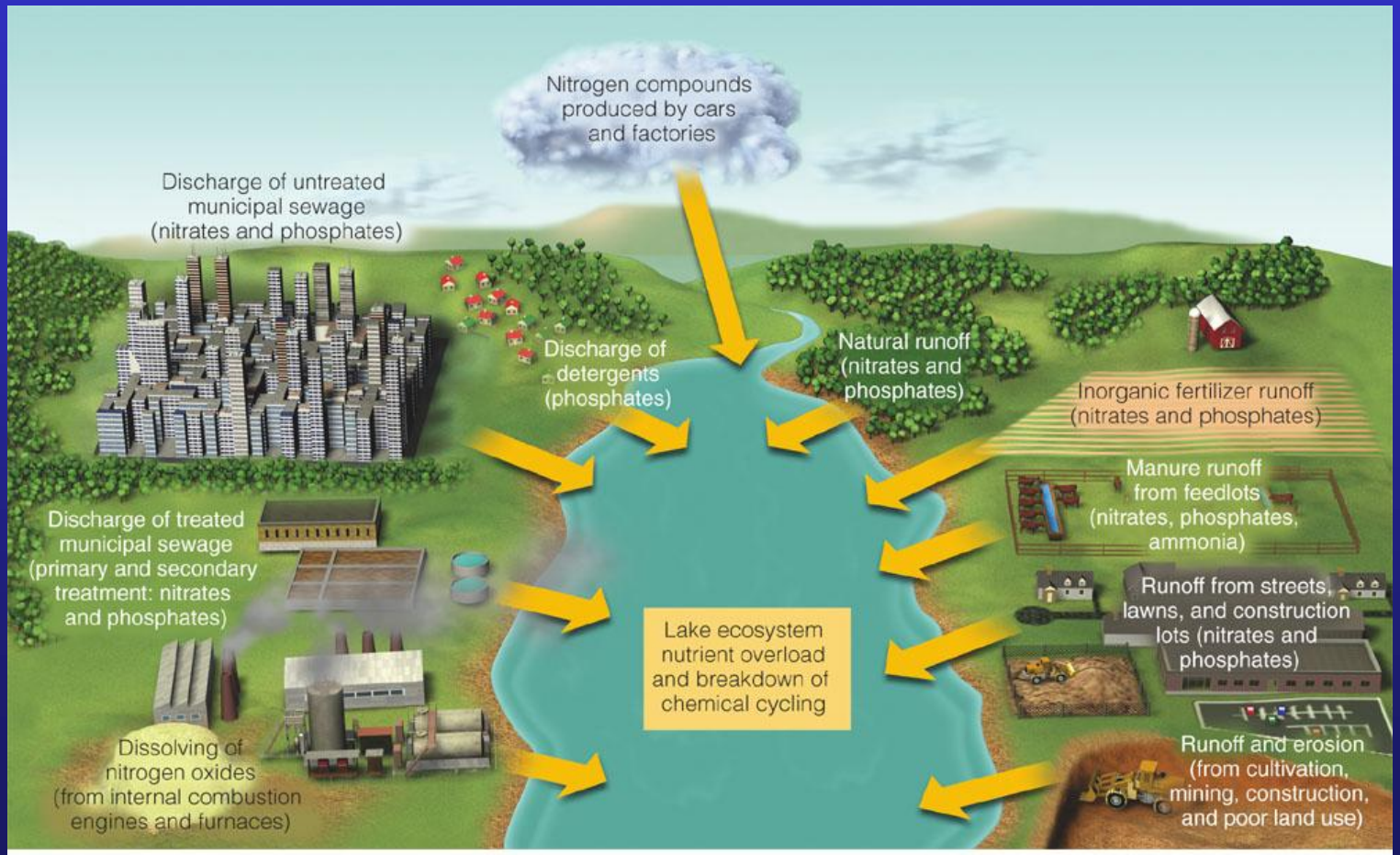


Fig. 22-7 p. 499

Groundwater Pollution: Causes

- Low flow rates
- Low oxygen
- Few bacteria
- Cold temperatures

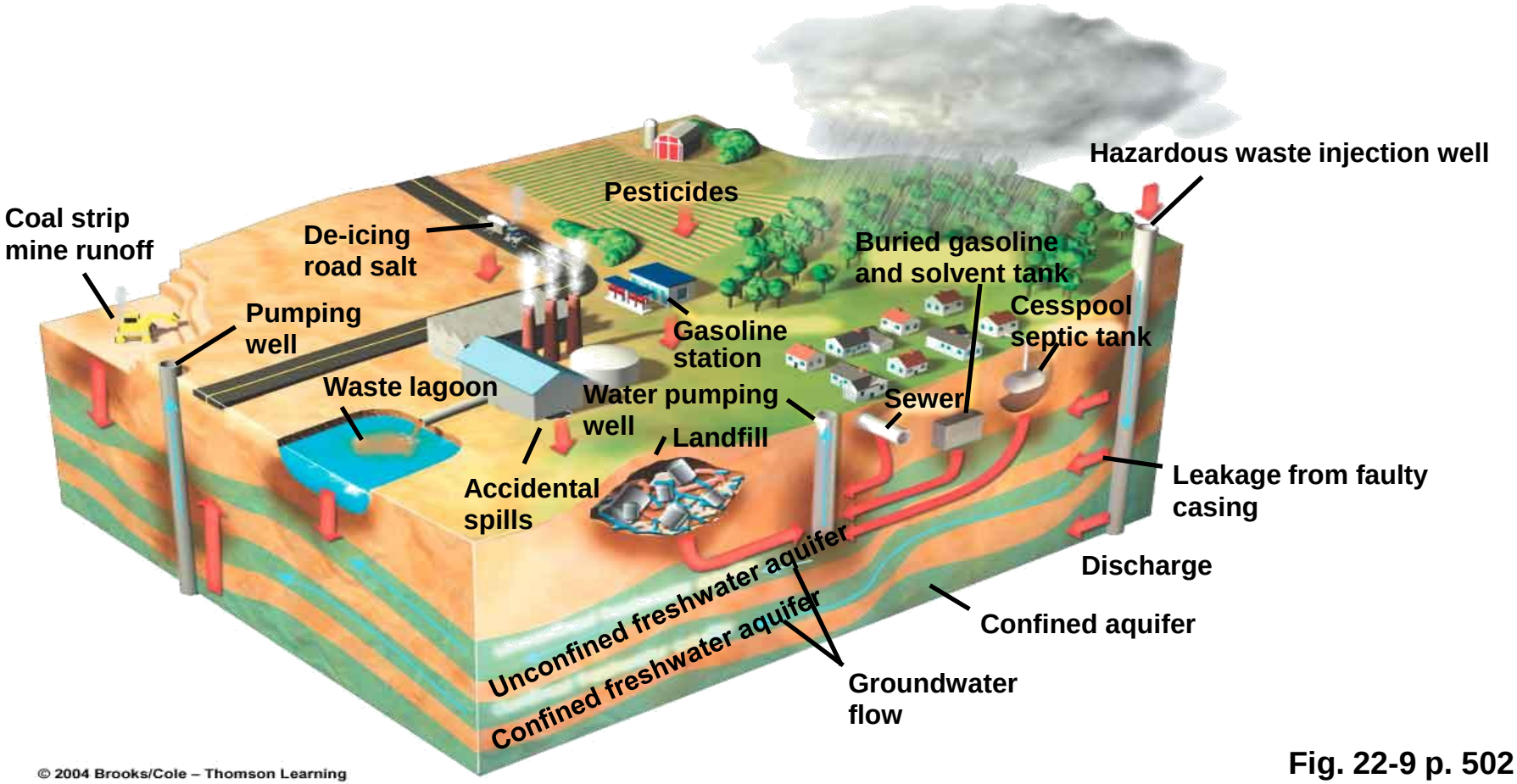


Fig. 22-9 p. 502

Groundwater Pollution Prevention

- Monitor aquifers
- Find less hazardous substitutes
- Leak detection systems
- Strictly regulating hazardous waste disposal
- Store hazardous materials above ground

One or more organic chemicals contaminate about 45% of municipal groundwater supplies in the US

About 26000 industrial waste ponds in US do not have liners

Leaking undergraound storage tanks

Nitrates, fluoride, arsenic

Case Study: Chesapeake Bay

- Largest US estuary
- Relatively shallow
- Slow "flushing" action to Atlantic
- Major problems with dissolved O_2

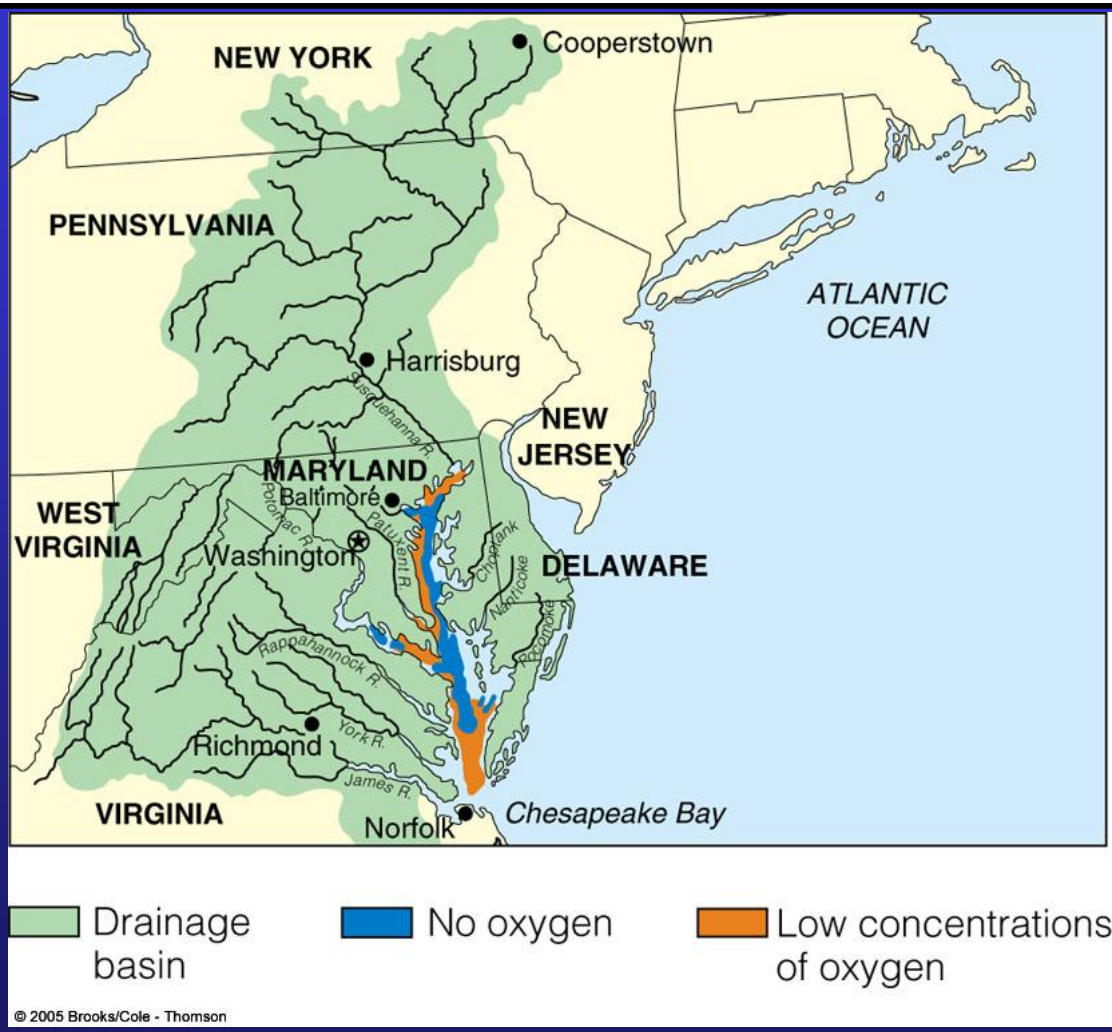


Fig. 22-13 p. 506

Ocean Pollution

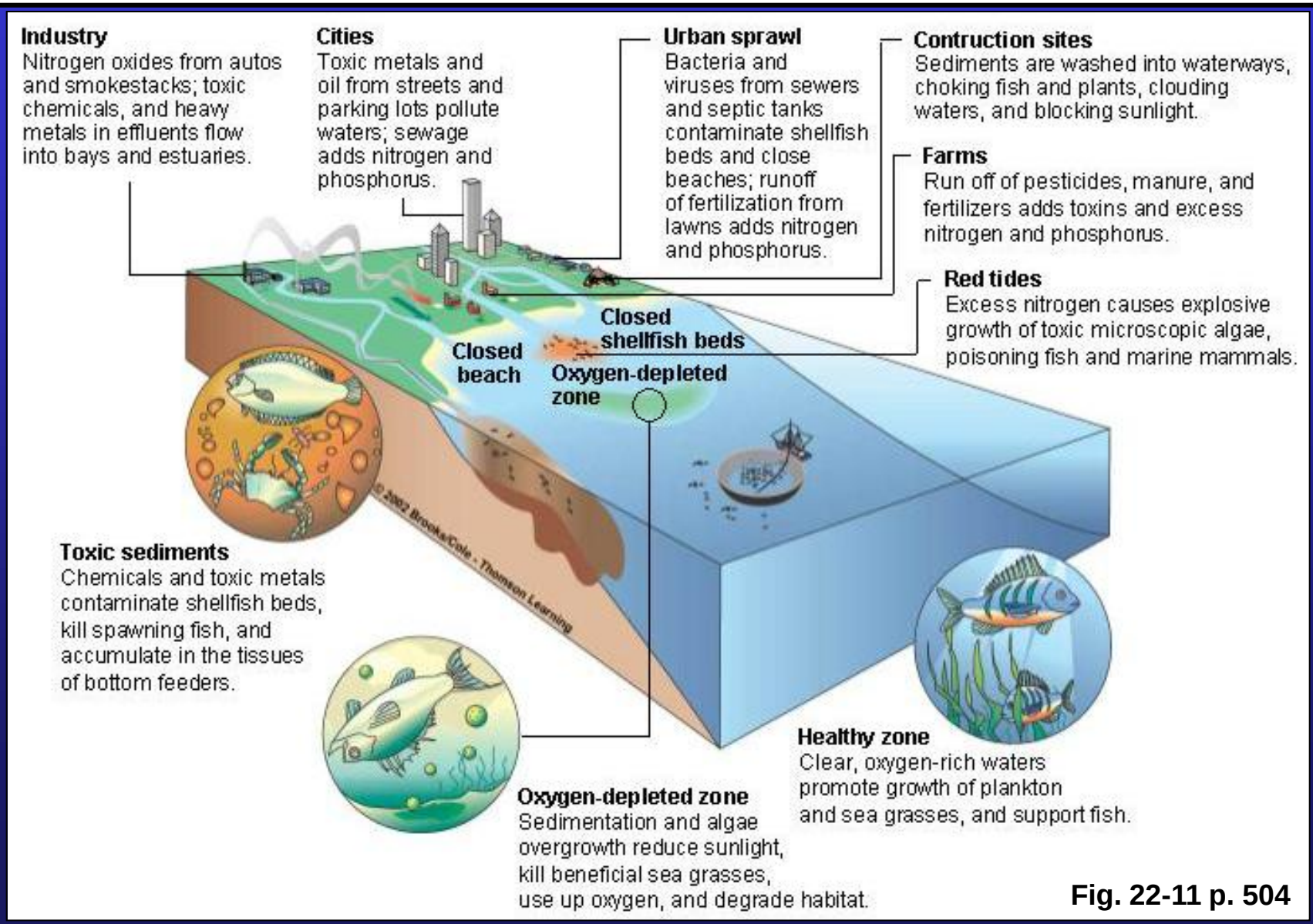


Fig. 22-11 p. 504

Dumping wastes in the oceans

- Dumping industrial wastes off US coasts has stopped, but dredge products are legally dumped at 110 sites in Atlantic, Pacific, and Gulf Coasts
- US has banned dumping sewage sludge in ocean since 1992
- 50 countries rep ~80% of world's shipping fleet have agreed not to dump sewage and garbage
- London Dumping Convention of 1972; 1994

Oil Spills

- Sources: offshore wells, tankers, pipelines and storage tanks
- Effects: death of organisms, loss of animal insulation and buoyancy, smothering
- Significant economic impacts
- Mechanical cleanup methods: skimmers and blotters
- Chemical cleanup methods: coagulants and dispersing agents

Oil Pollution in the Oceans

- Oil Pollution Act of 1990
- Only about 15% of an oil spill can now be recovered
- Crude oil—3 years
- Refined oil– 10-20 years

Exxon Valdez

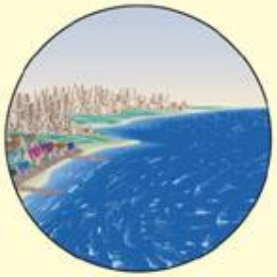
- 1989; contaminated about 1500 km of coastline; Prince William Sound
- $8 billion cost to Exxon
- 2006—17 years later, still toxic patches of oil along some parts of shoreline
- Still—largest source of oil pollution is runoff from land!

Solutions

Coastal Water Pollution

Prevention

- Reduce input of toxic pollutants
- Separate sewage and storm lines
- Ban dumping of wastes and sewage by maritime and cruise ships in coastal waters
- Ban ocean dumping of sludge and hazardous dredged material
- Protect sensitive areas from development, oil drilling, and oil shipping
- Regulate coastal development
- Recycle used oil
- Require double hulls for oil tankers



Cleanup

- Improve oil-spill cleanup capabilities
- Sprinkle nanoparticles over an oil or sewage spill to dissolve the oil or sewage without creating harmful byproducts (still under development)
- Require at least secondary treatment of coastal sewage
- Use wetlands, solar-aquatic, or other methods to treat sewage

Reducing water pollution

- Non point source
- Septic tanks and sewers

Reducing agriculturally produced pollution

- 2002: feed lot ruling
- Credit trading
- Agricultural: soil erosion, reforestation, cover crops, reduced fertilizers and pesticides, buffer zones

Technological Approach: Septic Systems

- Require suitable soils and maintenance

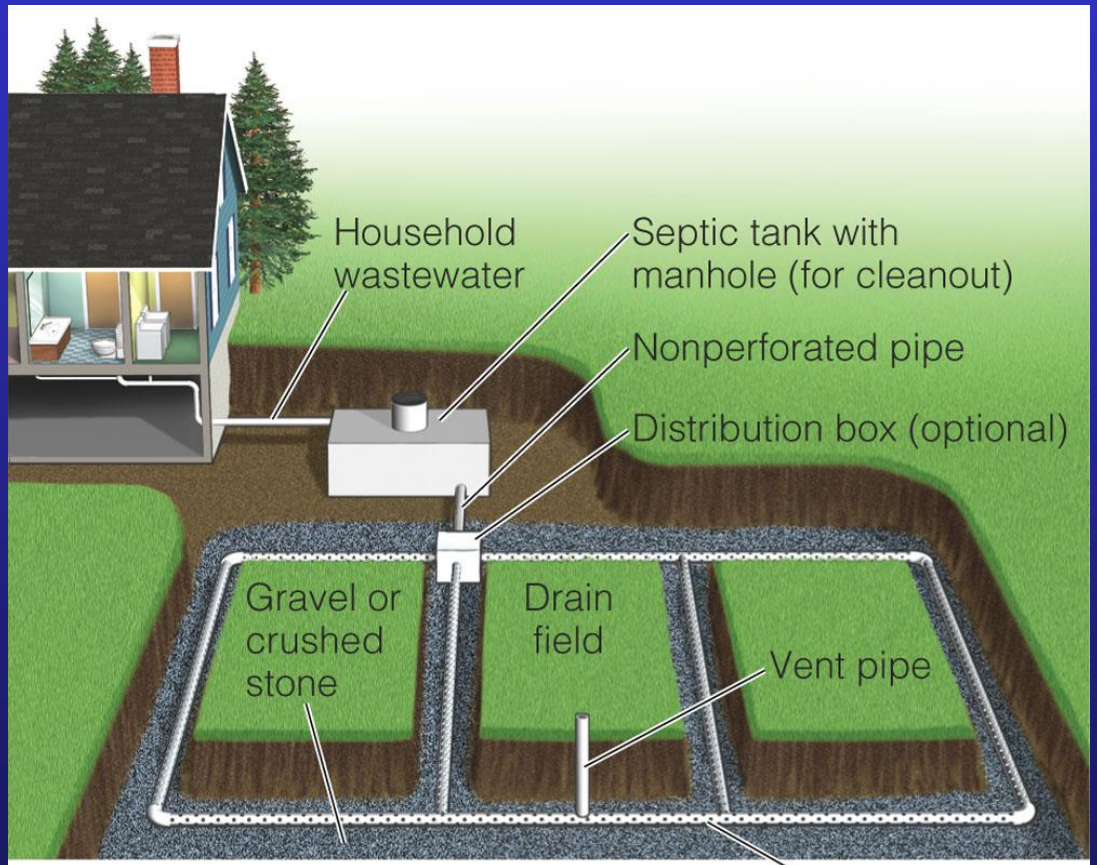
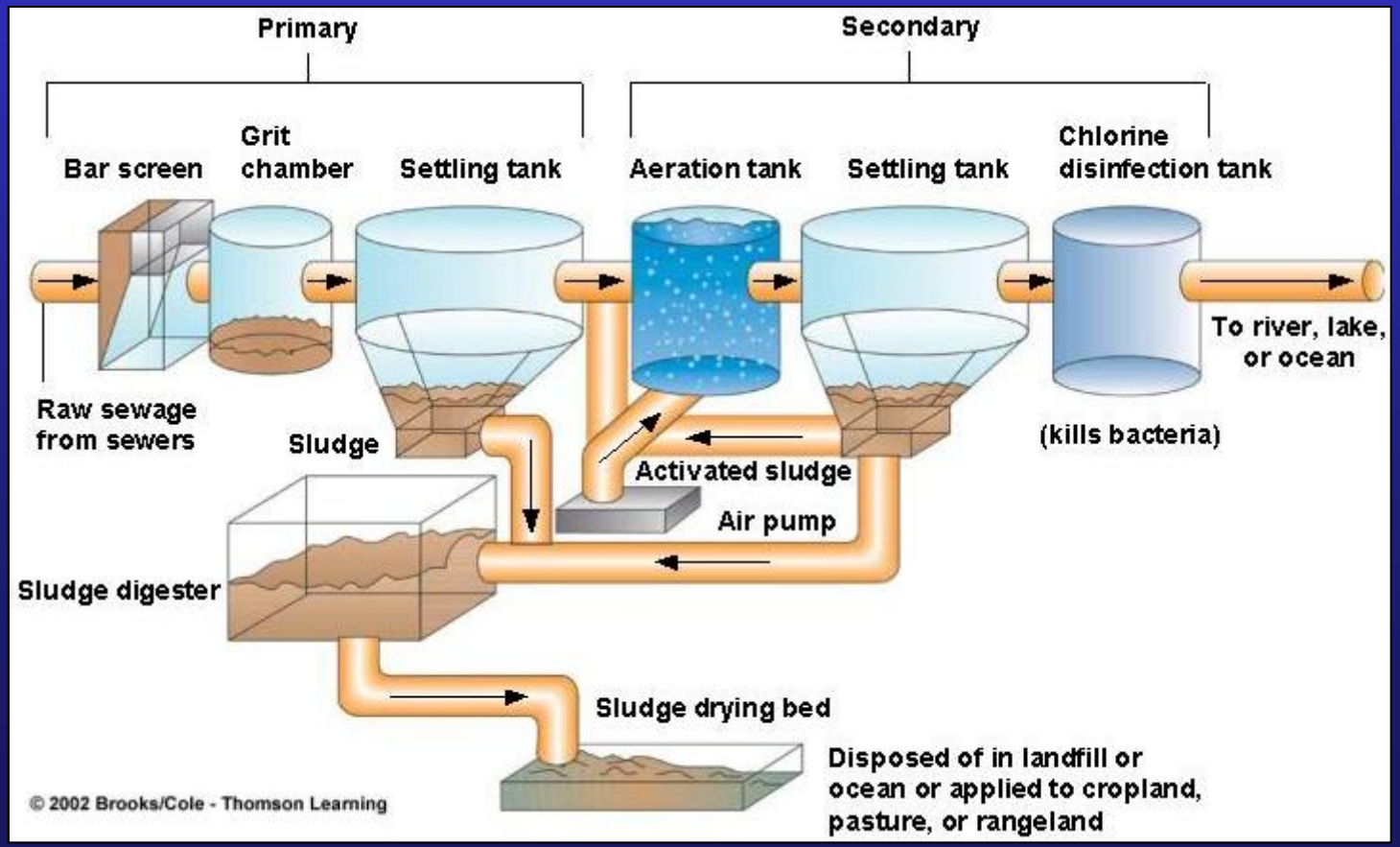


Fig. 22-15 p. 510

Sewage Treatment

- **Physical and biological treatment**

Fig. 22-16 p. 511



Advanced (Tertiary) Sewage Treatment

- **Uses physical and chemical processes**
- **Removes nitrate and phosphate**
- **Expensive**
- **Not widely used**

Technological Approach: Using Wetlands to Treat Sewage

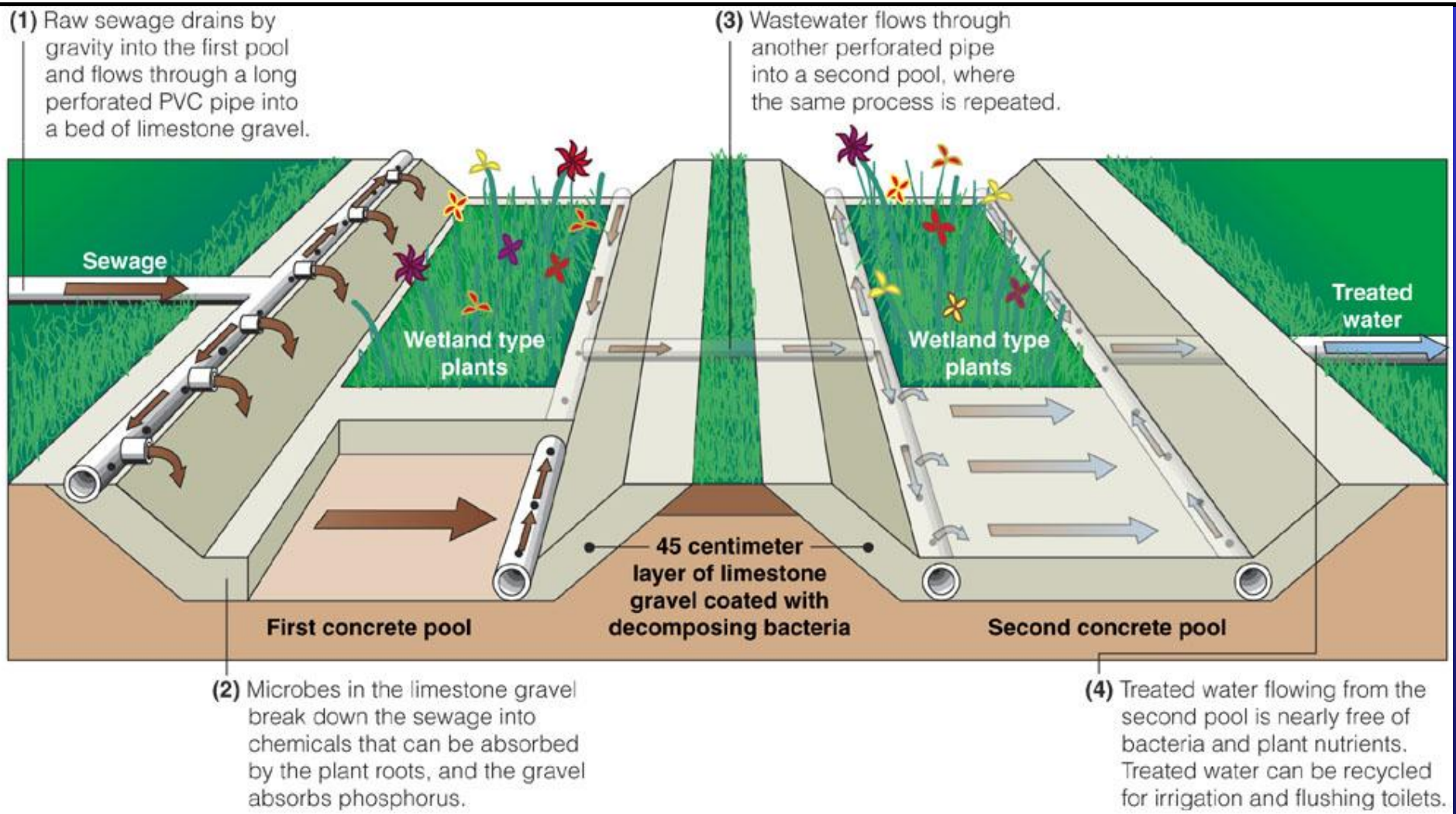


Fig. 22-18 p. 513

Drinking Water Quality

- Purification of urban drinking water
- Protection from terrorism
- Purification of rural drinking water
- Safe Drinking Water Act
- Maximum contaminant levels (MCLs)
- Bottled water

Solutions

Water Pollution

- Prevent groundwater contamination
- Greatly reduce nonpoint runoff
- Reuse treated wastewater for irrigation
- Find substitutes for toxic pollutants
- Work with nature to treat sewage
- Practice four R's of resource use (refuse, reduce, recycle, reuse)
- Reduce resource waste
- Reduce air pollution
- Reduce poverty
- Reduce birth rates

Wetlands

Home to ~33% of nation's threatened and endangered species

Statistics— 50% loss since 1900 in US; cities on filled wetlands; rising sea level

Mitigation banking—Nat'l Academy: ~half of attempts to build a wetland fail.

More than 500 wetland restoration banks in US

Virtues of Wetlands

- Home to wildlife and flora
- Flood protection
- Cycling and storage of chemical and biological substances
- Found at heads of rivers
- Remove toxins from sewage

How Wetlands are Destroyed

- Mostly by draining for development or farming
- To ‘reclaim’ land along coastlines

Wetlands Protection

A federal permit is required to fill or to deposit dredged material into wetlands occupying more than 3 acres. (Cut average annual wetland loss by 80% between 1969 and 2002)

Continuing efforts to weaken wetlands protection

- **Using unscientific criteria to classify wetlands**
- **Only about 6% of remaining inland wetlands are federally protected; laws are weak**
- **Mitigation banking**

The Everglades

- ~77,000 sq km; 3 sub-basins
- Thin sheet of water 40-60 miles wide
- Formed ~5000 yrs ago--how
- Human influences:

  late 1880's—first dredging

  1907 and 1928: canals—saltwater; draining south of Lake O.

  1961-1971: Kissimee River channelized
- 65% now drained
- Plants and animals depend on water level timing—seriously disturbed
- Number of species of wading birds—dropped 95% since 1947

Wetlands Protection Laws

- Clean Water Act of 1972: provisions, enforcement
- Food Security Acts of 1985 and 1990
- Wetland Reserve Program of 1990
- Jan 9, 2001 Supreme Court decision: Solid Waste Agency of Northern Cook County vs. US Army Corps of Engineers
- Oct 31, 2001 Army Corps of Engineers Regulation Guidance Letter
- January 15, 2002 --new NWP's
- 2002, 2003, March, 2005—Clean Water Authority Restoration Act—in response to Supreme Ct. decision

Protecting, Sustaining, and Restoring Wetlands

- Regulations
- Wetlands protection
- Mitigation banking
- Wetlands restoration
- Control of invasive species

Threats besides draining

- Millinery: Harriet L. Hemenway and Minna B. Hall—1896
- Fertilizers; sugar industry
- Non-native plants: melaleuca—from Australian—used by developers to drain wetlands.

Everglades Legislation

- 1988: US Federal Lawsuit against Florida
- 1991: US and Florida action against growers
- 1994: Everglades Forever Act
- 2000: Passage of Everglades Restoration Investment Act
- 2003: Proposed amendments to 1994 and 2000 acts