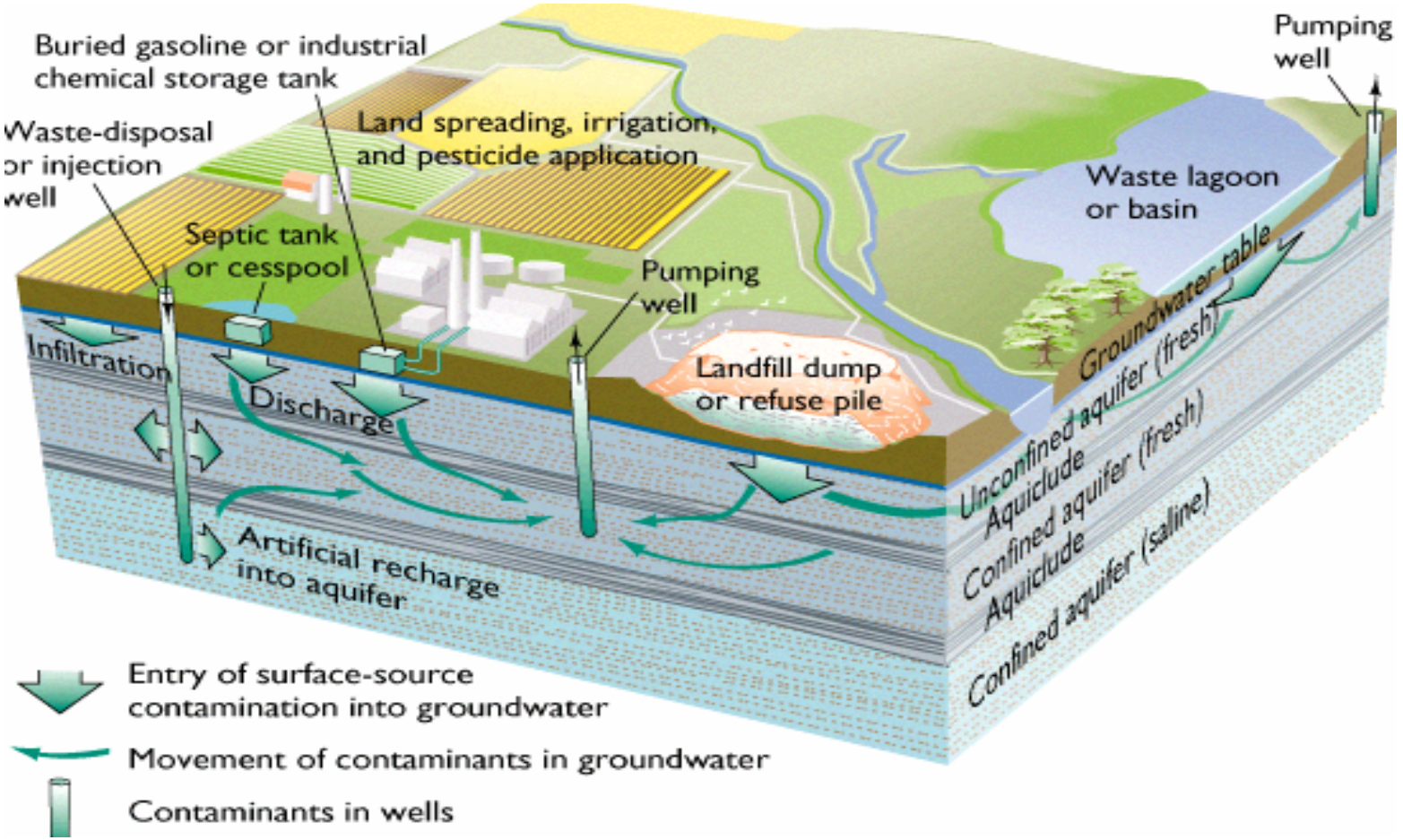
Aquifer Contamination

Sources of Contamination

Industrial, Municipal, Medical & Agricultural



Sources of Contamination

Mining, Military & Radioactive

Types of Groundwater Contaminants

- Organic compounds like
  - Aliphatic hydrocarbons
  - Aromatic hydrocarbons
  - Alcohols
  - Halogenated hydrocarbons
  - Other organic compounds

    (Refer to Bedient et al, 1999, Groundwater contamination: transport & remediation and Domenico & Schwartz, 1998, Physical and chemical hydrogeology)

- Inorganic compounds like
  - Nitrates
  - Trace elements

Organic Compounds
Aliphatic Hydrocarbons

- Major Compounds
  - Methane (CH_4)
  - Ethane (H_3CCH_3)
  - Propane ($H_3CCH_2CH_3$)
  - Halogenated CH_4 hydrocarbons

Organic Compounds
Aromatic Hydrocarbons

- Major Compounds (major constituents of petroleum-related products)
  - BTEX
    - Benzene
    - Toluene
    - Ethyl benzene
    - Xylene (ortho, meta, para-types)
- Environmental Risks
    - Benzene ➔ Carcinogen and toxic ➔ Liver damage, leukemia, skin irritant, and nerves system disorder.
    - Benzene ➔ Phenol (by oxidation reaction in the liver) ➔ highly toxic & non-biodegradable compound
    - Toluene ➔ moderately toxic (less toxic than benzene)

Organic Compounds
Aromatic Hydrocarbons

- Major Compounds (major constituents of petroleum-related products, asphalts, coal tar, creosote, and incomplete consumption of fossil fuel)
  - PAH (Polycyclic Aromatic Hydrocarbons)
    - Naphthalene
    - Phenanthrene
    - Benzo-a-pyrene
- Environmental Risks
  - Similar to BTEX health risks

Organic Compounds
Aromatic Hydrocarbons

- Major Compounds (associated with energy industry, was banned in the US in 1977)
  - PCBs (PolyChlorinatedBiphenyls)
- Environmental Risks
  - Resistant to chemical, thermal, and biological degradation
  - Persists in the environment

Organic Compounds
Alcohols

- Major Compounds (act as a solvent for other organics like NAPLs, and biodegradable)
  - Methanol (CH3OH)
  - Ethanol (C_2H_5OH)
  - Isopropyl (C_3H_7OH)
- Environmental Risks
  - Miscible with water
  - Potential for significant mobility

Organic Compounds
Halogenated Hydrocarbons

- Major Compounds (associated with industrial sites where solvents, cleansers, and degreasers are used. They may occur as byproducts from other chlorinated compounds in the production of plastics)
  - Tetrachloroethylene or perchloroethylene (PCE)
  - Trichloroethylene (TCE) ➔ degradation product of PCE
  - 1,2 Dichloroethylene (1,2 DCE)
  - Vinyl Chloride ➔ degradation product of chlorinated ethenes
  - Dichlorobenzene ➔ product of odor control chemicals used in toilets
- Environmental Risks
  - Halogenated hydrocarbons ➔ variable toxicity ➔ central nervous system, liver, and kidney disorders.
  - Vinyl Chloride ➔ Carcinogen and toxic ➔ central nervous system, liver, respiratory system, lymph system, and blood disorders.
  - Dichlorobenzene ➔ respiratory system, eyes, skin and liver disorders.

Organic Compounds
LNAPL

- LNAPL: Light Non Aqueous Phase Liquid
  - Gasoline spills
  - Refining industries
- LNAPL Characteristics
  - An organic compound that has a specific gravity < water's specific gravity
  - Floats on top of water table
  - Biodegradable under natural conditions
  - Naturally attenuated within a span of several years
- Examples
  - BTEX
  - Some aliphatic compounds

Organic Compounds

LNAPL Conceptual Model

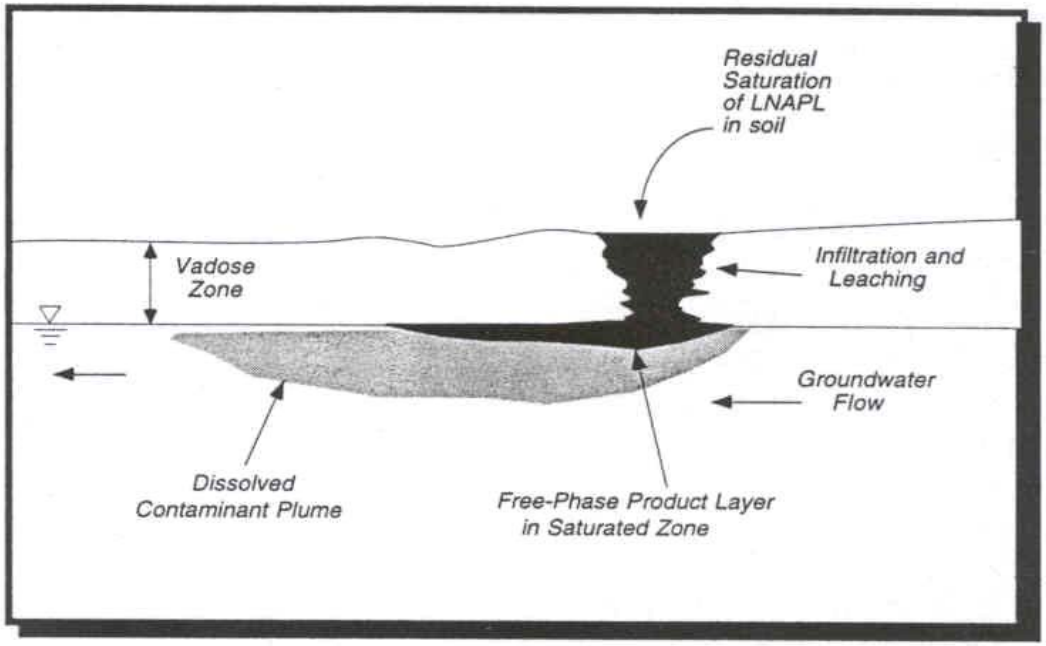


Figure 11.3 Conceptual model of LNAPL release.

Organic Compounds
DNAPL

- DNAPL: Dense Non Aqueous Phase Liquid
  - Chemical manufacturing
  - Degreasing agents
  - Pesticide production
  - Chlorinated solvents
- DNAPL Characteristics
  - An organic compound that has a specific gravity > water's specific gravity
  - Dense and viscous ➔ spreadable in the aquifer compared to LNAPL
  - Non biodegradable under natural conditions ➔ travels for longer distances and times in the aquifer
  - Can penetrate low permeability zones ➔hard to remediate
- Examples
  - PAH
  - PCB
  - EDC

Organic Compounds

DNAPL Conceptual Model

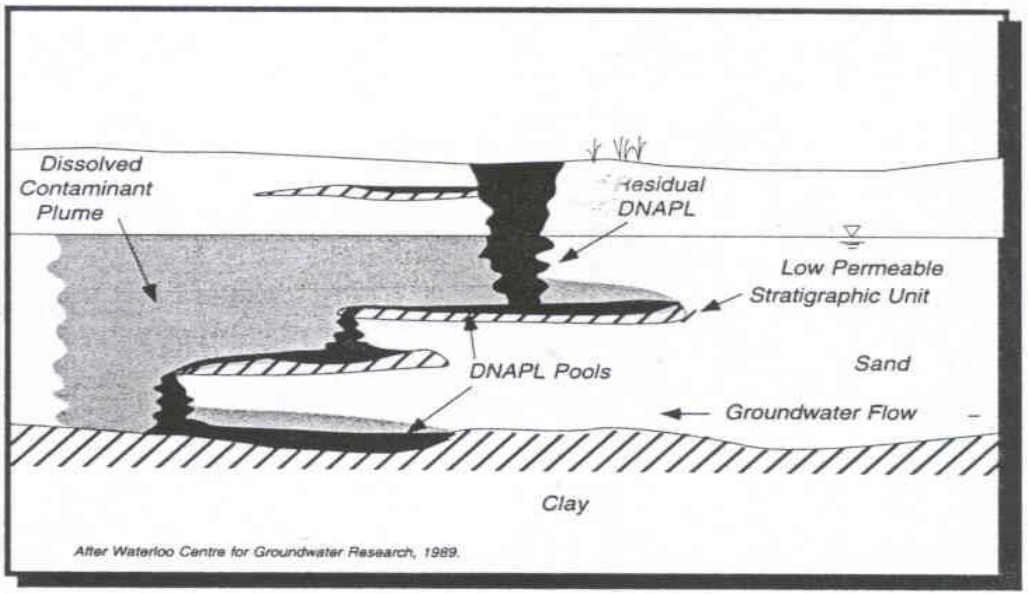


Figure 11.4 Conceptual model of DNAPL release. Source: Waterloo Centre for Groundwater Research, 1991.

Inorganic Compounds

- Major Compounds (associated with industrial, municipal and agricultural activities)
  - Nitrates ➔ fertilizers, sewage wastes, animal feedlots and septic tanks
  - Arsenic ➔ mining and mineral processing (phosphate, copper, lead, and gold)
  - Lead ➔ gasoline and lead pipes
  - Mercury ➔ discarded batteries, labs and fungicides & pesticides.
- Environmental Risks
  - Very toxic to human
  - Some of them are soluble (e.g. nitrates)
  - Great mobility

Remediation and Site Cleanup

- Key considerations:
  - Contaminated site will never be cleaned up completely, and
  - Cleanups actions are limited by funds available.

  As a result, develop a criteria to select sites that pose the greatest risks to public health. This is implemented by the application of **Risk Assessment** to:
    - Assess environmental impacts, and
    - Characterize the adverse health effects of human exposure to environmental hazards.