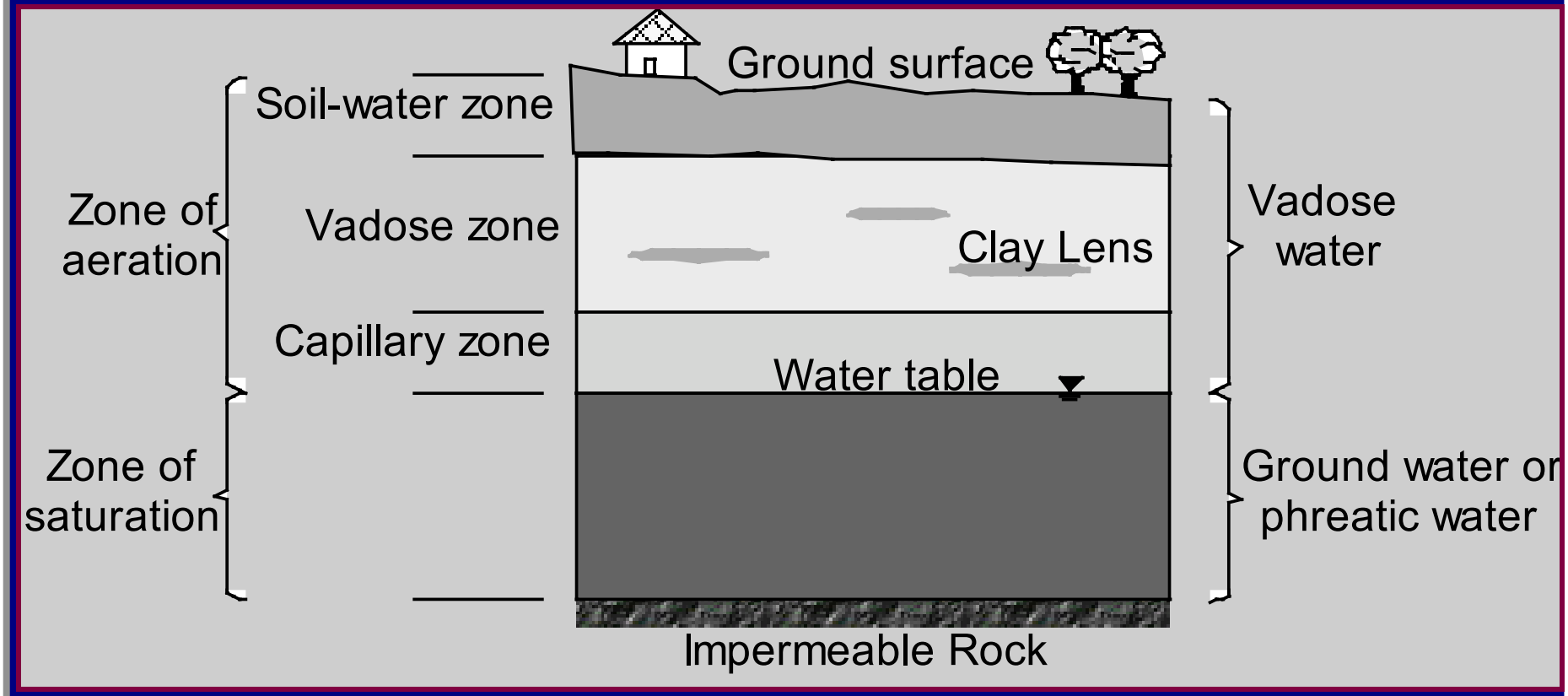
Ground Water Flow & Contamination: Introduction

Amended by Dr. Fuentes

after Original by Dr. Philip B. Bedient

(+2005)

Vertical Distribution of GW

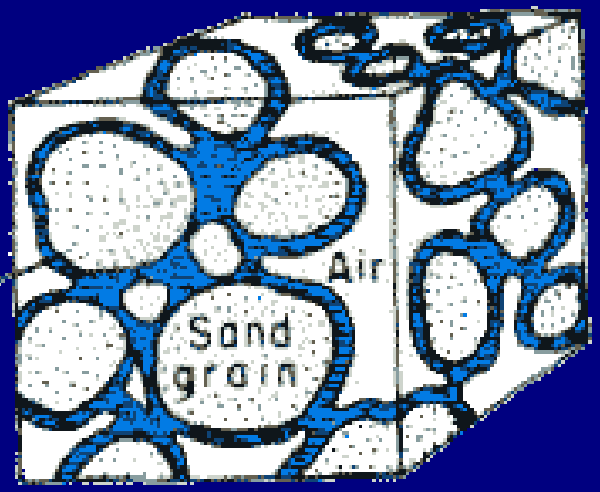


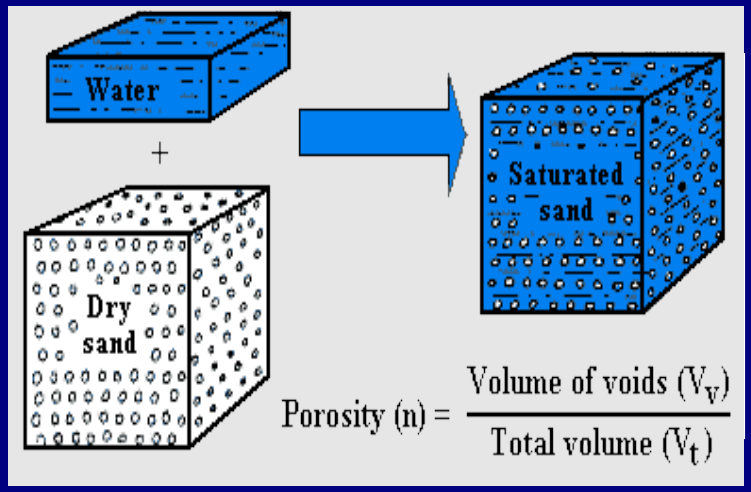
Vertical Zones of Subsurface Water

- Soil water zone: extends from the ground surface down through the major root zone, varies with soil type and vegetation but is usually a few feet in thickness
- Vadose zone (unsaturated zone): extends from the surface to the water table through the root zone, intermediate zone, and the capillary zone
- Capillary zone: extends from the water table up to the limit of capillary rise, which varies inversely with the pore size of the soil and directly with the surface tension

Porosity

Water





Soil Classification Based on Particle Size

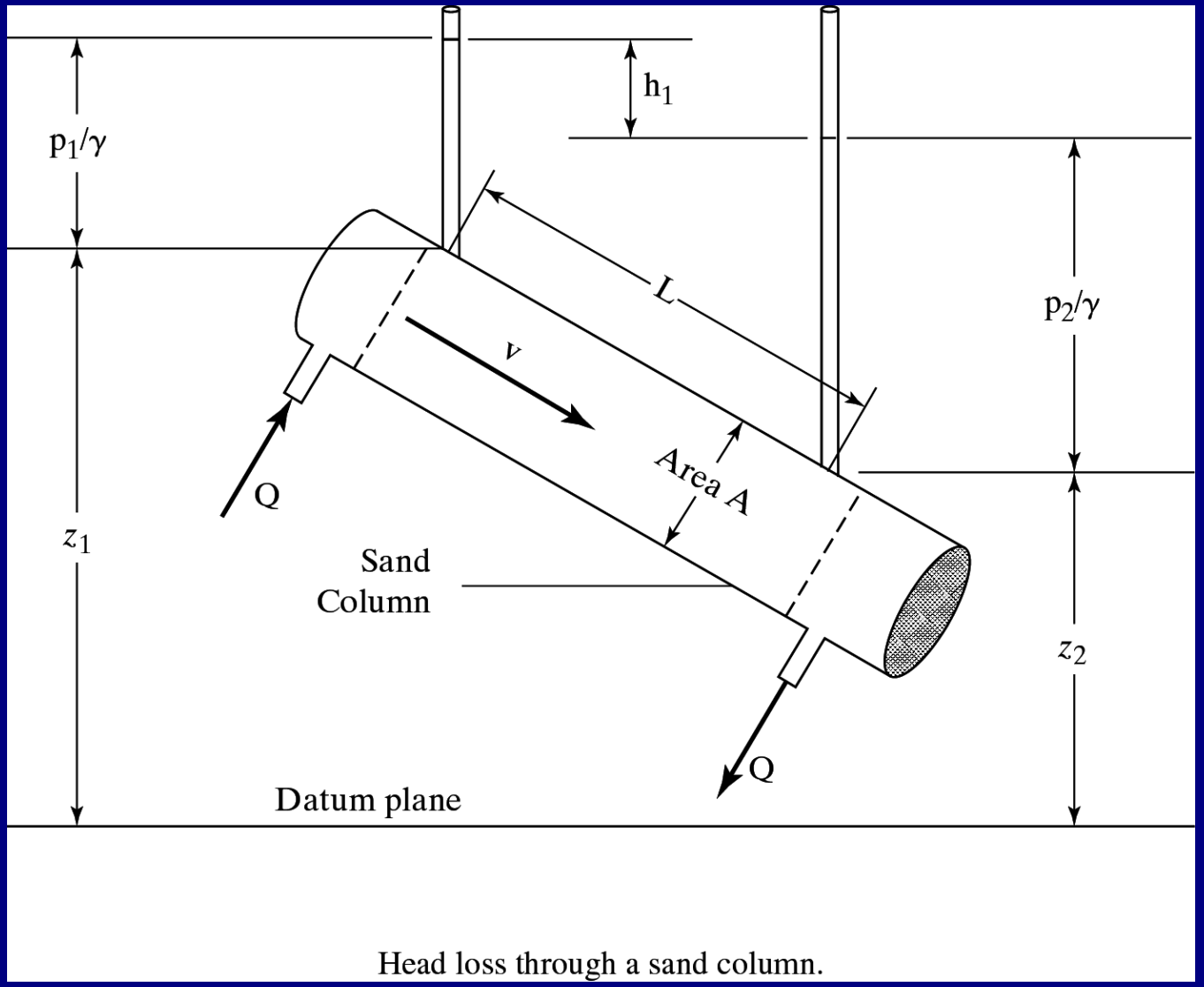
(after Morris and Johnson)

Material	Particle Size, mm
Clay	<0.004
Silt	0.004 - 0.062
Very fine sand	0.062 - 0.125
Fine sand	0.125 - 0.25
Medium sand	0.25 - 0.5
Coarse sand	0.5 - 1.0

Darcy's Law

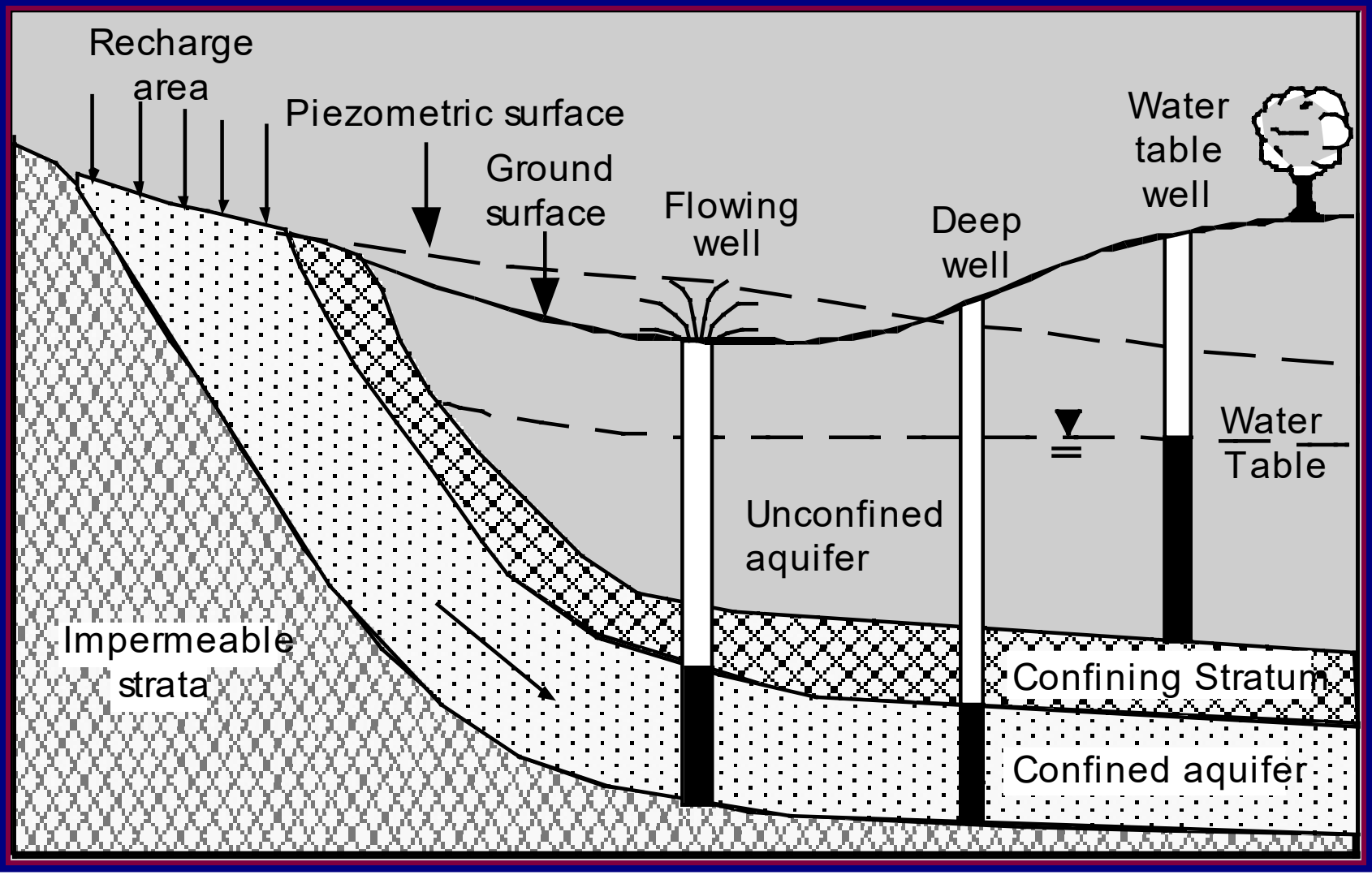
$$V = -K \frac{dh}{dl}$$

$$Q = -KA \frac{dh}{dl}$$

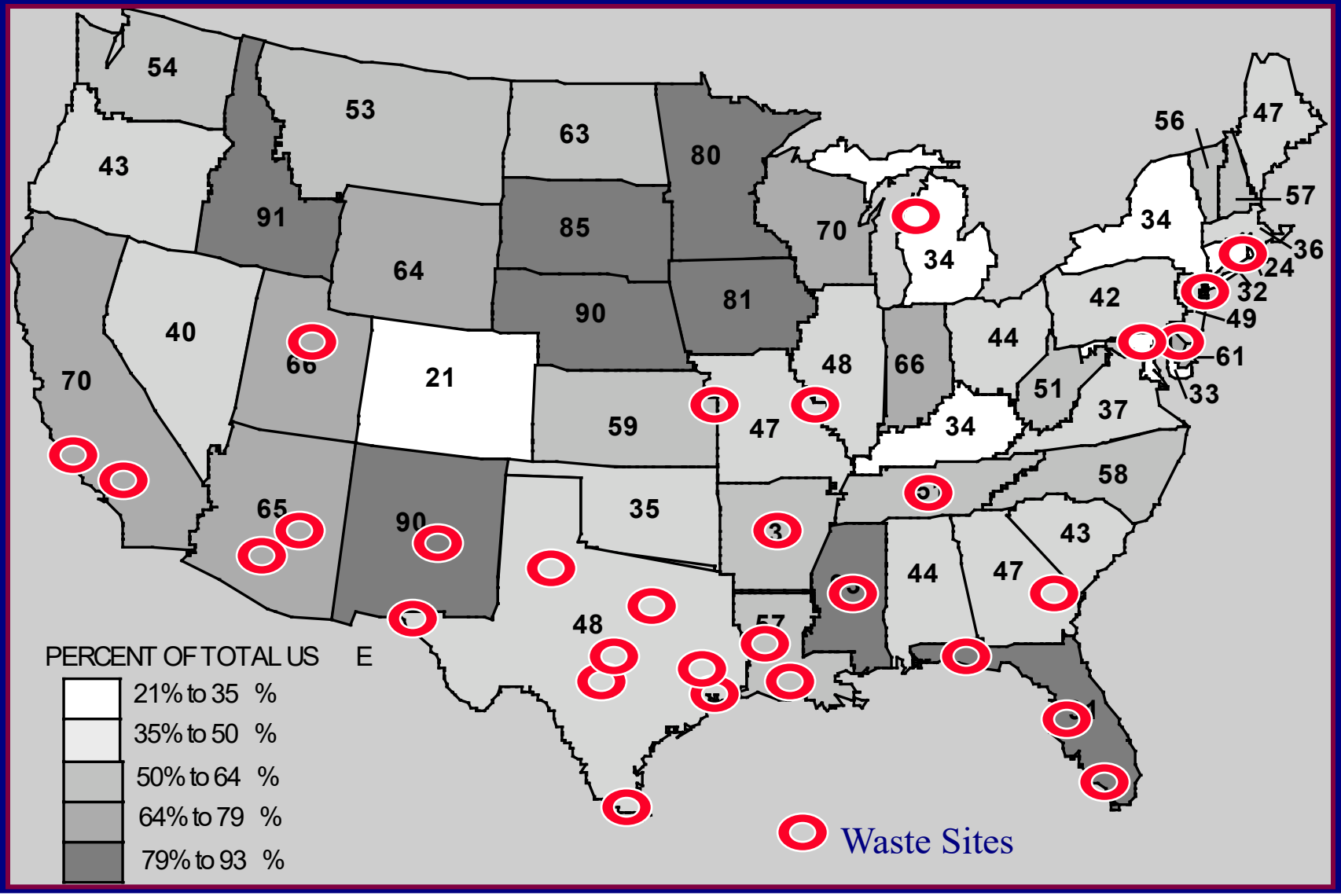


Head loss through a sand column.

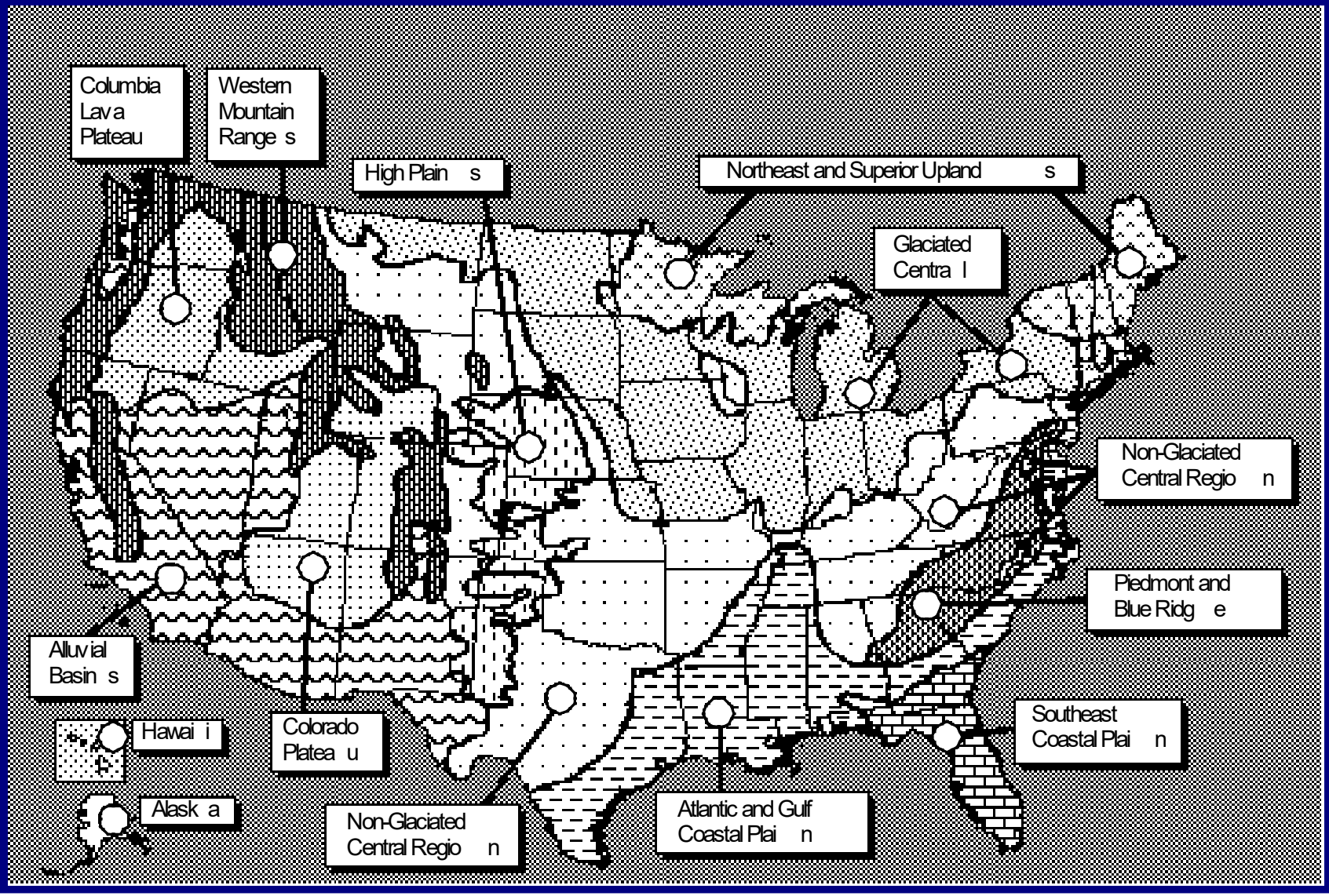
Aquifer Systems



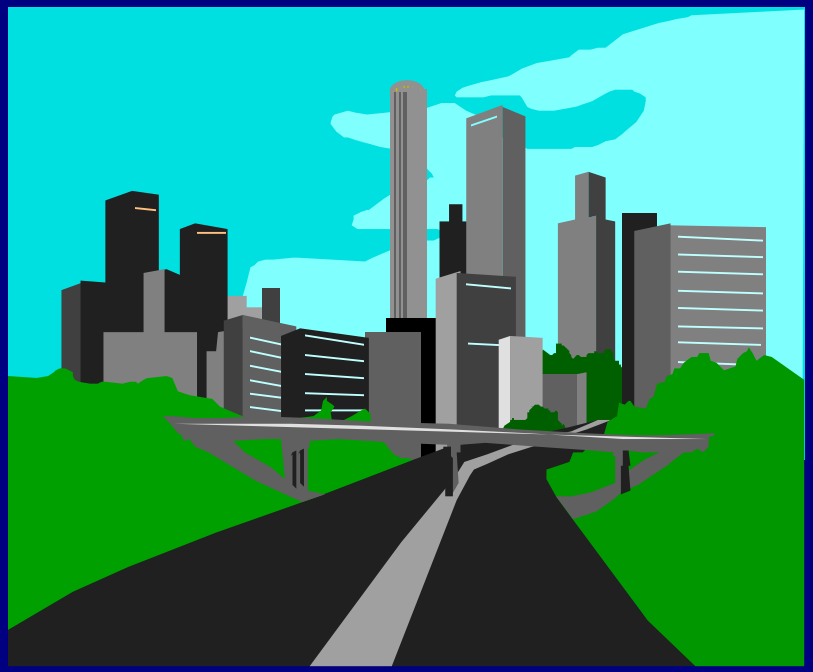
Ground Water Use in the U.S.A.



U.S. Ground Water Regions

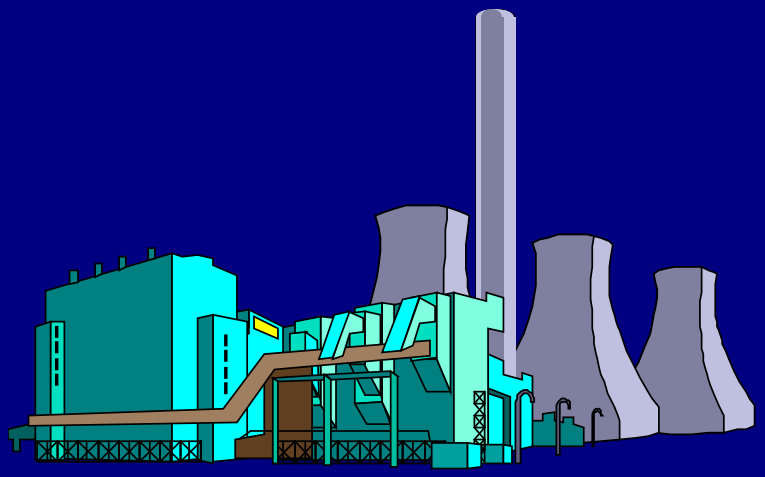


Contamination and Remediation



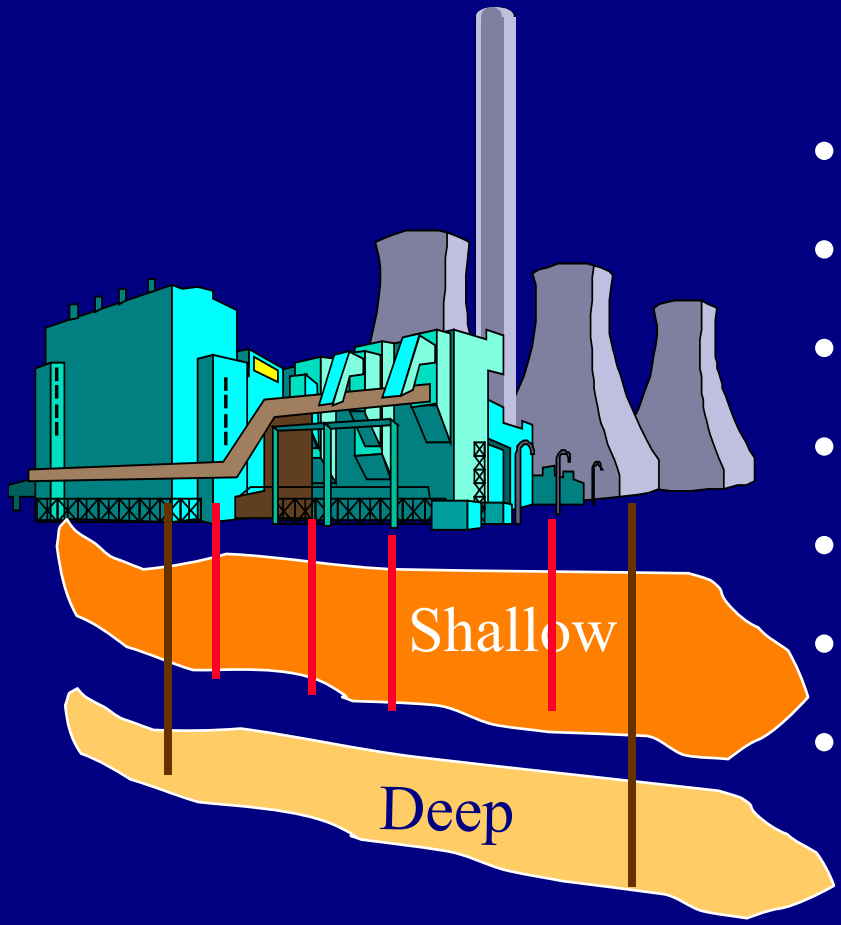
- Advective transport
- Diffusion and dispersion
- Volatilization
- Adsorption
- Biodegradation processes
- Chemical Reaction
- NAPLs
- Remediation Processes

Sources of Contamination



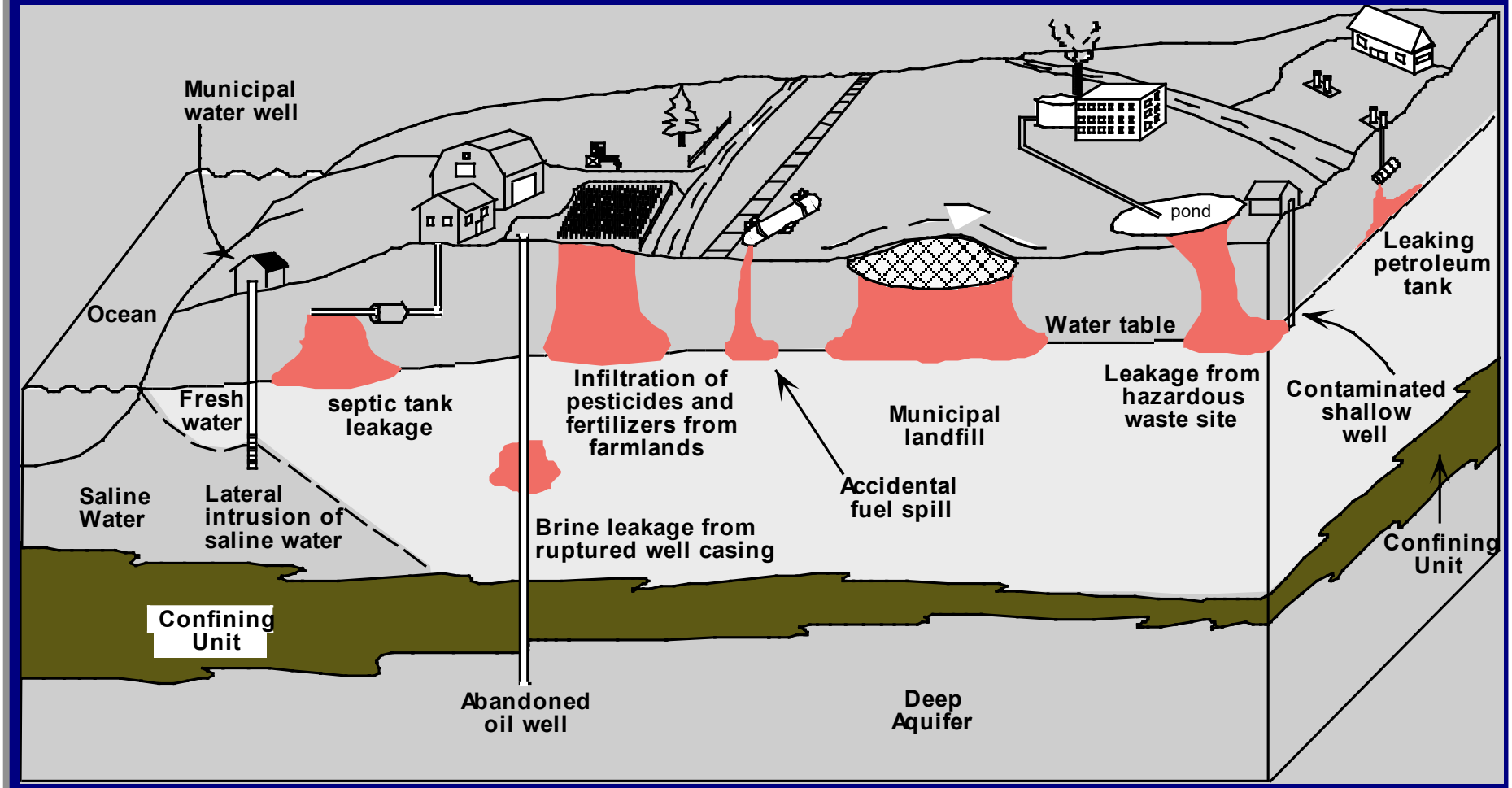
- Industrial spills and leaks
- Surface impoundments
- Storage tanks and pipes
- Landfills
- Burial areas and dumps
- Injection wells

Areas of Industrial Contamination

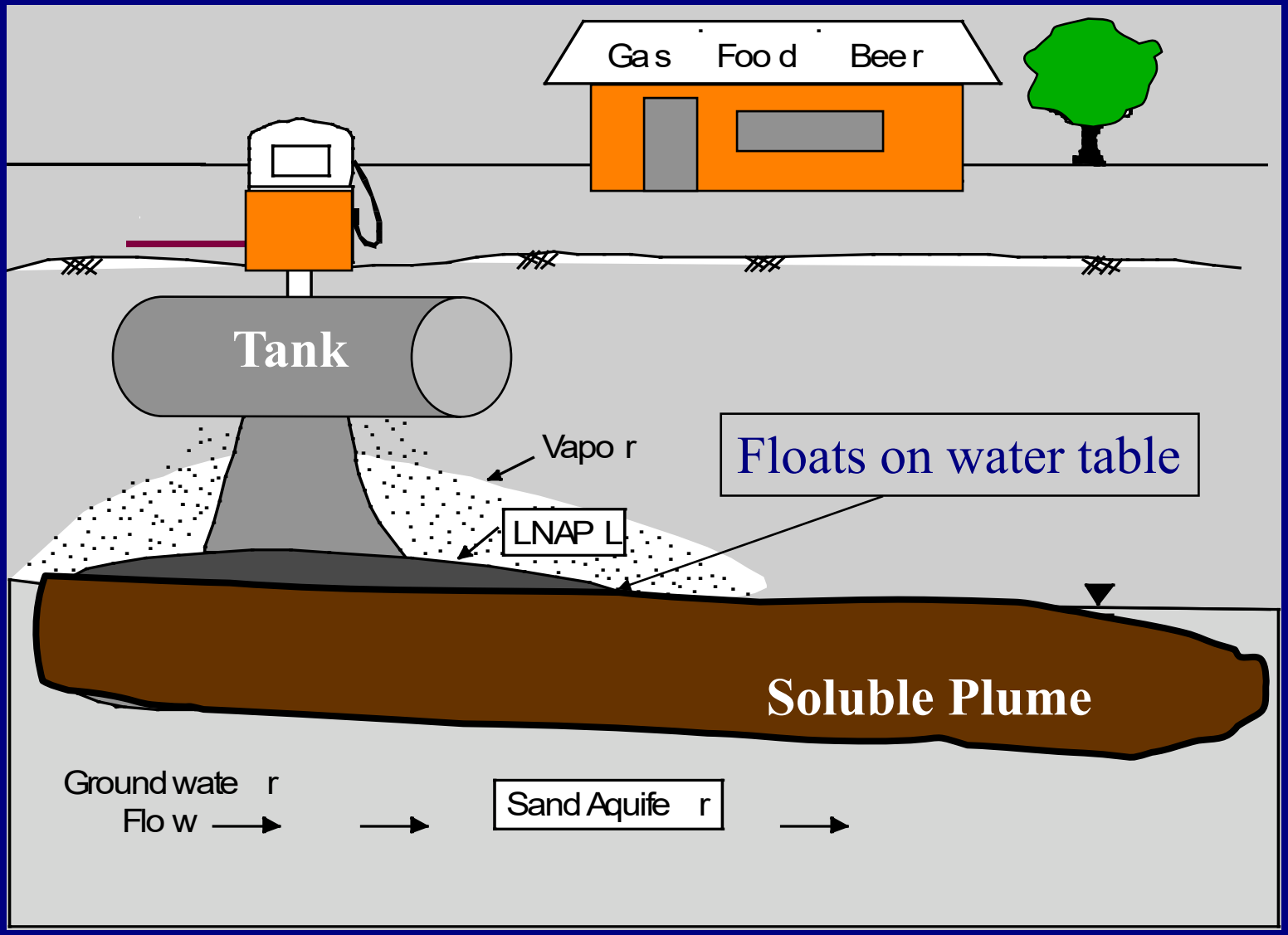


- **Surface soils**
- **Subsurface soils**
- **Shallow ground water**
- **Deep ground water**
- **Vapors above water table**
- **Drinking water wells**
- **Receiving streams/lakes**

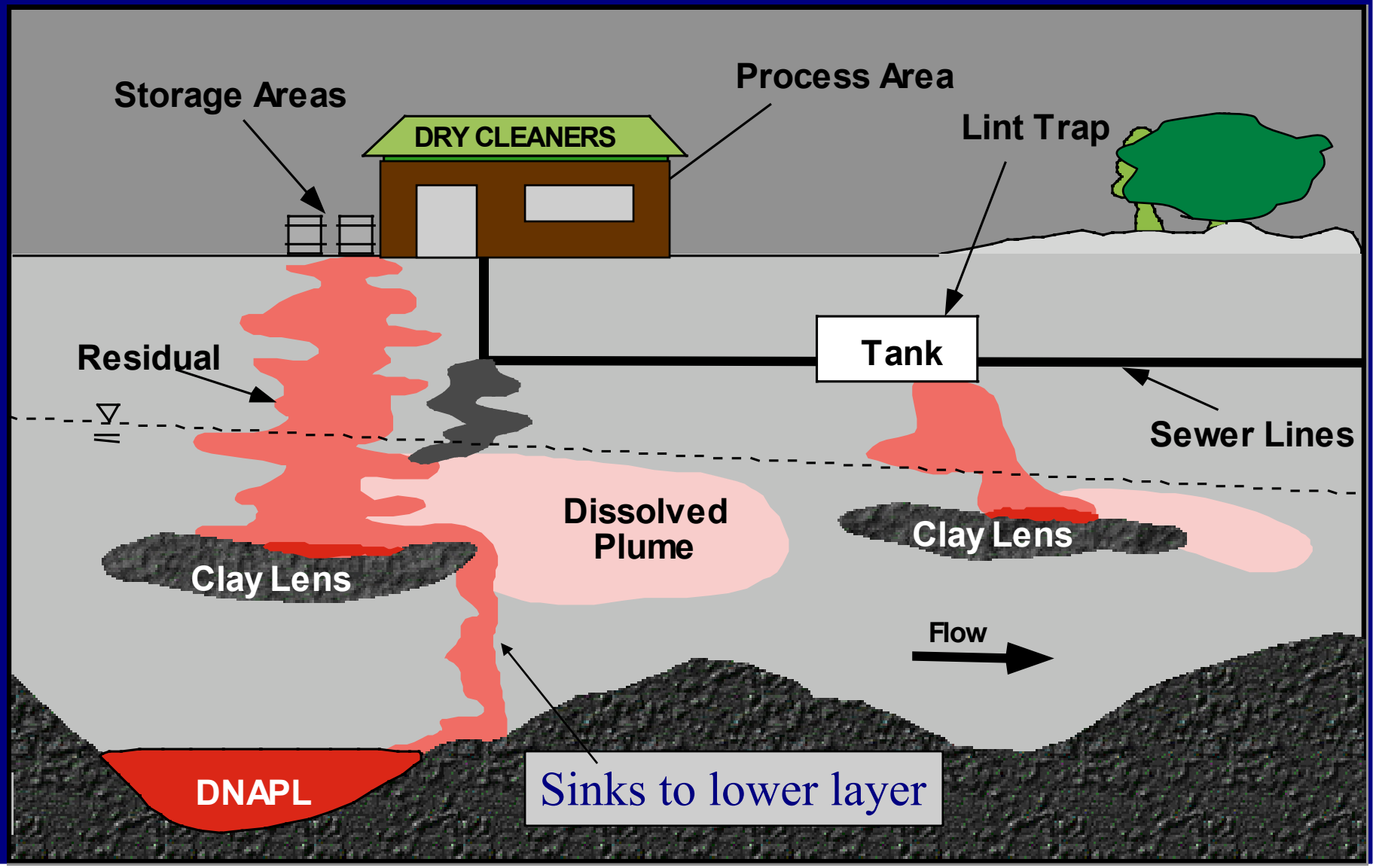
Contamination of Ground Water



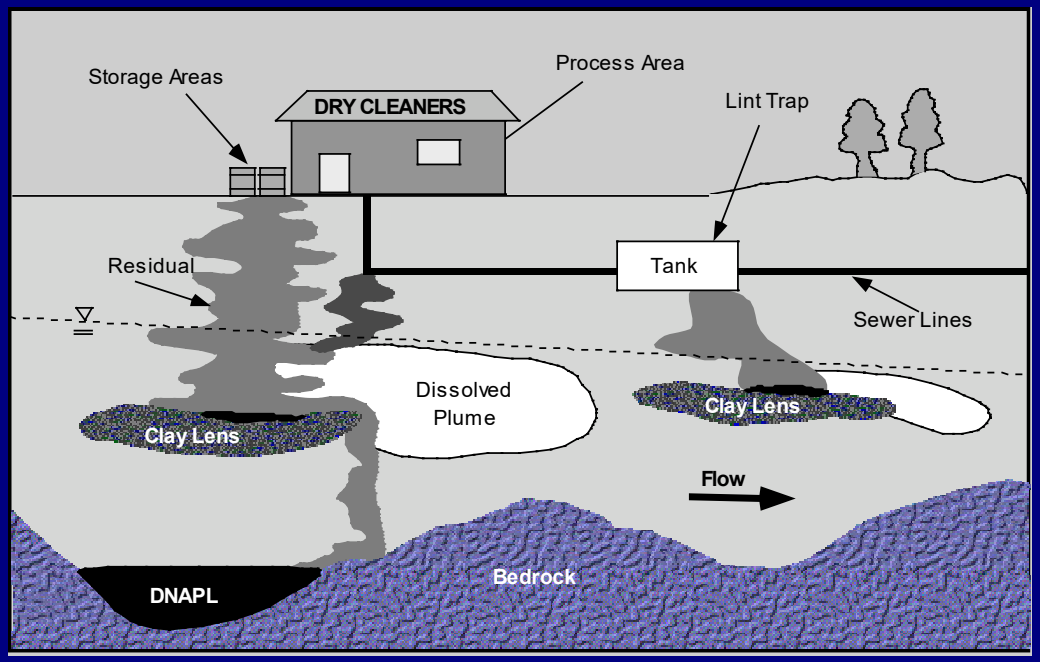
Typical Leaking UST - BTEX



Typical DNAPL Spill Zone



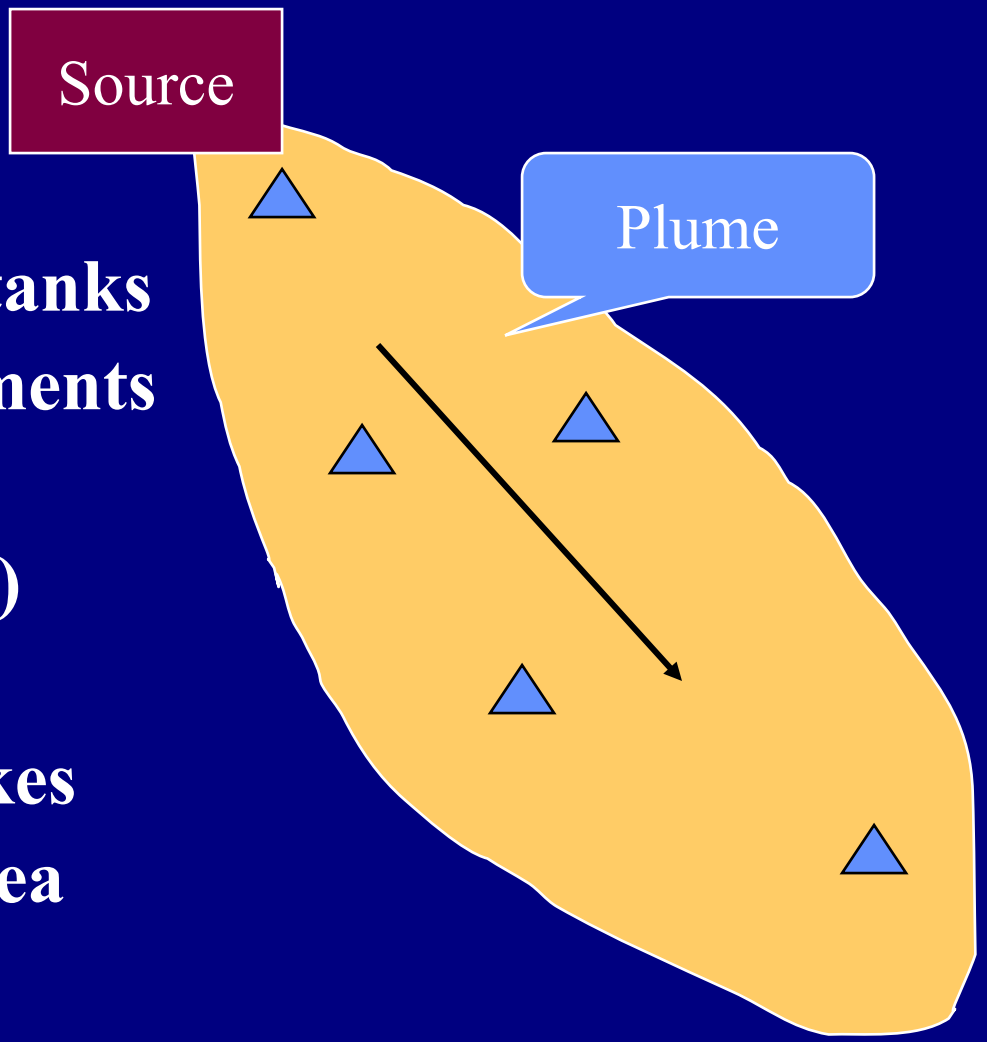
DNAPL
Our Most Difficult Challenge



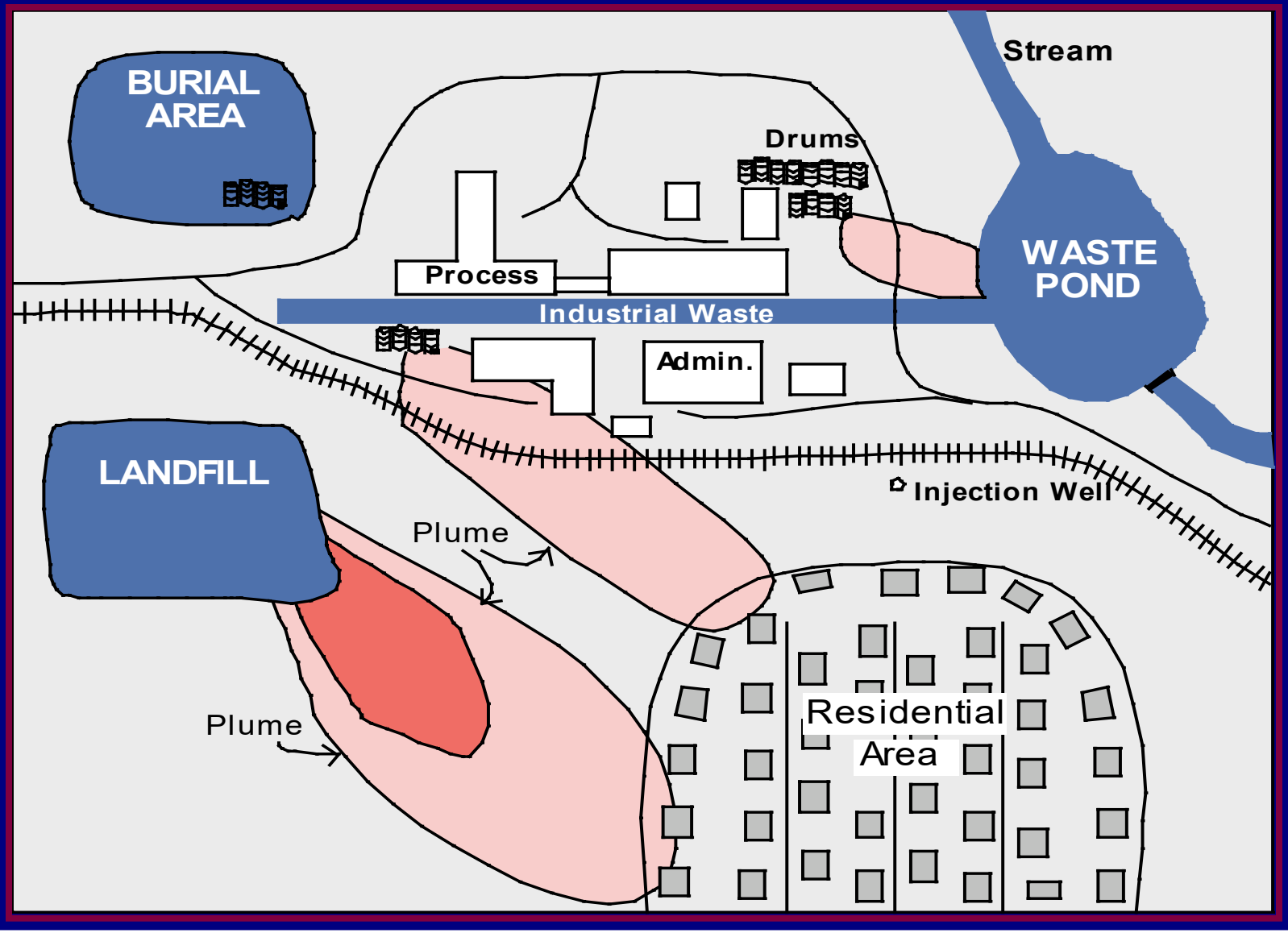
- DNAPL source
- Residual phase
- Trapped on lenses
- Pools in low areas
- Creates soluble plumes for years
- Extremely hard to remediate

Typical Industrial Site

- **Buried fuel tanks**
- **Above ground chem tanks**
- **Ponds and Impoundments**
- **Buried drums (older)**
- **Landfill area (hidden)**
- **Waste process area**
- **Receiving streams/lakes**
- **Nearby residential area**

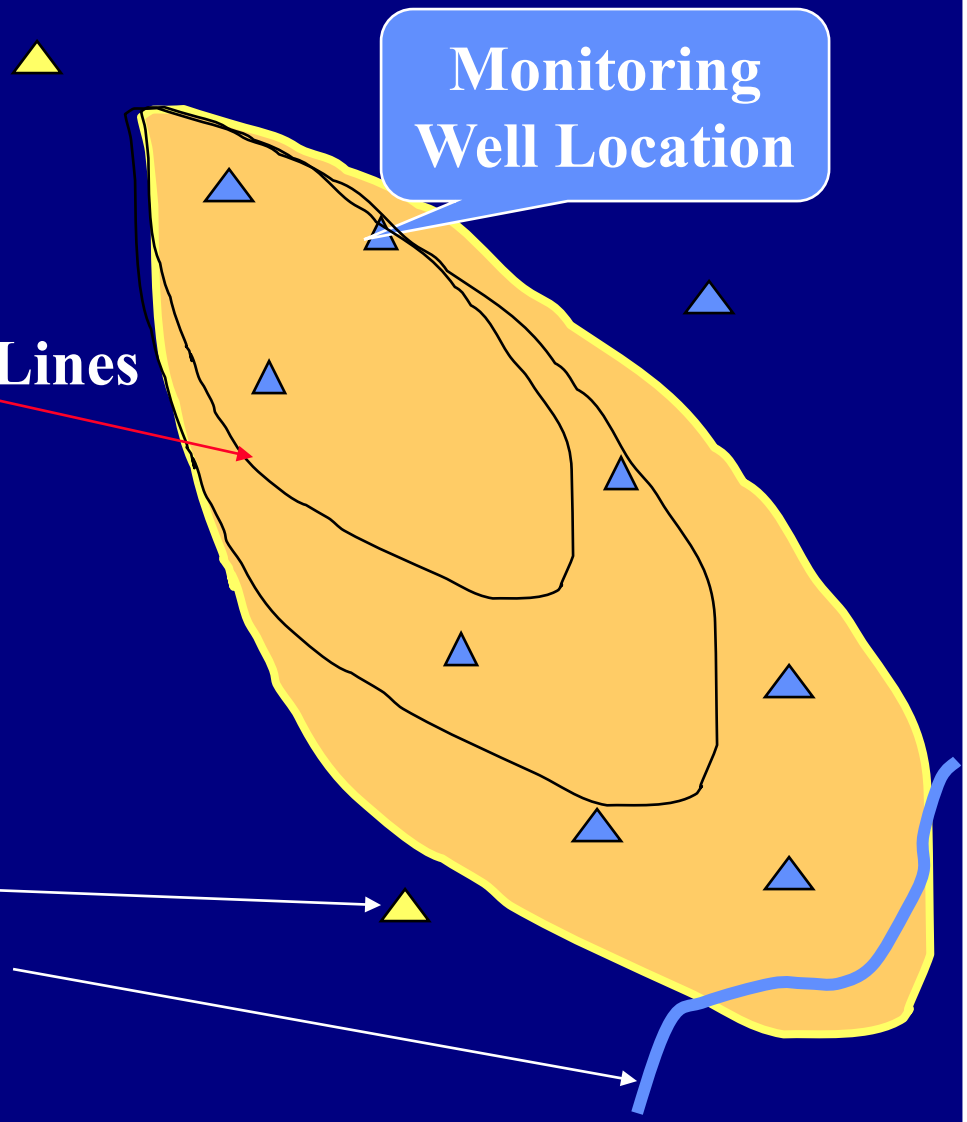


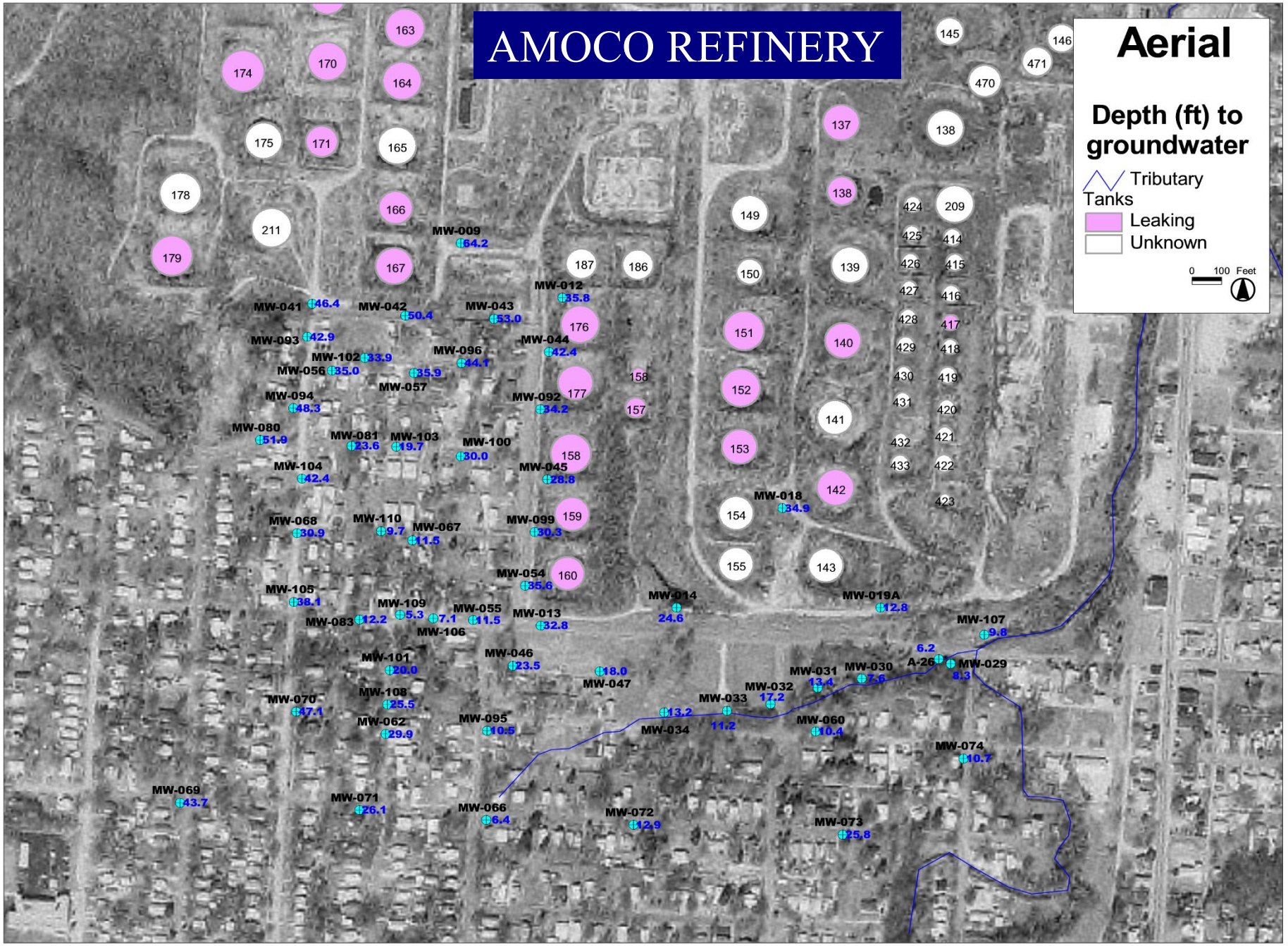
Typical Contaminated Site

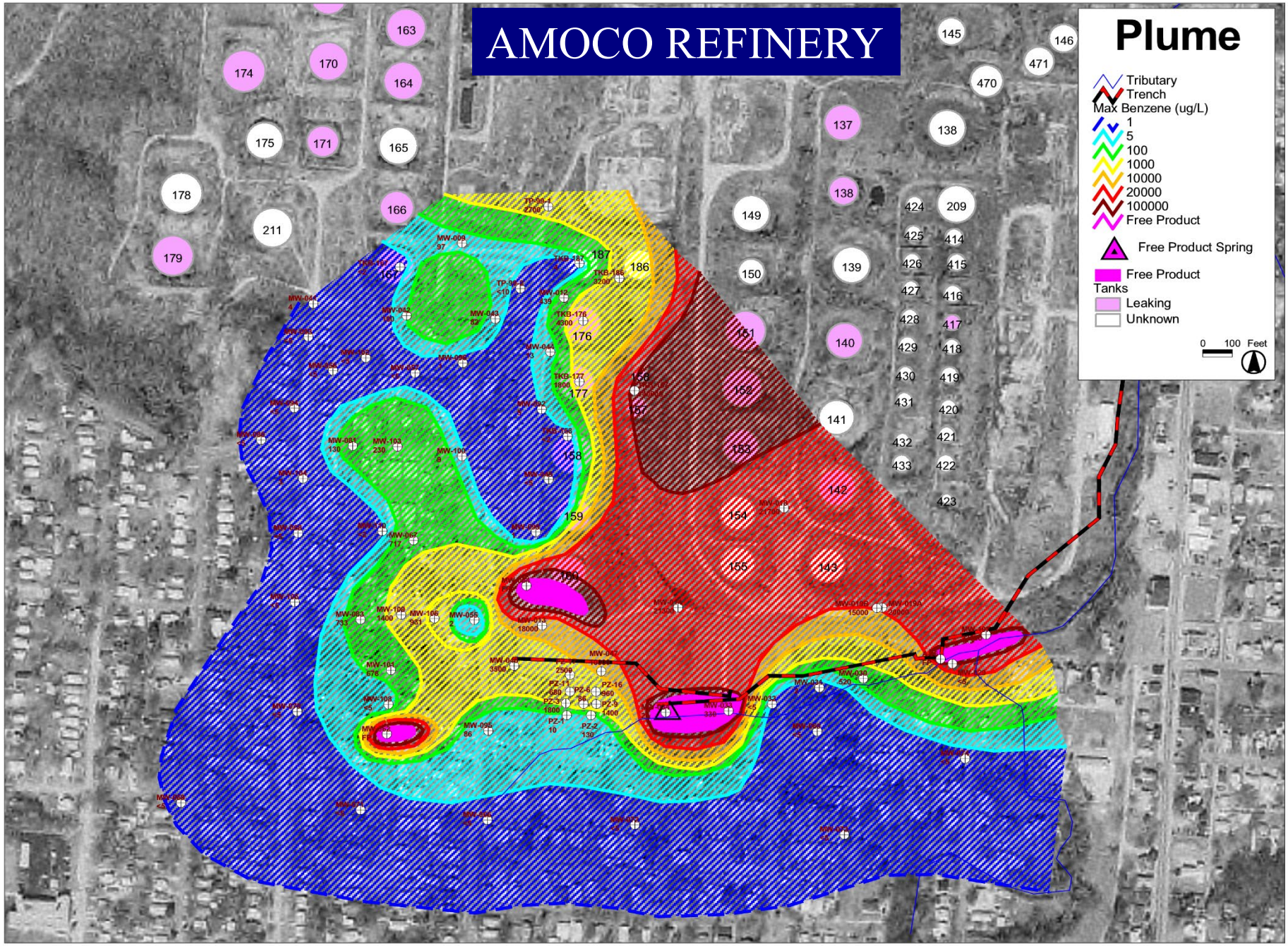


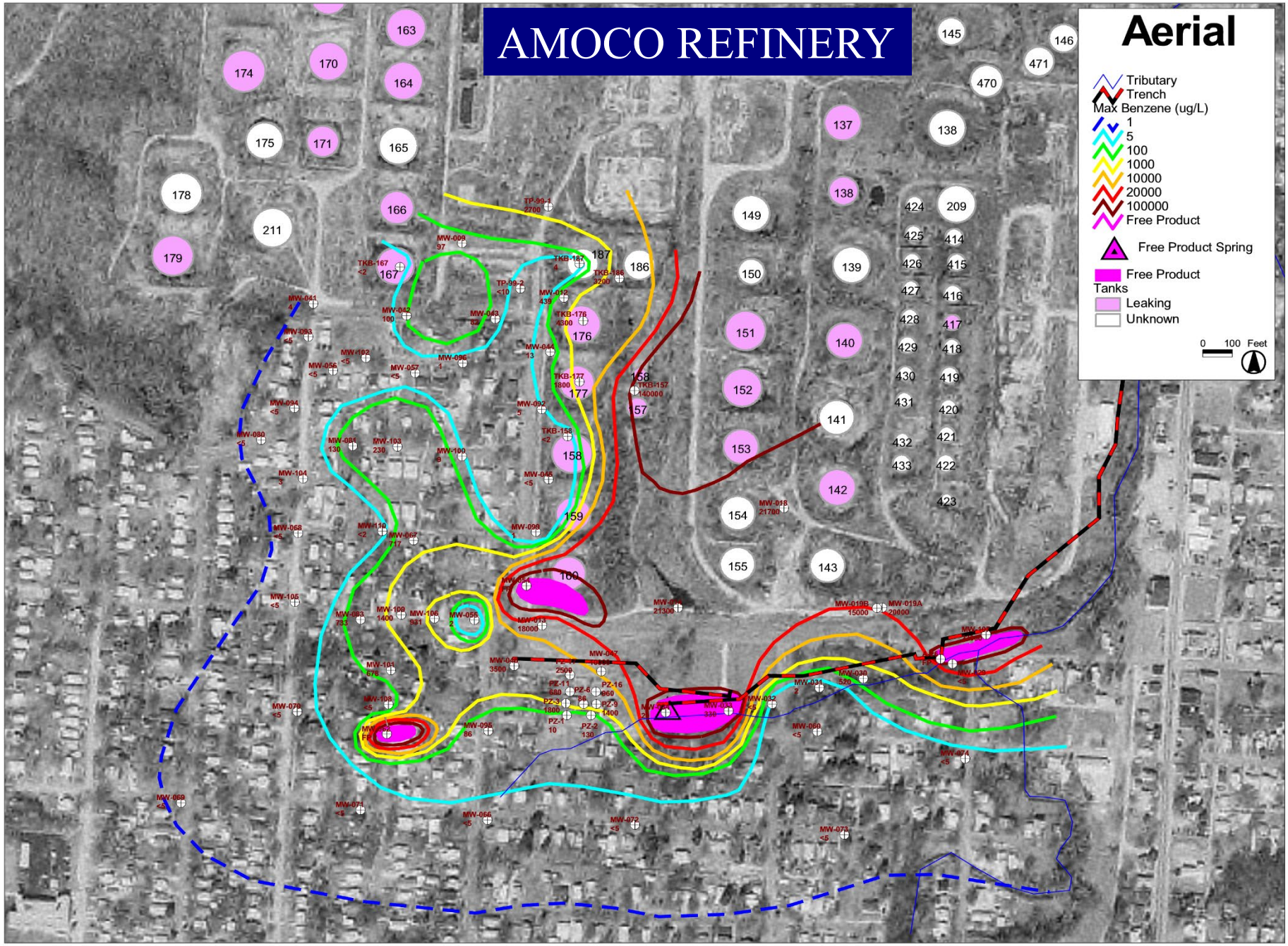
Objectives of a Field Site Study

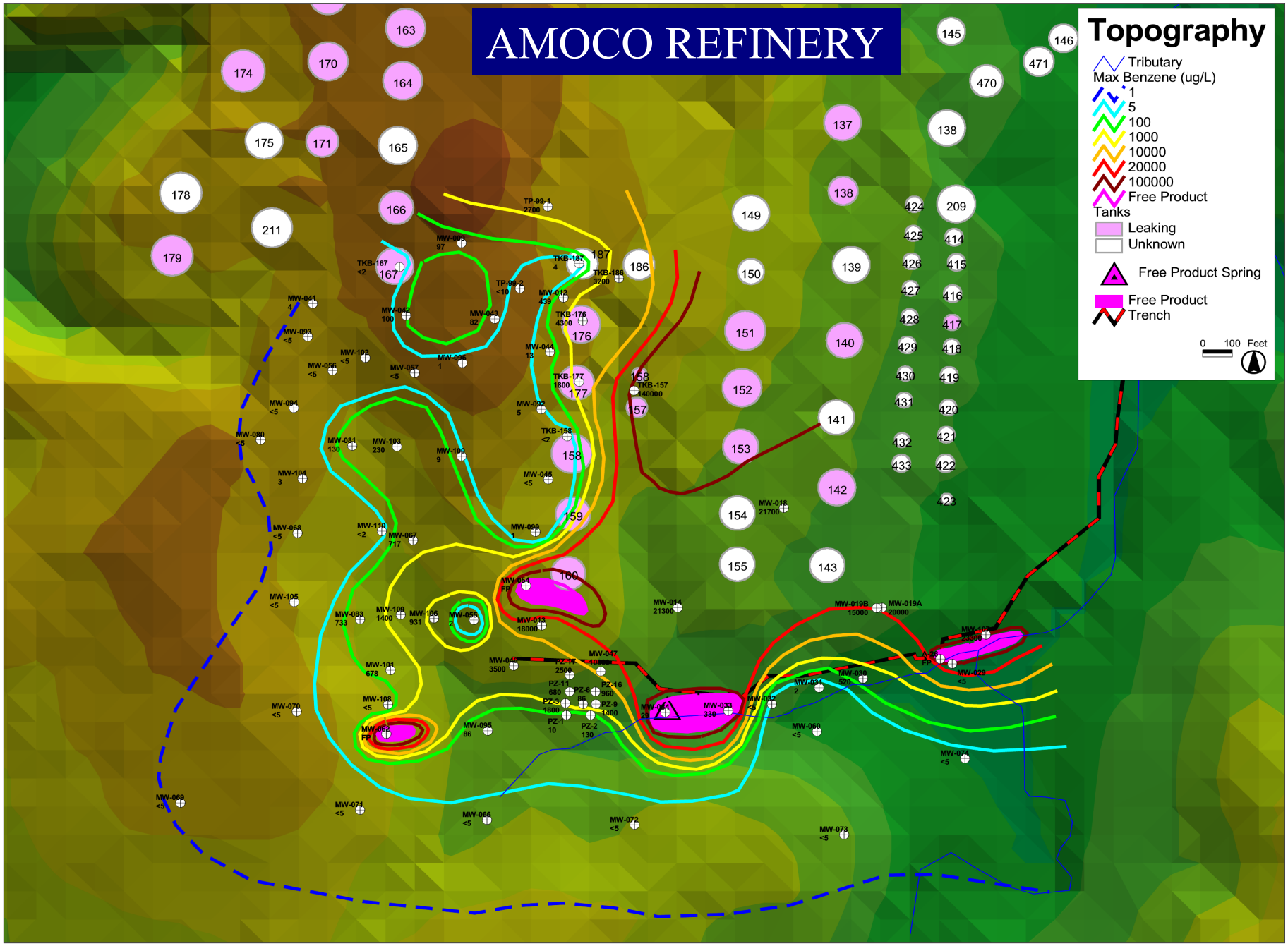
- **Evaluate:**
  - Surface soils
  - Subsurface soils
  - Shallow ground water
  - Deep ground water
  - Vapors in subsurface
  - Drinking water wells
  - Receiving streams/lakes

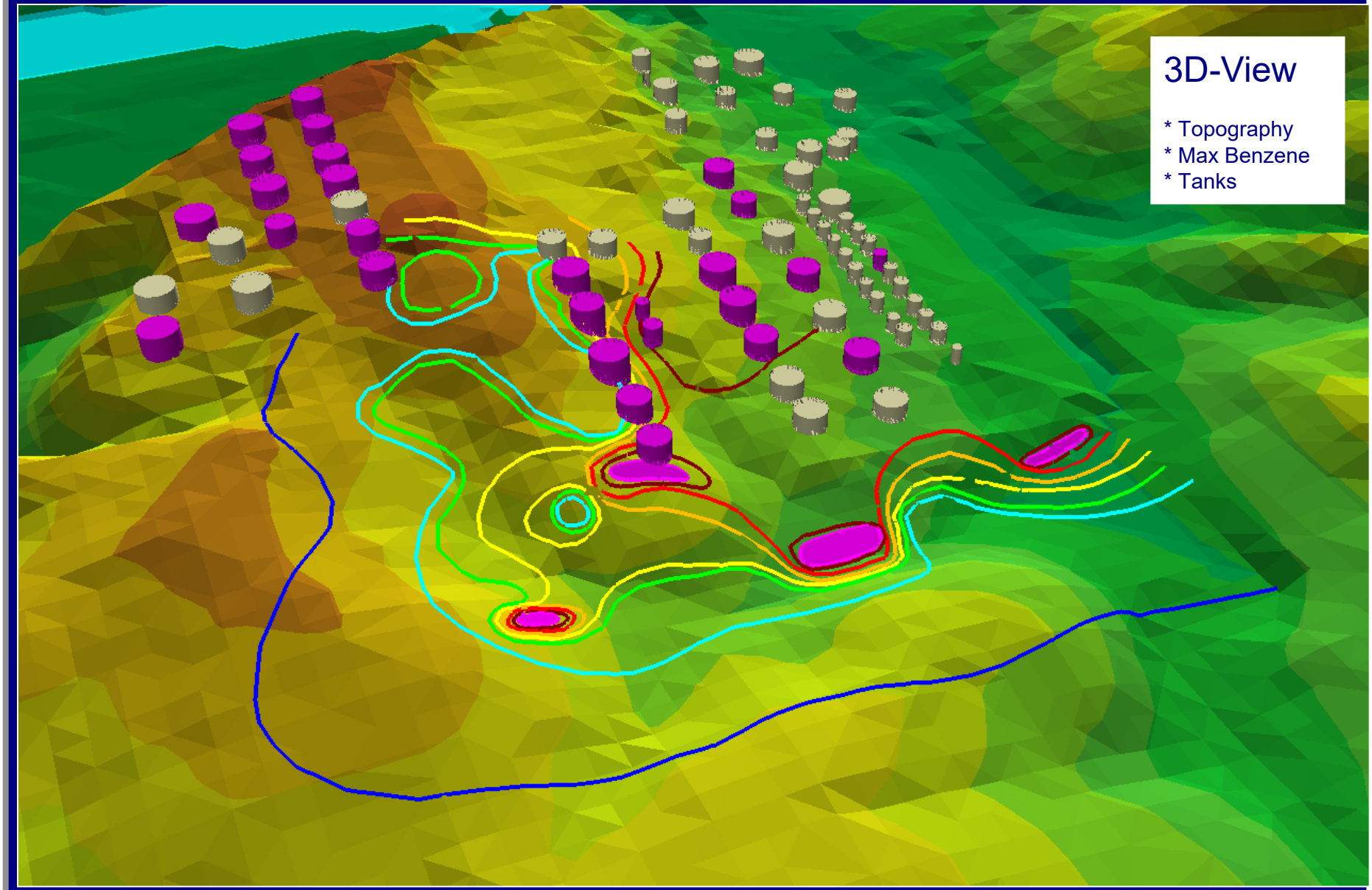



AMOCO REFINERY
Aerial
Depth (ft) to groundwater
Tributary
Tanks
Leaking
Unknown
0 100 Feet
MW-009 64.2
MW-012 35.8
MW-041 46.4
MW-042 50.4
MW-043 53.0
MW-093 42.9
MW-102 33.9
MW-096 44.1
MW-044 42.4
MW-056 35.0
35.9
MW-057
MW-094 48.3
MW-092 34.2
MW-080 51.9
MW-081 23.6
MW-103 19.7
MW-100 30.0
MW-104 42.4
MW-045 28.8
MW-018 34.9
MW-068 30.9
MW-110 9.7
MW-067 11.5
MW-099 30.3
MW-054 35.6
MW-105 38.1
MW-109 5.3
MW-055 11.5
MW-013 32.8
MW-083 12.2
7.1
MW-106
MW-014 24.6
MW-019A 12.8
MW-107 9.8
6.2
A-26
MW-029 8.3
MW-030 7.6
MW-031 13.4
MW-032 17.2
MW-033 13.2
11.2
MW-034
MW-060 10.4
MW-074 10.7
MW-101 20.0
MW-046 23.5
18.0
MW-047
MW-070 47.1
MW-108 25.5
MW-062 29.9
MW-095 10.5
MW-069 43.7
MW-071 26.1
MW-066 6.4
MW-072 12.9
MW-073 25.8

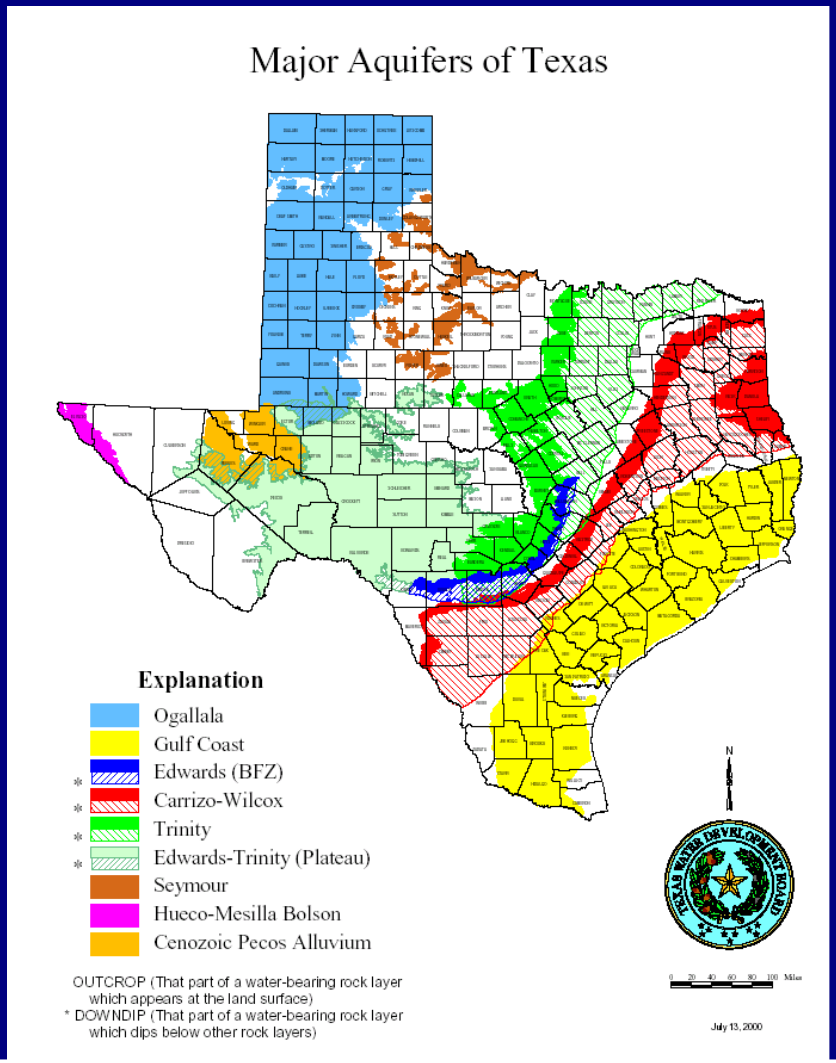

AMOCO REFINERY
Plume
Tributary
Trench
Max Benzene (ug/L)
1
5
100
1000
10000
20000
100000
Free Product
Free Product Spring
Free Product
Tanks
Leaking
Unknown
0 100 Feet


AMOCO REFINERY
Aerial
Tributary
Trench
Max Benzene (ug/L)
1
5
100
1000
10000
20000
100000
Free Product
Free Product Spring
Free Product
Tanks
Leaking
Unknown
0 100 Feet

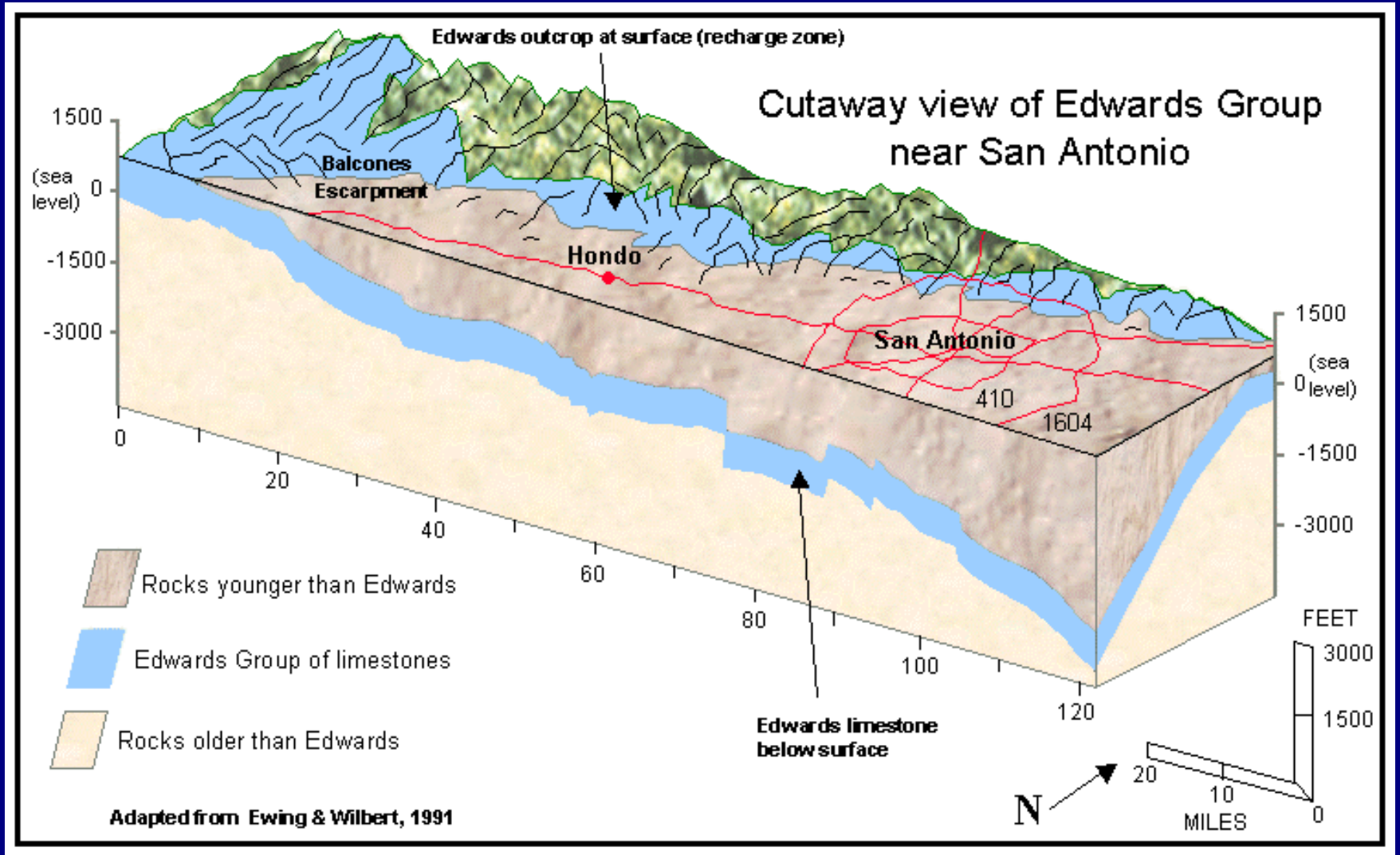

AMOCO REFINERY
Topography
Tributary
Max Benzene (ug/L)
1
5
100
1000
10000
20000
100000
Free Product
Tanks
Leaking
Unknown
Free Product Spring
Free Product
Trench
0 100 Feet


3D-View
* Topography
* Max Benzene
* Tanks

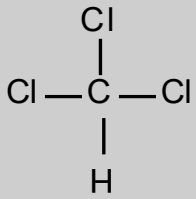
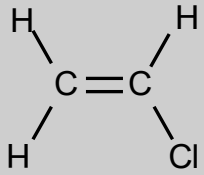
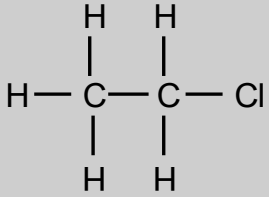
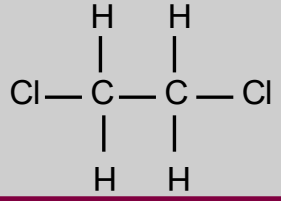
The Major Aquifers of Texas



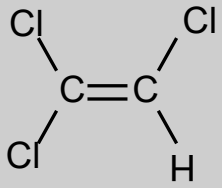
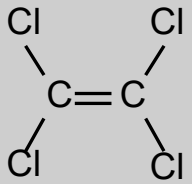
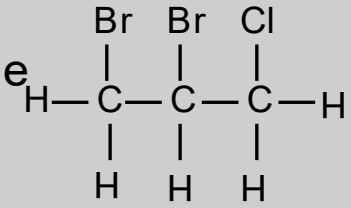
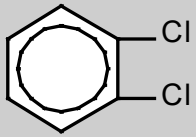
The Edwards Group



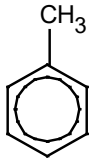
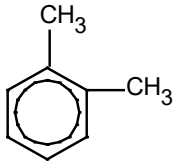
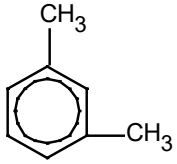
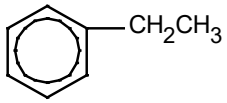
Chlorinated Solvents

Name	Structure	Uses and Other Sources
Trichloromethane (chloroform)		Liquid used in manufacture of anesthetics, pharmaceuticals, fluorocarbon refrigerants and plasics. Used as solvent and insecticide. Formed from methane when chlorinating drinking water.
Vinyl chloride (chloroethene)		Gas used in the manufacture of polyvinyl chloride. End product of microbial degradation of chlorinated ethenes.
Chloroethane		Liquid used to manufacture tetraethyl lead. Degradation product of chlorinated ethanes.
1,2-Dichloroethane		Liquid used to manufacture vinyl chloride. Degradation product of trichloroethane.

Chlorinated Solvents (con't)

Name	Structure	Uses and Other Sources
Trichloroethene (Trichloroethylene)		Solvent used in dry cleaning and meta degreasing. Organic synthesis. Degradation product of tetrachloroethene.
Tetrachloroethene (perchloroethene) (perchloroethylene)		Solvent used in dry cleaning and meta degreasing. Used to remove soot from industrial boilers. Used in manufacture of paint removers and printing inks.
1,2-Dibromo-3-chloropropane (DBCP)		Soil fumigant to kill nematodes. Intermediate in organic synthesis.
o-Dichlorobenzene (1,2-dichlorobenzene)		Chemical intermediate. Solvent. Fumigant and insecticide. Used for industrial odor control. Found in sewage form odor control chemicals used in toilets.

BTEX-Related Compounds

Name	Structure	Molecular Weight	Solubility in Water	Soil-Water Partition Coefficient
Benzene		78.11	1780 mg/L	97
Toluene		92.1	500 mg/L	242
Xylene, ortho		106.17	170 mg/L	363
Xylene, meta		106.17	173 mg/L	182
Xylene, para		106.17	200 mg/L	331
Ethyl benzene		106.17	150 mg/L	622