Haz Waste: Containment

- Soil
  - Vegetation (phytoremediation)
  - Cap
- Groundwater
  - Pump and Treat (active)
  - Cut-off walls (passive)
- Soil Vapor
  - Soil vapor extraction (active)

Passive Control: Cover

- Capillary barrier
  - Fine sand over coarse sand
  - Water held in upper sand lost by evaporation
  - Good for arid conditions where clay might crack
- Clay cover or composite with membrane
- Drainage layer

Vertical GW Barriers

- Slurry Trench Cut-off walls
  - Slurry trench allows vertical trench walls
  - Constructed of low permeability materials
  - Usu. K <1E-7 cm/s (soil:bentonite)
  - Key into confining layer if possible
- Other types
  - Cement-bentonite slurry wall
    - K 1E-5 to E-6 cm/s, excav soil not used
  - Plastic concrete slurry wall
    - K 1E-7, good strength, high chem resistance
  - Composite slurry wall
    - Geomembrane on trench walls decrease K, but chemical compatibility concerns

Other Vertical Barriers

- Steel sheet piling
  - Limited drive depth, limited soil types
  - "Sheet" 10-20'H x 20-40'L
  - Joints are "weak" spot where leakage can occur, usually grouted
- Grout curtain
  - Use in fractured rock (not excavatable soil)
  - Pressure inject cement or other chemical slurry into fractures and voids...then grout hardens
  - Hazardous chemicals can break down grout

Vertical Cut-off Wall Dsns:

- Plan Views
- Profile View

Pumping must capture leakage through the wall AND rainfall to prevent "bathtub"
Vertical GW Barriers
• Extreme water table gradients induced across the barriers
  – Note the large “dh” over the small “dl” thickness of the wall
  – If soil:bentonite slurry wall has K of 1E-7 cm/s, what is the flow through the up-gradient barrier if the upgradient water table is 500’ ASL and the water table immediately across the wall is 490’ ASL?
  • 1 m wide wall
  • Confining layer 488’ ASL, wall 20 m long
  • \( Q = K (dh/dl) A = 1E-7 \text{ cm/s}*(10/1\text{m})*(20\text{m} * 12) \)
  • \( Q = 0.223 \text{ cm}^3/\text{sec} = 19.3 \text{ L/d} \)

Reactive Walls
• “funnel and gate” approach
  – Use cut-off walls with low permeability to contain GW migration
  – Instead of pumping out water “captured” by the cut-off walls, route it through a reactive zone (gate) to treat it
  – Gate of higher permeability than the natural soil
    • Width of gate based on reaction rate with passing GW
    • Types of gates: bioreactive, iron reaction wall, volatilization, ...

Reactive Wall System

Reactive Wall
• Routing larger “Q” from aquifer thru zone
• Make zone with larger porosity to minimize velocity and prevent head build-up (ex: gravel)

Groundwater flow

Horizontal Barriers to GW flow
• Landfill liner systems & similar
• For remediation, need to construct under existing contamination, esp. for DNAPLs
  – Hydraulic fracturing by high pressure first, then grout pumped into fractures (soil)
  – Lagoon-sealing
    • Spread bentonite granules on water surface, particles sink, hydrate, and form liner

• Time needed in wall for reactions determines thickness
  – If natural i 0.01, K 1E-4 cm/s, n=0.3
  – Put 50 m cross-flow thru 5 m wide wall
  – Velocity in wall with K 0.1 cm/s, n=0.4, =?
    • \( Q_{aq} = K_i A = 1E-4 \text{ cm/s}/0.01/50\text{m}^2 = 5E-3 \text{ d cm/s} \)
    • \( V_{wall} = Q/A_n = 5E-3 \text{ d cm/s} / 5 \text{m} = 0.04 = 2.5E-5 \text{ cm/s} = 2.16 \text{ cm/d} \) (if gradient the same)
  – Gradient wall = dh/dl = Q/A Kw = 5E-3 \text{ d cm/s} / 5 \text{m} / 0.1 \text{ cm/s} = 0.0001 < natural (OK)
  – If 1st order reaction \( k=0.1 \text{ d}^{-1} \) to degrade 1 mg/L to 0.01 mg/L, what wall thickness needed?
    • \( \frac{dS}{dt} = k S \cdot \ln(1/0.01) = k t \cdot 4.6/0.1 \text{ d}^{-1} = 46 \text{ d} = t \)
    • Thickness = \( V_{wall} * t = 2.16 \text{ cm/d} * 46 \text{ d} = 1 \text{ m} \)