

# Wyckoff Remediation Options

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# General Observations

- DNAPL buoyancy marginal and temperature dependent
  - May become LNAPL in salt water with heating
- Sufficient level of heterogeneity exists to stifle mass-transfer-limited processes like oxidation
  - Ratio of radial K to vertical K  $\sim 100$
  - DNAPL inaccessible to injected fluids

# General Observations

- Thermal technologies will be effective in reducing mass of DNAPL if steam temperatures are obtained (at least)
  - Co-boiling of DNAPL and water strips volatile component from DNAPL, reducing mass and mobility
  - Vapor bubbles will transport DNAPL upward
  - Dominated by thermal conduction rates, not aqueous phase diffusion rates

# Thermal options

- Steam injection
  - Typically lowest energy cost
  - Can be highest rate energy input method if permeabilities are relatively high
- Electrical heating
  - Maybe problematic with high conductivity salt water in subsurface
  - Higher cost electrical energy needed
- Conductive heating
  - Predictable and robust
  - Higher cost electrical energy needed

# Prior Thermal Studies

- Bench-top experiments
  - Demonstrated effectiveness of steam injection
  - Showed complex relationship between DNAPL density and temperature, and groundwater density, salt content and temperature
- Pilot test
  - Inadequate steam injection rate
  - Failure of process equipment due to high contaminant production rates

# The Energy Issue

- If thermal technologies are applied on the full site basis, a large energy source must be identified
  - The demand for steam will require a large steam boiler operated for years
  - Electrical demand for conductive or resistive heat will also be extensive
  - Long-term operation may experience increasing energy costs depending on fuel and electrical energy sources

# Sustainable energy options

- Electrical energy for conductive or electrical resistive heating from waves, tidal, or wind.
- Biomass (forest product or yard waste) energy
  - Biomass thermal gasification
  - Co-generation
  - Carbon residual sequestration

# Sustainable energy options

- “Waste” thermal energy and/or electrical energy used for creosote recovery
- Renewable, carbon-negative electrical power to Island businesses and residents
- Potential air, landscape or water issues
  - New biomass power plants employ advanced stack air pollution control technologies
  - “Eye sore” of power plant and barges near Eagle Harbor
  - Sound water for eventual cooling

# Energy use and power generation

- Biomass energy power production may be good long term addition to community
  - Independent power source
  - Protection from rising electrical rates
  - Potential carbon sequestration credits
- Thermodynamic efficiency
  - Biomass energy to power plant = power + heat to environment
  - Heat to subsurface for steam or electrical input same overall cost.

# Concluding Recommendations

- Thermal technologies can meet the clean-up objectives in a reasonable time frame (~ 10 years) and short of excavation, those technologies should be most robust
- Community needs may be best met with a biomass waste steam power plant with waste heat used for steam injection into the subsurface and a portion of the electrical energy used for conductive or electrical resistance heating