Bioventing (is Still Bioventing)

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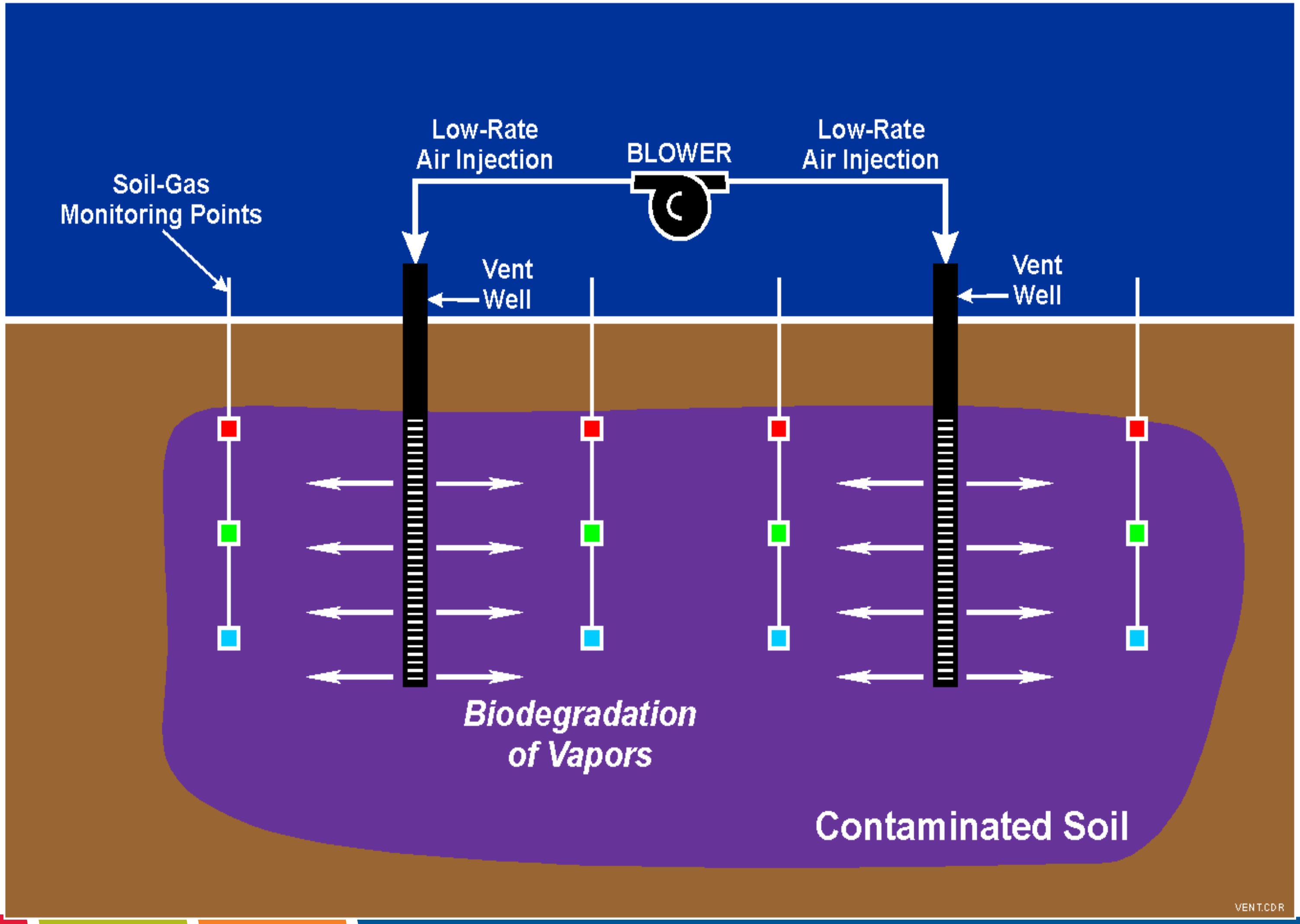
Priciples of Bioventing

- Subsurface injection or withdrawal of air to stimulate biodegradation of contaminants in the vadose zone
- Similar to soil vapor extraction, but with significantly different objectives
  - maximize biodegradation
  - minimize volatilization
- Applicable to any aerobically biodegradable compound
- Demonstrations established bioventing as preferred conventional technical option for remediation of petroleum hydrocarbons
- Inexpensive, safe, easily implemented technology

Schematic Diagram of a Typical Bioventing System



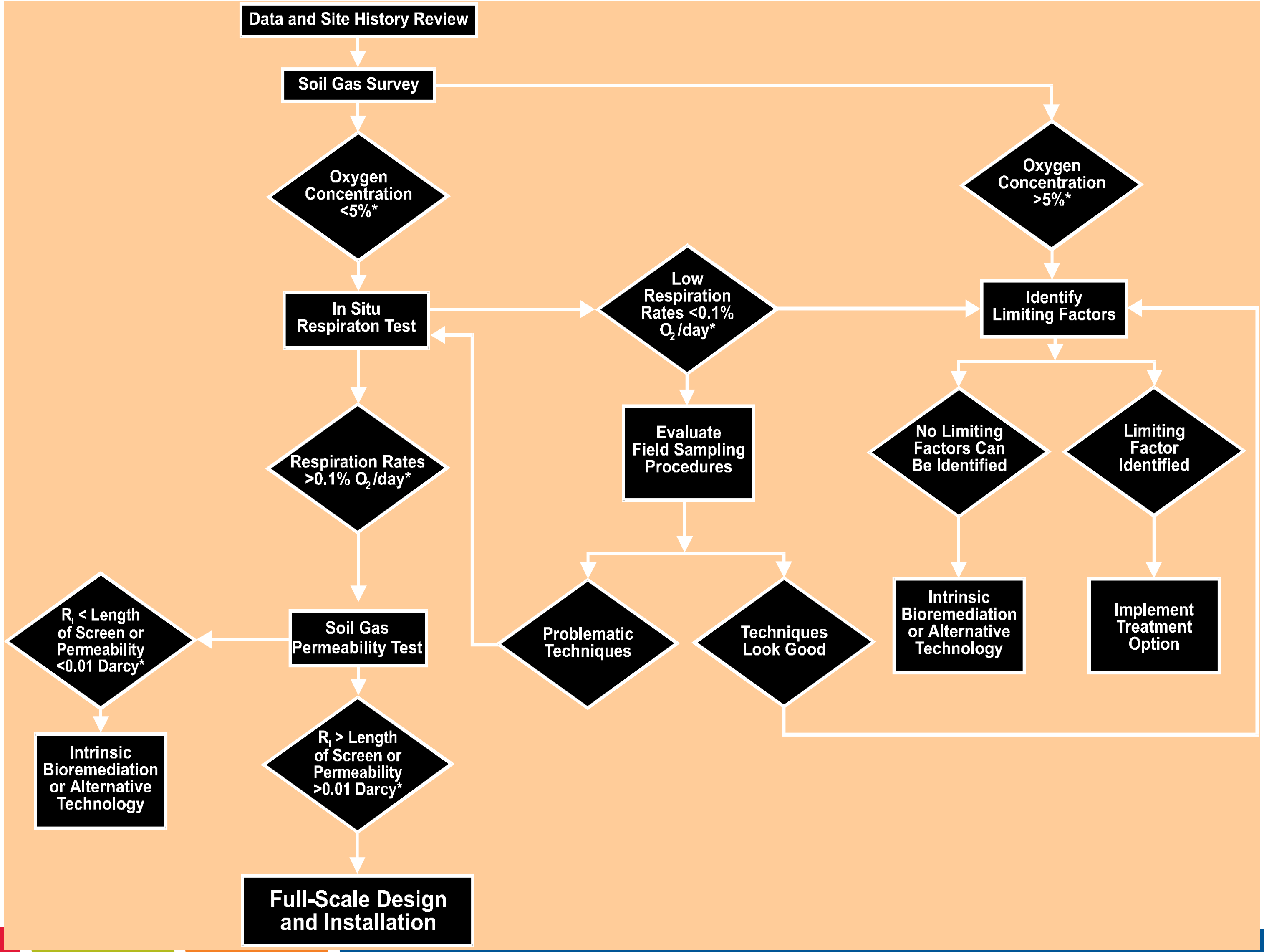
Applicability of Bioventing Positive Indicators

- Oxygen content is initially less than 5%
  - Indicates aerobic biological activity consumed oxygen
  - If not, identify potential limiting factors, such as nutrient limiting, toxic substances, lack of moisture and determine if these factors can be overcome through engineering controls
- Result of respiration test greater than 0.1% oxygen per day
  - Confirms aerobic biological activity
  - If not, identify potential errors in test procedures or limiting factors as discussed above
- Soil permeability high enough to maintain >5% oxygen over radius sufficient for cost effective system (i.e. greater than 0.01 Darcy)
  - Indicates bioventing will be effective
  - If not, consider fracturing

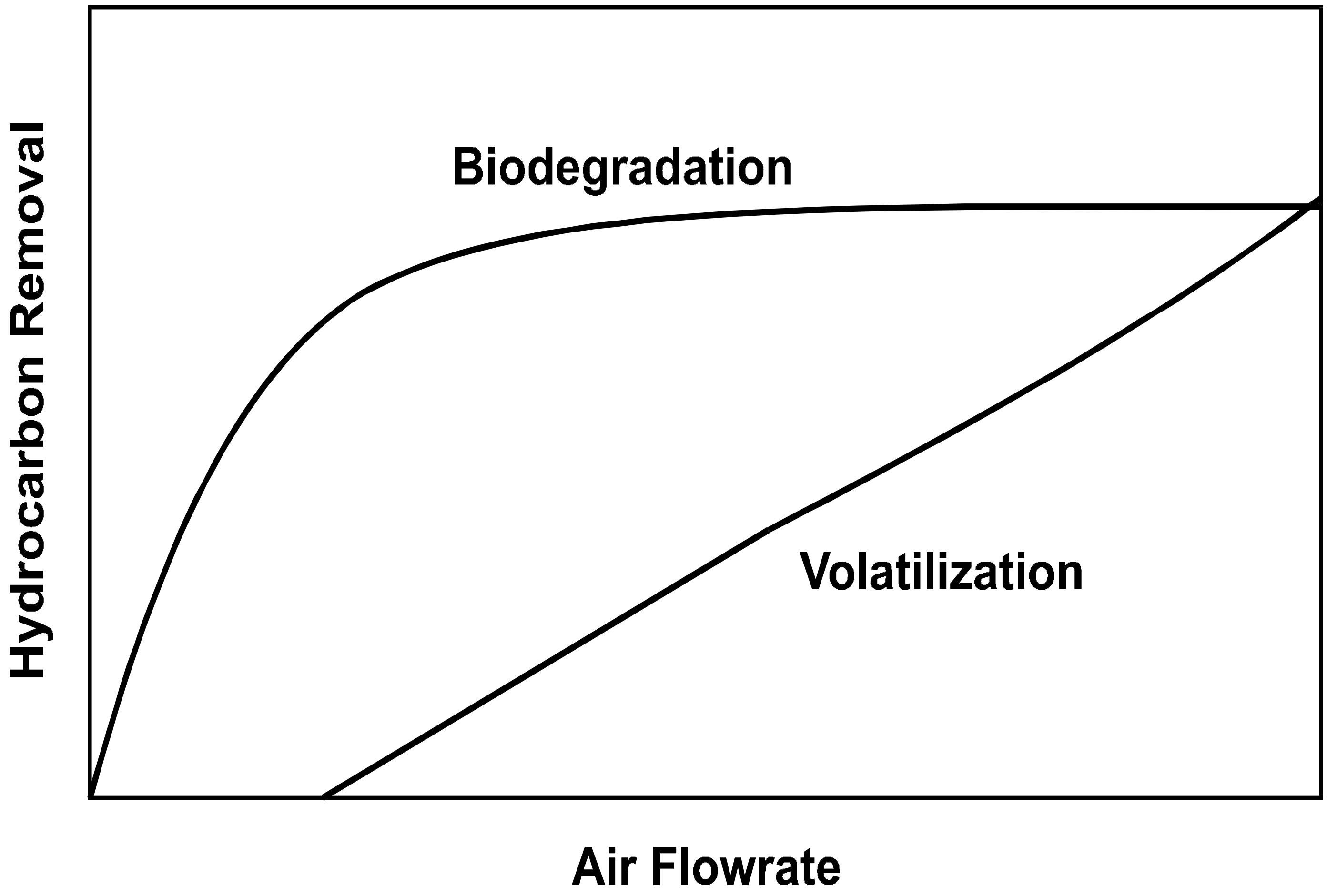
Key Technology Considerations

- Most Important Factor
  - ***Oxygen*** (petroleum hydrocarbons and other aerobically degraded compounds)
- Long-term Technology
  - Several years may be required to achieve remedial goals
- Other Factors
  - Temperature
  - Moisture
  - Nutrients

Flowchart for Determining Bioventing Applicability

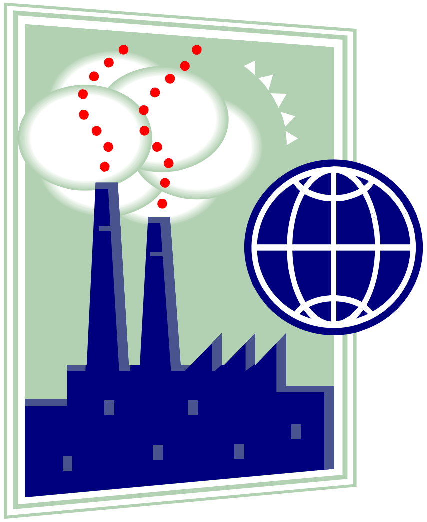


Hydrocarbon Biodegradation and Volatilization Rates as a Function of Flowrate



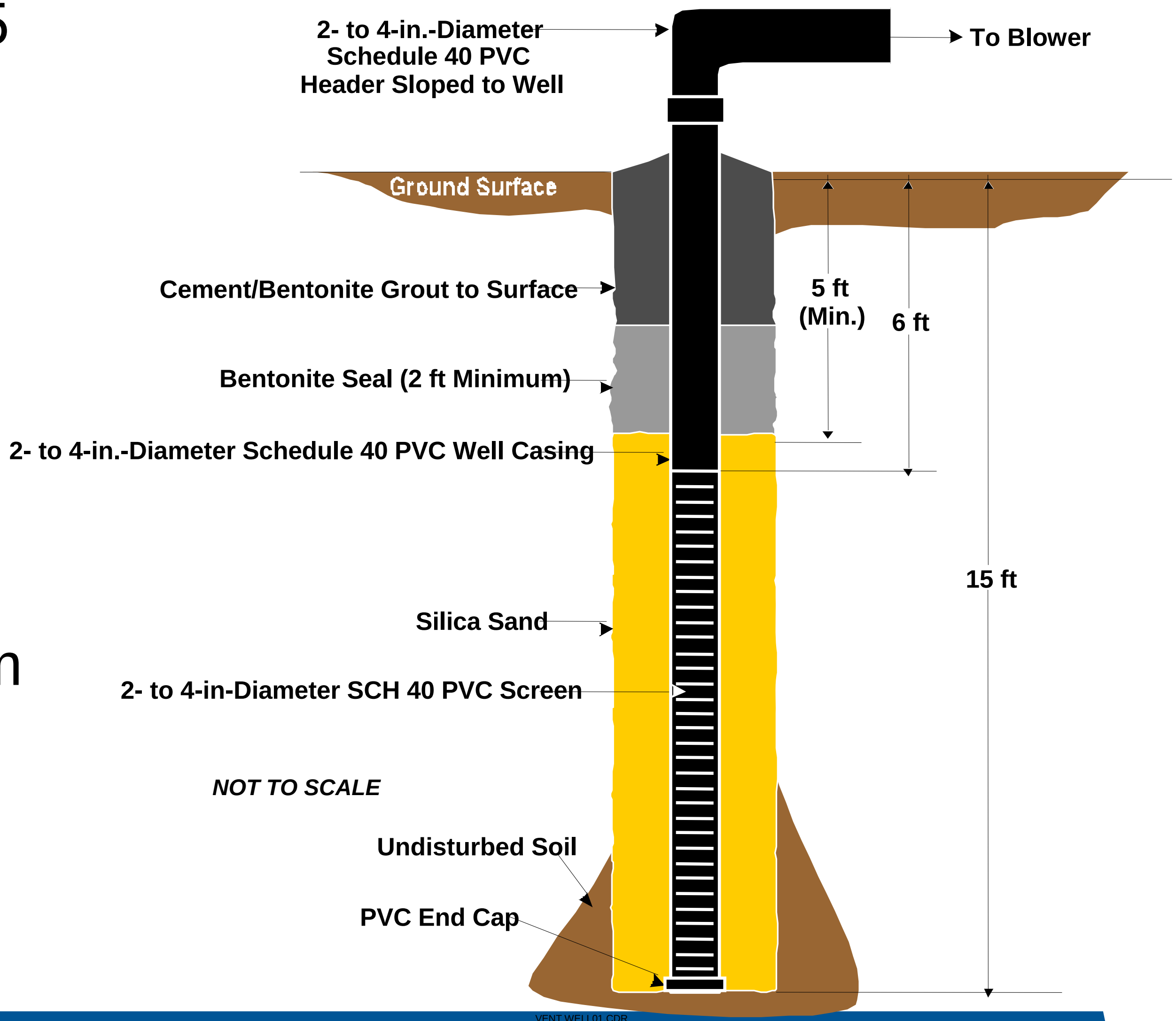
Health and Safety

- Vapors can migrate into buildings
- Vapors may be carcinogenic (benzene)
- Vapors and/or in within the explosive range
  - gasoline sites
  - Sites containing “fresh” contaminants



Components of a Bioventing System - Vent Well

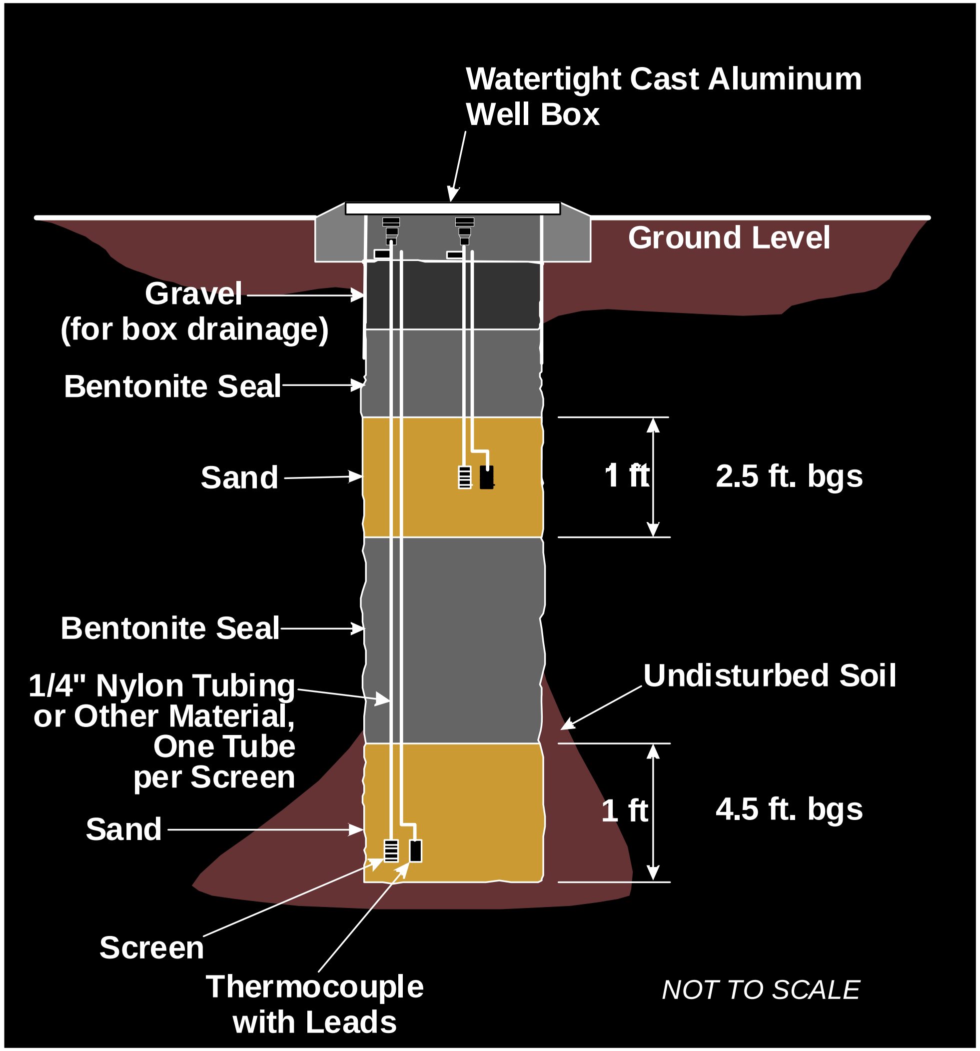
- Spacing typically 1.5 to 1.7 times the radius of influence
- Typically, 2- to 4-inch-diameter PVC
- Screen should extend through as much of the contamination as possible, with bottom corresponding to lowest historical water table level



Components of a Bioventing system - Monitoring Points

- Locate in contaminated soil
- Position considering soil-gas permeability test:

  minimum 3 locations from vent well
- Generally, 3 depths
  - Deepest, at bottom of contamination
  - Shallowest, 3 to 5 ft below ground surface



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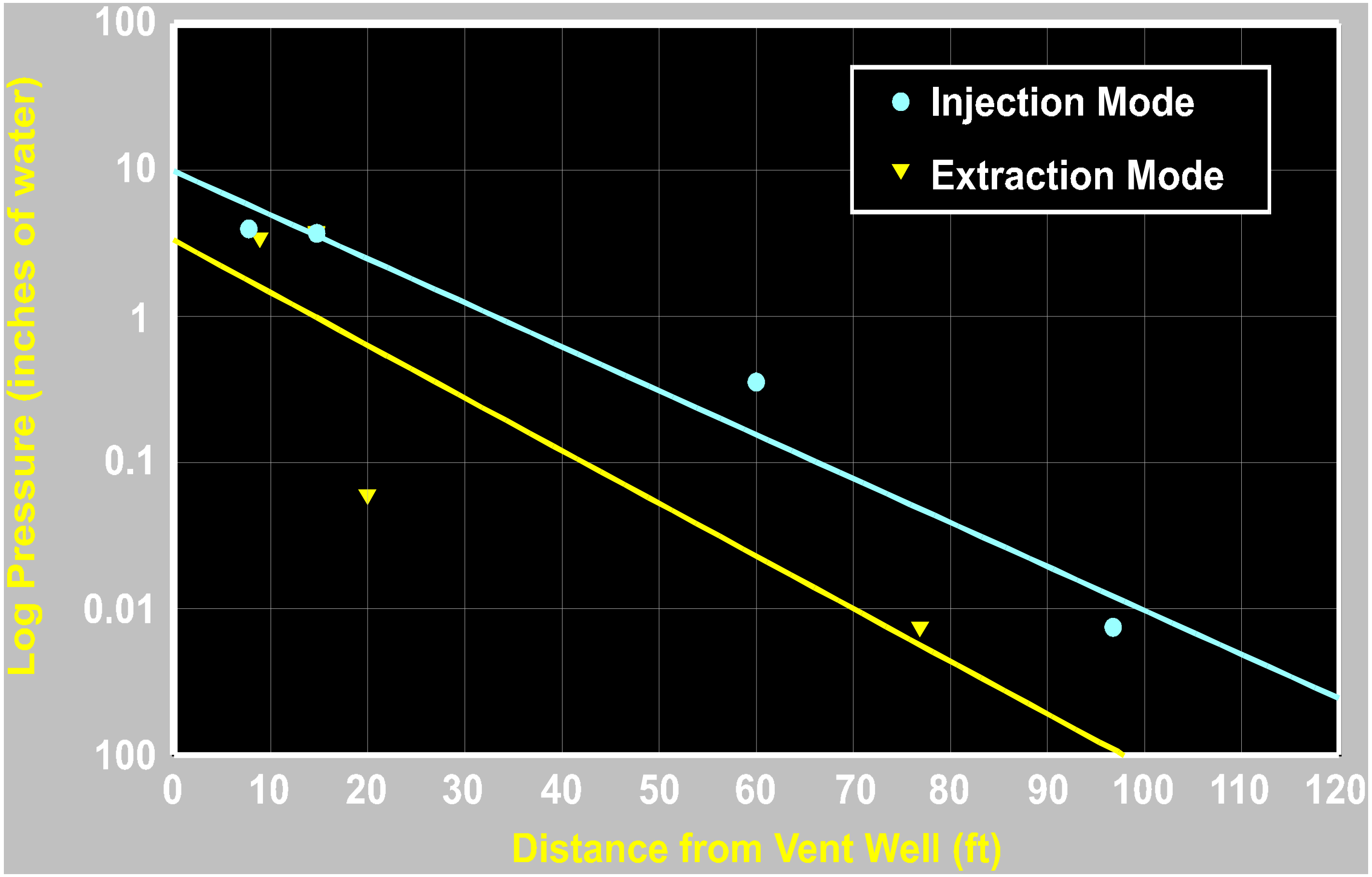
Monitoring Point Spacing

Soil Type	Depth to Top of Vent Well Screen (ft)	Spacing Interval
Coarse sand	5	5-10-20
	10	10-30-50
	>15	20-30-70
Medium sand	5	10-20-30
	10	15-25-45
	>15	20-40-70
Fine sand	5	10-20-40
	10	15-30-50
	>15	20-40-60
Silts	5	10-20-40
	10	15-30-50
	>15	20-40-60
Clay	5	10-20-30
	10	10-20-40
	>15	10-25-50

Air Delivery Systems

- Air injection
  - Actively inject air via blower system
- Air extraction
  - Air treatment may be required
  - Mounding may occur
- Passive venting
  - Capitalize on natural barometric pressure fluctuations or tidal influences to aerate contaminated areas

Radius of Influence During Air Injection and Air Extraction



Bioventing by Air Extraction

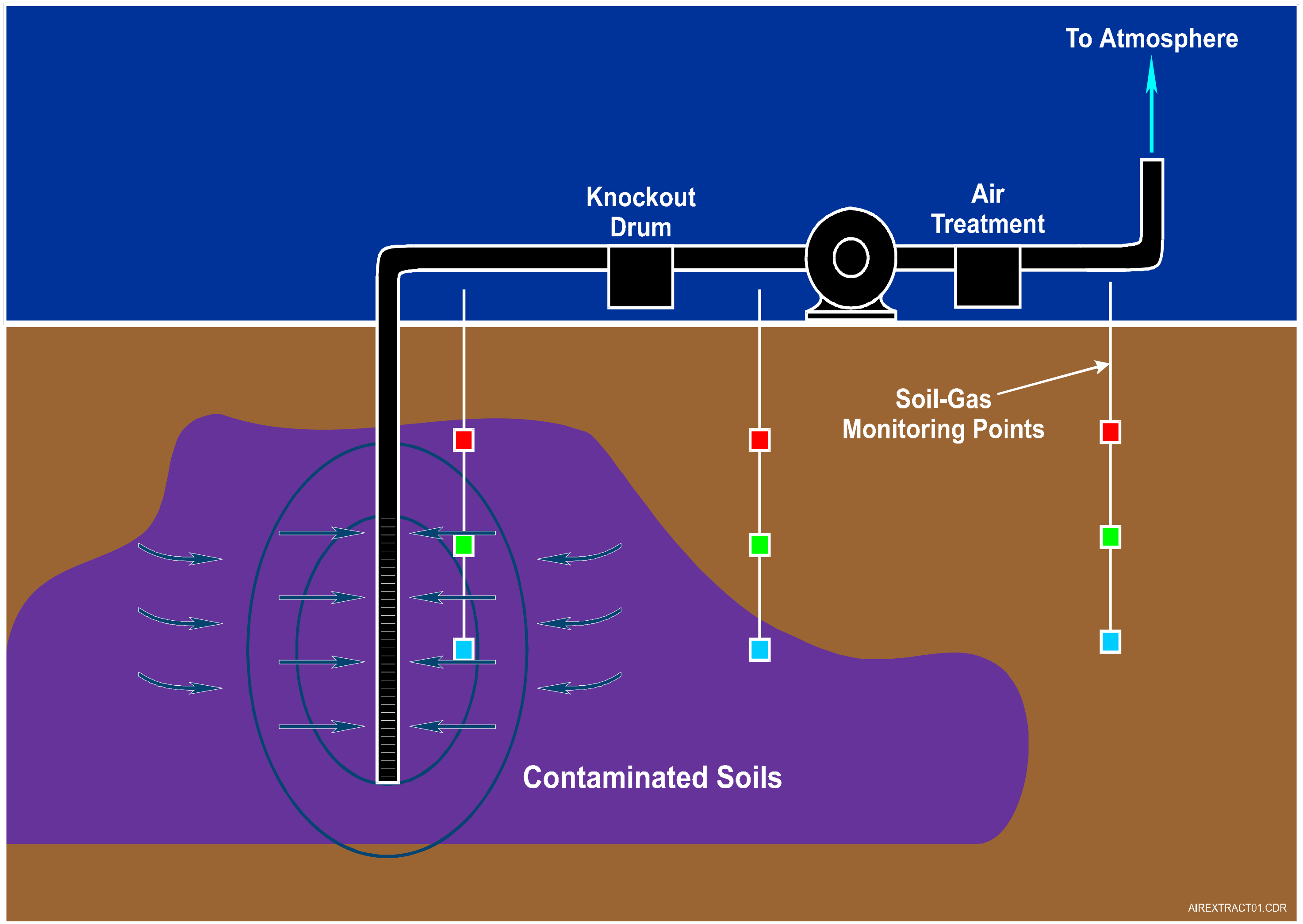
If air injection is better why would anyone use extraction for bioventing

Because we must in order to:

- Prevent migration of vapors into subsurface structures, which could cause indoor air issue or worse yet, an…

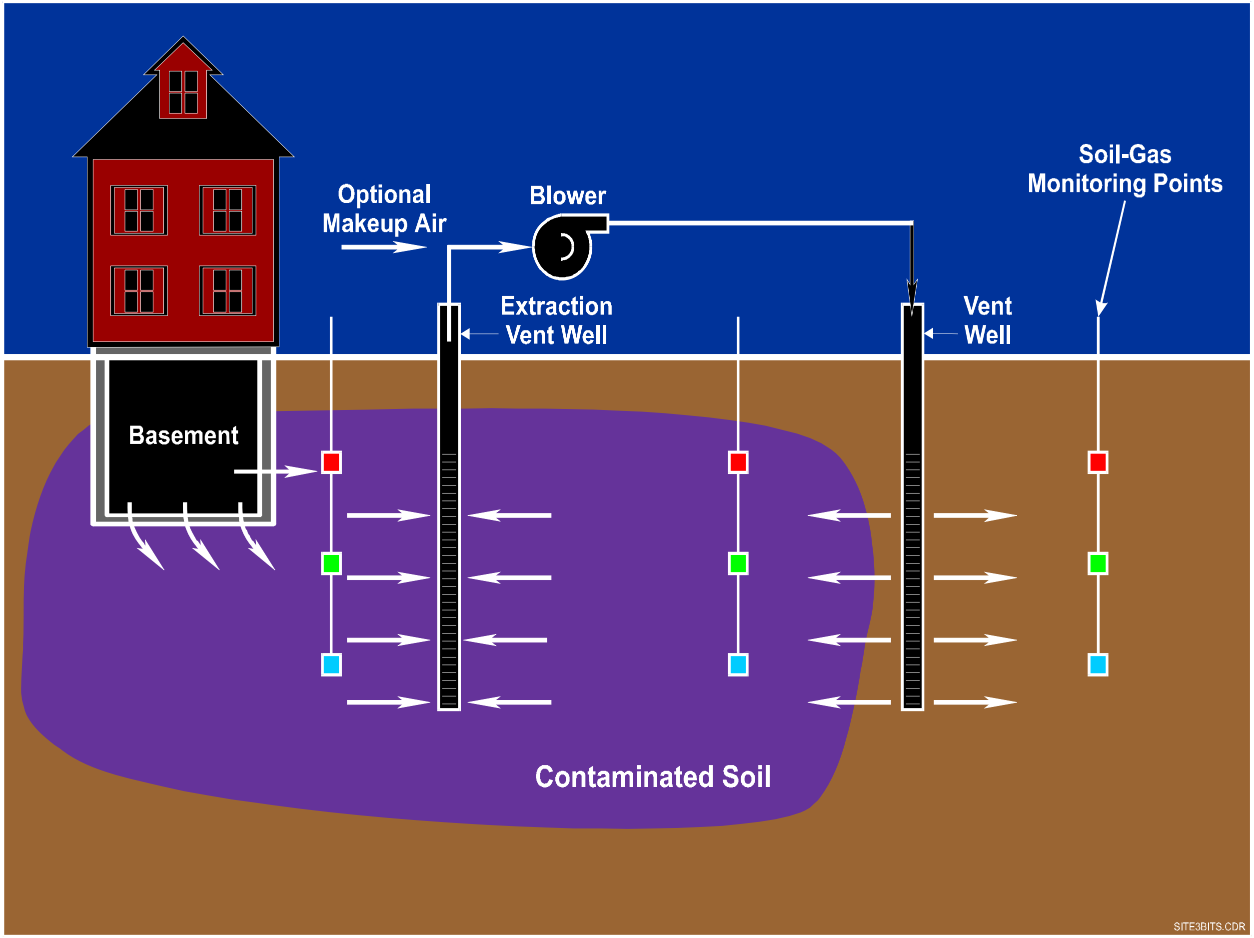
- Prevent excessive surface emissions
- Alleviate concerns over contaminant migration

Basic Air Extraction System



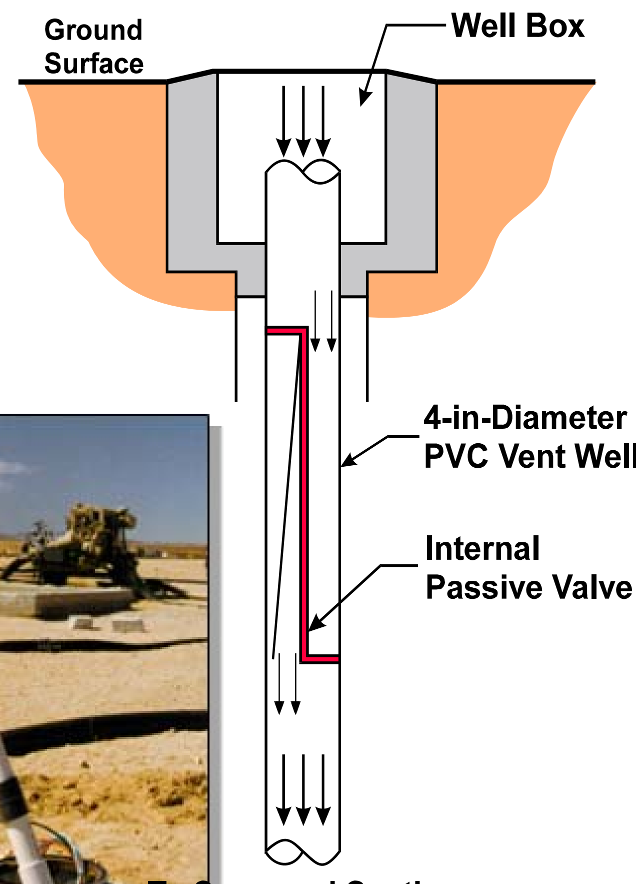
Alternatives to Direct Extraction with Emission

- Isolation of subsurface structure
- Reinjection

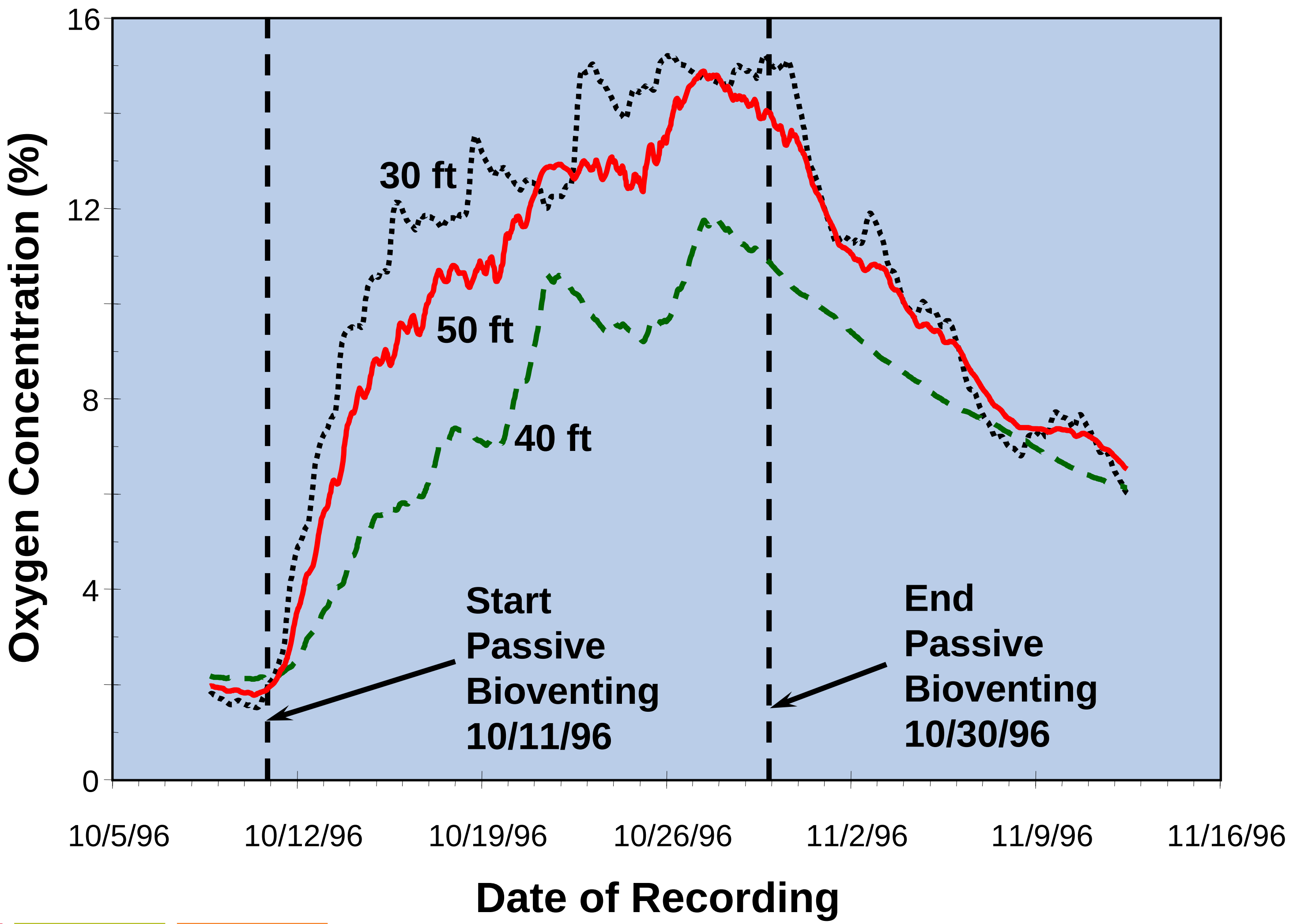


Passive Bioventing

- Barometric pressure changes
  - Drive natural air exchange in subsurface
- Simple and inexpensive
- Alternative for remote sites
- May be applied at sites with:
  - Large soil-gas reservoir
  - Porous media
  - Substantial temperature or barometric pressure fluctuations
  - Low permeability layer near ground surface
- Installed at MCAGCC 29 Palms
  - Depth to groundwater ~70 m
  - Deeper wells produced greater flowrates



Oxygen Concentrations During and Following Passive Aeration



Bioventing Monitoring

- In situ respiration test
  - Year 1 - Semi-annually
  - Year 2 to closure - annually
- When oxygen utilization approaches 0, initiate final sampling
- *No periodic soil sampling needed!!*

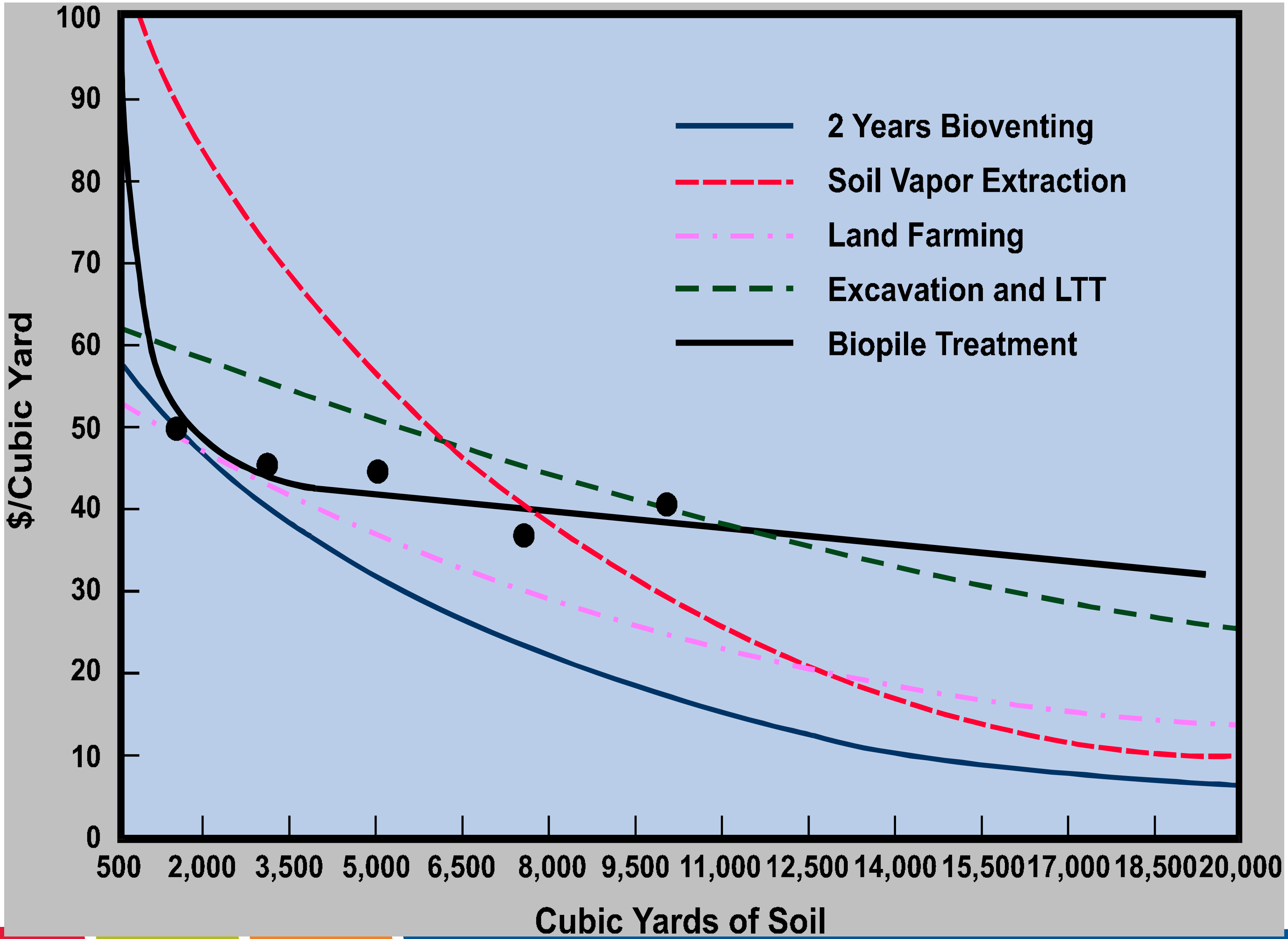
Cleanup Times and Costs are Site Specific

In General: 2 to 10 years for TPH
1 year for BTEX

Factors:

- Soil characteristics
- Contaminant location and distribution
- Soil moisture content
- Contaminant concentration
- Desired cleanup time
- Air emissions

Comparison of Costs for Soil Treatment



Key Factors to Success

- Sufficient site characterization
- Field testing (extensive pilot not always necessary but quick field test is important)
- Set realistic budget and schedule
- Design review by experienced personnel; this does not always happen even at firms having such experienced personnel
- Project planning and construction management
- Establish site-specific monitoring and optimization plan

Bioventing Design Tool (BVDT)

- Developed by Battelle to help analyze field data, construct tables, and construct charts that will help with full-scale design. Sections include:
  - Data collection
  - In situ respiration test
  - Permeability and radius of influence
  - Blower design
  - Vent well and monitoring point spacing
  - Soil gas monitoring

Bioventing Example – Jet Fuel Cleanup

- 100,000 liters spilled
  - About 8,000 L free product recovered
  - 3,800 m^3 contaminated soil, up to 20 m deep
  - TPH up to 10,200 mg/kg
- Converted SVE to bioventing
  - Removed off-gas treatment system – saved $13,000/month
  - 15 months operation
  - Biodegraded more than 40,000 kg fuel
  - Cleanup and regulatory closure achieved