Bioreactor Landfill Design

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- The design and engineering of bioreactor landfills is relatively new field and design techniques and methods continue to evolve.
- This presentation will provide an overview of design issues and approaches related to bioreactor landfills.

Bioreactor Landfill Design

- Modern landfill design entails many elements
  - Foundations
  - Liner systems
  - Leachate collection systems
  - Stormwater control systems
  - Slope stability considerations
  - Leachate management systems
  - Gas extraction systems
  - Capping and closure

Bioreactor Landfill Design

- The use of bioreactor technology at landfills can impact all of these phases of design.
- In addition, a design must be provided for the addition of liquids (and perhaps air) into the landfill.

Bioreactor Landfill Design

- This presentation will focus on:
  - Designing the leachate recirculation system
  - Meeting regulatory requirements (maintaining less than 1 ft of head on the liner)
- Other issues will be commented on briefly.
- Design issues surrounding gas and air addition will be discussed in the next section.

Elements of Leachate Recirculation System Design

- What to recirculate
- How much to recirculate
  - In total
  - Over a given period of time
- Method to recirculate
- Configuration and spacing of recirculation devices
- Develop operating constraints of system

Sources of Liquids to Recirculate

- Leachate
- Gas condensate
- Water
- Other bulk liquids (not currently permitted under rules)

Recirculation Amounts

- How much to recirculate:
  - Typical approach is to add enough liquid to bring the landfilled waste to field capacity.
  - Field capacity is the moisture content that the waste can “hold” under the influence of gravity.

Recirculation Amounts

- How much to recirculate:
  - Initial moisture content: 15-25% (wet wt)
  - Field capacity: 35-45% (wet wt)

- An increase from 20% to 35% in moisture content requires:

55 gallons per ton

Recirculation Rates

- Large amounts of water are thus required to get the landfill to field capacity
- What rate do you add the leachate? (i.e. how fast can you add the leachate)
- Depends on several issues:
  - Meeting regulatory requirements
  - The ability of the landfill and the devices to accept the liquids
  - Limitations on pressure buildup
  - Available liquids supply
  - Operational timeline
  - Minimizing seeps

Impact of Regulations on Determining Recirculation Rates

- Primary regulatory controlling factor: the requirement to meet less than one foot of head on the liner.
- For as-built landfills, the leachate collection system can be designed to handle the leachate recirculation rate you need (closer spacings, use of geonets)
- For retrofit landfills, the rate of leachate recirculation may be limited by the existing design.

Impact of Regulations on Determining Recirculation Rates

- Assessing impact of leachate recirculation on head on the liner.
- Predict head assuming that the leachate recirculation rate is equal to the impingement rate into the LCS.
- Perform the HELP model.

Impact of Regulations on Determining Recirculation Rates

- Using the HELP model to predict head on the liner:
  - HELP has a feature to recirculate a percentage of the leachate collected in one layer back to another layer
  - HELP also allows the addition of a constant “sub-surface” inflow into particular layers
  - HELP is limited when in comes to complicated recirculation scenarios

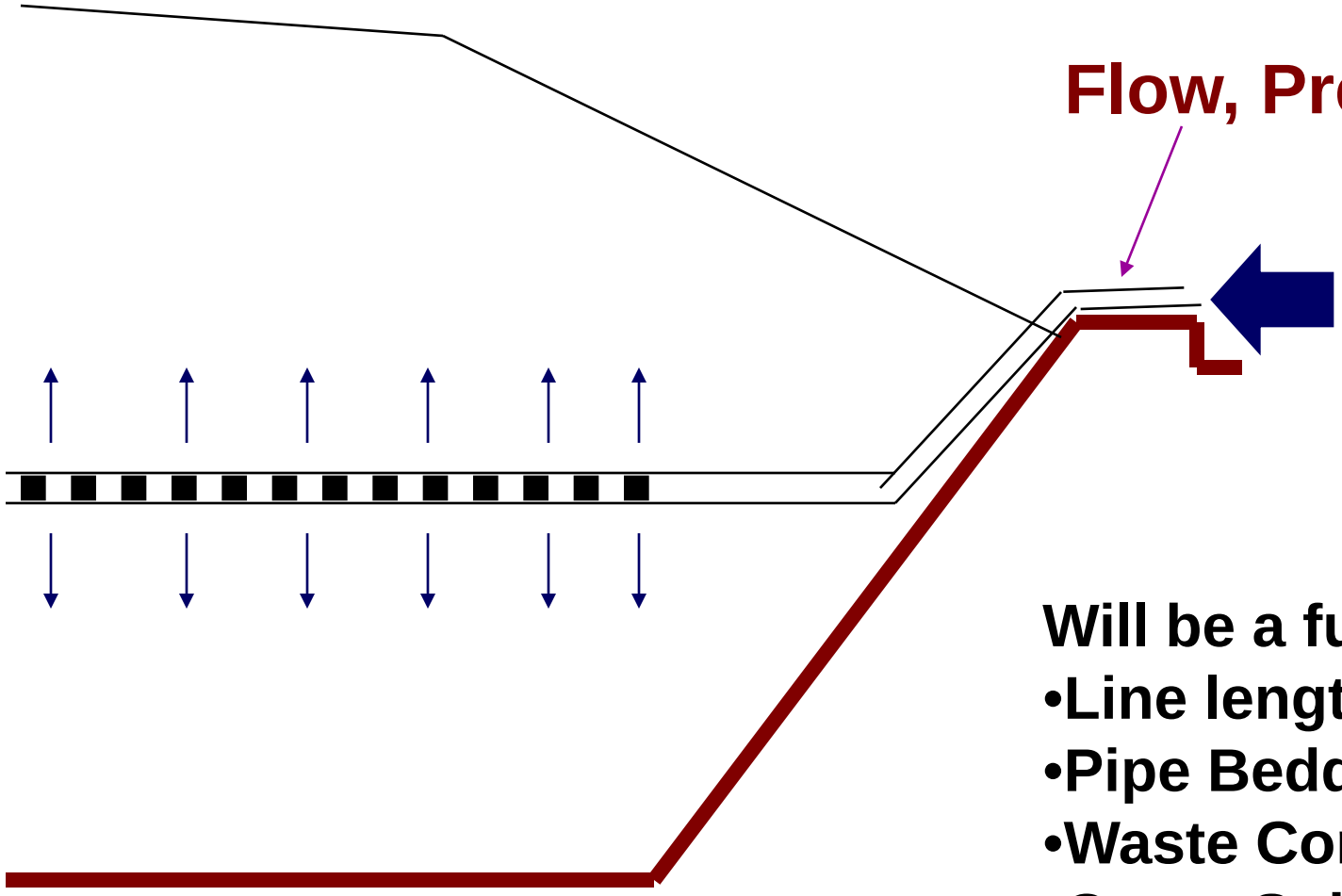
Impact of Regulations on Determining Recirculation Rates

- Other complicating factors:
- How do you account for all of the existing moisture storage capacity in the landfill?
- How do you account for the possible clogging in the leachate collection system?

Ability of Waste and Devices to Accept Leachate

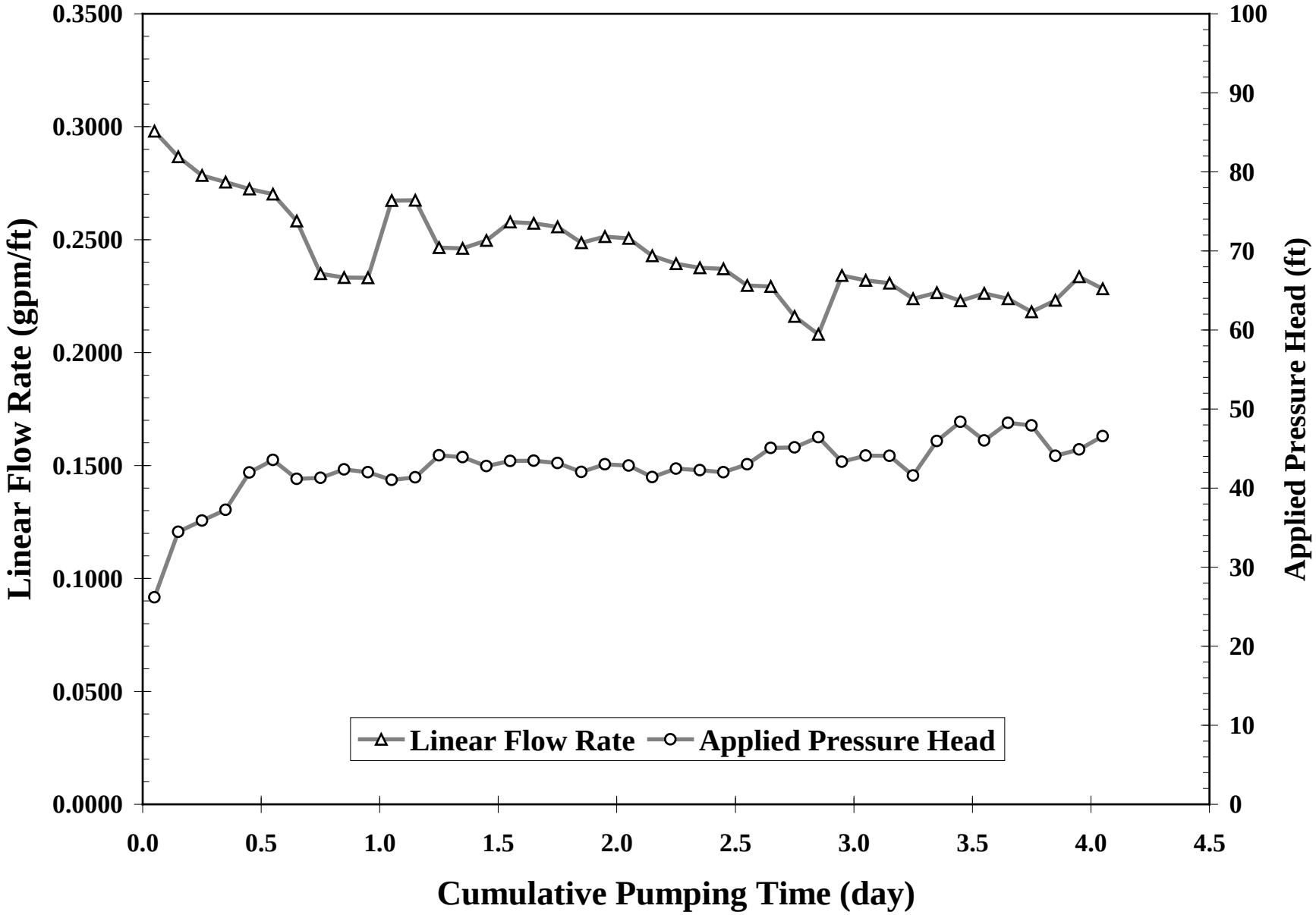
- It is important to remember that compacted waste is not very permeable, and the recirculation rate might be limited by the waste and the device.
- Examples:
  - Infiltration ponds at ACSWL:
    3,000 – 5,000 gallons per acre-day
  - Injection lines at ACSWL:
    0.005 gpm per ft of injection line per ft of pressure head

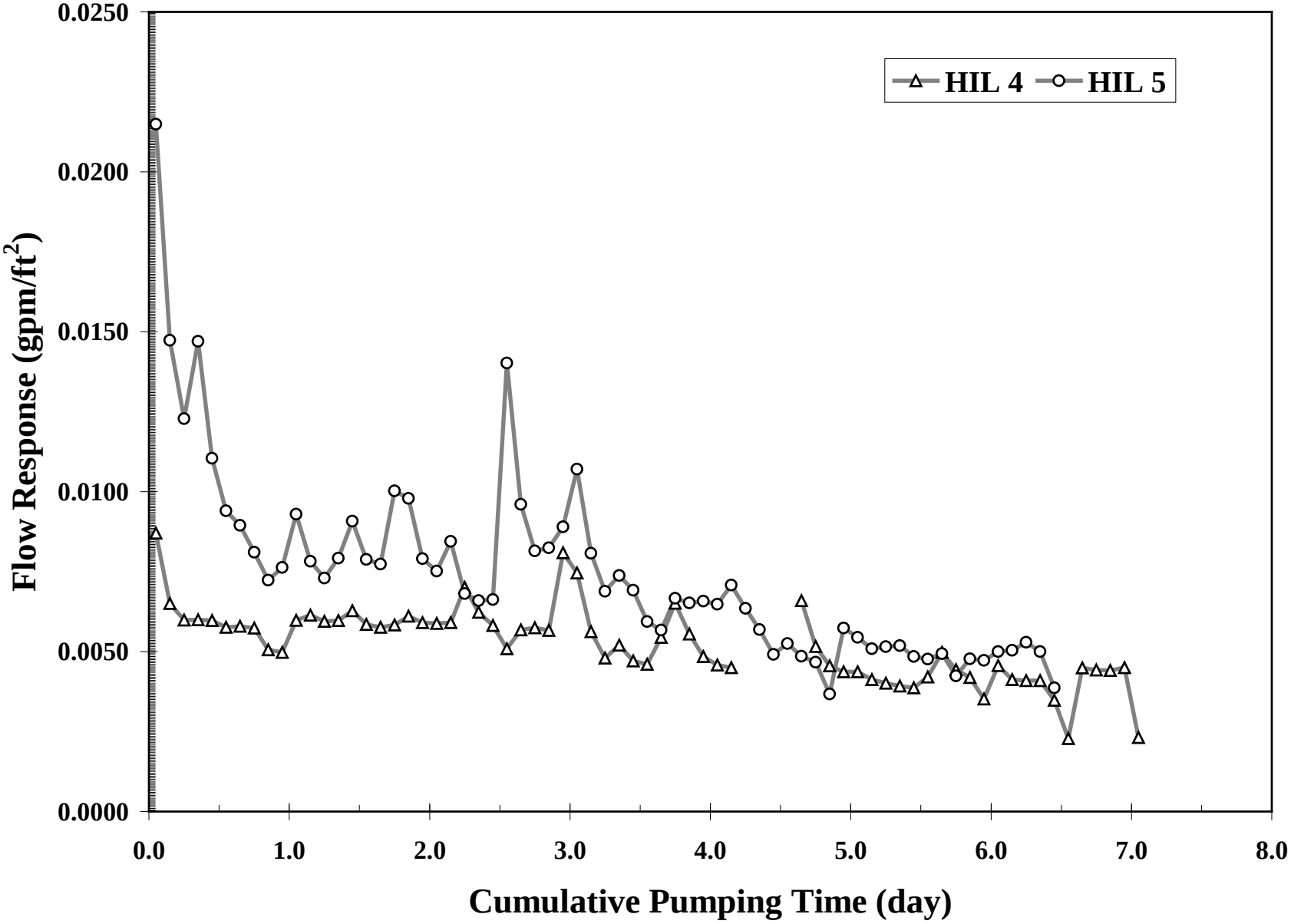
Consider a Horizontal Injection Line

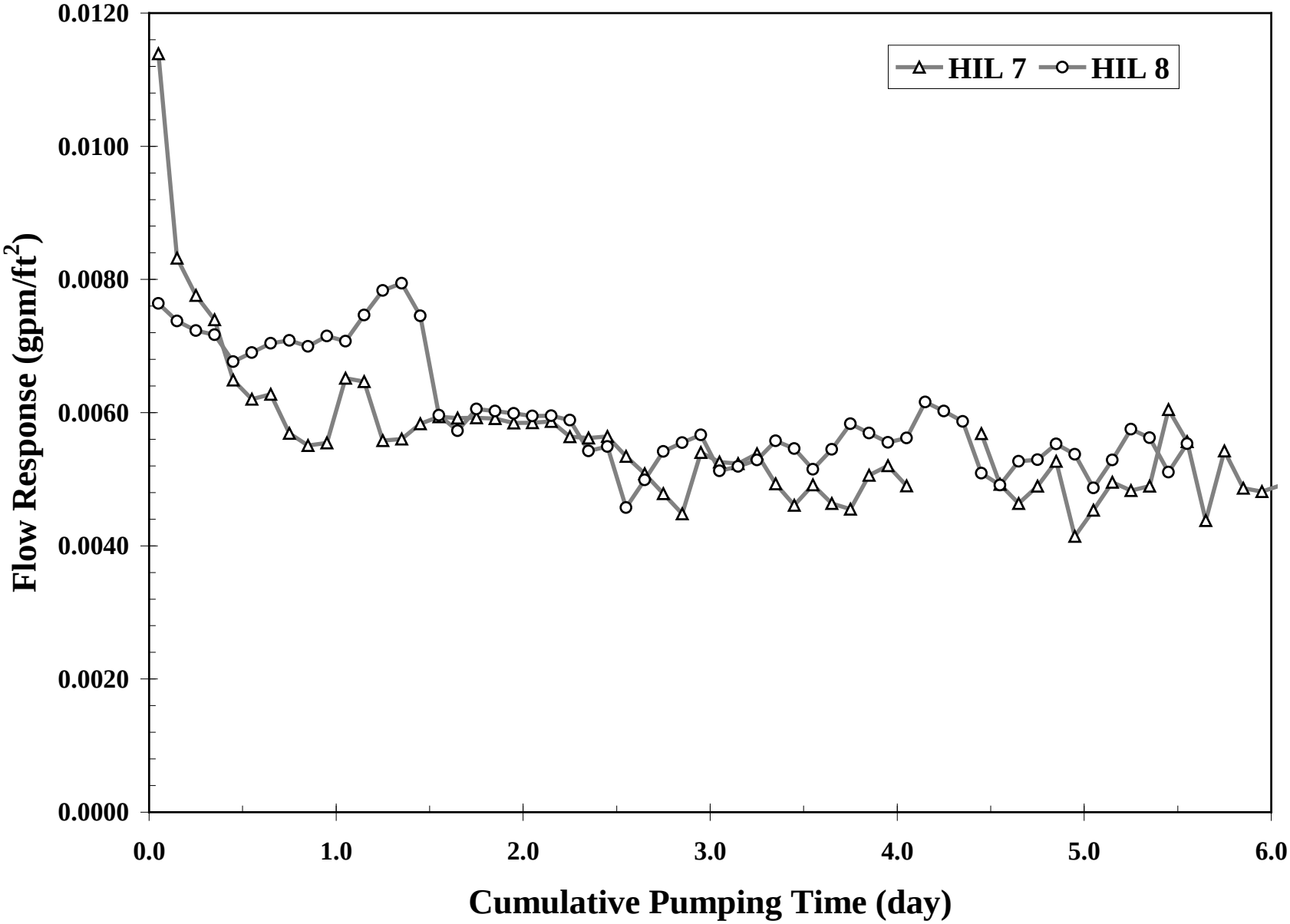


Will be a function of

- **Line length**
- **Pipe Bedding**
- **Waste Compaction**
- **Cover Soil**
- **Overburden**


0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Linear Flow Rate (gpm/ft)
100
90
80
70
60
50
40
30
20
10
0
Applied Pressure Head (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Cumulative Pumping Time (day)
Linear Flow Rate
Applied Pressure Head


HIL 4
HIL 5
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Flow Response (gpm/ft2)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Cumulative Pumping Time (day)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HIL 8
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0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
Flow Response (gpm/ft2)
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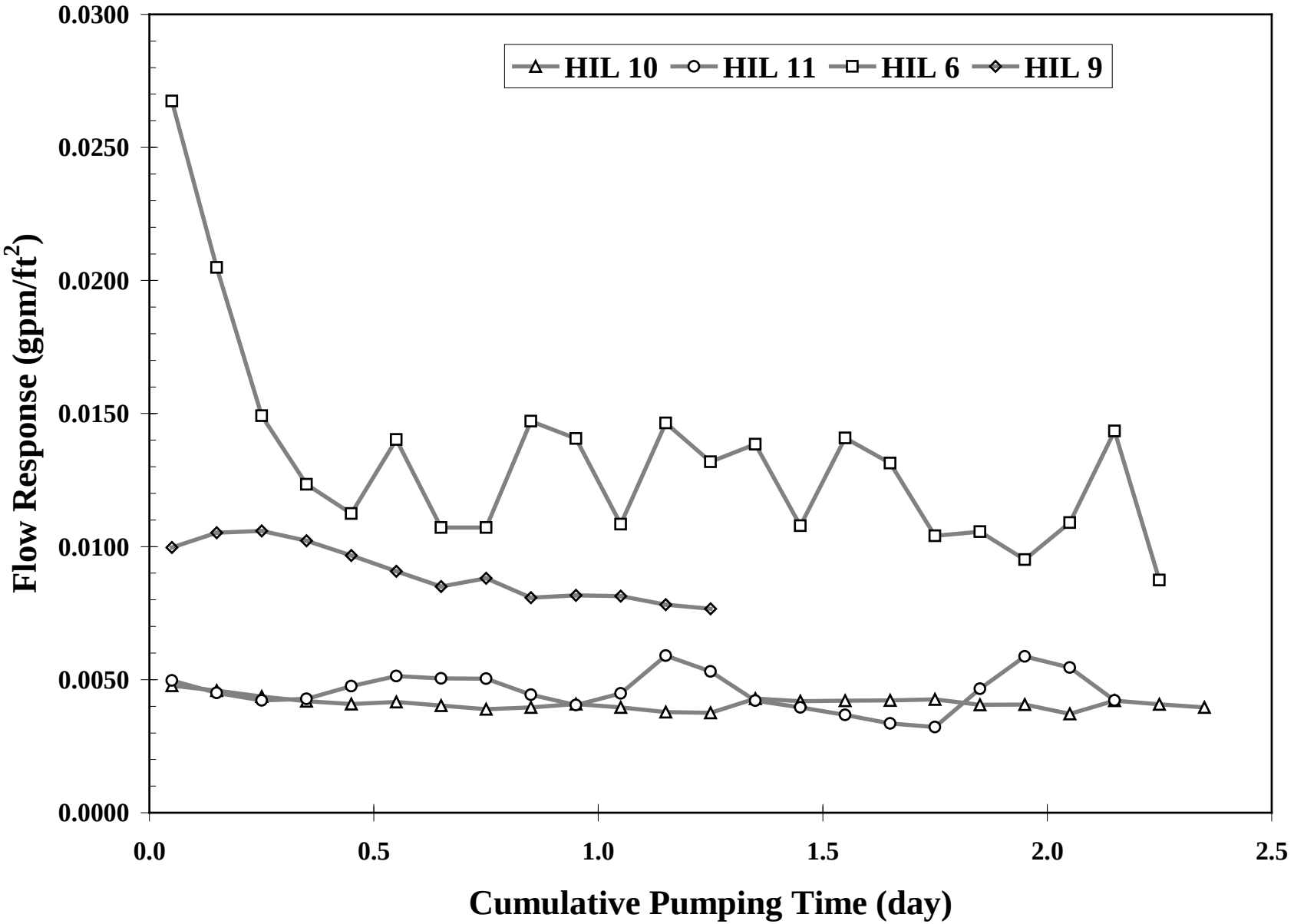
1.0
2.0
3.0
4.0
5.0
6.0
Cumulative Pumping Time (day)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HIL 11
HIL 6
HIL 9
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Flow Response (gpm/ft2)
0.0
0.5
1.0
1.5
2.0
2.5
Cumulative Pumping Time (day)

Other Factors Affecting Leachate Recirculation Rate

- Limitations on pressure buildup (slope stability concerns?)
- Available liquids supply
- Operational timeline
- Minimizing seeps

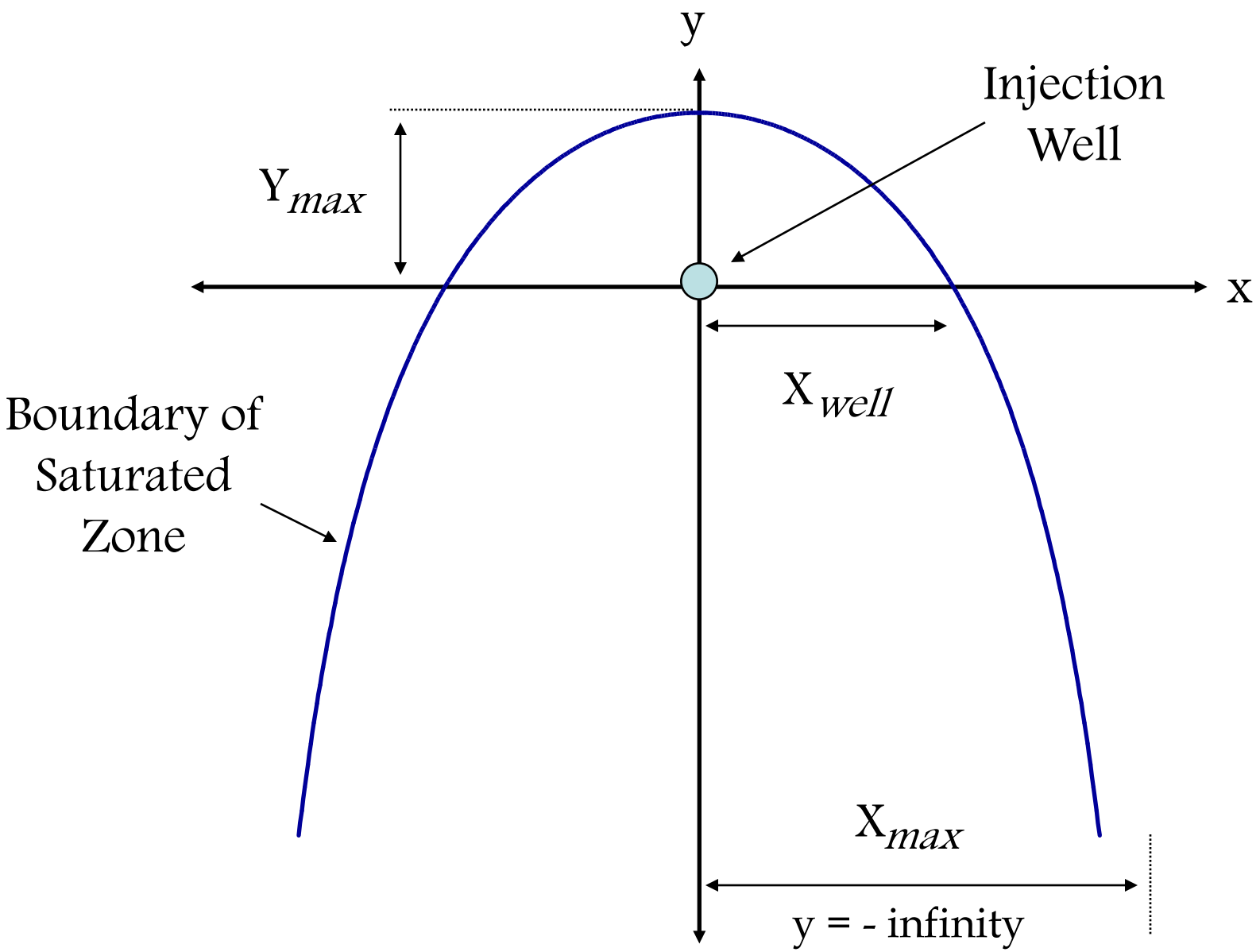
Methods to Recirculate

- Several methods were discussed in the “moisture management” lesson.
- Constraints at the site may dictate what method is selected.

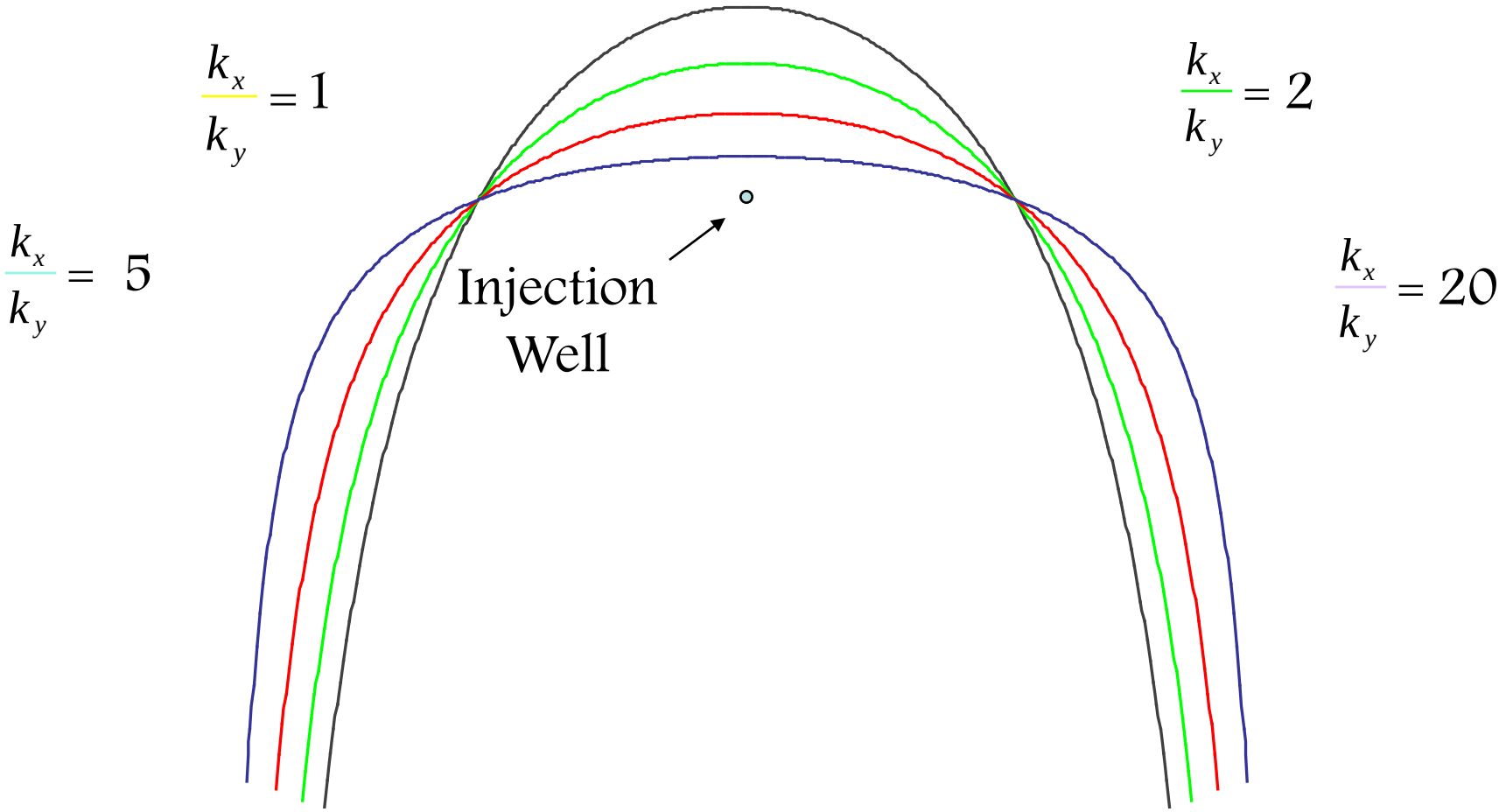
Sizing and Spacing of Devices

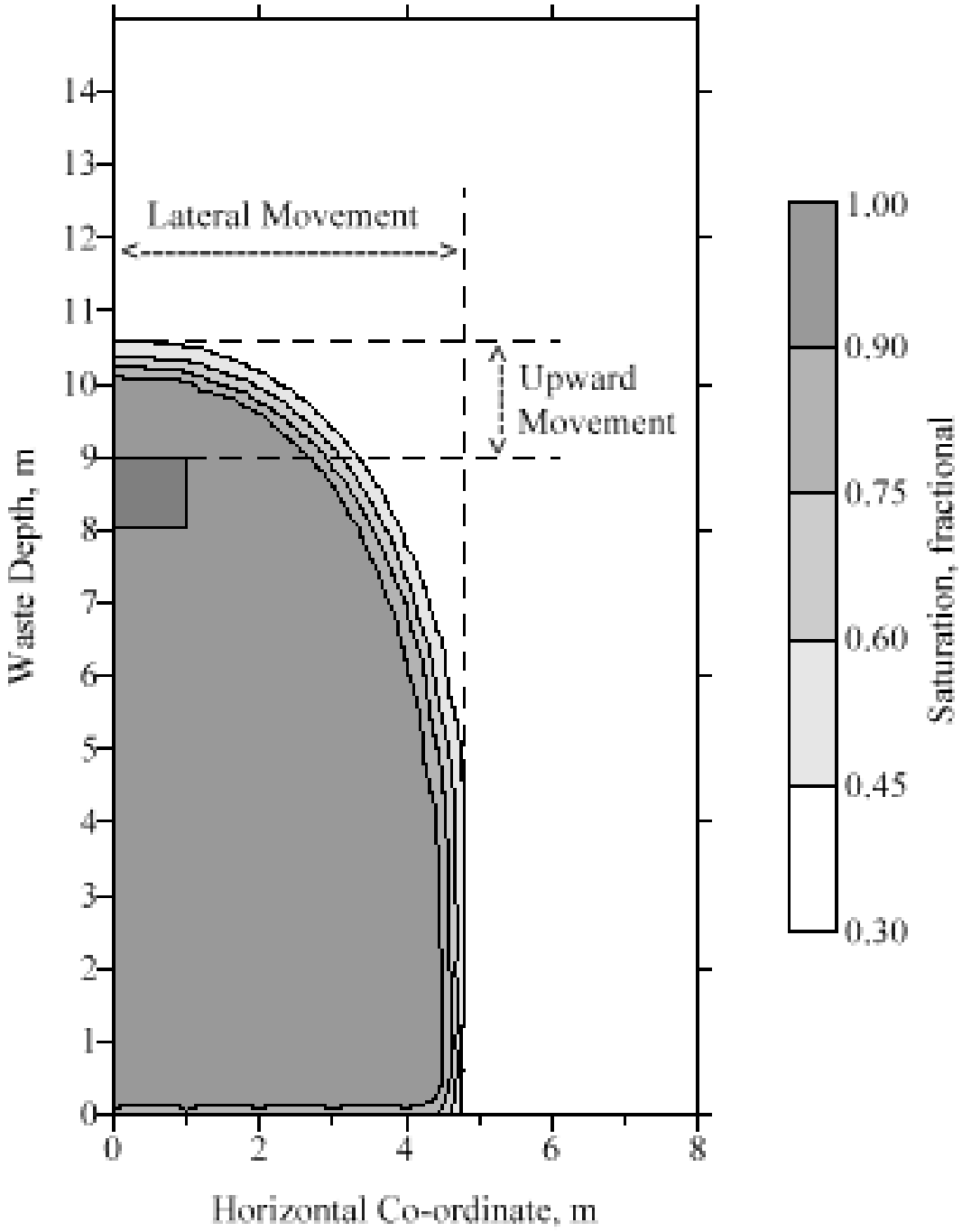
- The sizing and spacing of devices is somewhat limited by the lack of data regarding moisture distribution in operating bioreactor landfills.
- Methods are available to be estimate the distribution of liquids in landfills.
  - Analytical solutions
  - Numerical modeling

Flow System for Horizontal Injection Well



Effect of Anisotropy on Saturated Zone Surrounding Horizontal Injection Well





McCreanor and Reinhart

Results of Numerical Simulations (see supplemental materials)

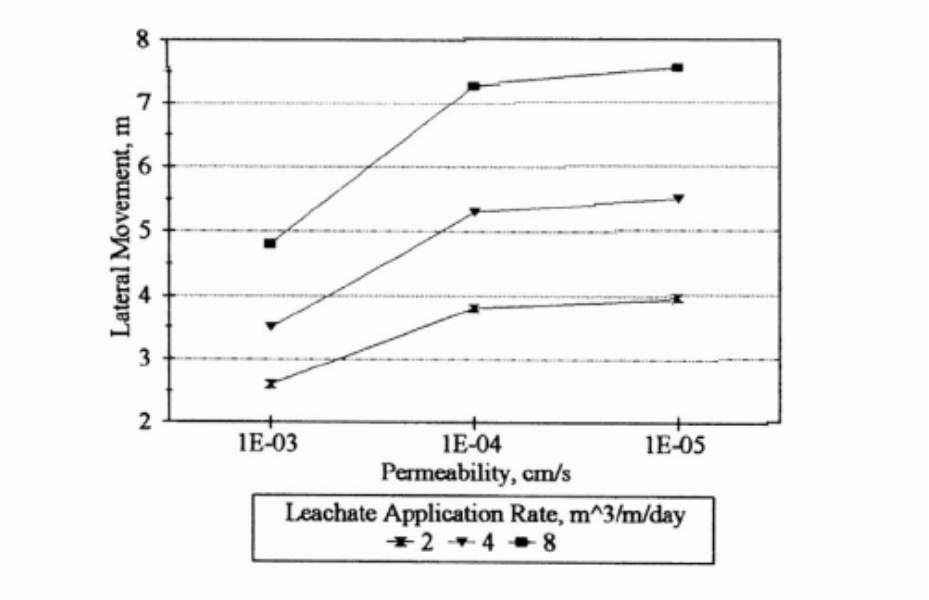


Fig. 4. maximum lateral movement versus hydraulic conductivity for intermittent leachate injection (8 hr on/16 hr off) via a horizontal trench. Application rates represent the total amount of leachate input per day

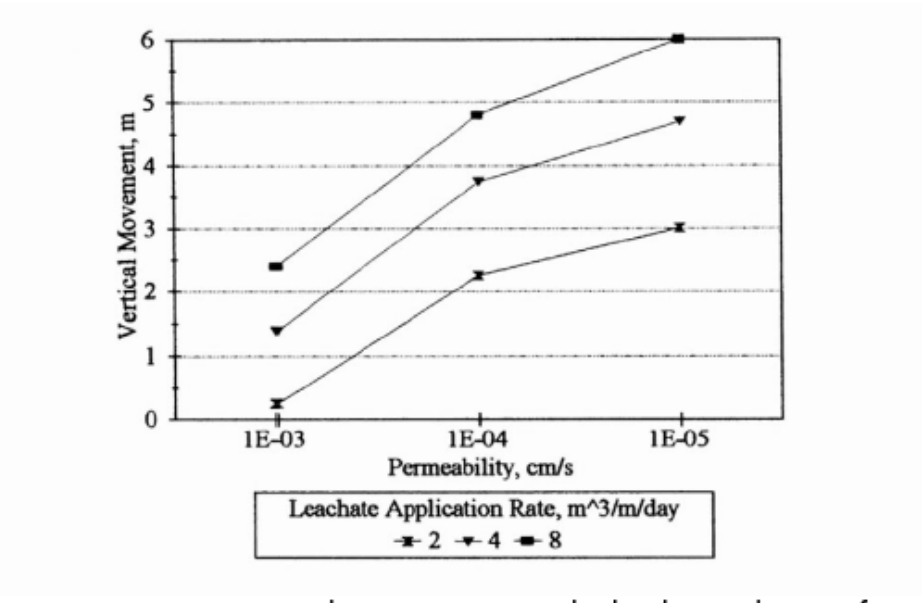
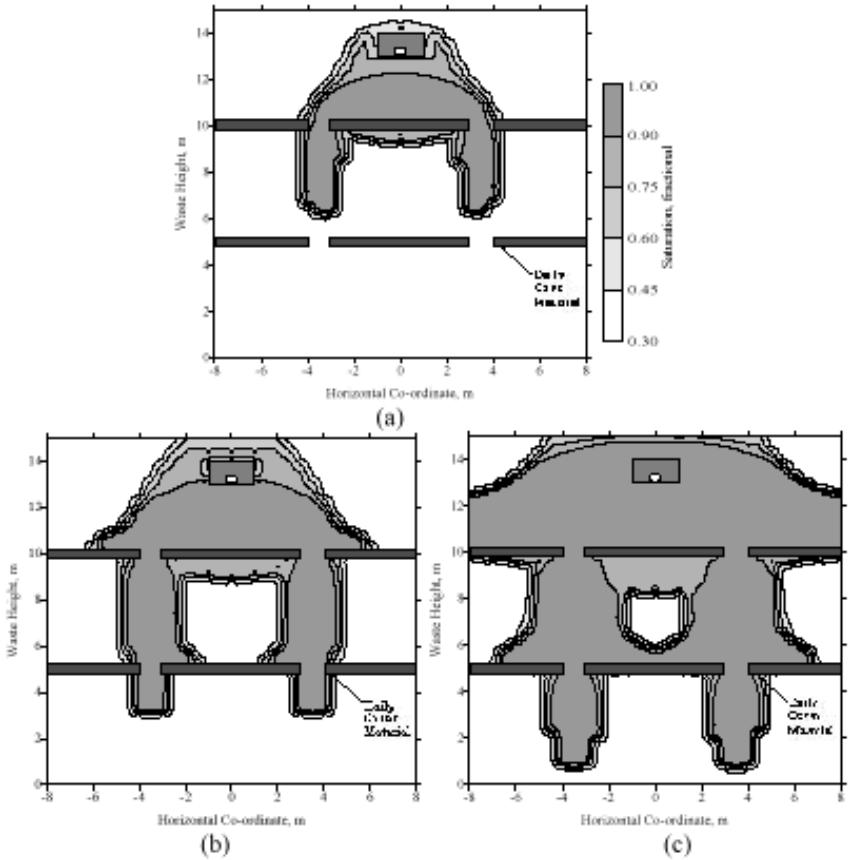


Fig. 5. Maximum upward movement versus hydraulic conductivity for intermittent leachate injection (8 hr on/16 hr off) via a horizontal trench. Application rates represent the total amount of leachate input per day

Sizing and Spacing of Devices

- Because of the uncertainty associated with the moisture distribution, the general approach is to build in redundancy into the system.



Development of Operating Constraints

- Operating constraints that should be considered include:
- Pressures and leachate depths
- Amount of time any one device is operated
- Rotation among devices

Review of Bioreactor Landfill Design Elements

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