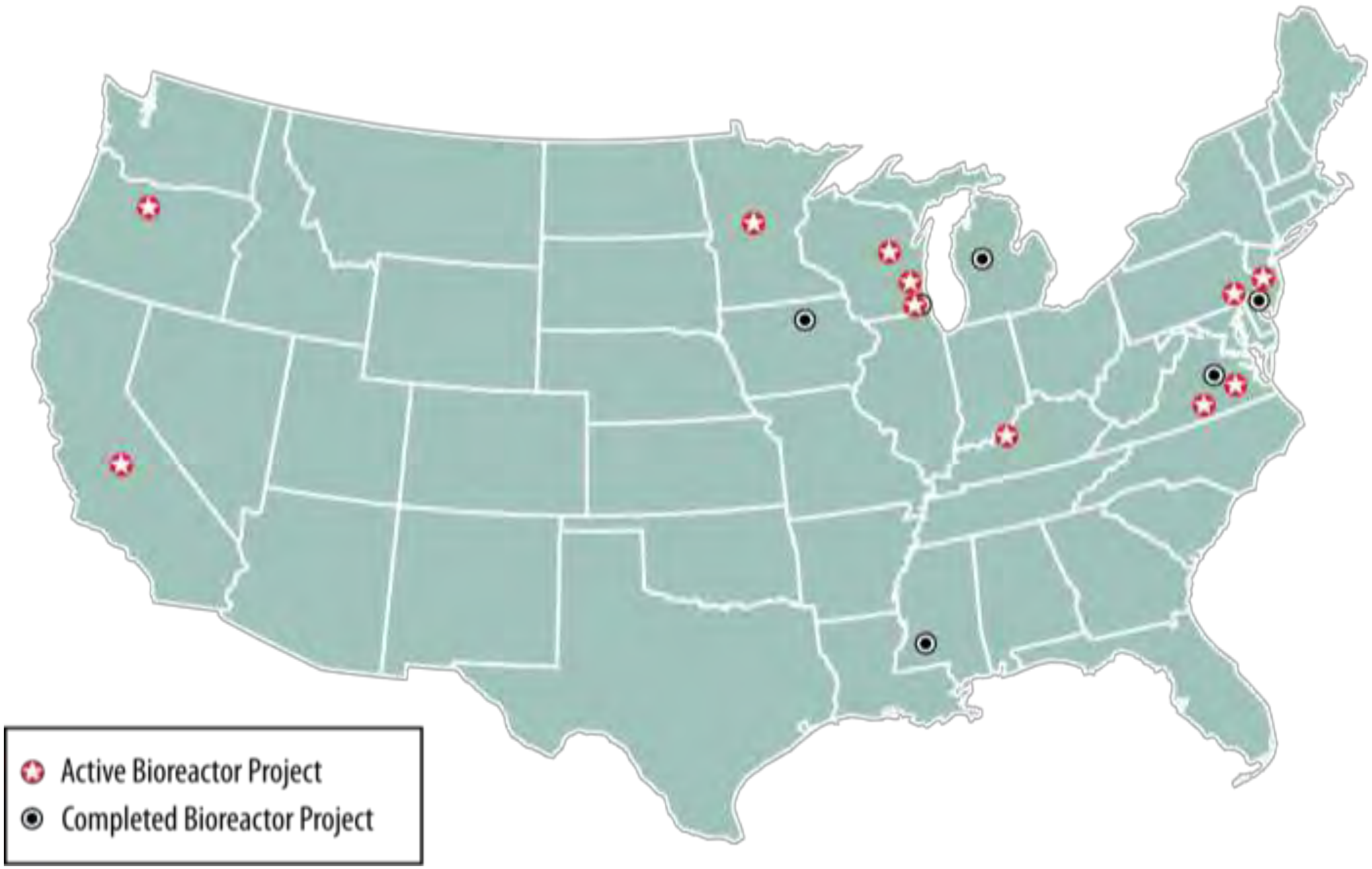
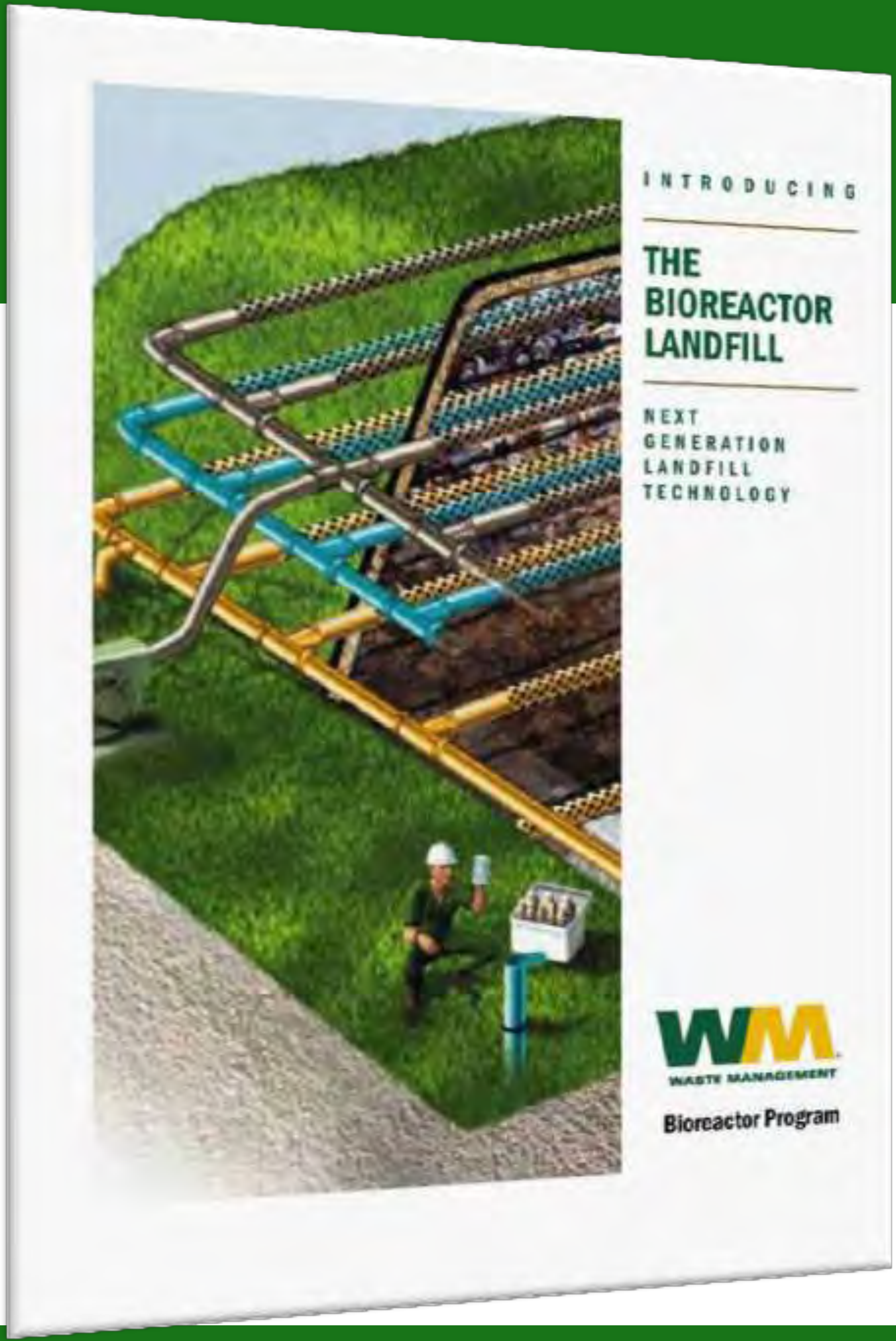
Industry Perspectives on Bioreactor Landfills

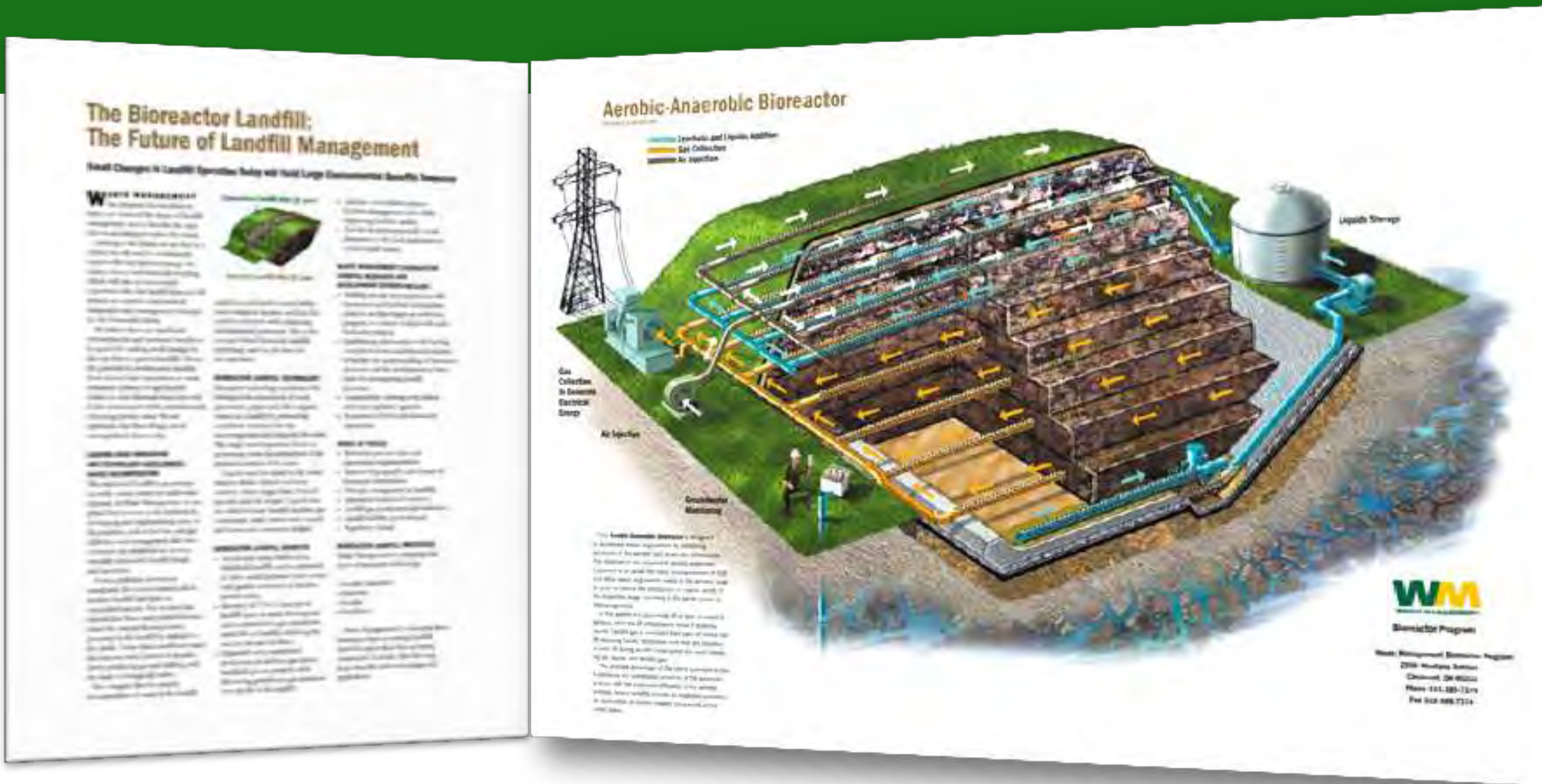
Roger B. Green

Waste Management, Inc.

WM bioreactor projects




INTRODUCING
THE BIOREACTOR LANDFILL
NEXT GENERATION LANDFILL TECHNOLOGY
WM
WASTE MANAGEMENT
Bioreactor Program


The Bioreactor Landfill:
The Future of Landfill Management
Aerobic-Anaerobic Bioreactor
Gas Collection
Air Injection
Liquids Storage
Gas Collection to Generate Electrical Energy
Groundwater Monitoring
WM
Bioreactor Program

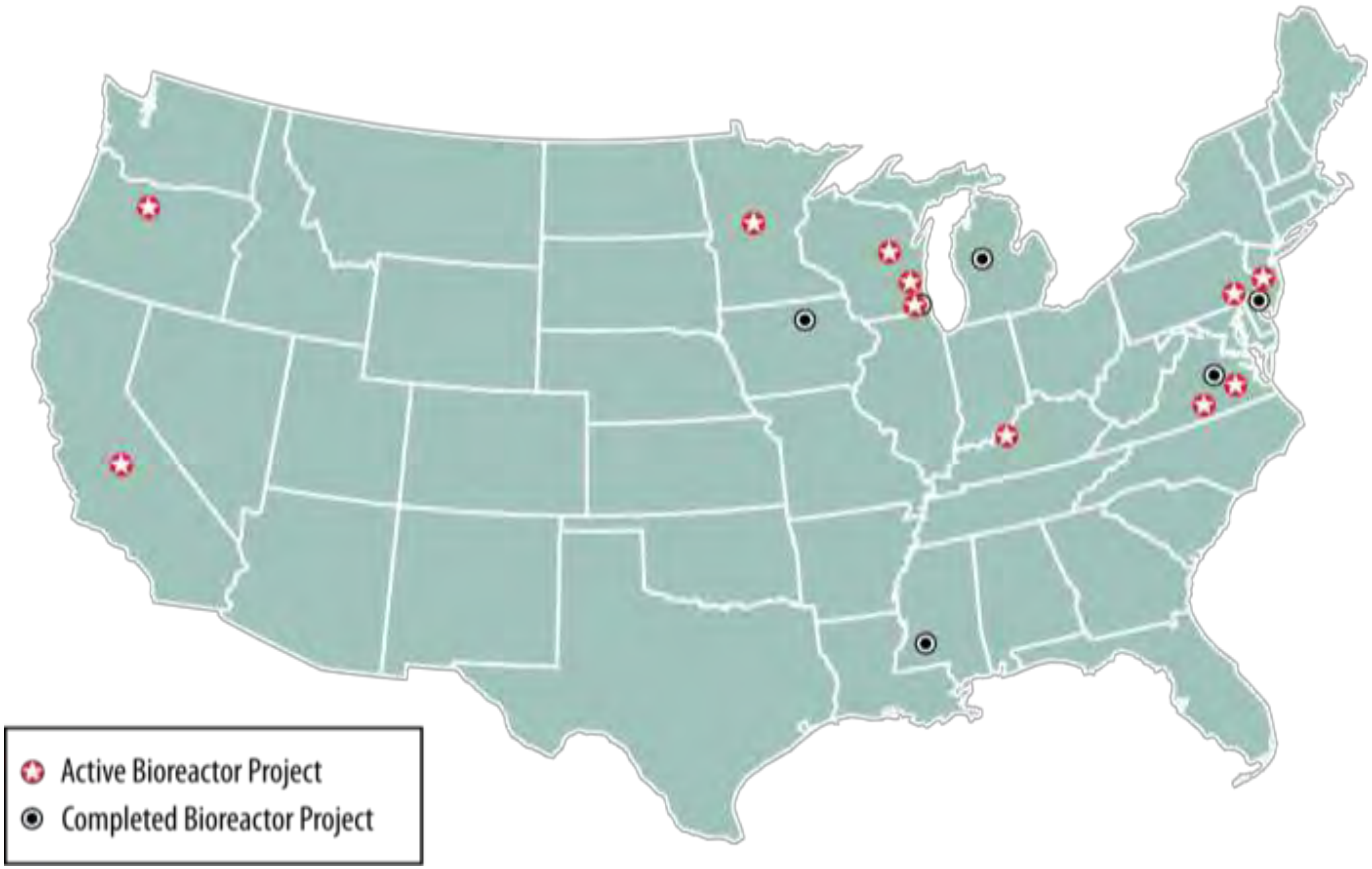
expected benefits

- Accelerated waste degradation.
- Increased gas production and potential for lower emissions.
- Enhanced waste settlement of 15-50%.
- Earlier stabilization of the waste mass.

questions

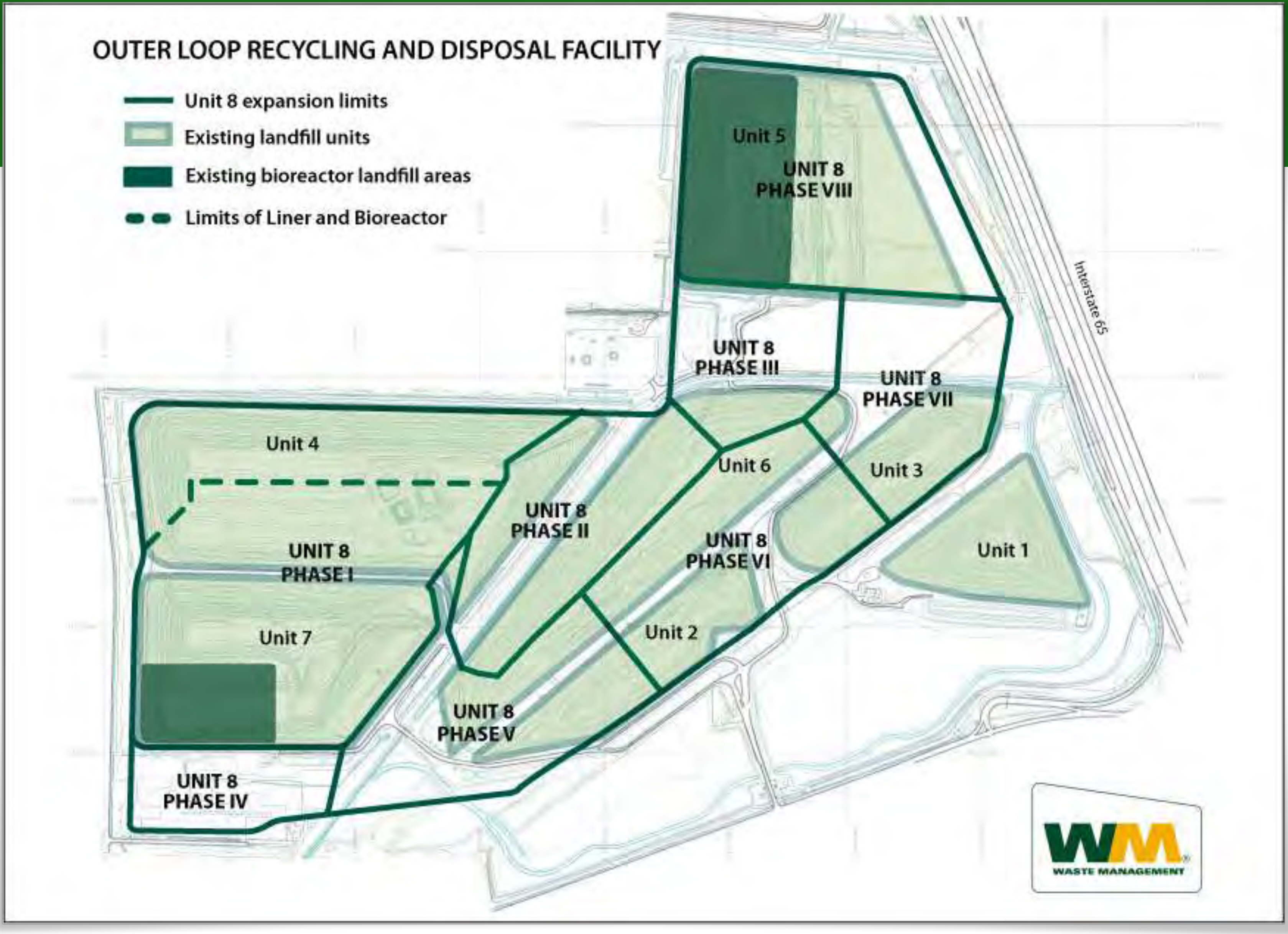
- What type of operations are most effective?
- What alternative sources of moisture can be accepted?
- Are bioreactors at least as protective as conventional landfills and how do you demonstrate this ?

WM bioreactor projects



CRADA project

- WM and US EPA ORD and OSW sign CRADA in 2000.
- Evaluate two bioreactor technologies at new and existing landfills.
- Progress measured by monitoring liquids, landfill gas and waste solids in replicate bioreactor and control cells.
- Original CRADA project spanned 2000-2005.
- CRADA extended to 2011 with amendments for landfill emissions research and development.


OUTER LOOP RECYCLING AND DISPOSAL FACILITY
Unit 8 expansion limits
Existing landfill units
Existing bioreactor landfill areas
Limits of Liner and Bioreactor
Unit 5
UNIT 8 PHASE VIII
UNIT 8 PHASE III
UNIT 8 PHASE VII
Interstate 65
Unit 4
Unit 6
Unit 3
UNIT 8 PHASE II
UNIT 8 PHASE I
UNIT 8 PHASE VI
Unit 1
Unit 7
Unit 2
UNIT 8 PHASE V
UNIT 8 PHASE IV
WM
WASTE MANAGEMENT

leachate and liquid storage and distribution

horizontal distribution and collection piping

surface liquid infiltration galleries

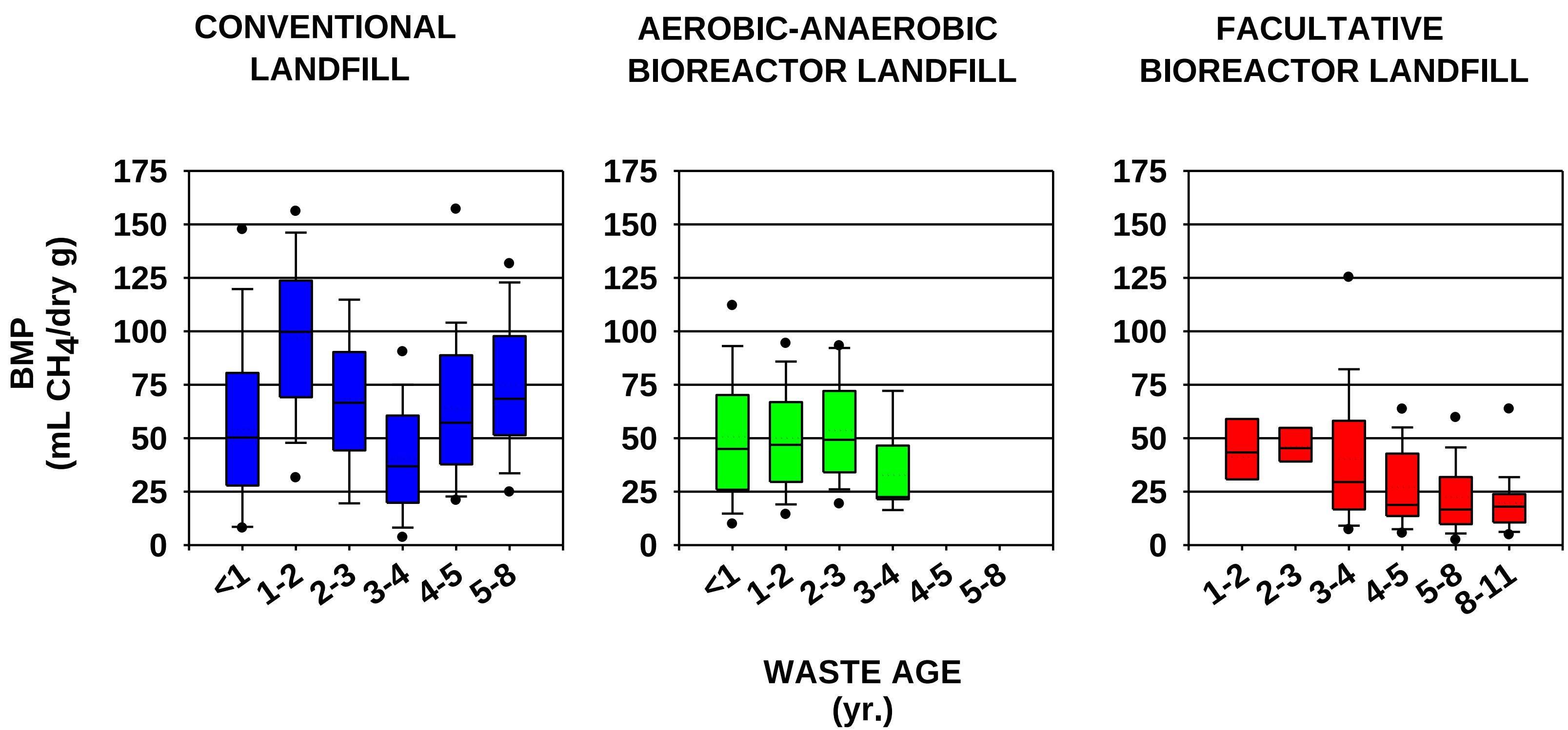
permeable layer installation

surface application

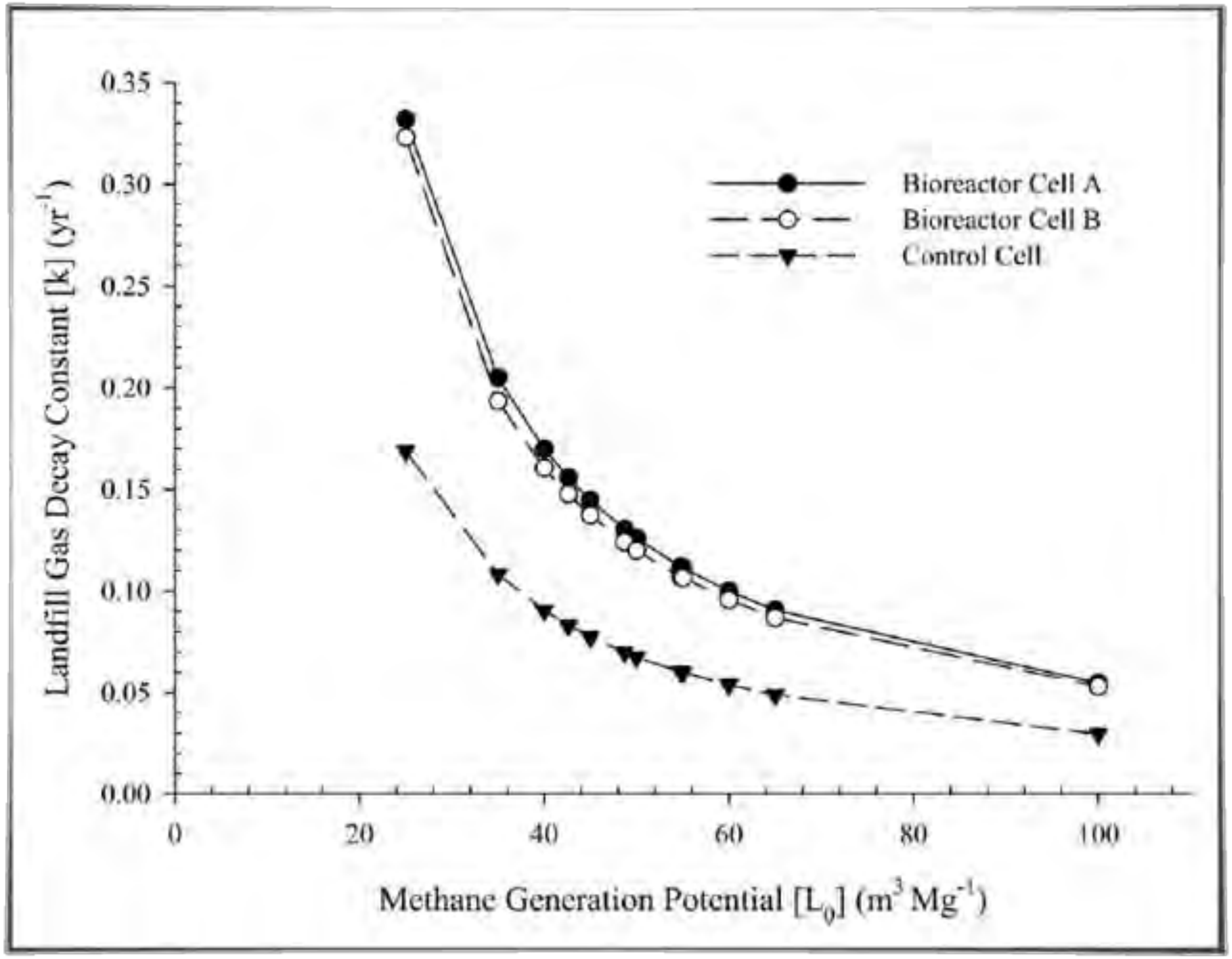
solids analyses

- Cellulose
- Hemicellulose
- Lignin
- Biochemical Methane Potential
- Organic solids (550 °C)
- Gravimetric moisture
- Samples dated by survey records for waste placement

biochemical methane potential



relating k to Lo

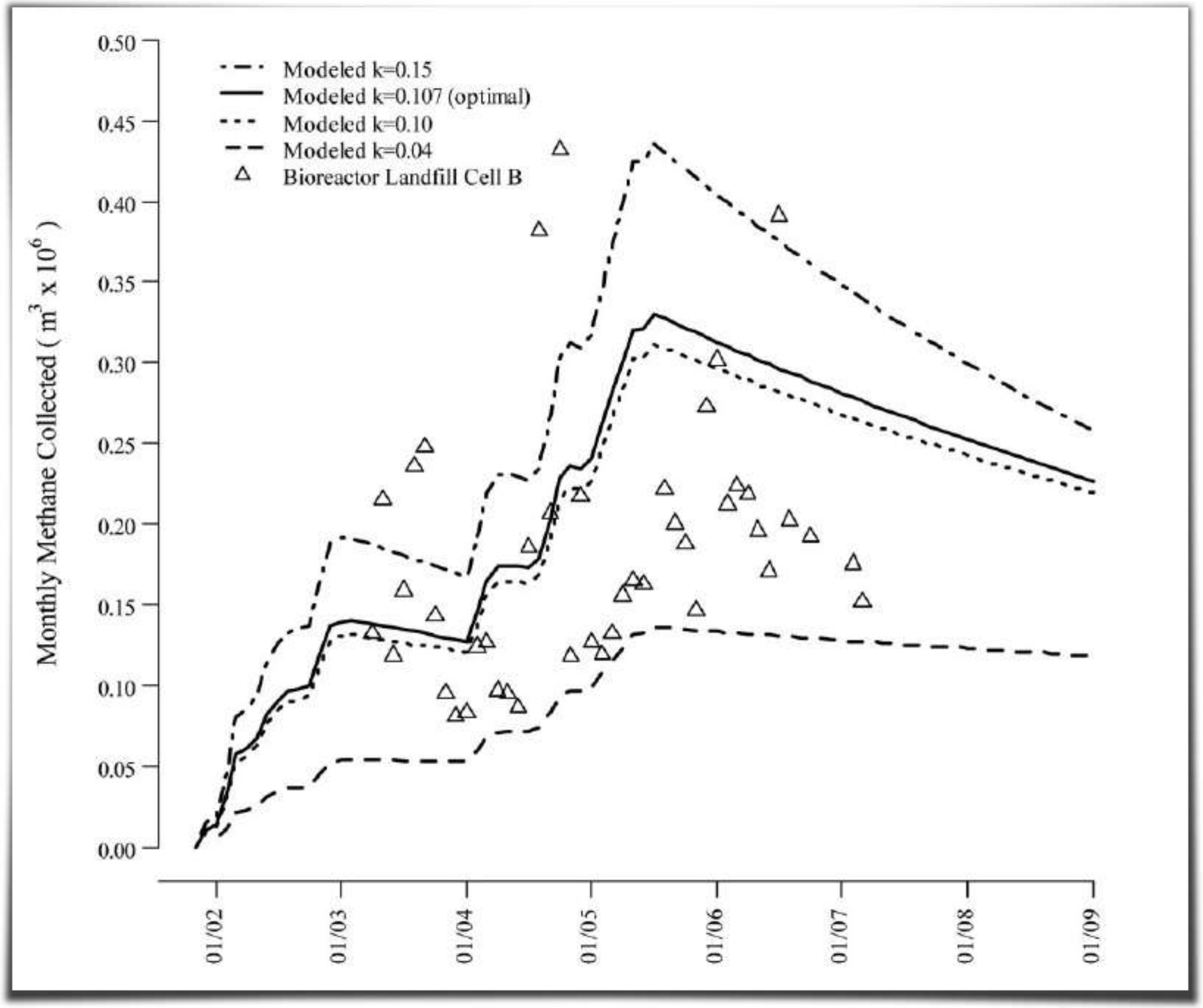


Tolaymat et al. 2010

gas generation rates

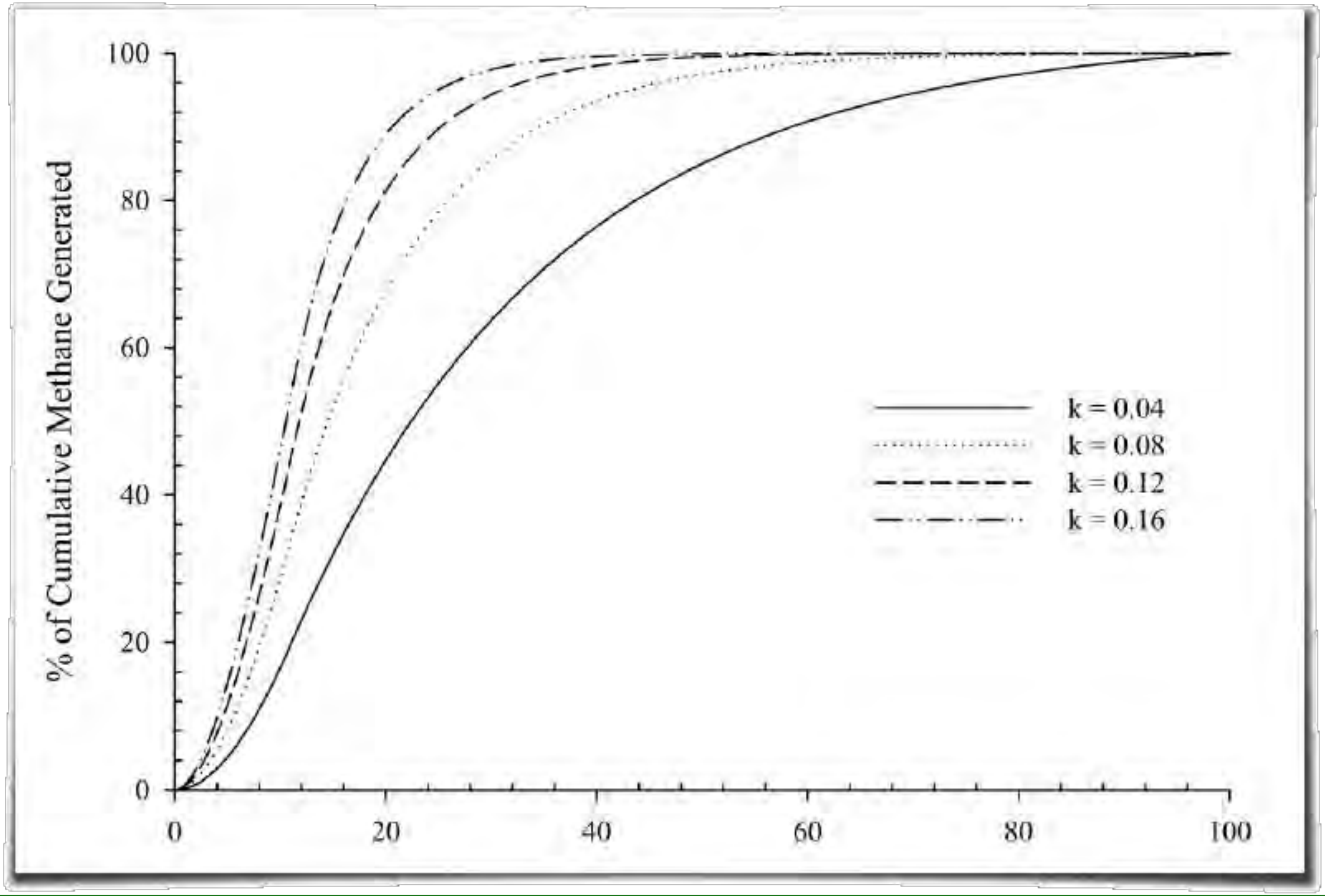
- The first-order decay equation in US EPAs LandGEM used to predict methane generation.
- A methane generation potential value, (L_0), of 55 m^3/Mg was used based on BMP results.
- The rate constant value, (k), varied from 0.04 $year^{-1}$ to 0.25 $year^{-1}$.

aerobic-anaerobic bioreactor gas production



Tolaymat et al. 2010

implications of bioreactor technology

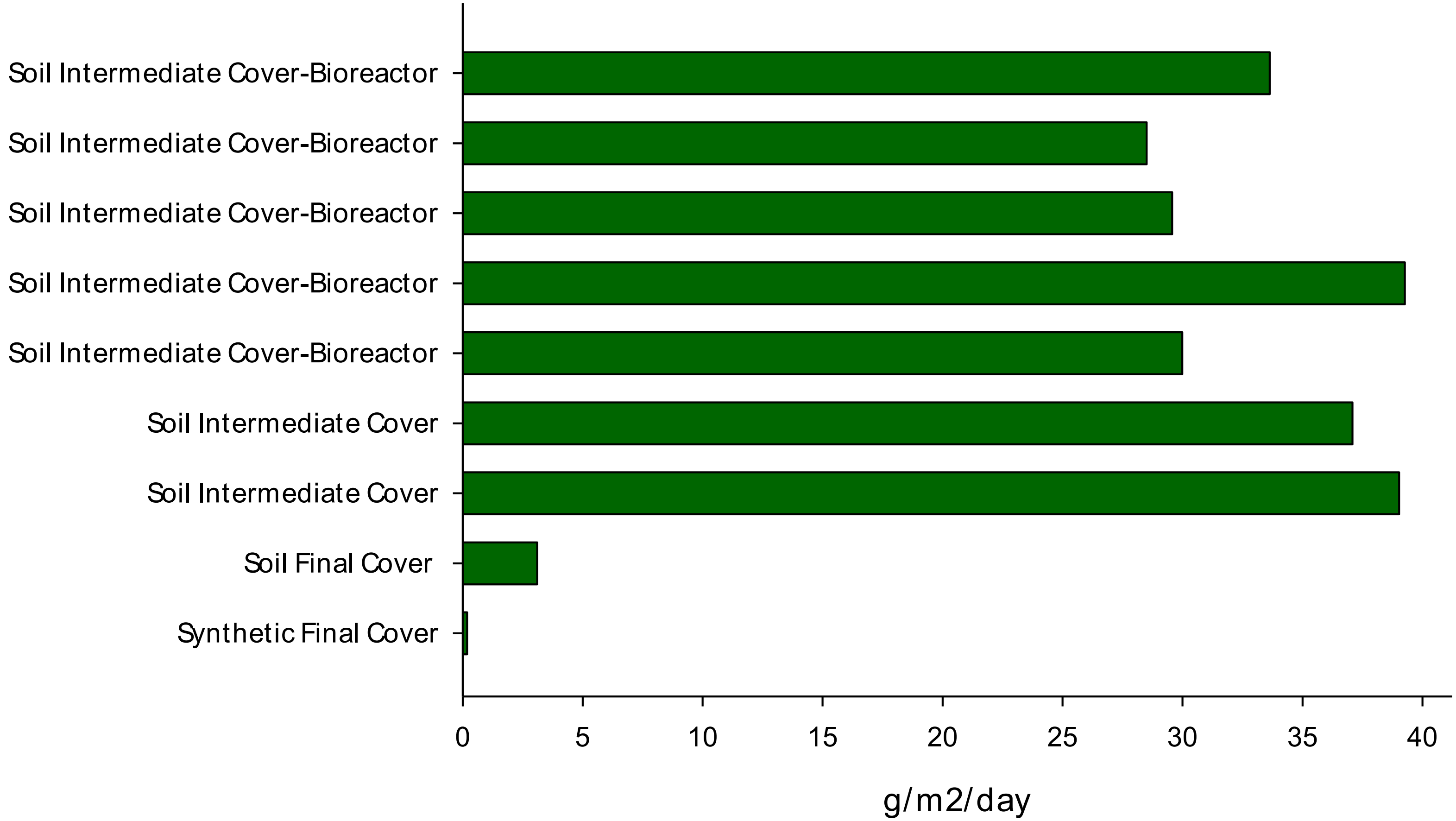


emissions measurements

VRPM and area contributing to flux

- WM, EPA and Arcadis collaborate on acetylene tracer release experiments in 2008-2009 to understand how mass flux (g/s) is related to landfill surface area being surveyed.
- Multiple linear regression model of tracer capture efficiency, release distance and wind data (Thoma, et al. 2009, J. Environmental Engineering, in press).

are bioreactor emissions higher?



Conclusion from EPA Interim Report

- "…it is concluded that the OLLB generally met the criteria of Subtitle D of the Resource Conservation and Recovery Act for design and operation of MSW landfills, and that other well-designed and well-operated bioreactor landfills should also be able to be operated in compliance with the requirements of Subtitle D."

Final Remarks

- Application of bioreactor operations returns the greatest benefits when applied to new landfill cells.
- The addition of non-hazardous liquid wastes can be performed safely with proper evaluation and provide an important source of moisture and revenue.
- Aeration of waste will increase waste temperatures and can be performed safely.
- The rate of landfill gas production is enhanced and can be effectively managed.

Thank you!

ROGER GREEN

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Project References

- *Landfill Bioreactor Performance: Second Interim Report Outer Loop Recycling & Disposal Facility Louisville, Kentucky* (2006) National Risk Management Research Laboratory, USEPA. EPA/600/R-07/060
- Green, R.B., Tolaymat, T., Hater, G.R., Barlaz, M.A., Powell, J., Black, P., Bronson, D. Solid waste decomposition at the Outer Loop landfill bioreactor. Presented at The 5th Intercontinental Landfill Research Symposium, Copper Mountain, CO, September 10-13, 2008.
- Tolaymat, T.M., Green, R.B., Hater, G.R., Bachus, R., Houlihan, M.F., Haydar, M., Powell, J., Barlaz, M.A., Black, P., Bronson, D., Performance of the Outer Loop landfill bioreactor. In Proceedings of the Global Waste Management Symposium, Copper Mountain, CO, September 7-10, 2008.
- Haydar, M., Tolaymat, T., Green, R.; Hater, G.; and Barlaz, M. Moisture balance assessment at the Outer Loop landfill bioreactor. In Proceedings of the Global Waste Management Symposium, Copper Mountain, CO, September 7-10, 2008.
- Tolaymat, T.M., Green, R.B., Hater, G.R., Barlaz, M.A.,, Black, P., Bronson, D., Powell, J. (2010) Evaluation of Landfill Gas Decay Constants for Municipal Solid Waste Landfills Operated as Bioreactors. *J. Air & Waste Manage. Assoc.* 60:90-97.

EREF's Regional Summit on
Sustainable Solid Waste Practices & Research
April 28, 2011

Bioreactor Research Directions

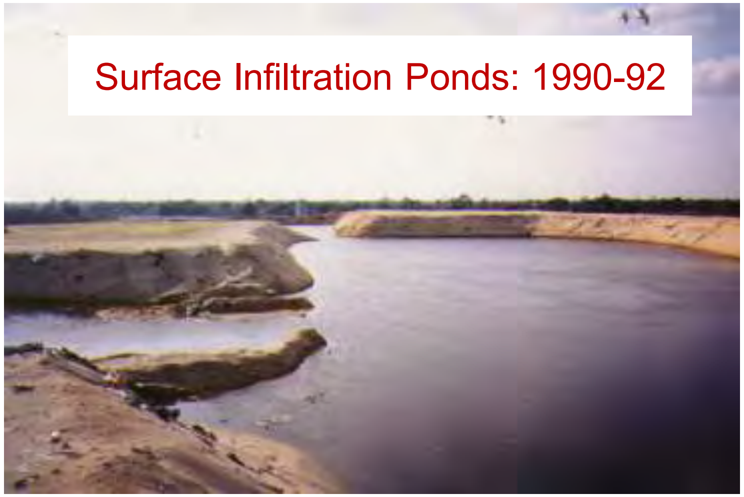
Timothy G. Townsend, PhD, PE
Professor
Department of Environmental Engineering Sciences
University of Florida

Objectives

- Share thoughts on important topics of bioreactor research based on two decades of bioreactor field studies.
- Focus on:
  - Design
  - Permitting
  - Operations

Alachua County Southwest Landfill

Evolution of Liquids Addition in Florida



Design, Permitting and Operational Challenges

- How much liquid to add?
- How do you get the liquids in?
  - Device
  - Flow rate
  - Pressure
  - Target wetting time
- How do you achieve liquids addition goals in light of:
  - Preventing seeps
  - Avoid instability of slopes
  - Need for gas collection

Liquids Addition 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

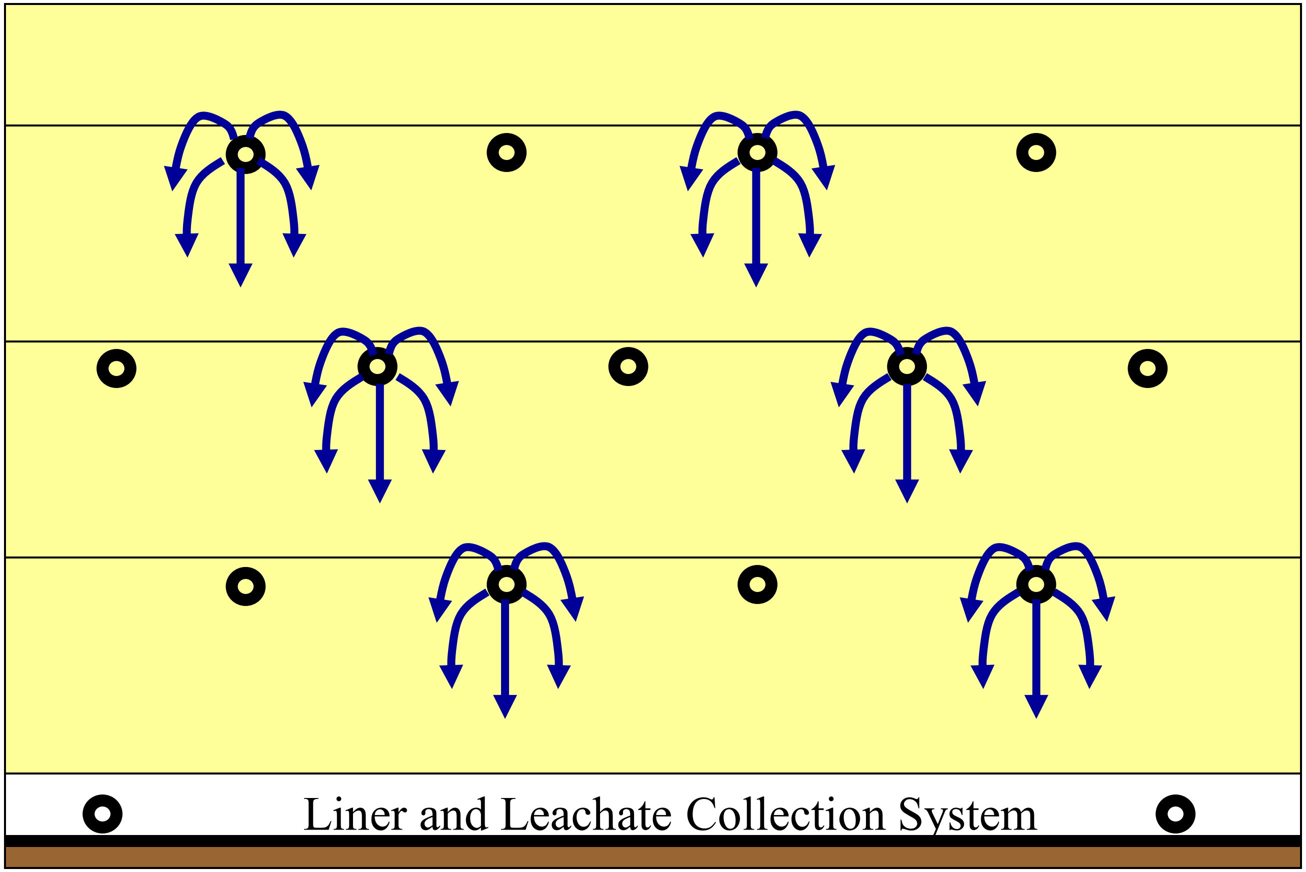
- How much addition is really needed to meet your goals.

Choice of Devices

- If you need to add a substantial volume of liquid, you normally must use buried systems.
- Options:
  – Vertical wells
  – Horizontal trenches or blankets
  – Combination?
- Decision will be based on factors such as cost, ease of installation, interference with operations, target volume, target time, …

Spacing and Sizing of Devices

→Rules of thumb, industry standards
→Fluid flow modeling, design charts



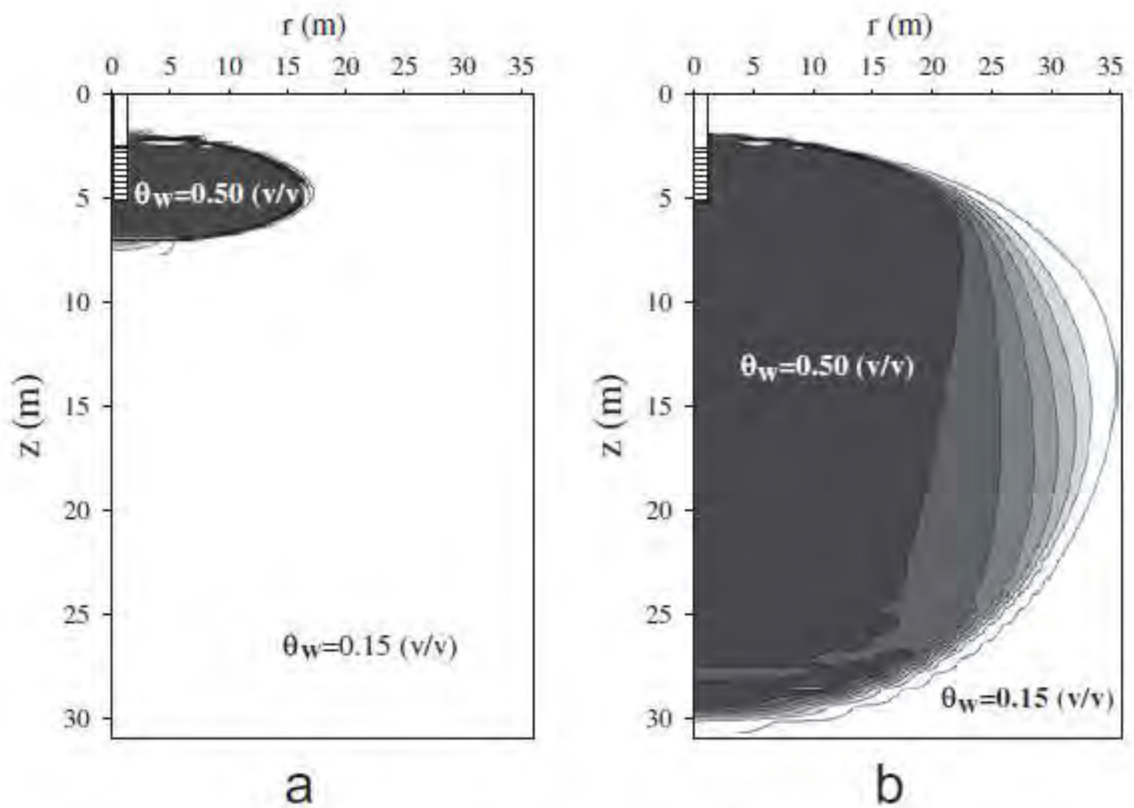


Fig. 2. Saturation profile for $K_z = 10^{-4}$ m s^{-1}, $w = 2.5$ m, $r_w = 2.5$ cm, injection pressure = 7.5 m of w.c., anisotropy = 100 after addition of (a) 1000 m^3, and (b) 20,000 m^3 liquid volume.

Jain, P., Townsend, T., Tolaymat, T. (2010). "Steady-State Design of Vertical Wells for Liquids Addition at Bioreactor Landfills." *Waste Management*, 30: 2022-2029.

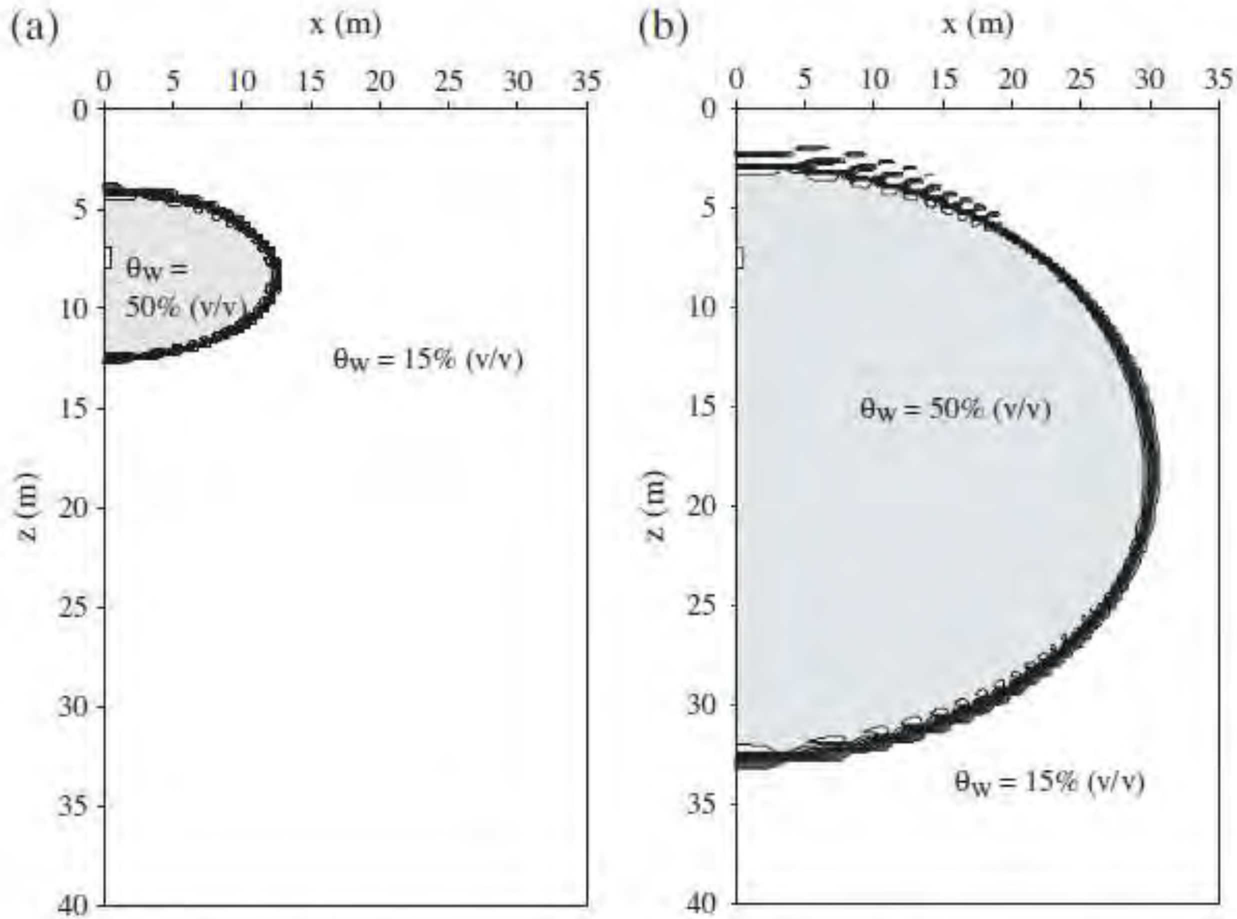


Fig. 2. Saturation profile for $K_z = 10^{-4}\,m\,s^{-1}$, $w = 1$ m, $l = 1$ m, $p_1 = 10$ m w.c., $a = 10$ after addition of (a) 50 m^3 and (b) 500 m^3 liquids volume per m trench length.

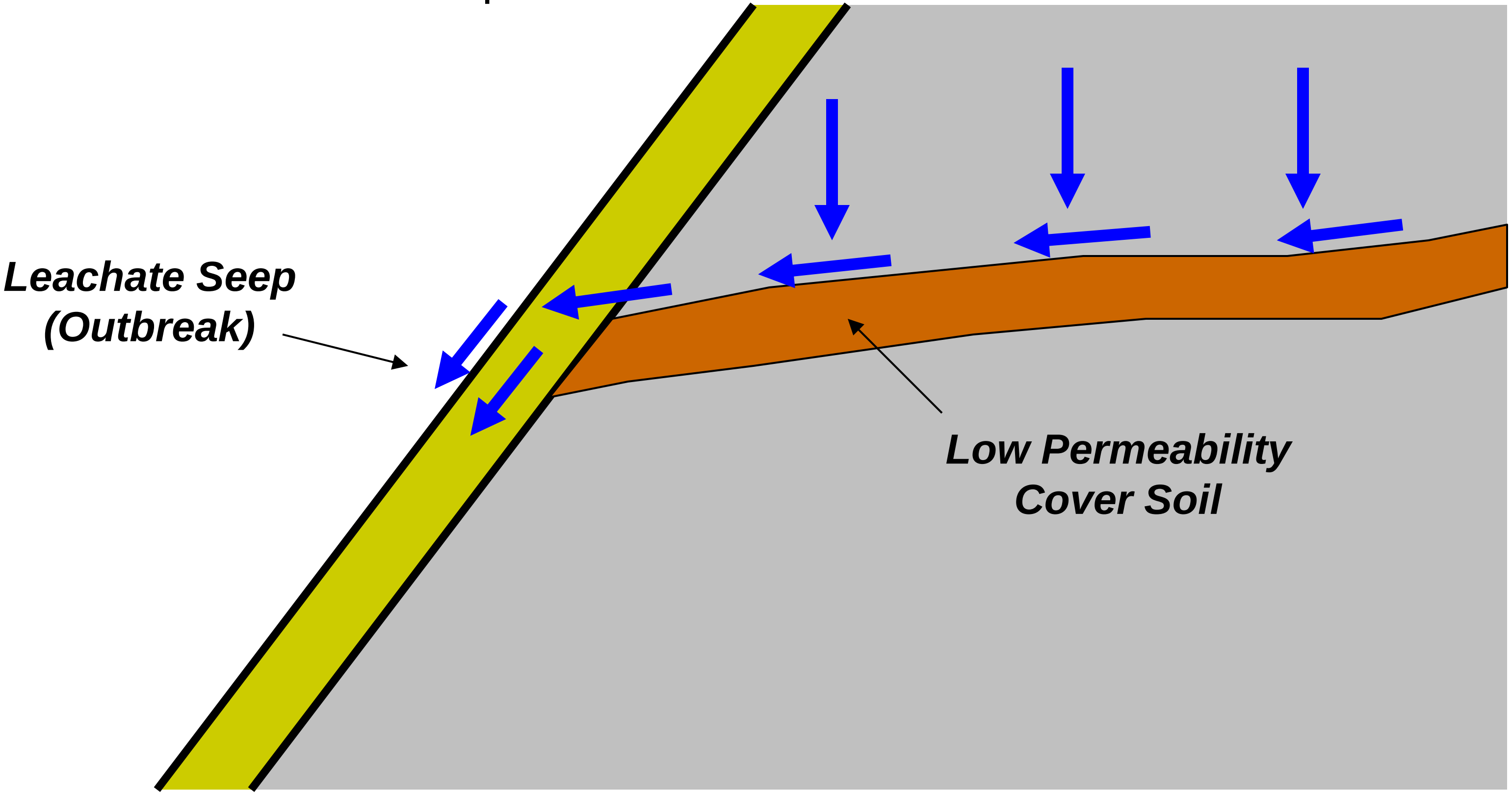
Jain, P., Townsend, T., Tolaymat, T. (2010) "Steady-state design of horizontal systems for liquids addition at bioreactor landfills." *Waste Management*, 30: 2560-2569.

Dealing with Landfill Seeps

- Seeps are nearly unavoidable at wet landfills.
- Consideration should be given to seep occurrence as part of permitting, design and operation.
- Plan for them.
- The bioreactor can be operated to minimize seeps, but it is a trade off with moisture addition capacity.

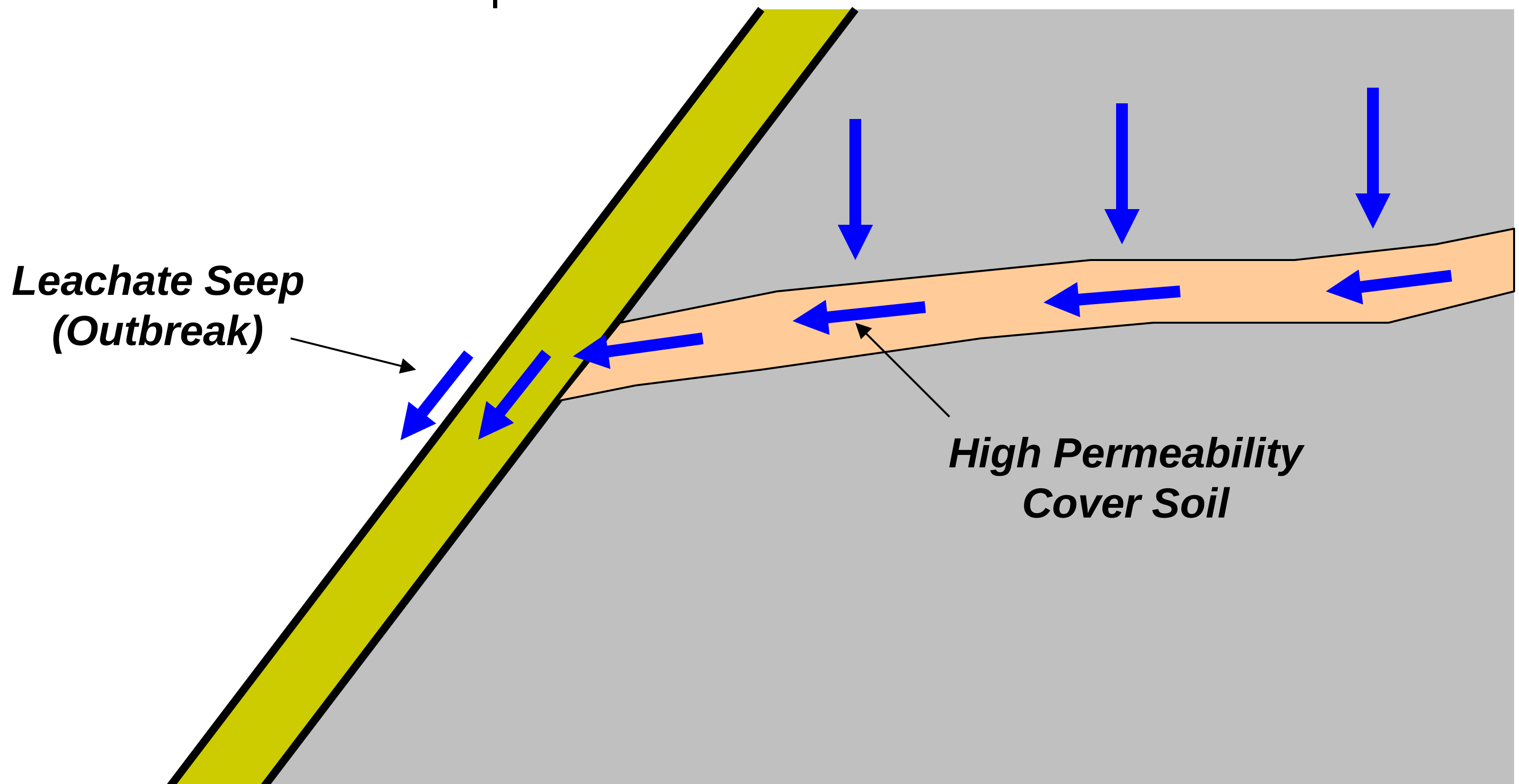
Landfill Seep Causes

Interception of leachate by low permeability cover layers and subsequent transmission of leachate to the side slope of the landfill can result in seeps



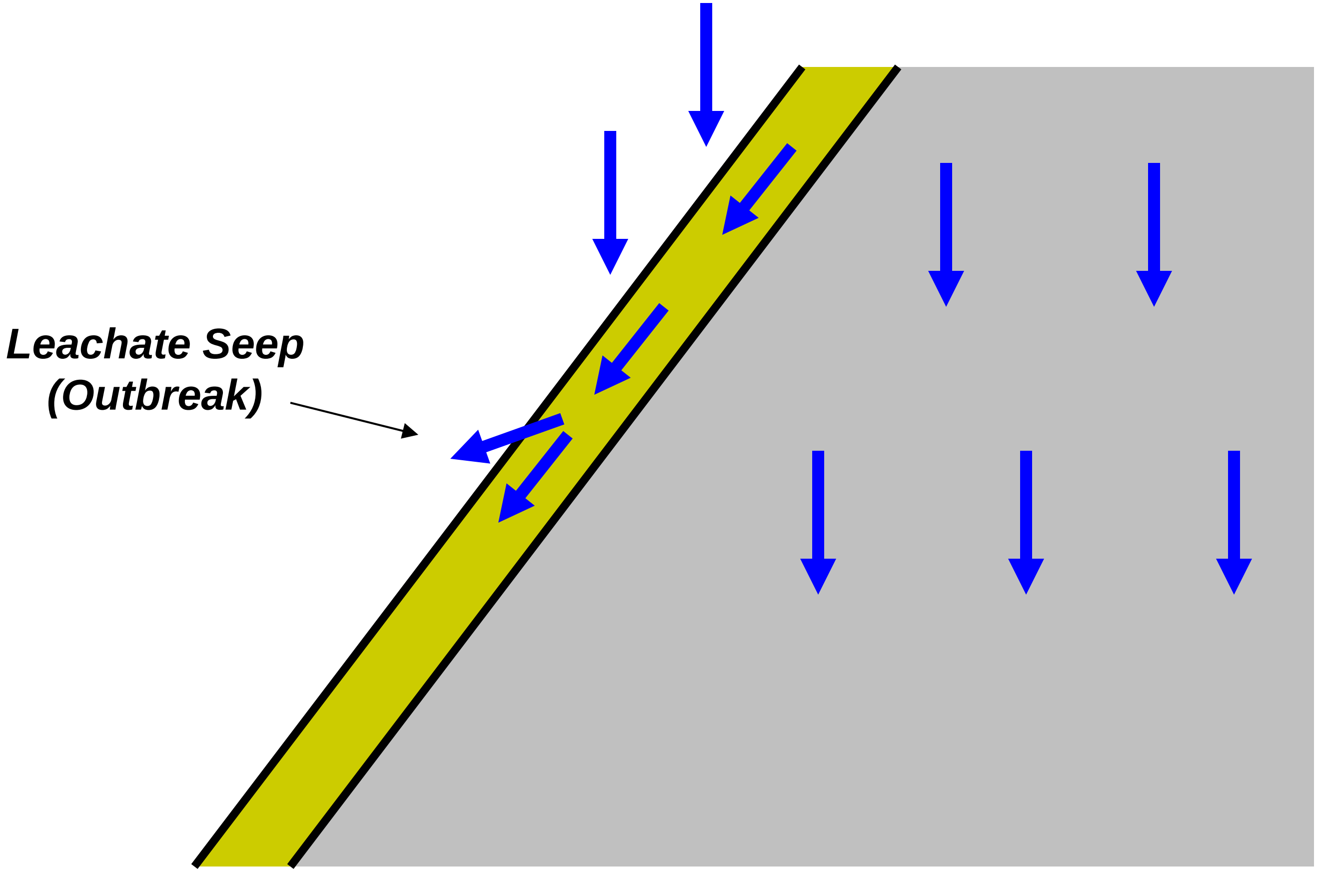
Landfill Seep Causes

Interception of leachate by <u>high</u> permeability cover layers and subsequent transmission of leachate to the side slope of the landfill can result in seeps



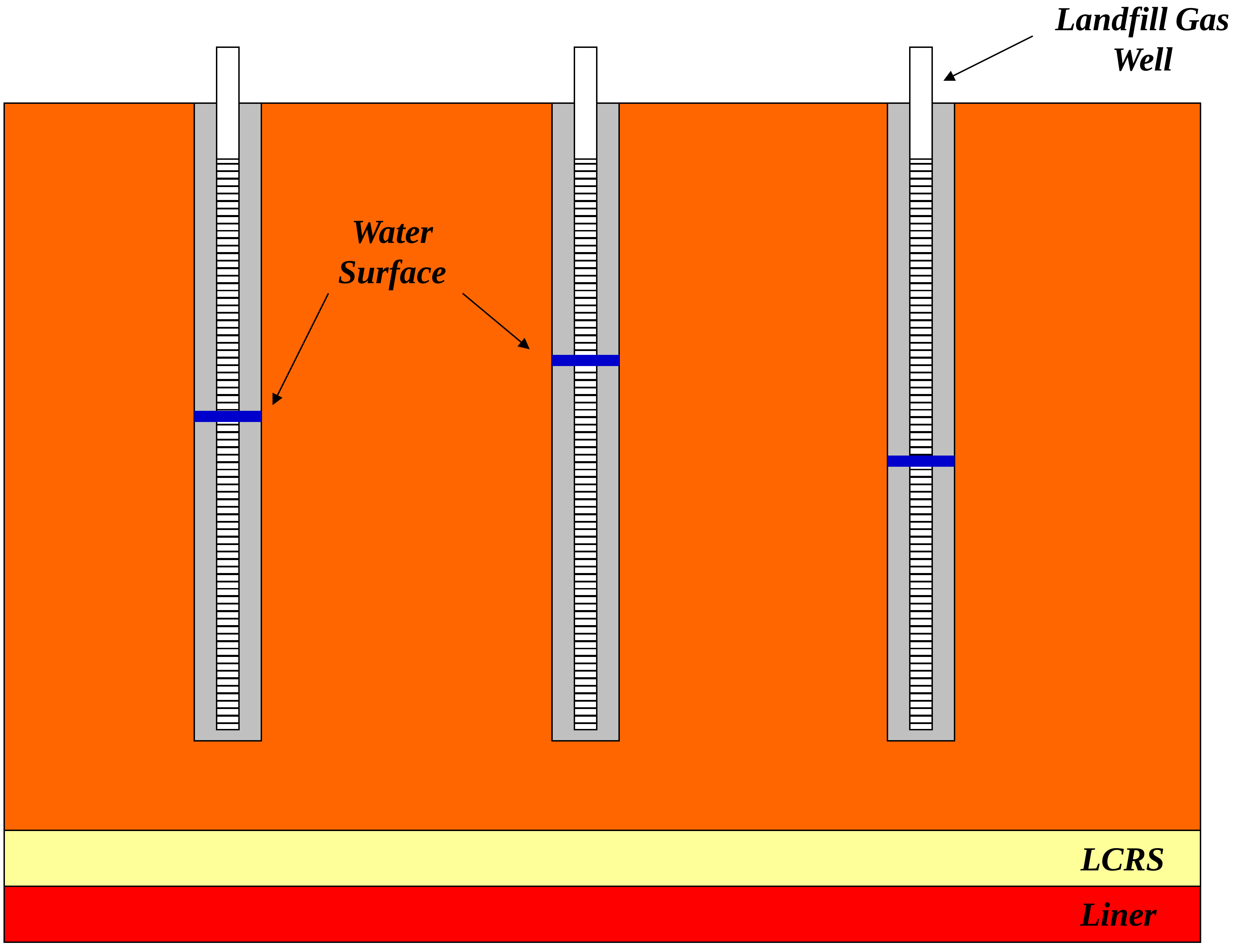
Landfill Seep Causes

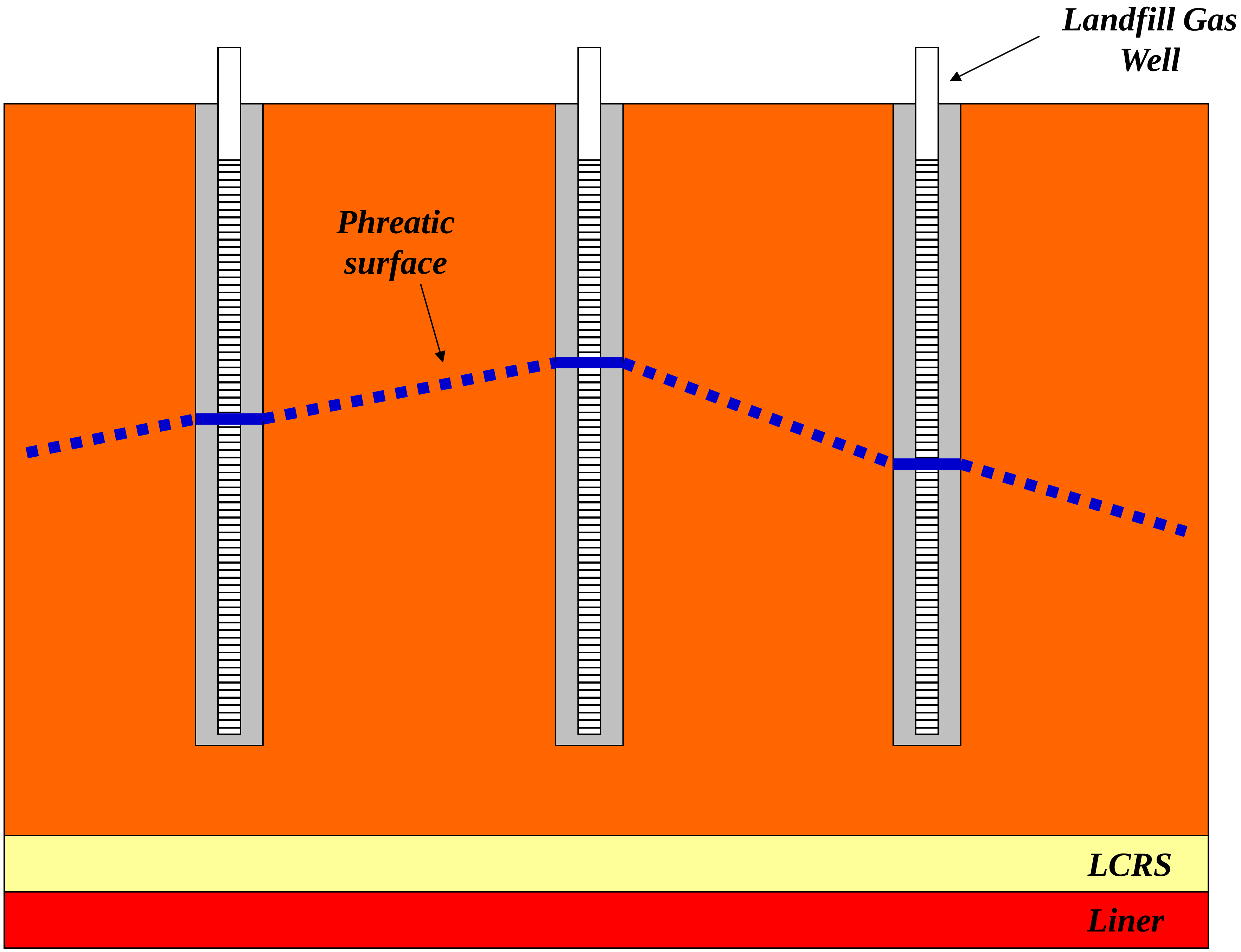
Interception of rainfall in permeable cover materials on the side slope can result in seeps

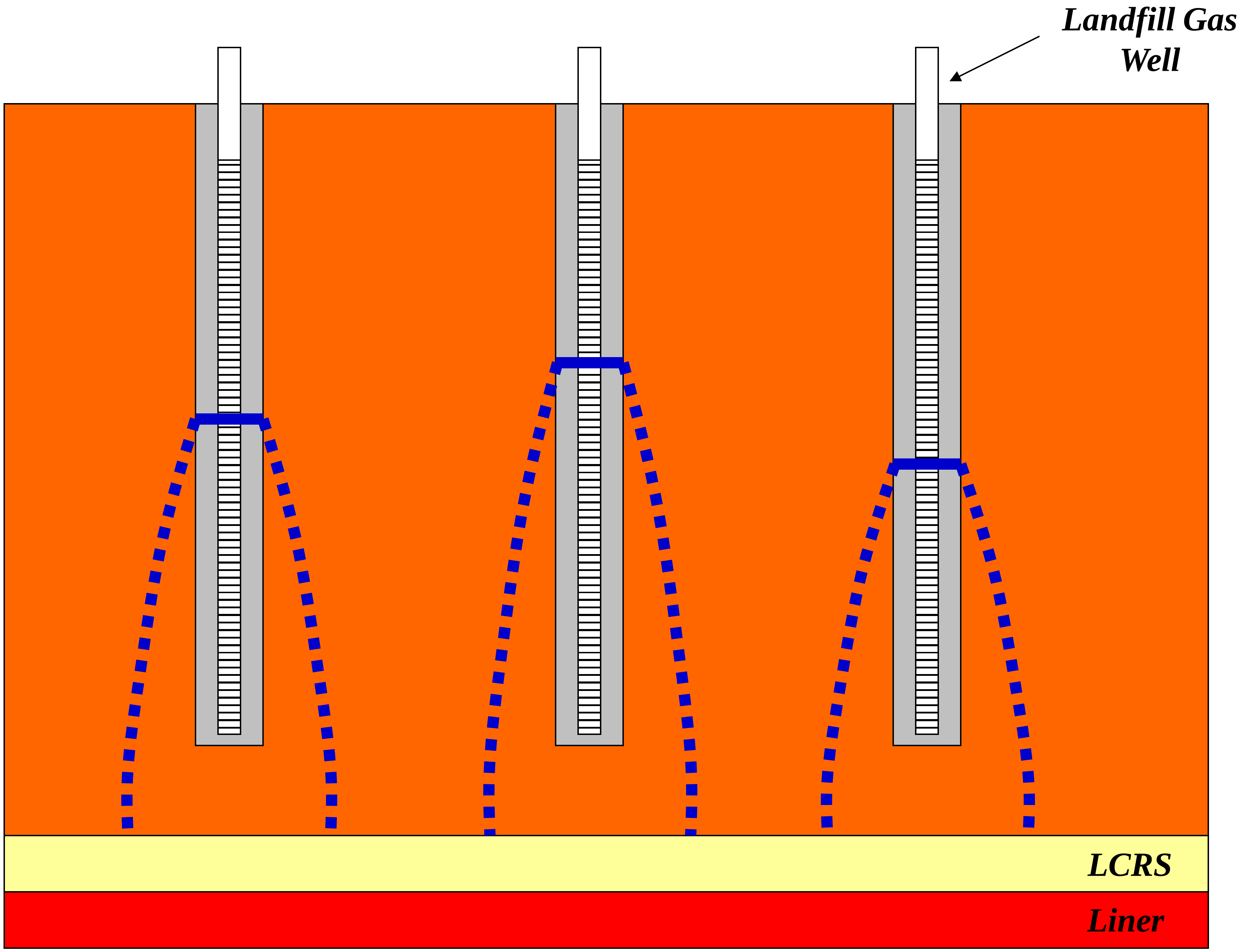


Slope Stability

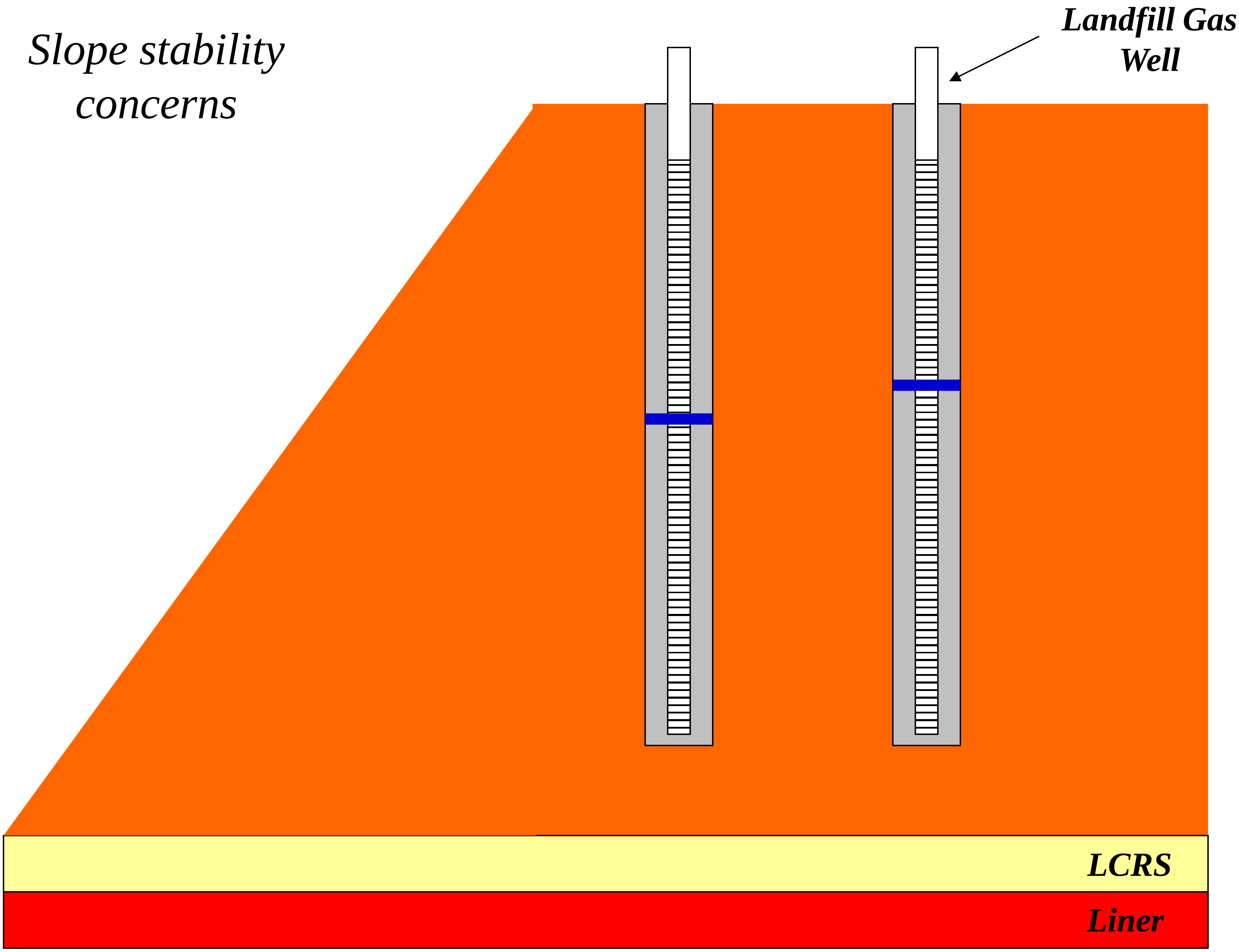
- If liquids are added under pressure, and increased pore pressure leads to slope instability, how much liquid pressure is safe in a landfill?
- Some engineers have suggested “don’t add liquid under pressure; don’t saturate the waste.” Not realistic for most bioreactors.


Landfill Gas
Well
Water
Surface
LCRS
Liner

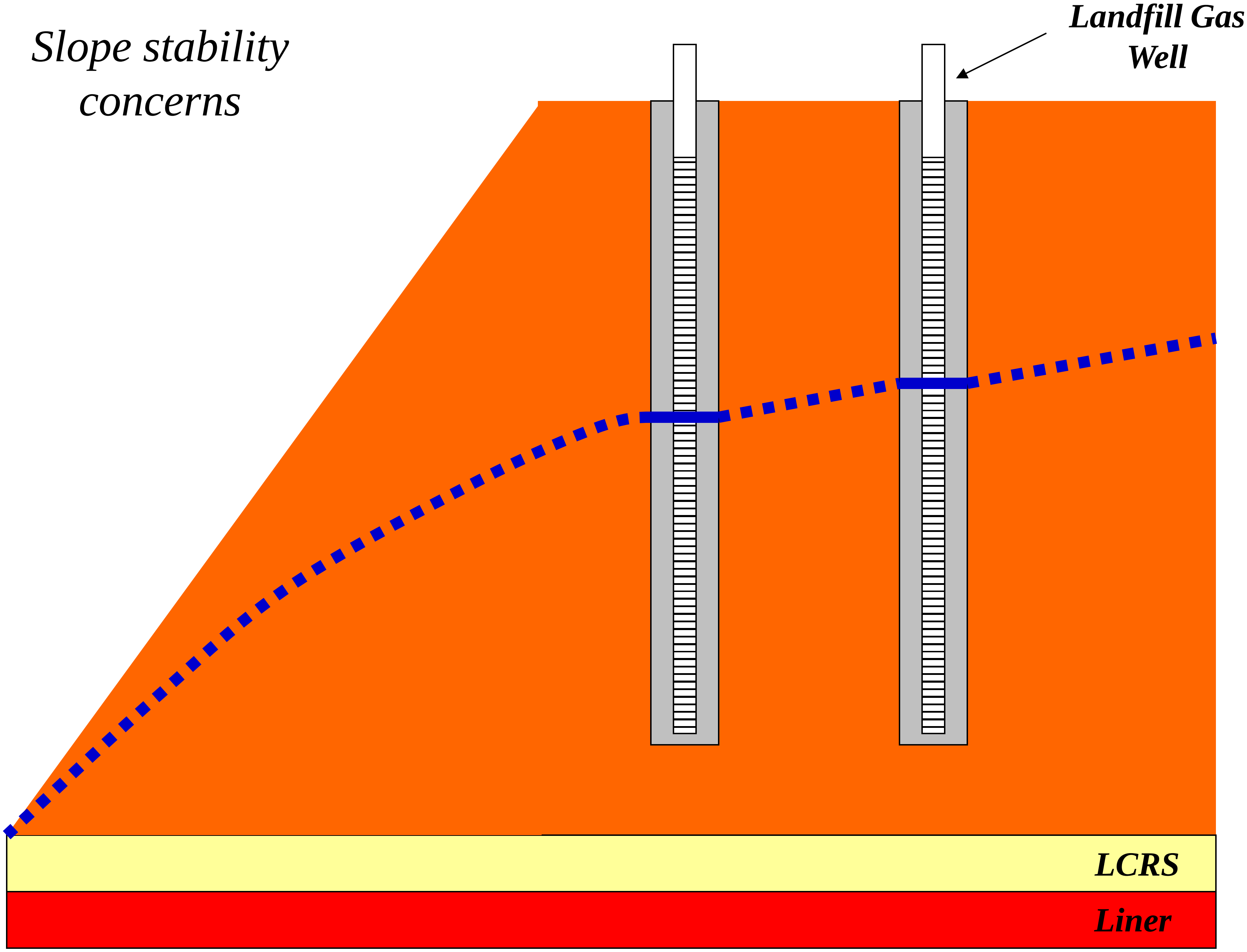

Landfill Gas Well
Phreatic surface
LCRS
Liner


Landfill Gas Well
LCRS
Liner

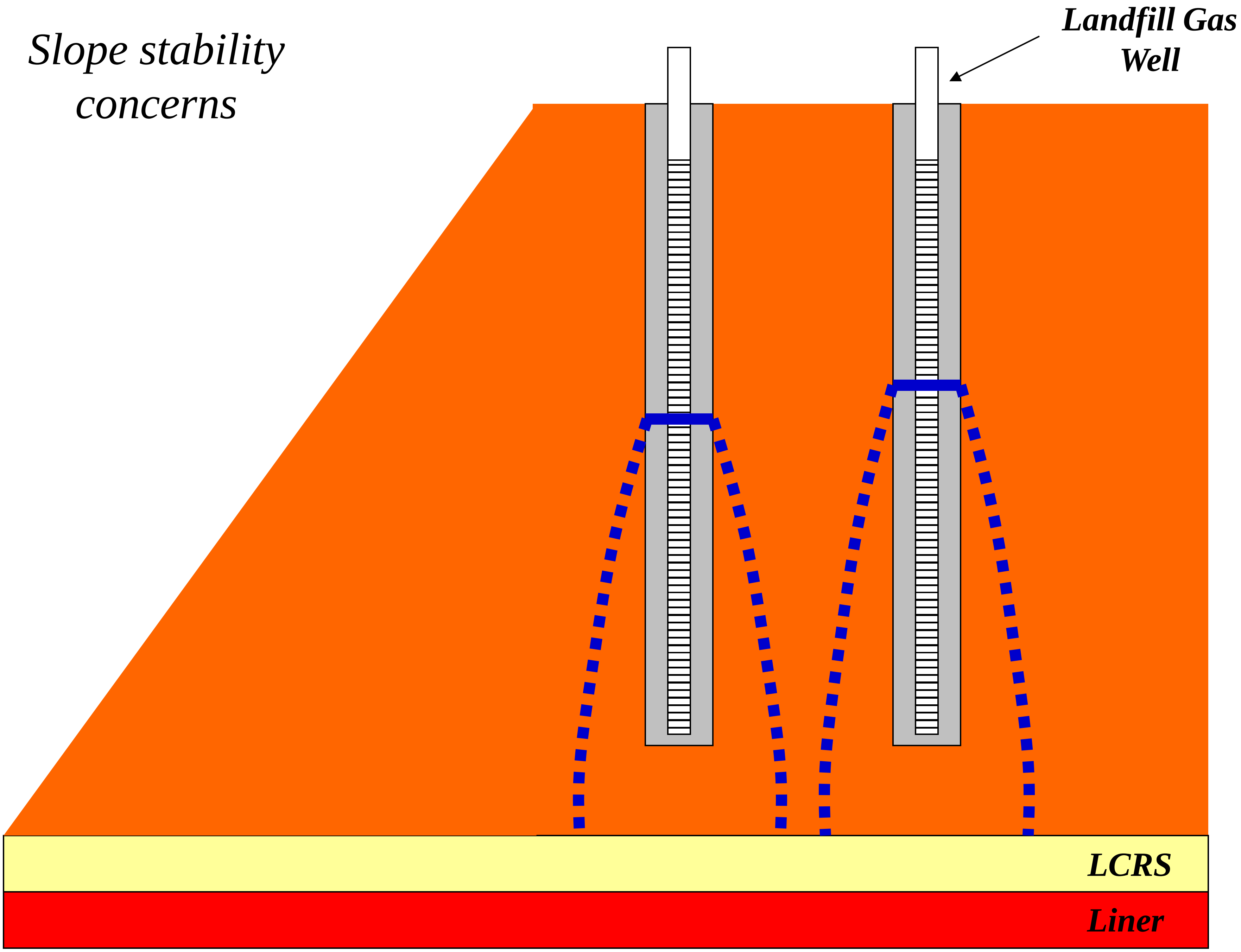
Slope stability concerns



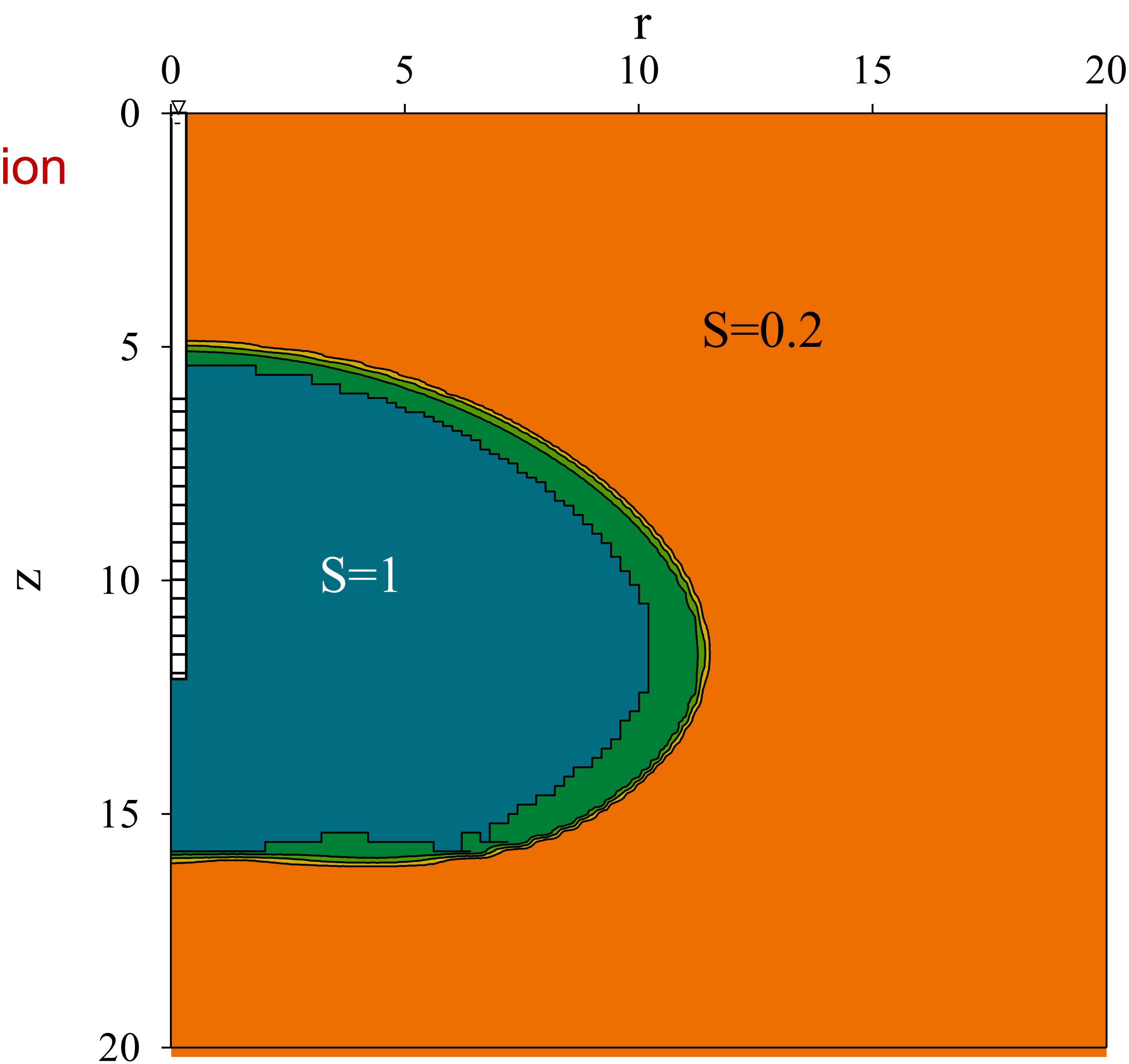
Slope stability concerns



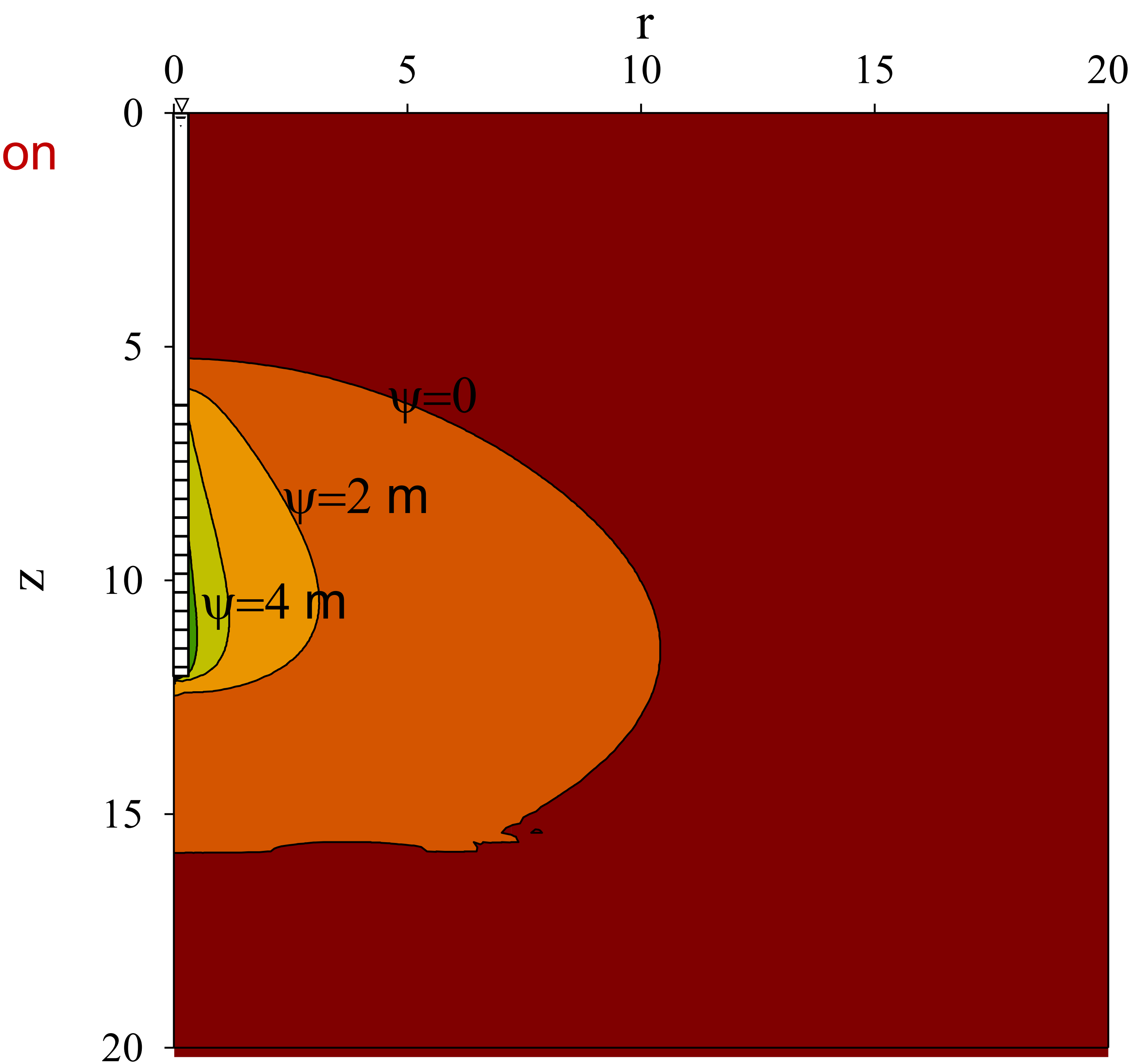
Slope stability concerns



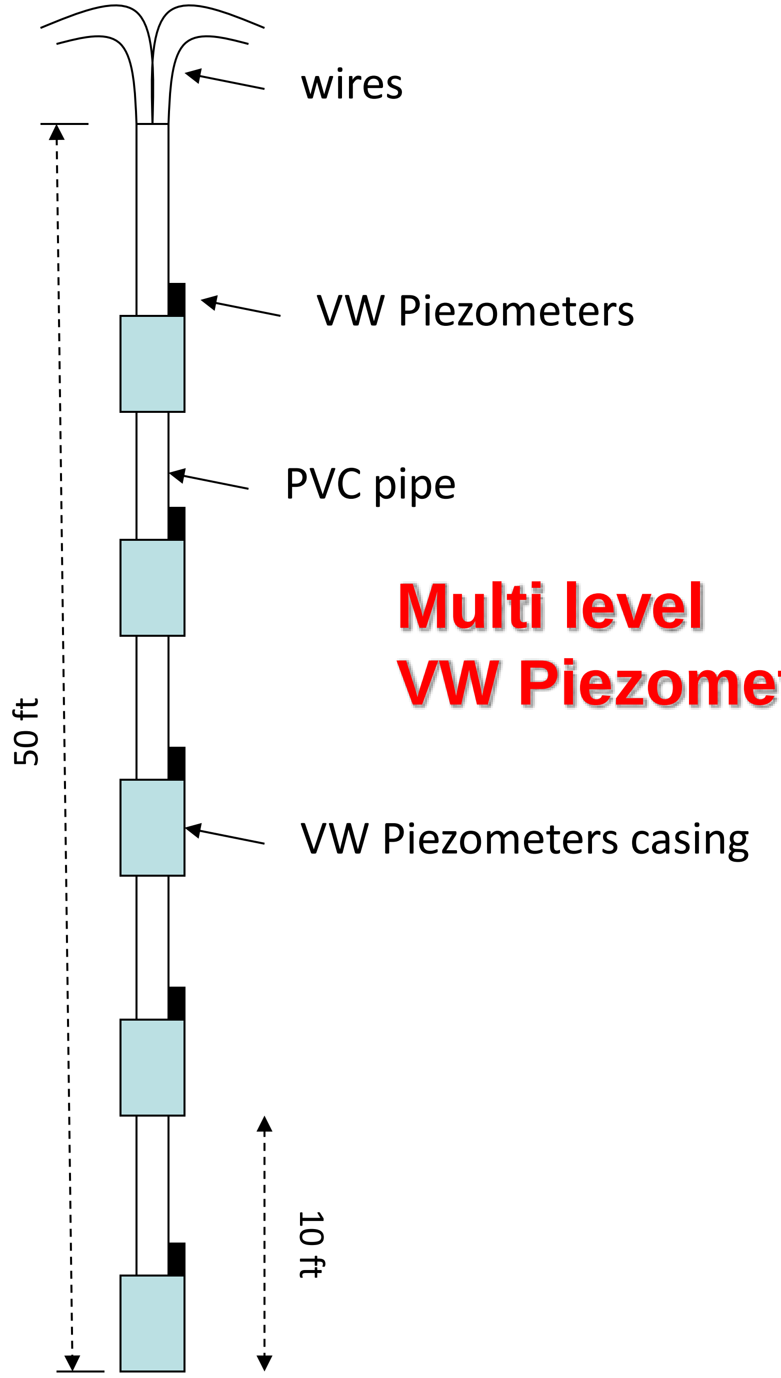
Saturation profile



Saturation profile




Vibrating Wire Transducer
pn 52611020 50 PSI
Thermistor
SLOPE INDICATOR
www.slopeindicator.com



Multi level
VW Piezometers assembly


Vibrating Wire Transducer
pn 52611020 50 PSI
Thermistor s/n 82284
SLOPE INDICATOR
www.slopeindicator.com
F2


NFU 76K


SLOPE

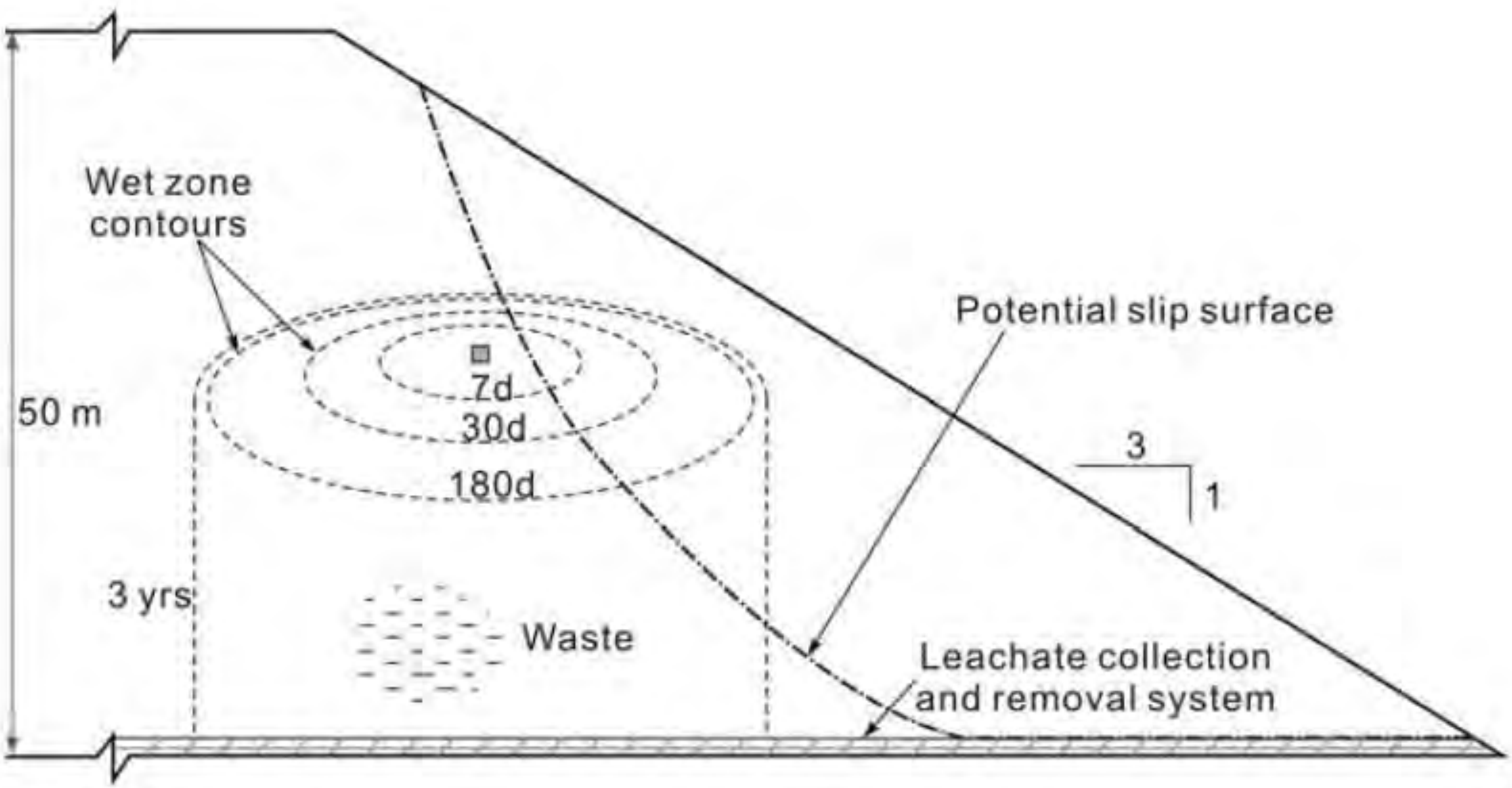

SLOPE
LISTED PVC

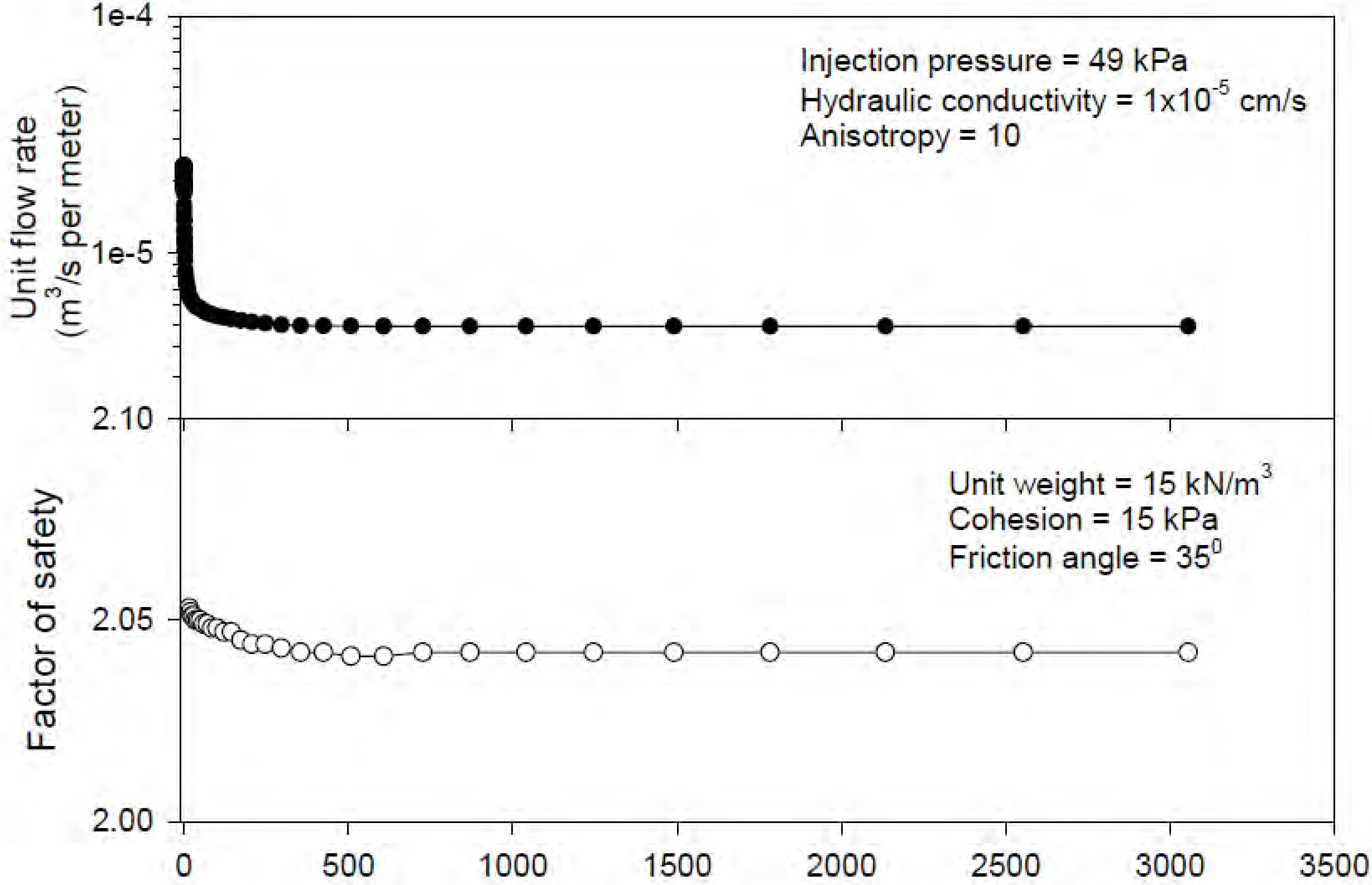

MFU 76K

What is an Appropriate Liquids Addition Pressure?

- A consideration in the permitting process (or should be).
- How far back from the slope should you be for a given injection pressure?
- Can you inject for short periods of time under high pressure?

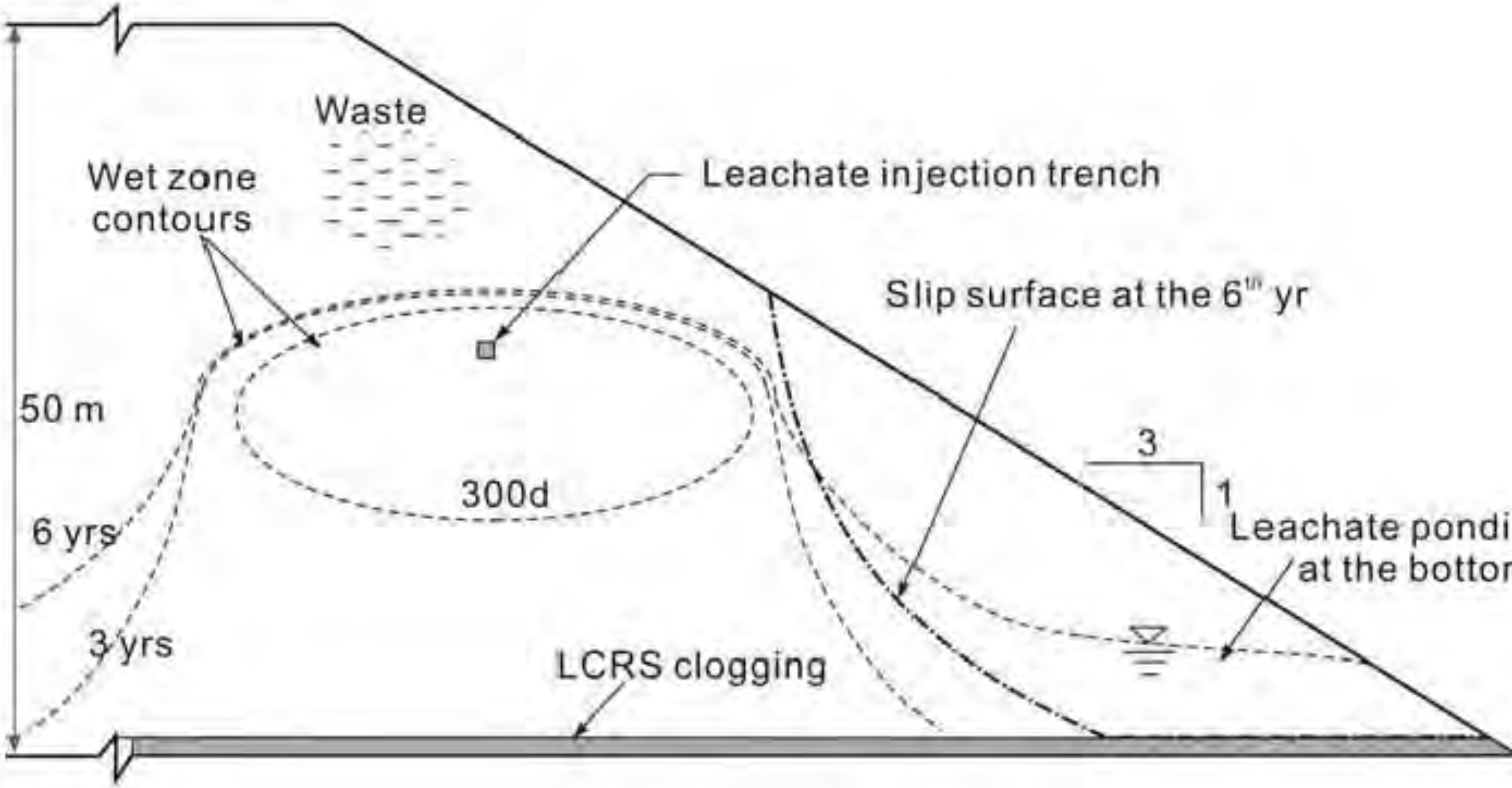
Example Simulation

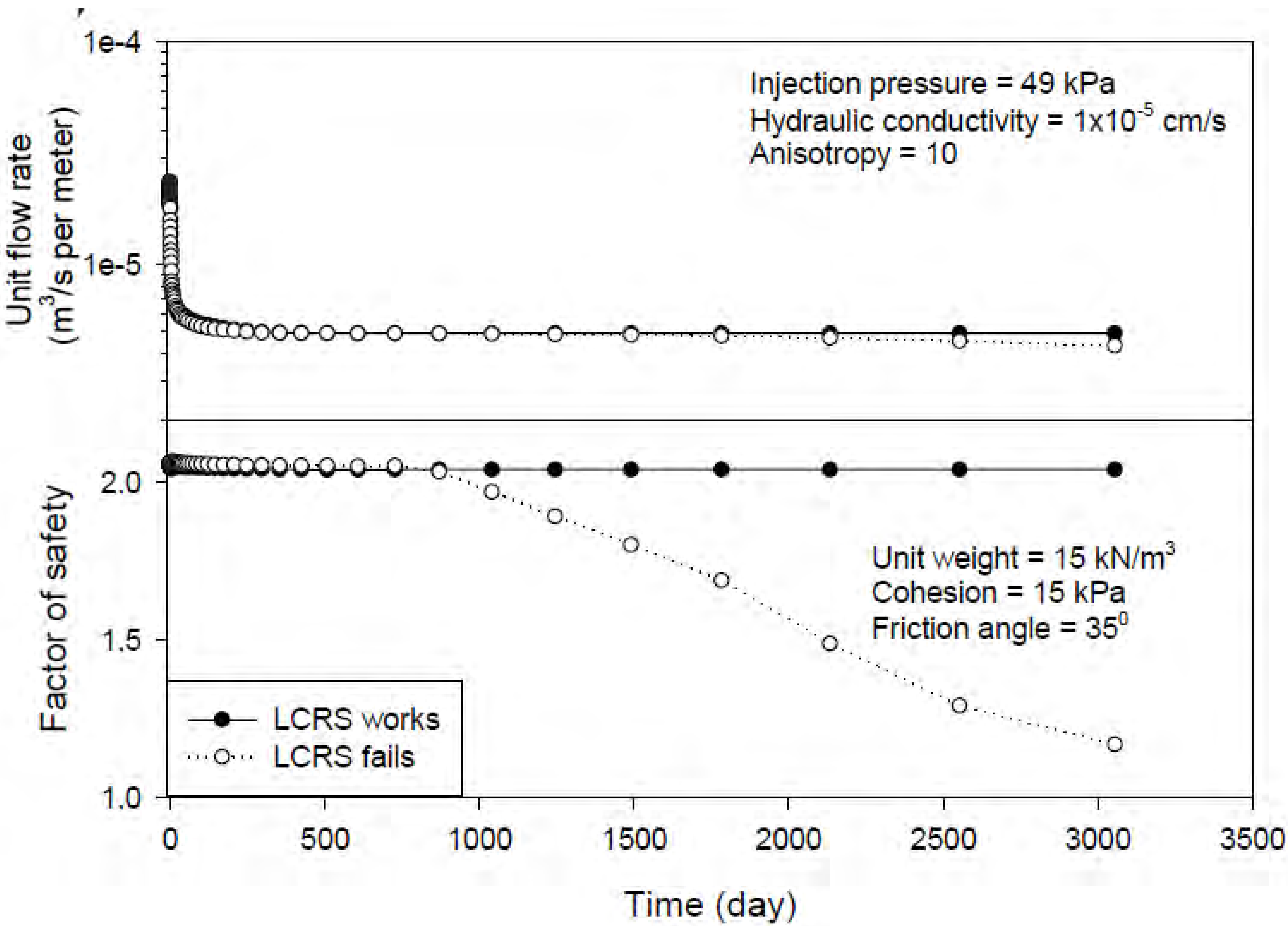




Unit flow rate
(m^3/s per meter)
1e-4
1e-5
Injection pressure = 49 kPa
Hydraulic conductivity = 1x10^-5 cm/s
Anisotropy = 10
Factor of safety
2.10
2.05
2.00
Unit weight = 15 kN/m^3
Cohesion = 15 kPa
Friction angle = 35^0
0
500
1000
1500
2000
2500
3000
3500

What if LCRS Not Functioning Well?





Injection pressure = 49 kPa
Hydraulic conductivity = 1x10^-5 cm/s
Anisotropy = 10
Unit flow rate (m^3/s per meter)
1e-4
1e-5
Factor of safety
2.0
1.5
1.0
Unit weight = 15 kN/m^3
Cohesion = 15 kPa
Friction angle = 35^0
LCRS works
LCRS fails
0
500
1000
1500
2000
2500
3000
3500
Time (day)

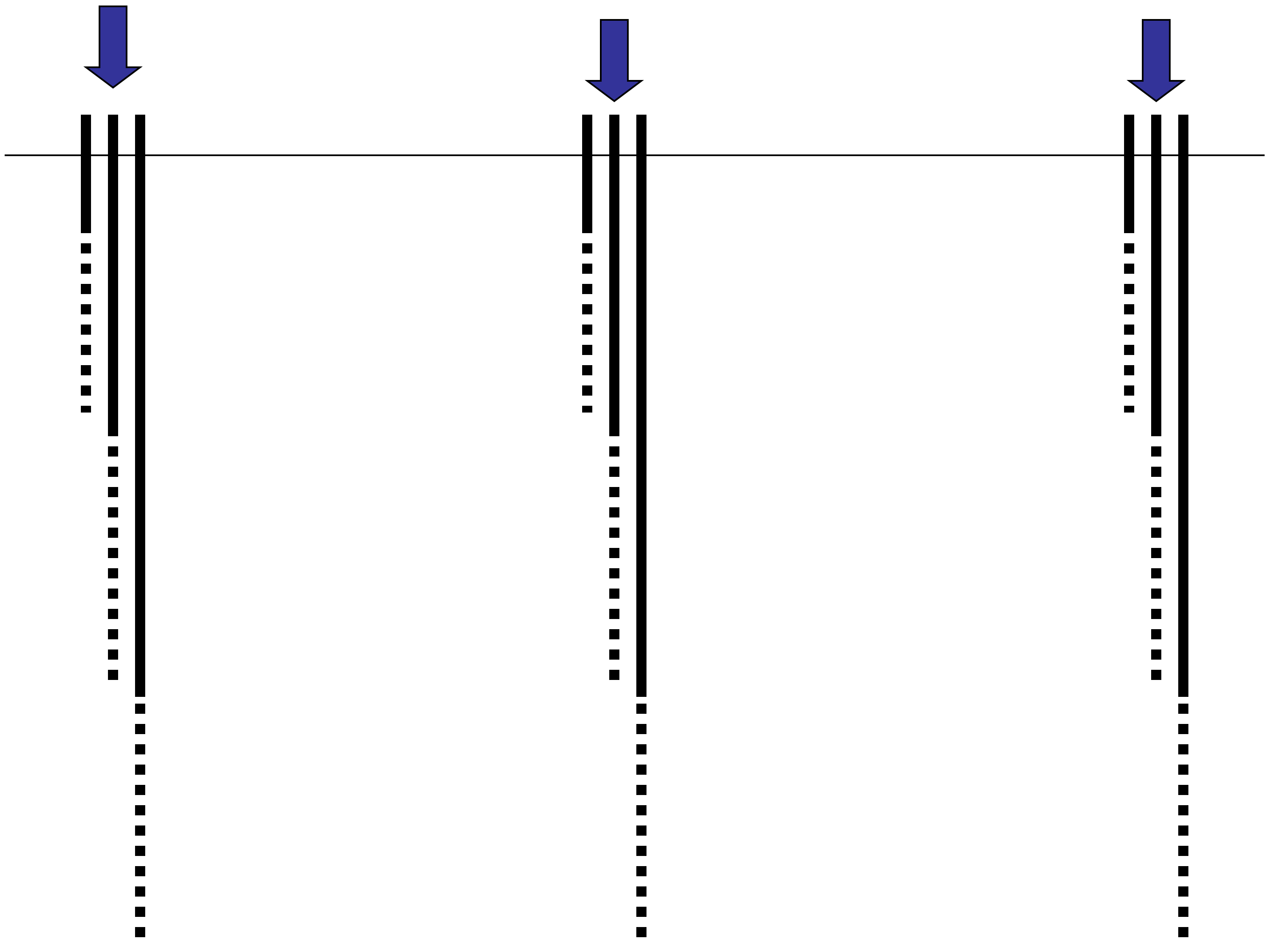
Back to Liquids Addition Methods

- We continue to explore alternative methods for liquids addition
- Motivations:
  - Reduce cost
  - Minimize interference with operations
  - Minimize seeps and related problems
  - Work with, not against, gas recovery

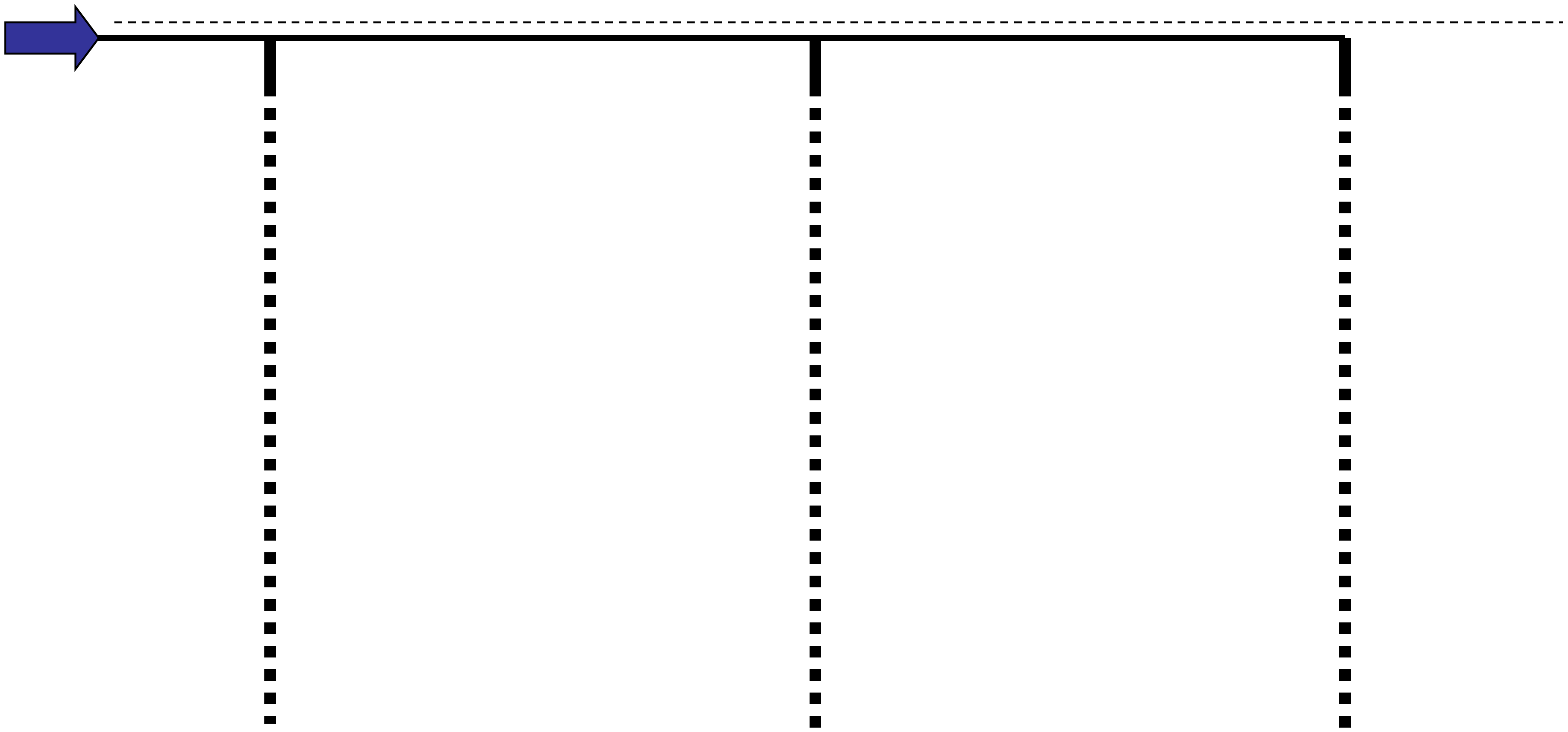
Vertical Wells at NRRL

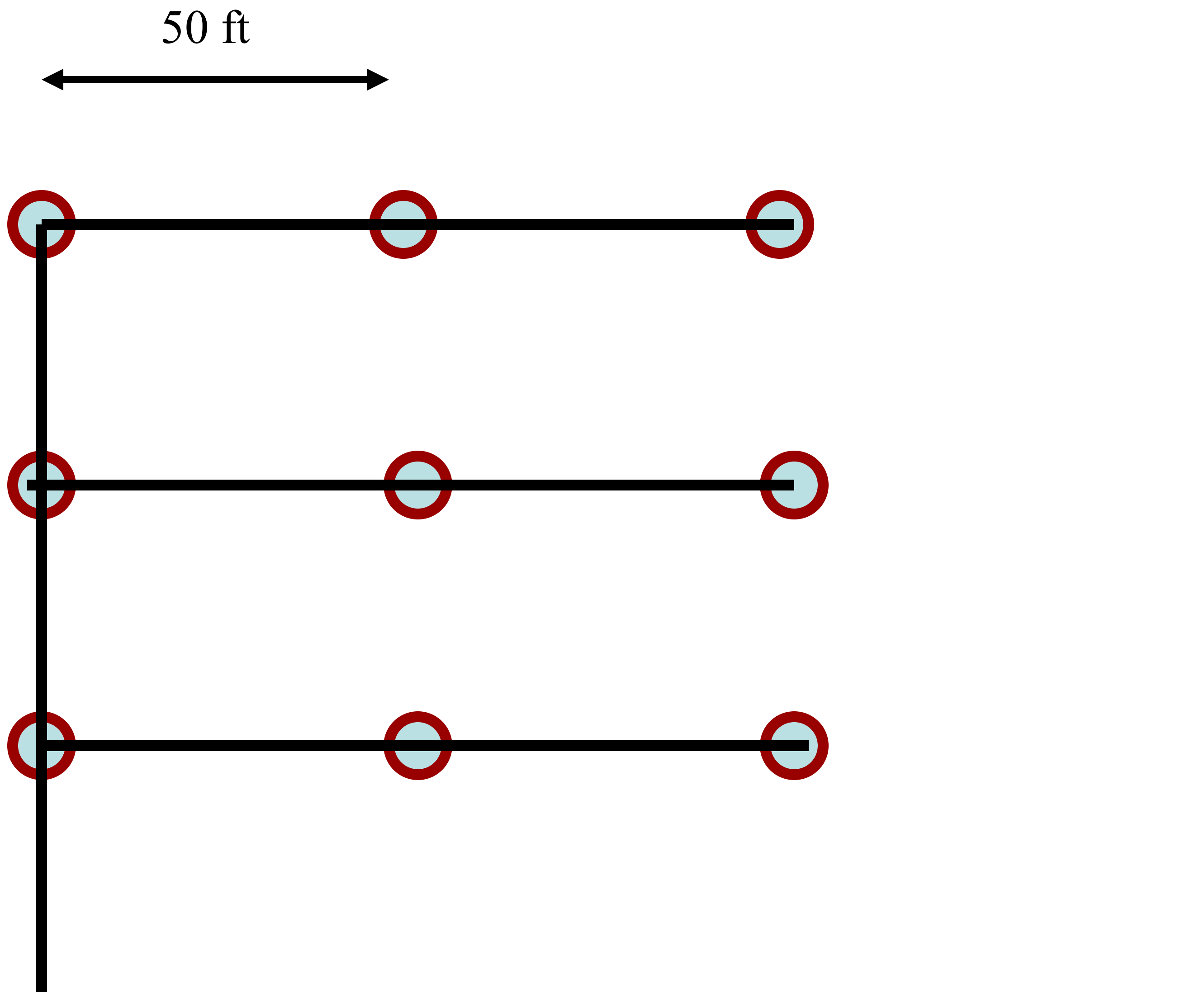
- System worked well → recirculated over 6.5 million gallons of liquid
- Good waste decomposition was achieved
- Problems:
  - Operationally intensive

Existing System



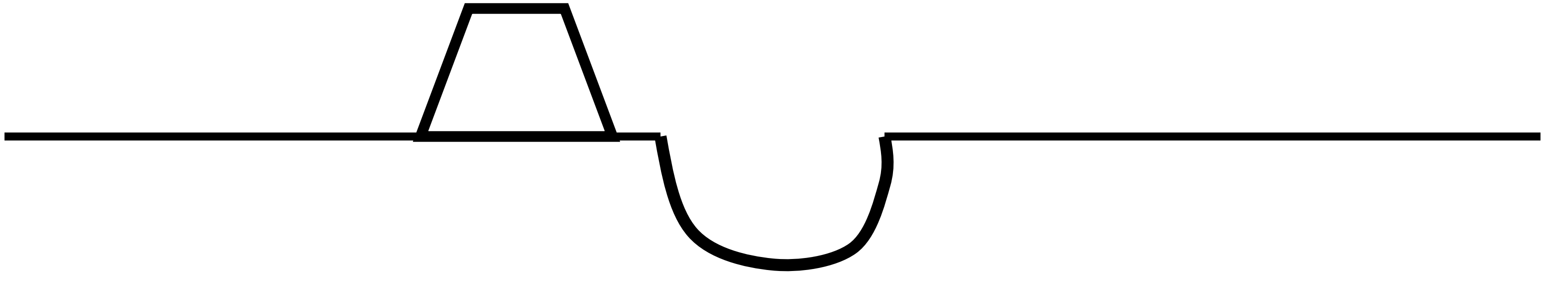
New System



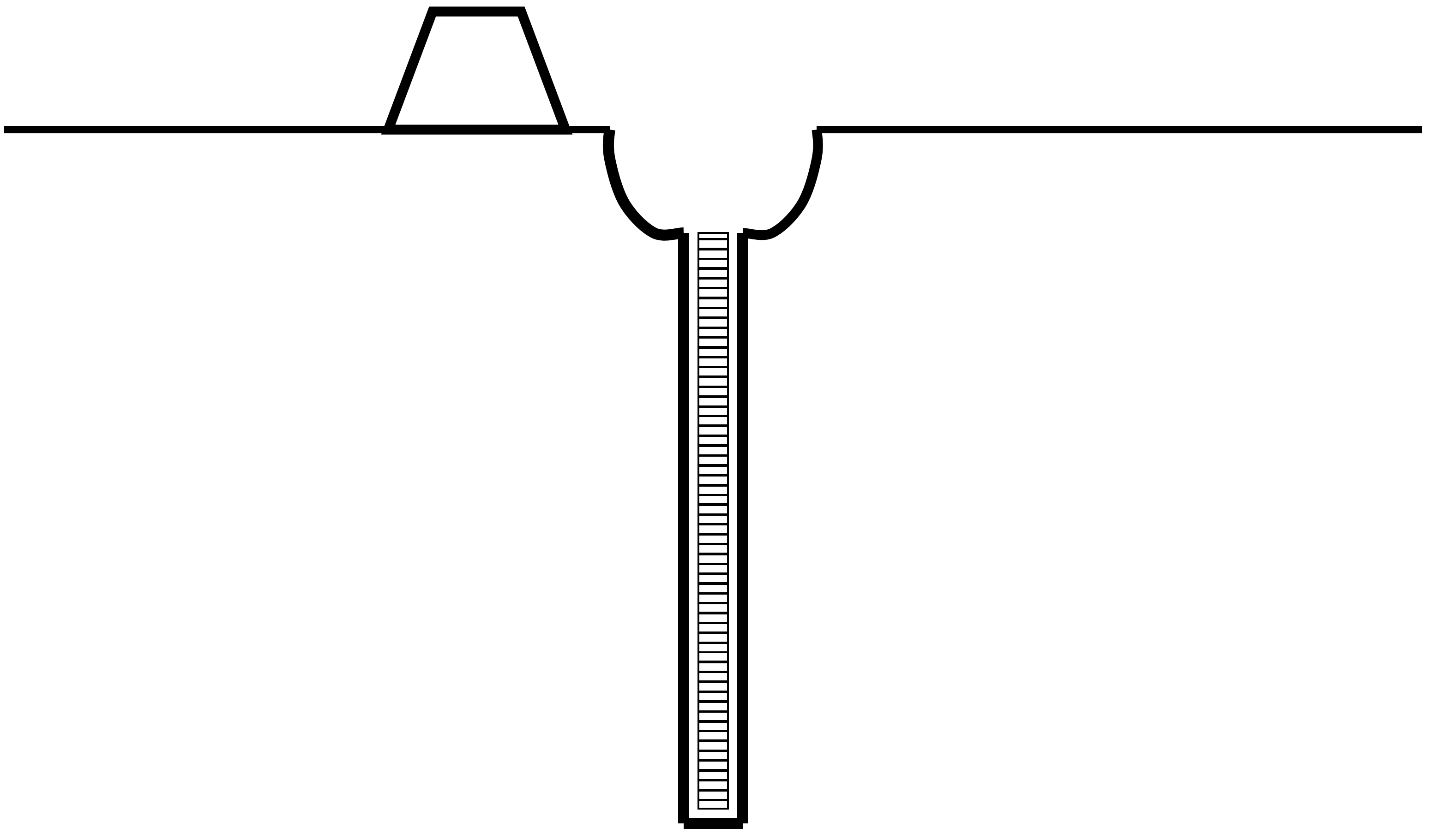

50 ft
Conceptual Plan View

Initial Landfill Surface

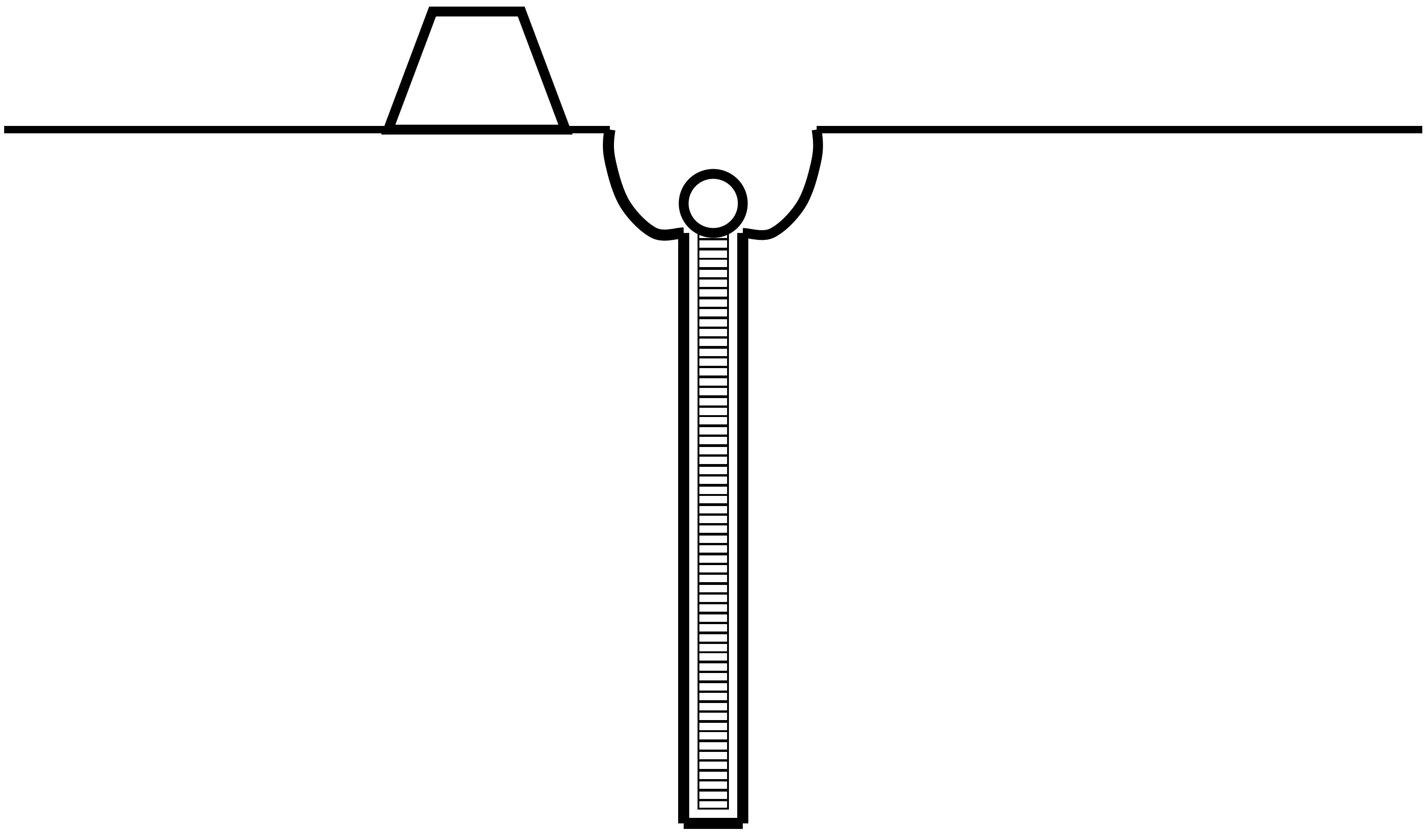
Excavate Trench



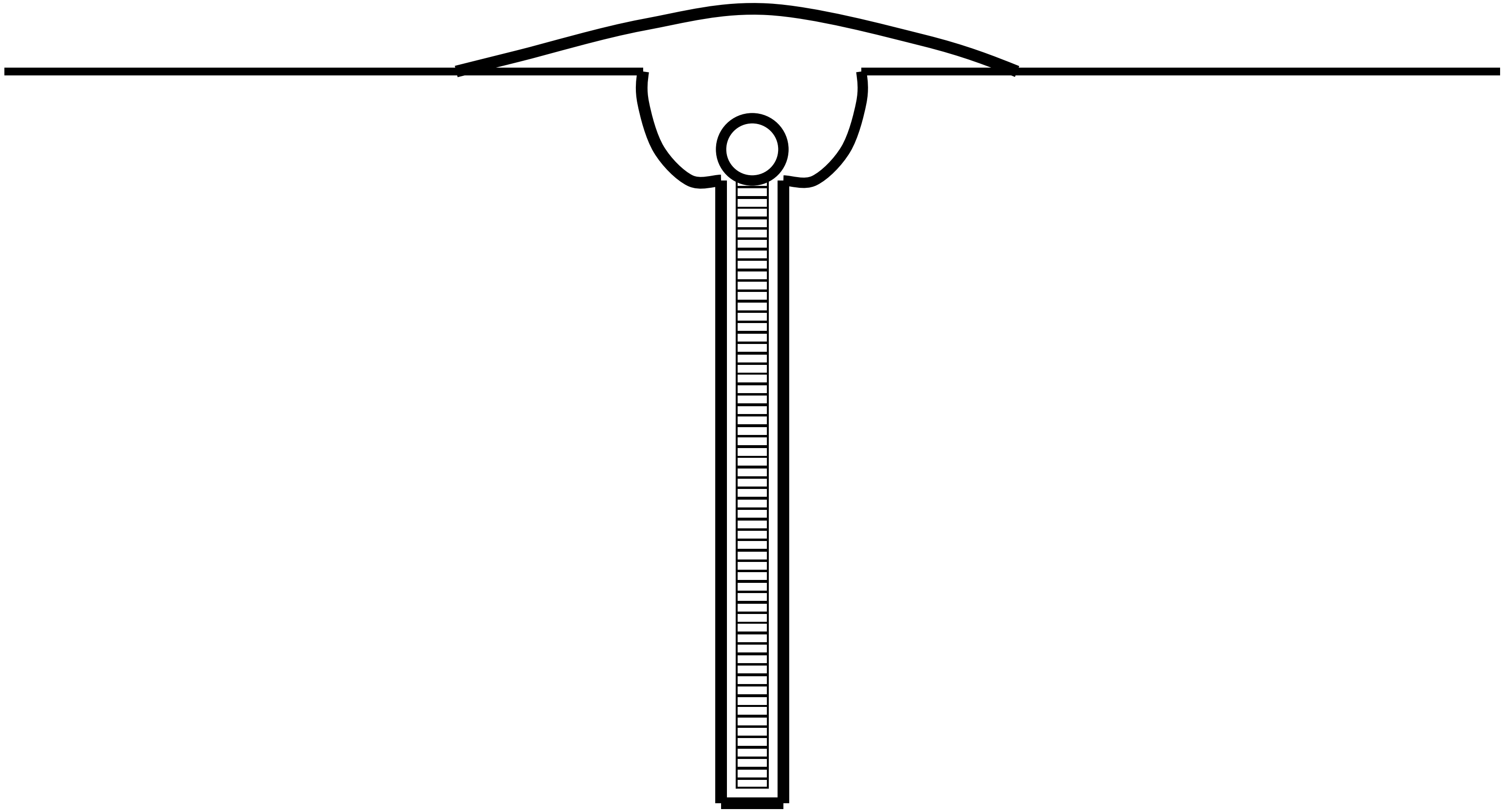
Install Vertical Well



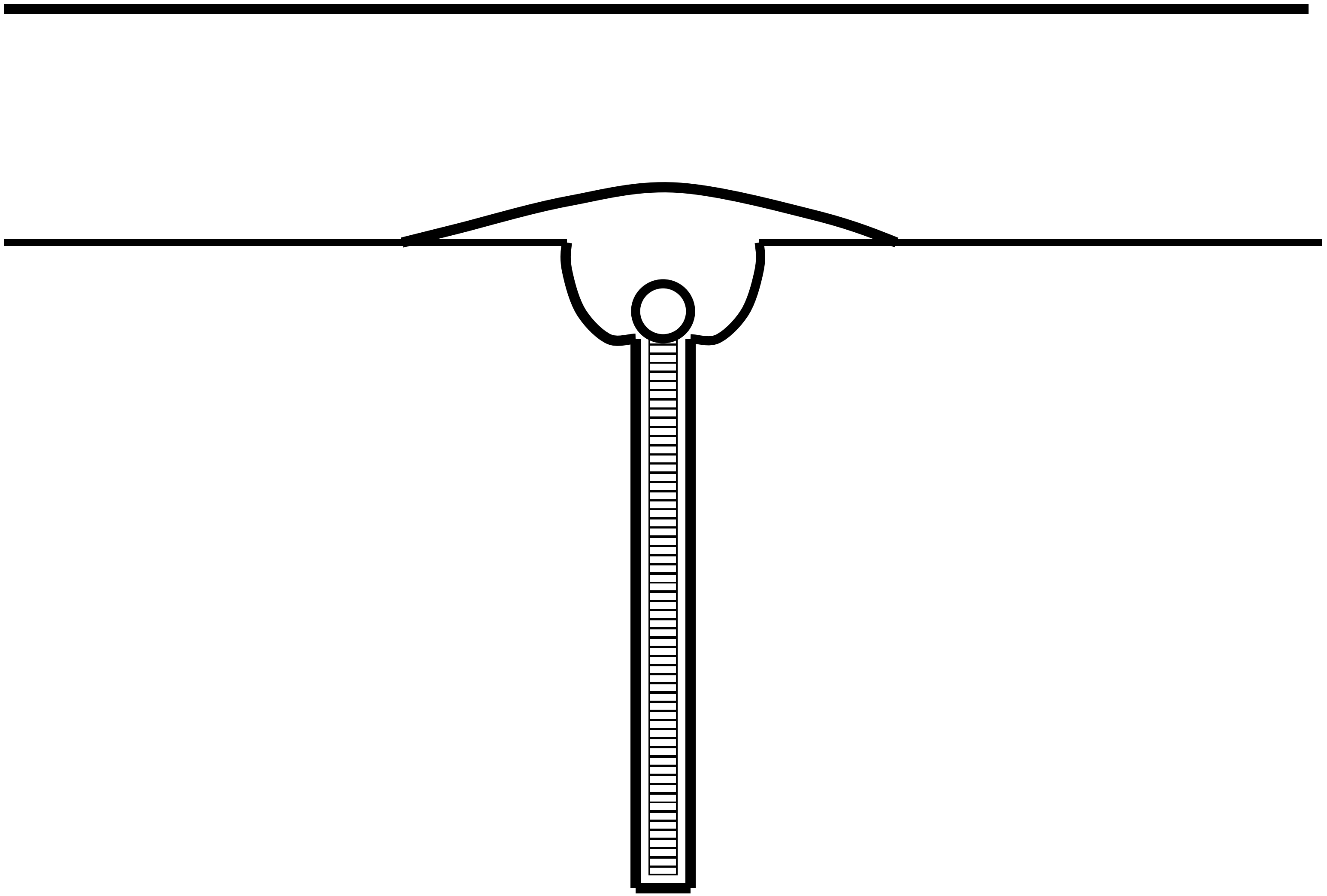
Connect to Wells to Manifold in the Trench

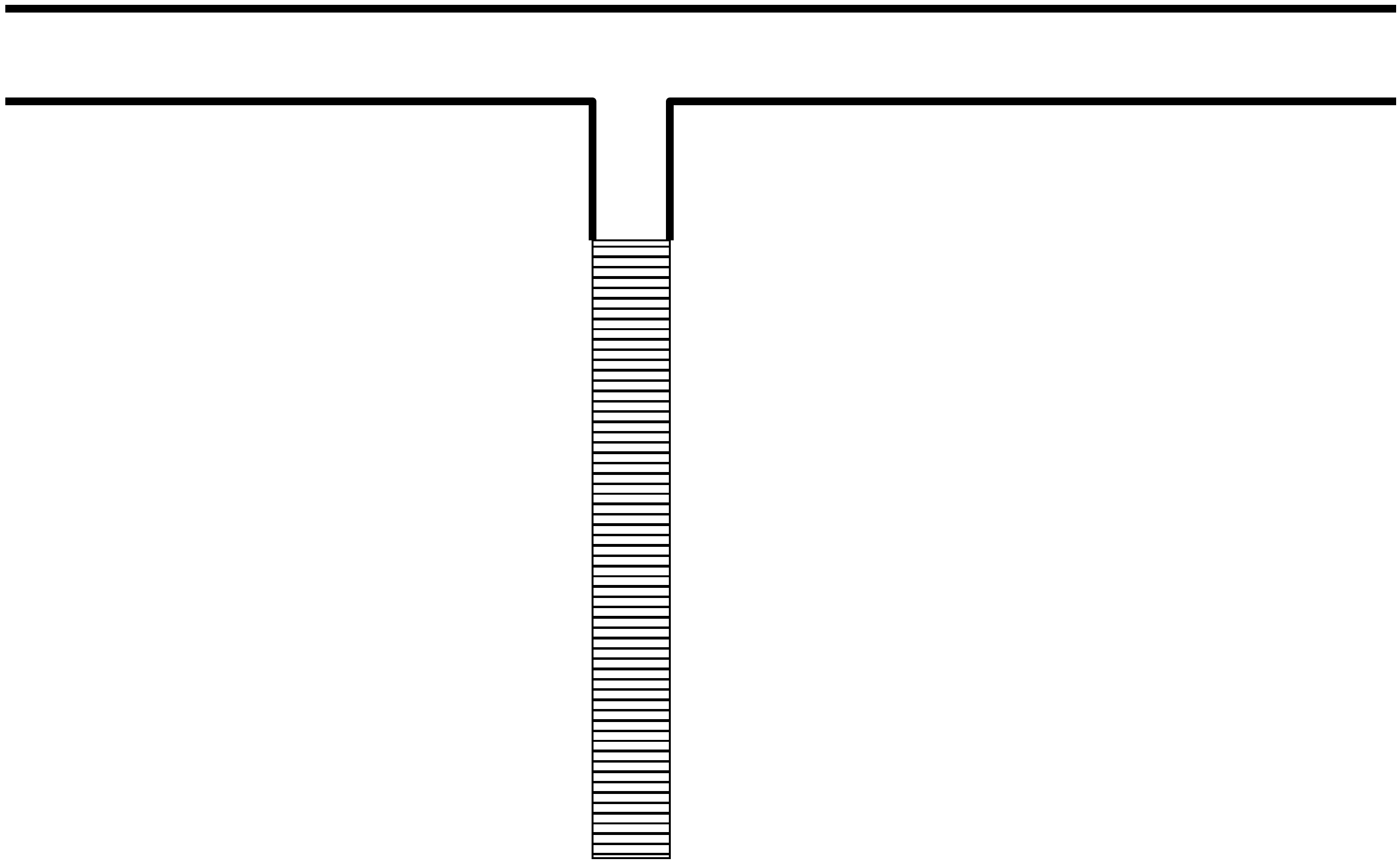


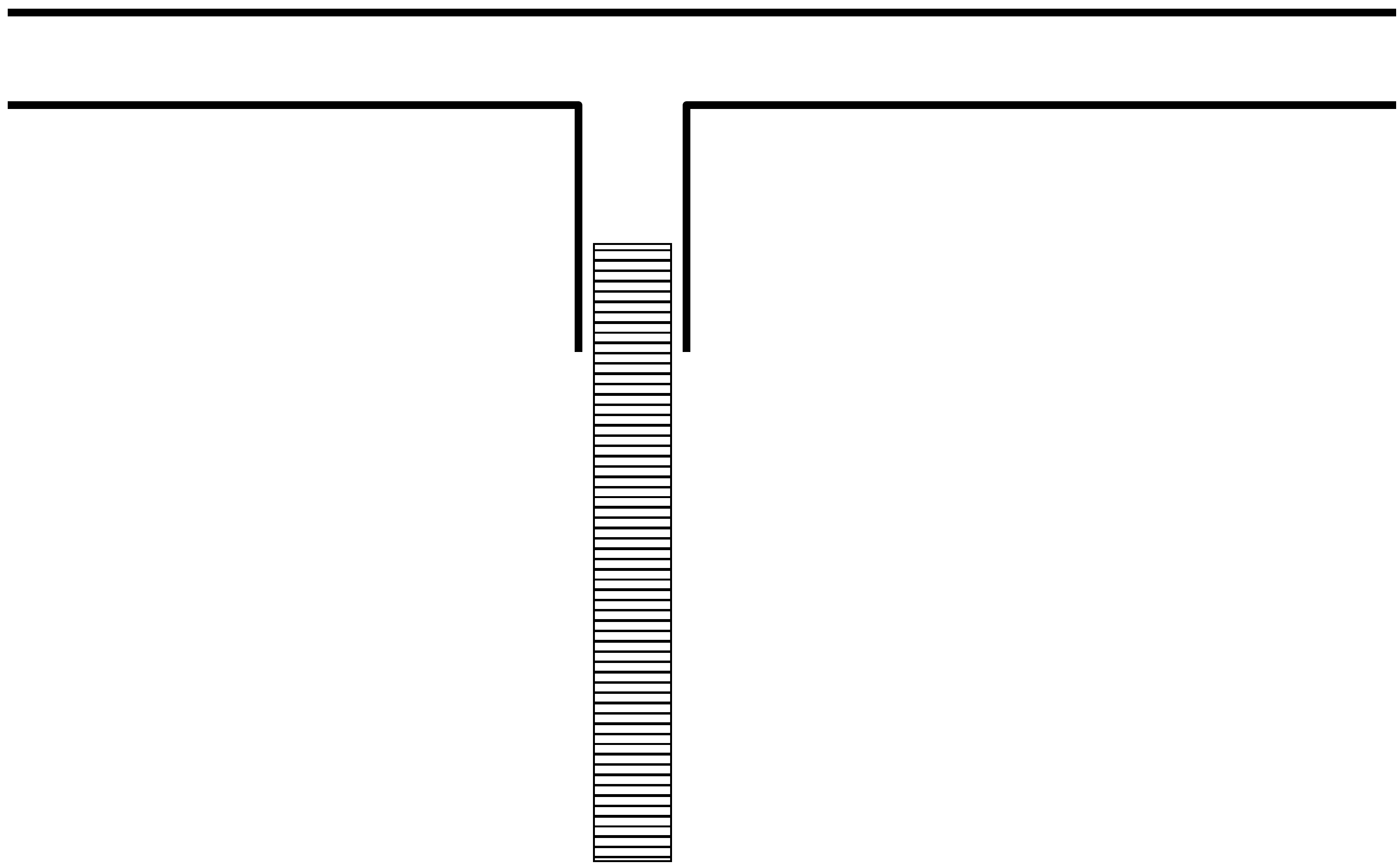
Cover Trench

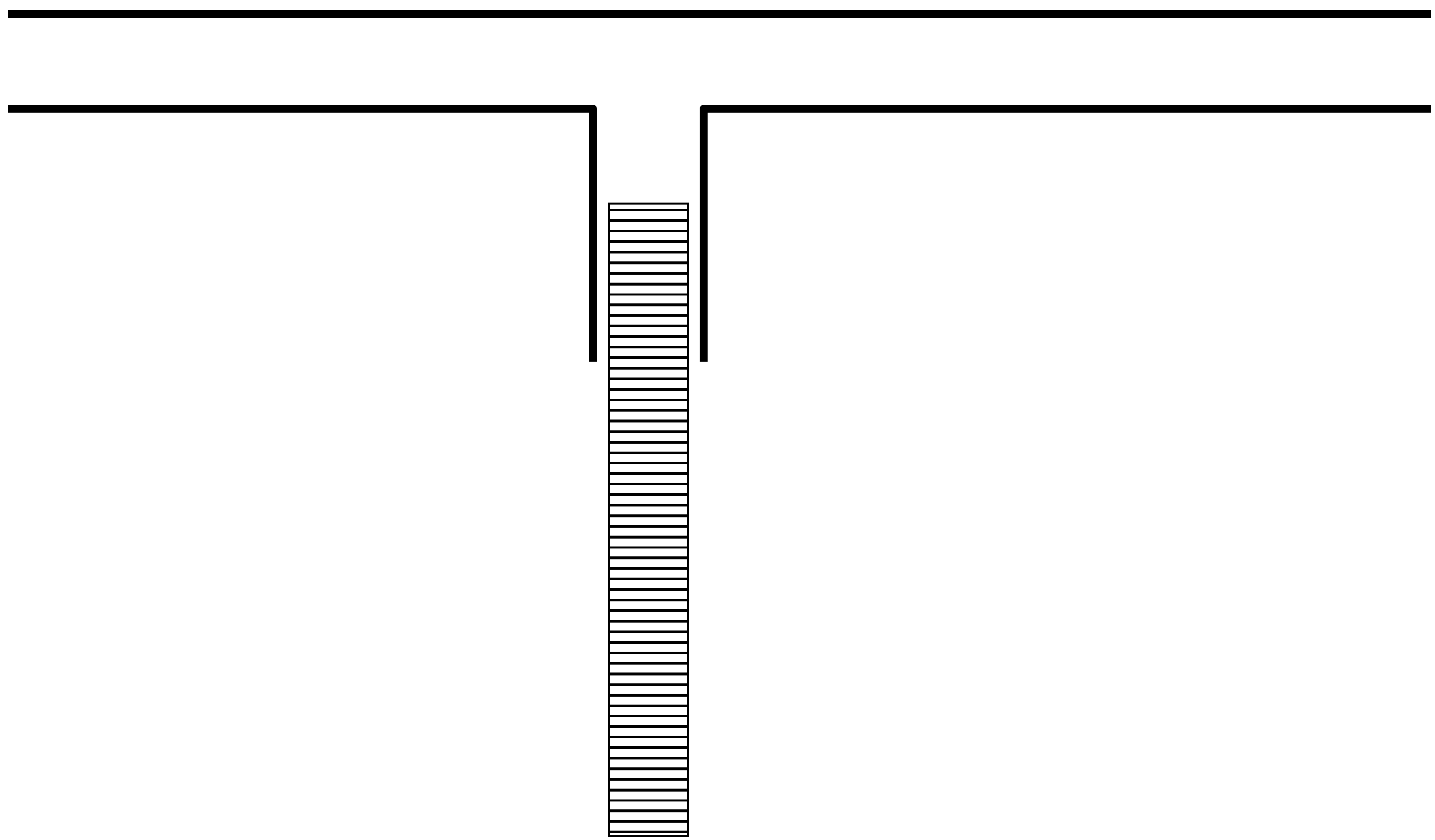


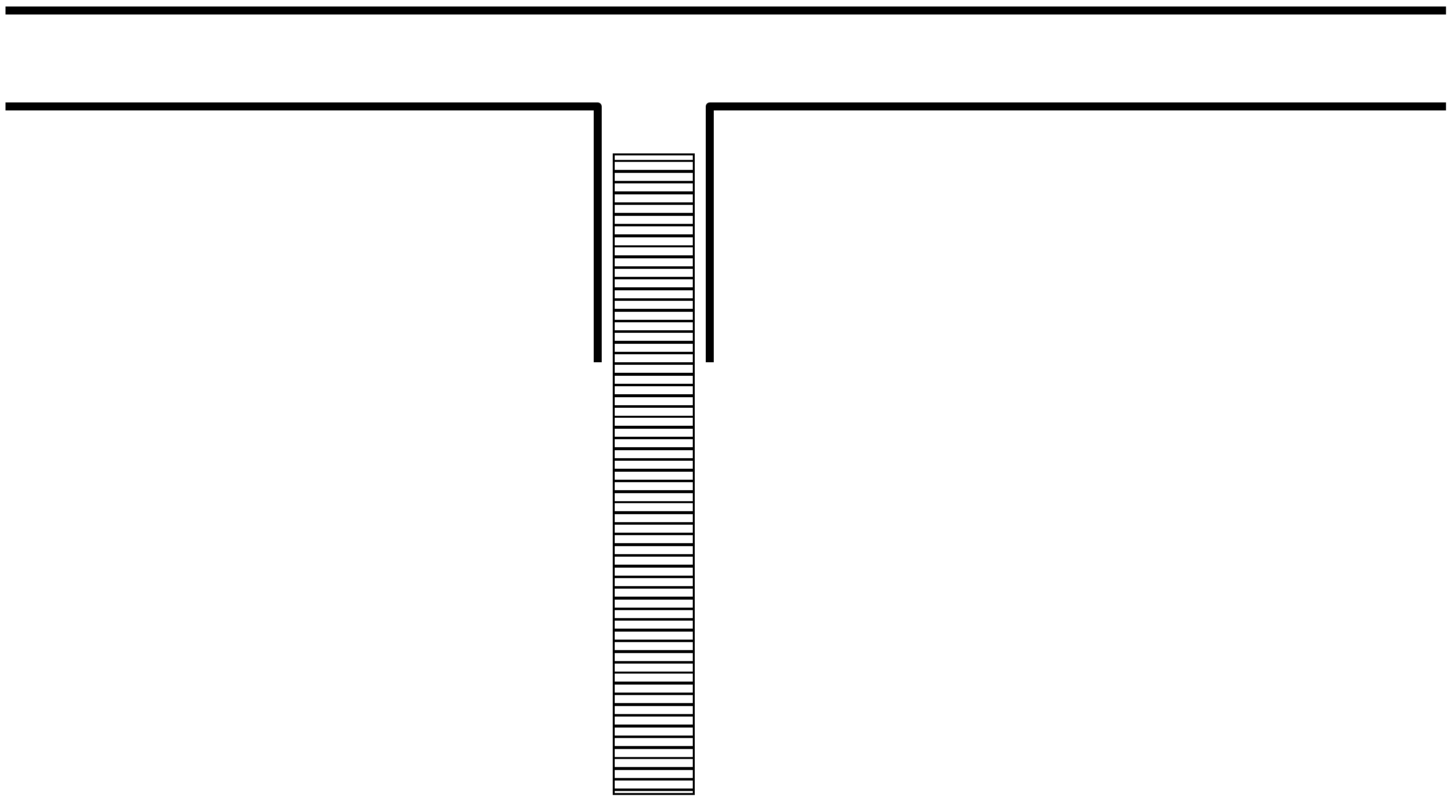
Add Next Lift of Waste



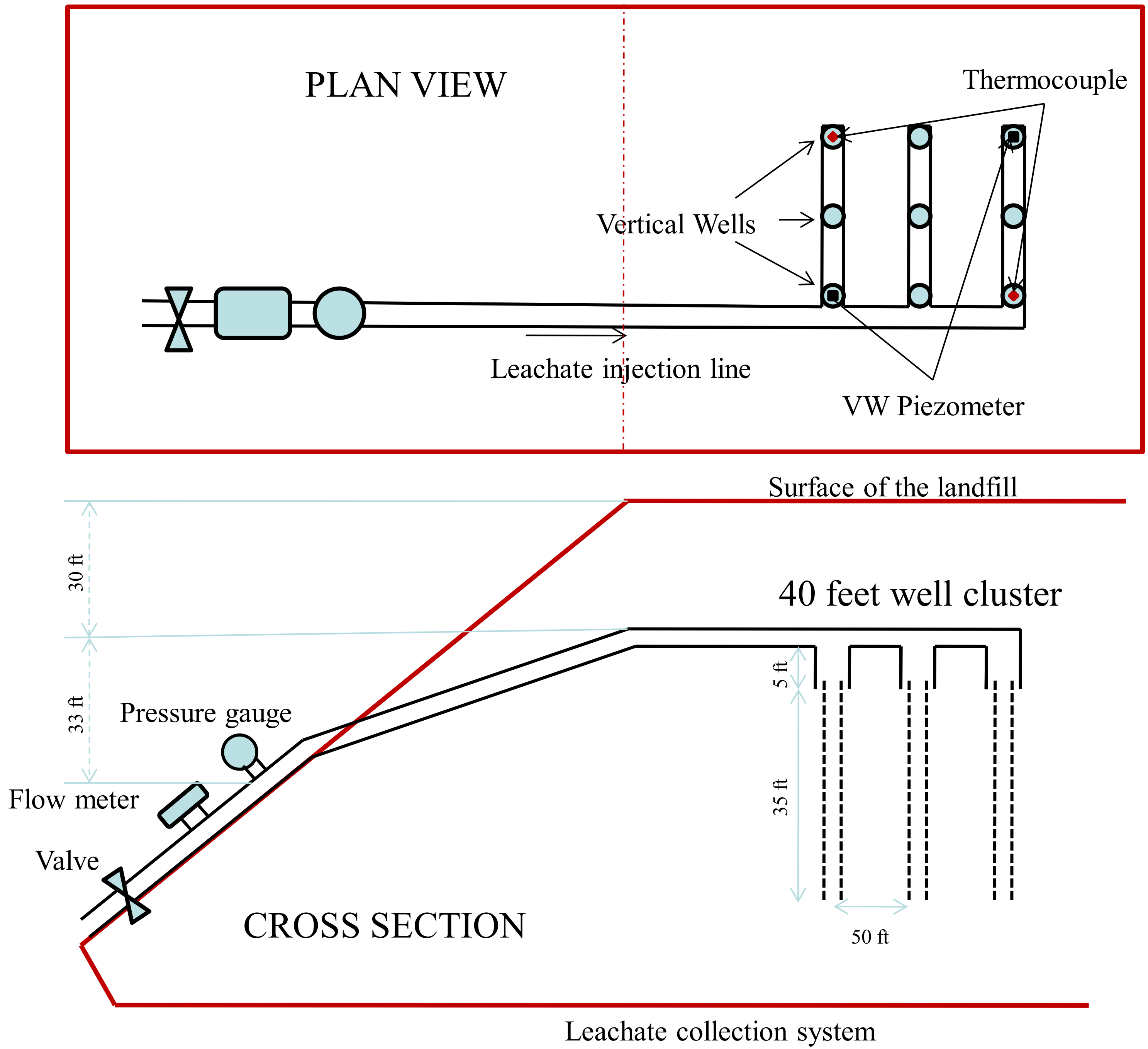









WM

PLAN VIEW
Thermocouple
Vertical Wells
Leachate injection line
VW Piezometer
Surface of the landfill
40 feet well cluster
30 ft
33 ft
5 ft
35 ft
50 ft
Pressure gauge
Flow meter
Valve
CROSS SECTION
Leachate collection system

System Performance

- Recirculated over 2 million gallons
- Mininal interference with daily operations after lift placement
- No seeps
- Much less penetrations through the liner system

Whole Tire Geoconduits

- Can whole tires be used instead of shredded tires?
- Potential advantages are ease of installation and costs/energy savings from shredding.

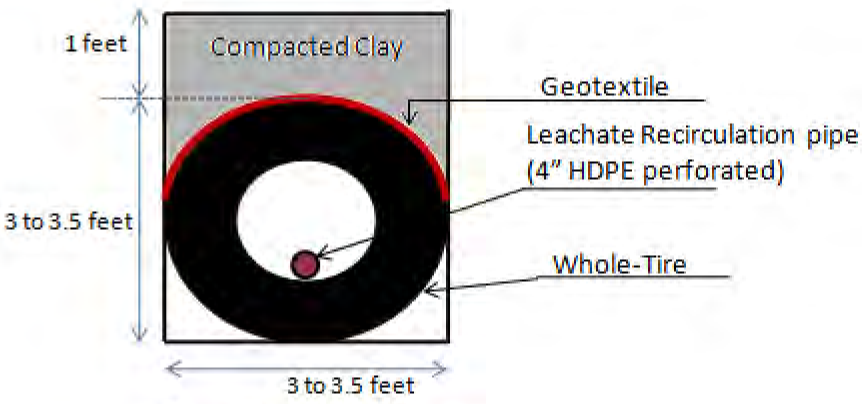
Phase I Construction


CAT
CAT

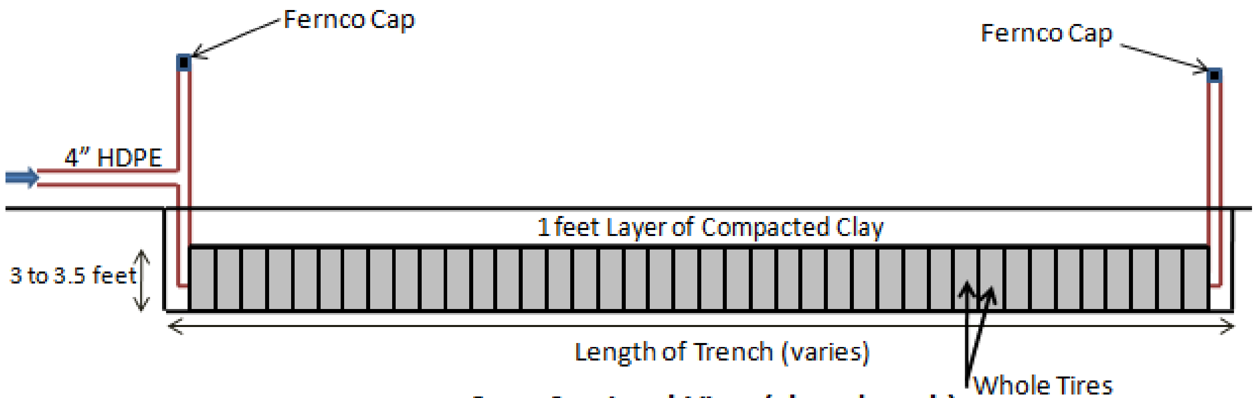

CAT


CAT
324D

Configuration A



Cross Sectional View (along width)



Cross Sectional View (along length)


Configuration C


Configuration A

1. Cover with soil
2. Operated
3. Cover with MSW
4. Operated

1. Cover with MSW
2. Operated

Leach bed of crushed glass