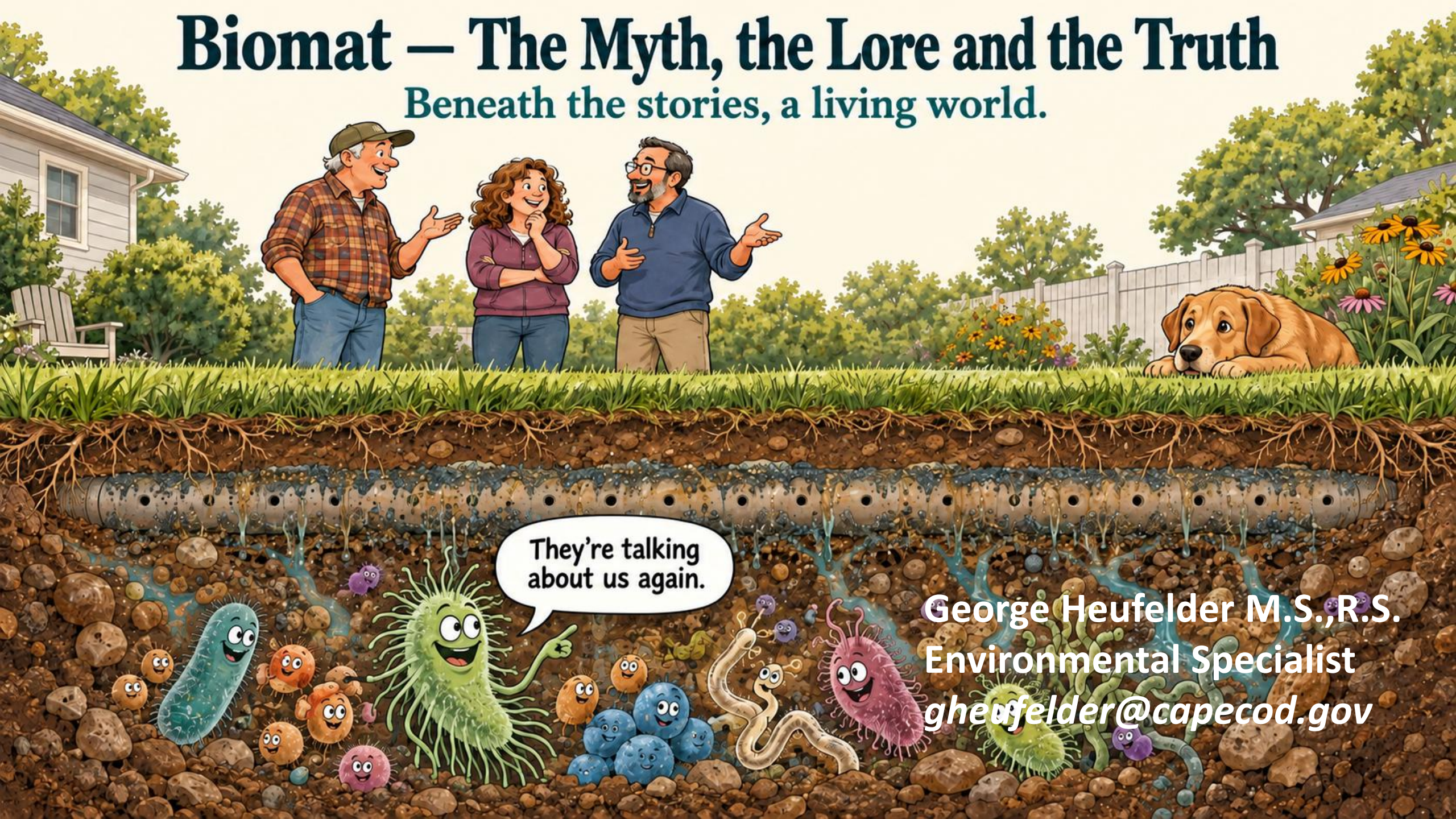
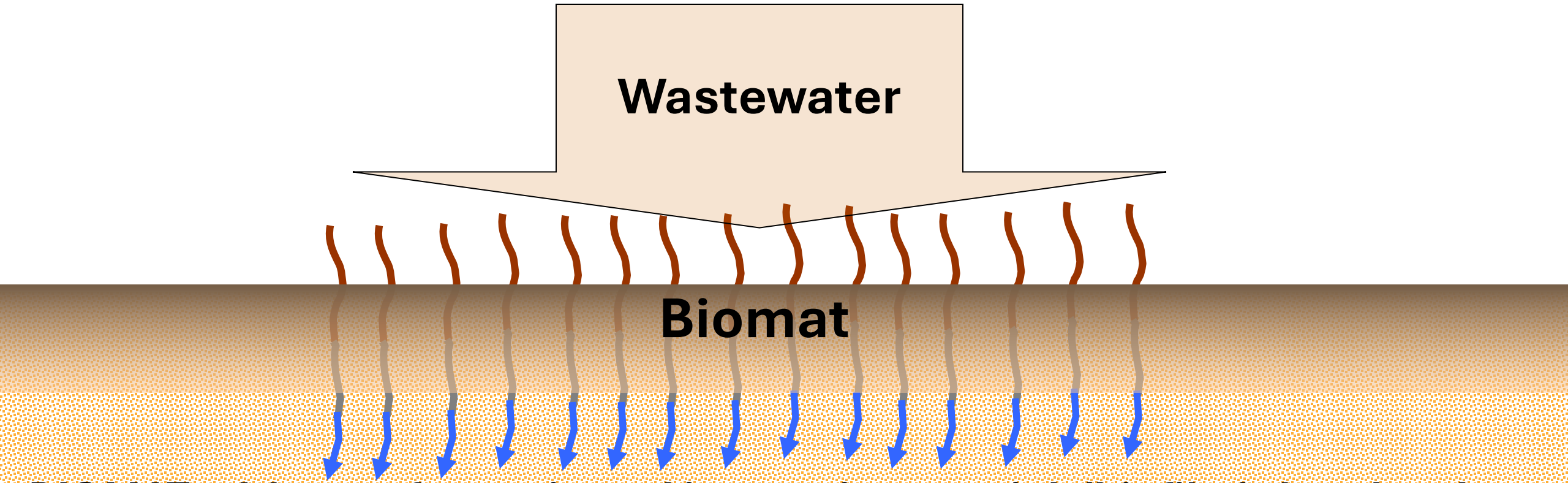
Biomat — The Myth, the Lore and the Truth

Beneath the stories, a living world.



George Heufelder M.S.,R.S.
Environmental Specialist
gheufelder@capecod.gov

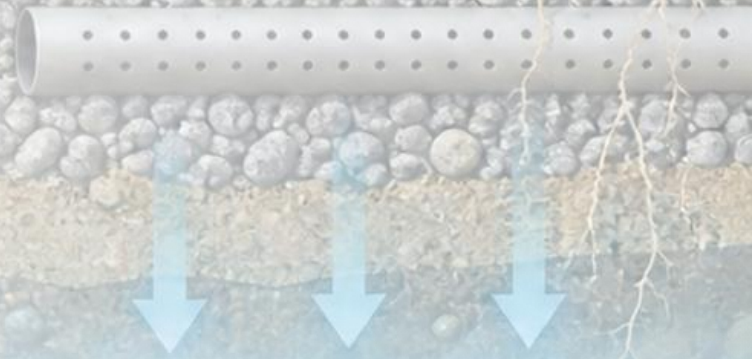
Just in case…….



BIOMAT – A layer of organic and inorganic material (biofilm) that develops on the soil interface in a soil absorption field as a result of microbial growth and activity.

Objectives

- Reintroduce and refine the concept of biomat
- Improve its reputation
- Understand its real function
- Learn ways manage biomat formation rather than fear it.



Real Objective ?

Get you excited about biomats so that you integrate your knowledge into septic systems design

(and discuss it with you family at the dinner table)

From Perc Test to LTAR

How onsite wastewater soil loading design evolved

Perc Era
1920s–
1960s

THE PERC TEST ERA HOW FAST CAN WE MAKE IT GO AWAY?

Biomat Insight
1960s–1970s
Realization

Interface clogging can controls long-term acceptance rates.
Laak

Soil Physics and LTAR
1970s – 1990s

Stop designing in what virgin soil can take in a perc test and start designing for long term sustainable acceptance
Bouma (1975), Converse, Tyler , McGauhey, Winneberger,and colleagues

TODAY
2000s+

Design on Long-Term Acceptance Rate (LTAR)+ soil morphology and wastewater strength
EPA 2002



From Perc Test to LTAR

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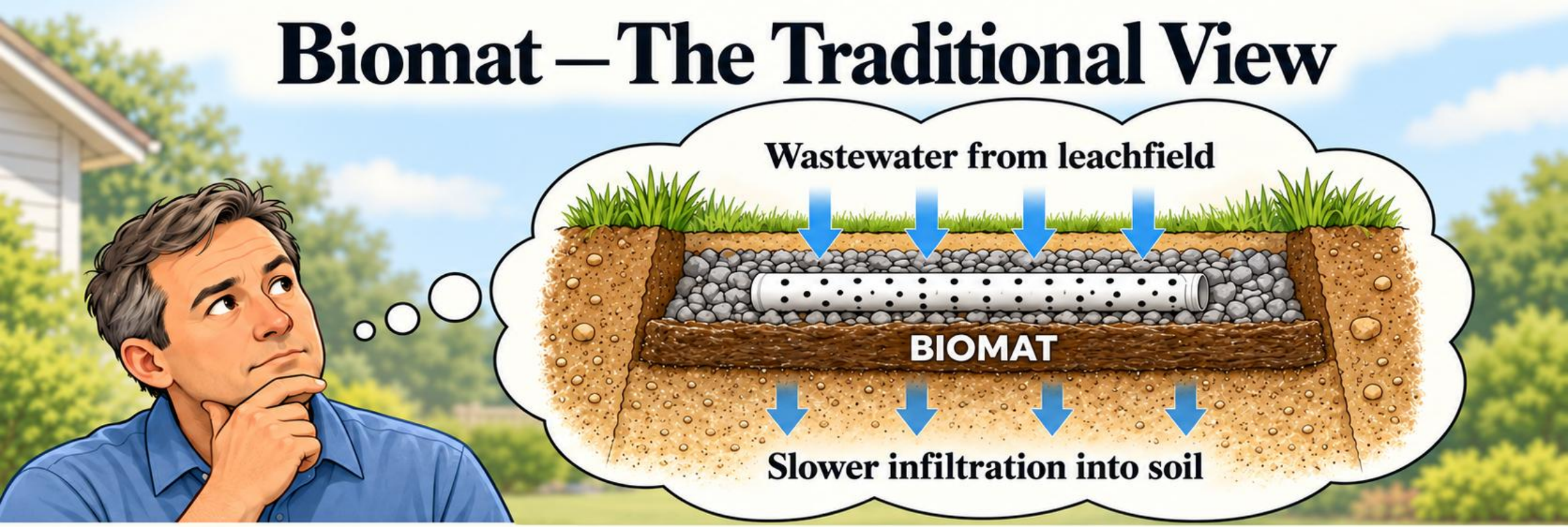
Soil Physics and LTAR
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Biomat Awareness Era

TODAY
2000s+
Design on Long-Term Acceptance Rate (LTAR)+ soil morphology and wastewater strength
EPA 2002



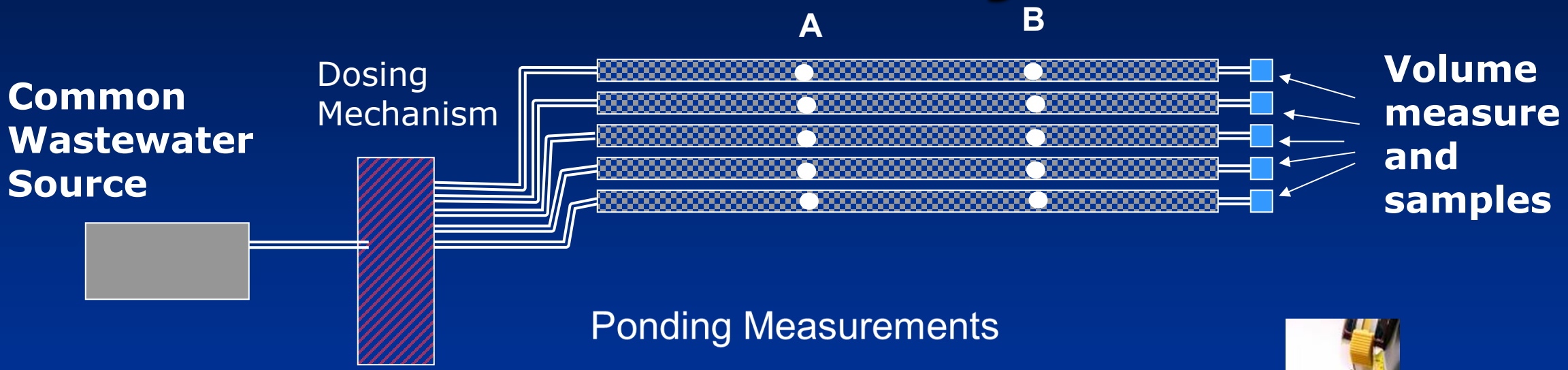
Biomat – The Traditional View



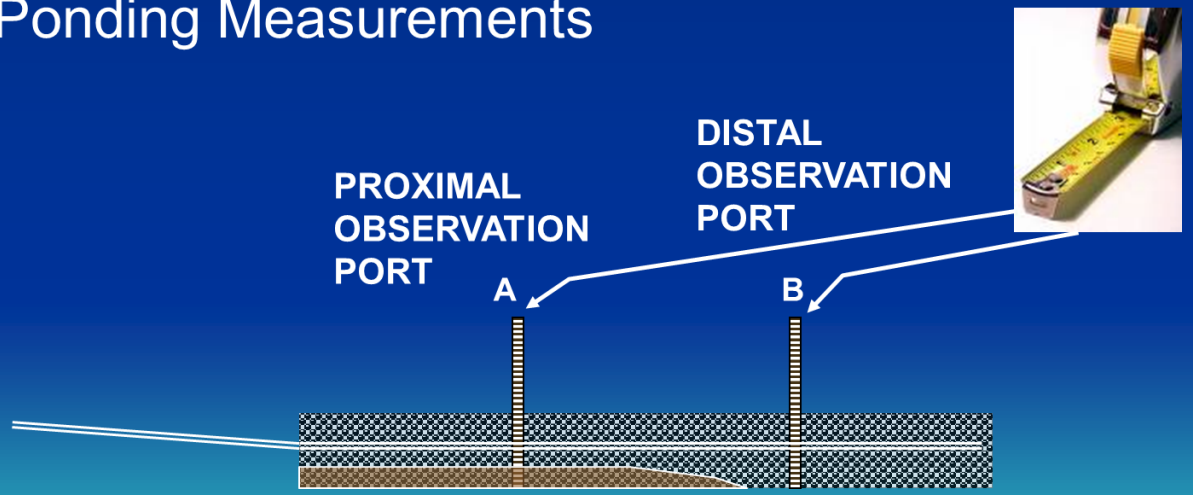
A biologically active, relatively low-permeability layer that develops at the infiltrative surface where wastewater enters the soil.

But does it really behave like a uniform mat?

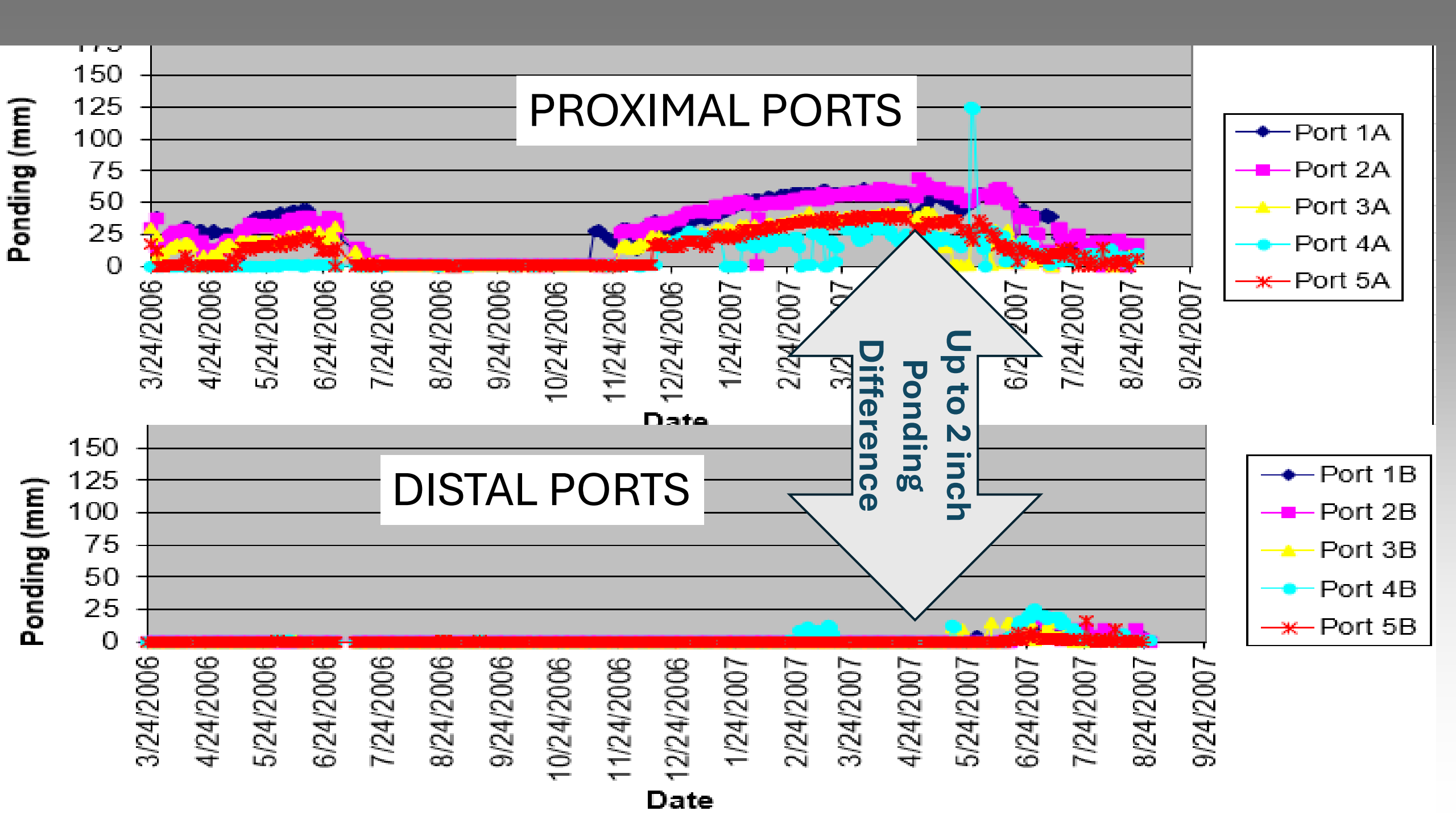
Not really !



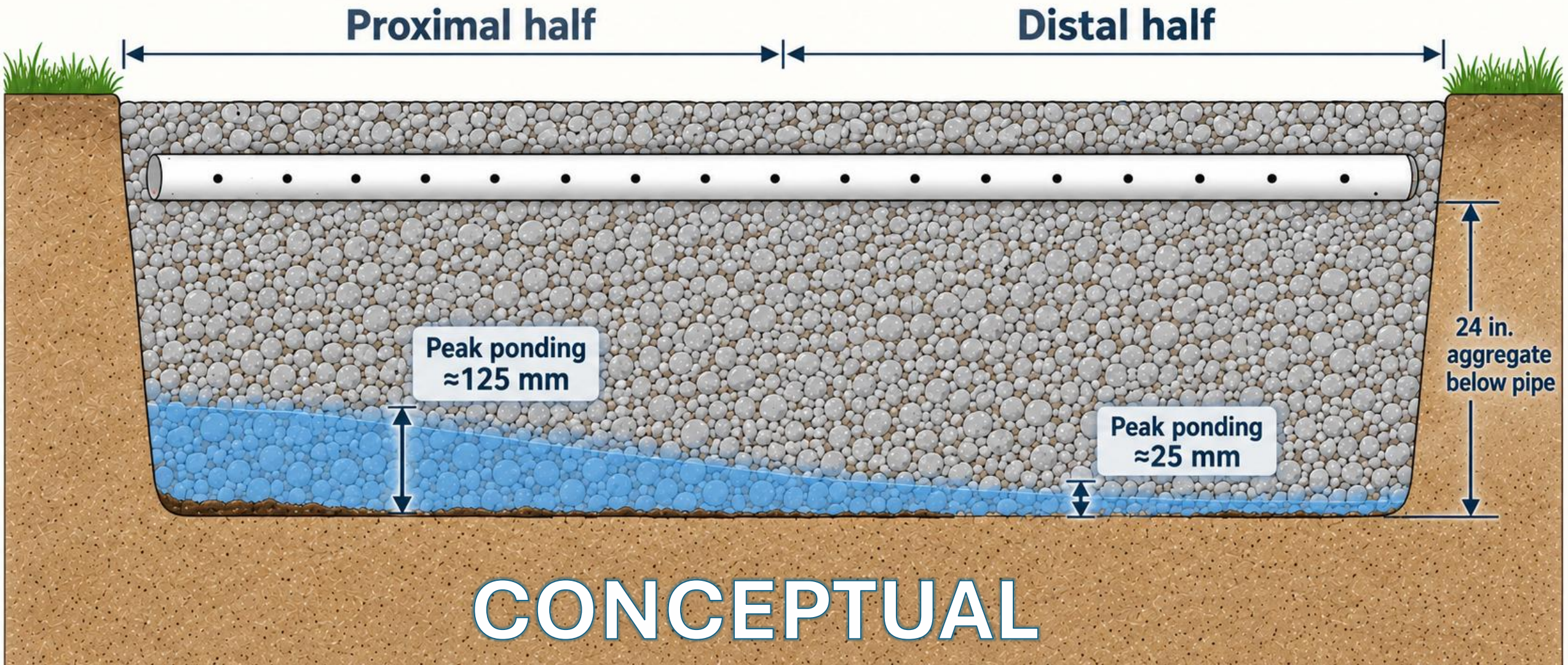
Ponding Measurements



Research conducted at Massachusetts Alternative Septic System Test Center

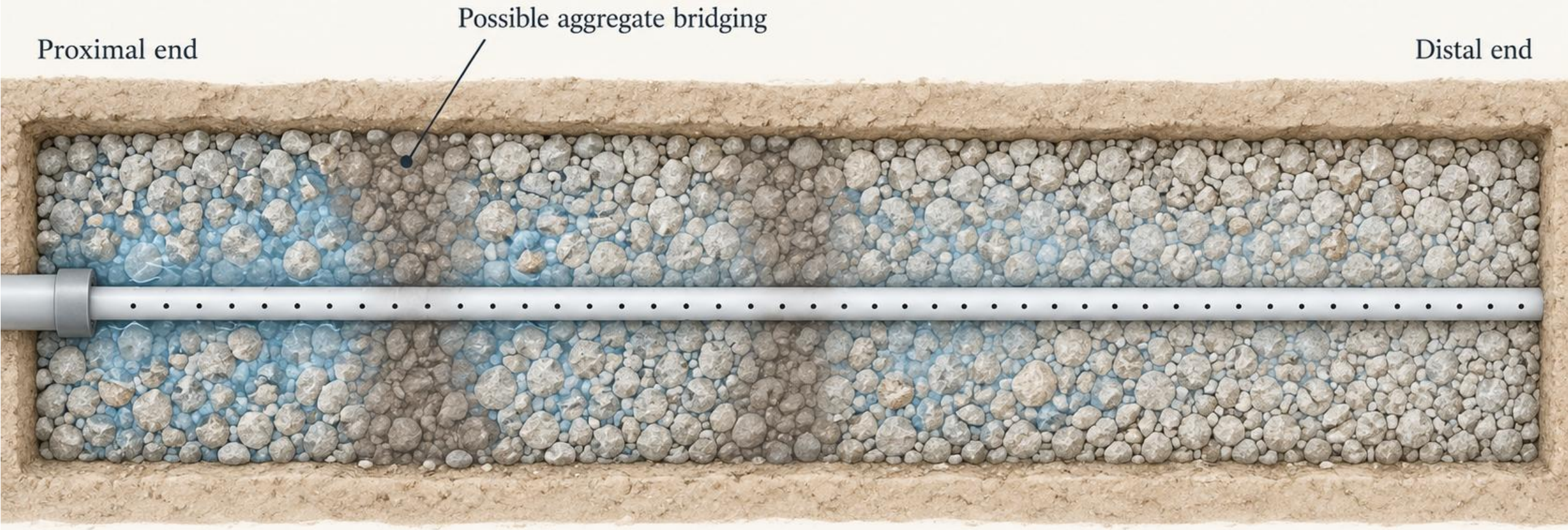

PROXIMAL PORTS
Ponding (mm)
150
125
100
75
50
25
0
3/24/2006
4/24/2006
5/24/2006
6/24/2006
7/24/2006
8/24/2006
9/24/2006
10/24/2006
11/24/2006
12/24/2006
1/24/2007
2/24/2007
6/2
7/24/2007
8/24/2007
9/24/2007
Date
Port 1A
Port 2A
Port 3A
Port 4A
Port 5A
Up to 2 inch
Ponding
Difference
DISTAL PORTS
Ponding (mm)
150
125
100
75
50
25
0
3/24/2006
4/24/2006
5/24/2006
6/24/2006
7/24/2006
8/24/2006
9/24/2006
10/24/2006
11/24/2006
12/24/2006
1/24/2007
2/24/2007
3/24/2007
4/24/2007
5/24/2007
6/24/2007
7/24/2007
8/24/2007
9/24/2007
Date
Port 1B
Port 2B
Port 3B
Port 4B
Port 5B

Uneven Ponding – Uneven Biozone Development



CONCEPTUAL

Aggregate Bridging and Uneven Ponding



Conceptual plan view

Biomat: The Misnomer of All Misnomers




The biozone is a living community whose composition and activity deserve considerable attention
Biozone
Bacteria
Archaea
Fungi
Protozoa
Rotifers
Microarthropods
Nematodes

The Biozone: A Dominant Control

The Living Valve

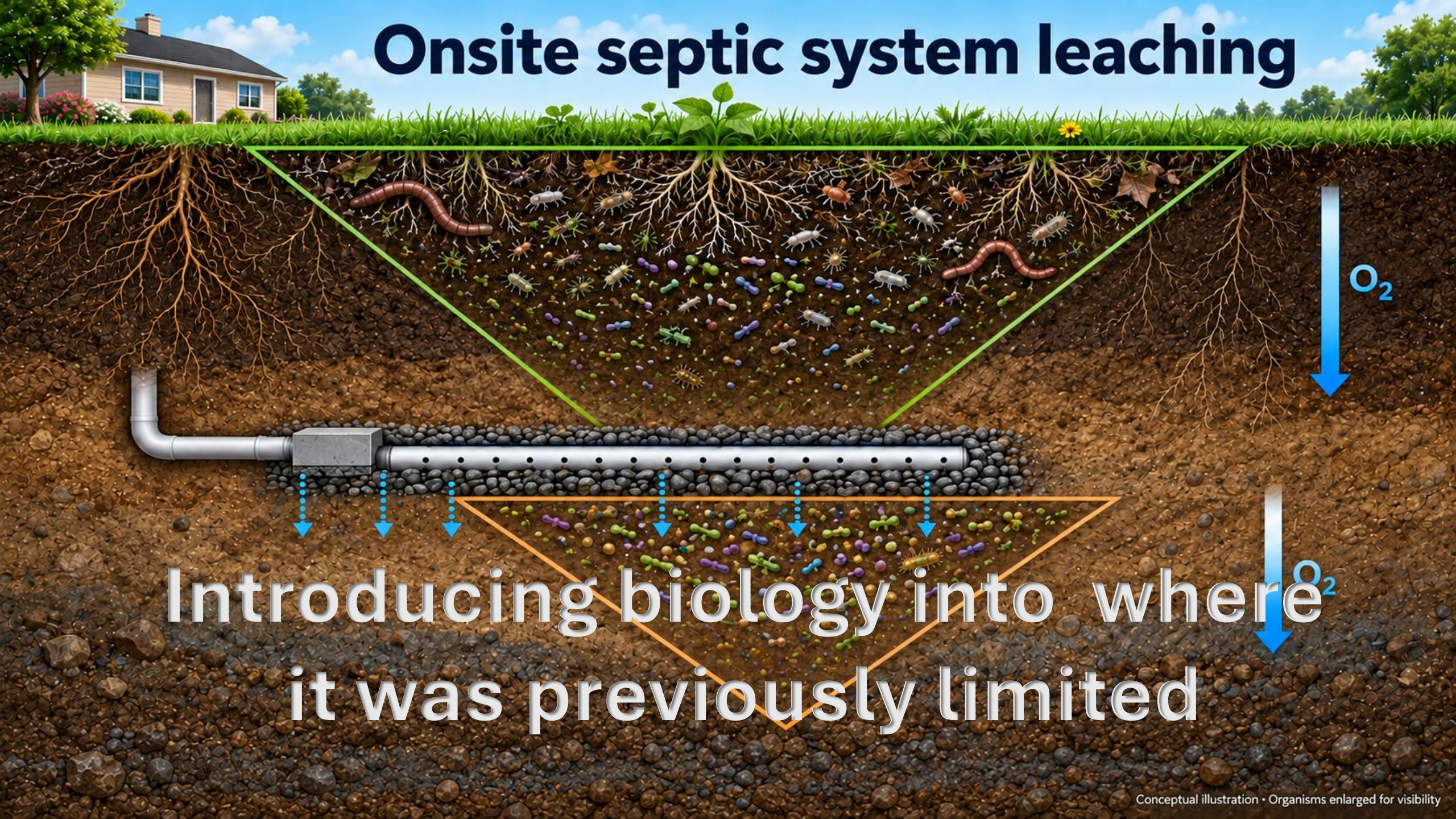


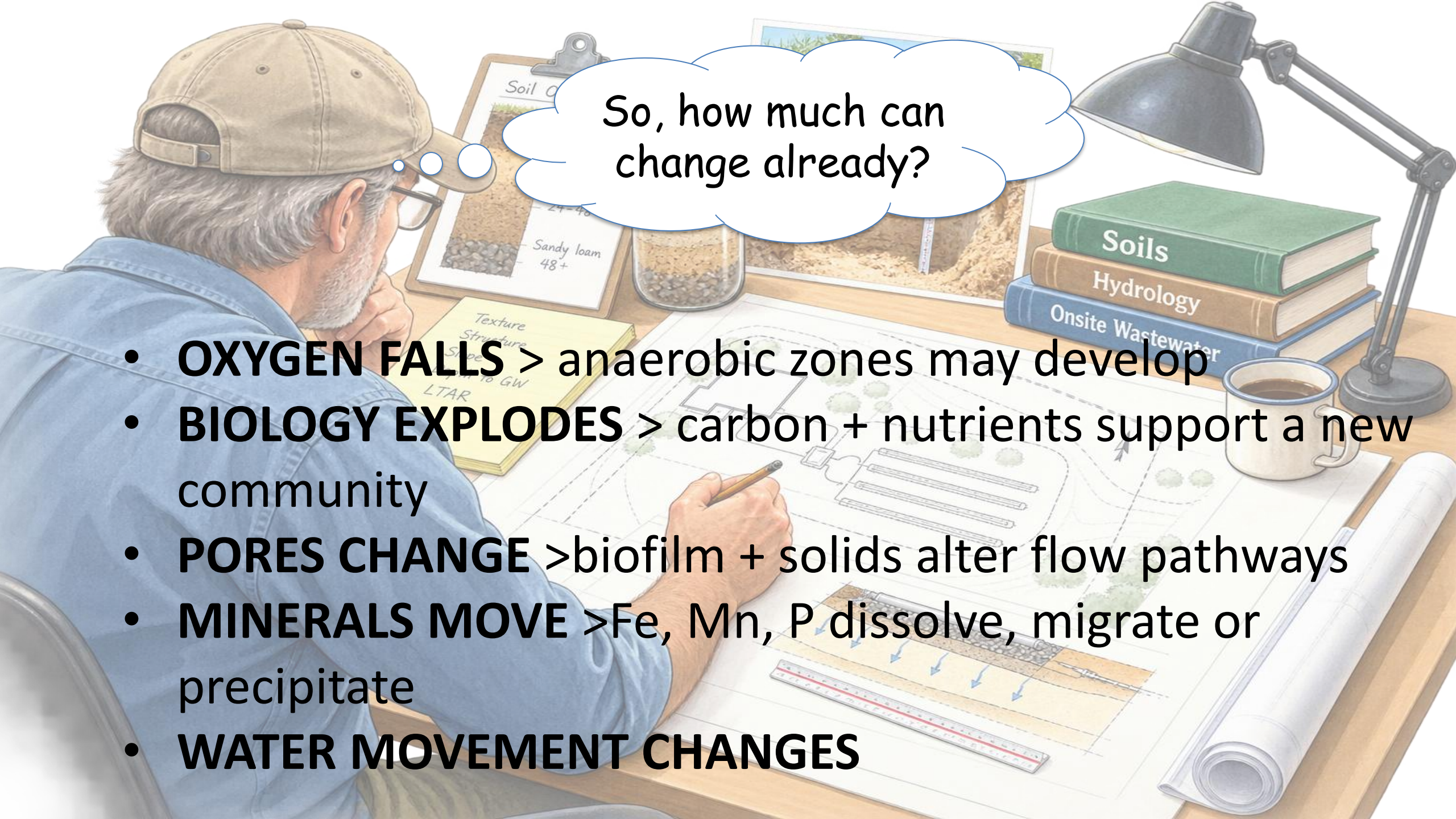
Understanding its development is essential to understanding long-term performance.

Short story ?



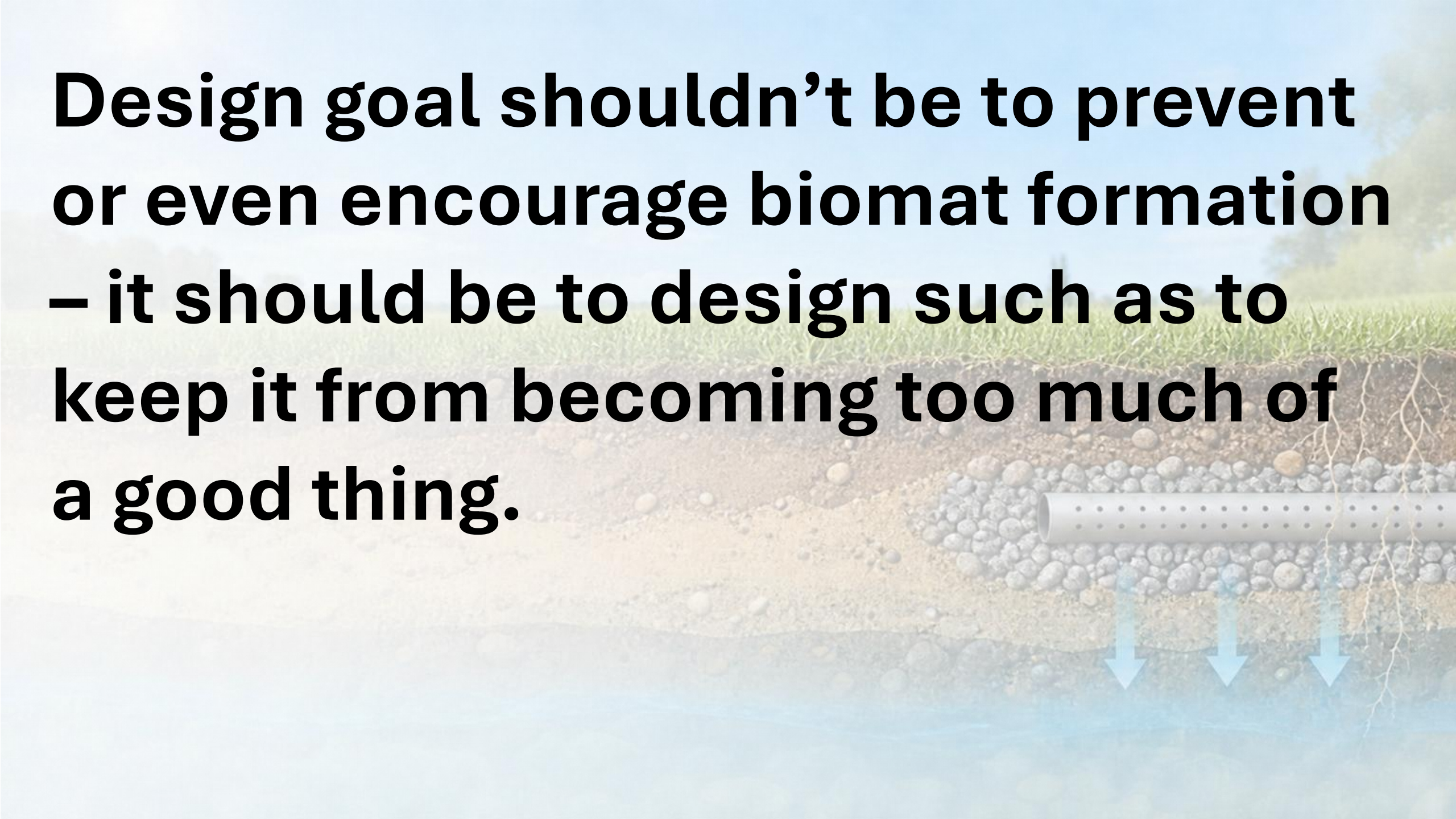
We design from the soil we find — but wastewater creates a soil–biological interface that wasn't there when we described it.


Onsite septic system leaching
O_2
O_2
Introducing biology into where it was previously limited
Conceptual illustration • Organisms enlarged for visibility



- **OXYGEN FALLS** > anaerobic zones may develop
- **BIOLOGY EXPLODES** > carbon + nutrients support a new community
- **PORES CHANGE** >biofilm + solids alter flow pathways
- **MINERALS MOVE** >Fe, Mn, P dissolve, migrate or precipitate
- **WATER MOVEMENT CHANGES**

Design goal shouldn’t be to prevent or even encourage biomat formation – it should be to design such as to keep it from becoming too much of a good thing.





The challenge

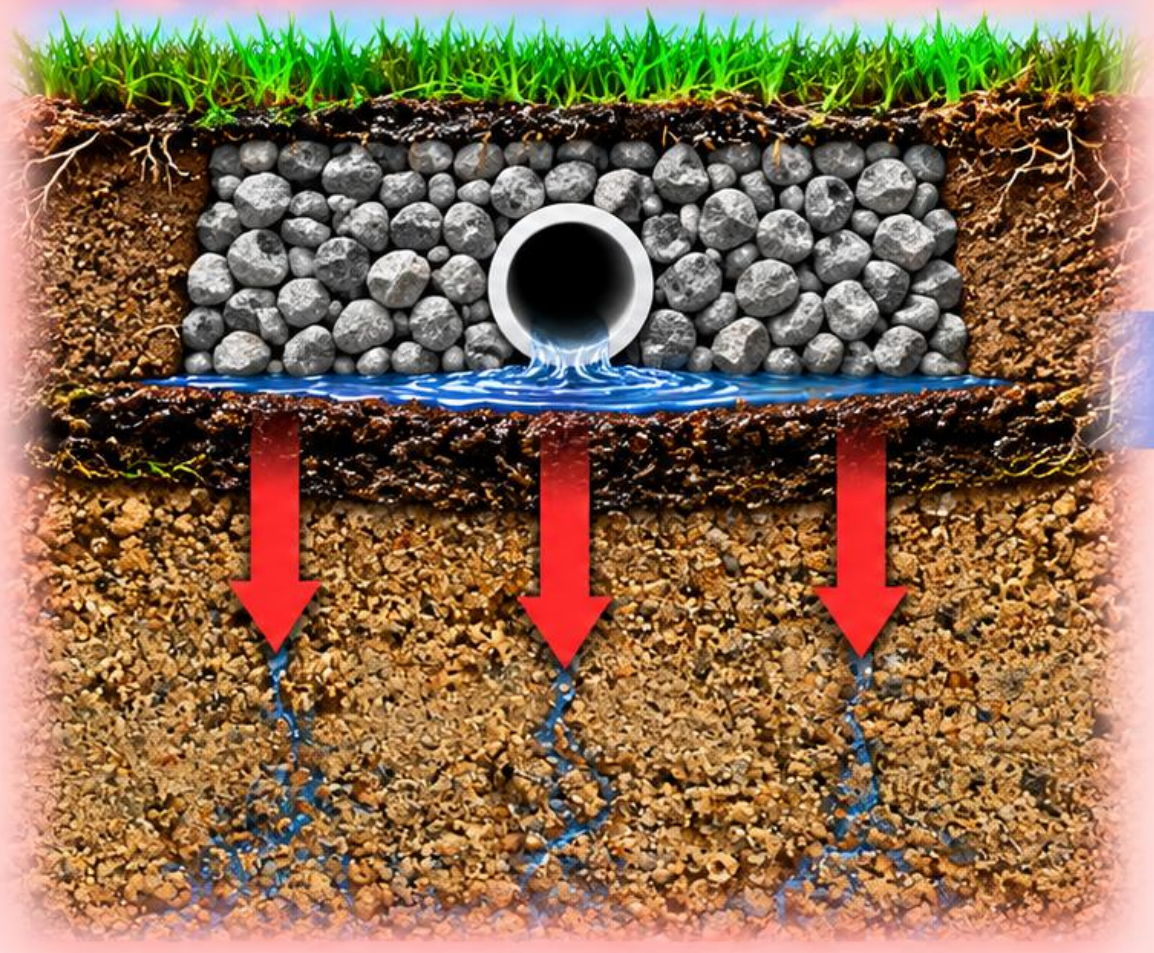
REMEMBER

We design around what we cannot fully predict LTAR is NOT a soil property, it is design loading rate assigned to a soil under specified or ***assumed*** wastewater and operating conditions.

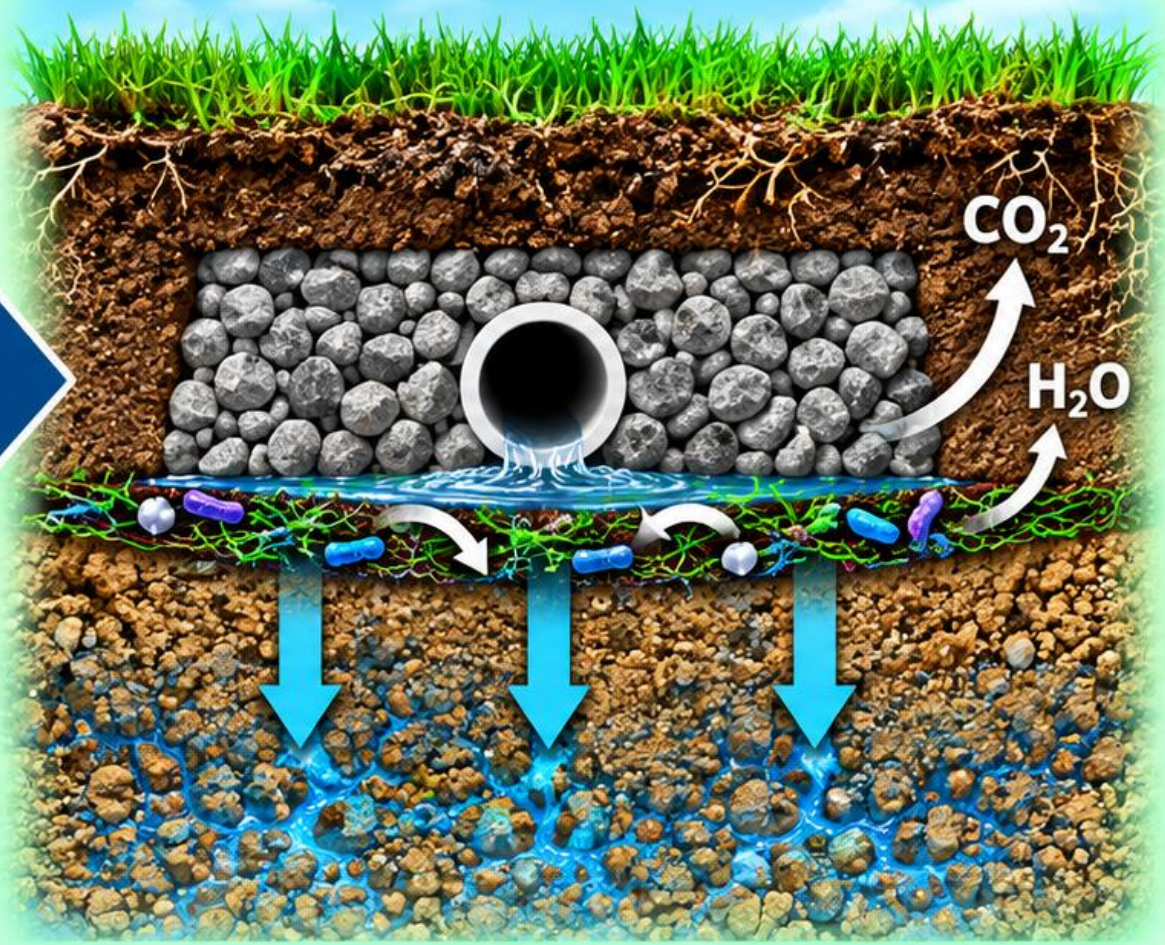
In other words – accounting for the biology that develops

Our thinking has to evolve

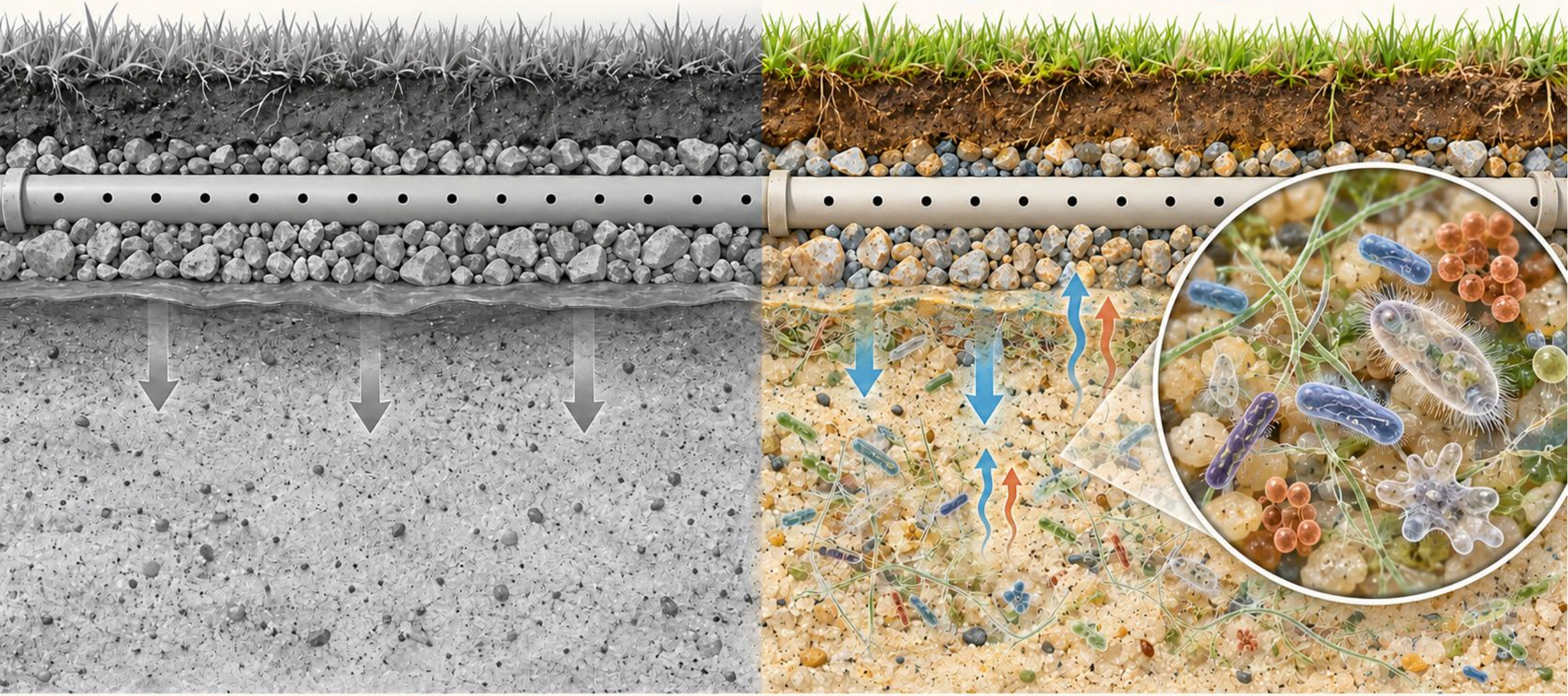
The Old View
"The Biomat as the Restrictor of Flow"



The Evolving View
"The Biozone as a Treatment Engine"



From Biomat to Biological Engine

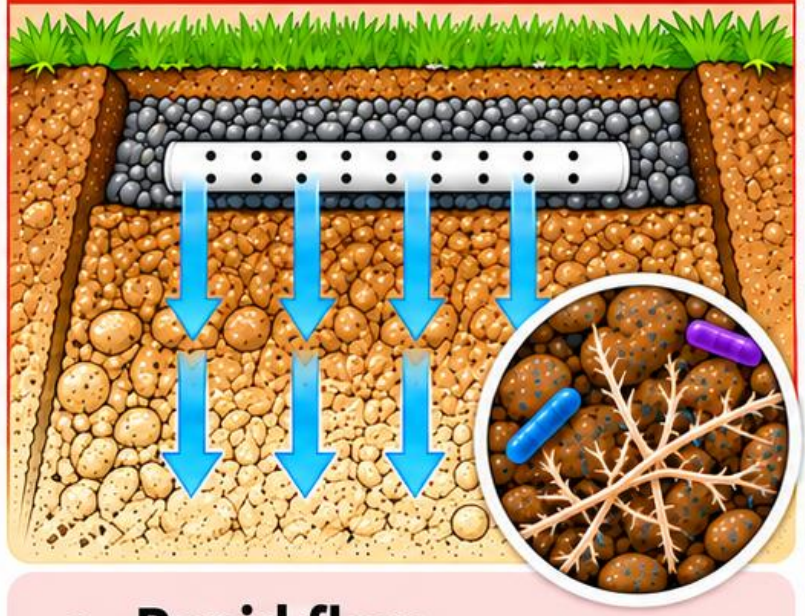


Kansas

OZ

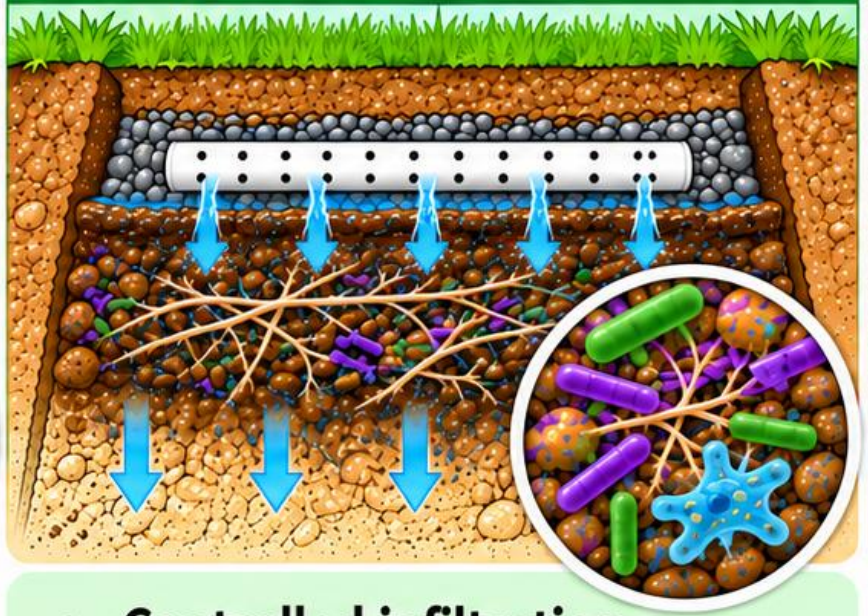
Conceptual illustration • Organisms enlarged

Too Little Control



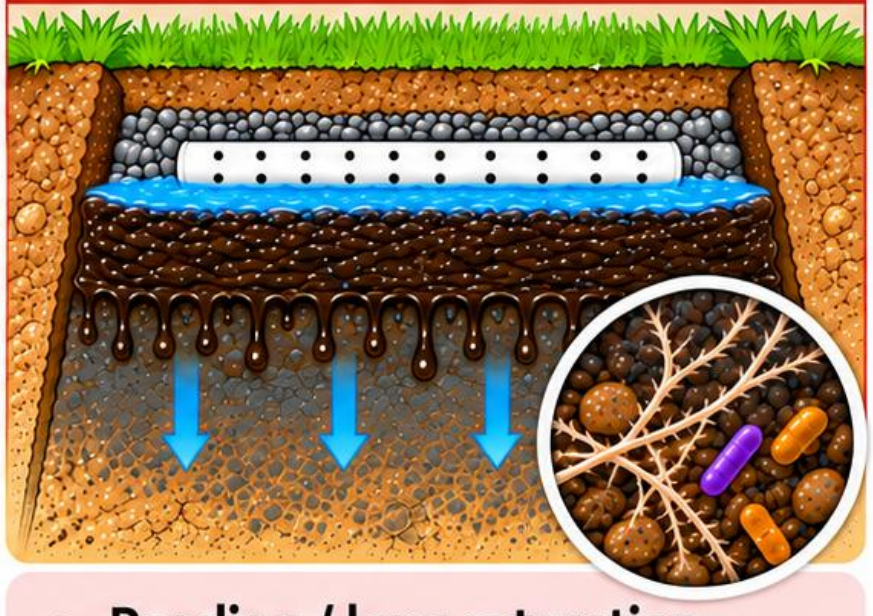
- Rapid flow
- Short contact time
- Preferential flow
- Lower treatment effectiveness

Optimal Biozone



- Controlled infiltration
- Unsaturated, oxygenated soil
- Diverse microbial community
- High treatment effectiveness

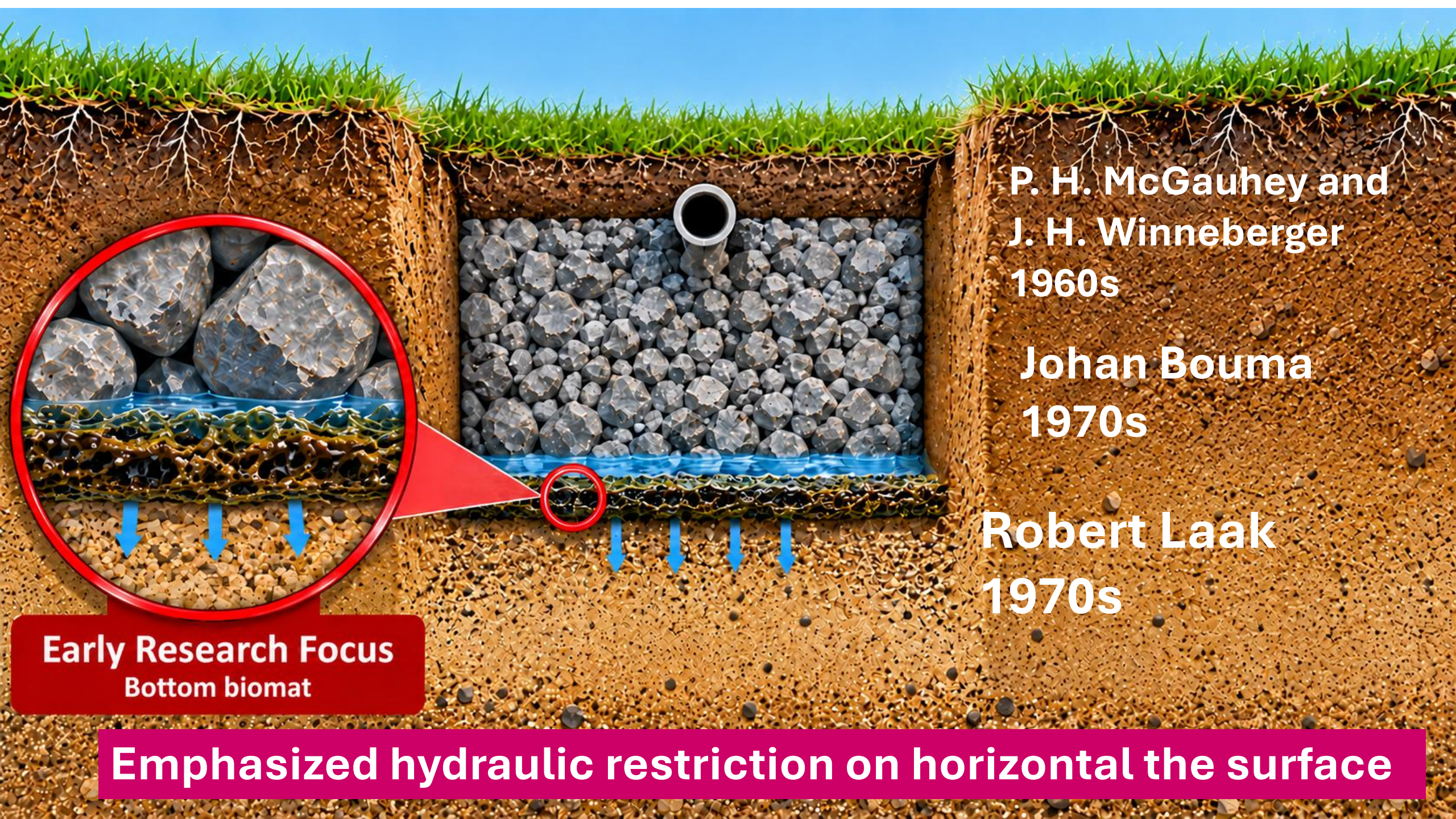
Excessive Restriction



- Ponding / long saturation
- Reduced oxygen availability
- Solids and EPS accumulation
- Declining hydraulic performance

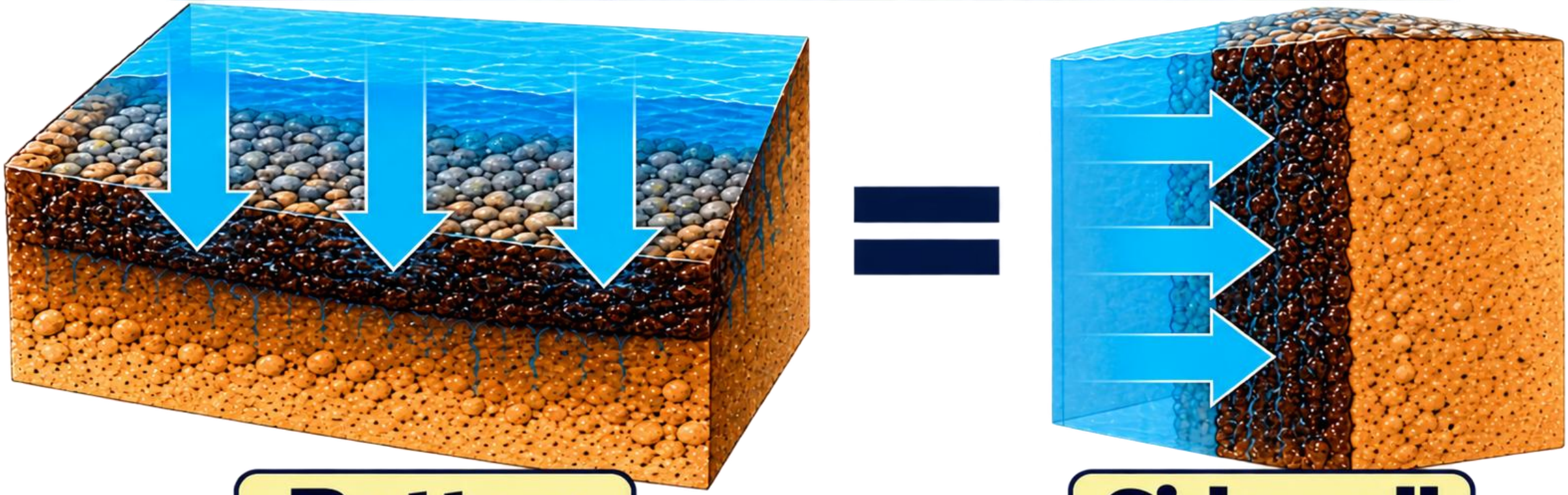
Biomat

The Traditional View and Approach


P. H. McGauhey and
J. H. Winneberger
1960s
Johan Bouma
1970s
Robert Laak
1970s
Early Research Focus
Bottom biomat
Emphasized hydraulic restriction on horizontal the surface

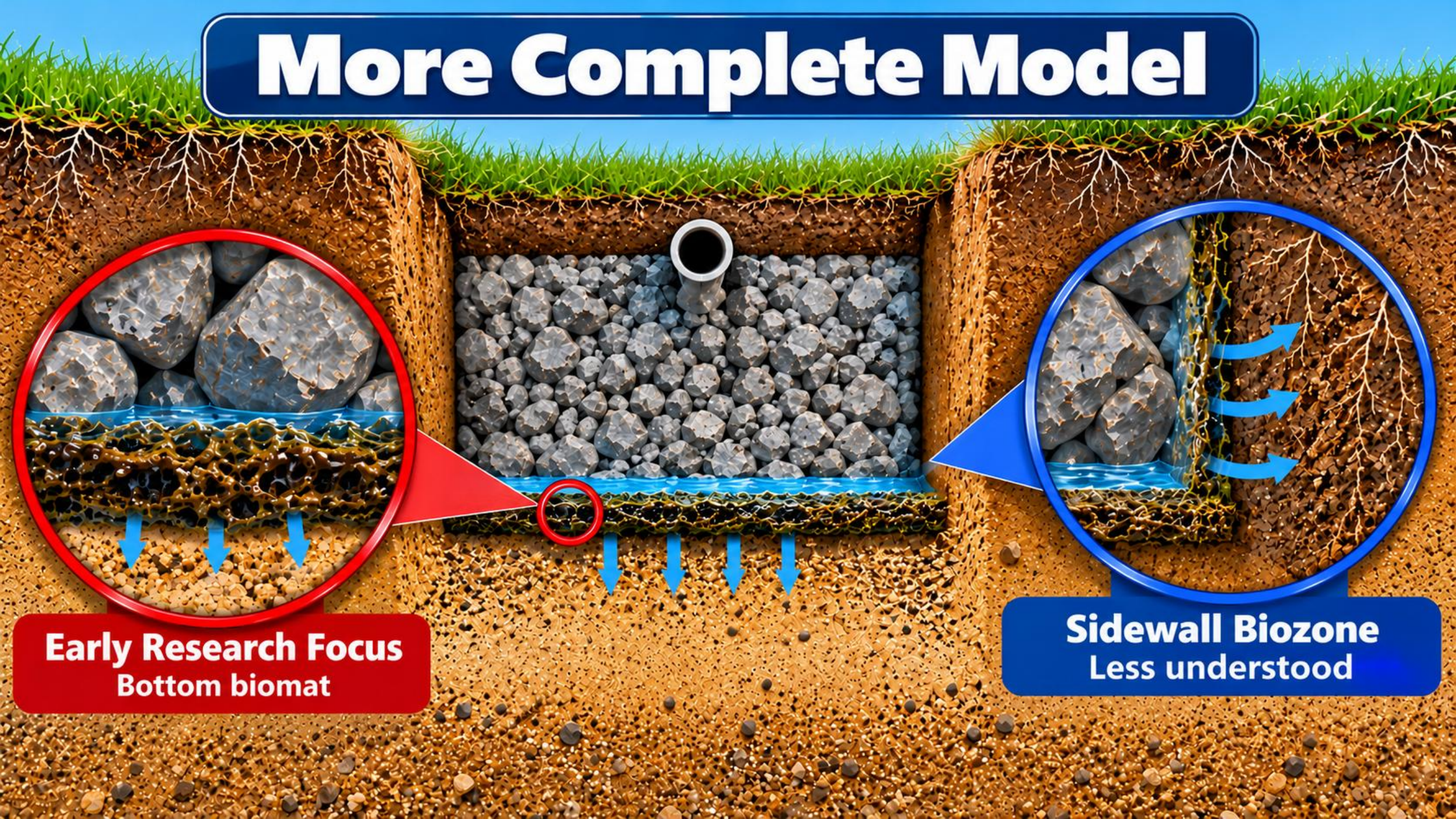
Traditional Model

Simplifying Assumption:
Sidewall Biomat = Bottom Biomat
(just turned 90°)



Bottom = **Sidewall**

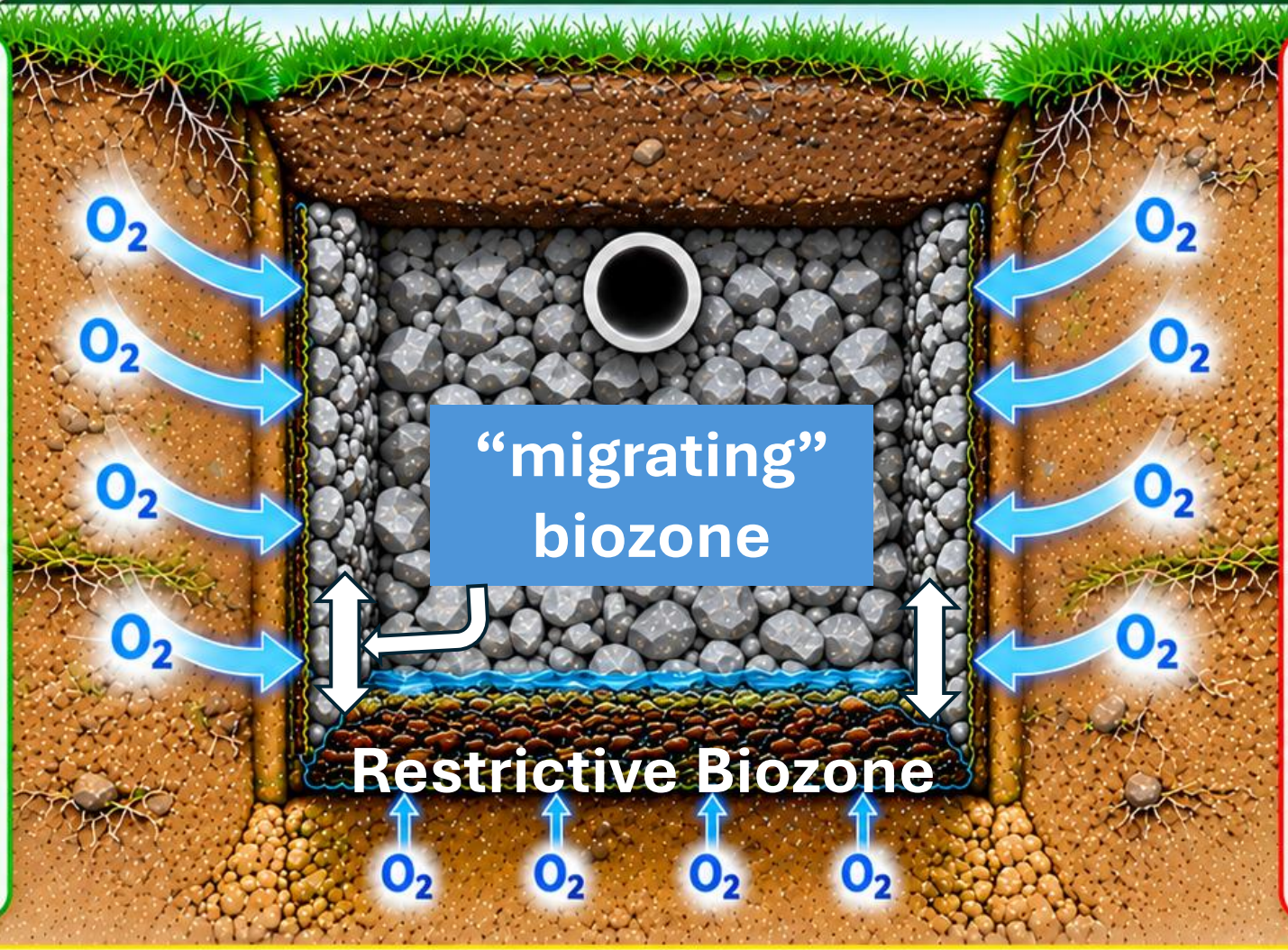
More Complete Model



Why Sidewalls Behave Differently

Sidewall

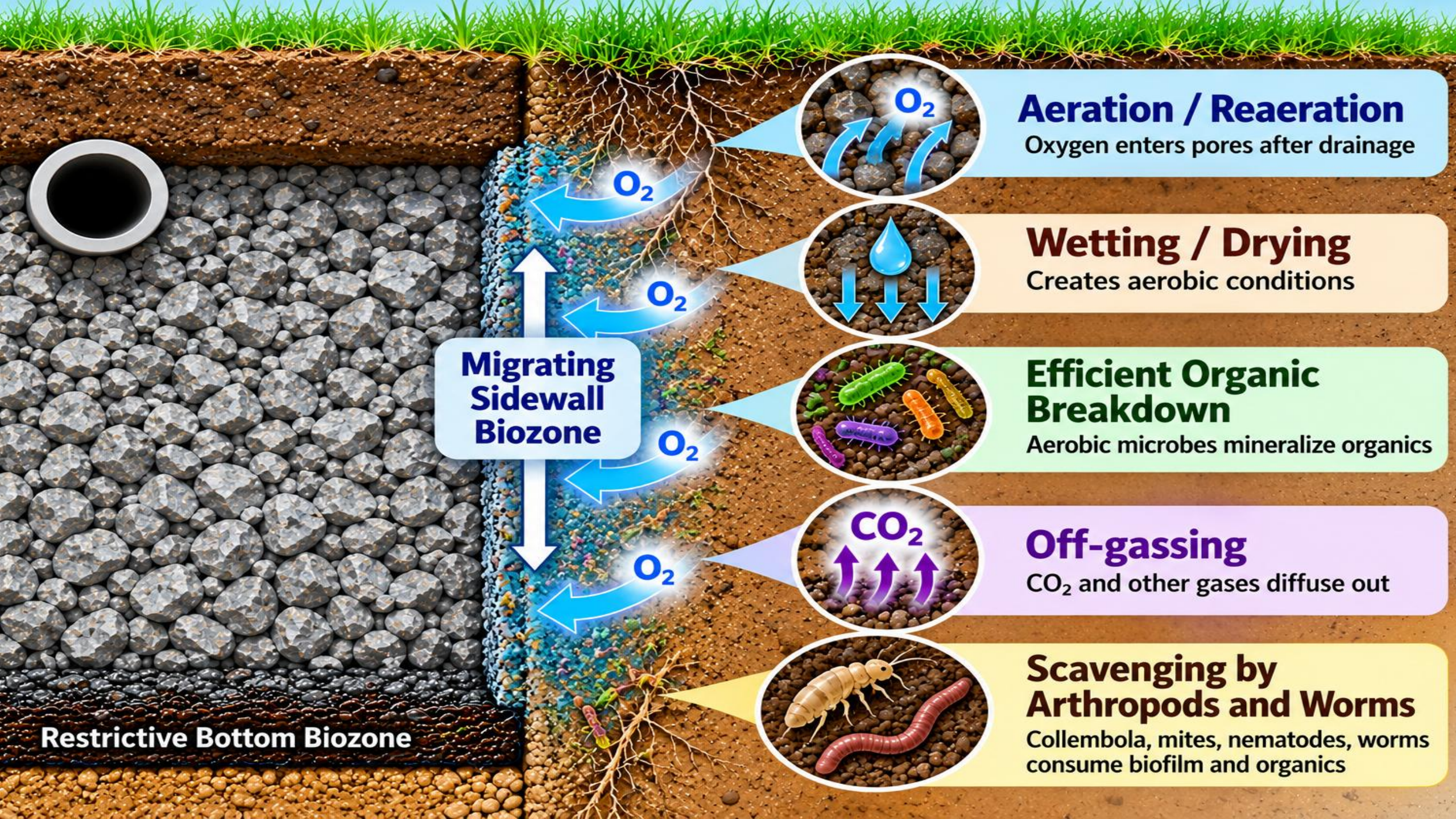
- ✓ Less solids accumulation
- ✓ Intermittent wetting
- ✓ More oxygen supply
- ✓ Often less hydraulic restriction

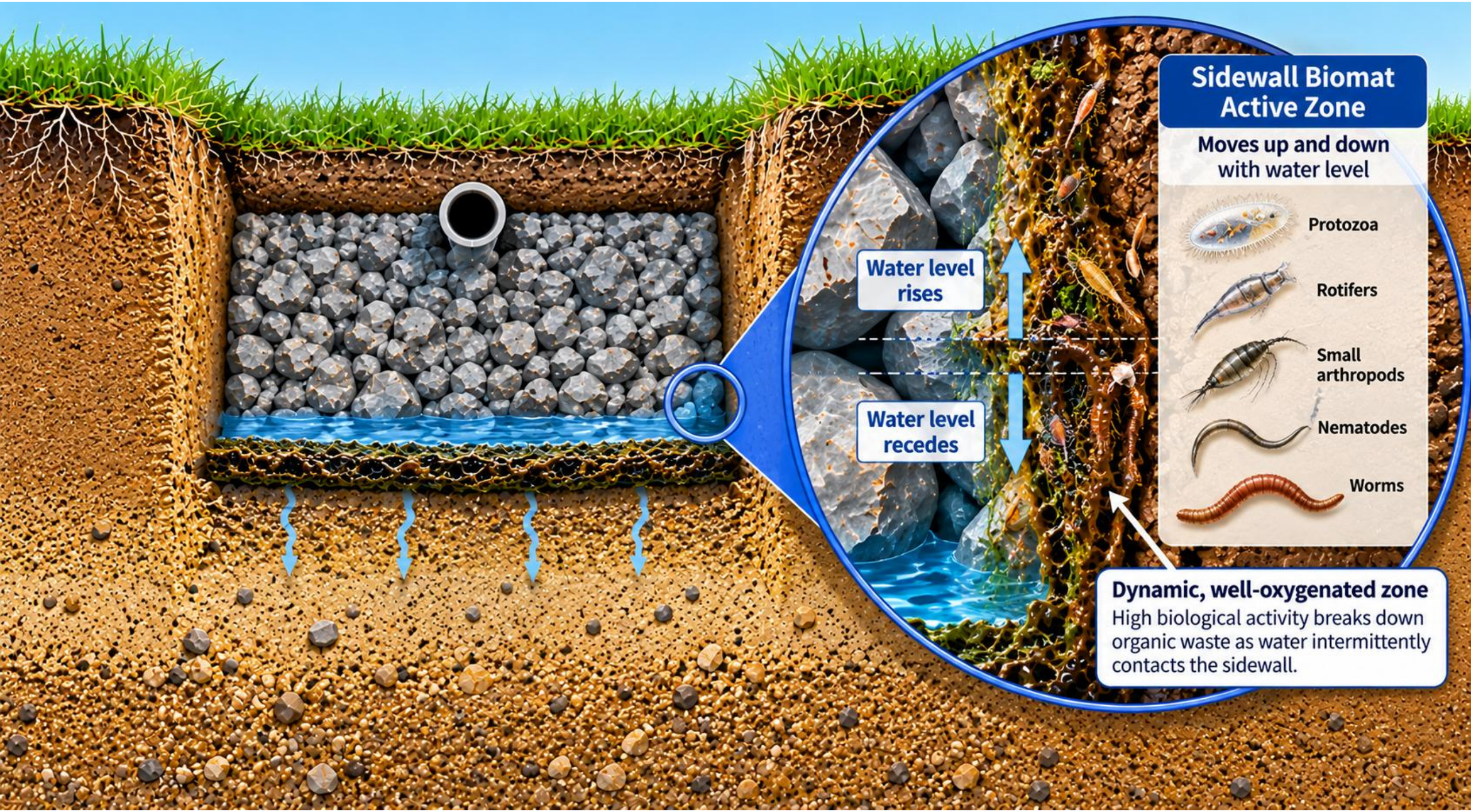


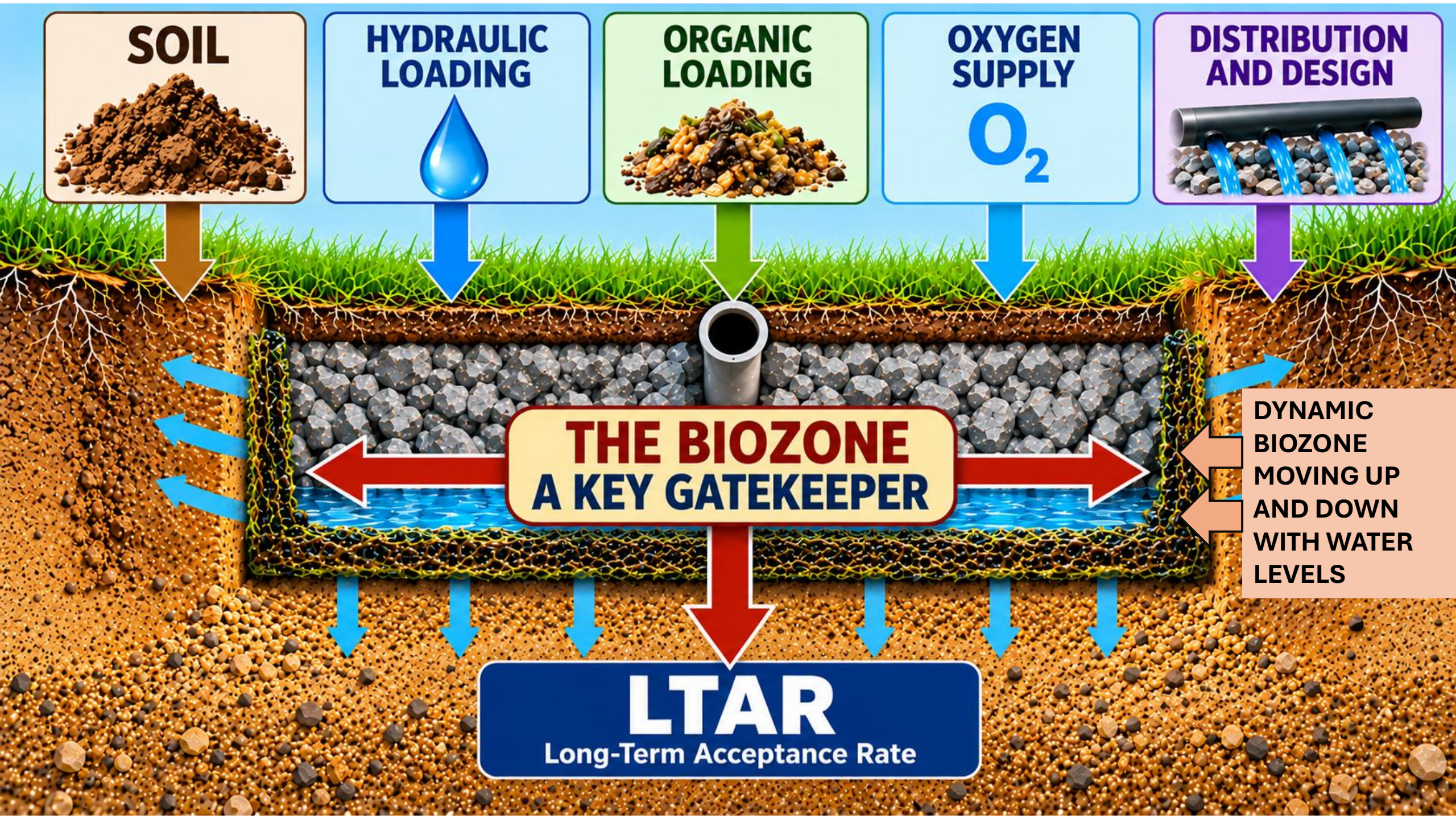
Bottom

- ✓ Receives settling solids
- ✓ Prolonged wetting
- ✓ Lower oxygen supply
- ✓ Often greater hydraulic restriction

Different orientation ● Different environment ● Different biozone


Migrating Sidewall Biozone
Restrictive Bottom Biozone
O_2
O_2
O_2
O_2
O_2
CO_2
Aeration / Reaeration
Oxygen enters pores after drainage
Wetting / Drying
Creates aerobic conditions
Efficient Organic Breakdown
Aerobic microbes mineralize organics
Off-gassing
CO_2 and other gases diffuse out
Scavenging by Arthropods and Worms
Collembola, mites, nematodes, worms consume biofilm and organics


Sidewall Biomat Active Zone
Moves up and down with water level
Protozoa
Rotifers
Small arthropods
Nematodes
Worms
Water level rises
Water level recedes
Dynamic, well-oxygenated zone
High biological activity breaks down organic waste as water intermittently contacts the sidewall.


SOIL
HYDRAULIC LOADING
ORGANIC LOADING
OXYGEN SUPPLY
O_2
DISTRIBUTION AND DESIGN
THE BIOZONE
A KEY GATEKEEPER
DYNAMIC BIOZONE MOVING UP AND DOWN WITH WATER LEVELS
LTAR
Long-Term Acceptance Rate


FOCUS: BOTTOM BIOMAT
BIOMAT
DESIGN CONSIDERATIONS:
Bottom biomat restriction
Hydraulic loading
LTAR
Infiltration rate
Treatment assumptions
Trench spacing
BIOMAT THEORY AND PRACTICE
DON'T FORGET ME!
O2
O2
O2
BIOMAT THEORY
LTAR DESIGN
BOTTOM RESTRICTION
HYDRAULIC LOADING
INFILTRATION RATES
TREATMENT ASSUMPTIONS
DESIGN BASED ON BIOMAT THEORY

How do we design for better treatment?



Design to optimize biological activity and apply what we've learned from sidewalls:

- **Intermittent wetting and drainage can help sustain hydraulic capacity.**
- **Promote gas exchange, particularly oxygen replenishment.**

Finding the Balance



Hydraulic Capacity

Treatment Capacity

General Principle

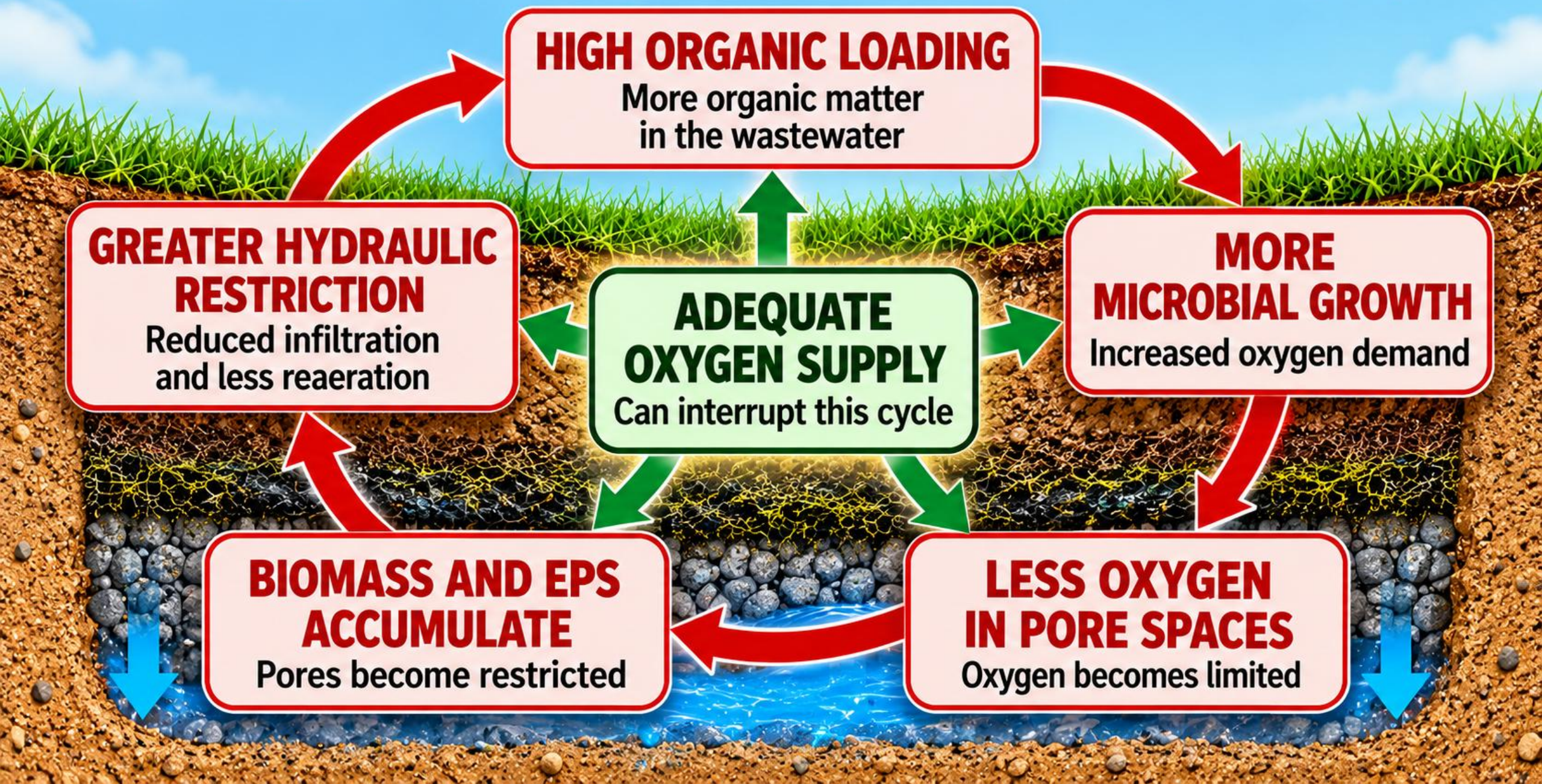
When the oxygen demand exceeds the oxygen supply in areas of applied wastewater the soil interface begins to change dramatically.

EPS Buildup
Sealed pores
Less oxygen exchange

Wastewater strength is a major driver in biomat development

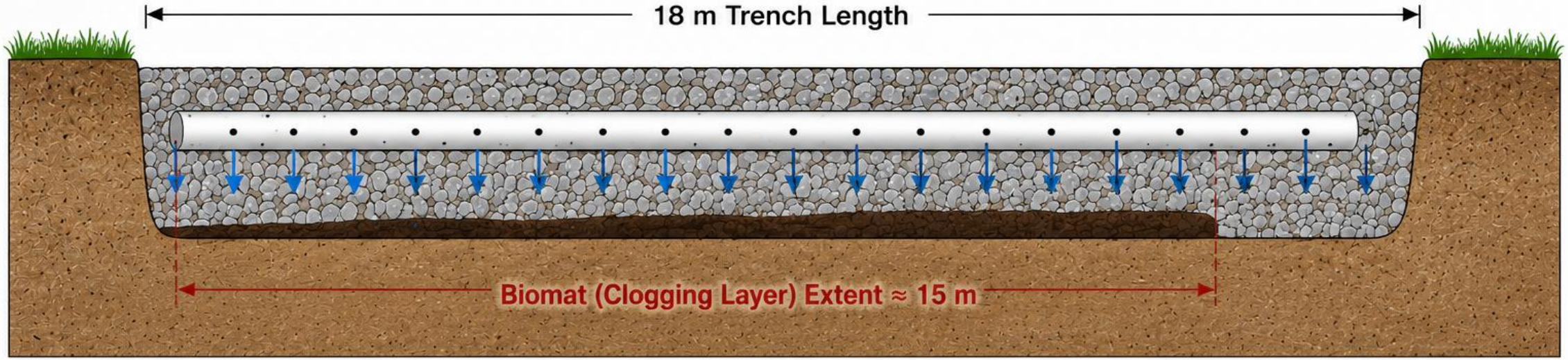


High Organic Loading Can Drive a Self-Reinforcing Cycle

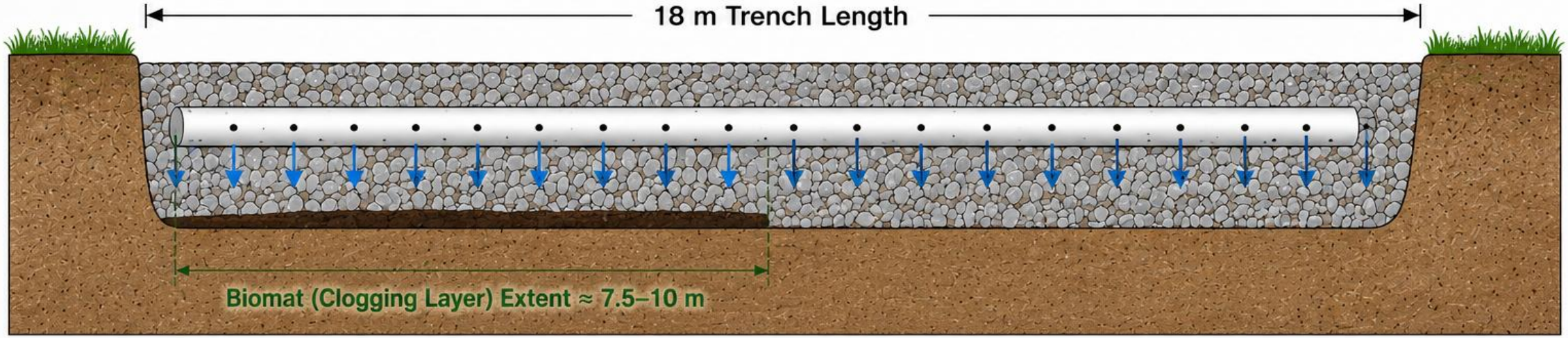


Reducing BOD before soil dispersal can reduce oxygen demand and help limit hydraulic restriction in the biozone

PRIMARY EFFLUENT (Septic Tank Effluent) – After 10–13 Months

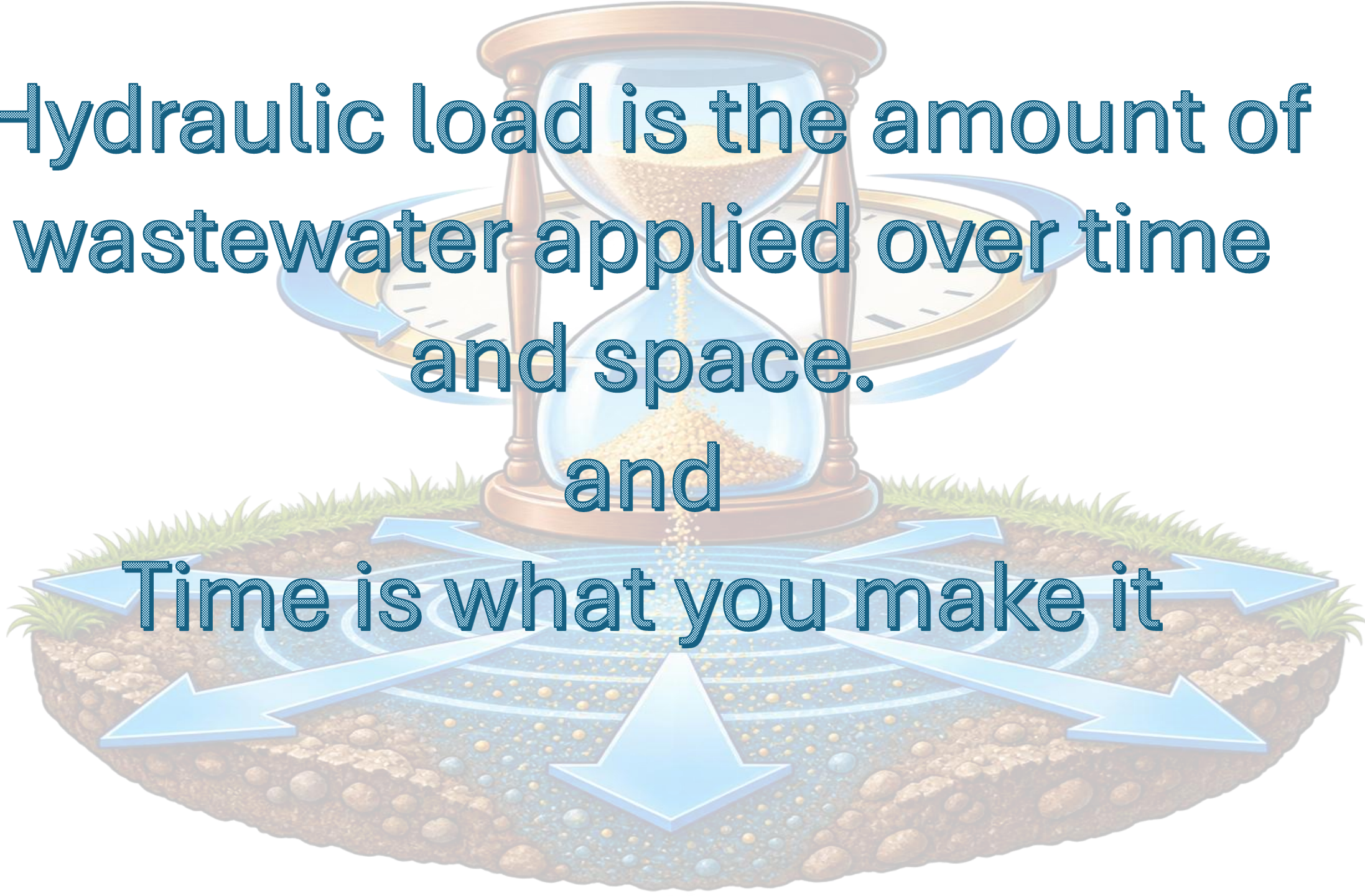


SECONDARY EFFLUENT (Treated Effluent) – After 3 Years



Biomat (clogging layer) forms progressively from left to right at the interface

Adapted from field observations
Jan Knappe, Celia Somlai, Andrew C. Fowler, Laurence W. Gill, The influence of pre-treatment on biomat development in soil treatment units, Journal of Contaminant Hydrology, Volume 232,



Hydraulic load is the amount of wastewater applied over time and space.

and

Time is what you make it

Time:

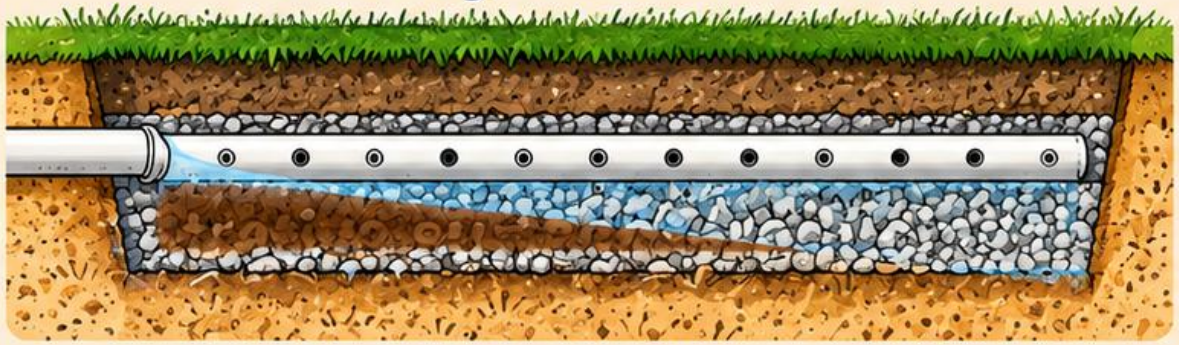
The often overlooked variable



Creating Optimal Conditions Beneath the Surface

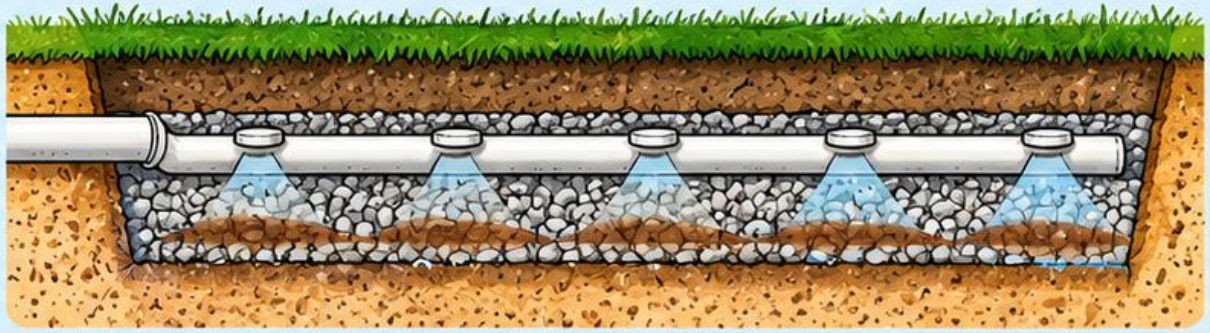


Gravity Distribution



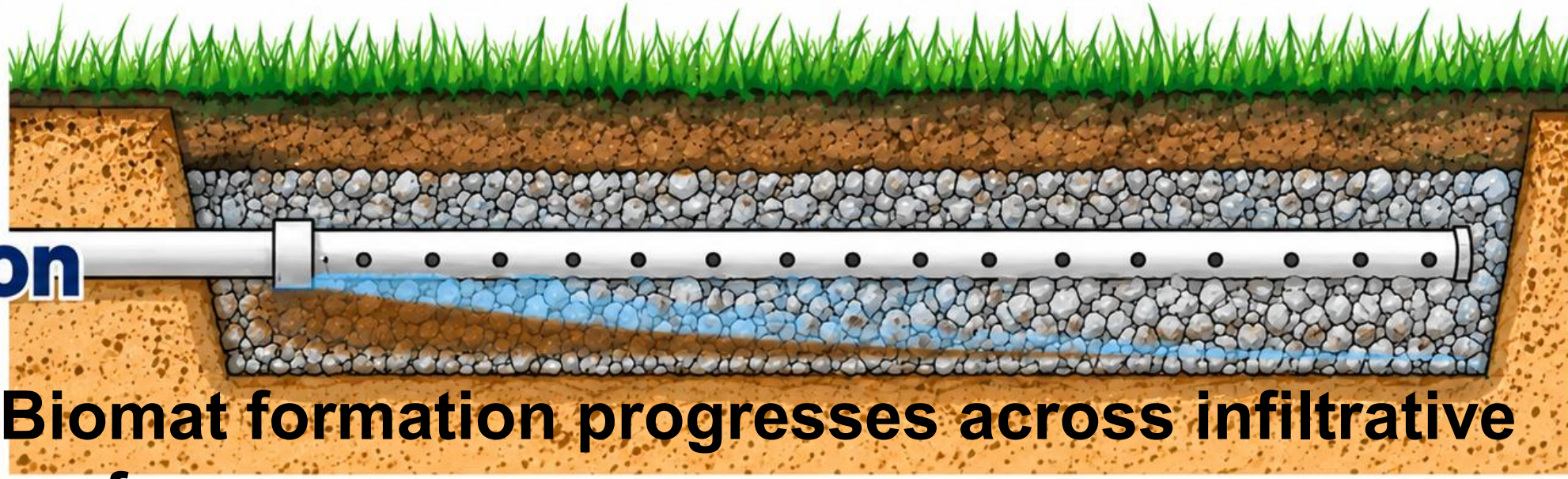
Effluent enters in one area, creating higher local loading and faster vertical movement near the inlet.

Pressure Demand Dosing



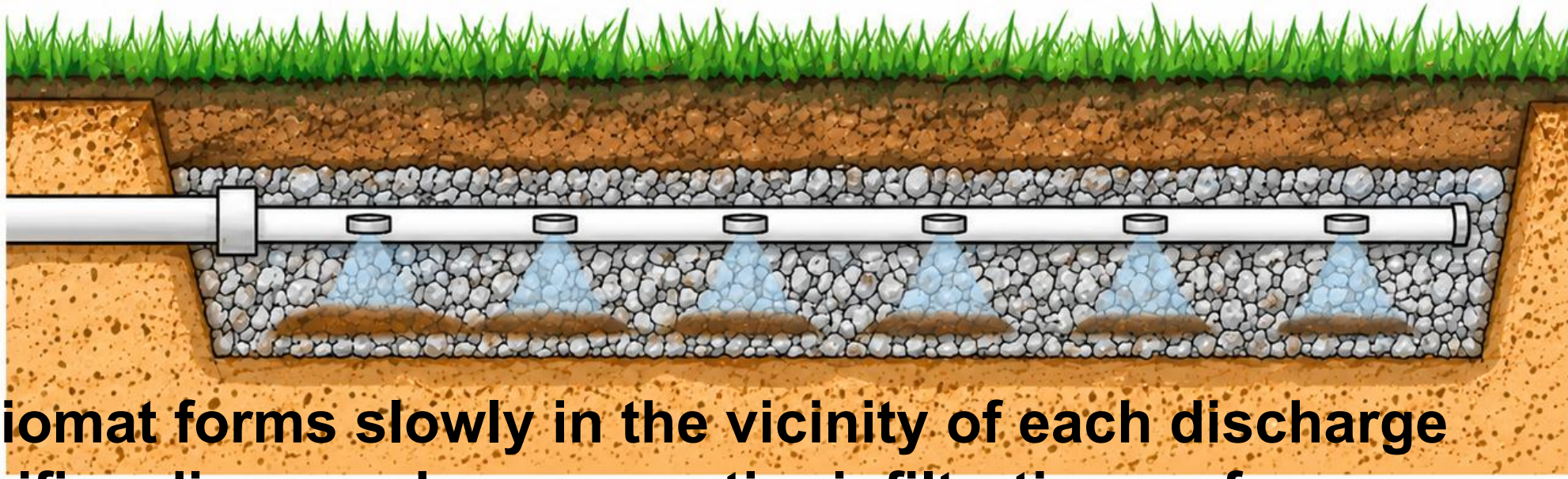
Distributes effluent over more of the infiltrative surface, reducing local hydraulic loading and promoting more uniform, unsaturated flow and effective soil contact.

Gravity Distribution

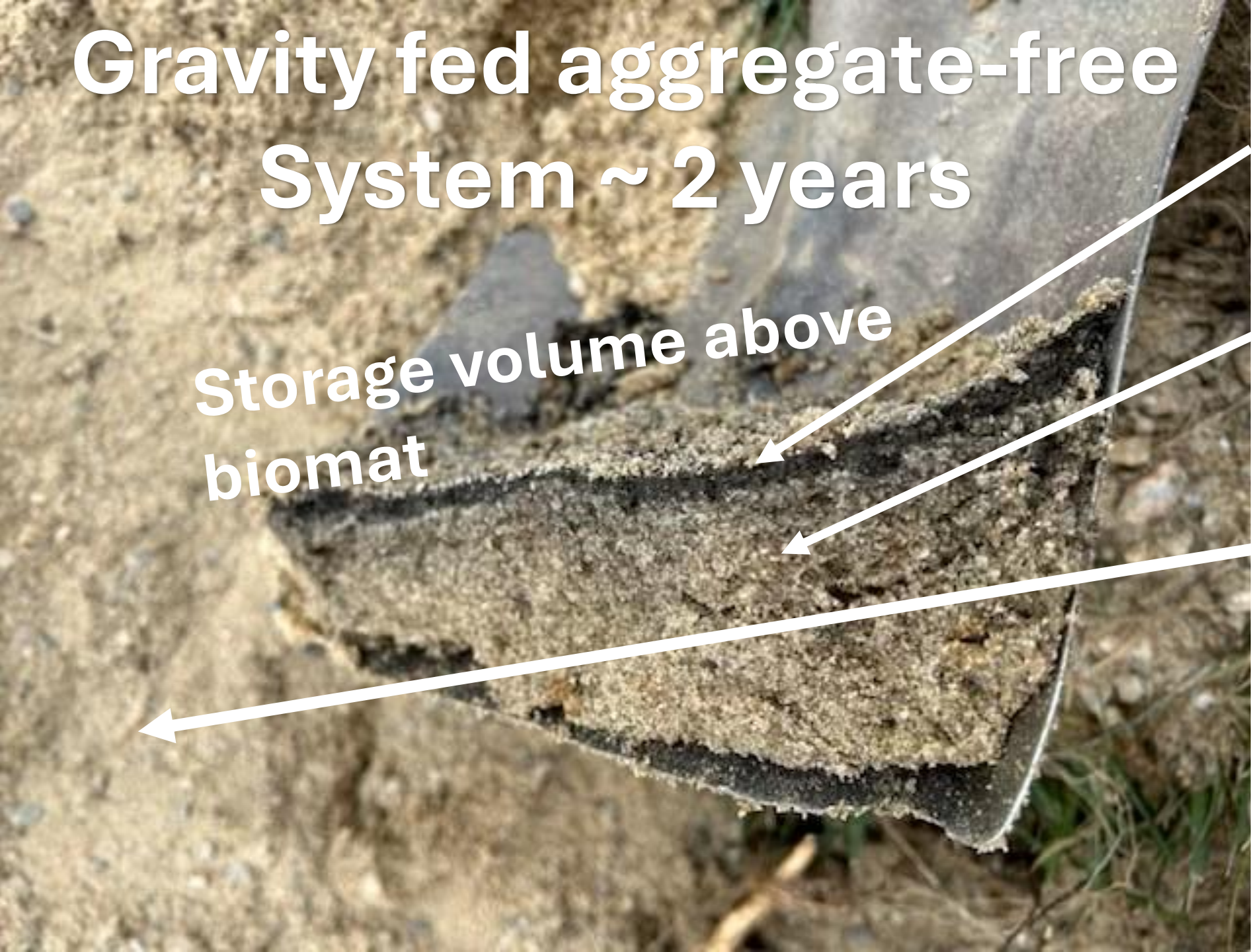


Biomat formation progresses across infiltrative surface

Pressure Demand Dosing



Biomat forms slowly in the vicinity of each discharge orifice dispersed across entire infiltrative surface



Restrictive biomat
~ 18 min/inch

~ 5 min/inch

6” down
<2 min/inch

Pressure timed-dosed system

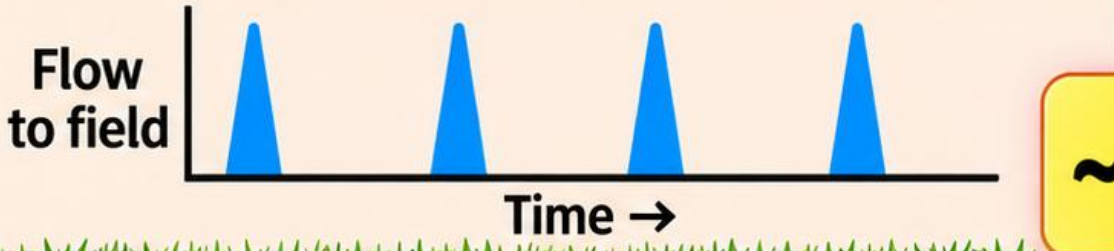
~ 2 years

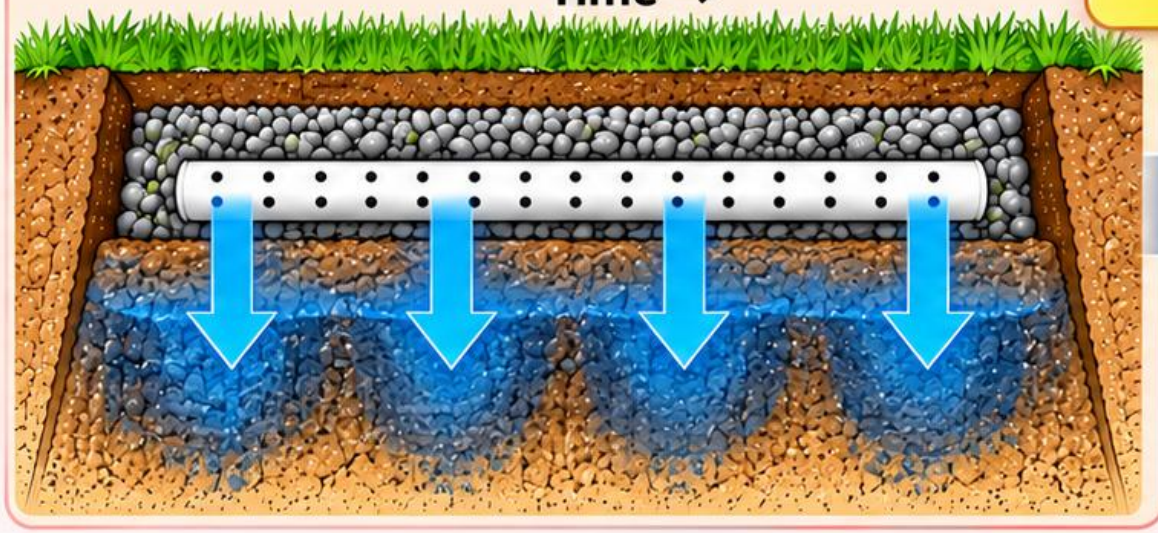
<2 min/inch

~ 5 min/inch

What Can $200 Get You?

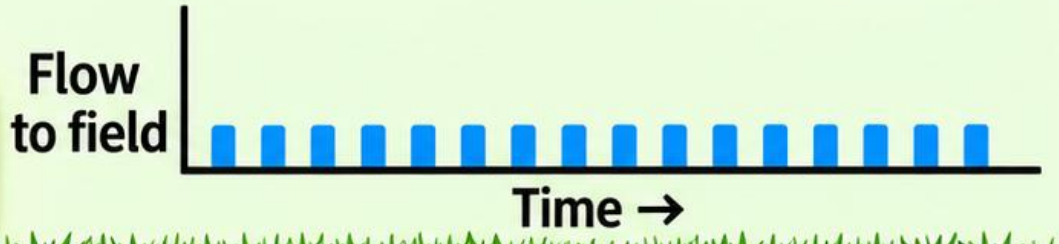
Demand Dosing

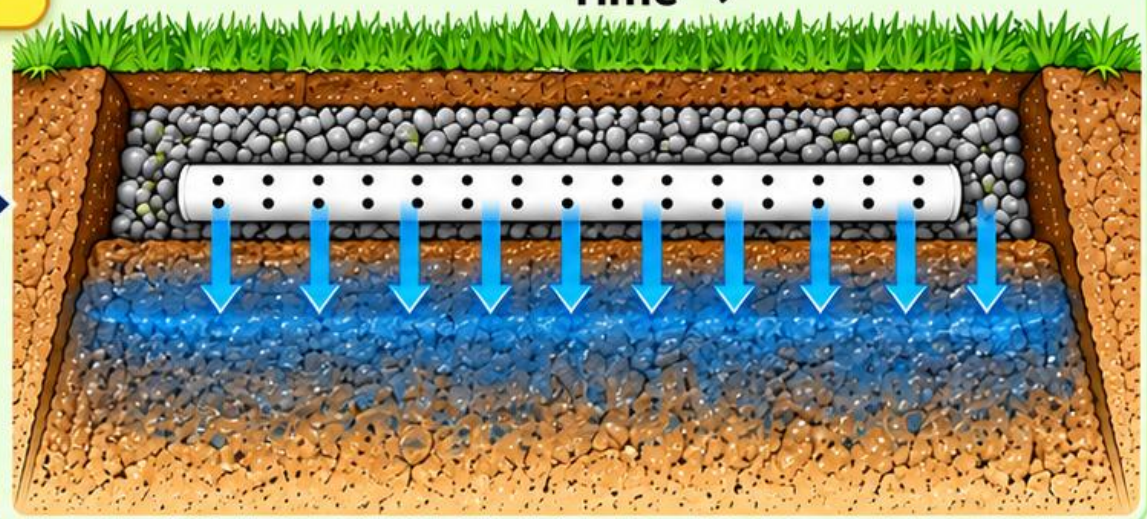




~$200

Timed Dosing



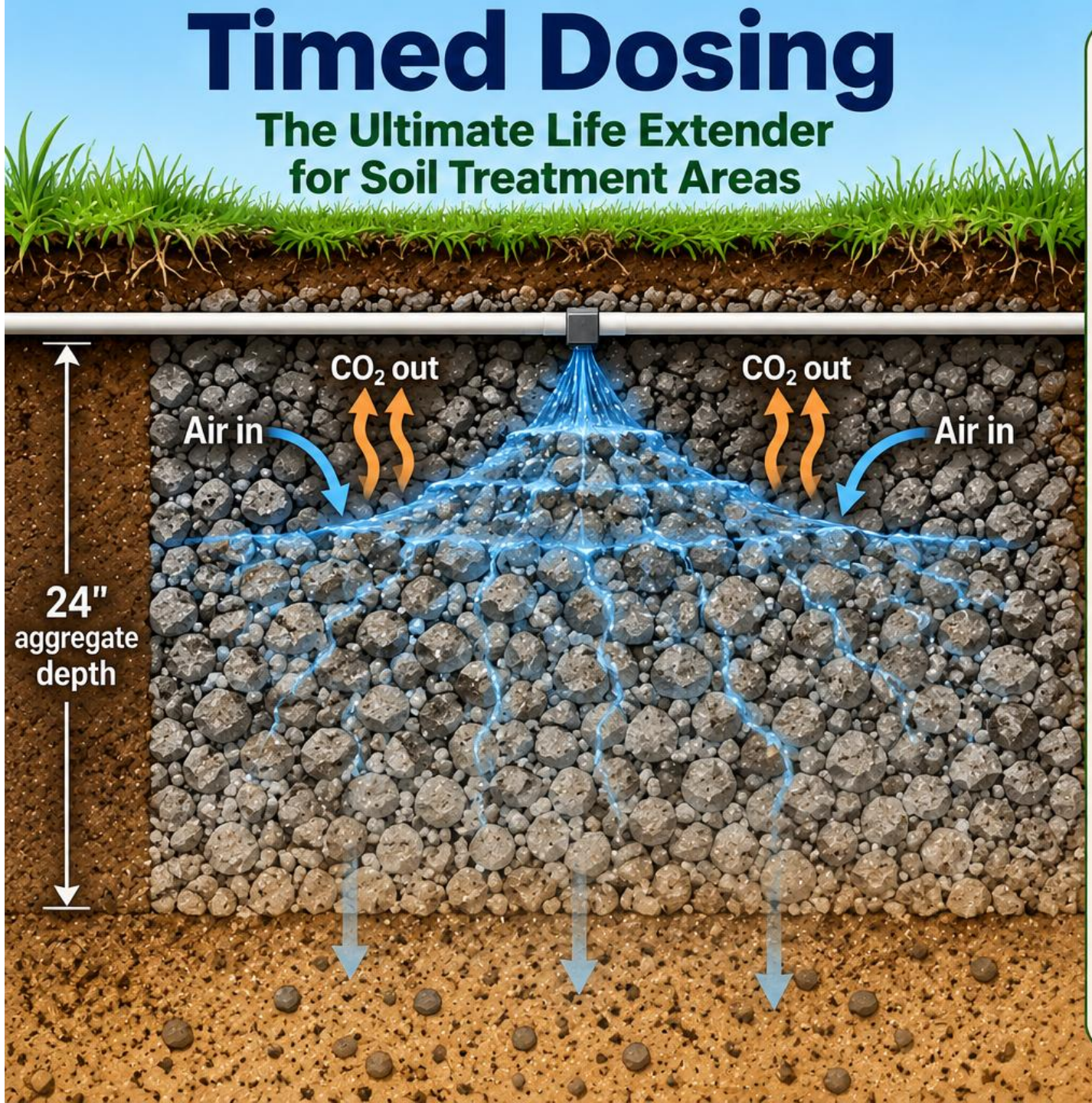


LONGER LEACHFIELD LIFE

BETTER TREATMENT

Timed Dosing

The Ultimate Life Extender for Soil Treatment Areas



- Applies small, controlled doses at set intervals.
- Spreads the daily load over more of the infiltrative surface.
- Allows effluent to move downward and laterally in the unsaturated soil.
- Draws in air behind the wetting pulse, replenishing oxygen.
- Allows CO_2 to diffuse out.
- Promotes drying between doses.
- Maintains a thin biomat and effective treatment conditions.
- Extends the life of the soil treatment area.

EFFLUENT TREATMENT REQUIRES THREE THINGS

Good septic treatment happens when soil provides the right balance of MOVEMENT, OXYGEN, and CONTACT TIME.



MOVEMENT

Effluent must move through the soil.



OXYGEN (AIR)

Soil must have air (oxygen).



CONTACT TIME

Effluent must remain long enough for treatment to occur.



TREATMENT

Microbes in the soil remove, transform and retain pollutants.

WHAT THIS MEANS



Effluent must **move** through the soil.



Soil must have **air** (oxygen).



Effluent must remain long enough for treatment to occur.

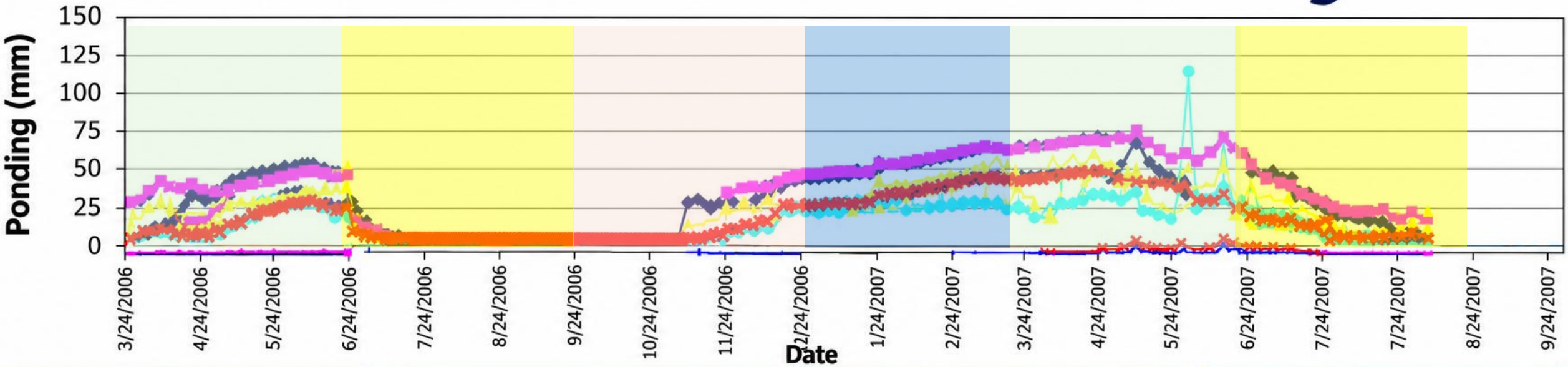


ALL THREE ARE REQUIRED — MISSING ONE = POOR TREATMENT



The goal is balance — not too fast, not too slow, but just right.

What About Seasonality?



Spring (Mar – May)

- Warming temperatures
- Increasing biological activity
- Ponding present at proximal ports
- Distal ports low

Summer (Jun – Aug)

- Warmest temperatures
- Peak biological activity
- Highest hydraulic acceptance
- Minimal ponding at proximal and distal ports

Fall (Sep – Nov)

- Cooling temperatures
- Declining biological activity
- Ponding increases at proximal ports
- Distal ports remain low

Winter (Dec – Feb)

- Colder temperatures
- Slower biological activity
- Greatest ponding at proximal ports
- Distal ports low


REMAINING
QUESTION
Soil Observations
Sandy loam
48+
Texture
Structure
Slope
Depth to GW
LTAR
Soils
Hydrology


Do I need a restrictive biomat to treat wastewater effluent for pathogens?
SEPTIC SYSTEM DESIGN
SOILS
HYDRAULICS
ONSITE WASTEWATER
REGULATIONS

No

Effective pathogen attenuation can be achieved without a highly restrictive biomat.

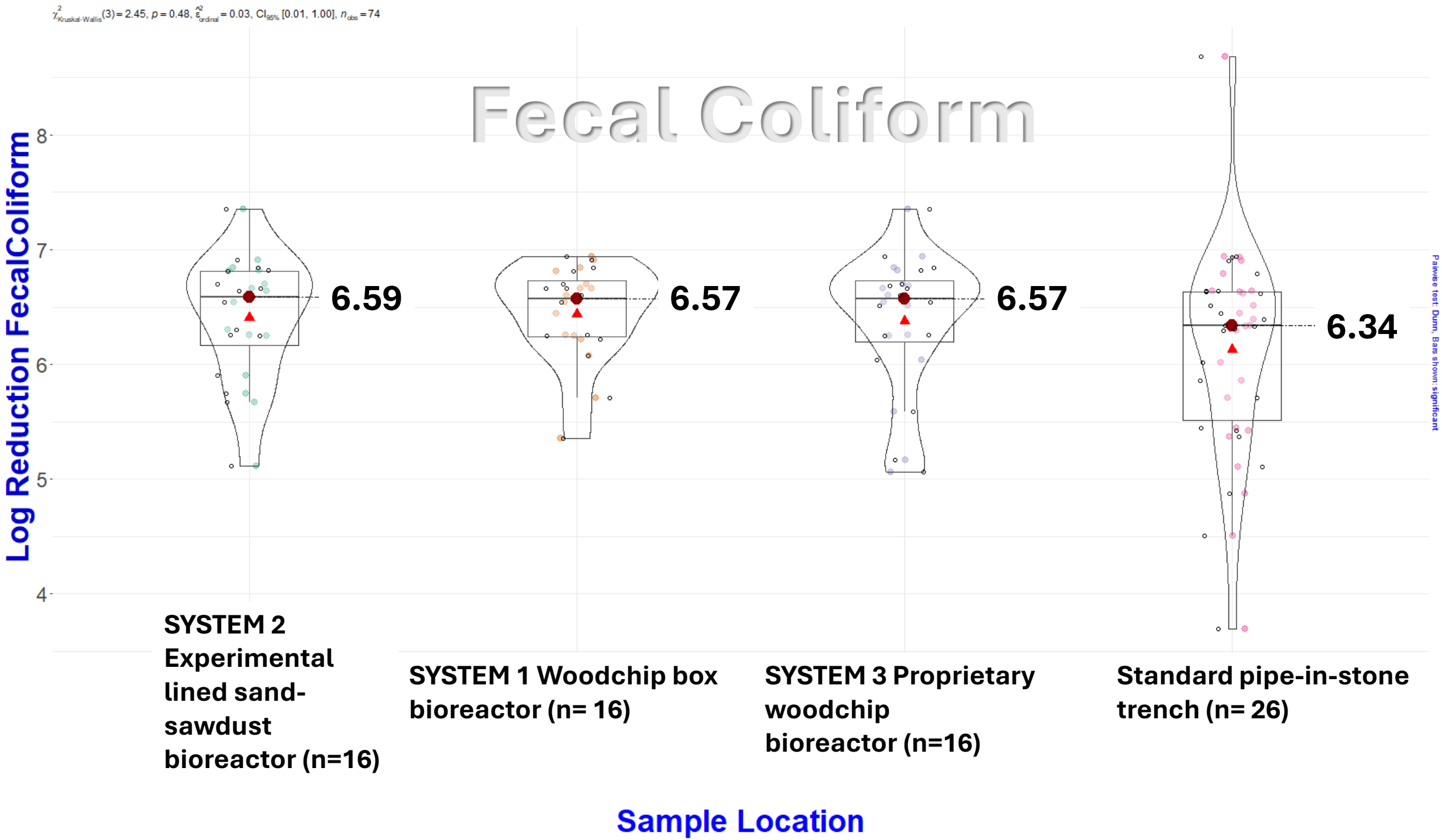
- Physical straining (larger organisms)
- Attachment to soil particles
- Adsorption and electrostatic interactions (especially viruses)
- Predation and biological antagonism
- Natural inactivation (time and depth)
- Unsaturated flow conditions (increase contact time and retention)

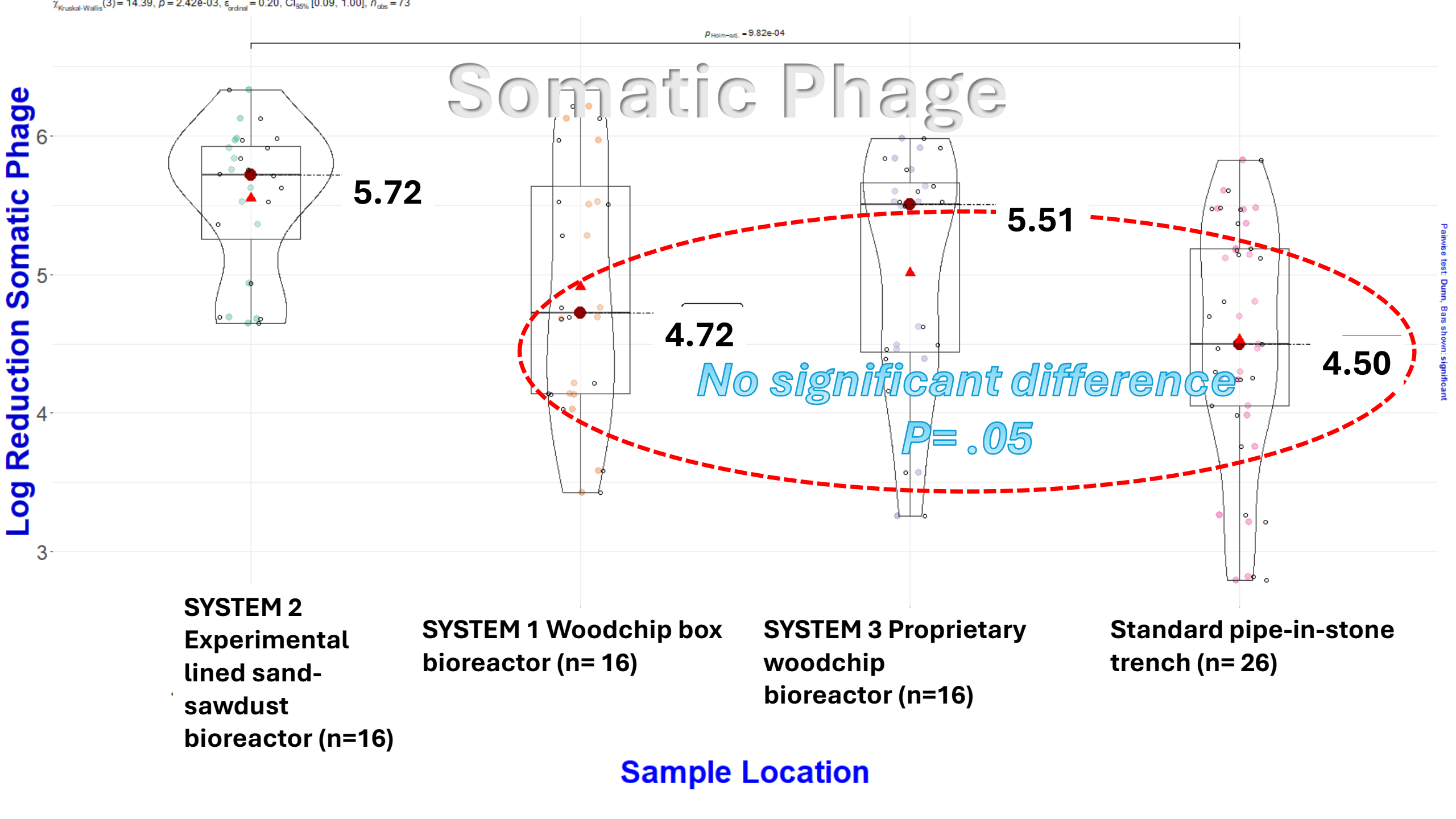
These processes occur in the biologically active soil–wastewater interface and underlying soil. They do not inherently require a strongly restrictive biomat.

Yes or Maybe

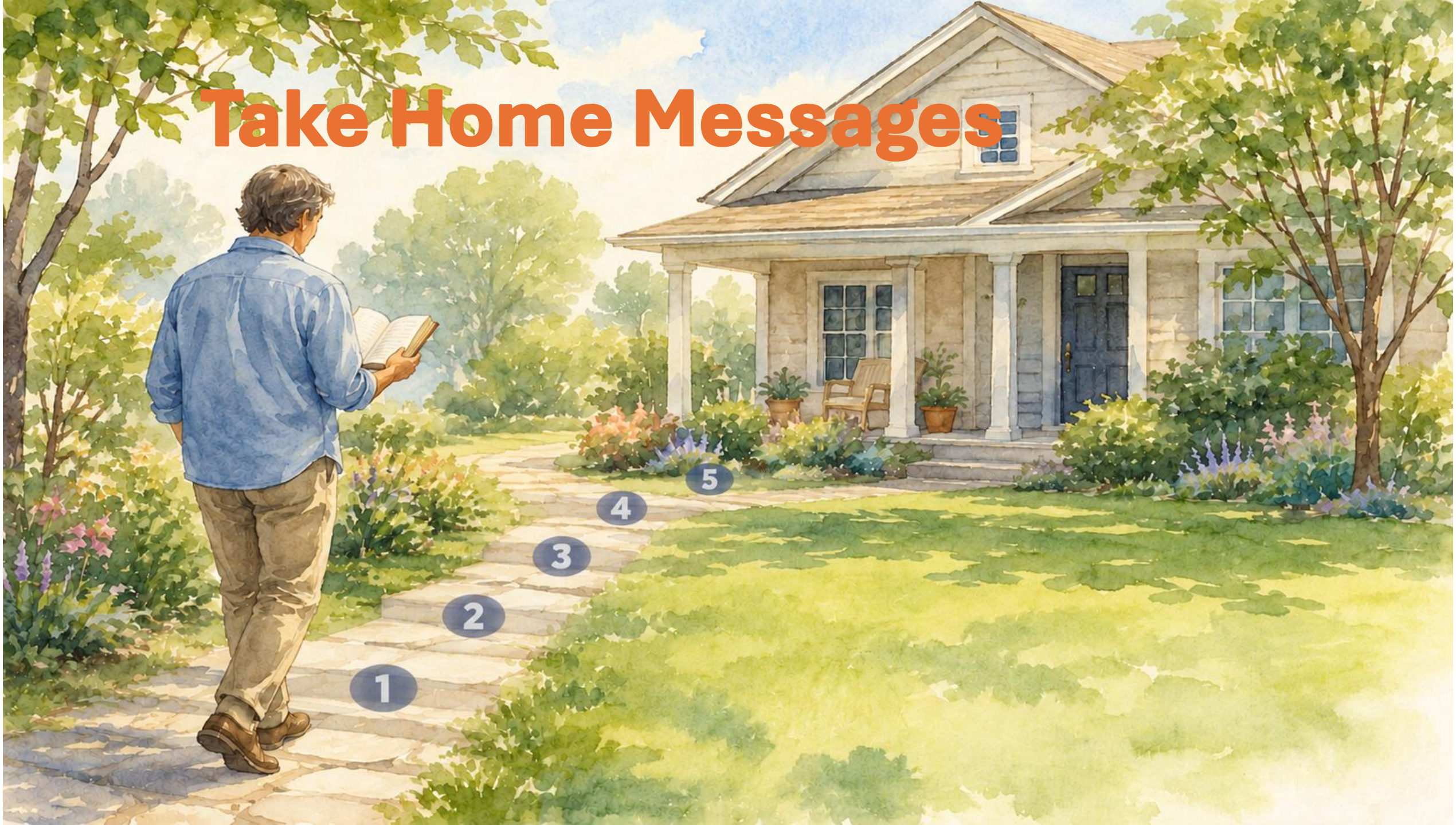
A more restrictive biomat may still be beneficial in very coarse, permeable soils (e.g., clean sands, gravels).

- Provides an initial physical/biological barrier to pathogen migration
- Increases retention time and contact with the biozone and soil
- Helps maintain unsaturated conditions beneath the infiltrative surface
- Compensates for low natural adsorption and limited straining


$\chi^2_{Kruskal\text{-}Wallis}(3) = 2.45$, $p = 0.48$, $\hat{\varepsilon}^2_{ordinal} = 0.03$, $CI_{95\%}$ [0.01, 1.00], $n_{obs} = 74$
Fecal Coliform
Log Reduction FecalColiform
8
7
6
5
4
6.59
6.57
6.57
6.34
Pairwise test: Dunn, Bars shown significant
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=16)
SYSTEM 1 Woodchip box bioreactor (n= 16)
SYSTEM 3 Proprietary woodchip bioreactor (n=16)
Standard pipe-in-stone trench (n= 26)
Sample Location


$\chi^2_{Kruskal-Wallis}(3) = 14.39$, $p = 2.42e-03$, $\varepsilon^2_{ordinal} = 0.20$, $CI_{95\%}$ [0.09, 1.00], $n_{obs} = 73$
$p_{Holm-adj.} = 9.82e-04$
Somatic Phage
Log Reduction Somatic Phage
6
5
4
3
5.72
4.72
5.51
4.50
No significant difference
P= .05
Pairwise test: Dunn, Bars shown: significant
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=16)
SYSTEM 1 Woodchip box bioreactor (n= 16)
SYSTEM 3 Proprietary woodchip bioreactor (n=16)
Standard pipe-in-stone trench (n= 26)
Sample Location

Take Home Messages



1. Biomat is Generally Not...

- A simple, continuous mat across the bottom of an aggregate stone trench.
- It is typically discontinuous in thickness and transmissivity.

2. Sidewalls are Not Just Bottom Biozones Rotated 90°.

- Sidewall biozones are inherently more dynamic.
- They expand and contract with wetting and drying cycles.
- Intermittent, controlled dosing enhances aeration and biological activity on the sidewalls.

3. A Restrictive Biomat is Not Required for Treatment.

- Effective pathogen removal can be achieved through a biologically active soil–wastewater interface.
- Multiple processes — physical straining, attachment, adsorption, predation, and natural inactivation — remove or inactivate pathogens.
- These processes do not require a highly restrictive biomat.

4. A Healthy Biozone Requires Adequate Air Supply.

- Oxygen supports aerobic microbes that break down organic matter and convert ammonia to nitrate.
- Sidewalls provide oxygen exchange, especially with intermittent, controlled dosing.
- Design and operation should maximize oxygen delivery to keep the biozone active for long-term performance.

5. Sidewall Biozones Provide Significant Treatment.

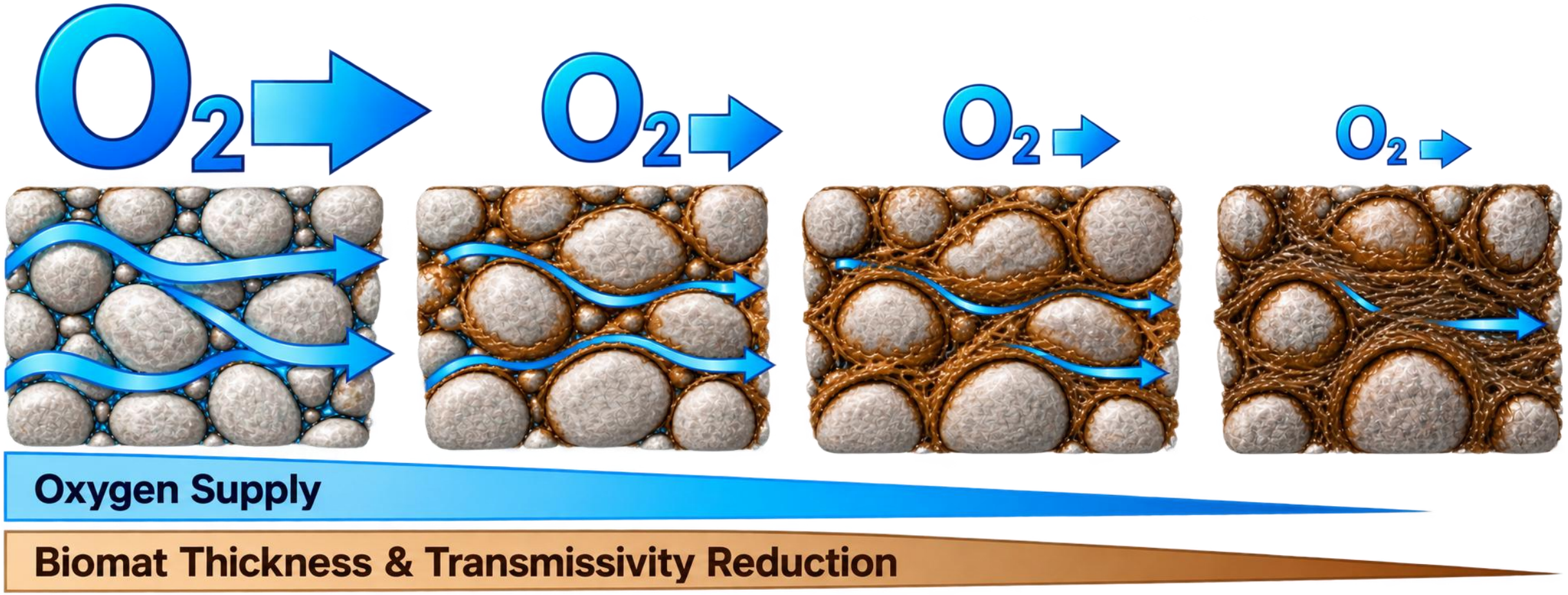
- Sidewall biozones are active treatment zones, not simply the bottom biozone rotated 90 degrees.
- They are more dynamic, with microbial activity that expands and contracts with the wetting and drying cycles.
- Intermittent, controlled dosing enhances sidewall activity and increases overall treatment capacity.

Take Home Message



If you only want one

More air = more treatment and more transmissivity (hydraulic performance)



Thank you

MASSTC
The Massachusetts Alternative
Septic System Test Center

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Questions?