2011 IDEQ REUSE CONFERENCE WORKSHOP RAPID INFILTRATION

Presenters
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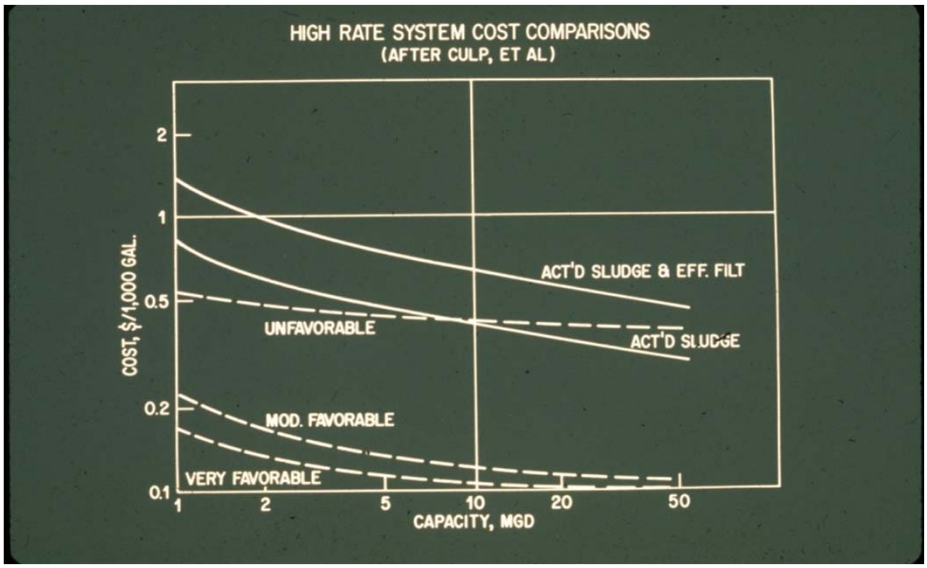
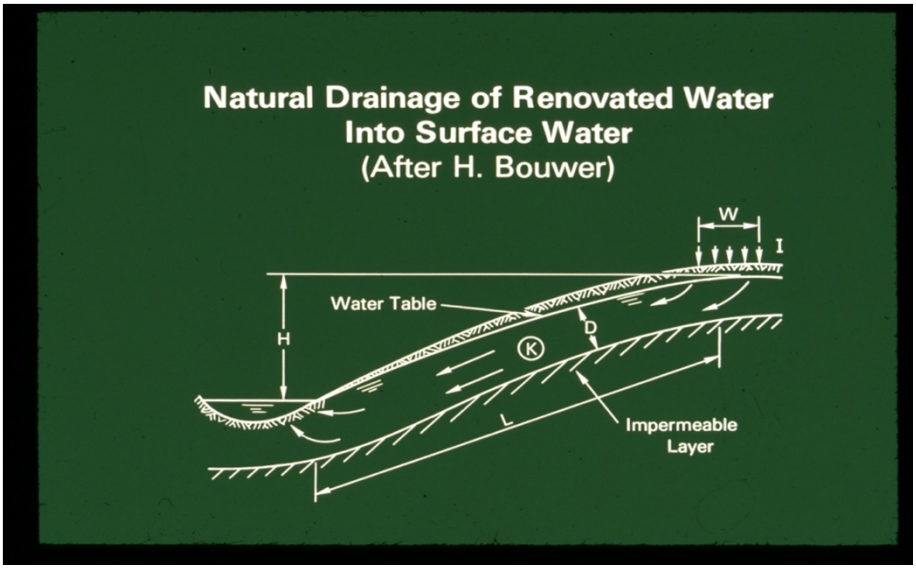
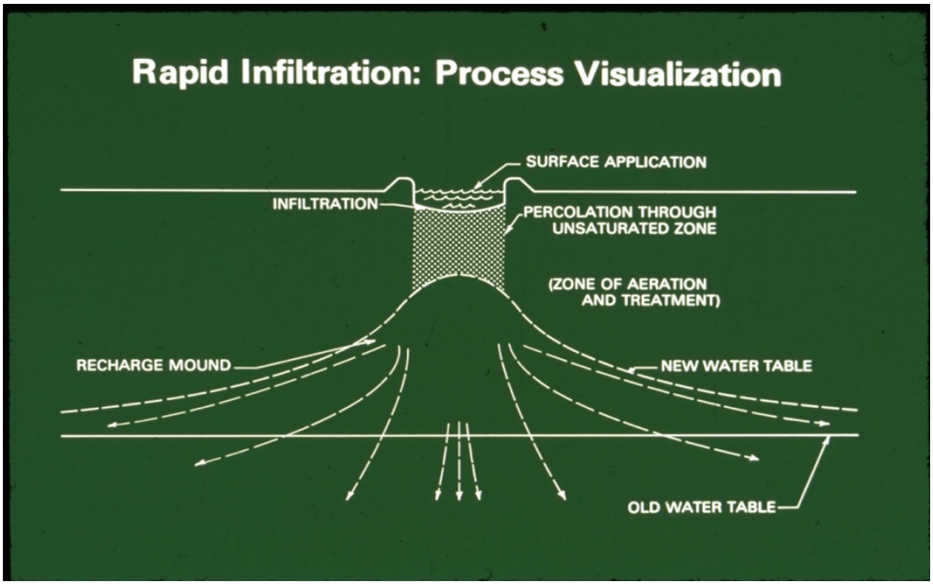
Economic Comparison With Conventional Technology
Range Of Conditions For RI Systems

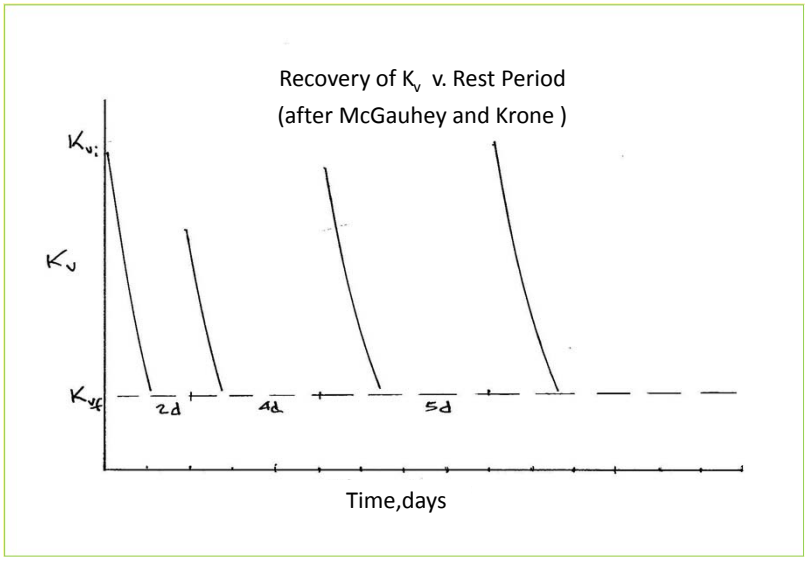
Parameter		Very Favorable	Unfavorable
			20
Storage, D		None	Lined
Transport Distance,			
ft.	1 mgd	1,000	4,000
	10 mgd	1,000	10,000

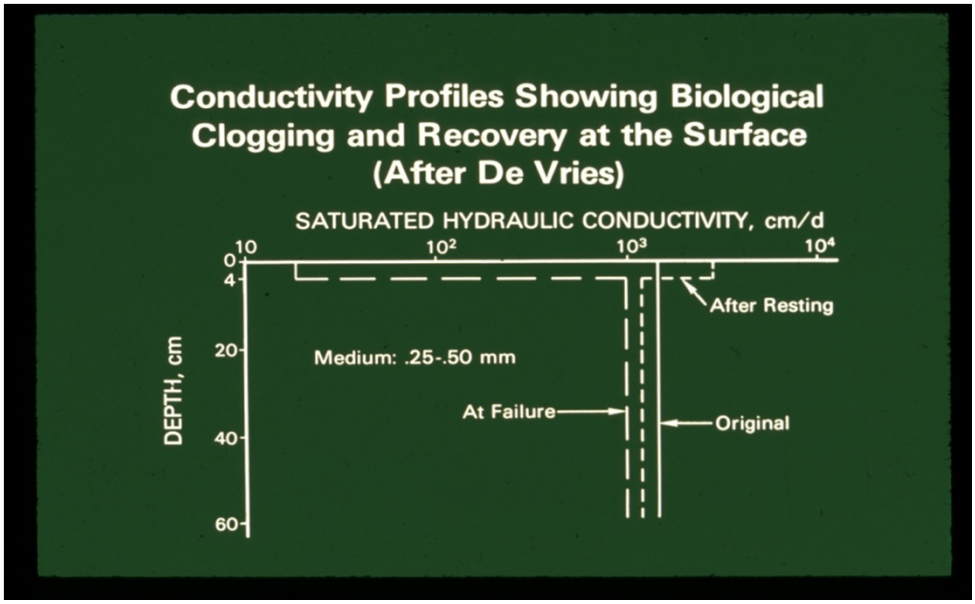
Parameter	Very Favorable	Unfavorable
Pumping Head, ft	25	150
Field Preparation	Grass	Brush & Trees
Area, ac/mgd	2.6	130
Recovery Wells,	50%	90%
100 ft	50%	90%
Land Costs, $/ac	750	3,000
Pre-applic.		3d. Aerated
Treatment	Clarifier	Lagoon

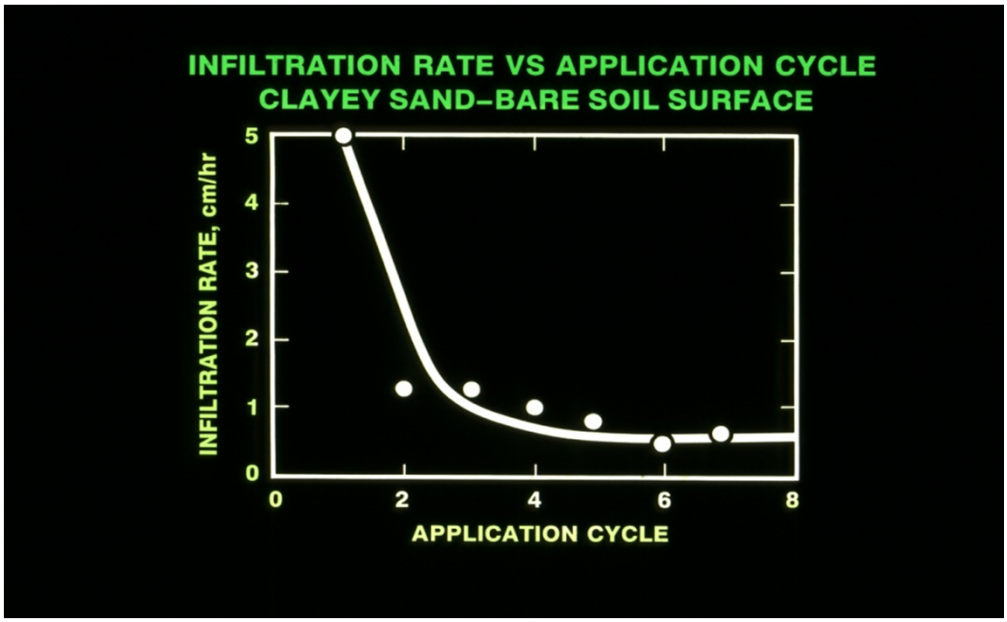

HIGH RATE SYSTEM COST COMPARISONS
(AFTER CULP, ET AL)
COST, $/1,000 GAL.
2
1
0.5
0.2
0.1
ACT'D SLUDGE & EFF. FILT
UNFAVORABLE
ACT'D SLUDGE
MOD. FAVORABLE
VERY FAVORABLE
1
2
5
10
20
50
CAPACITY, MGD

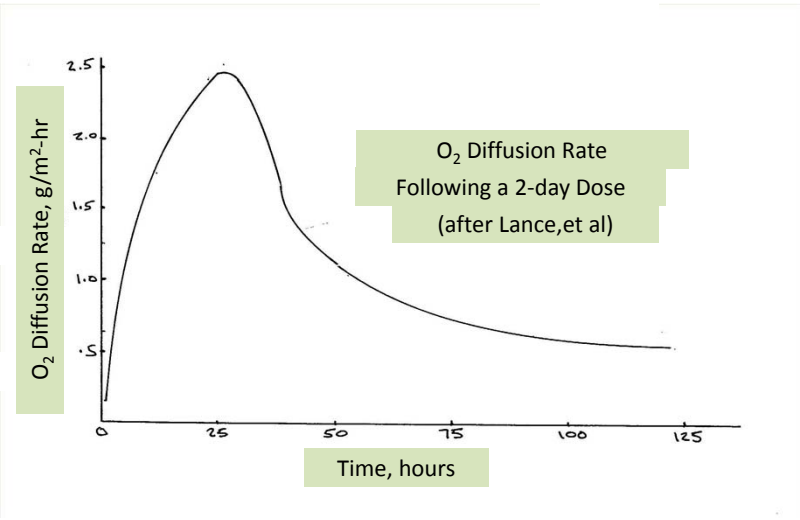

Natural Drainage of Renovated Water
Into Surface Water
(After H. Bouwer)
W
I
Water Table
H
D
K
L
Impermeable
Layer

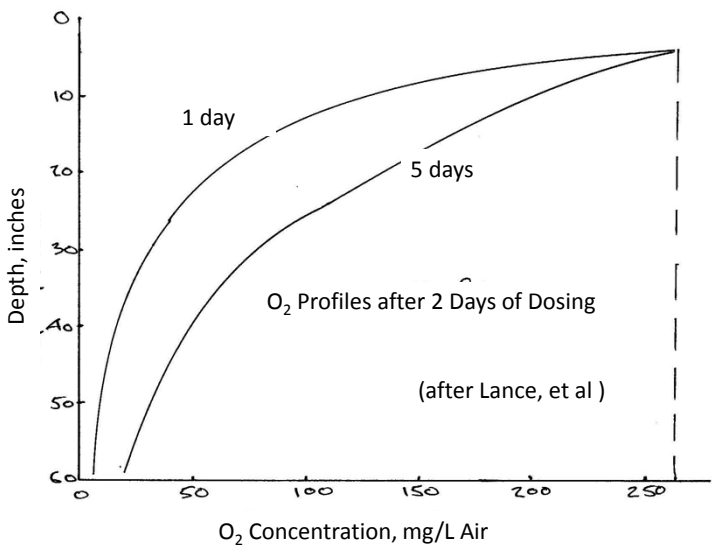

Rapid Infiltration: Process Visualization
SURFACE APPLICATION
INFILTRATION
PERCOLATION THROUGH UNSATURATED ZONE
(ZONE OF AERATION AND TREATMENT)
RECHARGE MOUND
NEW WATER TABLE
OLD WATER TABLE


Recovery of K_v v. Rest Period
(after McGauhey and Krone)
K_{v_i}
K_v
K_{v_f}
2d
4d
5d
Time,days


Conductivity Profiles Showing Biological Clogging and Recovery at the Surface (After De Vries)
SATURATED HYDRAULIC CONDUCTIVITY, cm/d
10
10²
10³
10⁴
0
4
20
40
60
DEPTH, cm
After Resting
Medium: .25-.50 mm
At Failure
Original

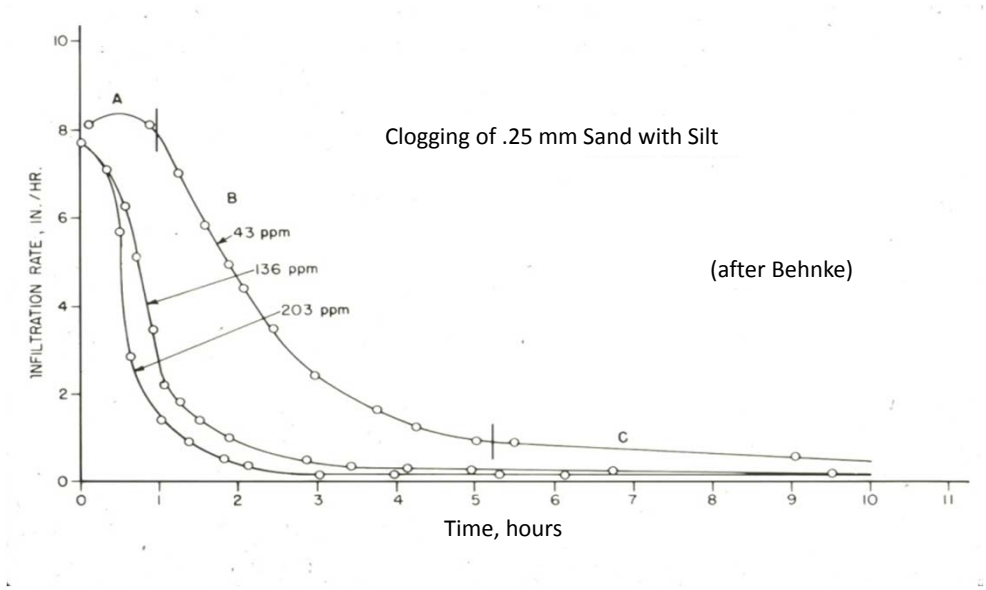

INFILTRATION RATE VS APPLICATION CYCLE
CLAYEY SAND–BARE SOIL SURFACE
INFILTRATION RATE, cm/hr
5
4
3
2
1
0
0
2
4
6
8
APPLICATION CYCLE


O_2 Diffusion Rate, g/m^2-hr
2.5
2.0
1.5
1.0
.5
0
25
50
75
100
125
Time, hours
O_2 Diffusion Rate
Following a 2-day Dose
(after Lance,et al)


Depth, inches
0
10
20
30
40
50
60
0
50
100
150
200
250
O_2 Concentration, mg/L Air
1 day
5 days
O_2 Profiles after 2 Days of Dosing
(after Lance, et al)

BOD Removal for Rapid Infiltration Systems				
Location	**Applied Wastewater BOD lb/ac-d***	**Applied Wastewater BOD mg/L**	**Percolate Concentration, mg/L**	**Removal %**
Boulder, CO	48†	131†	10†	92
Brookings, SD	11	23	1.3	94
Ft. Devens, MA	77	112	12	89
Hollister, CA	158	220	8	96
Lake George, NY	47	38	1.2	97
Milton, WI	138	28	5.2	91
Phoenix, AZ	40	15	0 – 1	93 - 100
Vineland, NJ	43	154	6.5	96

(Crites and Tchobanoglous, 1998)
*lb/acres per day (lb-acre/d) is total lb/ac applied during the operating period divided by number of days in the operating period
†Chemical Oxygen Demand (COD) basis



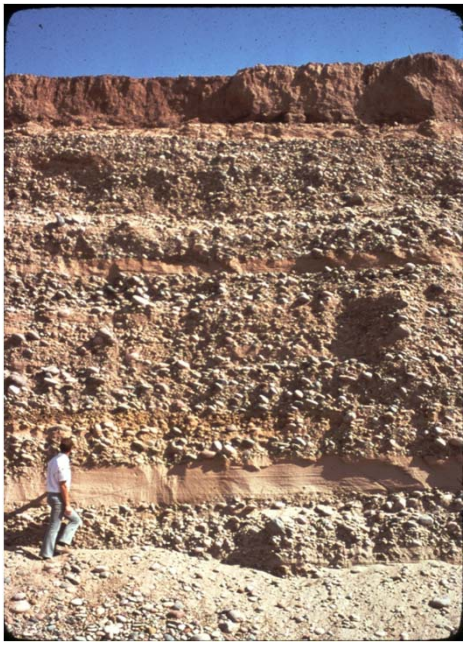
PHOSPHORUS RETENTION

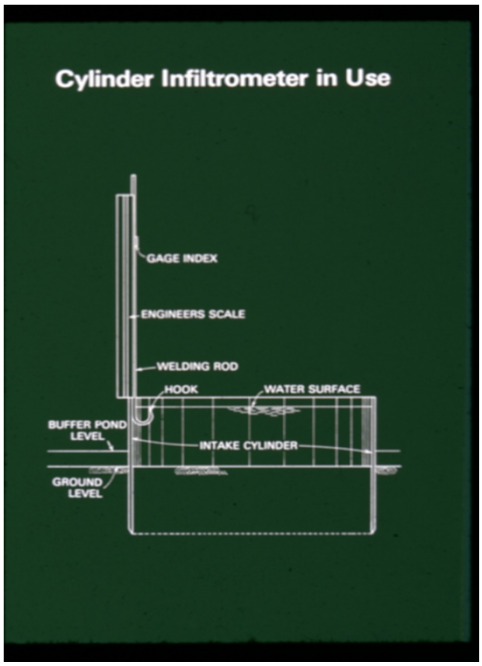
Retention = Adsorption (fast)+Precipitation(slow)

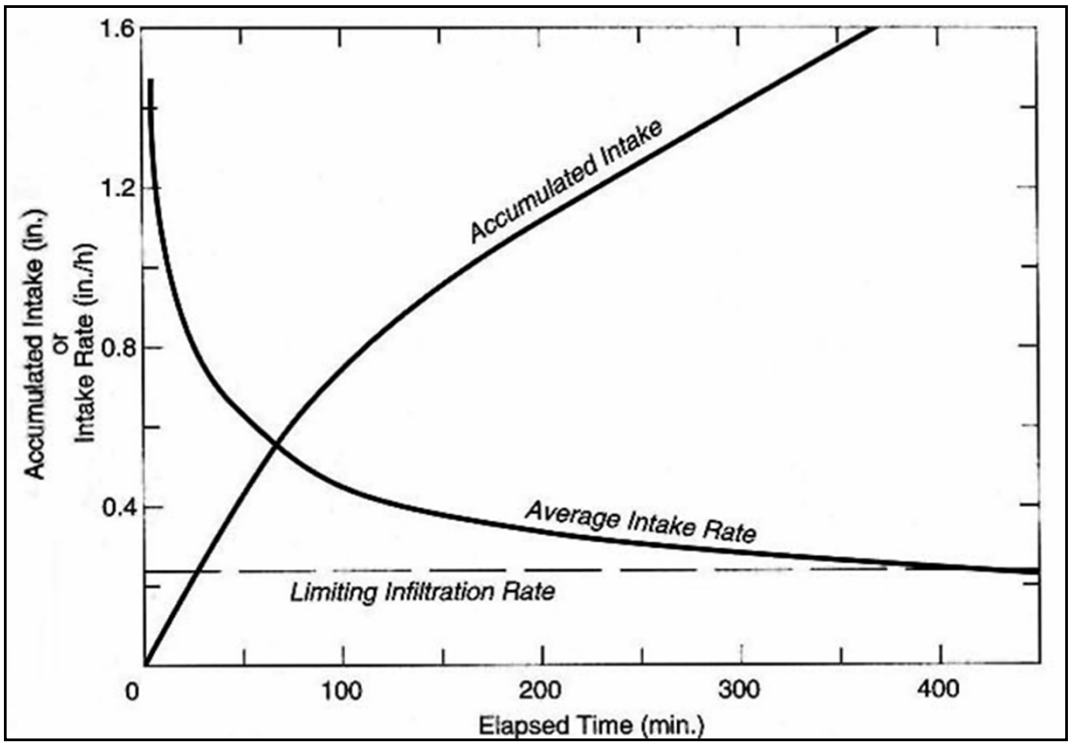
EPA Guidance: Probable long-term P retention
5 x Max. Adsorption by Isotherm Test

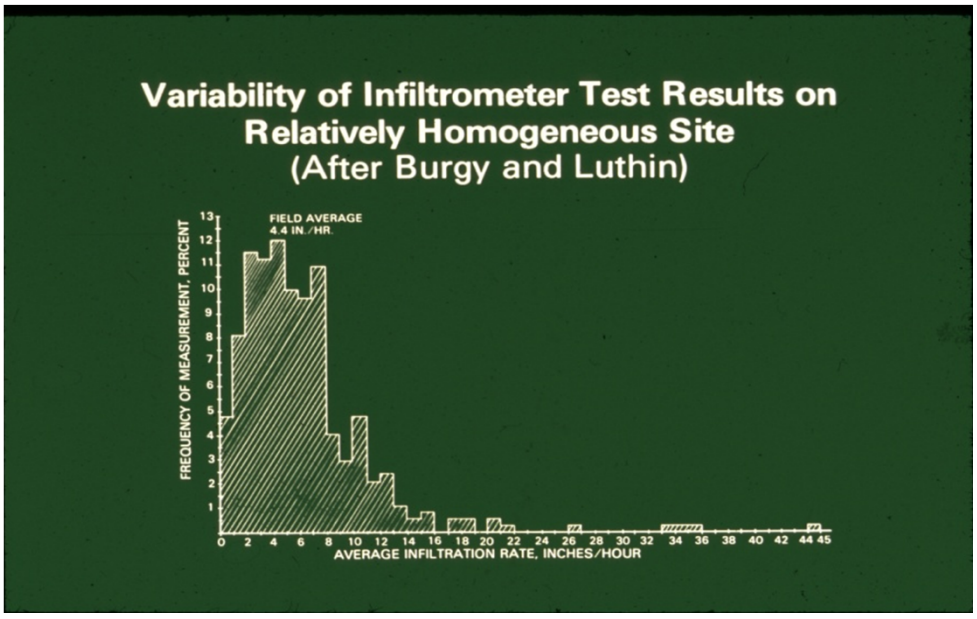
Rapid Infiltration:
Field Testing Requirements

Property	Method
Profile	Road Cuts, Backhoe Pits
Texture, Structure	SCS, Soils Specialist
Groundwater Table	Test Wells
Barrier Layer	Drilling
Infiltration Rate	Double-Ring Method
Permeability	Horizontal: Auger-Hole Vertical: Ring Permeameter



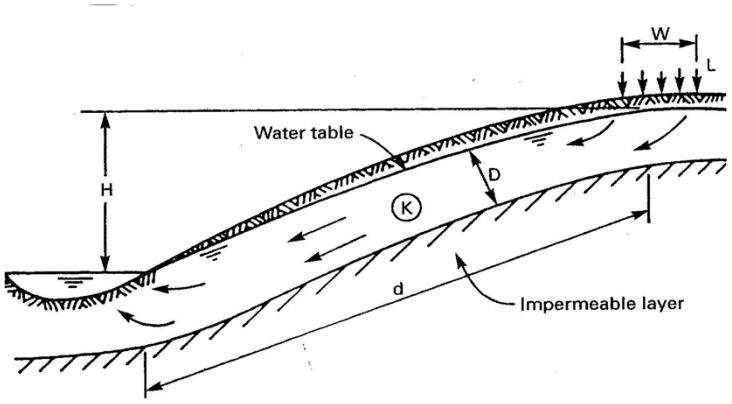

Cylinder Infiltrometer in Use
GAGE INDEX
ENGINEERS SCALE
WELDING ROD
HOOK
WATER SURFACE
BUFFER POND LEVEL
INTAKE CYLINDER
GROUND LEVEL


1.6
1.2
0.8
0.4
0
100
200
300
400
Accumulated Intake (in.)
or
Intake Rate (in./h)
Elapsed Time (min.)
Accumulated Intake
Average Intake Rate
Limiting Infiltration Rate

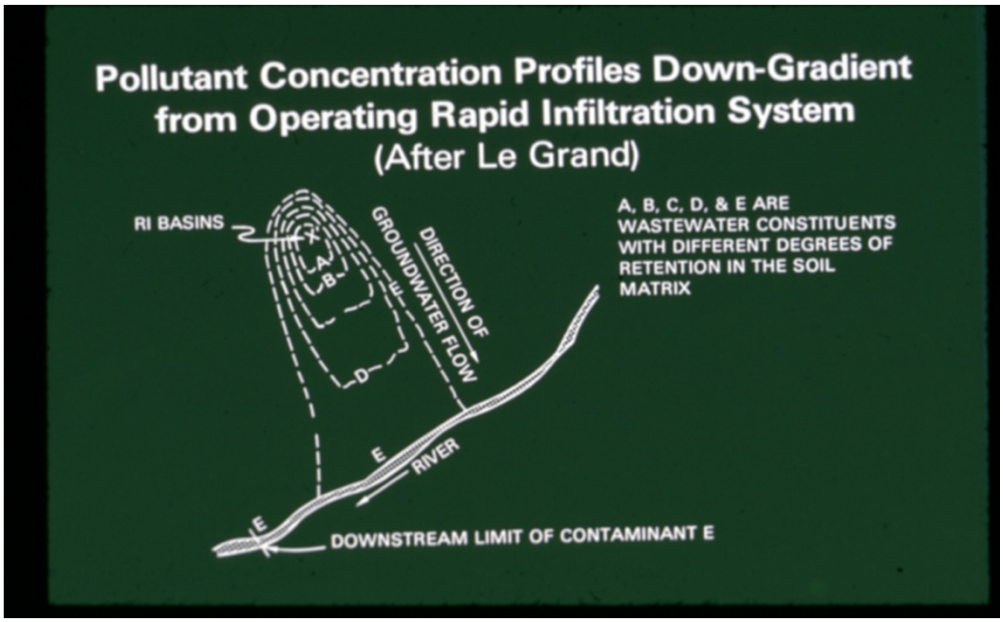

Variability of Infiltrometer Test Results on
Relatively Homogeneous Site
(After Burgy and Luthin)
FIELD AVERAGE
4.4 IN./HR.
FREQUENCY OF MEASUREMENT, PERCENT
AVERAGE INFILTRATION RATE, INCHES/HOUR

TEST BORE HOLES

- At least 3 – triangular pattern
- All should penetrate GWT
- Two should extend through saturated zone if possible.



Definition sketch for lateral drainage from RI systems.



COMPARISON OF EFFLUENT CHARACTERISTICS

All in mg/L

	BOD_5	TSS	TKN	Total-P
Lagoon	20-80	30-120	20-40	4-10
RI Percolate	2-10	1-3	1-8	.2-5

PHOSPHORUS REMOVAL

- Flooded soils remove more P
- Lower hydraulic loadings remove more P
- Use isotherm tests to estimate maximum P-adsorption, b

LINEARIZED LANGMUIR ISOTHERM

$$\frac{c}{x/M} = \frac{1}{Kb} + \frac{c}{b}$$

c = solution P concentration, mg/L

x/M = P on soil at equilibrium, mg/kg

b = maximum P adsorption, mg/Kg

K = a constant

APPROXIMATE 'CLASSES' OF P ADSORPTION

	mg/kg
• very low	50-300
• low	300-600
• medium	600-900
• high	900-1,500
• very high	>1,500

RYDEN, et al (Ref. 7) GUIDANCE

Amounts of P added should not be more than:

mgP/kg soil	Sorption Capacity
600	low
1500	medium
3000	high

SAMPLE CALCULATION

- "low" P sorption capacity
- 10 ft. of treatment zone
- soil bulk density, 50 kg/ft^3
- one acre basis

$$\frac{43{,}560\ ft^2}{10^6\ mg kg} \times 50 \frac{kg}{ft^3} \times 600\ \frac{mg\ P}{kg} = 13{,}068\ kg\ P$$

At 50 ft/yr, 8 mg/L P, 26 years

P REMOVAL ESTIMATE (Refs. 4, 8, 13)

$$P(x) = P_o \exp(-kt)$$

P(x) = total P at distance x

P_o = initial P (use 80-85 percentile)

K = .048/d at pH7 (worst case)

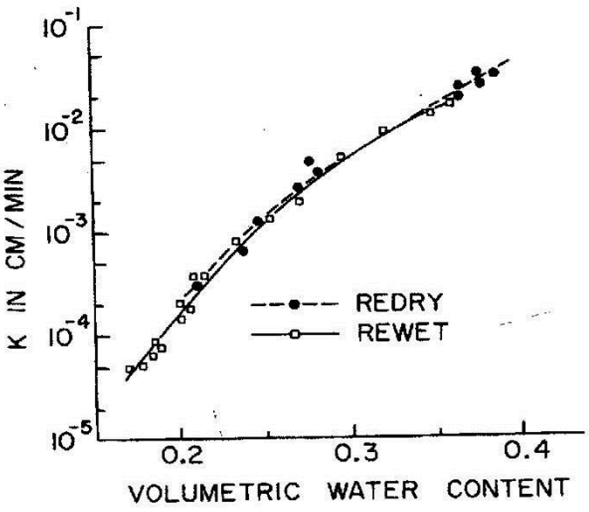
t = $(x \cdot \theta)/(K_x \cdot \Delta h/L)$

X = distance, ft

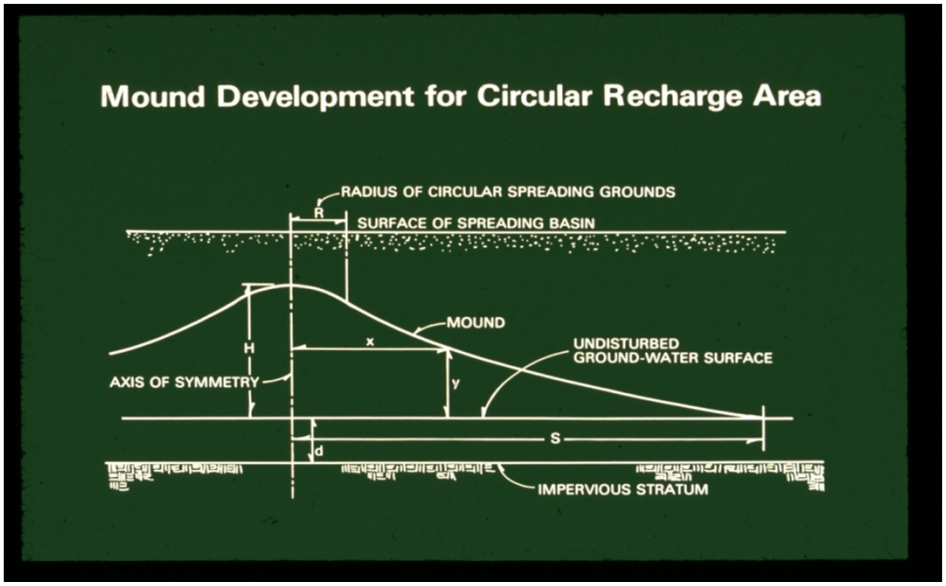
Θ = soil moisture content, use 0.4

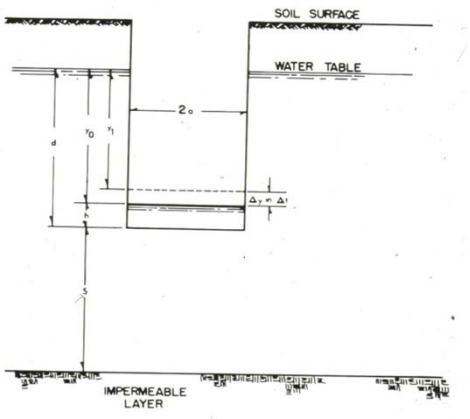
K_x = hydraulic conductivity in x direction, ft/d

Δh/L = hydraulic gradient

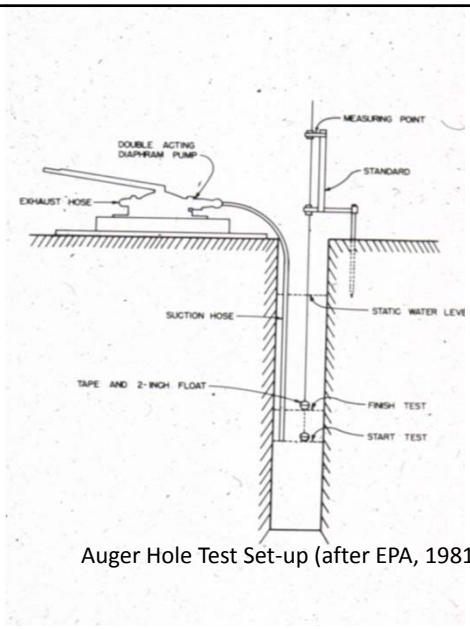


After Bouwer, Groundwater Hydrology



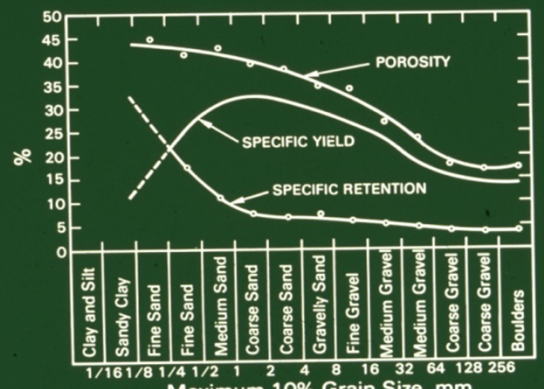


Definition Sketch for Auger Hole test set-up



Auger Hole Test Set-up (after EPA, 1981)

Porosity, Specific Retention, and Specific Yield Variations with Grain Size



Relationship Between Specific Yield and Hydraulic Conductivity (After U.S. Bu Rec Drainage Manual)

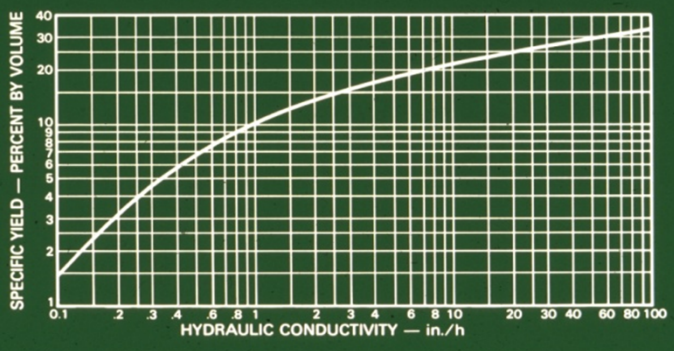


Table 9-8 Suggested SAT Loading Cycles

Loading Cycle Objective	Applied Wastewater	Season	Application period*, days	Drying Period, days
Maximize infiltration rates	Primary	Summer	1 – 2	5 – 7
		Winter	1 – 2	7 – 12
	Secondary	Summer	1 – 3	4 – 5
		Winter	1 – 3	5 – 10
Maximize nitrogen removal	Primary	Summer	1 – 2	10 – 14
		Winter	1 – 2	12 – 16
	Secondary	Summer	7 – 9	10 – 15
		Winter	9 – 12	12 – 16
Maximize nitrification	Primary	Summer	1 – 2	5 – 7
		Winter	1 – 2	7 – 12
	Secondary	Summer	1 – 3	4 – 5
		Winter	1 – 3	5 – 10

*Regardless of season or cycle objective, application periods for primary effluent should be limited to 1 to 2 days to prevent excessive soil clogging.

Table 10-9. Minimum Number of Basins Required for Continuous Wastewater Application

Loading Application Period, days	Cycle Drying Period, days	Minimum Number of Infiltration Basins
1	5 – 7	6 – 8
2	5 – 7	4 – 5
1	7 – 12	8 – 13
2	7 – 12	5 – 7
1	4 – 5	5 – 6
2	4 – 5	3 – 4
3	4 – 5	3
1	5 – 10	6 – 11
2	5 – 10	4 – 6
3	5 – 10	3 – 5
1	10 – 14	11 – 15
2	10 – 14	6 – 8
1	12 – 16	13 – 17
2	12 – 16	7 – 9
7	10 – 15	3 – 4
8	10 – 15	3
9	10 – 15	3
7	12 – 16	3 – 4
8	12 – 16	3
9	12 – 16	3