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SMR/402 - 20

COLLEGE ON SOIL PHYSICS
9 - 27 October 1989

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# "Field Infiltration Tests"

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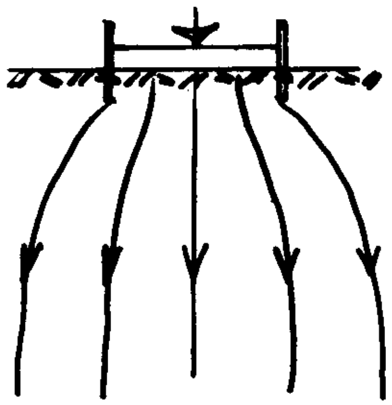
***Please note: These are preliminary notes intended for internal distribution only.***

# FIELD INFILTRATION TESTS

## [A] PONDED CONDITIONS

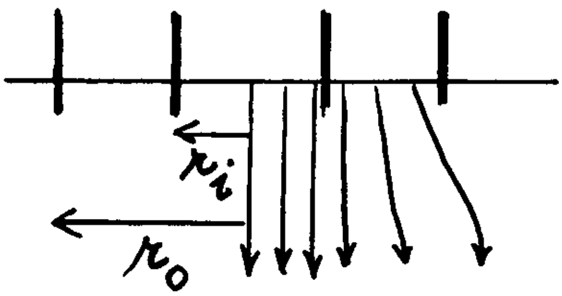
SINGLE RING



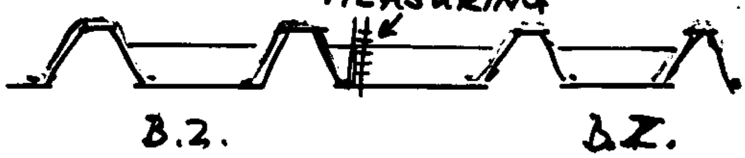
IF THE SOIL HYDRAULIC CHARACTERISTICS ARE NOT KNOWN, THE MAGNITUDE OF DIVERGENCE IS NOT PREDICTABLE

BUFFER ZONE WAS INTRODUCED

EITHER
DOUBLE RING
(METAL RINGS)




OR
BASIN TEST
(DIKES LINED BY PLASTIC SHEETS)




SWARTZENDRUBER & OLSEN

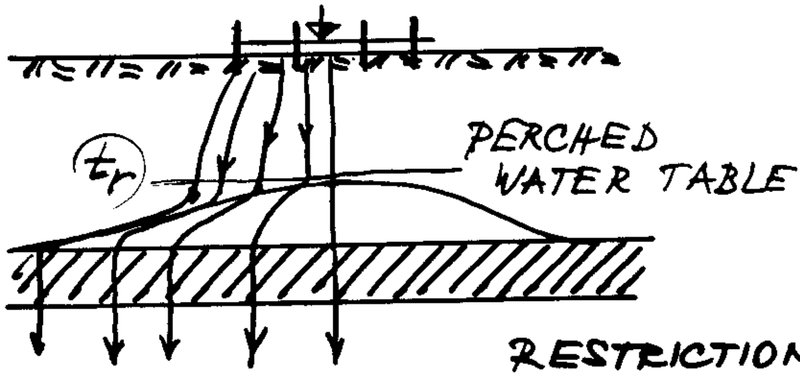
$r_o > 30\,cm \qquad (r_o - r_i)/r_o > 0.5$

VAUCLIN ET AL $\frac{r_o}{r_i}$ IS DECISIVE, NOT $r_i$

WHAT SIZE OF $r_i$?

(a) TO COVER REA
(b) ECONOMIC USE OF WATER
(LIMITS OF MINIMIZING $r_i$ : NO DATA — BETTER THAN FALSE DATA

# LAYERED SOIL




WITH INCLINED LAYER OF LOW $K_s$, LATERAL FLOW STARTS

RESTRICTION OF APPLICABILITY OF DATA: $\{I(t)\}$ $t \in \langle 0, t_r \rangle$

CRACKING SOIL, SOIL WITH INTERCONNECTED MACROPORES

HOW TO ELIMINATE THE OUTFLOW THROUGH THE SYSTEM OF CRACKS?

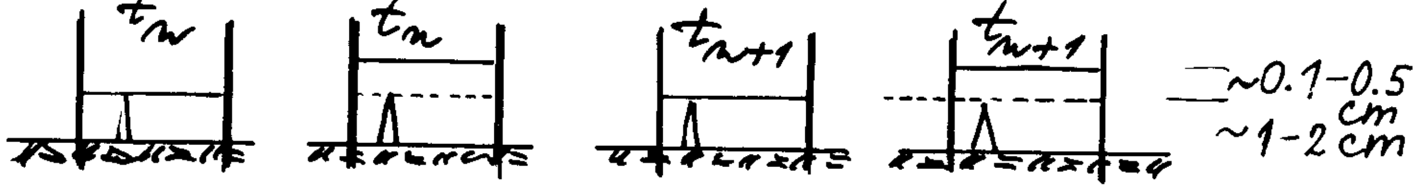
(a) DEPTH OF PENETRATION OF RINGS > DEPTH OF CRACKS

(b) INFILTRATION WITH $-H_0$
(DISADVANTAGE: CRACKS AS IMPORTANT FACTOR OF INFILTRATION ARE ELIMINATED)

(c) - OFTEN WITH (b): SOIL SURFACE IS COVERED BY
α) POROUS MATERIAL
β) SAND (FINE GRADE) THIN LAYER
DISADVANTAGE - SEE (b)

## MEASURING METHODS

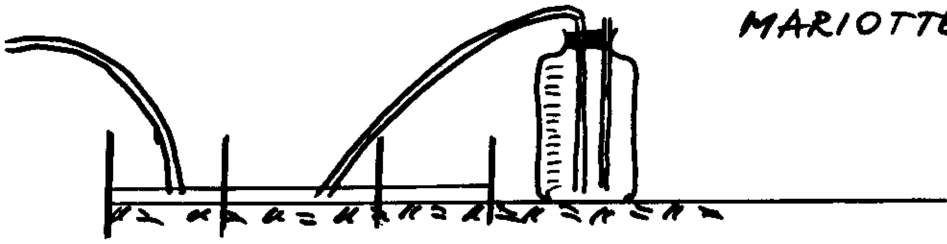
1. CONSTANT (OR QUASI-CONST.) HEAD



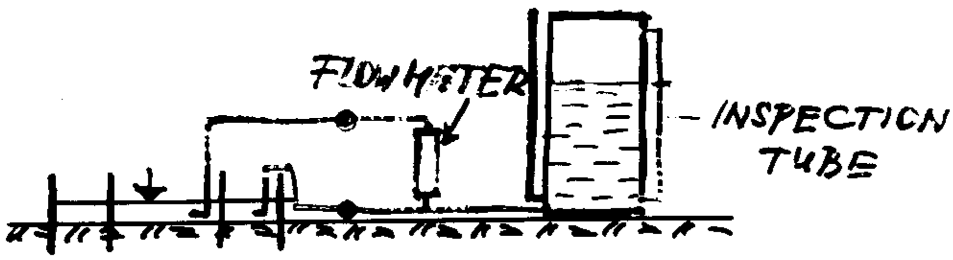

CONSTANT VOLUME $V_c$ IS ADDED & $t_n$ IS READ

[INNER RING [illegible]]

MARIOTTE SYPHON

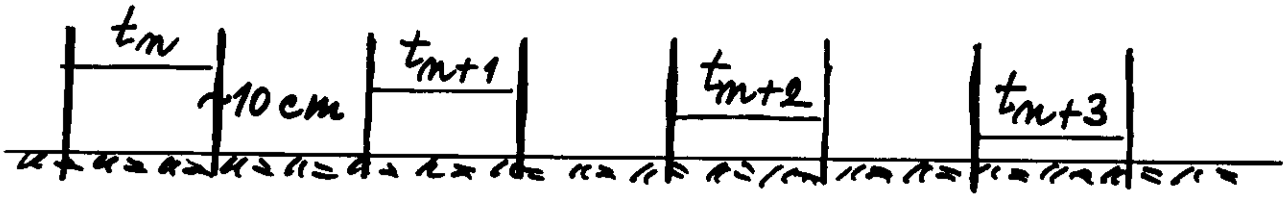


RESERVOIR - MARIOTTE FLASK




FLOATER INDICATOR OF WATER LEVEL IN THE INSIDE RING

## 2. FALLING HEAD




POSITION OF WATER LEVEL IS READ

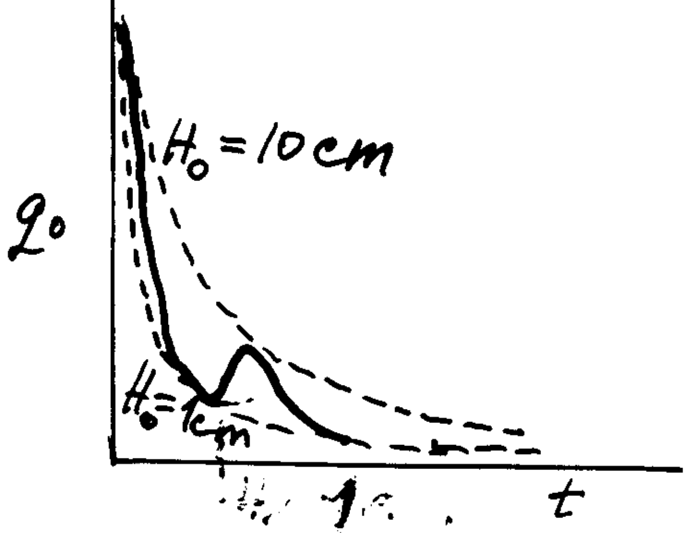
(a) DEPTH GAUGE

(b) FLOATER

α) MANUALLY

β) AUTOMATICALLY

PRINCIPLE DISADVANTAGE :



## B. RAIN SIMULATORS

CRITERIA FOR THE DESIGN:

1. DROP SIZES ≈ NATURAL RAINFALL ↦ REGULATION
2. DROP VELOCITY AT IMPACT ≈ TERMINAL VELOCITY ; 1+2 = KINETIC ENERGY (60% - 80%)
3. INTENSITY (= RATE) ≈ NATURAL RAINFALL ↦ REGULATION
4. UNIFORM DISTRIBUTION OVER THE PLOT
5. IMPACT OF DROPS ≈ VERTICAL
6. EXCESS WATER MEASUREMENT: IMMEDIATE, HIGH ACCURACY

CONSTRUCTION OF RAINFALL SIMULATORS:

A. DROP FORMERS (CAPILLARY NEEDLES, TUBES) — STRICTLY VERTICAL

APPLICATION RATE:

SPACING

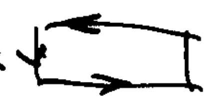
SIZE (UNIFORM — OR DISTRIBUTION IN RADIUS SIZE)

PRESSURE HEAD

RANDOMIZATION OF THE PATTERN OF DROP FORMERS: MOVEMENT OF THE RAIN SOURCE

ROTATION

ONE DIMENSIONAL ⟷

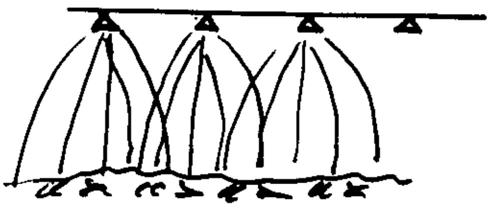
TWO — " —  OR 

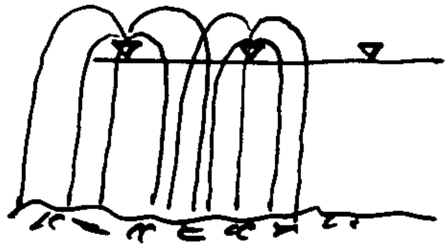
B. NOZZLE BASED SIMULATORS

CONTINUOUS SPRINKLING

DIS — " — — " —

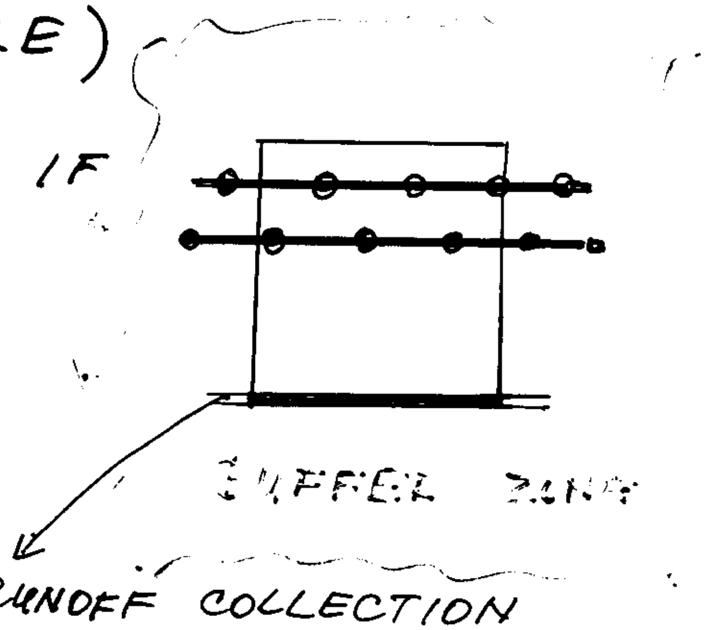
2) SET OF NOZZLES





3) (SINGLE NOZZLE)

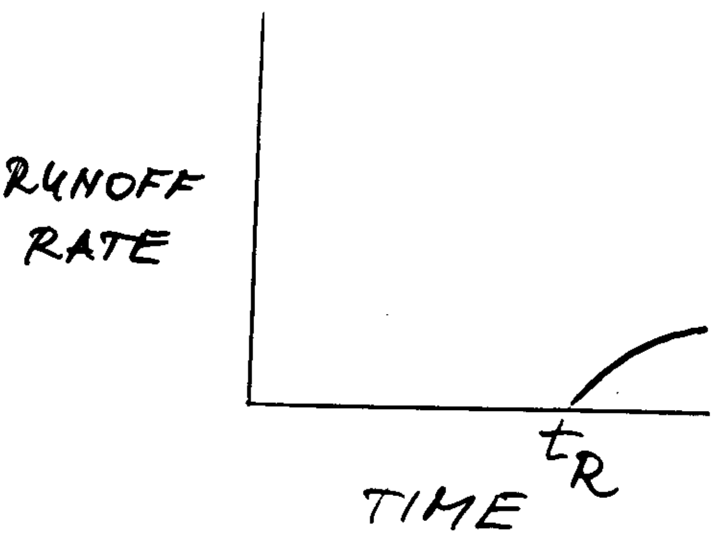
RANDOMIZATION IF




## RUNOFF COLLECTION

a) BY GRAVITY
b) VACUUM PICK-UP

} COLLECTION TRENCH (SEALING OF THE WALLS)




$$t_R = t_p + \text{STORAGE } t + \text{ROUTING LAG}$$

SWARTZENDRUBER & HILLEL 1974 ?

## A. TESTING OF ALGEBRAIC EQUATIONS

GREEN & AMPT (1911)

$$I = K_A t + \lambda \ln\left[1 + \frac{I}{\lambda}\right] \qquad \lambda = (\theta_S - \theta_i)(H_0 - H_f)$$

PHILIP'S 2 PARAMETERS EQ. (1957)

$$I = S t^{1/2} + A t \qquad K_p = m A \quad m < \underline{3/2}, 3 >$$

3 PARAMETERS EQUATIONS

BRUTSAERT (1977)

$$I = K_B t + \frac{S}{\beta K_B}\left\{1 - \left[1 + \beta \frac{K_B \sqrt{t}}{S}\right]^{-1}\right\}$$

FROM PHILIP'S SERIE SOLUTION (KUTÍLEK, KREJČA, 1987)

$$I = C_1 t^{1/2} + C_2 t + C_3 t^{3/2}$$

FOR $dq/dt \to 0$

$$t_{lim} \simeq \frac{C_1}{3 C_3}$$

APPROXIMATING $q(t_{lim}) \approx K_S$

$$\to K_3 \approx \sqrt{③ C_1 C_3} + C_2$$

SWARTZENDRUBER (1987)

$$I = \frac{S}{A_0}\left[1 - \exp\left(-A_0 t^{1/2} - B_0 t - C_0 t^{3/2} \ldots\right)\right] + K t$$

$$I \approx \frac{S}{A_0}\left[1 - \exp\left(-A_0 t^{1/2}\right)\right]$$

OF EQ #1 → SERIE EXPANSION [illegible]

[illegible]

[illegible]

[illegible]

$$\to K_S \approx \sqrt{\textcircled{3/2}\, C_1 C_3} + C_2$$

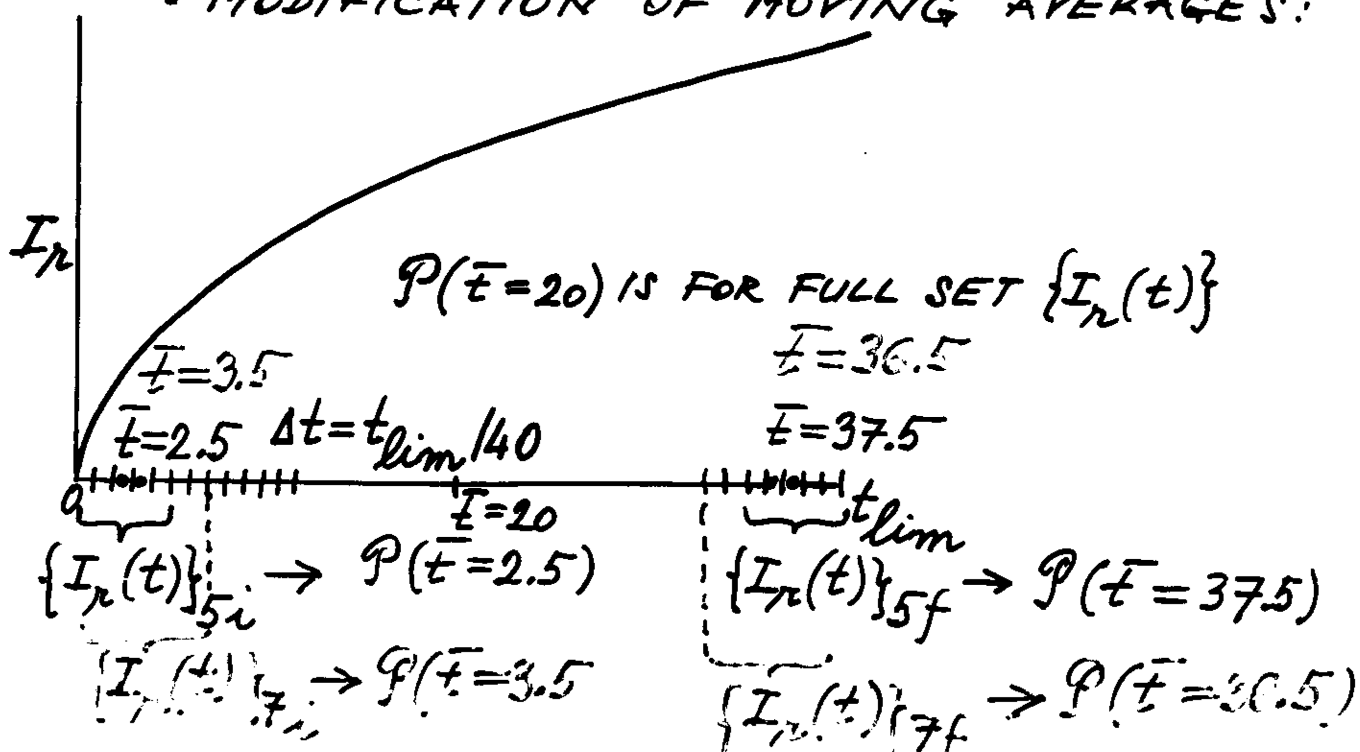
## A.1. TESTING AGAINST REFERENCE SOLUTION

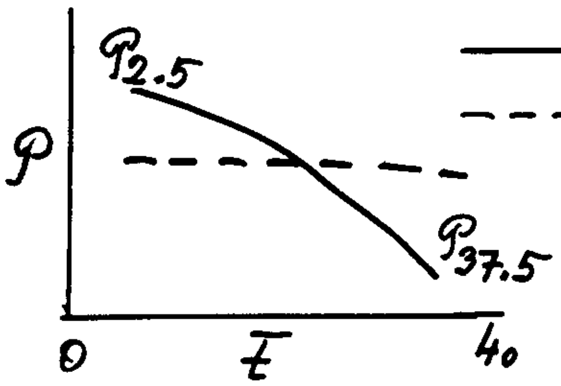
REFERENCE SOLUTION : $\{I_r(t)\}$ FOR

- YOLO LIGHT CLAY, SAND (SABLE D'ISERE),
- 9 TERMS OF PHILIP'S SERIE SOLUTION
- $H(\theta)$, $K(\theta)$, $K_s$, $S$ : KNOWN (HAVERKAMP 1987, 1988)

FITTING OF $\{I(t)\}_{REF.}$ TO ALG. EQ. → PARAMETERS $\mathcal{P}$

- MODIFICATION OF MOVING AVERAGES:




—— LOW STABILITY

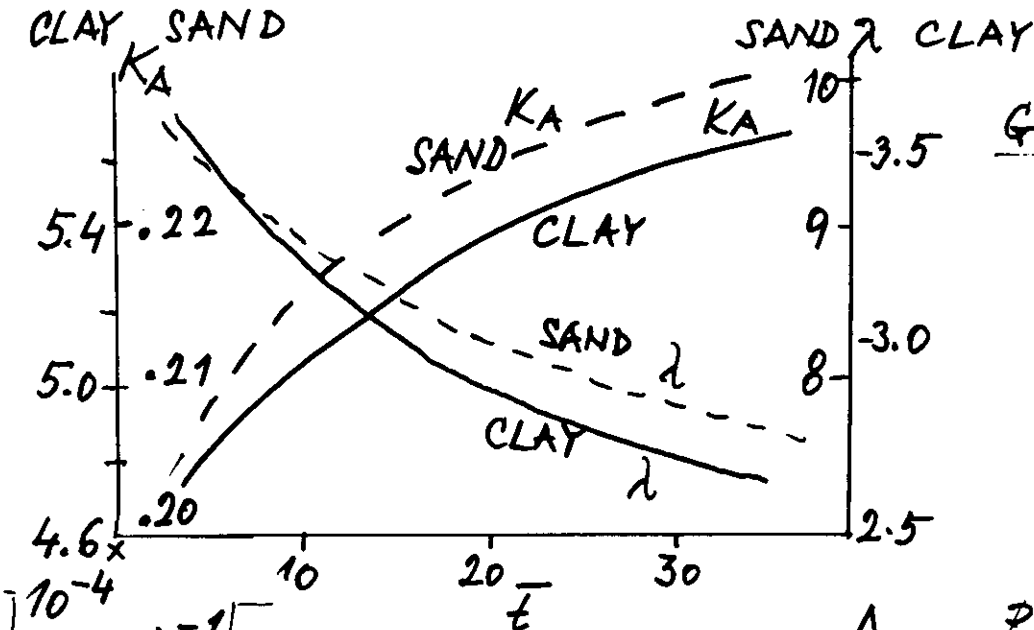
- - - HIGH STABILITY

$$\nu = \frac{\mathcal{P}_{MAX} - \mathcal{P}_{MIN}}{\mathcal{P}_{MAX}}$$

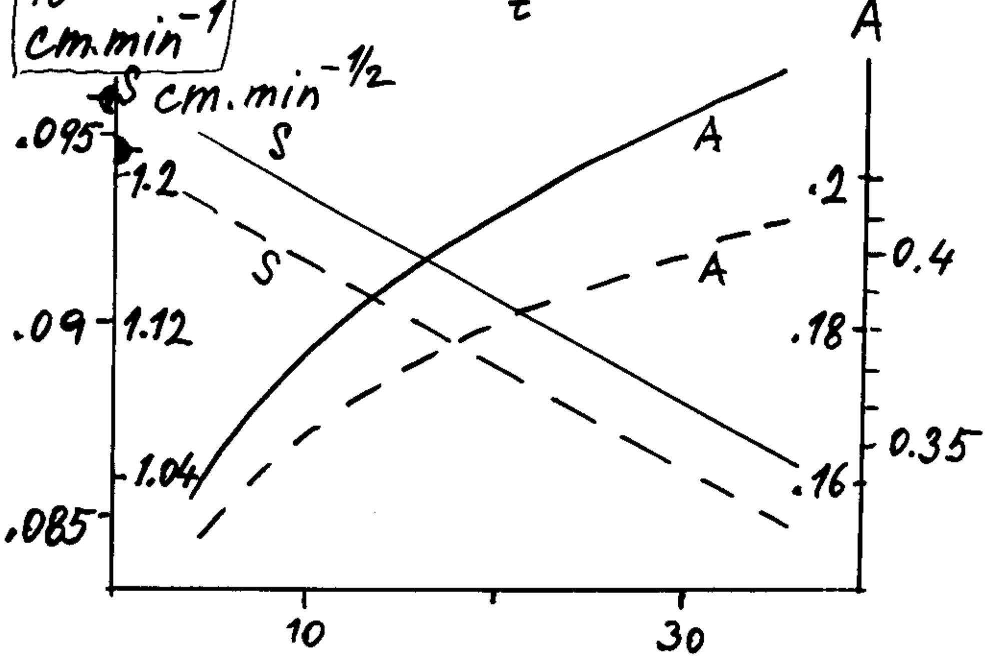
$\varepsilon$ ERROR

$$\varepsilon = \frac{\sqrt{(\mathcal{P} - \Pi)^2}}{\Pi}$$

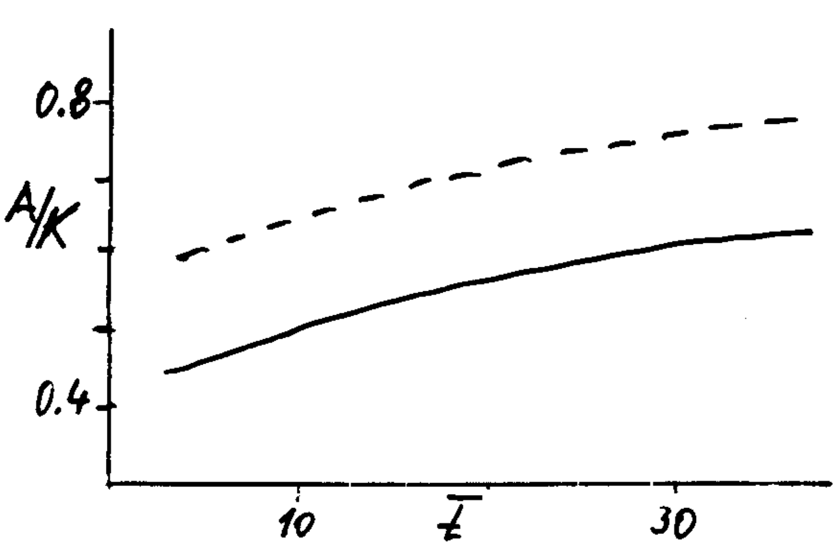
$\Pi$ – PHYSICAL PARAMETER




GREEN & AMPT



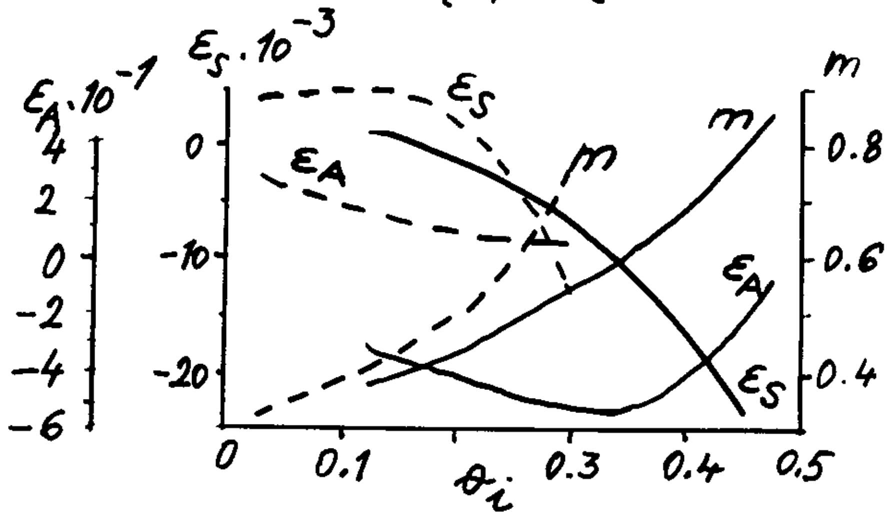

PHILIP -2 PARA.



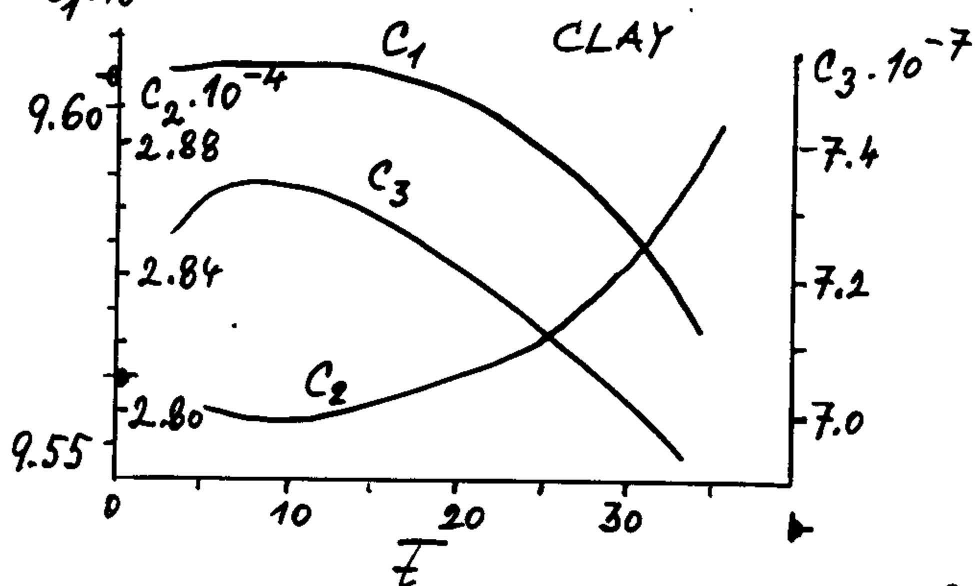
FULL SET $\{I_r(t)\}$

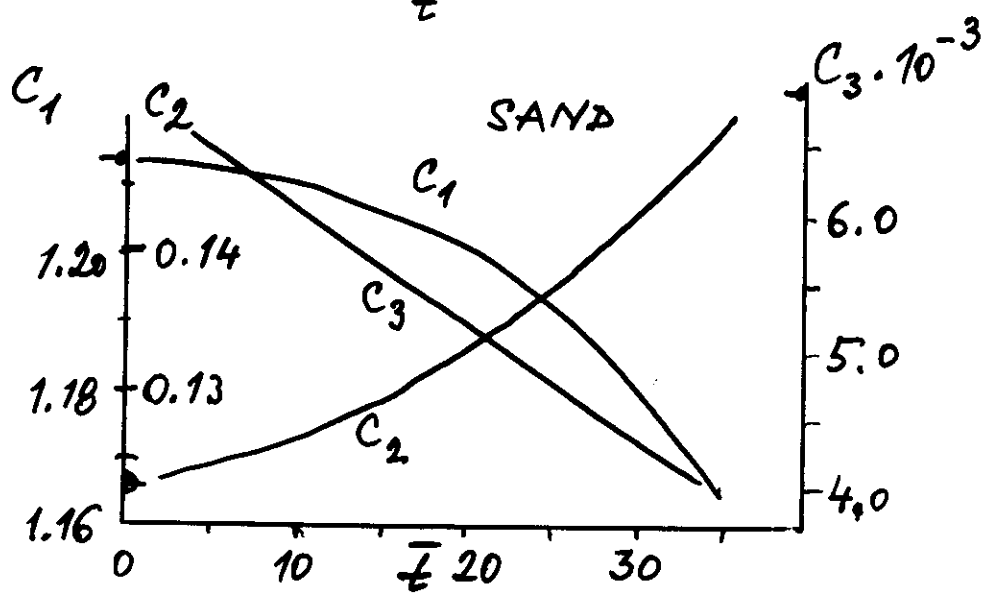
$$\varepsilon = \frac{\varphi - \pi_{EX}}{\pi_{EX}}$$

$$m = \frac{A}{K}$$



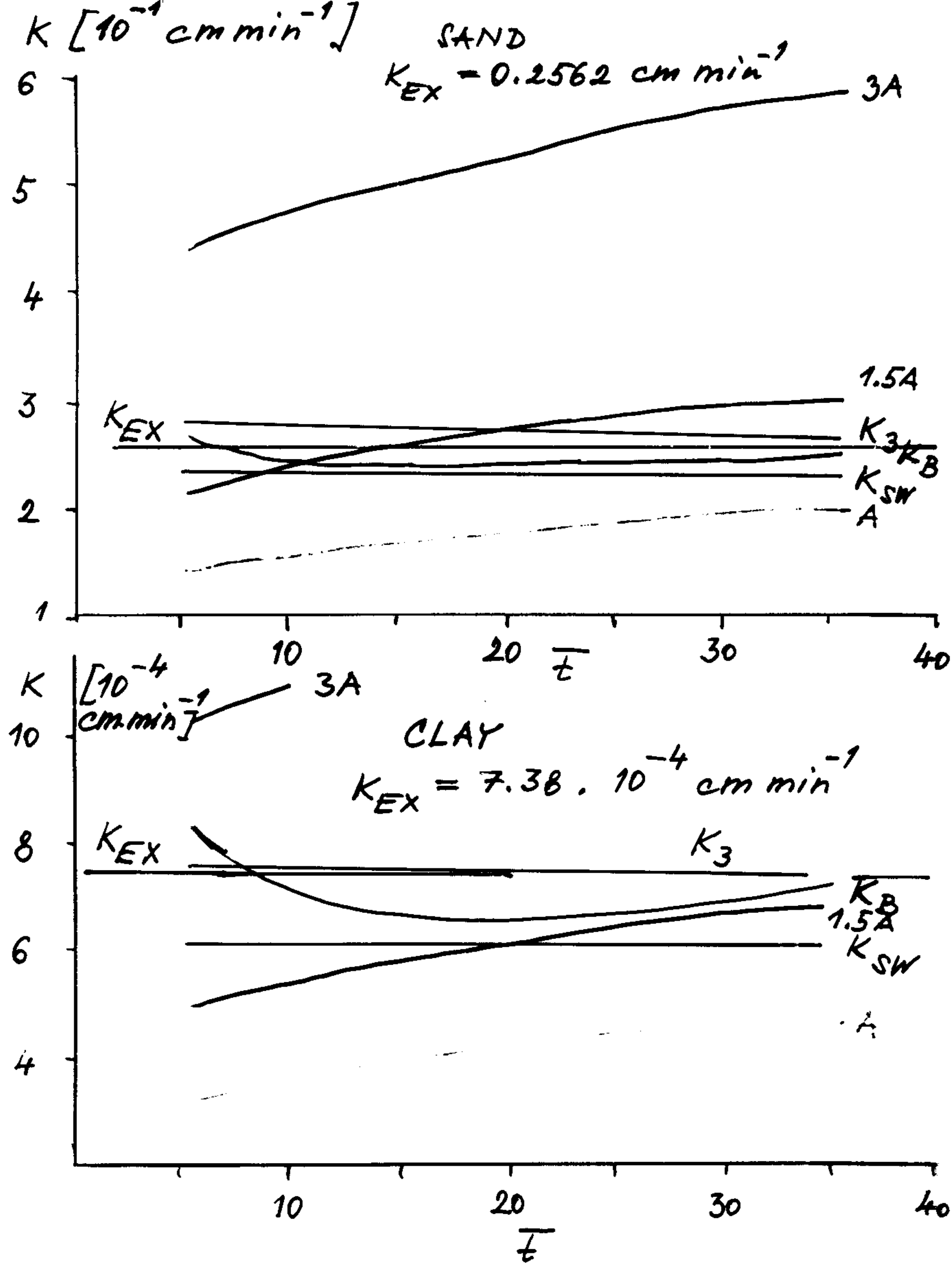

3 - PARAMETRIC



[illegible]

| [illegible] | MAX. DIFFERENCE SAND | MAX. DIFFERENCE CLAY | | MAX. ERROR SAND | MAX. ERROR CLAY |
|---|---|---|---|---|---|
| | $\vartheta$ | | | | |
| $\alpha$ | 0.30 | 0.42 | 0.5 | 0.34 | 0.5[illegible] |
| $C_1$ | 0.60 | 0.78 | $q_1$ | 0.67 | 0.73 |
| MEZENCEV | | | | | |
| $\beta$ | 0.16 | 0.19 | 0.5 | 0.22 | 0.23 |
| $C_2$ | 0.24 | 0.26 | $K_S$ | 0.4[illegible] | [illegible] |
| $C_3$ | 0.37 | 0.16 | — | — | — |
| $C_{II} = C_2 + C_3$ | 0.37 | 0.04 | $q_1$ | 0.62 | [illegible] |
| HORTON | | | | | |
| $\gamma$ | 0.93 | 0.92 | — | — | — |
| $C_4$ | 0.50 | 0.40 | $q_1$ | 1.14 | 0.78 |
| $C_5$ | 0.77 | 0.78 | — | — | — |
| GREEN & AMPT | | | | | |
| $K_1$ | 0.17 | 0.11 | $K_S$ | 0.36 | 0.21 |
| $\lambda$ | 0.21 | 0.24 | | — | — |
| PHILIP | | | | | |
| [illegible] | 0.09 | 0.14 | $S_1$ | 0.1[illegible] | 0.16 |
| $A$ | 0.25 | 0.2[illegible] | $(S_2+K_i)$ | 0.[illegible] | 0.[illegible] |



K [10^-1 cm min^-1]
SAND
K_EX = 0.2562 cm min^-1
3A
1.5A
K_EX
K_3
K_B
K_SW
A
6
5
4
3
2
1
10
20
30
40
t
K [10^-4 cm min^-1]
3A
CLAY
K_EX = 7.38 . 10^-4 cm min^-1
K_EX
K_3
K_B
1.5A
K_SW
A
10
8
6
4
10
20
30
40
t

MAX. DIFFERENCE (STABILITY INDEX) OF SOLUTION

$$\vartheta = \frac{\varphi_{MAX} - \varphi_{MIN}}{\varphi_{MAX}}$$

ERROR

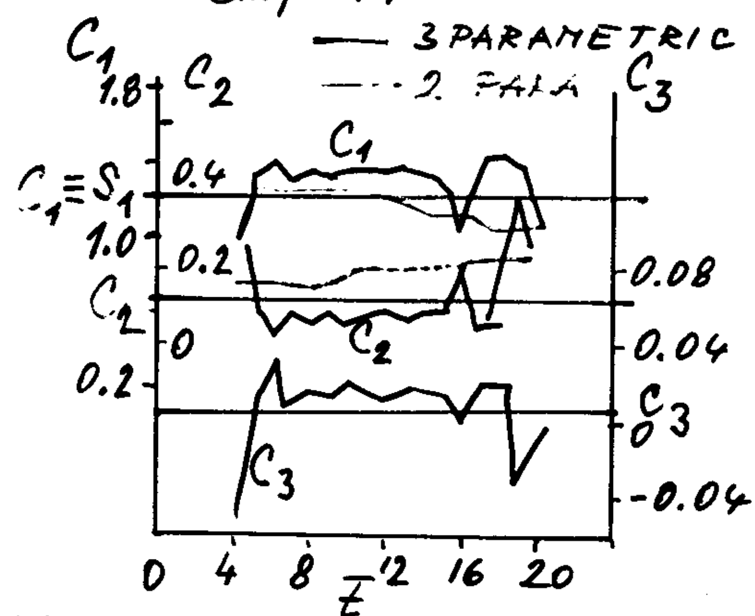
$$\varepsilon = \frac{\sqrt{(\varphi - \Pi_{EX})^2}}{\Pi_{EX}}$$

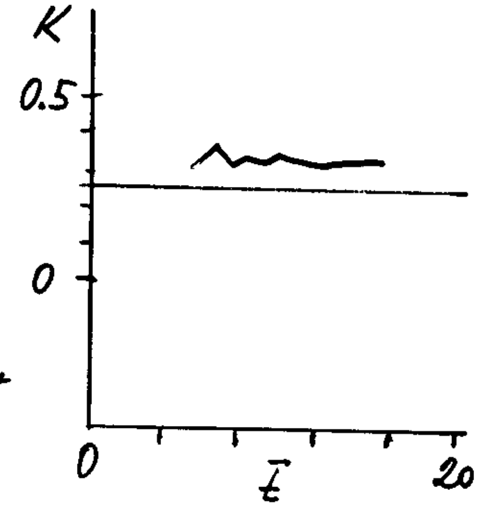
| | MAX. DIFFERENCE | | FULL SET $t = 20$ | | $\varepsilon_{MAX}$ | |
|---|---|---|---|---|---|---|
| | CLAY | SAND | CLAY | SAND | CLAY | SAND |
| $S_2$ (PHIL.) | 0.092 | 0.143 | 0.051 | 0.080 | 0.101 | 0.160 |
| $S_3 \equiv S_{SW}$ | 0.006 | 0.042 | 0.000 | 0.014 | 0.006 | 0.042 |
| $S_B$ | 0.126 | 0.067 | | | 0.159 | 0.087 |
| $K=1.5A$ (PHIL.) | 0.251 | 0.226 | 0.169 | 0.056 | 0.320 | 0.142 |
| $K_3$ | 0.009 | 0.054 | 0.004 | 0.055 | 0.046 | 0.092 |
| $K_{SW}$ | 0.009 | 0.054 | 0.170 | 0.102 | 0.180 | 0.121 |
| $K_B$ | 0.124 | 0.095 | 0.119 | 0.063 | 0.129 | 0.082 |
| $K_A$ | 0.172 | 0.122 | 0.165 | 0.084 | 0.365 | 0.208 |

## A.2. TESTING AGAINST LABORATORY DATA

cm, min

SABLE D'ISERE (SAND)




SAND (SABLE D'ISERE)

FULL SET $\{I(t)\}$ $K_{EXACT} = 0.2562$ cm.min$^{-1}$

$K_A = 0.252$ $K_B = 0.302$

$K_p = 1.5A = 0.295$ $K_{SW} = 0.263$

$K_3 = 0.338$

LOESS $K_{EXACT} = 4.5 \cdot 10^{-3}$ cm min$^{-1}$

$K_A = 3.2 \cdot 10^{-7}$ $K_B = 9.9 \cdot 10^{-3}$

$K_p = 1.5A = 4.2 \cdot 10^{-3}$ $K_{SW} = 7.5 \cdot 10^{-3}$

$K_3 = 10.1 \cdot 10^{-3}$

SORPTIVITY ESTIMATE : PHILIP 2 PARAMETERS EQ.

## A.3 TESTING IN FIELD.

| | S.L. | L | L | L |
|---|---|---|---|---|
| $K_A$ | 0.29 | | | |
| $K_p$ -1.5A | 0.33 | 0.085 | 0.151 | 0.0038 |
| $K_3$ | 0.37 | 0.077 | 0.317 | 0.0047 |
| $K_B$ | 0.33 | 0.041 | 0.094 | 0.0041 |
| $K_{SW}$ | 0.32 | 0.072 | 0.281 | 0.0035 |
| $\ell_{CONST}$ | 0.38 | 0.025 | 0.045 | 0.004 |

ARABLE FLUVISOL, COMPACTED, DESAGGREGATED, LOAM, N = 96

IN ~ 70% $K_3 < 0$ $K_{SW} < 0$

~ 30% $A < 0$

PERMANENT GRASS, CAMBISOL, SILTY LOAM, N = 163

IN ~ 25% $K_3 < 0$ $K_{SW} < 0$

~ 15% $A < 0$

$K_B$ IN ALL TESTS: $K_B > 0$

$\beta$ UP TO $\beta = 20$, ESPECIALLY WHEN $K_3 < 0$, $A < 0$

WHEN $\beta \to 0$

$S_B \to S_{PHIL.\ 2\ PARA}$

$K_B \to A_{PHIL.}$

OXISOL N=128 (MAIDUGURI – O.A. FOLORUNSO

CAMBISOL N=66

| | $\bar{X}$ | S | DISTRIB. | $\bar{X}$ | S | DISTR. |
|---|---|---|---|---|---|---|
| 1.5A | 0.194 | 0.068 | LG | 0.086 | 0.033 | G |
| $K_3$ | 0.214 | 0.050 | LG | 0.061 | 0.030 | LG |
| $K_{SW}$ | 0.159 | 0.046 | LG | 0.049 | 0.029 | LG |
| $K_{GA}$ | 0.162 | 0.049 | E | | | |
| $K_B$ | 0.206 | 0.112 | LG | 0.060 | 0.025 | LG |
| $q_{60}$ | 0.216 | 0.049 | G | 0.063 | 0.028 | LG |
| $q_{120}$ | 0.177 | 0.045 | LG | | | |

N – NORMAL DISTRIBUTION
LG – LOGNORMAL DISTRIBUTION
E – ERLANG'S
W – WEINBULL'S
G – GAMMA

| | |
|---|---|
| $S_{PH}$ | N |
| $S_3 \equiv S_W$ | E |
| $S_B$ | W |

TIME STABILITY OF SOIL MATRIX

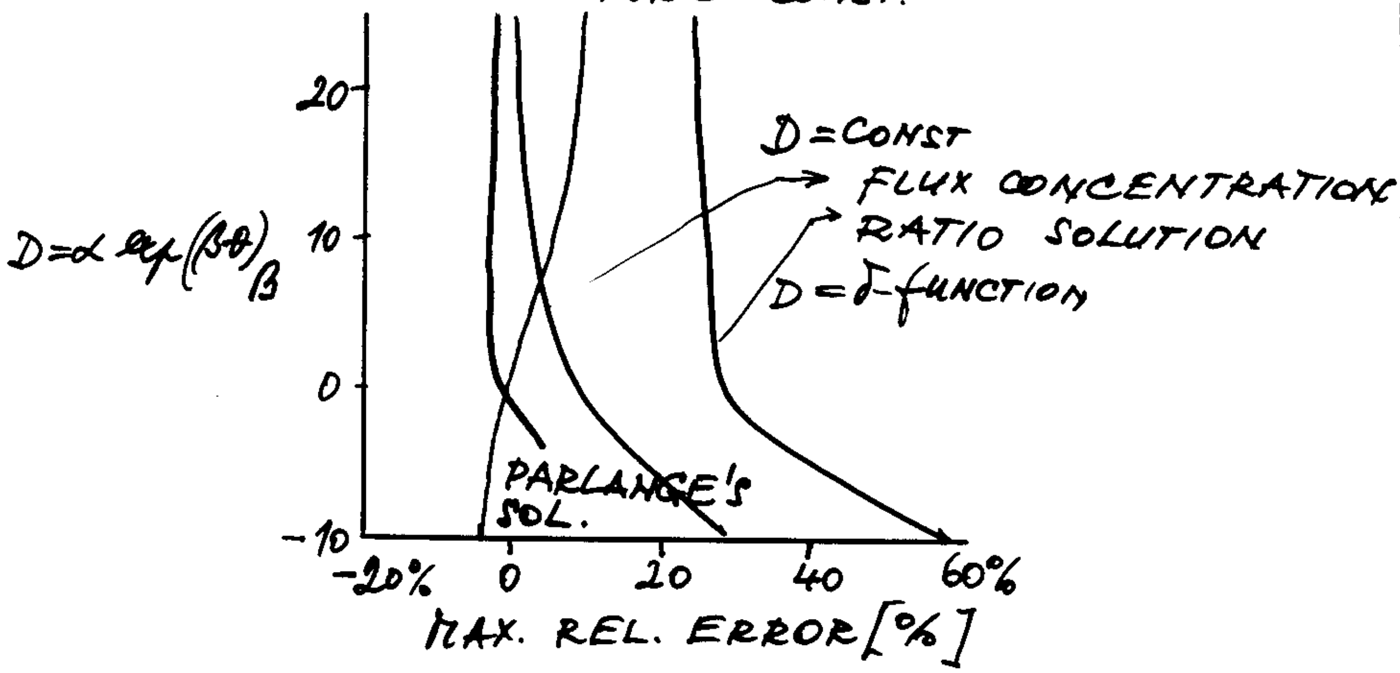
$\vartheta S < 5\%$ FOR $0 < t < t_{lim}/2$
FOR REFERENCE SOLUTIONS
FIELD TESTS: AGRIC. SOILS 82% $\vartheta S > 10\%$
GRASSLAND 65% $\vartheta S > 10\%$
$\Sigma$: INSTABILITY OF SOIL MATRIX

## B. SOLUTION OF THE INVERSE PROBLEM

### B.1. DIRECT ESTIMATES, e.g.

FROM S → D(θ), K(H) ... UNPREDICTABLE ERRORS: (KUTILEK, VALENTOVÁ, 1986)

FOR D = CONST.




### B.2. COMBINED METHODS:

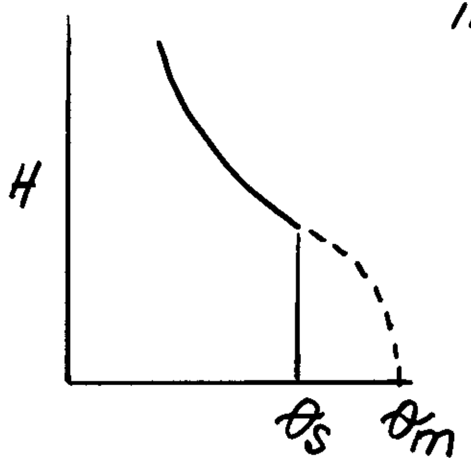
(a) EXPERIMENTAL METHODS: $H(\theta_E)$ $\{I_E(t)\}$

(b) NUMERICAL METHODS $\{I_N(t)\}$

(c) OPTIMIZATION

METHODICAL STEPS:

1. $H(\theta_E)$ IN LABORATORY WITH CORE SAMPLES



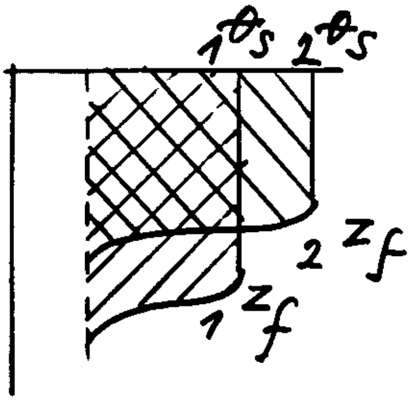

INSTEAD $\vartheta_e = \frac{\vartheta - \vartheta_r}{\vartheta_s - \vartheta_r}$ IS

$$\vartheta_E = \frac{\vartheta - \vartheta_a}{\vartheta_m - \vartheta_a}$$

$$\vartheta_a \lesseqgtr 0 \qquad \vartheta_m \geq \vartheta_s$$

"MODIFIED V. GENUCHTEN'S EQ."

2. INFILTRATIONTEST $\{I_E(t)\}$ AND $z_f$




3. FROM $\{I_E(t)\} \rightarrow {}_1K_s$

4. FROM ${}_1H(\vartheta_E)) \rightarrow K_r(\vartheta_E)$

5. NUMERICAL SIMULATION $\{I_N(t)\}$ WITH 1.3.,4.

6. OPTIMIZATION OF

$$\vartheta_m : [I_E(t) - I_N(t)]^2 \rightarrow MIN$$

$$\vartheta_s : [z_{fE} - z_{fN}]^2 \rightarrow MIN$$

7. $K_s$ FROM LINEAR SCALING (VOGEL)