INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR/220- 40

COLLEGE ON SOIL PHYSICS
2 - 20 November 1987

TRANSPARENCIES 1

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SDT (ppm) $\qquad$ CE (Siemen = $\frac{1}{Ohm}$ = mho)

dS/m = mmho/cm. $= 10^3$ μmho/cm

SDT (ppm) $\approx$ CE (dS/m) $\times$ 640

π (Pa) $\approx -0{,}36 \times 10^5 \times$ CE (dS/m) $\approx -\psi_o$ (Pa)

C (mg/l) $\approx$ 10 $\times$ CE (dS/m)

Corteza	Terrestre
O	49 %
Si	26 %
Al	7,5 %
Fe	4,2 %
Ca	3,2 %
Na	2,4 %
Mg	2,4 %
K	2,4 %
H	1 %
Ti	0,6 %
C	0,4 %
Cl	0,2 %
P	0,1 %
S	0,1 %
Mn	0,1 %

MIGRACION

Si < Fe, Al, Si < Si, P, Mn < Ca, Na, K, Mg < Cl, S, C

AGUAS

ROCAS SEDIMENTARIAS
Areniscas: Ca > Na > Mg
$HCO_3 > Cl > SO_4$
Evaporitas: SO_4, Cl, Ca, Mg, Na

ROCAS ERUPTIVAS (GRANITOS)
Y ROCAS METAMORFICAS (GNEISES):
Na > Ca > Mg ; Na > Cl

ROCAS VOLCANICAS (BASALTO):
Ca y Mg > Na

SOLUBILIDADES

(Agua destilada)
(25°C, $P(CO_2) = 0{,}003$ Atm.)

$NaCl$	6000	meq/l
$Na_2SO_4\ 10H_2O$	5800	"
$NaHCO_3$	800	"
Na_2CO_3	1500	"
$MgCl_2$	11000	"
$MgSO_4 \cdot 7H_2O$	6000	"
$MgCO_3$ ($Mg(HCO_3)_2$)	20	"
$CaCl_2 \cdot 6H_2O$	28000	"
$CaSO_4 \cdot 2H_2O$	30	"
$CaCO_3$ ($Ca(HCO_3)_2$)	1	"

SOLUCION

Concentracion	Composicion	
< 60 meq/l.	$HCO_3 > Cl > SO_4$	
	$HCO_3 > SO_4 > Cl$	$Ca > Mg > Na$
60 - 200 meq/l.	$SO_4 > HCO_3 > Cl$	$Ca > Na > Mg$
	$SO_4 > Cl > HCO_3$	$Na > Ca > Mg$
> 200 meq/l.	$Cl >> SO_4 >> HCO_3$	$Na \gg Mg > Ca$

AGUA MAR (35 g/l): $Cl = 550$ meq/l., $SO_4 = 53$ meq/l., $HCO_3 = 2{,}5$ meq/l
$Na = 460$ meq/l., $Mg = 100$ meq/l., $Ca = 20$ meq/l
$K = 10$ meq/l.

MAR MUERTO: 4.000 meq/l (200 g/l!!)

$$Ca_{\frac{1}{2}}X + Na^+ \rightleftharpoons NaX + \tfrac{1}{2}Ca^{++}, \quad RSI = \frac{[NaX]}{[Ca_{\frac{1}{2}}X]} = K_G \frac{[Na^+]}{[Ca^{++}]^{\frac{1}{2}}}$$ (Gapon, URSS, 1933)

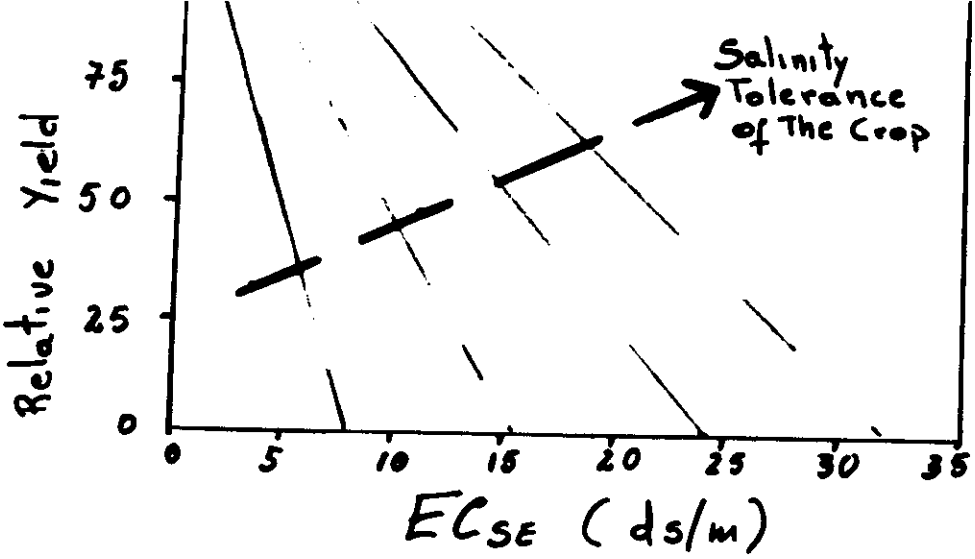
($K_G = 0{,}012$-$0{,}015$)

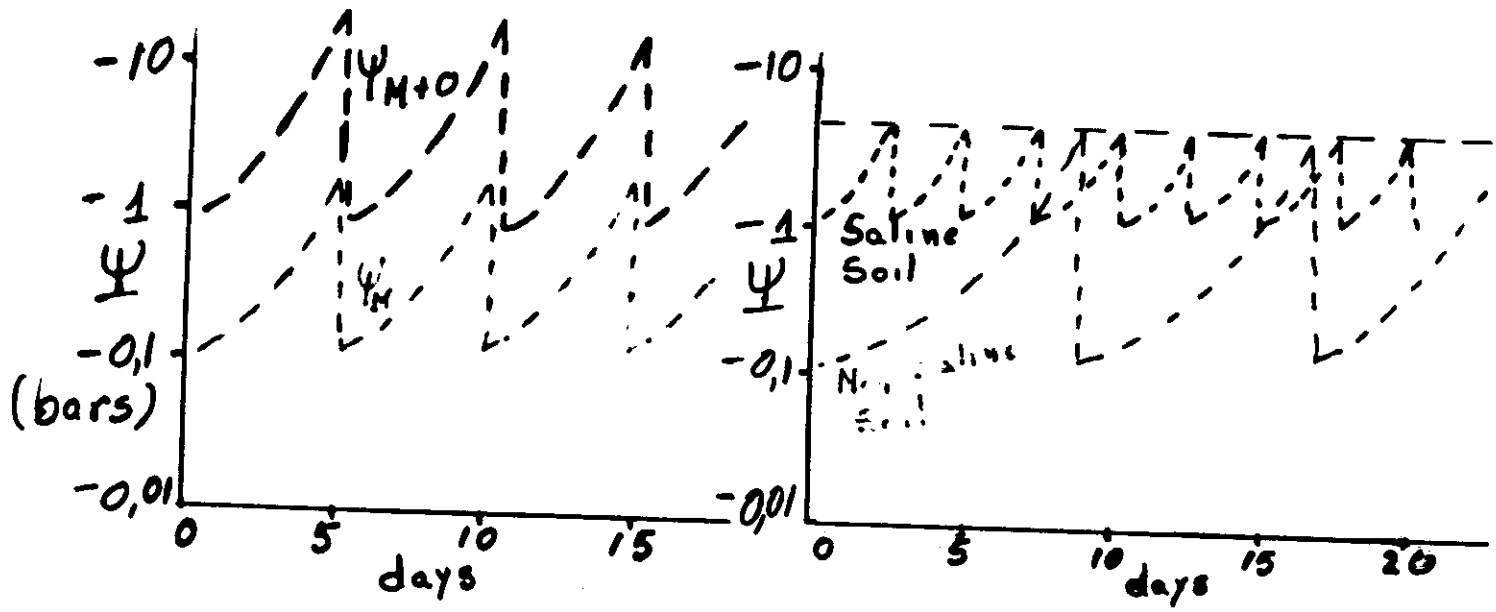
$$RAS = \frac{[Na^+]}{[Ca^{++} + Mg^{++}]^{\frac{1}{2}}} = \frac{RSI}{K_G\ (10;\ 0{,}01495)}, \quad RSI = 0{,}01495\ RAS$$

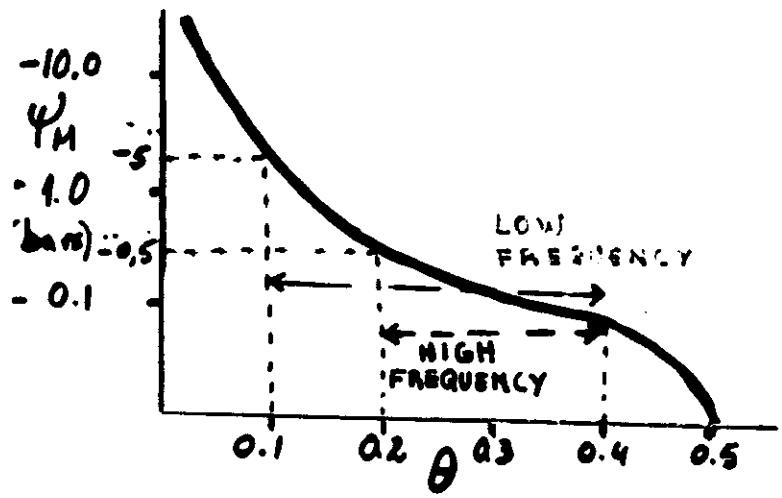
$$PSI = \frac{100(-0{,}0126 + 0{,}01495\ RAS)}{1 + (-0{,}0126 + 0{,}01495\ RAS)}$$

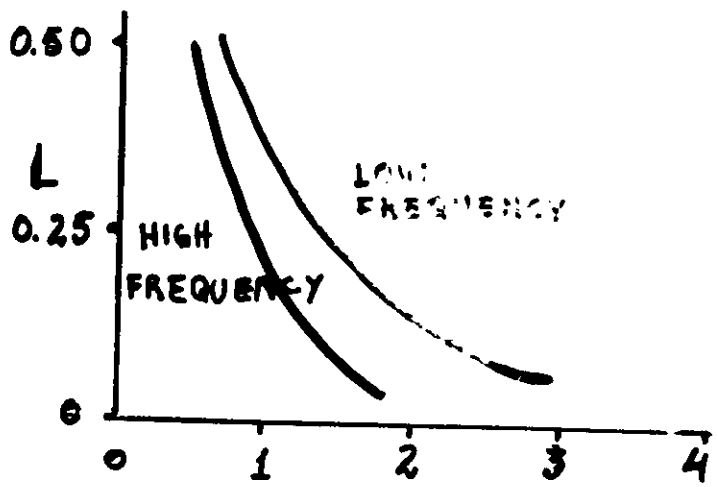
C: concentration (fraction)

$$RAS_{(c)} = \frac{C \cdot Na^+}{[C(Ca^{++} + Mg^{++})]^{\frac{1}{2}}} = C^{\frac{1}{2}} \cdot RAS$$ (USSL, 1954)

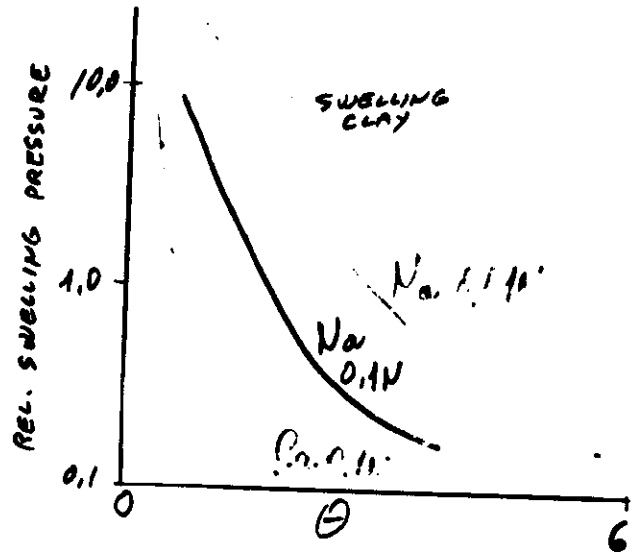


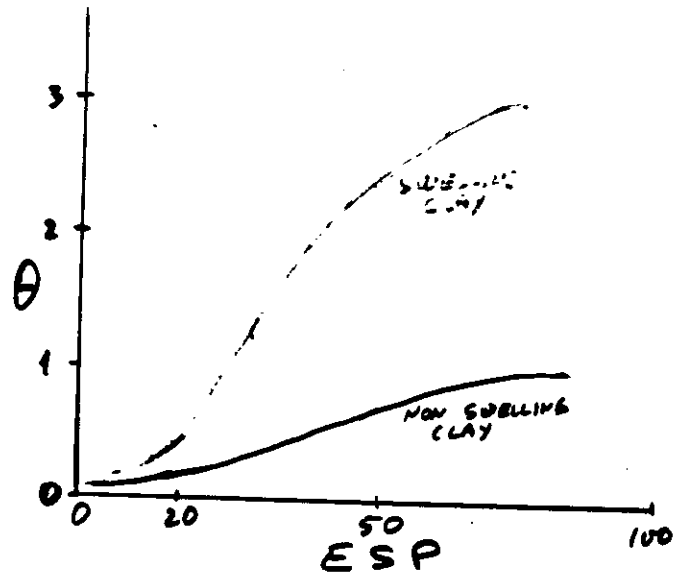


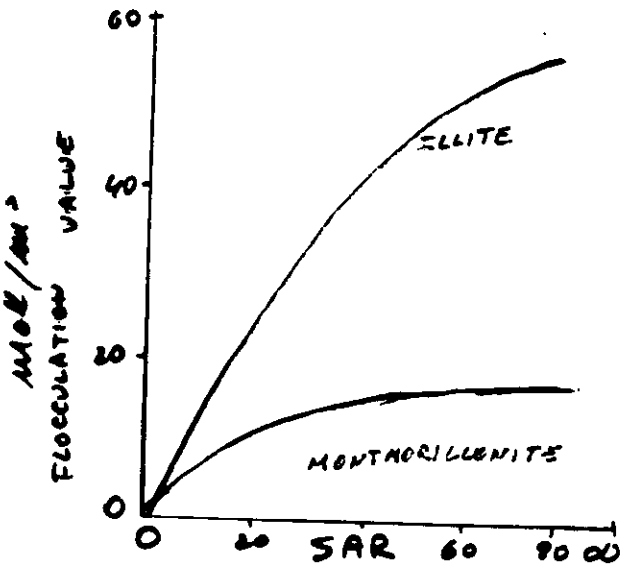


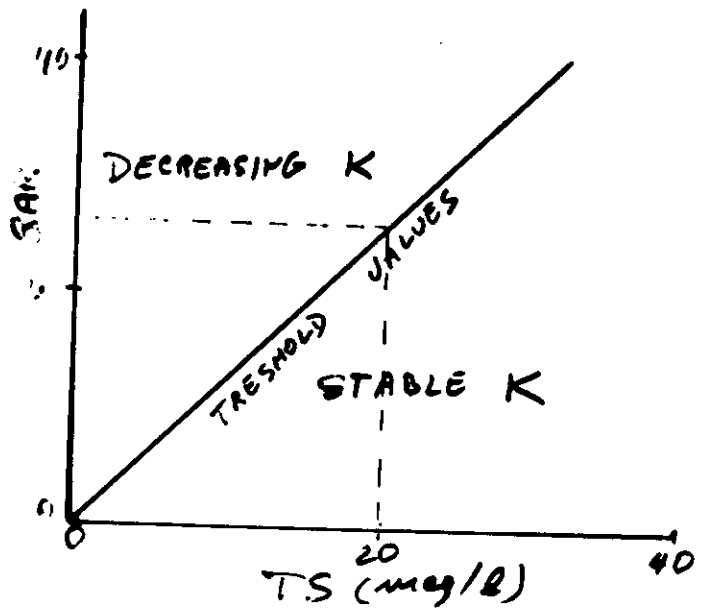


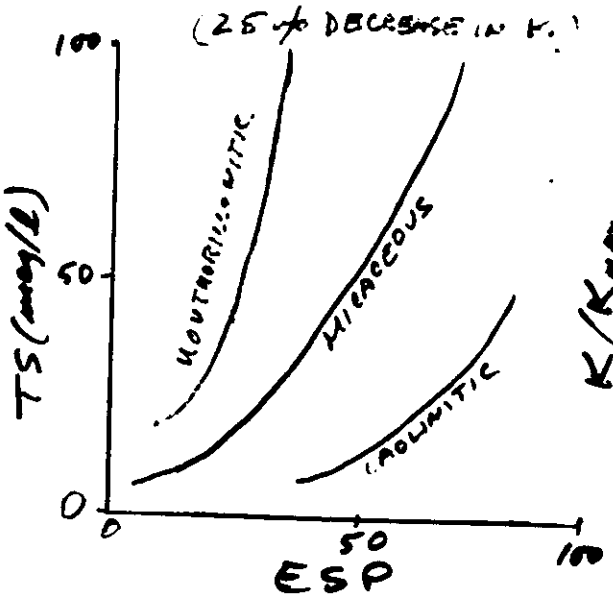
EC	16 ds/m	8 ds/m	4 ds/m
Ψ_0	-6 bars	-3 bars	-1.5 bars.
Ψ_{m+0}	-11 bars	-2.6 bars	-1.6 bars

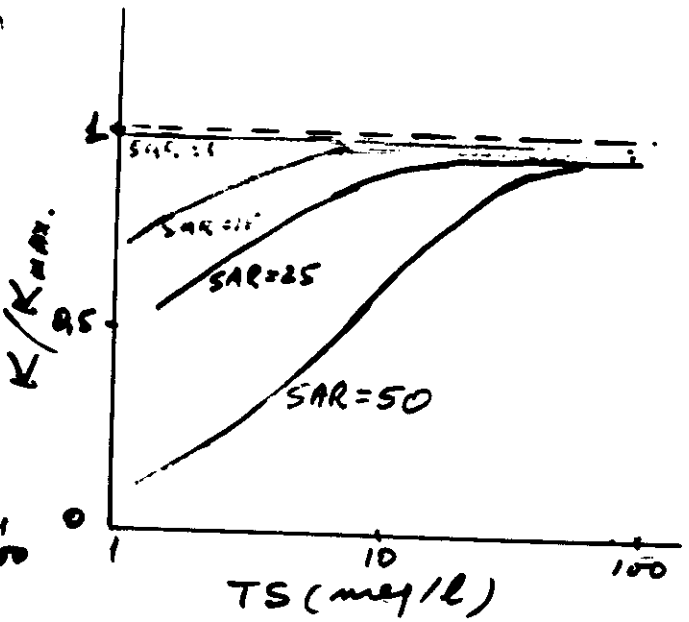

REL. SWELLING PRESSURE
10,0
1,0
0,1
SWELLING CLAY
Na
0,1N
0
θ
6

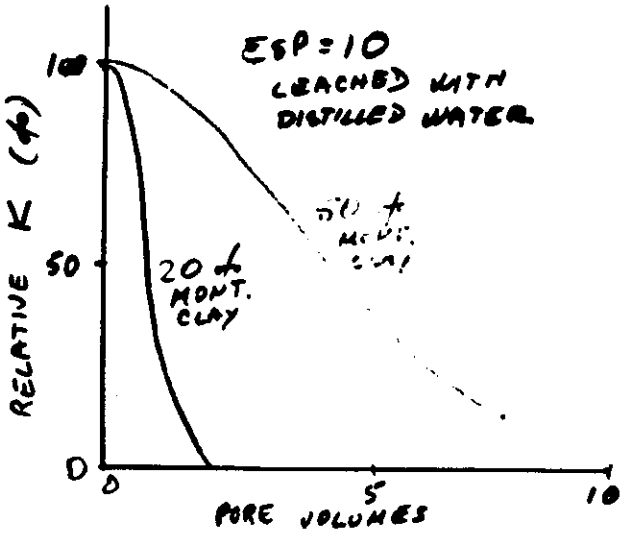

θ
3
2
1
0
NON SWELLING CLAY
0
20
50
100
ESP

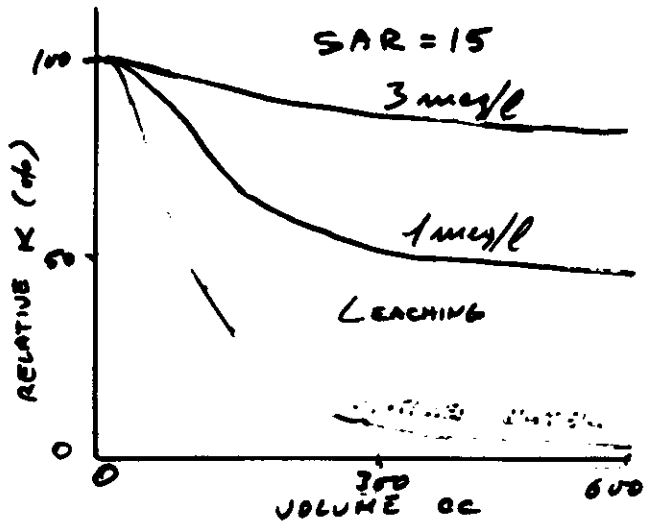

FLOCCULATION VALUE
60
40
20
0
ILLITE
MONTMORILLONITE
0
SAR
60
80
100

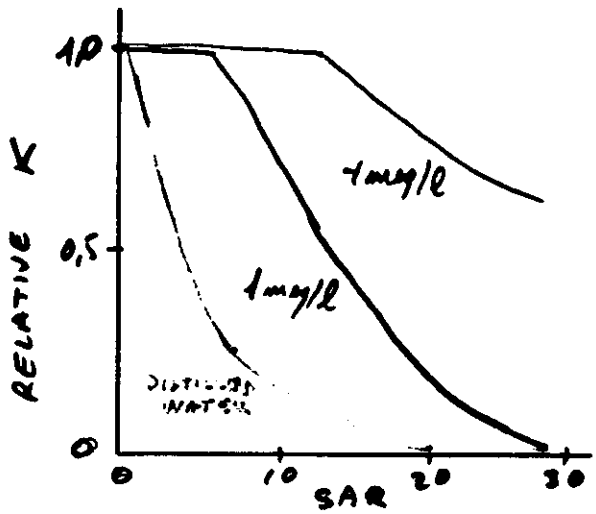

SAR
DECREASING K
VALUES
TRESHOLD
STABLE K
0
20
40
TS (meq/l)

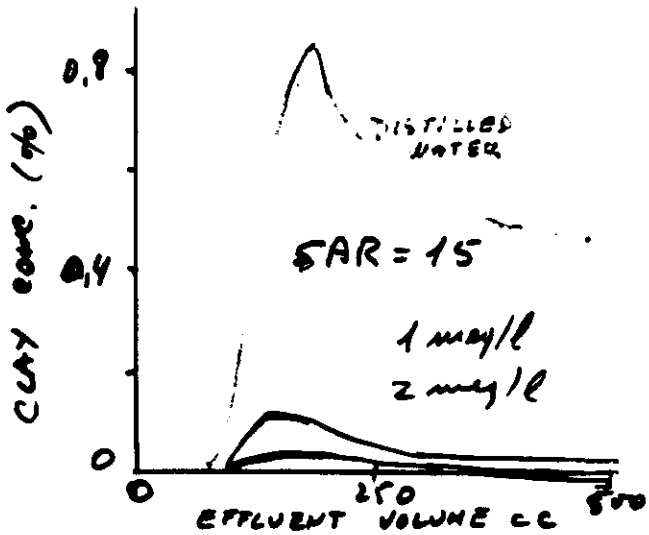

(25% DECREASE IN K)
TS (meq/l)
100
50
0
MONTMORILLONITIC
MICACEOUS
KAOLINITIC
0
50
100
ESP

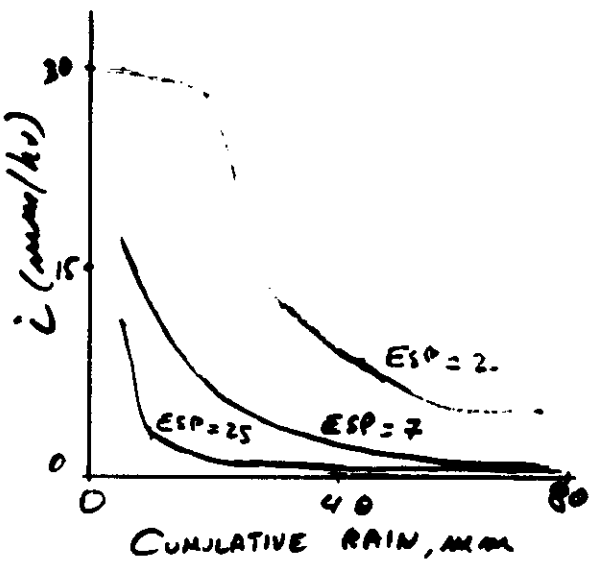

K/K
1
0,5
0
SAR=25
SAR=50
1
10
100
TS (meq/l)

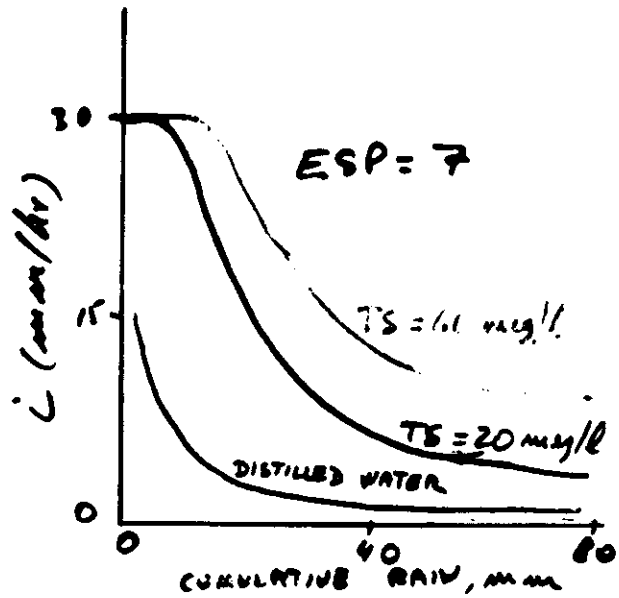

ESP = 10
LEACHED WITH DISTILLED WATER
20 % MONT. CLAY
RELATIVE K (%)
100
50
0
0
5
10
PORE VOLUMES

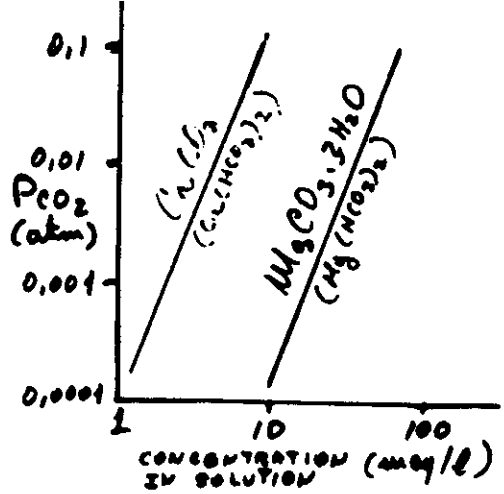

SAR = 15
3 meq/l
1 meq/l
LEACHING
RELATIVE K (%)
100
50
0
0
300
600
VOLUME cc

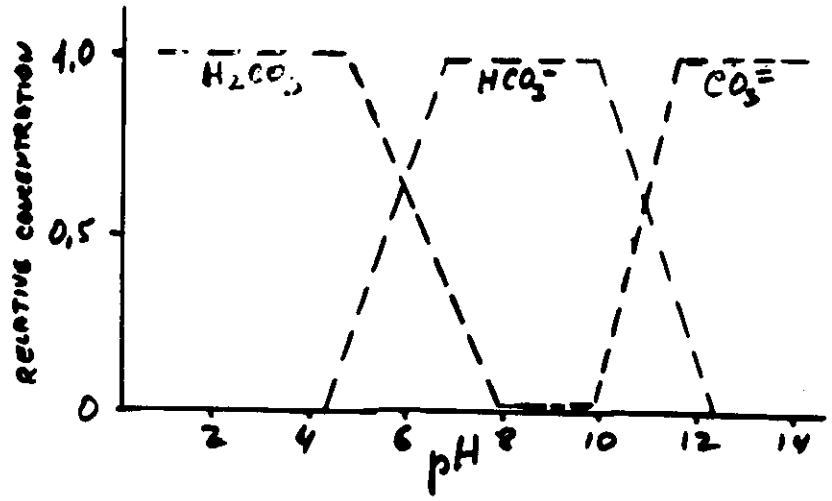

4 meq/l
1 meq/l
RELATIVE K
1,0
0,5
0
0
10
20
30
SAR

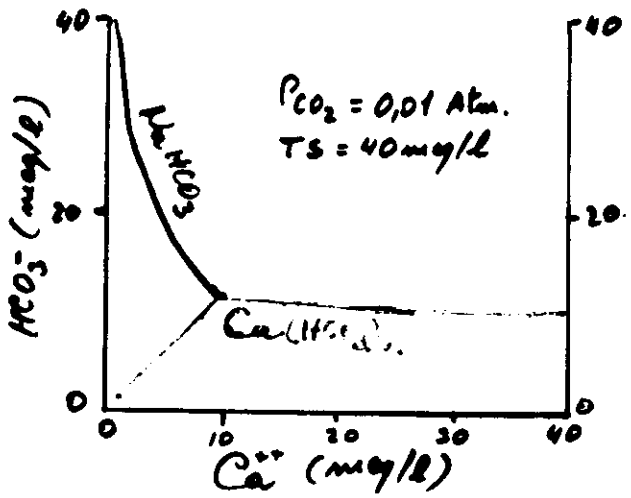

DISTILLED WATER
SAR = 15
1 meq/l
2 meq/l
CLAY conc. (%)
0,8
0,4
0
0
250
500
EFFLUENT VOLUME cc

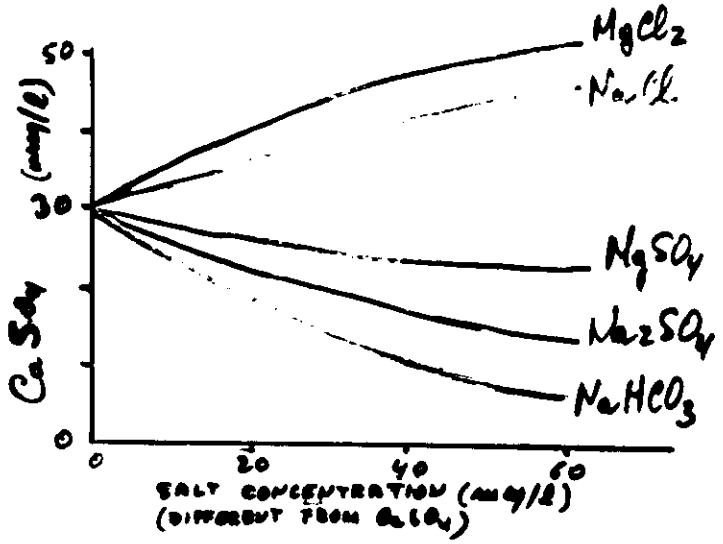

ESP = 2
ESP = 25
ESP = 7
i (mm/hr)
30
15
0
0
40
80
CUMULATIVE RAIN, mm

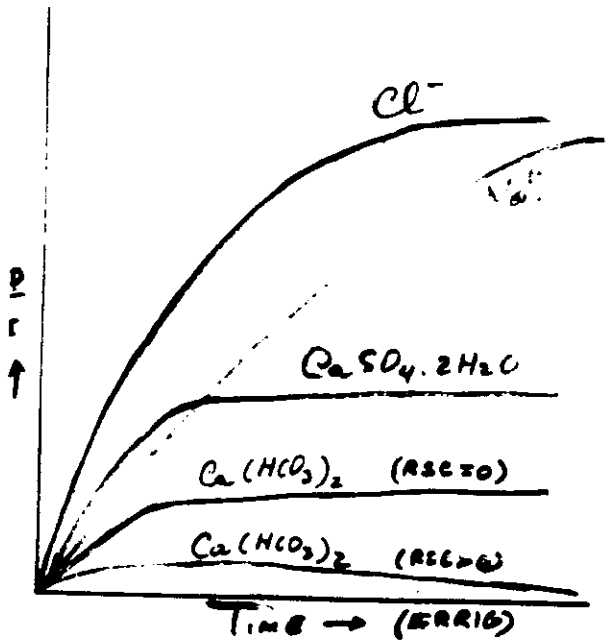

ESP = 7
TS = 161 meq/l
TS = 20 meq/l
DISTILLED WATER
i (mm/hr)
30
15
0
0
40
80
CUMULATIVE RAIN, mm

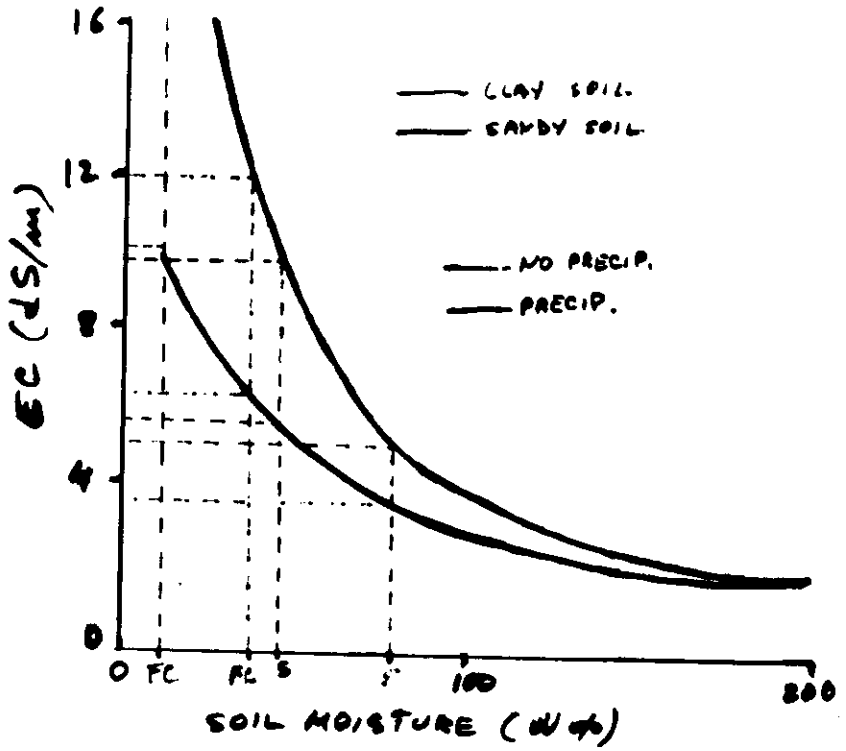

0,1
0,01
0,001
0,0001
P_{CO_2} (atm)
$Ca(HCO_3)_2$
$MgCO_3 \cdot 2H_2O$
$Mg(HCO_3)_2$
1
10
100
CONCENTRATION IN SOLUTION (meq/l)

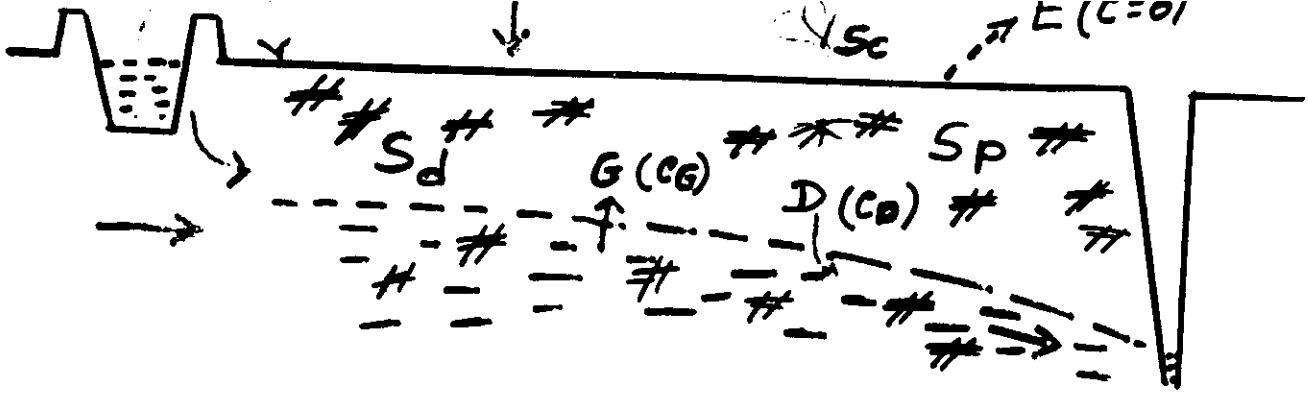

1,0
0,5
0
RELATIVE CONCENTRATION
H_2CO_3
HCO_3^-
$CO_3^=$
2
4
6
8
10
12
14
pH


40
20
0
HCO_3^- (meq/l)
Na_2HCO_3
P_{CO_2} = 0,01 Atm.
TS = 40 meq/l
$Ca(HCO_3)_2$
10
20
30
40
Ca^{++} (meq/l)


50
30
0
$CaSO_4$ (meq/l)
$MgCl_2$
NaCl
$MgSO_4$
Na_2SO_4
$NaHCO_3$
20
40
60
SALT CONCENTRATION (meq/l)
(DIFFERENT FROM $CaSO_4$)


Cl^-
$CaSO_4 \cdot 2H_2O$
$Ca(HCO_3)_2$ (RSC=0)
$Ca(HCO_3)_2$ (RSC>0)
P
r
↑
Time → (IRRIG)


16
12
8
4
0
EC (dS/m)
CLAY SOIL
SANDY SOIL
NO PRECIP.
PRECIP.
0
FC
PL
S
100
200
SOIL MOISTURE (W %)



SALTS BALANCE IN THE SOIL

$$\Delta C_s = H_R C_R + H_G C_G + H_I C_I + S_d - H_D^* C_D - S_p - S_c$$

If: $H_R C_R \approx 0$; $S_d \approx 0$; $S_p \approx 0$, and $S_c \approx 0$

and: $H_D^* C_D - H_G C_G = H_D C_D$

$$H_I C_I - H_D C_D = 0 \quad \text{for} \quad \Delta C_s = 0$$

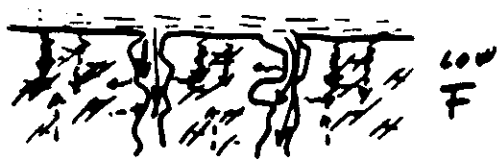
$$H_D / H_I = C_I / C_D = L$$

$$J(\text{gr/cm}^2/\text{sec}) = D(\bar{V}\theta)\frac{dc}{dz} + qc$$

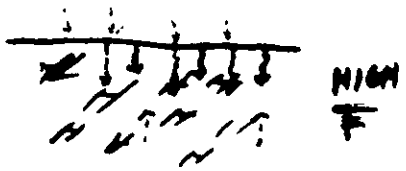
(DIFFUSION / DISPERSION) (MASS FLOW)

$$C_D / C_{SE} = F \qquad L_F = C_I / C_{SE}$$

$$TS_{SE} = TS_I / L\,(T_S)\,F$$



$$NA_{SE} = NA_I / L\,(NA)\,F$$



$$SAR_{SE} = NA_{SE} / (CA_{SE})^{1/2}$$

FROM:

$$H_I = i \cdot T_I \qquad H_{ET} = h_{ET} \cdot T_{AI}$$
$$H_D = h_D \cdot T_{AI} \qquad L = h_D / (h_{ET} + h_D)$$

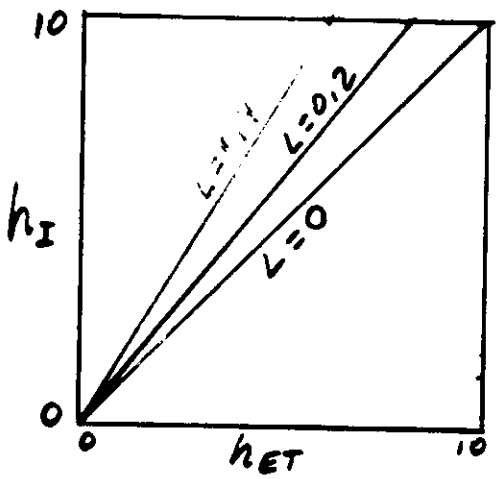
and: $h_D \cdot T_{AI} = i \cdot T_I - h_{ET} \cdot T_{AI}$

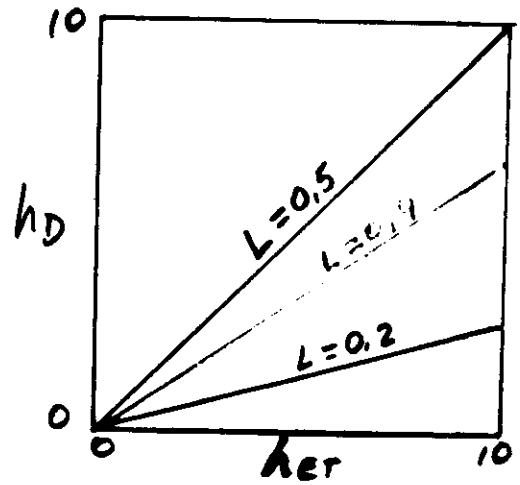
it results:

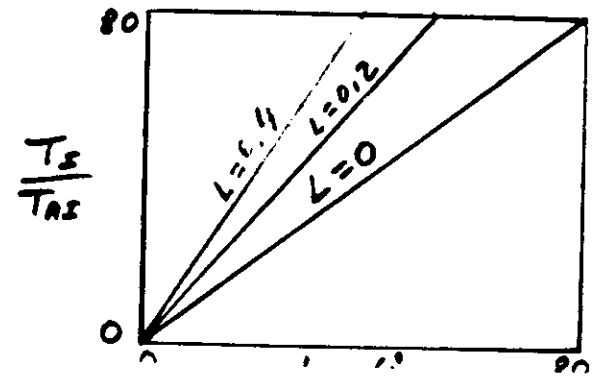
$$\frac{h_I}{h_{ET}} = \frac{1}{1-L} \qquad \frac{h_D}{h_{ET}} = \frac{L}{1-L} \qquad \frac{T_I}{T_{AI}} = \frac{h_{ET}}{i(1-L)}$$

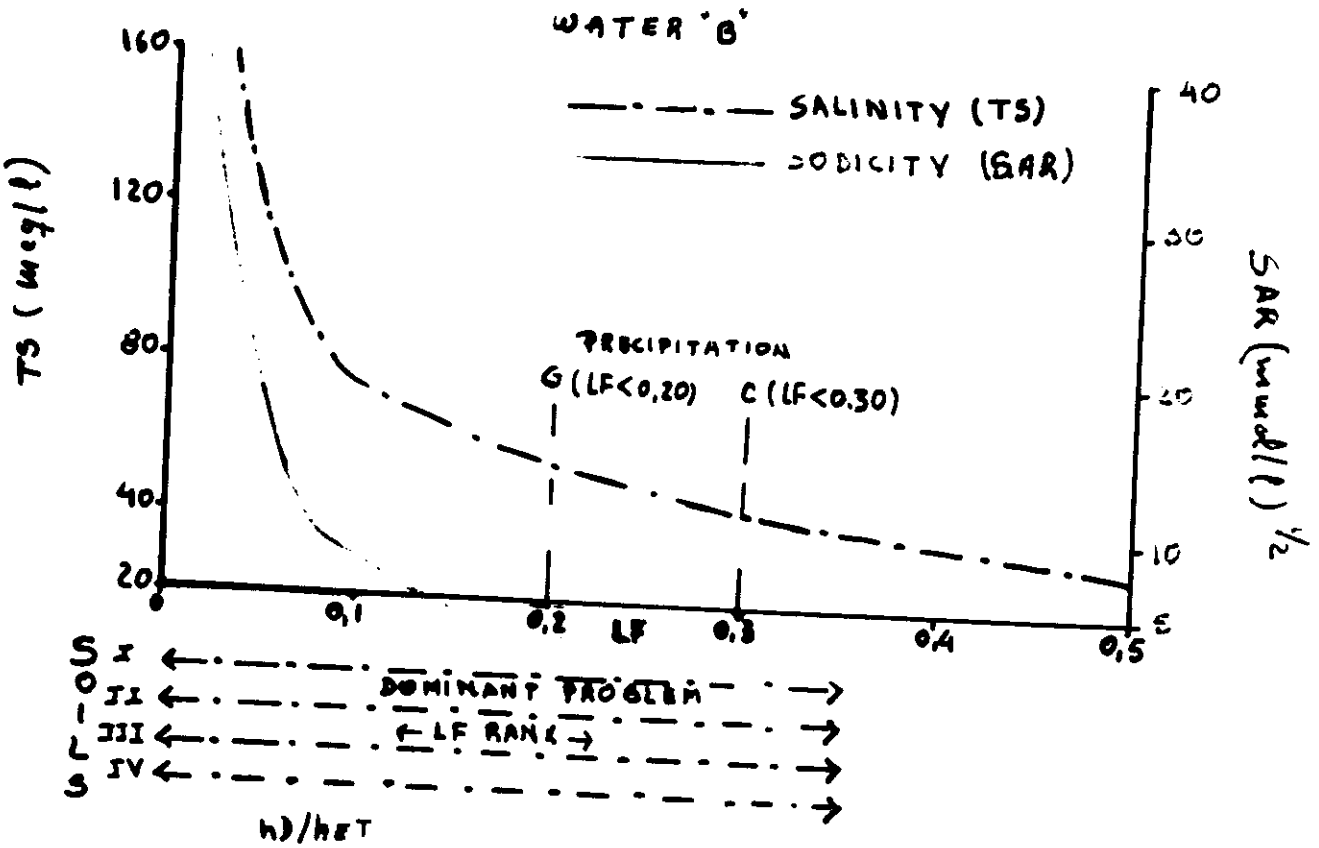
WATER (IRRIGATION) REQUIREMENTS | DRAINAGE REQUIREMENTS | IRRIGATION MANAGEMENT REQUIREMENTS

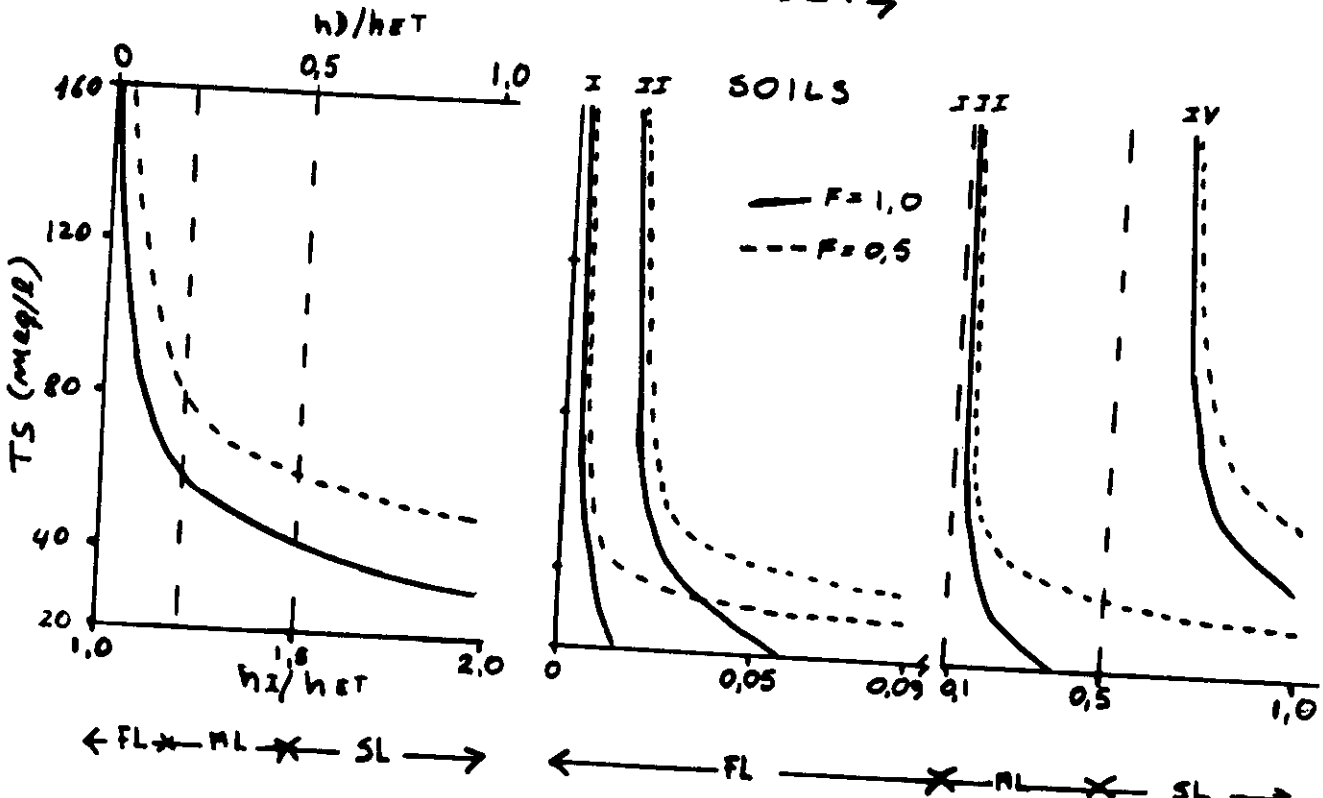
where h_I, h_D and h_{ET} are amounts of irrigation (I), drainage (D) and evapo-transpiration (ET) in length per unit time; L is leaching fraction; i is infiltration rate in length per unit time and T_I and T_{AI} are the times (using the same units) for irrigation (I) and among irrigations (AI).







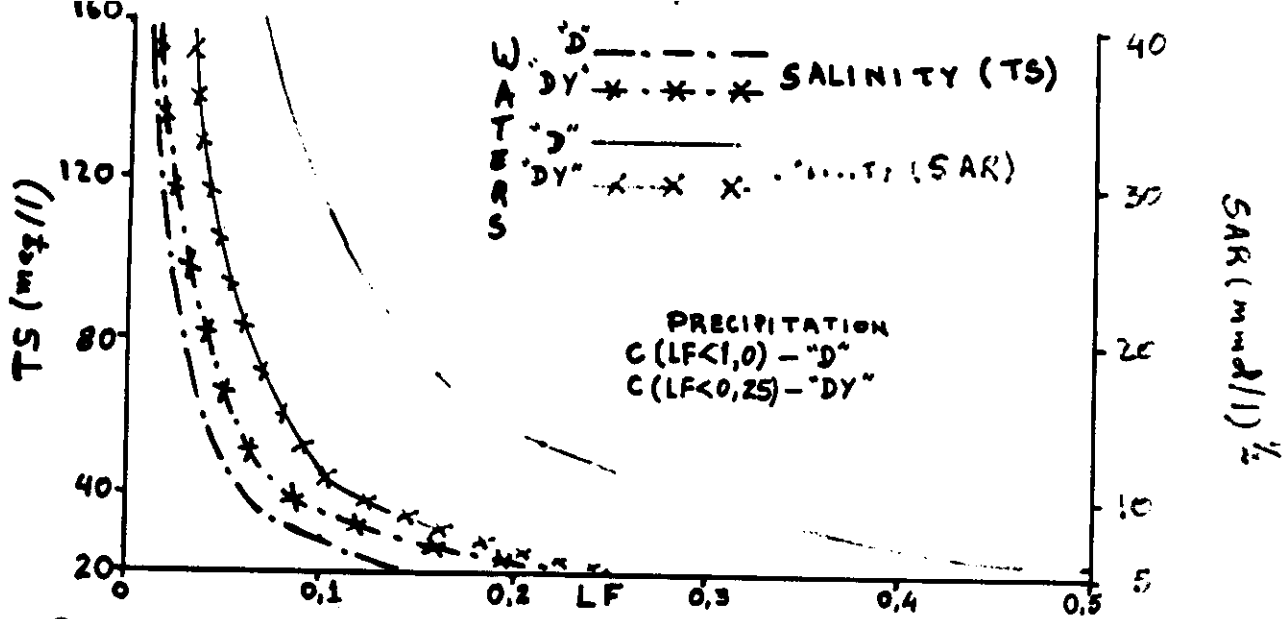


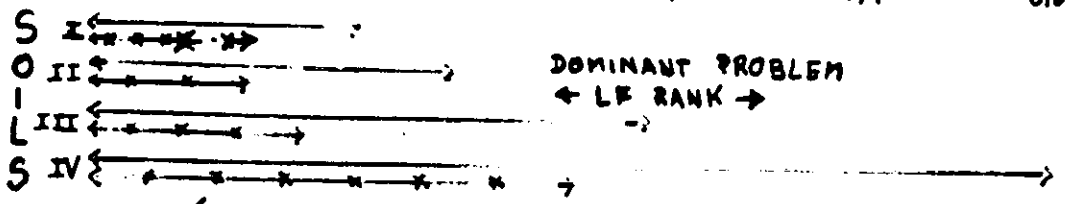


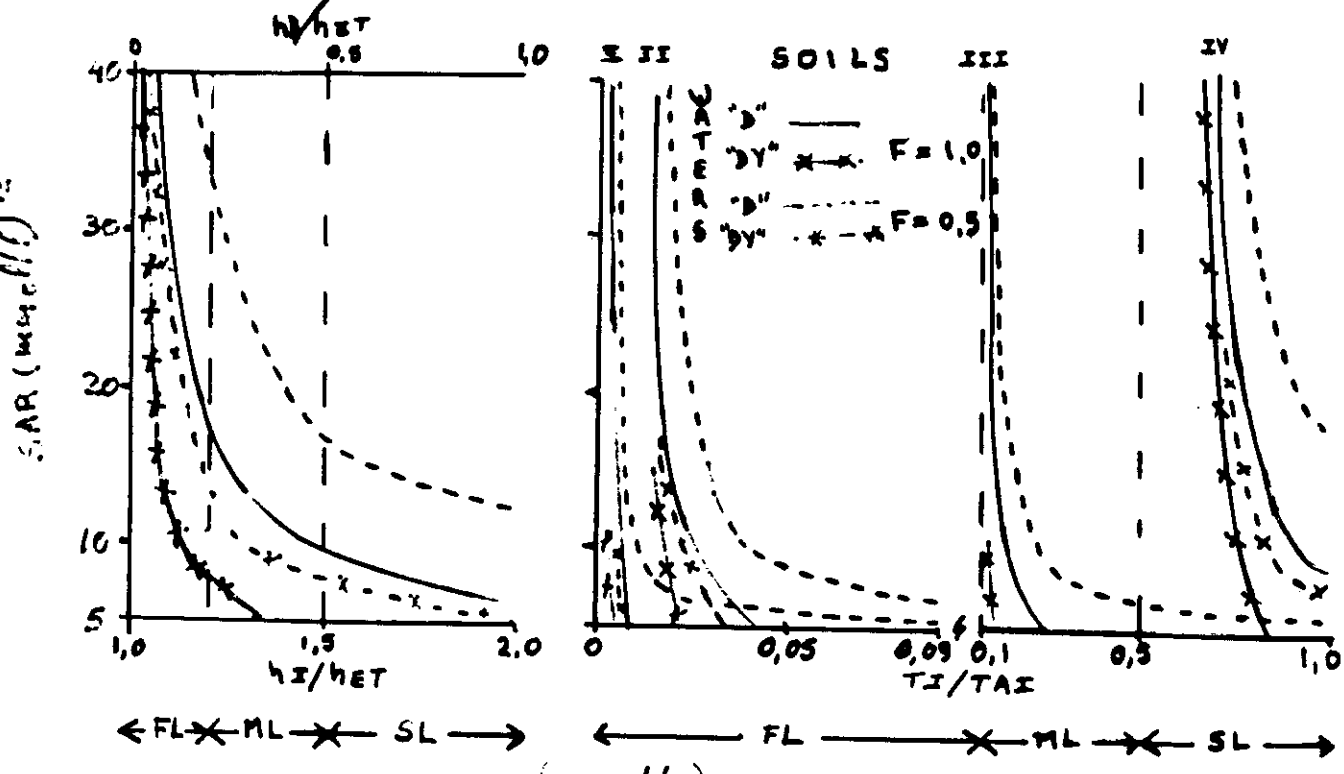
B"

HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+
2,0	2,0	10,0	8,0	3,0	3,0

	I	II	III	IV
i (cm/h)	8.0	2.0	0.5	0.05
TS (meq/l)	Limiting SAR			
40	20	5	10	5
80	20	20	15	10







(meq/l)

	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^{++}
"D"	2,5	1,0	0,5	1,0	0,5	2,5
"DY"	2,5	1,0	1,5	2,0	0,5	2,5