308 --- Q200312100010

Scientific Notebooks No. 068: Stochastic
Project: BIGFLO Modification and Simulations
(03/08/1993 through 12/16/1996)

S149
R
150

129.162.50.12 — ASHOK PC

cf77 filename -o ex ← to compile on INEL CRAY

129.162.200.219 — DIV 20 IRIS

mail abagtzog@sisyphus

Subject: . . .

⋮

CTRL D

mohanty@sebastian.cnwra.swri.edu

ASHOK NEDUNGADI
x 3965

SHAW'S
PIONEERS SINCE 1831

SUBJECT: BIGFLO MODS & SIMULATIONS

PROJECT: 20-5704-053 (STOCHASTIC)

Used by:

Ashok Nedungadi

All work conducted under the auspices of the Stochastic Project. Tasks described in Project Plan.

0 78910 13932 5

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Available in 150 and 300 pages

CNWRA CONTROLLED COPY 068

No Units

Record Ruled, 27 Lines

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[redacted]

BIGFLOW version 2.0
is used throughout

03/08/93

- In NLCOND : J1, J2, J3 & I1, I2, I3 are used inconsistently as well especially if J1 cells are active.
- In NLCOND: when ALFDEV was changed to BTDEV, the code has become inflexible
  - for Vangenucht → need BTDEV
  - for other (as was) → need ALFDEV
  - Not using BTGM anywhere in code.

needs to be corrected if NLCOND is to be made flexible

NLAGA1
NLAGA2
NLAGA3

03/09 IN THETA3ϕ : ACAP(N1, N2, N3)

However in SUBFLO

ACAP (N1CAP, N2CAP, N3CAP)

For LTRANS = ϕ (Steady State)

N1CAP = 1

N2CAP = 1

N3CAP = 1

∴ IN NLCOND, when calling

THETA3ϕ → ACAP(N1, N2, N3)

did this because ACAP was not being passed properly from THETA3ϕ to NLCOND.

∴ NLCOND → ACAP (N1CAP, N2CAP, N3CAP)

because in the original code, Calling routine of THETA3ϕ had ACAP (N1CAP, N2CAP, N3CAP)

This didn't work either.

ACAP defined correctly in THETA3ϕ but when it is passed to NLCOND, I get only "ϕ" ???

NLAGA1, . . 3 = ϕ

NLCOND ← PROBLEM of NPP1/NP1 → THETA3ϕ needs to be corrected in all cases of NLCOND ! Presently, only implemented for case (4).

NPP1 = Tot Nodes

NP1 = NPP1 - 1

N1 = NPP1 - 2

In THETA3ϕ ACAP(J1, J2, J3)

instead (J-1 . . .)

ADDING ANOTHER 3D DIMENSION [MOIST]

VERIFICATION

- W POREFLOW
- W OLD BIGFLO USING BEST GARDNER FIT TO THE VANGEN THAT WE ARE USING

HEAD_TM → messed up.

MIDFLOW — VANGEN TRUE THEN
LD(51) = LD(50) + NPP1 × .. 3
ELSE
Don't add.

- VANGEN needs to be in a common block
- Also dont compute faces of TMOIST if VANGEN is false in THETA3φ

To make the change to ABIG:
(To add): Do the following:

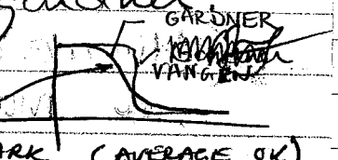
- LD(51) = LD(50) + NPP1 × NPP2 × NPP3
  req array
  MMDIM = MMDIM + MPP1

03/10/93

From INPUT1 (VANGEN STYLE)

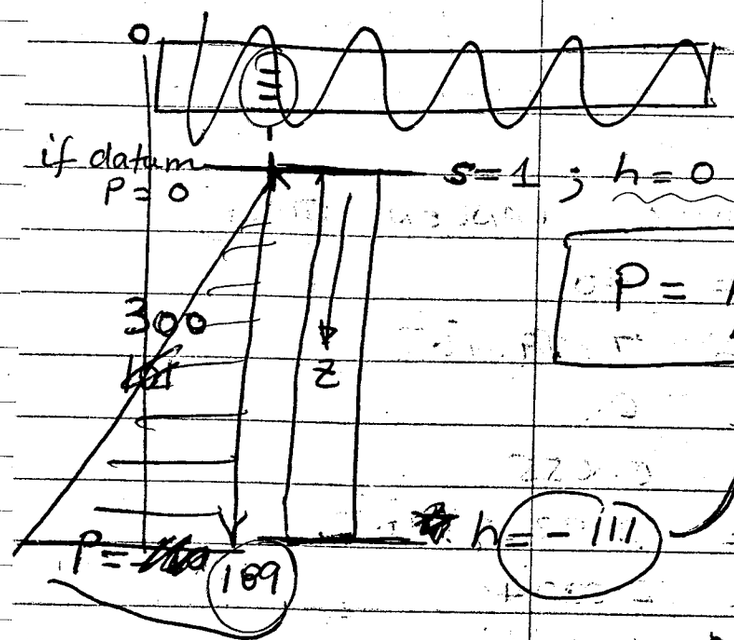
K_{SAT} = 140
α = $7.299 \cdot 10^{-2}$
θ_s = 0.3
θ_r = 0.055
β = $2.9227 \cdot 10^{-2}$
n = 2.0304

We used this above to calculate K(h) vangenuchten then fitted a straight line in semi-log scale to get the $\tilde{K}_s$ and $\tilde{\alpha}$. This was then inputted into BIGFLO with gardner. Compared results.
(OK)



set terminal/width=132/sx

Comparison w. PORFLOW
θ, K Vangenuchten – Mualem



$s = 1$; $h = 0 - 111$

$$\boxed{P = h + z}$$

Initial P = grad..

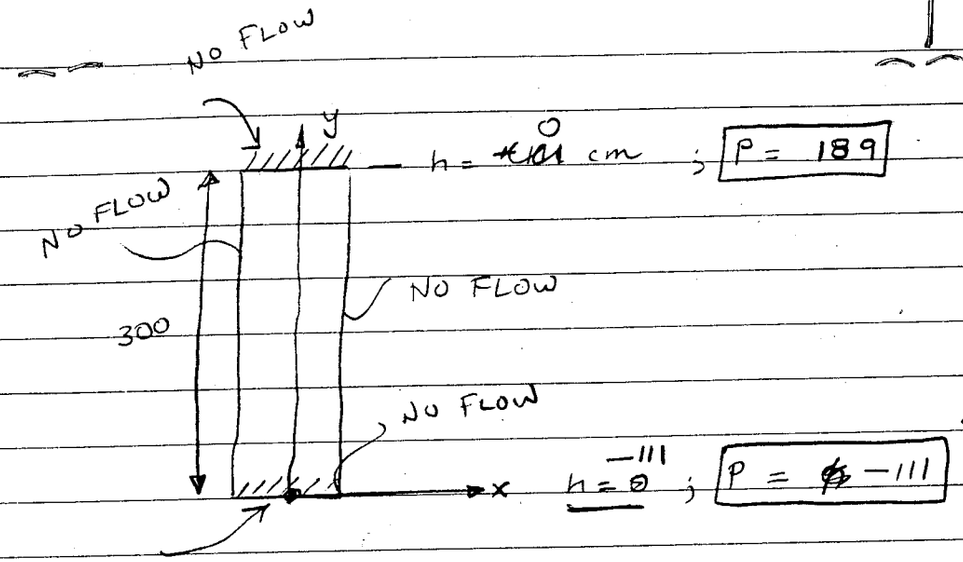
BC $P(z=0) = 0$

$P(z=300) = 189$

Later:

Single Source } compare
Half Ship } Bigflow/porflow

(MULTIFLOW) ← VAN WITH
MULT MUAL



Initial $h = -111$
throughout ✓ grad x = 0,
INITIAL P is -111 grad y = 1

$$\boxed{= \frac{\theta_r}{\theta_s} = S_r}$$

$$\frac{5.5 \cdot 10^{-2}}{0.3} = 0.1833$$

$$\boxed{\text{effective porosity} = \boxed{\theta_s} \overset{!}{=} S_r}$$

θ_r = TOT POR – EFF. POROSITY

θ_r, θ_s } → $$\boxed{S_{r\,porflow} = \frac{\theta_r}{\theta_s}}$$

$$S = \frac{\theta - \theta_r}{\theta_s - \theta_r}$$

$S_r =$ normalized

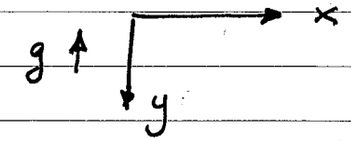
$$S^* = \frac{S - S_r}{1 - S_r}$$

$$\hat{S}^*(h) = \frac{(S - S_r)}{(1 - S_r)}$$

$$S = \frac{\theta}{\theta_s}$$

03/14/93

RAN PORFLOW 1D INFILTRATION WITH G_z (0, −981, 0). IT SEEMED TO GIVE BETTER RESULTS. WE ALSO CHANGED OUR COORD. FRAME, K_s CONVERTED



TO .../SEC TO MATCH WITH g UNITS IN M/SEC^2 AND TIME WAS CHANGED FROM DAYS TO SECONDS.

THESE MODS PRODUCED BETTER RESULTS AND COMPARED WELL W. BIGFLOW

BIG QUESTION: WHY DID G = (0, 981, 0) NOT WORK ALTHOUGH y AXIS IS GOING DOWN!?

Because heads were such that we were forcing flow to take place in the opposite direction of gravity. Vertical infiltration takes places in the direction of gravity!

3/25/93

POR2DREAD:

So that POR2DREAD can process a porflow output file do the following:

① Remove initial "junk" from file

1st Line → I = 1 2 . . .

2nd Line X = 0.5 . . . .

Y UNDE . . . .

[

END needed

→ Empty line Needed

EOF

② Cutoff x must correspond to the number of grids along x, otherwise more nodes will appear with "0" values!

4/1/93

To time ~~ex~~ programs:

Time ~~f~~ executable

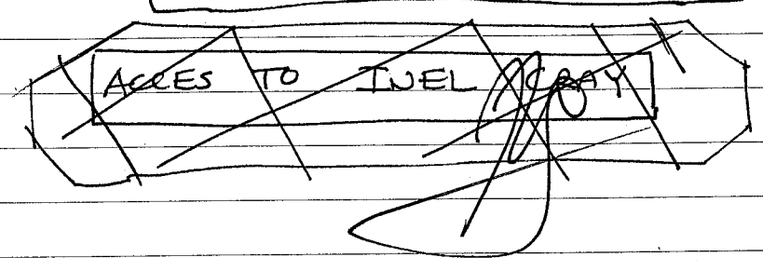
5.97u	OVERHEAD	REALTIME	CPU %

↑ CPU Time in Sec

[Keep all except OUT10, OUTBAD]

OUT11, OUT12, OUT13

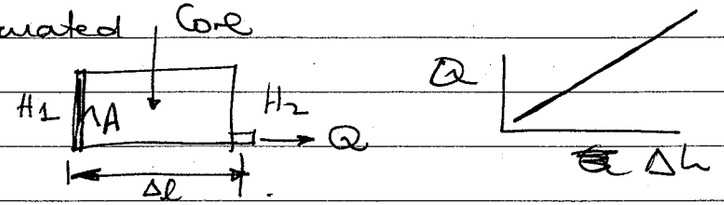
KTYM in OUT13



04/10/93

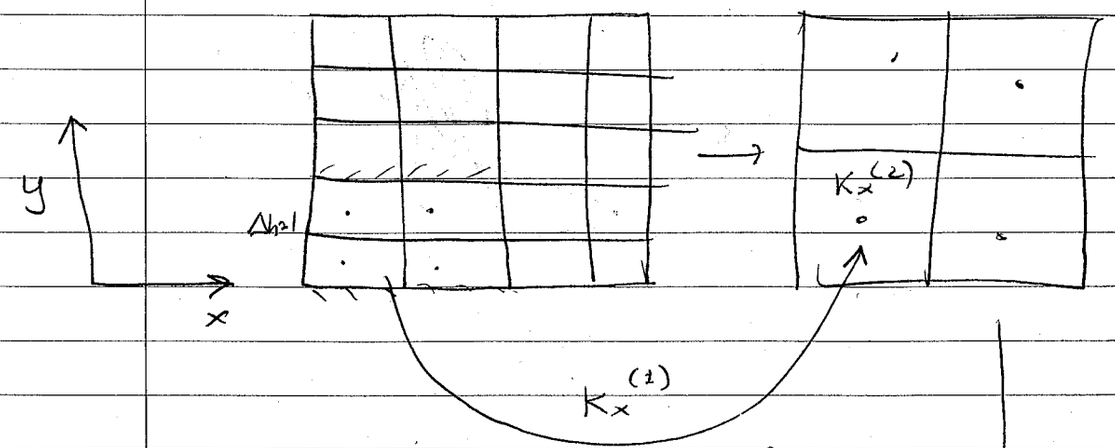
Real Space Renormalization Group Method

Effective properties

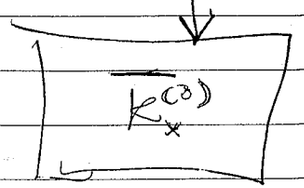


$$Q = K \frac{\Delta h}{\Delta \ell} A$$

"average" value in core
≈ effective



calculate effective k



$\underline{\underline{K}}$ is a tensorial Quantity

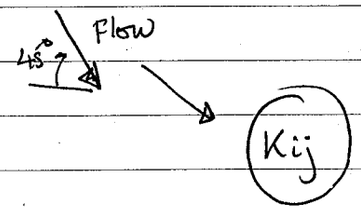
$$\underline{\underline{K}} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$ Symmetric

K_{21}: coupling

anisotropic $\Rightarrow K_{11} \neq K_{22}$

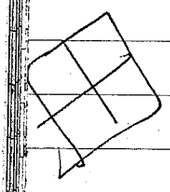
Typically K_{ij} $(i \neq j) = 0$

$$\underline{\underline{K}} = \begin{bmatrix} K_{11} \\ & K_{22} \end{bmatrix} \begin{bmatrix} \underline{\underline{I}}_{2\times 2} \end{bmatrix}$$

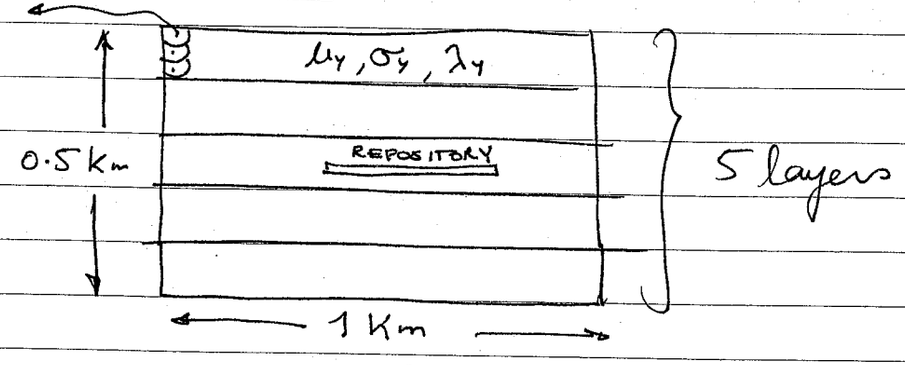


NON LINEAR FLOW / UNSAT FLOW

YUCCA Mnts



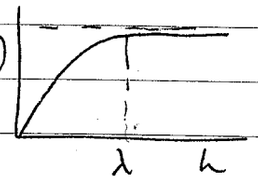
effective property



μ_Y = mean $\ln(k)$

σ_Y = std $(\ln(k))$

λ_Y =



Assume $(\mu_Y, \sigma_Y, \lambda_Y)$ for each layer

CTURN,

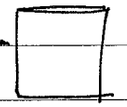
α, β, K_{SAT} (STOCHASTIC)

θ_{SAT}

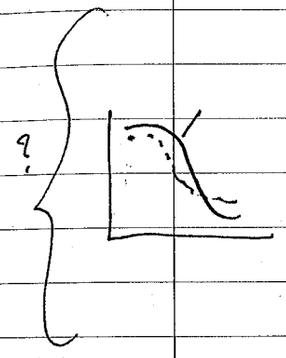
2D

1 Km ⇒ 100 cells

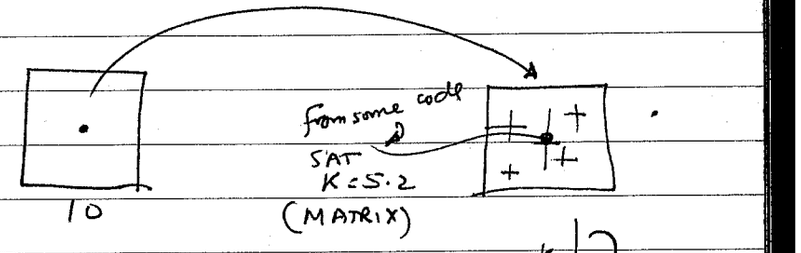
0.5 Km = 50 cells

for each 10m  → conductivity, $\theta(h)$ curve } "Van Genuchten" properties

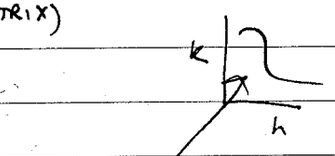
for each of the VG Curves (β, n)



fit for the best VG Curve (IMSL) routines



Need: K_S
α
β
$n=4$



fit the best VG Curve and get θ_S, β

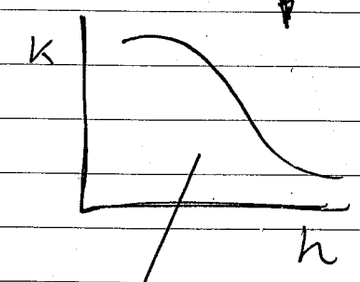
for every 10x10 cm, I will have a mean density and frequency of fractures.

k_{sat}
α
β
n const
mean length of fracture
frequency (isotropic)

semi-analytic

(anti correlated)

after summer activity



fit best β, θ_s for Vanguechten

This is how the property of the 10x10 domain

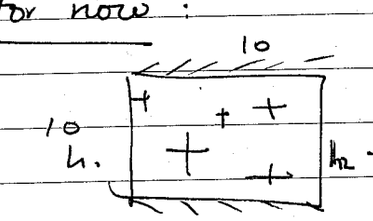
Water travel time uncertainty

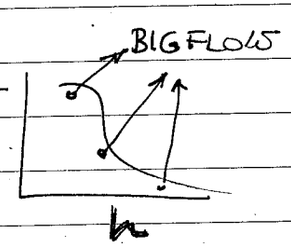
Parameter Variability

Multiple Simulations

Multiple transport paths and velocities

For now:





(Sisyphus)

semi

~~pre~~ code

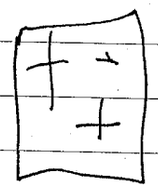
data

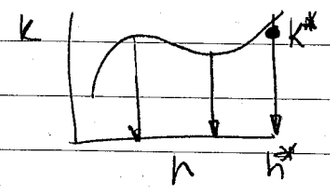
α
β
K_{sat}
} in "BIGFLOW" format

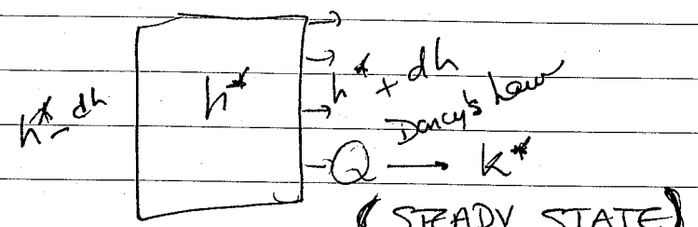
INEL

NUMER / BIG / C1000

extract → OUT13
QAB







(STEADY STATE)

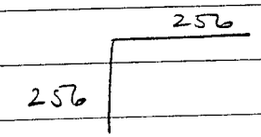
BIGFLO DATAFILES:

IN1
INPUT2
INPUT3
INPUT4
~~INPUT5~~ IN5
~~INPUT6~~ IN6
INPUT7
IN8
INPUT9

4/12/93
/semi/code
FRACGEN 4 } Random Fracture Generator
FRACGEN 5
FRACRG2D
FRACVAR 6
SEE README

RELPRMVG4 UNSAT COND FOR BINARY COND FIELD

4/15/93 f77 file.f -o ex.x



nnx = 64 } 256
imult = 4

>> 1 input data interactive
>> 2 No of Realizations for variogram
>> .0025 horz frac density
>> 1 Frac. center distribution < random 0, expo 1 ← some difficulties
>> 2 { frac length distribution 0, 1, 2
>> .7 Vert frac Density (1) → for every vert fract ∃ a horz frac
>> 0 { cluster center loc. 0 .. fixed center, 1 ... random loc

Plot variogram

Recommended: Do NOT EXCEED 10% of frac Vol.

1 ← effective properties (SATURATED) < 0 No / 1 yes

1 ← deter unsat cond < 0 / 1

(1) ∅ Ave. cond ? < 0 / 1

1 Superimpose fract

image

mag factor 7)

*. lis = OUTPUT FILES

OUTPT1. LIS ⇒ ~~UNSAT~~

OUTPT4. LIS ⇒ UNSAT K(h)

SOE1 SOE2 AVE SOE1 SOE2 head θ norm Uns K Ph

Unsat K phase II Ave KI/KII

Uns K Phase I

K phase II KI/KII

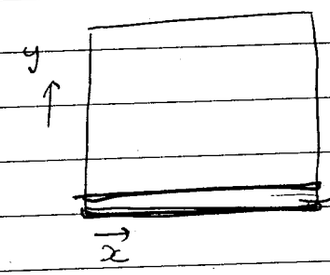
(Image of matrix & fracture)!

White → highest conductivity
Black — lower "

(NEED) OUTPUT2D.DAT — actual Matrix Kond. @ node.

↓ scaled if necessary

OUTPUT2D1.DAT



first blk in OUTPUT2D-DAT

FRACMAT.DAT

final composition of matrix & fracture SATURATED K @ node

FRAC1.DAT PORTION of field
FRAC2.DAT (?)
FRAC3.DAT (Same as FRAC1)

GARBAGE (DONT worry)
OUTPUT.LIS — (NOTHING IN IT)
OUTPT1.LIS

OUTPT2. LIS (nothing)
OUTPT3. LIS effective Sat Kond.

OUTPT4. LIS Unsat K

OUTPT5. LIS (NOTHING)

DIST1. LIS output (Don't Worry)

i Sirl Soeang heak thik Hare

dist2

relprmdist2 (dist2.lis)

an

an

relprmdist2 (fracmat.dat)

relprmdist1 (fracmat.dat)

4/15/93 CONTD

MODIFYING Fracvar6.f

15 main (fracmat.dat) [unsat K]

unit 7 main (frac1.dat)
relprmdist2 (head_d2.lis)

17 fracvg2d1 (output3.lis)

unit 16 main (frac2.dat)

unit 12 main (frac3.dat)
relprmdist2 (BETA.DAT)

8 relprmvg4 (outpt4.lis)
relprmdist1 (dist1.lis)

unit 11 main (garbage)
RELPRMDIST2 (ALFA.DAT)

unit 9 main (output.lis)

unit 10 main (outpt1.lis)
fracvg2d1 (outpt5.lis)
RELPRMDIST2 (KSAT.DAT)

14 main (outpt2.lis)

19 main (output2d1.dat)

Running fracvar6

Inputs:

>> 1 Usr to input data interactively
>> 2 Number of Realizations
>> 0.0025 horz fracture Density
>> 1 fracture center distribution
>> 2 fracture length distribution
>> 1 Vert. fracture density
>> 1 cluster center location

Code OUTPUT

>> 0 Plot Variogram
>> 1 Effective properties ?
>> 1 Determine unsat conductivity
>> 1 Distribution of Conductivity

... Superimposing fracture on matrix ....

>> 1 Method A or B

iter Seemin seeavg hh θ k-Kunve

>> 0 Image of fracture network ?

following files were found to be empty:

output2.lis
output.lis
garbage.dat

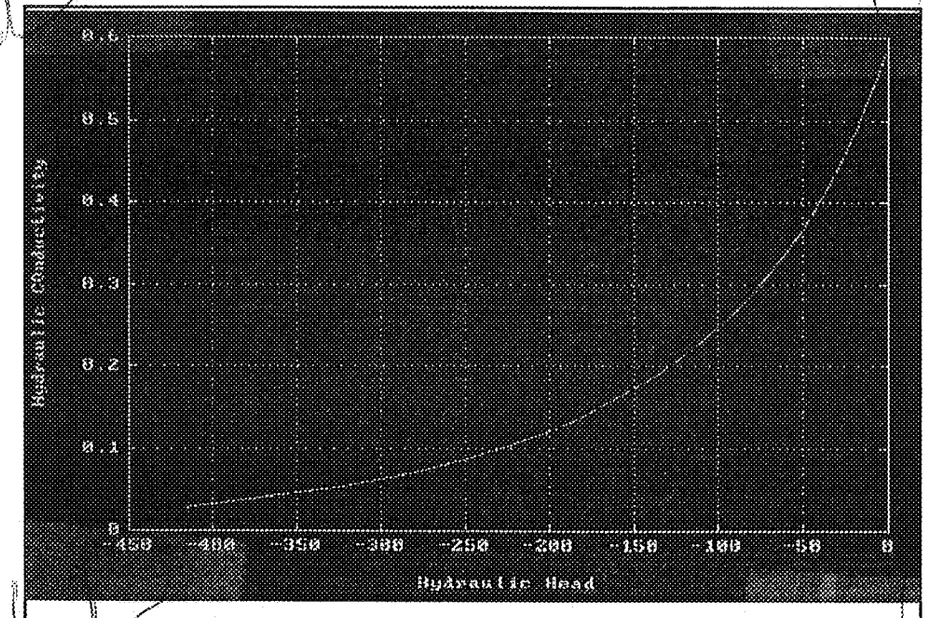
Questions:

? ONLY 16 NODES IN x

SUBROUTINE RESIZE ← FORMAT (1X, 16F8.4) ?

WRITE (19, 101)

"OUTPUT2D1.DAT"



4/16/93 BIGFLD

4/16/93 BIGFLO

OUT 13 → STEADY STATE

∴ $Q_{A1} = Q_{B1}$

$$Q_A = \left(q_F\right) A = \left(\bar{K}\,\frac{\Delta h}{\Delta \ell}\right) A \quad *$$

EXTRACT

OUT13

↓

(INDEX) (QAB) KSA[illegible]

ER FOR ALFA (INPUTS), BETA(

for

Header BIGFLOW [illegible]

IDNxx IDPTxx LFILxx [illegible]

KTYMxx TYMxx

NXX1 NXX2 NXX3

DXX1 DXX2 DXX3

GRVX1 GRVX2 GRVX3

TXXM TXXDEV FXXL1 FXXL2 TXVL3

→ FKGM → FKDEV → FKL1 → FKL2 → FKL3

EMPTY LINE

-200, -50, -100

RAN BIGFLOW FOR

HIN = -100

— 98 — 102

64×64×3

CP: 1248.245s / Wall clock: 2054.159s

FOR EXTRACT:

KTYM must be total

KTYM − 1 (from OUT 3)

BIGFLO → $Q_{FA1} \cdot AREA1 = QA1$

∴ comparing *:

@ -100 = h

$$Q_{FA1} = \frac{\bar{K}\,\Delta h}{\Delta \ell}$$

64

64

$$\therefore \bar{K} = \frac{\Delta \ell \cdot Q_{FA1}}{\Delta h} = 64 \cdot \frac{0.014}{4} = 0.224$$

$$q_F = \frac{Q_{HA1}}{A_1}$$

1

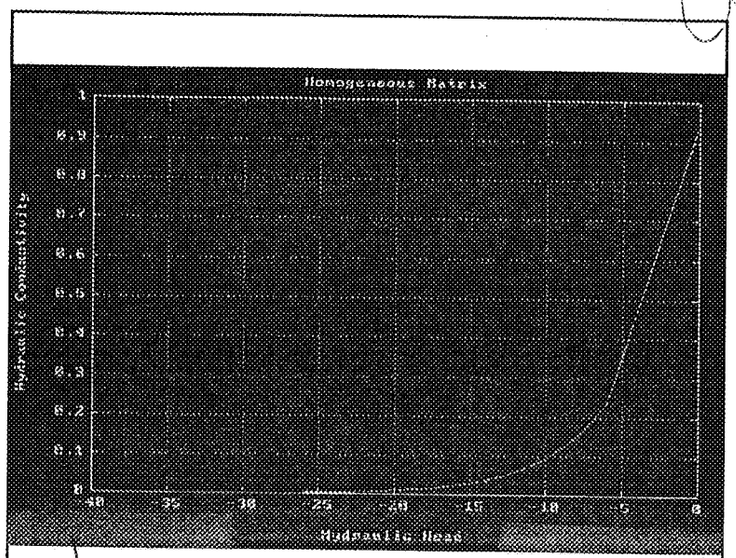
$A_1 = N2 * N3 * DX2 * DX3$

$$q_F = \bar{K}\,\frac{\Delta h}{\Delta \ell}$$

$Q_{A1} = 0.88$ $q_{F1} = \frac{0.88}{192} = (4.583 \cdot 10^{-3})$

→ Try a homogeneous matrix !!!
Method B

Ashok



Ashok

Ashok

Ashok

alfa1 } → fracture
Beta1 } (1)

Didn't do any further. Sita Kanta is still working on the subroutine.

Homogeneous Method B

	h	K	
1	−5	.208	
2	−10	.074	(not completely steady state)
3	−15	.027	1804 CPU
4	−20	.0095	
5	−25	.003144	1831.75 CPU

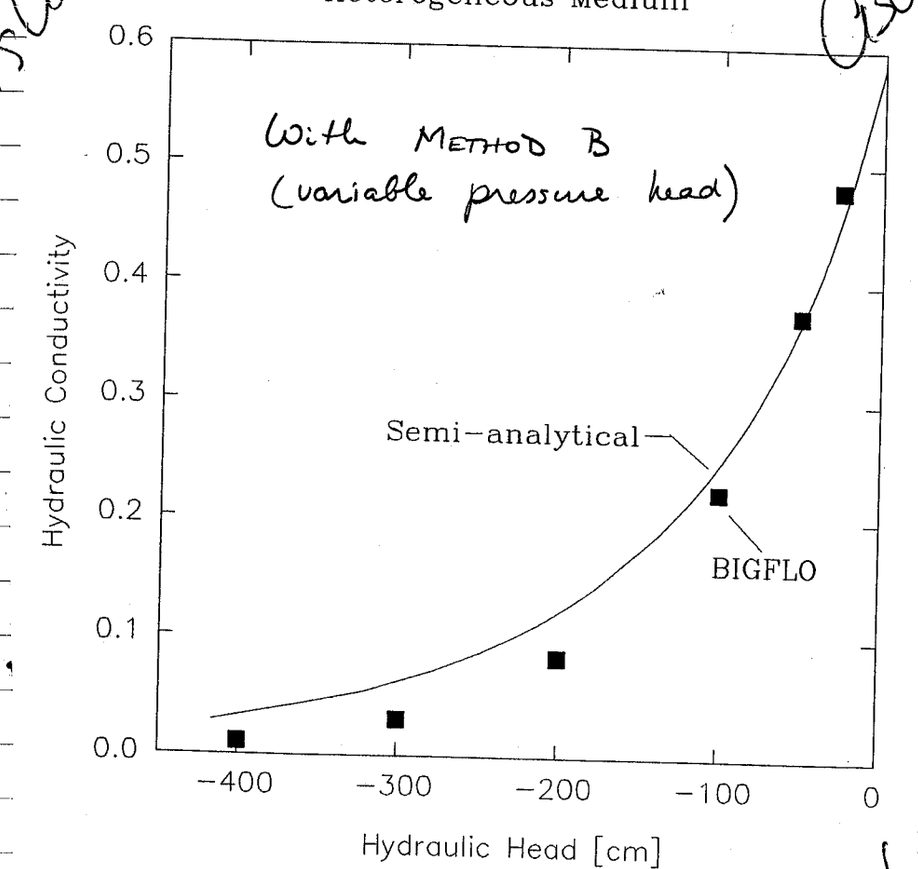
homogeneous Method B

BIGFLOW SIMULATIONS

1. $h = -100$ cm → $\bar{K} = 0.2240$
2. $h = -50$ cm → $\bar{K} = 0.3744$
   $\frac{.0237 * 64}{4}$
3. $h = -200$ cm → $\bar{K} = 0.0835$
   $\frac{.00522 * 64}{4}$
4. $h = -300$ → $\bar{K} = 0.0307$
   $\frac{.00192 * 64}{4}$
5. $h = -400$ → $\bar{K} = 0.0113$
   $\frac{.000707 * 64}{4}$
6. $h = -85$ → $K = 0.48096$
   $(.03006 * 64)/4$

NOTICED:
The higher the suction, the faster BIGFLO converged.
i.e. The further away from $h = 0$, the more ~~iterations~~ time reqd ~~for~~ to converge.

Ashok



4/30/93

Mods to BIGFLO & FLOPROC to incorporate heterogeneous "n" when using Van Genuchten.

VGNMAT VGNDEV

NVAN1, NVAN2, NVAN3

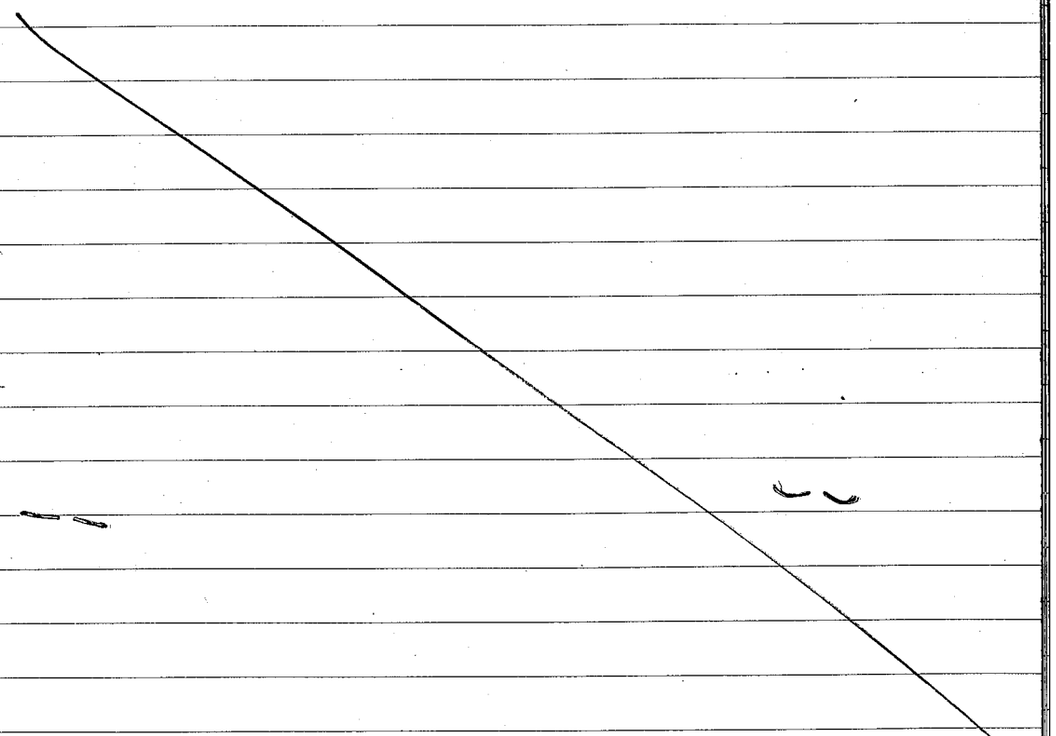
INPUT1ϕ

TOT GRIDS

MI = NGRID1 − 2

MPI = MI + 1

MPPI = MI + 2 = NGRID1



Reading a PORENDID OUTPUT IN MATLAB

```
for j = 1:ny
  for i = 1:nx
    h(i,j) = mat((j-1)*nx+i,3)
  end
end
for j = 1:ny
  for i = 1:nx
    lmp = mat((j-1)nx+i,2)
  end
  y(j) = lmp
end
for i = 1:nx
  v(i) = mat(i,1)
end
```

2D MAT

y vec

x vec

5/3/93 Printing from MATLAB

1. print (within MATLAB)
2. rename *.ps (mv *.ps → ?ps.)
   remove *.met.
3. lpqps ?.ps → (sends to printer)

5/5/93 TESTING heterogeneous "n"
Modification of BIGFLOW

ZONE 1	ZONE 2
$\beta = 0.05$	$\beta = 0.06$
$n = 3.872$	$n = 2.5$
$K_s = 1.112 \cdot 10^{-3}$	$K_s = 2.24E-5$
(NOTUSED) → $\alpha = 0.1258$	$\alpha = 0.0839$

$\theta_s = 0.4411$
$\theta_r = 0.0189$

Timing BIGFLOW
⟹ 13347.9647 u 255.4118 s 4:19:34 87 %

Timing PORFLOW
2460 u

5-10-93

Without any changes to new version of BIGFLOW (this version ~~xxxx~~ is able to process variable "n"):

~~1305.348 CPU 22.54665 23:58 92%~~

SIMULATION TIME 353 SEC

(1) → 623.65 CPU 11.868 11:22 93%

Changed SUBROUTINE THETA3Ø CASE (6) SO THAT IF STATEMENTS ARE OUTSIDE DO LOOPS ! BIG1.FOR → BIG1.EXE

(2) → 614.05 CPU 7.322 12:48 80%

Changed SUBROUTINE NLCOND CASE (2) SO THAT IF STATEMENTS ARE OUTSIDE DO LOOP ONLY FOR INTERNAL ~~*~~ NODES. BNDRY NODES OLD WAY

(3) 248.72 CPU 6.16s 6:15 67%

Changed NLCOND CASE (2) SO THAT IF STATEMENTS ARE OUTSIDE DO Loop ~~ONLY FOR I~~ FOR BNDRY NODES AS WELL

(4) 152.36 CPU 3.07 5:03 51%

(5) TOTAL SIMULATION NOW TAKES:

3419.35u 39.74s 1:49:03 52%

5-11-93

Comparing HEAD FILES concludes:

(1) There is a difference in the 5th digit after the comma!

ex: HEAD_T1 → -76.52801

H1 & HEAD_T1 H1 → -76.52800

(diff. H1)

(2) H2 & HEAD_T2 revealed same as above (diff. H2)

(3) H3 & HEAD_T3 had differences in the 2nd digit after the comma

ex: HEADT3 → -8.723324

H3 → -8.726127

as (diff. H3)

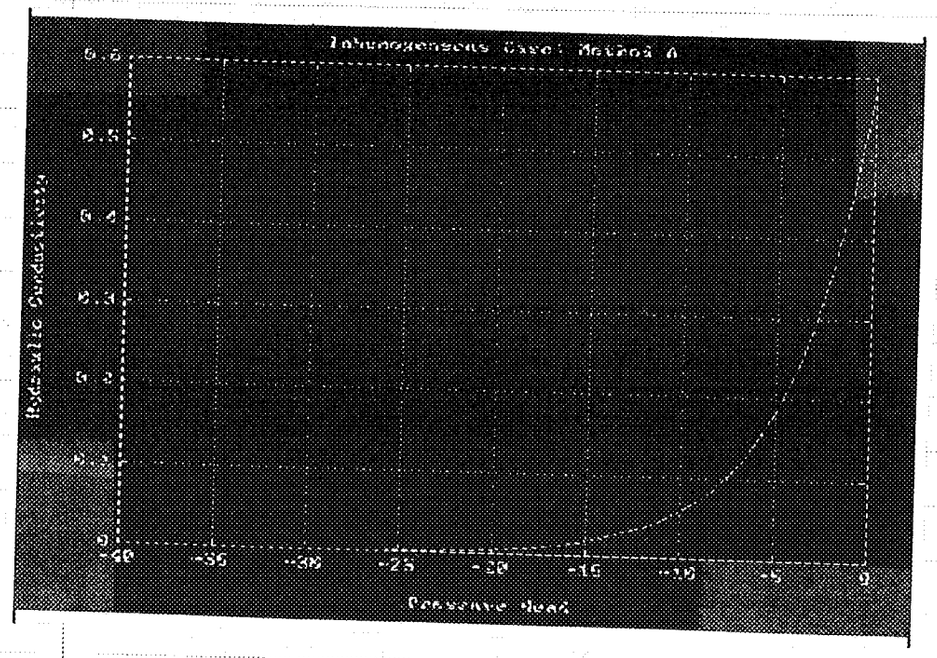
NO

(4) Differences between OUT13 & 013

BIGVAR was run again and all files ~~xxxx~~ HEAD* compared to same generated by BIG1 (version in which IF statements outside DO Loops)

Method A :

inhomogeneous



BIGFLO Simulations

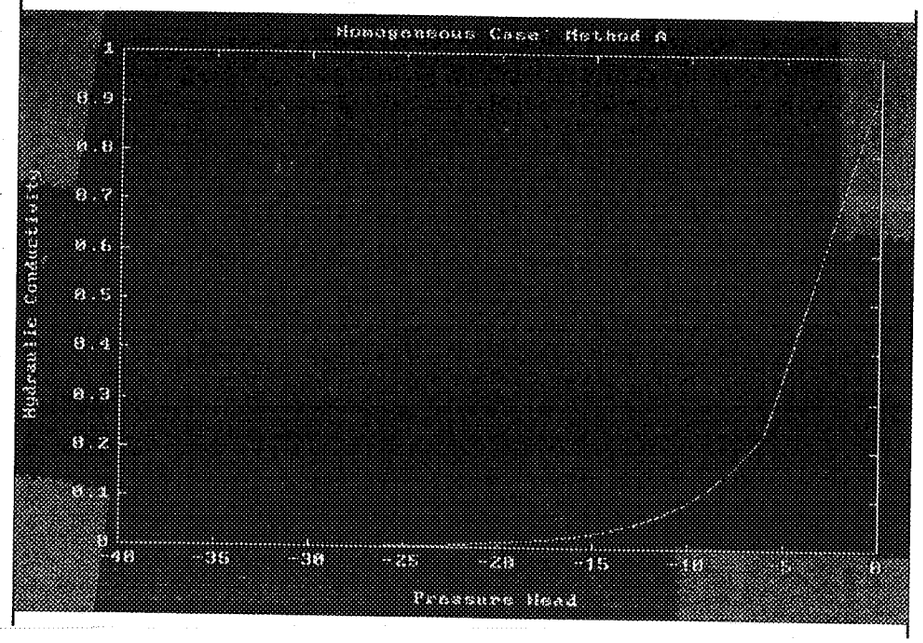
	h	K	K (scaled as in fraction!)	
①	−5	0.2144	.093	1790 CPU
②	−10	0.077	.013	
③	−15	0.029	$1.82 \cdot 10^{-3}$	
④	−20	0.010	$2.58 \cdot 10^{-4}$	
⑤	−25	$3.33 \cdot 10^{-3}$		

⑤ ④ } 0.3058
h = −2 }

same observation as (A)

Method A

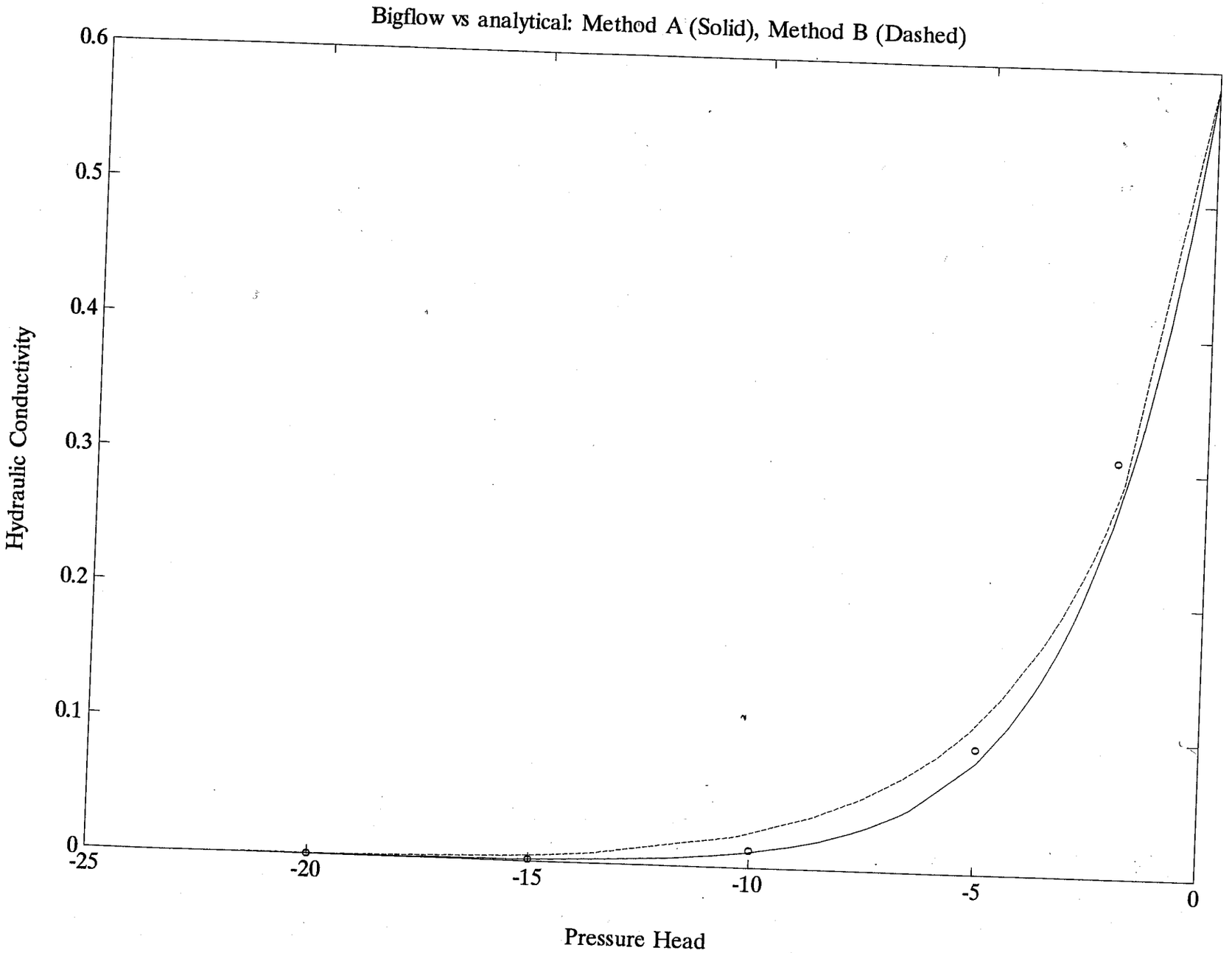
Homogeneous



BIGFLO Simulations

	h	K
①	−5	0.208
②	−10	0.0736
③	−15	0.0272
④	−20	9.6 E-3
⑤	−25	3.12 E-3

(A) ← The further away from h = 0, the more (time) iterations required for steady state


Bigflow vs analytical: Method A (Solid), Method B (Dashed)
Hydraulic Conductivity
0.6
0.5
0.4
0.3
0.2
0.1
0
-25
-20
-15
-10
-5
0
Pressure Head

OW

5-26-93 REALISTIC DATA

Yucca Data [·5 fracture/m min ; average = 0.8 fra/m
Max = 4.3 fract/m

fracture density in fracvar ?
~ No of centers per domain
(tot No Nods)

Area fracture density

$\cdot 0025 \times (\cancel{64})^2 \approx \cancel{10}$ centers ✓
check with number of centers ✓

If 128 × 128 domain = (10 m × 10 m)
then fracture aperture ~~= 6 cm~~ 7.8 cm

$$\frac{1}{128} \times 10\,m = 7.8\,cm$$

Length distribution :
Mean length ≈ 60 cm

$$\text{int}\,(nx * ny * \underbrace{xfrac}_{\text{density of centers}}) * (1 + ppp) = \text{fracture density}$$

vertical fractures density
(~~[illegible]~~)

For every center ∃ a horizontal fracture

Linear density $\sqrt{\frac{20}{L^2}} = \frac{4.47}{L} = 1$

$\frac{1}{64} \times 4.5 \approx 7.0\,cm$ ← Length domain ← $\boxed{L = 4.47}$
fracture aperture

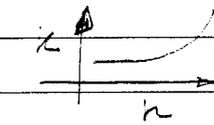
① fracture centers ?
"Put a cross "X" on center. NOT NECCY

Key parameters of fracture ?
- Length
- Isotropy of fracture → No crosses
- fracture density
- Isotropy of fracture length

- Begin with homogeneous with average.
then heterogeneous.

6-14-93

xlmean } full domain
ylmean }



ppp = 0.5
Ratio of cond = 1000
Homogeneous

② Half as many [illegible] fractures

③ Reduce # of hor. frac.

④ [illegible] of [illegible] frac.

6-15-93

xlmean = ylmean = 1.5
fractures not extending the entire length.
(See readme file) 6/15/93

7-26-93

EXPT 1:

Effect of fractures on HOMOGENEOUS MEDIUM (Method A)

LONG FRAC xlmean = ylmean = .001	xfrac	Vol of fractures	
	0	0	solid (A)
	.0025	16.97 %	dashed (B)
	.025	57.28 %	dotted (C)
	.25	68.68 %	dash dot (D)

EXPT 2

Effect of Length HOMOGENEOUS MEDIUM (Method A)

xmean \ ymean	xfrac	Vol	
(LONG FRAC) .001	0.0005	3.6 %	(A)
(SHORT FRAC) 1.5	0.003	3.6 %	(B)

EXPT 3

Effect of length on HET MED. (Method A) & B

values Same as EXPT 2

EXPT 4

Effect of heterogeneity on conductivity with a fixed percentage of fracture volume

Method B

IMULT = 1, 4, 64

Long fractures: xlmean = ylmean = 0.001

Imult (A) (B) (C)	xfrac	Frac Vol
(1, 4, 64)	0.001	7.18 %
(1, 4, 64)	0.002	13.62 % ←
(1, 4, 64)	0.02	54.2 %
(1, 4, 64)	0.25	68.68 %

Same as above for SHORT FRACTURES

Method B ⇒ xlmean = ylmean = 1.5

maintaining above Frac Volumes

xfrac	Frac Vol
0.005	7.18 %
→ 0.015	13.72 %
0.2	54.83 %
0.45	68.95 %

14%

(Xfrac = 0.005)
short
long (0.002)

Het. imult = 1
Hom. imult = 64

Hom: short, long
Het: short, long

$n, \theta_s, \theta_r, h_b$

$\boxed{\alpha.dat;\ \beta.dat;\ Ksat.dat}$

09/22/93 Negative α can result if

$\underline{K_s < 10^{-3}}$ for α_{max} UVL

$K_s < 3.2E{-5}$ for $\alpha_{max} \simeq 0.075$

$$\alpha = \alpha_{max} + s\,(\alpha_{min} - \alpha_{max})$$

$$s = \log\left(\frac{\sigma_b}{K_s}\right) \Big/ \log\left(\sigma_b/\sigma_a\right)$$

∴ Expect positive α only for ($\alpha_{min} \approx \alpha_{max}$) !

∴ Change α_{min} / α_{max} for different K_{sat} values.

09/

Not

$K_s < 0.00103$ for $\sigma_a = 0.01$

$K_s < 0.033$ for $\sigma_a = 0.1$

$K_s < \frac{1}{e^{3.41}}$

$K_s e^{3.41} < 1$

$e^{3.41} < 1/K_s$

$3.41 < \ln(1/K_s)$

FILES

dimen

ok ✓

15 BC	1249300
K2_16 BC	249860
17	"
18	999440

ACT-5 — File path
default path

$$\alpha = \alpha_{max} + \frac{\log\left(\frac{\sigma_b}{K_s}\right)}{\log\left(\frac{\sigma_b}{\sigma_a}\right)} \left(\alpha_{min} - \alpha_{max}\right)$$

(1) $\alpha_{min} = 0.025$
$\alpha_{max} = 0.075$
$\sigma_b = 1$
$\sigma_a = .001$

$$\alpha = 0.075 + \frac{\log\left(\frac{1}{K_s}\right)}{\log(1000)} (-0.05)$$

$$\alpha = [0.075 + \log(1/K_s)(-7.24E\text{-}3)]$$

$$\alpha < 0 \curvearrowright .075 - 7.24E\text{-}3 \log(1/K_s) < 0$$

$$.075 < 7.24E\text{-}3 \log(1/K_s)$$

$$10.36 < \log(1/K_s)$$

$$e^{10.36} < \frac{1}{K_s}$$

$$K_s \cdot e^{10.36} < 1$$

$$K_s < \frac{1}{e^{10.36}}$$

$$\boxed{K_s < 3.2\,E\text{-}5} \curvearrowright \boxed{\alpha < 0}$$

(2)

$$\alpha = \alpha_{max} + \frac{\ln\left(\frac{\sigma_b}{K_s}\right)}{\ln\left(\frac{\sigma_b}{\sigma_a}\right)} (\alpha_{min} - \alpha_{max})$$

$\alpha_{min} = 0.025$
$\alpha_{max} = 0.075$
$\sigma_b = 1$
$\sigma_a = 0.1$ / 0.01

$$\alpha = 0.075 + \frac{\ln\left(1/K_s\right)}{\ln\left(1/0.1\right)} (-0.05)$$

$$\alpha = 0.075 + \frac{\ln\left(1/K_s\right)}{\ln\left(1/0.01\right)} (-0.05)$$

$$\alpha = 0.075 + \ln\left(1/K_s\right)(-0.022)$$

$$\alpha < 0 \curvearrowright \left[0.075 - 0.022 \ln\left(1/K_s\right)\right] < 0$$

$$0.075 < 0.022 \ln\left(1/K_s\right)$$

$$3.41 < \ln\left(1/K_s\right)$$

$$e^{3.41} < 1/K_s$$

$$K_s e^{3.41} < 1$$

$$K_s < \frac{1}{e^{3.41}}$$

$$K_s < 0.033 \quad \text{for } \sigma_a = 0.1$$

$$K_s < 0.00103 \quad \text{for } \sigma_a = 0.01$$

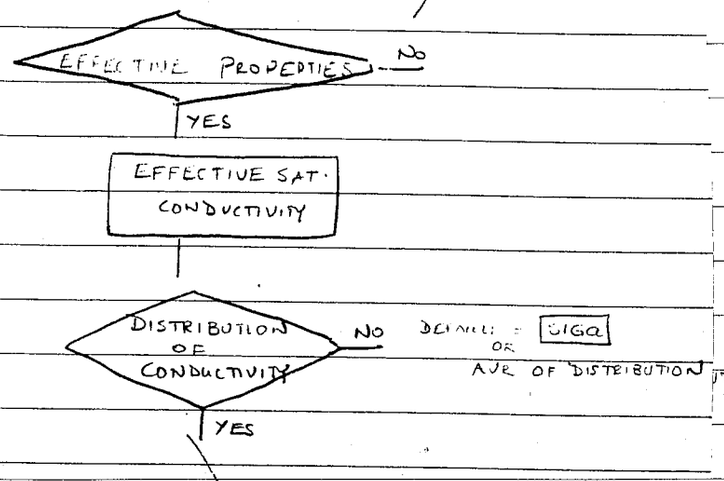
09/22/93

Clip xxlat(i,j) where it is read ∩ xxlat = threshold.
Threshold calculated from pg 44.

$\sigma_b = 1$; $\sigma_a = .001$ $\Rightarrow \alpha_{min} < \alpha < \alpha_{max}$

NOTE: ∴ K_s must be in the above range to get good positive values

- SENDING YEH ONLY HOMOGENEOUS FILES
  Regenerate xxlat with values in between .001 & 1.
- Regenerate xxlat with mild/medium/high conductivity
- Try $\sigma_b \simeq 10^6$. Something is hardwired
- As long xxlat is in between σ_a and σ_b, all should be ok ~



BIGFLO Read format: 5(1X, E14.7)
10(2X, F6.4)

10/16 Frachet* is indeed fracvan11.f with imult = 1, nnx = 64

fachom* is fracvan11.f with imult = 64, nnx = 1

xn=1.5!

fracvan11.f divides all Ksat values from output2d.dat by 1e4

∴ 1e4 ~~divide~~ multiply in sig2frac.

10/1 Duplicate graphs (results) for heterogeneous output2d_new.dat.
See expt 5 directory
Only imult = 1 investigated.
We will observe effect of heterogenity / stochastsicity & stratification using TURNING BAND.

7, 14, 55, 69 { % FRACTURE, λ (correlation), σ (mean)

See pg 43 for parameters for long / short fractures.

EXPT 6 directory

	xfrac	xlmean	Fracture Vol %	Method A
long ←	0.0005	0.001	3.6%	"
shrt ←	0.003	1.5	3.6%	"

EXPT 7 directory
same as EXPT6 except Method [B] instead of (A) !

11/9

EXPTS PERFORMED SO FAR:

→ f = 3.6%, 7%, 14%, 54%.

→ short, long fracture (isotropic length, isotropic density) ← $x_{l_{mean}} = y_{l_{mean}}$

→ hom, het matrix

always a cross ppp = 1.0

$\frac{K^f}{K^m} = 1000$, $nmc^f = 25$, $nmc^m = 1$

$K_f^m = 1.0 = \sigma_b$

K_G^m (het) $= .001 = \sigma_a$

level of stochasity ← σ_x (het) $= 0.75$

λ_x (het) $= \lambda_y$ (het) $= 4$

$\Delta x = \Delta y = 1$

Need to do:

① het
$\begin{cases} \frac{K^f}{K^m} = 1000, \; nmc^f = 25 \\ nmc^m = 1 \\ f = 7\% \text{ short fracture} \end{cases}$

② hom
$\begin{cases} \frac{K^f}{K^m} = 1000, \; nmc^f = 25 \\ nmc^m = 1 \\ f = 7\%, \text{ short fracture} \end{cases}$

③ hete $K_G^m = 0.001$

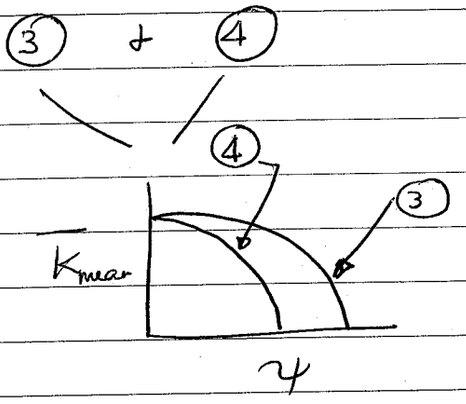
$nmc^m = 1$, $nmc^f = 25$

$nmc^m = 25$, $nmc^f = 25$

$nmc^m = 25$, $nmc^f = 1$

Need an additional flag for $nmc > 1$

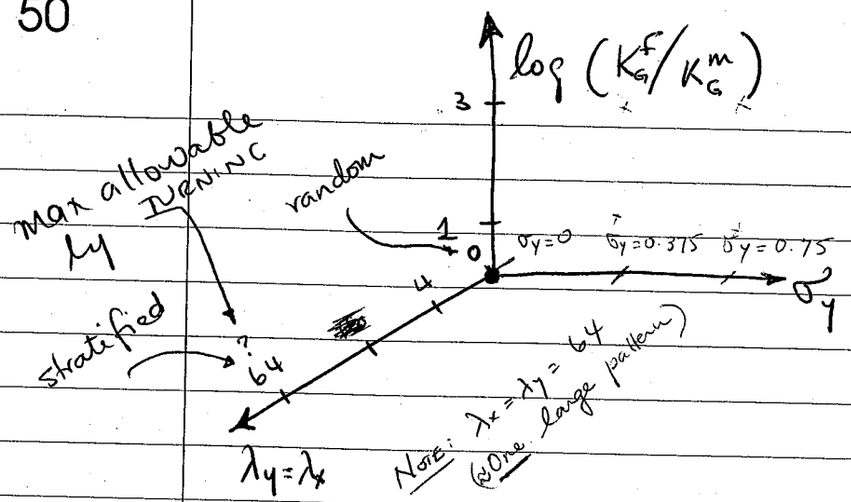
④ hete $K_G^m = 0.1$ (same as ③)



Effect of background ξ fracture network

⑤ $K_G^m = .001$, $\sigma_y = \begin{cases} 0.33 \\ 0.50 \\ 0.67 \end{cases}$

$\sigma_y < 1$ for $\alpha > 0$



(6) fully random vs Structured backg.
$\lambda = 0$ $\lambda = L$

(7) Study (6) by varying K_G^m (at varying σ) for fixed λ and fixed fracture density.

	σ	λ	$\log(K_G^f / K_G^u)$
hom	0	N/A	1
	0	N/A	3
	0.375	0	1
	0.375	4	1
	0.375	64	1
	0.375	0	3
	0.375	4	3
	0.375	64	3

	σ	λ	$\log(K_G^f / K_G^u)$
	0.75	0	1
	0.75	4	1
	0.75	64	1
	0.75	0	3
	0.75	4	3
	0.75	64	3

14 Single Realizations

Multiple Realizations:

	σ	λ	$\log(K_G^f / K_G^u)$
Hom	0	N/A	1/3
	0	N/A	3
HET	0.375	4	3
	0.375	4	1

4 Multiple

EXTENSIONS:
- fracture density > 7%
- longer fracture

PREDICT:
$\lambda = 0$ (totally random)
RSRG will match numerical model better
BUT how will γ combination of matrix & fracture compare / perform?

~~[illegible]~~

(A) Set fracture Vol = 0% to remove all fractures in the system, scale α & β between ~~K_S^{matrix} and K_S^{matrix}~~ $K_{S\,min}$ (leave as is) $K_{S\,max}$, let

structured

$\lambda = \phi$ (random) for $\log(K_G^f / K_S^m)$

$= 1$ & 3

$\sigma_y = 0.375$

unstructured

$\{ .001$
$\{ .1$

K_G^m different

(B) and $\lambda =$ ~~[illegible]~~ 4

Both (A) & (B) need to be compared with BIGFLOW.

4 ; $\log(\ ) = \{ 1, 3 \}$

(C) Stratification :

$\lambda_y \neq \lambda_x$

Anisotropic fracture density → (D)

Anisotropic fracture length → (E)

because we don't want the fractures to be fully connecting

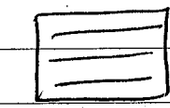
xlmean = short
ylmean < long
≈ 0.01

anisotropic fracture length or fracture density

(D) $f = 7\%$ $\sigma_y = 0$ (Homo) $\log(K_G^f / K_S^m)$

$= 1$ & 3

2

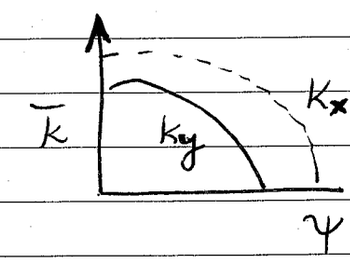
(E) $f = 0\%$ $\{ \lambda_x = 64, \lambda_y = 2$ → 

$\log(..) = \{ 1, 3$

$\sigma = 0.75$ → anisotropic matrix

2

~~[illegible]~~ (D) & (E) have to be done with flow along x & y direction.



By transposing XXLAT just before it is processed !!!!
Also α, β ——

~~[illegible]~~

26 & 4 BIGFlow comparisons

Assumptions for all 26 expts :

- Method B
- α scaled between K_s^{m*} & K_s^f

$n = 1.51$

$\alpha_{min} = 0.025$ $\quad \beta_{min} = 0.01$

$\alpha_{max} = 0.075$ $\quad \beta_{max} = 0.05$

$\theta_s = 0.44$ $\quad \theta_r = 0.05$

$hhb = 0$

$$\alpha = \alpha_{max} + \frac{\ln\left(K_s^f / K_s^m\right)}{\ln\left(K_s^f / K_s^{m*}\right)} \left(\alpha_{min} - \alpha_{max}\right)$$

$K_s^f = 1.0$

$K_s^{m*} = 0.001$

$\therefore K_s^m = K_s^{m*} \curvearrowright \alpha = \alpha_{min}$

$\{ K_s^m = K_s^F \curvearrowright \alpha = \alpha_{max}$

$$\beta = \beta_{min} + \left(\beta_{max} - \beta_{min}\right) K_s^m$$

$\therefore K_s^m = K_s^f \Rightarrow \beta = \beta_{max}$

$K_s^m \to K_s^{m*} \Rightarrow \beta \to \beta_{min}$

- Fracture centers are exponentially distributed
- Fracture length is exponentially distributed and y length is independent of x length (dependent on x_{mean}, y_{mean})
- For different Realizations, cluster center randomly selected
- Probability of a vertical crack = 1.0

11/16 **Long** fracture (14%) HET- METHOD B

Keff = $\frac{\Delta}{\Delta h}$ QFA1	h	QFA1	QFB1	Time (sec)
9.02064	−10	0.1286E-2	0.1288E-2	·811E4
5.58E-3	−30	0.349E-3	0.349E-3	·2E5
9.18E-4	−60	0.573E-4	0.575E-4	·2E5
1.27E-4	−100	0.791E-5	0.792E-5	·2E5
5.87E-5	−120	0.367E-5	0.367E-5	·2E5
5.09E-6 4.40E-6 → DID NOT CONVERGE.	−200	0.318E-6	0.275E-6	·4E5

$\Delta l = 64$

$\Delta h = 4$

11/17 Short fractures (14%) HET METHOD B

Keff	h	QFA1	QFB1	Time
5.68E-3	−10	·352E-3	·358E-3	·2E5
2.62E-3	−30	·162E-3	·165E-3	·2E5
7.10E-4	−60	0.443E-4	0.445E-4	·2E5
1.24E-4	−100	0.776E-5	0.776E-5	·2E5
5.34E-6	−200	0.339E-6	0.329E-6	·29E5

11/22

① • Xn ↑ → 3.7
② • Ksat avg ?
③ • Met A compares better ?
④ • Old Ksat file (Sita's orig file)
won't work because $\alpha < 0$!!!!

① Changing Xn from [1.51] to [3.7]
xImean = 0.001 / xfrac = 0.002
→ identical to Xn = 1.51

Effective ~~Ksat~~ ~~avg~~ Sat conductivity ≈ 3.2E-3

Δl = 64 ; Δh = 2

4/23
xfrac = 0.25
xImean = 0.001
∴ Free Vol = 69%
Het, Met B

Keff	h	QFA1	QFB1	Time
0.426	-1	0.133E-1	0.133E-1	0.2E5
0.218	-10	0.681E-2	0.681E-2	0.2E5
0.05	-30	0.156E-2	0.156E-2	0.2E5
5.66E-3	-60	0.177E-3	0.177E-3	"
3.52E-4	-100	0.110E-4	0.110E-4	"
1.76E-6	-200	0.549E-7	0.561E-7	"

11/24

Homogeneous Matrix, Long fracture
(sent to YEH)

Δl = 64
Δh = 2
fracvar
0.0005
.0004
.0003
≈ 7.86E-5

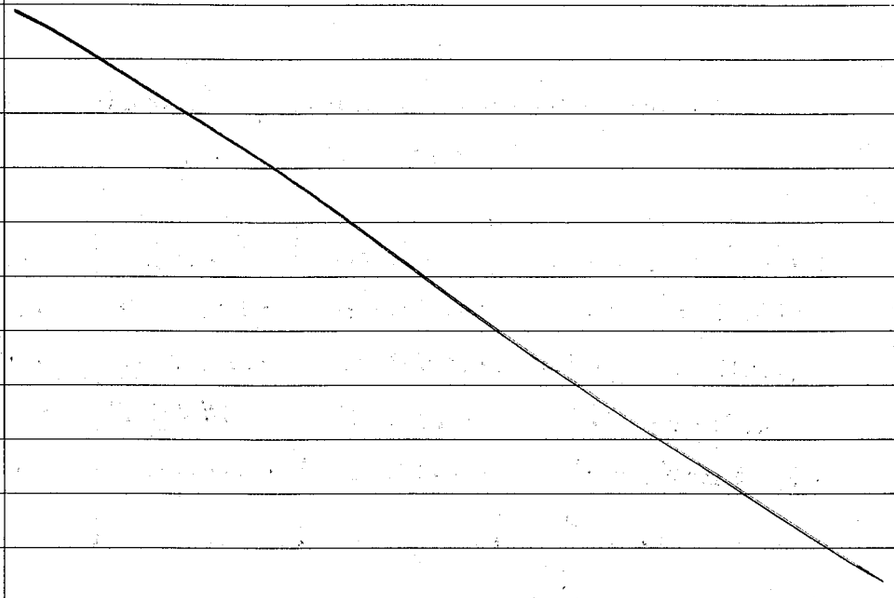
Keff	h	QFA1	QFB1	Time
0.013	-10	0.407E-3	.408E-3	.2E5
3.65E-3	-30	0.114E-3	0.114E-3	.2E5
5.57E-4	-60	0.173E-4	0.175E-4	.2E5
	-100			
	-200			

Homogeneous Matrix, Short fracture
(sent to YEH)

Δl = 64
Δh = 2
.00014

Keff	h	QFA1	QFB1	Time
5.41E-4	-10	.133E-4	.205E-4	.2E5
4.19E-4	-30	.105E-4	.157E-4	.2E5
2.26E-4	-60	.645E-5	0.987E-5	.2E5
7.23E-5	-100	.241E-5	.211E-5	.2E5
	-200			

11/30 In RELPRMVG4, α is either α_{max} or α_{min} and β is either β_{max} or β_{min}. Not to be used for homogeneous matrix. Use uniform background (generated by TURNING BAND) and regard field as heterogeneous.



12/6 Plot

(A) 1 { 1, 4, 10 → effect of σ $K_G^F/K_G^m = 1$
2, 7, 13 → effect of σ $K_G^F/K_G^m = 3$

(B) 2 { 3, 4, 5
6, 7, 8

(C) 3 { 9, 10, 11
12, 13, 14

15, 17 → mean / std dev
16, 18 → mean / std dev

CHECK K2 files:

- mean ( )
- Std ( ) / log10 (exp(1))

→ Std (log (k))

(D) { 19, 20
21, 22 } Effect of λ for no fractures.

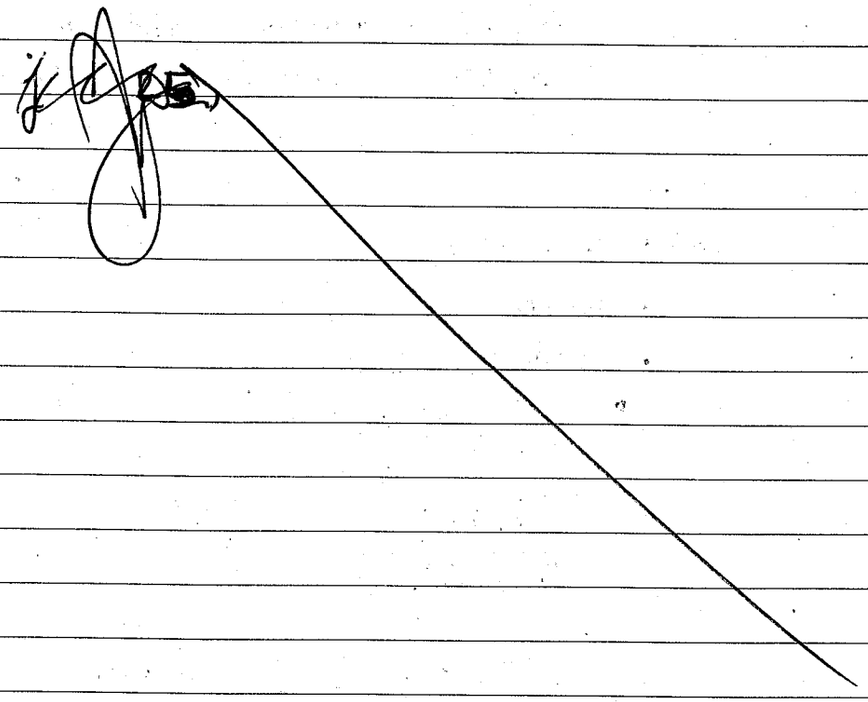
(E) { 19, 3
20, 6 } → Vol effect fracture
Vol, fracture

(F) { 21, 4
22, 7 }

(g) { 23 & 1 : Effect of fracture length anisotropy
" 24 & 2 "

(h) { 25 & 26 Effect of Ratio $\log(K_G^F/k_c^m)$!

(i) 19, 20, 27, 28 Effect of $\bar{\sigma}$ on unfractured medium



1/5/94 Expt #11, 12 have same fracture Volume in Expt 15A & 16A
Check to see if the difference in effective conductivity is due to differences in network.

Indeed fracture network is different . ∴ Variability in fracture network (although fracture Volume constant) causes slight differences in effective conductivity.

COMPARING WITH BIGFLOW : $\Delta l = 64$, $\Delta h = 2$

EXPT # 11 :

SEMI-ANALYTICAL	KEFF	h	QFA1	QFB1	Time
0.011	0.0166	−1	0.51204E-3	0.52597E-3	.2E5
	0.0125	−10	0.38928E-3	0.39492E-3	.2E5
	0.00653	−30	0.20352E-3	0.20433E-3	.2E5
	0.00248	−60	0.77565E-4	0.77599E-4	.2E5
	0.00083	−100	0.25901E-4	0.25898E-4	.2E5

EXPT # 14

SEMI-ANALYT	KEFF		QFA1	QFB1	Time
.00115	2.08E-3	−1	0.591E-4	0.7061E-4	.4E5

$\Delta l = 64$
$\Delta h = 2$

EXPT # 25

Semi-analytical	KEFF	h	QFA1	QFB1	Time
0.013	0.01082	−1	0.3375 E-3	0.3378E-3	.2E5
0.0099	0.00861	−10	0.2688E-3	0.2690 E-3	.2E5
0.005	0.00517	−30	0.1614E-3	0.1615E-3	"
	0.00237	−60	0.7415E-4	0.7416E-4	"
	0.000821	−100	0.2567E-4	0.2567E-4	"

$\Delta l = 64$
$\Delta h = 2$

EXPT #26

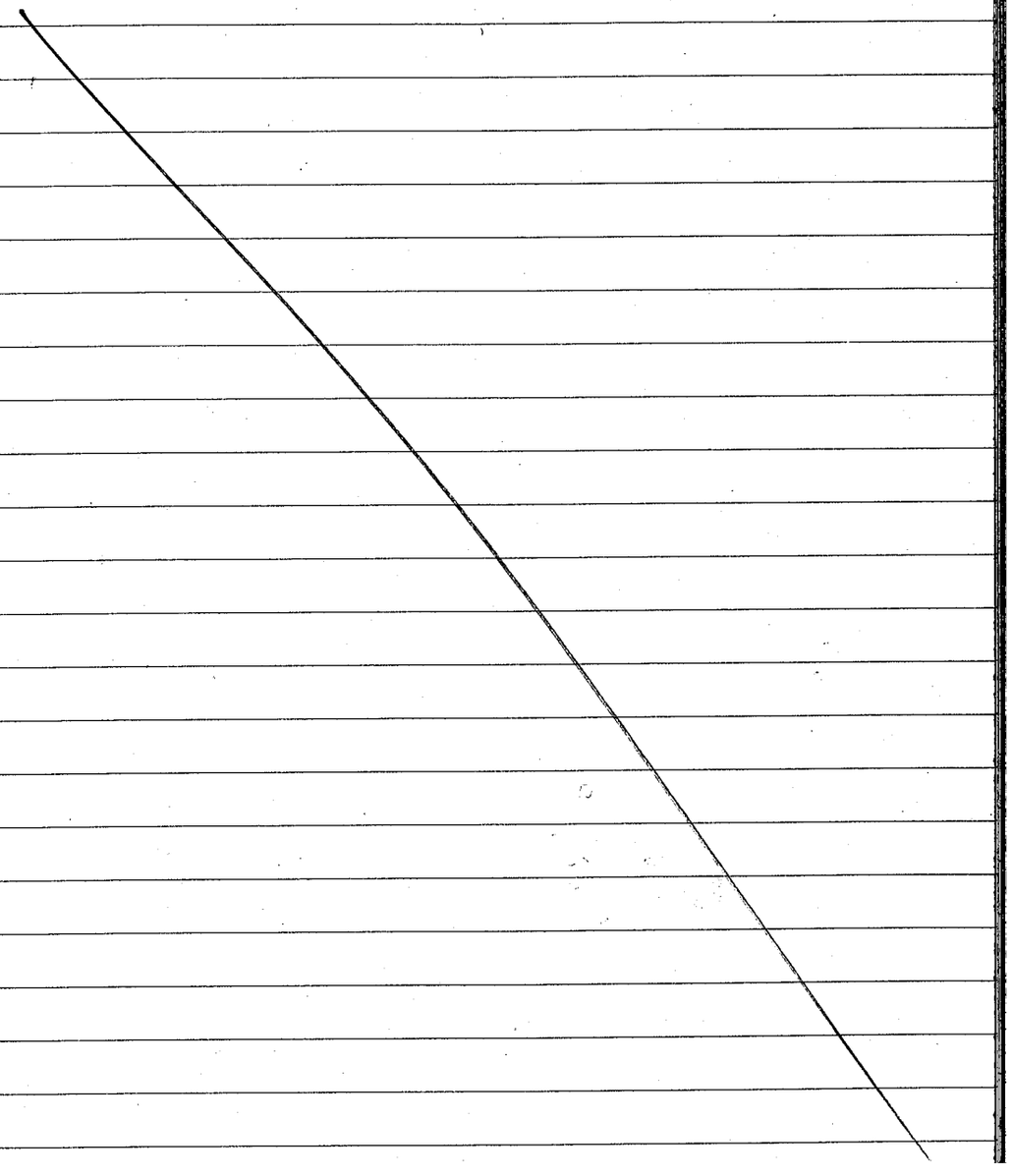
	KEFF	h	QFA1	QFB1	Time
.0013	1.033E-3	−1	0.3226 E-4	0.3229 E-4	.2E5
.0010	8.26 E-4	−10	0.258 E-4	0.258 E-4	"
.0006	5.02E-4	−30	0.157E-4	0.157E-4	"
.000100	2.37E-4	−60	0.7398 E-5	0.7401E-5	"
	8.58E-5	−100	0.268E-5	0.268E-5	"

- "Gardner Region"
- Shrt frac (7%, .. 69%) invite 1 [check]
  Is this homogeneous.

  EXPT # 14 ? sigα 1.0
- Is it the contrast in matrix / fracture that causes a discrepancy between Bigflow & semi-analytical. → ((Ross))

- Stochasticity → correlation length
- σ → stochasticity

Flowchart of FRACVAR (General-High level)



Pages 1 through 63 of this Scientific Notebook were reviewed for compliance with QAP-001 in response to Corrective Action Request 94-02. Corrections and clarifications were made as appropriate. In some cases, the date of a change will reflect the date of this review rather than the date of the original Scientific Notebook entry.

Randy Fudge
SwRI - QA
12/13/94

Project was closed December 1994 because it reached completion.

12/16/96

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK No.: 065, 067, 068, and 069

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Remarks: (computer runs, etc.)	Media contains: data and output files relative to the stochastic project.