308 --- Q199905270009
Scientific Notebooks No. 284: Modeling Studies Using the MULTIFLO 1.2B, Two-Phase Non-Isothermal Coupled Thermal-Hydrologic-Chemical Flow Simulator (07/29/1998 through 06/03/1999)

# LABORATORY NOTEBOOK

CNWRA / SWRI

NOTEBOOK NO. 284

ISSUED TO Debra L. Hughson

ON July 28, 1998 19

DEPARTMENT 20

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COPY 284

—SCIENTIFIC NOTEBOOK CO.—
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| Properties I've used in most of the thermal & isothermal models | 6-8 |
| Results presented in Rockville at the TEF program review Oct 1998 | 48-60 |
| Geochem modeling & Benchmarks | 62-96 |

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Initial Entry

Thermal Effects on Flow in the Unsaturated Zone at the Yucca Mtn proposed High-level Waste Repository

Debra L. Hughson conducting modeling studies using the Multiflo 1.2β Two-phase non isothermal coupled thermal-hydrologic-chemical flow simulator (written by Peter C. Lichtner and Mohan S. Seth) This code was developed under the CNWRA Software Configuration Procedures but note this is a β version

Direction provided by Ron Green
Previous work by George Rice

for a general description of the Unsaturated Zone thermohydrology (UZTH) see (for ~~exp~~ example) DH 6-29-98 Total System Performance Assessment - Viability Assessment (TSPA-VA) Methods and Assumptions B0000000000-01717-2200-00193 Rev. 01 November 7 1997 Prepared by TRW Environmental Safety Systems Inc. pg 6-16 to ~~6-28~~ 6-30

For documentation of the Multiflo code see Multiflo User's Manual ver 1.2β Contract NRC-02-97-009

A summary of the conceptual & mathematical model & solution technique is included as Appendices in the Multiflo documentation

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Initially I'm going to start with a 2D grid established by George Rice. Grid is vertical with sides at centerline of waste container in drift and centerline between adjacent drifts. TOP is land surface and bottom is water table.

July 31, 1998

Initial test run of input file given to me by George Rice. This and related files in original condition are located in

/home1/bigbend/dhughson/grice

Main input file 8x62-5mm.dat

Run started at 12:00 PM yesterday July 30 1998 and still running at 5:30 PM when I left. This morning I see it crashed at time step 4850, simulation time 128.5 years with error message

Floating point exception 7, invalid operand, occurred at address eef8dba4

G. Rice has 21 stratigraphic units
T. Buscheck has 28 stratigraphic units
Near Field/Altered-Zone Models Report UCRL-ID-129179
I need to resolve the hydrostratigraphy, double check all the parameters, and calibrate the steady state ~~critical~~ initial condition to my own satisfaction before proceeding on to waste package loaded non isothermal transient simulation

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~~Aug 3, 1998~~ Aug 4, 1998

I'm going to try to approximately reproduce the results of T. Buscheck (Near-Field/Altered-Zone Models Report UCRL-ID-129179) Case Number 3, Table 3-4, page 3-33 of the report.

Hydrostratigraphy obtained by scaling from column (b) I4c2 at Northing 233748m which is attached by cut and paste on the following page. Measurements of unit depth and thickness measured w/ ruler from attached figure & to nearest 1/10 meter.

| Units | Thickness (meters) | Depth to Contact (meters) | number of blocks in z |
|---|---|---|---|
| tcw11 | 53.2 | 53.2 ≤ Bottom of layer | 6 |
| tcw12 | 53.3 | 106.5 | 6 |
| tcw13 | 4.5 | 111.0 | 1 |
| ptn21 | 7.0 | 118.0 | 1 |
| ptn22 | 7.0 | 125.0 | 1 |
| ptn23 | 4.6 | 129.6 | 1 |
| ptn24 | 13.9 | 143.5 | 2 |
| ptn25 | ~~7.0~~ 21.5 | 165.0 | 3 |
| tsw31 | ~~85.0~~ 7.0 | 172.0 | 1 |
| tsw33 | ~~136.5~~ 85.0 | 257.0 | 7 |
| tsw35 | ~~37.5~~ 136.5 | 393.5 | 24 |
| tsw36 | ~~7~~ 37.5 | 431.0 | ~~3~~ 5 |
| tsw37 | 71.3 | 502.3 | 5 |
| ch1vc | 16.2 | 518.5 | 1 |
| ch2vc | 50.5 | 569.0 | 4 |
| ch3zc | 9.7 | 578.7 | 1 |
| ch4zc | 26.3 | 605.0 | 2 |
| pp3vp | 47.0 | 652.0 | 3 |
| pp2zp | 68.4 | 720.4 | 5 |
| bf3vb | 6.5 | 726.9 | 1 |

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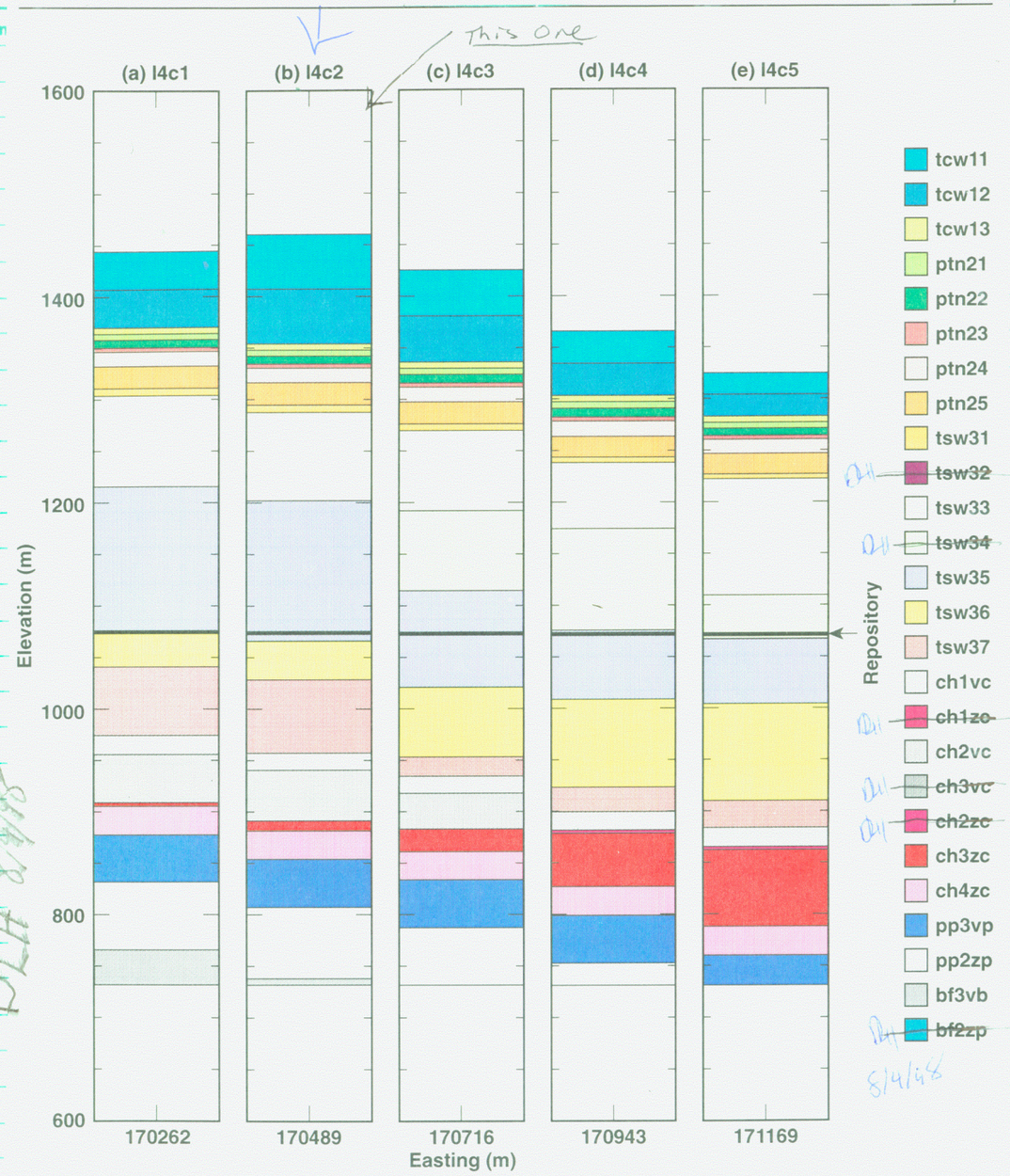


DLH 8/4/98

**Figure 3-13.** Vertical distribution of hydrostratigraphic model units shown for drift-scale model locations (in Nevada-State coordinates), including (a) l4c1 at Northing = 233760 m, (b) l4c2 at Northing = 233748 m, (c) l4c3 at Northing = 233736 m, (d) l4c4 at Northing = 233724 m, and (e) l4c5 at Northing = 233712 m

Wit



DLH 8/4/98



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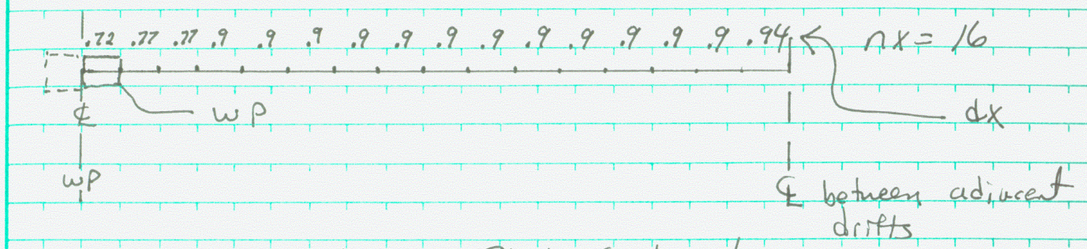
From ℄ waste package to ℄ between drifts = 14m




From Ground surface Block Centered

| K | dz | unit | K | dz | unit | K | dz | unit | K | dz | unit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.0 | tcw11 | 21 | 7.0 | ptn25 | 41 | 5.0 | tsw35 | 61 | 4.3 | tsw37 |
| 2 | 8.2 | " | 22 | 7.0 | tsw31 | 42 | 5.0 | " | 62 | 15.0 | " |
| 3 | 9.0 | " | 23 | 7.0 | tsw33 | 43 | 5.0 | " | 63 | 15.0 | " |
| 4 | 9.0 | " | 24 | 8.0 | " | 44 | 5.0 | " | 64 | 16.2 | ch1vc |
| 5 | 10.0 | " | 25 | 11.0 | " | 45 | 5.0 | " | 65 | 15.0 | ch2vc |
| 6 | 10.0 | " | 26 | 14.0 | " | 46 | 5.0 | " | 66 | 15.0 | " |
| 7 | 10.0 | tcw12 | 27 | 16.0 | " | 47 | 3.48 | " | 67 | 11.5 | " |
| 8 | 10.0 | " | 28 | 15.0 | " | 48 | 2.08 | " | 68 | 9.0 | " |
| 9 | 10.0 | " | 29 | 14.0 | " | 49 | 1.44 | " | 69 | 9.7 | ch3zc |
| 10 | 9.0 | " | 30 | 13.0 | tsw35 | 50 | 1.0 | " | 70 | 12.3 | ch4zc |
| 11 | 8.0 | " | 31 | 12.0 | " | 51 | 1.5 | " | 71 | 14.0 | " |
| 12 | 6.3 | " | 32 | 11.0 | " | 52 | 2.0 | " | 72 | 15.0 | pp3vp |
| 13 | 4.5 | tcw13 | 33 | 10.0 | " | 53 | 3.0 | " | 73 | 15.0 | " |
| 14 | 7.0 | ptn21 | 34 | 9.0 | " | 54 | 5.0 | tsw36 | 74 | 17.0 | " |
| 15 | 7.0 | ptn22 | 35 | 8.0 | " | 55 | 6.0 | " | 75 | 18.0 | pp2zp |
| 16 | 4.6 | ptn23 | 36 | 7.0 | " | 56 | 7.0 | " | 76 | 16.0 | " |
| 17 | 6.9 | ptn24 | 37 | 6.0 | " | 57 | 9.0 | " | 77 | 14.0 | " |
| 18 | 7.0 | " | 38 | 6.0 | " | 58 | 10.5 | " | 78 | 12.0 | " |
| 19 | 7.0 | ptn25 | 39 | 5.0 | " | 59 | 13.0 | tsw37 | 79 | 8.4 | " |
| 20 | 7.5 | " | 40 | 5.0 | " | 60 | 14.0 | " | 80 | 6.5 | bf3vb |

ny = 1 nz = 80 WP @ 384.6m

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**Table 3-10 Matrix property values for the November 1997 TH hydrologic parameter set calibrated against the SHT**

| Geologic Unit | Model Unit | Porosity | Permeability ($m^2$) | $S_r$* | $\alpha_m$ ($Pa^{-1}$)** | $m$** |
|---|---|---|---|---|---|---|
| Tpcp11 | tcw11 | 0.066 | 5.40E-18 | 0.13 | 1.15E-06 | 0.2310 |
| Tpcpln | tcw12 | 0.066 | 5.40E-18 | 0.13 | 2.01E-06 | 0.2447 |
| Tpcpv | tcw13 | 0.140 | 5.69E-17 | 0.33 | 3.74E-06 | 0.4548 |
| Tpcpv1 | ptn21 | 0.369 | 1.61E-14 | 0.10 | 3.98E-05 | 0.2531 |
| Tpy | ptn22 | 0.234 | 3.30E-15 | 0.14 | 7.94E-06 | 0.4925 |
| Tpbt3 | ptn23 | 0.353 | 5.40E-14 | 0.17 | 5.44E-05 | 0.3002 |
| Tpp | ptn24 | 0.469 | 8.80E-14 | 0.10 | 3.43E-05 | 0.3859 |
| Tpbt2 | ptn25 | 0.464 | 3.18E-13 | 0.10 | 1.81E-04 | 0.3195 |
| Tptrv | tsw31 | 0.042 | 7.76E-17 | 0.11 | 5.84E-05 | 0.2304 |
| Tptrn | tsw32 | 0.140 | 1.82E-16 | 0.04 | 2.00E-05 | 0.2681 |
| Tptpul | tsw33 | 0.135 | 2.04E-17 | 0.06 | 6.21E-06 | 0.2479 |
| Tptpmn | tsw34 | 0.089 | 4.08E-18 | 0.18 | 1.19E-06 | 0.3212 |
| Tptp11 | tsw35 | 0.115 | 2.22E-17 | 0.08 | 4.01E-06 | 0.1983 |
| Tptpln | tsw36 | 0.092 | 8.70E-18 | 0.18 | 8.08E-07 | 0.5138 |
| Tptpv | tsw37 | 0.020 | 8.39E-18 | 0.50 | 5.30E-07 | 0.3709 |
| Tpbt1 | ch1zc | 0.193 | 1.36E-17 | 0.36 | 4.29E-06 | 0.3489 |
| Tac(z) | ch2zc | 0.240 | 2.50E-18 | 0.20 | 2.16E-05 | 0.2119 |
| Tac(z) | ch3zc | 0.240 | 2.50E-18 | 0.20 | 2.16E-05 | 0.2119 |
| Tacbt | ch4zc | 0.169 | 5.49E-18 | 0.33 | 1.03E-06 | 0.4322 |
| Tpbt1 | ch1vc | 0.265 | 1.60E-12 | 0.04 | 7.60E-05 | 0.1592 |
| Tac(v) | ch2vc | 0.321 | 5.50E-14 | 0.06 | 4.12E-05 | 0.2291 |
| Tac(v) | ch3vc | 0.321 | 5.50E-14 | 0.06 | 4.12E-05 | 0.2291 |
| Tabt1 | ch4vc | 0.321 | 5.50E-14 | 0.06 | 4.12E-05 | 0.2291 |
| Tcp(3) | pp3vp | 0.274 | 1.91E-15 | 0.07 | 1.66E-05 | 0.3142 |
| Tcb(w) | bf3vb | 0.274 | 1.91E-15 | 0.07 | 1.66E-05 | 0.3142 |
| Tcb(w) | tm3vt | 0.274 | 1.91E-15 | 0.07 | 1.66E-05 | 0.3142 |
| Tcp(2) | pp2zp | 0.197 | 1.75E-17 | 0.18 | 8.39E-06 | 0.3568 |
| Tcb(n) | bf2zb | 0.197 | 1.75E-17 | 0.18 | 8.39E-06 | 0.3568 |

* $S_r$ is the residual liquid-phase saturation (not in situ saturation).

** $\alpha$ and $m$ are fitting parameters for capillary pressure and relative permeability curves, respectively.

DH 8/4/98 Units not used crossed out

parameters used in model

8/4/98



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Fro

**Table 3-11 Fracture property values for the November 1997 TH hydrologic parameter set that was calibrated against the SHT.**

| Geological Unit | Model Unit[a] | Porosity | Permeability ($m^2$) | | $S_r$[b] | $\alpha^c$ ($Pa^{-1}$) | $m$[c] | FMX |
|---|---|---|---|---|---|---|---|---|
| | | | Vertical | Horizontal | | | | |
| Tpcp11 | tcw11 | 2.33E-04 | 2.29E-11 | 6.03E-12 | 0.01 | 2.37E-03 | 0.667 | 5.00E-04 |
| Tpcpln | tcw12 | 2.99E-04 | 1.38E-11 | 6.03E-12 | 0.01 | 2.37E-03 | 0.669 | 5.00E-04 |
| Tpcpv | tcw13 | 7.05E-05 | 2.82E-12 | 2.40E-13 | 0.01 | 9.12E-04 | 0.669 | 5.00E-04 |
| Tpcpv1 | ptn21 | 4.84E-05 | 5.25E-13 | 5.25E-13 | 0.01 | 1.10E-03 | 0.669 | 5.02E-01 |
| Tpy | ptn22 | 4.83E-05 | 1.95E-13 | 1.95E-13 | 0.01 | 1.85E-03 | 0.669 | 5.00E-01 |
| Tpbt3 | ptn23 | 1.30E-04 | 2.57E-13 | 2.57E-13 | 0.01 | 3.45E-03 | 0.667 | 5.00E-01 |
| Tpp | ptn24 | 6.94E-05 | 6.17E-14 | 6.17E-14 | 0.01 | 9.13E-04 | 0.667 | 5.00E-01 |
| Tpbt2 | ptn25 | 3.86E-05 | 7.76E-14 | 7.76E-14 | 0.10 | 1.81E-04 | 0.320 | 5.00E-01 |
| Tptrv | tsw31 | 8.92E-05 | 1.07E-11 | 1.00E-12 | 0.01 | 1.44E-04 | 0.566 | 4.68E-01 |
| Tptrn | tsw32 | 1.29E-04 | 1.51E-11 | 7.08E-13 | 0.01 | 1.42E-03 | 0.667 | 5.00E-04 |
| Tptpul | tsw33 | 1.05E-04 | 2.63E-11 | 8.91E-13 | 0.01 | 1.73E-03 | 0.667 | 5.00E-04 |
| Tptpmn | tsw34 | 1.24E-04 | 6.76E-12 | 4.27E-13 | 0.01 | 9.34E-04 | 0.643 | 1.23E-03 |
| Tptp11 | tsw35 | 3.29E-04 | 3.80E-12 | 9.12E-13 | 0.01 | 1.26E-03 | 0.667 | 5.00E-04 |
| Tptpln | tsw36 | 3.99E-04 | 1.20E-12 | 1.20E-12 | 0.01 | 1.32E-03 | 0.667 | 5.00E-04 |
| Tptpv | tsw37 | 4.92E-04 | 1.20E-12 | 1.20E-12 | 0.01 | 1.19E-03 | 0.659 | 5.00E-04 |
| Tpbt1 | ch1zc | 1.10E-05 | 2.51E-14 | 2.40E-14 | 0.01 | 1.14E-03 | 0.667 | 5.00E-01 |
| Tac(z) | ch2zc | 1.10E-05 | 2.51E-14 | 1.17E-14 | 0.01 | 1.12E-03 | 0.654 | 9.22E-01 |
| Tac(z) | ch3zc | 1.10E-05 | 2.51E-14 | 1.17E-14 | 0.01 | 1.12E-03 | 0.654 | 9.22E-01 |
| Tacbt | ch4zc | 1.10E-05 | 2.51E-14 | 1.55E-14 | 0.01 | 1.14E-03 | 0.667 | 5.00E-01 |
| Tpbt1 | ch1vc | 7.14E-05 | 1.74E-13 | 1.74E-13 | 0.01 | 1.18E-03 | 0.669 | 5.00E-01 |
| Tac(v) | ch2vc | 7.14E-05 | 2.88E-13 | 2.88E-13 | 0.01 | 1.18E-03 | 0.667 | 5.00E-01 |
| Tac(v) | ch3vc | 7.14E-05 | 2.88E-13 | 2.88E-13 | 0.01 | 1.18E-03 | 0.667 | 5.00E-01 |
| Tabt1 | ch4vc | 7.14E-05 | 2.88E-13 | 2.88E-13 | 0.01 | 1.18E-03 | 0.667 | 5.00E-01 |
| Tcp(3) | pp3vp | 7.14E-05 | 7.08E-13 | 6.92E-13 | 0.01 | 1.42E-03 | 0.667 | 5.00E-04 |
| Tcb(w) | bf3vb | 7.14E-05 | 7.08E-13 | 6.92E-13 | 0.01 | 1.42E-03 | 0.667 | 5.00E-04 |
| Tcb(w) | tm3vt | 7.14E-05 | 7.08E-13 | 6.92E-13 | 0.01 | 1.42E-03 | 0.667 | 5.00E-04 |
| Tcp(2) | pp2zp | 1.10E-05 | 2.51E-14 | 6.46E-14 | 0.01 | 1.14E-03 | 0.667 | 5.00E-01 |
| Tcb(n) | bf2zb | 1.10E-05 | 2.51E-14 | 6.46E-14 | 0.01 | 1.14E-03 | 0.667 | 5.00E-01 |

$S_r$b is the residual liquid-phase saturation (not in situ saturation).

$\alpha^c$ and $m$ are fitting parameters for capillary pressure and relative permeability curves, respectively.

NOT USED

DH 8/4/98 units not used crossed out

Parameters used in model

8/4/98



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**Table 3-5 TSPA-VA thermal properties for the rock matrix**

| Geologic Unit | Model Unit[a] | $K_{wet}$ (W/mK) | $K_{dry}$ (W/mK) | Rock Density (kg/m³) | Specific Heat (J/kgK) |
|---|---|---|---|---|---|
| Tpcp11 | tcw11 | 1.76 | 1.02 | 2510 | 847 |
| Tpcpln | tcw12 | 1.88 | 1.28 | 2510 | 837 |
| Tpcpv | tcw13 | 0.98 | 0.54 | 2470 | 857 |
| Tpcpv1 | ptn21 | 0.50 | 0.35 | 2340 | 1080 |
| Tpy | ptn22 | 0.97 | 0.44 | 2400 | 849 |
| Tpbt3 | ptn23 | 1.02 | 0.46 | 2370 | 1020 |
| Tpp | ptn24 | 0.82 | 0.35 | 2260 | 1330 |
| Tpbt2 | ptn25 | 0.67 | 0.23 | 2370 | 1220 |
| Tptrv | tsw31 | 1.00 | 0.37 | 2510 | 834 |
| Tptrn | tsw32 | 1.62 | 1.06 | 2550 | 866 |
| Tptpul | tsw33 | 1.80 | 0.71 | 2510 | 883 |
| Tptpmn | tsw34 | 2.33 | 1.56 | 2530 | 948 |
| Tptp11 | tsw35 | 2.02 | 1.2 | 2540 | 900 |
| Tptpln | tsw36 | 1.84 | 1.42 | 2560 | 865 |
| Tptpv | tsw37 | 2.08 | 1.69 | 2360 | 984 |
| Tpbt1 | ch1zc | 1.31 | 0.70 | 2310 | 1060 |
| Tac(z) | ch2zc | 1.20 | 0.61 | 2350 | 1150 |
| Tac(z) | ch3zc | 1.20 | 0.61 | 2350 | 1150 |
| Tacbt | ch4zc | 1.35 | 0.73 | 2440 | 1170 |
| Tpbt1 | ch1vc | 1.31 | 0.70 | 2310 | 1060 |
| Tac(v) | ch2vc | 1.17 | 0.58 | 2240 | 1200 |
| Tac(v) | ch3vc | 1.17 | 0.58 | 2240 | 1200 |
| Tabt1 | ch4vc | 1.17 | 0.58 | 2240 | 1200 |
| Tcp(3) | pp3vp | 1.26 | 0.66 | 2580 | 841 |
| Tcb(w) | bf3vb | 1.26 | 0.66 | 2580 | 841 |
| Tcb(w) | tm3vt | 1.26 | 0.66 | 2580 | 841 |
| Tcp(2) | pp2zp | 1.35 | 0.74 | 2510 | 644 |
| Tcb(n) | bf2zb | 1.35 | 0.74 | 2510 | 644 |

Properties used in model

DH 8/4/98



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Steady State simulations to obtain in-balance Initial Condition.

Flux boundary at top recharge = 16 mm/year
Constant Pressure boundary at bottom = water table

Start time approx 11 AM
Had to reboot PC, restart transient case (steady state option gave run-time divide by zero errors) at 3:54 PM by PC clock
Aug 5, 1998
Run stopped sometime during the night at time step 1036 time 0.5566 year. dt = 3.62E-23 yr
At time step 1035 ~~the 04:18/5/98~~ dt = moving into time step 1036 dt was cut 25 times the max, to .256 E-45 yr. RUN STOPPED because number of time step cuts, icut, exceeded the maximum

New Run started around 10:30 AM set to write output at 0.25 years and 0.5 years and stop. Attempt to restart from one of these times for a later run. I made a number of changes to the input file, most important is the grid.

8 x 80 = 640 nodes

dx spacing 1.49 1.67 1.8 1.8 1.8 1.8 1.8 1.84

* Interesting result. Using the Init for initial condition change in temperature was too great ~ 15-18°C so the time step never got above 1 sec. So I used the Equil option for initial condition and the run went to 0.5 yr in 38.4 s

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August 6, 1998

The run set for steady state convergence (tolerances for steady state are default) ran quickly to 2500 years with the Equil initial condition option. Then circa 2557.45 began to bog down & cut the time step repeatedly to $10^{-2}$ $10^{-3}$ years. Between 0 and 2500 yr the time steps were ~ 2 to 9 years. Presume that the wetting front had reached the water table and that the small time step was due to moisture redistribution into the matrix. This run was lost when the power supply to my PC was interupted in a thunderstorm.

Started a new run ~ 5:30PM set for 10,000 years with target times of 2500, 3000, 5000, 10,000 years.

Arrive at 7:45 & run had reached 2601 yr with time steps $10^{-1}$ to $10^{-3}$ years

By 5:15PM this 2-D run reached 2663 years with timesteps around $10^{-1}$ $10^{-2}$ yr.

Change grid to 1-D with $\Delta x = 1$ and $dx = 7m$. No other changes. Start this on skippy at 5:15 PM

Finished in about 5 minutes to a time of 3760 years. Run stopped because icut > 25 Left the input file w/ spaces to help debug

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Aug 7, 1998

The 2-D run which I started Aug 5 at 5:30 PM has reached 2732 yr as of 8:05 AM Aug 7. time step $10^{-2}$ to $10^{-4}$ yr. I'm going to kill this job because it's apparent from the 1-D run that it will eventually die

① Use Init instead of Equil for the initial condition. For grize file 8x62-5mm.dat get approx

p = 9.5e+4 t = 25.0 sg = .75 xa = 0 pm = 9.5e+4 tm = 25
sgm = 5e-3 xam = 0

Run lasted for 1795 timesteps to 2.219 years with time steps ~ $10^{-9}$ to $10^{-2}$ yr. 8/7/98
Run stopped when icut > 25 dt cut to $10^{-21}$ yr

② Changed the Time target (first one in a list of 4) from Time[4] 2500 to Time[4] 2.2 so I could use the restart from where it crashed. this time the run lasted to time step 2484 at 45.23 yr, time step 9.048 yr and died due to Floating pt exception 7 invalid operand

③ Set Time[4] 4.5 and got crash # ①

Set Time[4] 1
Time[4] 2

Died at timestep 1864 2.258 yr
when icut > 25

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|---|---|---|---|
| | | Recorded by | 8/7/98 |

From Page No. | Aug 7, 1998

First successful 1-D run to steady state. Not sure why this one worked. Save input file in

~dhughson/multi1d/inputbulk/multi.2

Perhaps because I used the equil option for initial condition.

total time 6.7645 e+5 yr (not a cross-out - slip of the pen DH 8/7/98) time step 8598

Boundary condition at the top
prescribed liquid flux of 16 mm/yr = 5.07e-7 kg/m²/s
matrix & fracture BC's are the same.
Pbc = 101325 Pa = 1 atm
sgbc = .9 xabc = 0 emsivt = 0

Boundary condition at the bottom
prescribed pressure = to water table
qbcf = 0 pbcf = 101325 Pa sgbcf = 0.
xabcf = 0 emsivtf = 0

Initial condition is hydrostatic capillary fringe from water table in balance with all the rest no-flow boundaries

Turn on liquid flux at the top, this then becomes a NO-FLOW BOUNDARY FOR GAS!

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| | | Recorded by DH | 8/7/98 |



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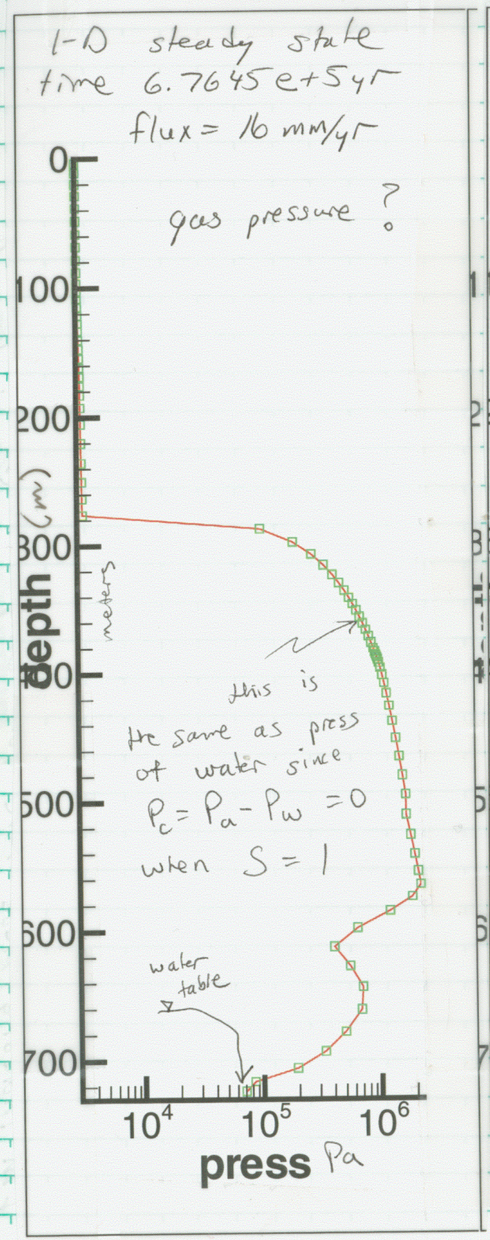


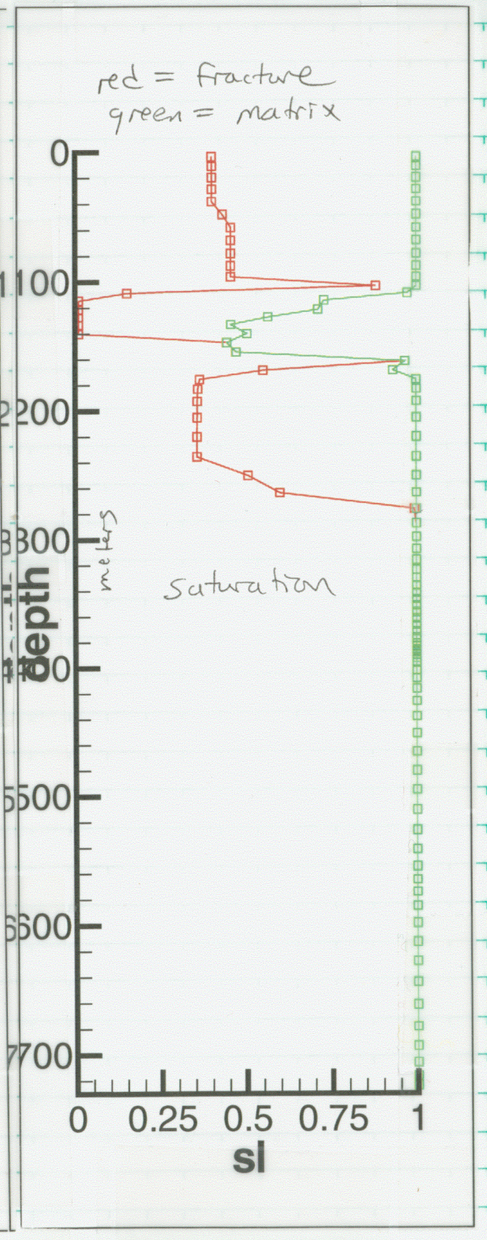


So basically in this simulation I've caused the water table to rise up over the level of the repository

Gas pressure builds because water is displacing gas & gas has nowhere to go. ??

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| Witnessed & Understood by me, | Date | Invented by | Date |
|---|---|---|---|
| | | Recorded by DH | 8/7/98 |