SOFTWARE RELEASE NOTICE

01. SRN Number: PA-SRN-140	
02. Project Title: Support Revision of the EPA & NRC Rule Technical Assistance	Project No. 20-5708-771
03. SRN Title: CHAINT Version 2.3	
04. Originator/Requestor: Bruce Mabrito	Date: 12/12/96

05. Summary of Actions

- ■ Release of new software
- □ Release of modified software:
  - □ Enhancements made
  - □ Corrections made
- □ Change of access software
- ☑ Software Retirement AW 11/30/2001

06. Persons Authorized Access

Name	RO/RW	A/C/D
Robert Baca	RW	
Robert Rice	RW	
Gordon Wittmeyer	RW	

07. Element Manager Approval: RG Baca Date: 12/13/96

08. Remarks:

CNWRA Form TOP-6 (06/95)

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SOFTWARE SUMMARY FORM

01. Summary Date: August 26, 1996	02. Summary prepared by (Name and phone) Robert W. Rice (915) 581-0853	03. Summary Action: NEW
04. Software Date: August 21, 1996	05. Short Title: CHAINT, Version 2.3	
06. Software Title: CHAINT, Version 2.3		07. Internal Software ID: none

08. Software Type: □ Automated Data System ■ Computer Program □ Subroutine/Module	09. Processing Mode: □ Interactive ■ Batch □ Combination	10. APPLICATION AREA a. General: □ Scientific/Engineering □ Auxiliary Analyses □ Total System PA ■ Subsystem PA □ Other b. Specific: 2-D Saturated Zone Transport Modeling

11. Submitting Organization and Address: CNWRA 6220 Culebra Rd. San Antonio, TX 78228	12. Technical Contact(s) and Phone: Robert G. Baca (210) 522-3805

13. Narrative: The CHAINT computer code models contaminant transport in fractured porous media and accounts for the physical properties of advection, dispersion, diffusion, retardation, radionuclide chain decay coupling, and mass sources/sinks. CHAINT input requirements includes an input file and files from MAGNUM-2D simulations. The CHAINT model will be used to help develop EPA Standards for Yucca Mountain.

14. Computer Platform SUN Sparc 20	15. Computer Operating System: SUNOS 4.1.3_U1	16. Programming Language(s): FORTRAN	17. Number of Source Program Statements: 8704
18. Computer Memory Requirements: Varies with application	19. Tape Drives: N/A	20. Disk/Drum Units: N/A	21. Graphics: DISSPLA software

22. Other Operational Requirements: none

23. Software Availability: ■ Available □ Limited □ In-House ONLY	24. Documentation Availability: ■ Available □ Inadequate □ In-House ONLY

Software Custodian: [signature] Date: 12/13/96

CNWRA Form TOP-4-1

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```
 ####   #   #     ###     ###  ###   #  #####
##  ##  #   #     # #      #   # #   #  # # #
#       #   #    ## ##     #   # ##  #    #
#       #####    #   #     #   #  #  #    #
#       #   #   #######    #   #  ## #    #
##  ##  #   #   #     #    #   #   ##     #
 ####   #   #  ##     ##  ###  #   ###    #
```

VERSION 2.3 (REVISION 1.)

USER = BACA

I.D. = **********

1 CHAINT PARAMETER VALUES

parameter	value	explanation
mql	3	max constituents
maxe	11000	max elements
maxp	30000	max nodes
nmax	500	max front width
maxmat	20	max materials
ntt	50	max time intervals
maxflx	100	max flux elements
maxpf	600	max flux nodes
maxfs	25	max surfaces
maxslt	200	max source load times
maxpar	1	max parents per nuclide
maxsr	25	max source files per i/o file
mipf	3	max binary input files

1 ***** FINITE ELEMENT MODEL FOR CONTAMINANT TRANSPORT ANALYSIS *****

*** MULTICOMPONENT NUCLIDE TRANSPORT WITH DECAY CHAIN PROCESSES ***

CHAINT 1-D Tes[illegible] (decay chain) for NEFTRAN comparison

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...PROBLEM CONTROL PARAMETERS...

NUMBER OF CONSTITUENTS................................	3
NUMBER OF ELEMENTS....................................	60
NUMBER OF NODES.......................................	303
NUMBER OF SPECIFIED BOUNDARY NODES....................	3
NUMBER OF MATERIAL TYPES..............................	1
INPUT ECHO PRINT OPTION (0-NONE, 1-PRNT)..............	0
OUTPUT PRINT OPTION (1-FULL, 2-ABRV)..................	2
VEL FIELD TYPE (0-ONE CARD, 1-BY ROCK TYPE . . 2-VARYING ON FILE, 3-STEADY ON FILE)...	3
NUMBER OF MASS FLUX CONSTITUENTS......................	0
COORD SYSTEM (0-CARTESIAN, <>0-RADIAL ABOUT X=0.0)......	0
CONTAMINANT INTEGRATION OPTION (0-INHIBIT, 1-PERFORM)...	0
INITIAL CONDITION TYPE (<>0-MULT CARDS, 0-SINGLE CARD...	0
INPUT VELOCITY FILE (LU)..............................	11
INPUT RESTART FILE (LU)...............................	0
OUTPUT RESTART FILE (LU)..............................	0
PLOT OUTPUT FILE (LU) (0-NONE, <0-STP SAV, >0-INTV SAVE)	14
INPUT GEOMETRY FILE (LU)..............................	15
OUTPUT MASS FLUX FILE (LU)............................	0
STARTING TIME (YEARS)............................	0.0
X SCALE FACTOR......................................	1.000
Y SCALE FACTOR......................................	1.000
U SCALE FACTOR......................................	1.000
V SCALE FACTOR......................................	1.000
WEIGHTING FACTOR....................................	1.800

1

......TIME CONTROL AND RUN SPECIFICATIONS......

NUMBER OF TIME STEPS	PRINT INTERVAL	TIME STEP (YRS)	TIME (YRS)	ZONEL (M)	ZONER (M)	ZONET (M)	ZONEB (M)

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500	500	0.2000	100.0	0.000[illegible]	0.000E+00	0.000E+00	0.000E+00
900	900	1.000	1000.	0.000E+00	0.000E+00	0.000E+00	0.000E+00
800	800	5.000	5000.	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.1500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.2500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.3500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.4500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.5500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.6500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
500	500	20.00	0.7500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1000	1000	20.00	0.9500E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
1000	1000	20.00	0.1150E+06	0.000E+00	0.000E+00	0.000E+00	0.000E+00

SOFTWARE QA FILE FOR CHAINT COMPUTER CODE Version 2.3

Prepared by:

Robert W. Rice

prepared by: ____________ date 8/26/96

accepted by: ____________ date 8/26/96

August 26, 1996

Prepared for:

Center for Nuclear Waste Regulatory Analyses

TABLE OF CONTENTS

CHAINT COMPUTER CODE DEVELOPMENT AND CONTROL SUMMARY

The CHAINT (Kline et al., 1985) computer code was selected for use in support of technical studies related to the Environmental Protection Agency (EPA) Standard for Yucca Mountain. In particular, the CHAINT code was acquired and installed on the Center for Nuclear Waste Regulatory Analyses (CNWRA) SUN Sparc workstation computer resources for the purpose of modeling contaminant transport in saturated groundwater flow.

The CHAINT computer code was developed for the Basalt Waste Isolation Project (BWIP) at Rockwell Hanford Operations to study nuclear waste disposal in deep geologic repositories. CHAINT is a two-dimensional numerical model designed to simulate the transport of dissolved radionuclides and daughter products in saturated, fractured porous media. The physical processes accounted for include advection, dispersion, diffusion, retardation, radionuclide chain decay coupling, and mass injection. The governing mass balance equation for concentration which includes an advection term, a dispersion term, a first order decay term,and a mass source/sink term is solved subject to the initial and boundary conditions using a Galerkin finite-element method and block diagonal frontal solution technique. CHAINT input requirements consist of files from MAGNUM-2D and a file containing transport properties, initial conditions, boundary conditions, and time steps for simulation output. Results from CHAINT simulations are plotted using the DISSPLA software available from Computer Associates, Inc.

A more complete description of the CHAINT code is available in the CHAINT users guide (Kline et al., 1985). The CHAINT users guide is provided in this document along with the CHAINT FORTRAN source code on a 3.5" diskette and a copy of TOP 18.

The objective of this report is to document the testing and control of the CHAINT code and thereby satisfy the requirements of the CNWRA Technical Operating Procedure 18 (TOP 18) - "The Development and Control of Scientific and Engineering Software."

1.0 SOFTWARE REQUIREMENTS DESCRIPTION

The CHAINT (Kline et al., 1985) computer code was selected for use in support of technical studies related to the Environmental Protection Agency (EPA) Standard for Yucca Mountain. In particular, the CHAINT code was acquired by the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the purpose of modeling contaminant transport in saturated groundwater flow. The software was not developed or modified by the CNWRA, therefore, the software requirements description presented in CNWRA Technical Operating Procedure 18 (TOP 18) is not applicable.

2.0 DESIGN AND DEVELOPMENT

The CHAINT computer code was aquired for use at the CNWRA. The software was not developed or modified by the CNWRA, therefore, the software design and development documentation requirement presented in CNWRA TOP 18 is not applicable.

3.0 DESIGN VERIFICATION

The CHAINT computer code was aquired for use at the CNWRA. The software was not developed or modified by the CNWRA. Future modifications of the software by CNWRA are not anticipated. Therefore, the design verification requirement presented in CNWRA TOP 18 are not applicable.

4.0 INSTALLATION TESTING

4.1 INSTALLATION TESTING DOCUMENTATION

An installation test was prepared to test the CHAINT computer code for proper installation. The test problem consisted of using MAGNUM-2D to establish the flow file. The MAGNUM-2D run consisted of ten elements with a head of 1.0 at one boundary and a head of 0.0 at the other. This was then run to steady-state.

The CHAINT test consisted of ten elements with a constant source concentration of 1.0 at one boundary and 0.0 at the other. A one year simulation time was used. The concentration at this time for each element is given in the output of this section. The input and output for this test problem are included in this section for future use in installation testing. A computer disk is also included with the installation test problem files.

A more rigorous test of the installation of the computer code was also completed using the validation test cases in Section 7.1. These tests were aimed at several features of the computer code intended for use at Yucca Mountain. The results of these tests compared to analytical solutions indicated that the computer code was successfully installed at CNWRA.

```
MAGNUM - Installation Problem
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
   1     0     1     53    10     1    0    0     0    1     1    0
#  irs   isv   icf   igi   ig   ivel inpt icsv
   0    13     0    10     0    12    0    0
  [illegible]f   alfa  tref
  0.0    1.8   20.0
#  nts  ntsg    dlt
   1     1      1000.
 9999    1      1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#   n       To       Ho
    1   20.000     0.5
#  kspec
     6
#        n     n1 n2  Tbc      Hbc
         1         0   1   20.0000    1.0
         2         0   1   20.0000    1.0
         3         0   1   20.0000    1.0
        50         0   1   20.0000    0.0
        51         0   1   20.0000    0.0
        52         0   1   20.0000    0.0
      #   L    cvm      tkk(1)  tkk(2)  poros     hkax         hkay         nme
#        sp1       rhom    alpal    alpat    width
         1         0         0        0       0.07     5.0e-6     5.0e-6     mat1
   1.0e-6      2400        0        0        0
#  nld  nlt  scf
   0    0      0.0
```

```
  10   53             0  BACA      GEOMETRY    MESHER  2.00
MAGNUM geometry file for installation test
   1    1     4     5     6     7     8     3     2     1     1
   2    5     9    10    11    12    13     7     6     1     2
   3   10    14    15    16    17    18    12    11     1     3
[illegible]   15    19    20    21    22    23    17    16     1     4
   5   20    24    25    26    27    28    22    21     1     5
   6   25    29    30    31    32    33    27    26     1     6
   7   30    34    35    36    37    38    32    31     1     7
   8   35    39    40    41    42    43    37    36     1     8
   9   40    44    45    46    47    48    42    41     1     9
  10   45    49    50    51    52    53    47    46     1    10
   1     0.000     0.000       0.00     0.00
   2     0.000     5.000       0.00     0.00
   3     0.000    10.000       0.00     0.00
   4     5.000     0.000       0.00     0.00
   5    10.000     0.000       0.00     0.00
   6    10.000     5.000       0.00     0.00
   7    10.000    10.000       0.00     0.00
   8     5.000    10.000       0.00     0.00
   9    15.000     0.000       0.00     0.00
  10    20.000     0.000       0.00     0.00
  11    20.000     5.000       0.00     0.00
  12    20.000    10.000       0.00     0.00
  13    15.000    10.000       0.00     0.00
  14    25.000     0.000       0.00     0.00
  15    30.000     0.000       0.00     0.00
  16    30.000     5.000       0.00     0.00
  17    30.000    10.000       0.00     0.00
  18    25.000    10.000       0.00     0.00
[illegible]    35.000     0.000       0.00     0.00
  20    40.000     0.000       0.00     0.00
  21    40.000     5.000       0.00     0.00
  22    40.000    10.000       0.00     0.00
  23    35.000    10.000       0.00     0.00
  24    45.000     0.000       0.00     0.00
  25    50.000     0.000       0.00     0.00
  26    50.000     5.000       0.00     0.00
  27    50.000    10.000       0.00     0.00
  28    45.000    10.000       0.00     0.00
  29    55.000     0.000       0.00     0.00
  30    60.000     0.000       0.00     0.00
  31    60.000     5.000       0.00     0.00
  32    60.000    10.000       0.00     0.00
  33    55.000    10.000       0.00     0.00
  34    65.000     0.000       0.00     0.00
  35    70.000     0.000       0.00     0.00
  36    70.000     5.000       0.00     0.00
  37    70.000    10.000       0.00     0.00
  38    65.000    10.000       0.00     0.00
  39    75.000     0.000       0.00     0.00
  40    80.000     0.000       0.00     0.00
  41    80.000     5.000       0.00     0.00
  42    80.000    10.000       0.00     0.00
  43    75.000    10.000       0.00     0.00
  44    85.000     0.000       0.00     0.00
[illegible]    90.000     0.000       0.00     0.00
  46    90.000     5.000       0.00     0.00
  47    90.000    10.000       0.00     0.00
  48    85.000    10.000       0.00     0.00
```

49	95.000	0.000	0.00	0.00
50	100.000	0.000	0.00	0.00
51	100.000	5.000	0.00	0.00
52	100.000	10.000	0.00	0.00
53	95.000	10.000	0.00	0.00

1

```
###   ###     ###      ####   ###   #  #    #  ###   ###
# #   # #     # #     ##  ##  # #   #  #    #  # #   # #
# ## ## #    ## ##    #       # ##  #  #    #  # ## ## #
#  ###  #   #    #    #   ##  #  #  #  #    #  #  ###  #
#   #   #   #######   #    #  #  ## #  #    #  #   #   #
#       #   #     #   ##  ##  #   # #  #    #  #       #
#       #  ##     ##   ####   #   ###  ######  #       #
```

VERSION 3.2 (REVISION 1.)

USER = BACA

I.D. = **********

1 MAGNUM PARAMETER VALUES

parameter	value	explanation
maxe	11000	max number of elements
maxp	30000	max number of nodes
maxmat	25	max materials types
nmax	300	dimension for eq array
ntt	25	max time intervals
maxh	225	max heat source elements
maxt	50	max thermal load data points
maxsr	15	max source file per binary i/o file
mipf	5	max input binary files

1 MAGNUM - Installation Problem

TABLE 1. - PRINCIPAL PROBLEM SPECIFICATIONS

SIMULATION MODE (0-TIME VARYING, .NE.0-STEADY STATE)..... 1

HEAT TRANSPORT (0-ISOTHERMAL, .NE.0-NONISOTHERMAL)....... 0

GROUNDWATER FLOW (0-HYDROSTATIC, .NE.0-FLUID FLOW).......	1
NUMBER OF NODES..	53
NUMBER OF ELEMENTS.....................................	10
NUMBER OF ROCK TYPES...................................	1
INITIAL CONDITION INPUTS (0-UNIFORM, 1-SPATIALLY VARYING)	0
INPUT DATA PRINT CONTROL (0-PARTIAL ECHO, 1-TOTAL ECHO...	0
DIAGNOSTIC PRINTOUT (0-NO ACTION,1-CONVERGENCE INFO).....	0
VELOCITY PRINT CONTROL (0-SUPPRESS PRINT,1-PRINT VELS)...	1
RESULTS FILE WRITE CONTROL (0-AT TIME STEP,1-AT PRT FREQ)	1
COORD SYSTEM (0-CARTESIAN, 1-AXISYMMETRIC ABOUT X=0.)....	0

INPUT RESTART FILE (LU)................................	0
RESULTS FILE (LU)......................................	13
OUTPUT RESTART FILE (LU)...............................	0
INPUT GEOMETRY FILE (LU)...............................	10
OUTPUT GEOMETRY FILE (LU)..............................	0
STREAM/PATHLINE DATA FILE (LU).........................	12
TEMPERATURE INPUT FILE (TEMPERATURE INACTIVE)...........	0
INITIAL CONDITION OUTPUT FILE (FORMATTED)...............	0
SCALE FACTOR FOR X COORDINATES..........................	1.00
SCALE FACTOR FOR Y COORDINATES..........................	1.00
LEFT BOUNDARY FOR QUAD ELEMENTS.........................	0.00
RIGHT BOUNDARY FOR QUAD ELEMENTS........................	0.00
TOP BOUNDARY FOR QUAD ELEMENTS..........................	0.00
BOTTOM BOUNDARY FOR QUAD ELEMENTS.......................	0.00
START TIME (YEARS)......................................	0.00
WEIGHTING FACTOR..	1.8
DENSITY/VISCOSITY REFERENCE TEMP (>0.05 TO IMPLEMENT)....	20.0

TIME CONTROL AND RUN SPECIFICATIONS

NUMBER OF TIME STEPS	PRINT INTERVAL	TIME STEP	TIME(YEARS)
1	1	1000.	1000.

TABLE 5. - SPECIFIED BOUNDARY CONDITIONS

NUMBER OF SPECIFIED BOUNDARY NODES 6

NODE TYPE	T(C)	H(M)
1 (01)	20.000	1.000
2 (01)	20.000	1.000
3 (01)	20.000	1.000
50 (01)	20.000	0.000
51 (01)	20.000	0.000
52 (01)	20.000	0.000

1 TABLE 6. - ROCK PROPERTIES

PARAMETER	ROCK TYPES
	1
	mat1
1. SPECIFIC HEAT (J/KG-C)	0.000E+00
2. THERMAL CONDUCTIVITY IN X (J/SEC-M-C)	0.000E+00
3. THERMAL CONDUCTIVITY IN Y (J/SEC-M-C)	0.000E+00
4. EFFECTIVE POROSITY (FRACTION)	7.000E-02

5. HYDRAULIC CONDUCTIVITY (KXX-M/SEC)	5.000E-06
HYDRAULIC CONDUCTIVITY (KZZ-M/SEC)	5.000E-06
7. SPECIFIC STORAGE (1/M)	1.000E-06
8. ROCK DENSITY (KG/M**3)	2.400E+03
9. LONGITUDINAL DISPERSIVITY (M)	0.000E+00
10. LATERAL DISPERSIVITY (M)	0.000E+00
11. FRACTURE/FAULT THICKNESS (M)	0.000E+00

MAGNUM2D, VERSION 3.2, THE RUN I.D. IS **********, THE USER IS BACA , PAGE 4

1 TABLE 7. - HEAT GENERATION HISTORY

NUMBER OF HEAT SOURCE ELEMENTS..........	0
NUMBER OF TIME POINTS..................	0
SCALE FACTOR FOR HEAT LOAD.............	1.00

```
1               **** INPUT BINARY FILE TRACEBACK INFORMATION *****



        GEOMETRY FILE READ ON UNIT     10, CREATED BY   MESHER  2.0
                 THE RUN I.D. IS          0,  THE USER IS BACA
                 THE TITLE IS:
                  MAGNUM geometry file for installation test
```

1 MAGNUM - Installation Problem

RESULTS FOR STEADY STATE

NODE	H(M)		NODE	H(M)	NODE	H(M)	NODE	H(M)	
1	1.000	*	15	0.7000	29	0.4500	43	0.2500	
2	1.000	*	16	0.7000	30	0.4000	44	0.1500	
3	1.000	*	17	0.7000	31	0.4000	45	0.1000	
4	0.9500		18	0.7500	32	0.4000	46	0.1000	
5	0.9000		19	0.6500	33	0.4500	47	0.1000	
6	0.9000		20	0.6000	34	0.3500	48	0.1500	
7	0.9000		21	0.6000	35	0.3000	49	0.5000E-01	
8	0.9500		22	0.6000	36	0.3000	50	0.	*
9	0.8500		23	0.6500	37	0.3000	51	0.	*
10	0.8000		24	0.5500	38	0.3500	52	0.	*
11	0.8000		25	0.5000	39	0.2500	53	0.5000E-01	
12	0.8000		26	0.5000	40	0.2000			
13	0.8500		27	0.5000	41	0.2000			
14	0.7500		28	0.5500	42	0.2000			

1 MAGNUM - Installation Problem

RESULTS FOR VELOCITY (M/YR) OF STEADY STATE

ELEMENT		GSS PNT 1	GSS PNT 2	GSS PNT 3	GSS PNT 4	GSS PNT 5	GSS PNT 6	GSS PNT 7	GSS PNT 8	GSS PNT 9
1	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	4.6992E-06	0.0000E+00	-1.7622E-06	0.0000E+00	0.0000E+00	-1.8112E-07	0.0000E+00	7.0488E-06	-3.8181E-06
2	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	0.0000E+00	-4.6992E-06	-2.3496E-06	-2.3496E-06	-3.5244E-06	-1.4920E-06	-4.6992E-06	2.3496E-06	2.9370E-07
3	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	-2.3496E-06	-2.3496E-06	-5.8740E-07	-2.9370E-06	-2.3496E-06	-1.2726E-08	4.6992E-06	-1.1748E-06	-2.3496E-06
4	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	2.3496E-06	-1.1748E-06	1.4685E-06	-1.7622E-06	-1.1748E-06	-2.2223E-07	0.0000E+00	1.1748E-06	-1.1748E-06
5	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	2.3496E-06	-1.1748E-06	2.9370E-07	0.0000E+00	-1.1748E-06	-3.5832E-07	0.0000E+00	-1.1748E-06	-1.1748E-06
6	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	1.1748E-06	0.0000E+00	1.1748E-06	-2.9370E-07	-5.8740E-07	2.3986E-07	-1.1748E-06	-1.1748E-06	-2.7902E-06
7	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	1.1748E-06	0.0000E+00	2.9370E-07	0.0000E+00	0.0000E+00	3.2405E-07	-1.1748E-06	-5.8740E-07	-7.3425E-07
8	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	0.0000E+00	5.8740E-07	1.3217E-06	-2.9370E-07	0.0000E+00	5.1838E-07	-2.3496E-06	-5.8740E-07	-1.0280E-06
9	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	2.3496E-06	2.6433E-06	1.9091E-06	1.4685E-07	4.4055E-07	5.1887E-08	-5.8740E-07	-1.4685E-06	-2.7167E-06
10	VEL X	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00	1.5768E+00
	VEL Y	2.9370E-06	3.3776E-06	1.2482E-06	3.6713E-07	1.8356E-06	1.1457E-06	-1.7622E-06	2.9370E-07	6.9754E-07

SECONDS TO EXECUTE MAGNUM = 0.3

CHAINT Installation Test Program

```
#  nqal   ne     np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1      10     53    3     1      0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
    0   11    0    0   14   15    0
#  sf   alfa  xscale  yscale  uscale  vscale
    0.   1.8     0.      0.      0.      0.
#  nts  ntsg   dlt   zonel  zoner  zonet  zoneb
  1     1     1.     0.     0.     0.     0.
9999   0     0      0      0      0      0
#   j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1       5.0       0.0      2400.      0.07       0.      mat1
#  islt
    1
#   L   amu    diag    isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1  99.0  2.13E+05    0        0.0       0        0.0    Tc99   0.0
#   i    dml(i,1..n2)  m2/yr
    1   0.0
#   i    xkdi(i,1..n2)  ml/g
    1    0.0
#  lk    Ci
    1    0.0
#   L    bcs
    1    1.0
    2    1.0
    3    1.0
#   nld   scf   relz
     0    1.0    0.
```

1

```
 ####  #  #    ###    ###  ###   #  #####
## ##  #  #    # #     #   # #   #  # # #
#      #  #   ## ##    #   # ##  #    #
#      #####  #   #    #   #  #  #    #
#      #  #  #######   #   #  ## #    #
## ##  #  #  #     #   #   #   # #    #
 ####  #  # ##     ## ###  #   ###    #
```

VERSION 2.3 (REVISION 1.)

USER = BACA

I.D. = **********

1 CHAINT PARAMETER VALUES

parameter	value	explanation
mql	1	max constituents
maxe	11000	max elements
maxp	30000	max nodes
nmax	500	max front width
maxmat	20	max materials
ntt	50	max time intervals
maxflx	100	max flux elements
maxpf	600	max flux nodes
maxfs	25	max surfaces
maxslt	200	max source load times
maxpar	1	max parents per nuclide
maxsr	25	max source files per i/o file
mipf	3	max binary input files

1 ***** FINITE ELEMENT MODEL FOR CONTAMINANT TRANSPORT ANALYSIS *****

*** MULTICOMPONENT NUCLIDE TRANSPORT WITH DECAY CHAIN PROCESSES ***

...PROBLEM CONTROL PARAMETERS...

NUMBER OF CONSTITUENTS.................................. 1
NUMBER OF ELEMENTS...................................... 10
NUMBER OF NODES... 53
NUMBER OF SPECIFIED BOUNDARY NODES...................... 3
NUMBER OF MATERIAL TYPES................................ 1
INPUT ECHO PRINT OPTION (0-NONE, 1-PRNT)............... 0
OUTPUT PRINT OPTION (1-FULL, 2-ABRV).................... 2
VEL FIELD TYPE (0-ONE CARD, 1-BY ROCK TYPE . .
2-VARYING ON FILE, 3-STEADY ON FILE)... 3
NUMBER OF MASS FLUX CONSTITUENTS........................ 0
COORD SYSTEM (0-CARTESIAN, <>0-RADIAL ABOUT X=0.0)...... 0
CONTAMINANT INTEGRATION OPTION (0-INHIBIT, 1-PERFORM)... 0

INITIAL CONDITION TYPE (<>0-MULT CARDS, 0-SINGLE CARD... 0
INPUT VELOCITY FILE (LU)................................ 11
INPUT RESTART FILE (LU)................................. 0
OUTPUT RESTART FILE (LU)................................ 0
PLOT OUTPUT FILE (LU) (0-NONE, <0-STP SAV, >0-INTV SAVE) 14
INPUT GEOMETRY FILE (LU)................................ 15
OUTPUT MASS FLUX FILE (LU).............................. 0

STARTING TIME (YEARS)............................ 0.0

X SCALE FACTOR...................................... 1.000
Y SCALE FACTOR...................................... 1.000
U SCALE FACTOR...................................... 1.000
V SCALE FACTOR...................................... 1.000

WEIGHTING FACTOR.................................... 1.800

......TIME CONTROL AND RUN SPECIFICATIONS......

NUMBER OF TIME STEPS	PRINT INTERVAL	TIME STEP (YRS)	TIME (YRS)	ZONEL (M)	ZONER (M)	ZONET (M)	ZONEB (M)
1	1	1.000	1.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1
......ROCK CHARACTERISTICS......

ER	X DISPERSIVITY (M)	Y DISPERSIVITY (M)	DENSITY (KG/M3)	POROSITY	FRAC WIDTH (M)	
1	5.00000E+00	0.00000E+00	2400.00	0.07000	0.00000E+00	mat1

1 ......INPUT DECAY CHAIN DATA......

CONSTITUENT	NAME	ATOMIC WEIGHT	HALF LIFE (YEARS)	DAUGHTER CONSTITUENT 1	SPLITTING FRACTION	DAUGHTER CONSTITUENT 2	SPLITTING FRACTION	CUT-OFF THRESHOLD
1	Tc99	99.00	2.13000E+05	0	0.0000	0	0.0000	0.000E+00

"*" MEANS CONSTITUENT IS NON-COMPUTATIONAL

1 ......NUCLIDE MOLECULAR DIFFUSION COEFFICIENTS ......

CONSTITUENT		ROCK TYPES 1) mat1
1	Tc99	3.00E-02

** WARNING, MOLECULAR DIFFUSIVITY VALUES LESS THAN
** OR EQUAL TO ZERO WERE RESET TO 3.000E-02.

1 ......NUCLIDE SORPTION (ML/GM)......

CONSTITUENT		ROCK TYPES
		1) mat1
1	Tc99	0.00E+00

1 ......DECAY CHAIN CONNECTIVITY AND DECAY RATES......

CONSTITUENT		DECAY RATE
1)	Tc99	3.25E-06

1 ......SPECIFIED BOUNDARY NODES AND VALUES......

BOUNDARY VALUES FOR CONSTITUENTS 1 THROUGH 1

NODE	Tc99
1	1.000E+00
2	1.000E+00
3	1.000E+00

```
CHAINT   , VERSION  2.3, THE RUN I.D. IS **********, THE USER IS BACA     ,     PAGE   8

VELOCITY FILE CREATED BY  MAGNUM2D ( 3.20)
         RUN I.D. IS     **********
         PROGRAM USER     BACA
MAGNUM - Installation Problem
FILE TRACEBACK:   FILE TYPE    RUN I.D.    SOURCE PROGRAM/USER
                   GEOMETRY           0       MESHER/BACA
1                **** INPUT BINARY FILE TRACEBACK INFORMATION *****



         GEOMETRY FILE READ ON UNIT     15, CREATED BY   MESHER  2.0
                  THE RUN I.D. IS          0,  THE USER IS BACA
                  THE TITLE IS:
                   MAGNUM geometry file for installation test
```

1

THE FOLLOWING DECAY CHAIN HAS BEEN SELECTED, SIMULATION TIME = 0.000E+00

CONSTITUENT	USAGE	DECAY RATE(S)
1) Tc99	1	3.254E-06

```
***** WARNING *****  PECLET NUMBER AT ELEMENT    1 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    2 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    3 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    4 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    5 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    6 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    7 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    8 (mat1    ) IS  9.9973E-01
***** WARNING *****  PECLET NUMBER AT ELEMENT    9 (mat1    ) IS  9.9973E-01
    * WARNING *****  PECLET NUMBER AT ELEMENT   10 (mat1    ) IS  9.9973E-01
1                                 ...RESULTS AFTER   1.000    YEARS OF SIMULATION...

                 ..... CONCENTRATIONS FOR CONSITIUENT NUMBER   1  Tc99  ,   MG/LIT  .....
```

1 1.000E+00*	8 7.550E-01	15 1.607E-01	22 8.717E-02	29 3.485E-02	36 1.391E-02	43 1.025E-02	50 2.740E-03
2 1.000E+00*	9 4.027E-01	16 1.607E-01	23 1.185E-01	30 2.564E-02	37 1.391E-02	44 5.571E-03	51 2.740E-03
3 1.000E+00*	10 2.964E-01	17 1.607E-01	24 6.425E-02	31 2.564E-02	38 1.890E-02	45 4.136E-03	52 2.740E-03
[illegible] 7.550E-01	11 2.964E-01	18 2.184E-01	25 4.728E-02	32 2.564E-02	39 1.025E-02	46 4.136E-03	53 3.147E-03
5 5.464E-01	12 2.964E-01	19 1.185E-01	26 4.728E-02	33 3.485E-02	40 7.547E-03	47 4.137E-03	
6 5.464E-01	13 4.027E-01	20 8.717E-02	27 4.728E-02	34 1.890E-02	41 7.547E-03	48 5.571E-03	
7 5.464E-01	14 2.184E-01	21 8.717E-02	28 6.425E-02	35 1.391E-02	42 7.547E-03	49 3.147E-03	

SECONDS TO EXECUTE CHAINT = 0.4

4.2 DISCREPENCY RESOLUTION

Discrepency resolution was not required since the installation problem and validation tests indicate that the code is operating properly on the CNWRA computer system.

5.0 CONFIGURATION CONTROL INFORMATION

The information provided in this section is for use by the Software Custodian for configuration control of the CHAINT computer code, version 2.3.

5.1 SOFTWARE SUMMARY FORM

The Software Summary Form (CNWRA Form TOP-4) is provided for configuration control.

5.5 VERSION CONTROL

The information provided in this document applies to version 2.3 of the CHAINT computer code.

5.6 SOFTWARE RELEASE NOTICE

The Software Release Notice (SRN) Form (CNWRA Form TOP-2) is used to release software and documentation to the QA files, to request software/documentation be released to the user, and to establish access rights to software/documentation.

6.0 SOFTWARE PROBLEM REPORTING AND RESOLUTION

After the initial version (ver. 2.3) is established for configuration control, all subsequent changes, whether required to enhance/alter software performance or resolve operational problems, shall be documented using the Software Problem and Change Request (SPCR) form (CNWRA Form TOP-5) as per TOP 18.

7.0 SOFTWARE VALIDATION

7.1 SOFTWARE VALIDATION TEST PLAN

It is anticipated that CHAINT simulations will be performed for saturated zone transport of radionuclides at Yucca Mountain. Based upon this anticipated application, validation test cases with corresponding analytical solutions were designed. Steady-state MAGNUM-2D flow simulations employing hydraulic and materials properties similar to those present at Yucca Mountain were performed and the results used as CHAINT input.

A total of seven validation cases are presented which test the basic features and functionality of the CHAINT code for the intended applications and conditions at Yucca Mountain. The seven validation test cases included: (1) one dimensional transport; (2) two dimensional transport; (3) one dimensional transport with decay and sorption; (2) two dimensional transport with decay and sorption; (5) two dimensional transport without decay for a flux source; (6) two dimensional transport with decay for a flux source; and (7) one dimensional transport with a three member decay chain. The complete description of each case including the CHAINT and analytical solution input parameters are provided below.

7.1.1 Validation Test Case 1 - One Dimensional

MAGNUM-2D

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 5 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The grid represented a one dimensional strip and consisted of 60 elements and 303 nodes. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. Attachment 1 provides figures showing the finite element grid and the MAGNUM-2D geometry file for this validation test case.

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

The results for this validation test case are provided in Section 7.2, Software Validation Test Report. The test report provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing constant one dimensional flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling was performed using files from MAGNUM-2D simulations. Transport of a conservative contaminant, Technetium-99 (Tc-99), with a half-life of 213,500 years was modeled with two boundary condition scenarios. The first scenario consisted of

type two boundary conditions for the top, bottom, and right side of the grid and a type one boundary condition with a constant concentration of 1.0 mg/L for the left side of the grid. The second scenario employed the type two boundary conditions for all sides of the grid and a constant flux into the left-most element of the grid. The constant flux was specified at a value that resulted in a Tc-99 concentration of 1.0 mg/L in the element. Consequently, even though the two scenarios utilized a different type of source term, both scenarios were equivalent in their treatment of the contaminant source.

ANALYTICAL SOLUTION

The CHAINT model results for validation test case 1 were compared to an analytical solution. Analytical solutions to one, two, and three dimensional solute transport are available in a United States Geological Survey (USGS) Water Resources manual (Wexler, 1992). An equation representing one dimensional solute transport with advection, dispersion, first order chemical transformation, uniform groundwater velocity, and a constant source is:

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} - \lambda C \tag{1}$$

with boundary conditions:

$$C = C_o \qquad at\ x = 0$$

$$\frac{\partial C}{\partial x} = 0 \qquad at\ x = L$$

and initial conditions:

$$C = 0 \qquad for\ 0 < x < L \qquad at\ t = 0$$

where,

C	=	solute concentration (mg/L)
t	=	time (yr)
D	=	longitudinal dispersion coefficient (m^2/yr)
x	=	flow direction (m)
V	=	groundwater velocity (m/yr)
λ	=	rate coefficient (natural logarithm of 2 divided by the half-life in 1/yr)
C_0	=	source concentration (mg/L)
L	=	length of modeled domain (m)

The analytical solution to Equation 1, subject to the boundary conditions and initial conditions described above, was coded into a FORTRAN program called FINITE (Wexler, 1992). FINITE was acquired on a 3.5" diskette from the USGS with an accompanying users manual. The FINITE source code is presented in Attachment 1. Following guidance in the users manual, the FINITE source code was modified to provide output in a tabular format which could be imported into SigmaPlot. SigmaPlot is a windows application with capabilities to generate graphs and contours from spreadsheet data.

A sample problem with plotted results was provided in the users manual and the sample problem input file was included with the FINITE source code. To check the functionality of the code, FINITE was compiled with FORTRAN 77 and a simulation performed using the sample problem input file. The sample problem results were plotted with SigmaPlot and the graphs matched the figures in the users guide (Wexler, 1992).

FINITE simulations utilizing input parameters equivalent to the parameters employed in the CHAINT simulations were conducted. The input parameters were 300 m column length, 8 m/yr velocity, 40 m^2/yr dispersion coefficient, no first order chemical transformation, and 1.0 mg/L source concentration. The FINITE input file and results are provided in Section 7.2.

7.1.2 Validation Test Case 2 - Two Dimensional

MAGNUM-2D

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 300 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. The finite element grid and the MAGNUM-2D geometry file for this validation test case are presented in Section 7.2.

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

The results for this validation test case are provided in Section 7.2, Software Validation Test Report. The test report provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing uniform flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling was performed using files from MAGNUM-2D simulations. Transport of a conservative contaminant, Technetium-99 (Tc-99), with a half-life of 213,500

years was modeled with two boundary condition scenarios. The first scenario consisted of type two boundary conditions for the top, bottom, left, and right side of the grid except for a type one boundary condition with a strip source with a constant concentration of 1.0 mg/L from y = 140 m to y = 160 m on the left side of the grid (i.e., x = 0 m). The second scenario employed the type two boundary conditions for all sides of the grid and a constant flux into elements from y = 140 m to y = 160 m at x = 0 m. The constant flux was specified at a value that resulted in a Tc-99 concentration of 1.0 mg/L in the element. Consequently, even though the two scenarios utilized a different type of source term, both scenarios were equivalent in their treatment of a contaminant source.

ANALYTICAL SOLUTION

The CHAINT model results for validation test case 2 were compared to an analytical solution. Analytical solutions to one, two, and three dimensional solute transport are available in a USGS Water Resources manual (Wexler, 1992). An equation representing two dimensional solute transport with advection, dispersion, first order chemical transformation, uniform groundwater velocity, and a constant source is:

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} - V \frac{\partial C}{\partial x} - \lambda C \tag{2}$$

with boundary conditions:

$$C = C_o \qquad at\ x = 0\ and\ Y_1 < y < Y_2$$

$$C = 0 \qquad at\ x = 0\ and\ y < Y_1\ or\ y > Y_2$$

$$C, \frac{\partial C}{\partial y} = 0 \qquad at\ y = 0$$

$$C, \frac{\partial C}{\partial y} = 0 \qquad at\ y = W$$

and initial conditions:

$$C, \frac{\partial C}{\partial x} = 0 \qquad at\ x = \infty$$

$$C = 0 \qquad for\ 0 < x < \infty\ and\ 0 < y < W \qquad at\ t = 0$$

where,

C	=	solute concentration (mg/L)
t	=	time (yr)
D_x	=	longitudinal dispersion coefficient in the flow direction (m^2/yr)
D_y	=	transverse dispersion coefficient perpendicular to the flow direction (m^2/yr)
x	=	flow direction (m)
V	=	groundwater velocity (m/yr)
λ	=	rate coefficient (natural logarithm of 2 divided by the half-life in 1/yr)
C_0	=	source concentration (mg/L)
L	=	length of modeled domain (m)

The analytical solution to Equation 2, subject to the boundary conditions and initial conditions described above, was coded into a FORTRAN program called STRIPF (Wexler, 1992). STRIPF was acquired on a 3.5" diskette from the USGS with an accompanying users manual. The STRIPF source code is presented in Section 7.2. Following guidance in the users manual, the STRIPF source code was modified to provide output in a tabular format which could be imported into SigmaPlot. SigmaPlot is a windows application with capabilities to generate graphs and contours from spreadsheet data.

A sample problem with plotted results was provided in the users manual and the sample problem input file was included with the STRIPF source code. To check the functionality of the code, STRIPF was compiled with FORTRAN 77 and a simulation performed using the sample problem input file. The sample problem results were plotted with SigmaPlot and the graphs matched the figures in the users guide (Wexler, 1992).

STRIPF simulations utilizing input parameters equivalent to the parameters employed in the CHAINT simulations were conducted. The input parameters were 300 m by 300 m modeled domain, 8 m/yr velocity, 40 m^2/yr longitudinal dispersion coefficient, 8 m^2/yr transverse dispersion coefficient, no first order chemical transformation, and 1.0 mg/L source concentration located at x = 0 m from y = 140 m to y = 160 m. The STRIPF input file and results are provided in Section 7.2.

7.1.3 Validation Test Case 3 - One Dimensional with Decay and Sorption

MAGNUM-2D

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 5 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The grid represented a one dimensional strip and consisted of 60 elements and 303 nodes. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. The finite element grid and the MAGNUM-2D geometry file for this validation test case are provided in Section 7.2.

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

Section 7.2 provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing constant one dimensional flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling with decay and sorption was performed using files from MAGNUM-2D simulations. Transport of Plutonium-239 (Pu-239), with a half-life of 24,110 years and a partitioning coefficient of 130 ml/g (NUREG-1464, 1995), was modeled with two boundary condition scenarios. The first scenario consisted of type two boundary conditions for the top, bottom, and right side of the grid and a type one boundary condition with a constant concentration of 1.0 mg/L for the left side of the grid. The second scenario employed the type two boundary conditions for all sides of the grid and a constant flux into the left-most element of the grid. The constant flux was specified at a value that resulted in a Pu-239 concentration of 1.0 mg/L in the element. Consequently, even though the two scenarios utilized a different type of source term, both scenarios were equivalent in their treatment of the contaminant source.

Results from the CHAINT simulations for constant source concentration and constant flux are presented in Section 7.2.

ANALYTICAL SOLUTION

The results from the CHAINT simulations were compared to results from a one dimensional analytical model. Analytical solutions to one, two, and three dimensional solute transport are available in a United States Geological Survey (USGS) Water Resources manual (Wexler, 1992). An equation representing one dimensional solute transport with advection, dispersion, first order chemical transformation (e.g., radioactive decay), uniform groundwater

velocity, linear sorption, and a constant source is:

$$\frac{\partial C}{\partial t} = D^{*} \frac{\partial^2 C}{\partial x^2} - V^{*} \frac{\partial C}{\partial x} - \lambda C \qquad (3)$$

with boundary conditions:

$$C = C_o \qquad at\ x = 0$$

$$\frac{\partial C}{\partial x} = 0 \qquad at\ x = L$$

and initial conditions:

$$C = 0 \qquad for\ 0 < x < L \qquad at\ t = 0$$

where,

C	=	solute concentration (mg/L)
t	=	time (yr)
D^{*}	=	scaled or retarded longitudinal dispersion coefficient (D/R in m^2/yr)
R	=	retardation factor (defined below, unitless)
x	=	flow direction (m)
V^{*}	=	scaled or retarded groundwater velocity (V/R in m/yr)
λ	=	rate coefficient (natural logarithm of 2 divided by the half-life in 1/yr)
C_0	=	source concentration (mg/L)
L	=	length of modeled domain (m)

For linear equilibrium sorption, the dispersion coefficient and groundwater velocity are scaled using the retardation factor, R, which is defined in the following relation (Wexler, 1992):

$$R = 1 + \frac{k_d\, \rho_b}{\eta}$$

where,

k_d	=	distribution or partitioning coefficient (ml/g)
ρ_b	=	bulk density of the solid matrix (g/cm^3)
η	=	moisture content or the porosity for saturated conditions (unitless)

The analytical solution to Equation 3, subject to the boundary conditions and initial conditions described above, was coded into a FORTRAN program called FINITE (Wexler,

1992). FINITE was acquired on a 3.5" diskette from the USGS with an accompanying users manual. The FINITE source code is presented in Attachment 3. Following guidance in the users manual, the FINITE source code was modified to provide output in a tabular format which could be imported into SigmaPlot. SigmaPlot is a windows application with capabilities to generate graphs and contours from spreadsheet data.

A sample problem with plotted results was provided in the users manual and the sample problem input file was included with the FINITE source code. To check the functionality of the code, FINITE was compiled with FORTRAN 77 and a simulation performed using the sample problem input file. The sample problem results were plotted with SigmaPlot and the graphs matched the figures in the users guide (Wexler, 1992).

FINITE simulations utilizing input parameters equivalent to the parameters employed in the CHAINT simulations were conducted. The input parameters were 300 m column length, 8 m/yr velocity, 40 m^2/yr dispersion coefficient, first order decay using the half-life of Pu-239 (24,110 years), a 1.0 mg/L source concentration, and a retardation factor of 4,458 (calculated with values for k_d , ρ_b , and η of 130 ml/g, 2.4 g/cm^3, and 0.07, respectively [NUREG-1464, 1995]). The velocity and dispersion coefficient were scaled by the retardation factor. The FINITE input file and results are provided in Section 7.2.

7.1.4 Validation Test Case 4 - Two Dimensional with Decay and Sorption

MAGNUM-2D

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 300 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. The finite element grid and the MAGNUM-2D geometry file for this validation test case are provided in the test report given in Section 7.2..

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

Section 7.2 provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing uniform flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling with decay and sorption was performed using files from MAGNUM-2D simulations. Transport of Plutonium-239 (Pu-239), with a half-life of 24,110 years and a partitioning coefficient of 130 ml/g (NUREG-1464, 1995), was modeled with two

boundary condition scenarios. The first scenario consisted of type two boundary conditions for the top, bottom, left, and right side of the grid except for a type one boundary condition with a strip source with a constant concentration of 1.0 mg/L from y = 140 m to y = 160 m on the left side of the grid (i.e., x = 0 m). The second scenario employed the type two boundary conditions for all sides of the grid and a constant flux into elements from y = 140 m to y = 160 m at x = 0 m. The constant flux was specified at a value that resulted in a Pu-239 concentration of 1.0 mg/L in the element. Consequently, even though the two scenarios utilized a different type of source term, both scenarios were equivalent in their treatment of the contaminant source.

Results from the CHAINT simulations for constant source concentration and constant flux are presented in the test report given in Section 7.2

ANALYTICAL SOLUTION

The results from the CHAINT simulations were compared to results from a two dimensional analytical model. Analytical solutions to one, two, and three dimensional solute transport are available in a USGS Water Resources manual (Wexler, 1992). An equation representing two dimensional solute transport with advection, dispersion, first order chemical transformation (e.g., radioactive decay), uniform groundwater velocity, linear sorption, and a constant source is:

$$\frac{\partial C}{\partial t} = D_x^* \frac{\partial^2 C}{\partial x^2} + D_y^* \frac{\partial^2 C}{\partial y^2} - V^* \frac{\partial C}{\partial x} - \lambda C \qquad (4)$$

with boundary conditions:

$$C = C_o \qquad at\ x = 0\ and\ Y_1 < y < Y_2$$

$$C = 0 \qquad at\ x = 0\ and\ y < Y_1\ or\ y > Y_2$$

$$C,\ \frac{\partial C}{\partial y} = 0 \qquad at\ y = 0$$

$$C, \frac{\partial C}{\partial y} = 0 \qquad at\ y = W$$

$$C, \frac{\partial C}{\partial x} = 0 \qquad at\ x = \infty$$

and initial conditions:

$$C = 0 \qquad for\ 0 < x < \infty\ and\ 0 < y < W \qquad at\ t = 0$$

where,

C	=	solute concentration (mg/L)
t	=	time (yr)
D^*_x	=	scaled or retarded longitudinal dispersion coefficient in the flow direction (D_x/R in m^2/yr)
D^*_y	=	scaled or retarded transverse dispersion coefficient perpendicular to the flow direction (D_y in m^2/yr)
x	=	flow direction (m)
V^*	=	scaled or retarded groundwater velocity (V/R in m/yr)
λ	=	rate coefficient (natural logarithm of 2 divided by the half-life in 1/yr)
C_0	=	source concentration (mg/L)
L	=	length of modeled domain (m)

For linear equilibrium sorption, the dispersion coefficient and groundwater velocity are scaled using the retardation factor, R, which is defined in the following relation (Wexler, 1992):

$$R = 1 + \frac{k_d\ \rho_b}{\eta}$$

where,

k_d	=	distribution or partitioning coefficient (ml/g)
ρ_b	=	bulk density of the solid matrix (g/cm^3)
η	=	moisture content or the porosity for saturated conditions (unitless)

The analytical solution to Equation 4, subject to the boundary conditions and initial conditions described above, was coded into a FORTRAN program called STRIPF (Wexler, 1992). STRIPF was acquired on a 3.5" diskette from the USGS with an accompanying users manual. The STRIPF source code is presented in Attachment 4. Following guidance in the

users manual, the STRIPF source code was modified to provide output in a tabular format which could be imported into SigmaPlot. SigmaPlot is a windows application with capabilities to generate graphs and contours from spreadsheet data.

A sample problem with plotted results was provided in the users manual and the sample problem input file was included with the STRIPF source code. To check the functionality of the code, STRIPF was compiled with FORTRAN 77 and a simulation performed using the sample problem input file. The sample problem results were plotted with SigmaPlot and the graphs matched the figures in the users guide (Wexler, 1992).

STRIPF simulations utilizing input parameters equivalent to the parameters employed in the CHAINT simulations were conducted. The input parameters were 300 m by 300 m modeled domain, 8 m/yr velocity, 40 m^2/yr longitudinal dispersion coefficient, 8 m^2/yr transverse dispersion coefficient, first order decay using the half-life of Pu-239 (24,110 years), a 1.0 mg/L source concentration located at x = 0 m from y = 140 m to y = 160 m, and a retardation factor of 4,458 (calculated with values for k_d , ρ_b , and η of 130 ml/g, 2.4 g/cm^3, and 0.07, respectively [NUREG-1464, 1995]). The velocity and dispersion coefficients were scaled by the retardation factor.

The STRIPF input file and results are provided in test report given in Section 7.2.

7.1.5 Validation Test Case 5 - Two Dimensional Transport Without Decay for a Flux Source

MAGNUM-2D

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 300 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. The finite element grid and the MAGNUM-2D geometry file for this validation test case are provided in the test report given in Section 7.2.

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

Section 7.2 provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing uniform flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling was performed using files from MAGNUM-2D simulations. Transport of a conservative contaminant, Technetium-99 (Tc-99), with a half-life of 213,500 years was modeled. The scenario employed the type two boundary conditions for all sides of the grid and a constant flux into elements from y = 140 m to y = 160 m and x = 15 m to x = 35 m. The constant flux was specified at a value that resulted in a Tc-99 maximum concentration of 1.0 mg/L.

Results from the CHAINT simulations are presented in the test report given in Section 7.2.

ANALYTICAL SOLUTION

The results from the CHAINT simulations were compared to results from a two dimensional analytical model. The Nuclear Regulatory Commission has developed straightforward groundwater models for evaluating the transport of radionuclides in groundwater. The models were developed for the limiting case of unidirectional advective flow and dispersion in an isotropic aquifer.

The GROUND model (NRC 1982) was developed to model a horizontal area source of length l and width b centered at 0,0,0 in an aquifer of constant depth h. The following equations were used by NRC:

$$\frac{\partial C}{\partial t} = D_x^* \frac{\partial^2 C}{\partial x^2} + D_y^* \frac{\partial^2 C}{\partial y^2} - V^* \frac{\partial C}{\partial x} - \lambda C \qquad (5)$$

where,

C	=	solute concentration (mg/L)
t	=	time (yr)
D^*_x	=	scaled or retarded longitudinal dispersion coefficient in the flow direction (D_x/R in m^2/yr)
D^*_y	=	scaled or retarded transverse dispersion coefficient perpendicular to the flow direction (D_y in m^2/yr)
x	=	flow direction (m)
V^*	=	scaled or retarded groundwater velocity (V/R in m/yr)
λ	=	rate coefficient (natural logarithm of 2 divided by the half-life in 1/yr)
C_0	=	source concentration (mg/L)
L	=	length of modeled domain (m)

For linear equilibrium sorption, the dispersion coefficient and groundwater velocity are scaled using the retardation factor, R, which is defined in the following relation (NRC, 1982):

$$R = 1 + \frac{k_d \rho_b}{\eta}$$

where,

k_d	=	distribution or partitioning coefficient (ml/g)
ρ_b	=	bulk density of the solid matrix (g/cm^3)
η	=	moisture content or the porosity for saturated conditions (unitless)

Equation 5 is solved in terms of Green's functions resulting in:

$$C_i = \frac{1}{\eta R} X(x,t)\ Y(y,t)\ Z(z,t)$$

where:

C_i	=	concentration at any point in space for an instantaneous release (mg/L)
X,Y,Z	=	Green's functions in the x,y,z coordinate directions

and

$$X(x,t) = \frac{1}{2l}\left(erf\frac{(x+\frac{l}{2}) - \frac{ut}{R}}{\sqrt{4D_x t/R}} - erf\frac{(x+\frac{l}{2}) - \frac{ut}{R}}{\sqrt{4D_x t/R}} \right)$$

$$y(x,t) = \frac{1}{2b}\left(erf\frac{(\frac{b}{2}+y) - \frac{ut}{R}}{\sqrt{4D_y t/R}} - erf\frac{(\frac{b}{2}+y) - \frac{ut}{R}}{\sqrt{4D_x t/R}} \right)$$

Also:

$$Z(z,t) = \frac{1}{h}$$

This equation is formulated only in terms of instantaneous releases. They are applied to arbitrary releases by use of the convolution integral:

$$\theta = \int_0^t f(\tau)\ \theta_i(t-\tau)\ d\tau$$

where:

θ = the solution at time t for the arbitrary release
$\theta_i(t - \tau)$ = the solution time $(t - \tau)$ for an instantaneous release at $(t - \tau) = 0$
$f(\tau)$ = the source release rate at time τ (g/s)

The analytical solution to Equation 5, subject to the boundary conditions and initial conditions described above, was coded into a FORTRAN program called GWMODF2 (Rood, 1992). GWMODF2 is an updated version of GROUND. The source code is provided in this document. The output from GWMODF2 was graphed using SigmaPlot.

GWMODF2 simulations utilizing input parameters equivalent to the parameters employed in the CHAINT simulations were conducted. The input parameters were a 8 m/yr velocity, 40 m^2/yr longitudinal dispersion coefficient, 8 m^2/yr transverse dispersion coefficient, a contaminant of Tc-99 with a half-life of 213,500 years, with a constant flux of 4.09E-7 g/s and a distribution coefficient of 0 mL/g.

The GWMODF2 input files and results are provided in the test report given in Section 7.2.

7.1.6 Validation Test Case 6 - Two Dimensional Transport With Decay for a Flux Source

MAGNUM-2D

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 300 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. The finite element grid and the MAGNUM-2D geometry file for this validation test case are provided in the test report given in Section 7.2.

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

Section 7.2 provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing uniform flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling with decay and sorption was performed using files from MAGNUM-2D simulations. Transport of Plutonium-239 (Pu-239), with a half-life of 24,110 years and a partitioning coefficient of 130 ml/g (NUREG-1464, 1995), was modeled. The scenario employed the type two boundary conditions for all sides of the grid and a constant flux into elements from y = 140 m to y = 160 m and at x = 15 m to x = 35 m. The constant

flux was specified at a value that resulted in a Pu-239 concentration of 1.0 mg/L in the element.

Results from the CHAINT simulations are presented in the test report given in Section 7.2.

ANALYTICAL SOLUTION

The results from the CHAINT simulations were compared to results from a two dimensional analytical model. The Nuclear Regulatory Commission has developed straightforward groundwater models for evaluating the transport of radionuclides in groundwater. The models were developed for the limiting case of unidirectional advective flow and dispersion in an isotropic aquifer.

The GROUND model (NRC 1982) was developed to model a horizontal area source of length l and width b centered at 0,0,0 in an aquifer of constant depth h. The following equations were used by NRC:

$$\frac{\partial C}{\partial t} = D_x^* \frac{\partial^2 C}{\partial x^2} + D_y^* \frac{\partial^2 C}{\partial y^2} - V^* \frac{\partial C}{\partial x} - \lambda C \qquad (5)$$

where,

C	=	solute concentration (mg/L)
t	=	time (yr)
D^*_x	=	scaled or retarded longitudinal dispersion coefficient in the flow direction (D_x/R in m^2/yr)
D^*_y	=	scaled or retarded transverse dispersion coefficient perpendicular to the flow direction (D_y in m^2/yr)
x	=	flow direction (m)
V^*	=	scaled or retarded groundwater velocity (V/R in m/yr)
λ	=	rate coefficient (natural logarithm of 2 divided by the half-life in 1/yr)
C_0	=	source concentration (mg/L)
L	=	length of modeled domain (m)

For linear equilibrium sorption, the dispersion coefficient and groundwater velocity are scaled using the retardation factor, R, which is defined in the following relation (NRC, 1982):

$$R = 1 + \frac{k_d \rho_b}{\eta}$$

where,

k_d = distribution or partitioning coefficient (ml/g)
ρ_b = bulk density of the solid matrix (g/cm^3)
η = moisture content or the porosity for saturated conditions (unitless)

Equation 5 is solved in terms of Green's functions resulting in:

$$C_i = \frac{1}{\eta R} X(x,t)\ Y(y,t)\ Z(z,t)$$

where:

C_i = concentration at any point in space for an instantaneous release (mg/L)
X,Y,Z = Green's functions in the x,y,z coordinate directions

and

$$X(x,t) = \frac{1}{2l}\left(erf\frac{(x+\frac{l}{2}) - \frac{ut}{R}}{\sqrt{4D_x t/R}} - erf\frac{(x+\frac{l}{2}) - \frac{ut}{R}}{\sqrt{4D_x t/R}}\right)$$

$$y(x,t) = \frac{1}{2b}\left(erf\frac{(\frac{b}{2}+y) - \frac{ut}{R}}{\sqrt{4D_y t/R}} - erf\frac{(\frac{b}{2}+y) - \frac{ut}{R}}{\sqrt{4D_x t/R}}\right)$$

Also:

$$Z(z,t) = \frac{1}{h}$$

This equation is formulated only in terms of instantaneous releases. They are applied to arbitrary releases by use of the convolution integral:

$$\theta = \int_0^t f(\tau)\ \theta_i(t-\tau)\ d\tau$$

where:

θ = the solution at time t for the arbitrary release
$\theta_i(t - \tau)$ = the solution time $(t - \tau)$ for an instantaneous release at $(t - \tau) = 0$
$f(\tau)$ = the source release rate at time τ (g/s)

The analytical solution to Equation 5, subject to the boundary conditions and initial conditions described above, was coded into a FORTRAN program called GWMODF2 (Rood, 1992). GWMODF2 is an updated version of GROUND. The source code is provided in this document. The output from GWMODF2 was graphed using SigmaPlot.

GWMODF2 simulations utilizing input parameters equivalent to the parameters employed in the CHAINT simulations were conducted. The input parameters were a 8 m/yr velocity, 40 m^2/yr longitudinal dispersion coefficient, 8 m^2/yr transverse dispersion coefficient, a contaminant of Pu-239, with a constant flux of 5.2E-7 g/s and a distribution coefficient of 130 mL/g.

The GWMODF2 input files and results are provided in the test report given in Section 7.2.

7.1.7 Validation Test Case 7 - One Dimensional Transport with Three Member Decay Chain

To provide the steady-state flow field for the CHAINT simulations, a MAGNUM-2D finite element grid with overall dimensions of 5 m by 300 m and individual element dimensions of 5 m by 5 m was constructed for one material type. The grid represented a one dimensional strip and consisted of 60 elements and 303 nodes. The material layer was conceptualized as homogeneous and isotropic. MAGNUM-2D flow simulations were performed and the results used as CHAINT input. The finite element grid and the MAGNUM-2D geometry file for this validation test case is the same as for Validation Test Cases 1 and 3 and are provided in Section 7.2.

The MAGNUM-2D flow simulations utilized a first type boundary condition for the left and right sides of the grid and a second type boundary condition for the top and bottom of the grid. The overall hydraulic gradient (dH/dx) of 3.3×10^{-3} was consistent with measured and modeled hydraulic gradients at Yucca Mountain. The hydraulic head specified on the left and right sides of the grid were 1.0654 and 0.0 meters, respectively. The porosity was 7.0% and the hydraulic conductivity was 5×10^{-6} m/s.

Section 7.2 provides the MAGNUM-2D input file, plots of calculated hydraulic heads with 0.05 m contours, and a Darcy velocity vector plot showing constant one dimensional flow which is consistent with the input parameters. The plots were generated using the DISSPLA software.

CHAINT modeling with a three member decay chain was performed using files from MAGNUM-2D simulations for two cases: equal distribution coefficients (K_ds) and unequal K_ds. Radionuclide transport was modeled for a decay chain with Americium-243 (Am-243), Plutonium-239 (Pu-239), and Uranium-235 (U-235) which have half-lives of 7,593, 24,400, and 710,000,000 years, respectively. In one case, retardation coefficients of 2,000 which correspond to a K_d of approximately 58 ml/g were chosen. For the second case, reasonable K_d values were selected for Am-241 (100ml/g), Pu-239 (60 ml/g), and U-235 (20 ml/g) (NUREG-1464, 1995). The conversion between the K_ds and the retardation coefficients was accomplished with the porosity (0.07) and density (2.4 g/cm^3). Boundary conditions

consisted of type two boundary conditions for the top, bottom, and right side of the grid and a type one boundary condition for the left side of the grid.

Results from the CHAINT simulations are presented in Section 7.2.

NEFTRAN II SOLUTION

The results from the CHAINT simulations were compared to results from the one dimensional model, NEFTRAN II. The computer code NEFTRAN II (NEtwork Flow and TRANsport in Time-Dependent Velocity Fields) was developed as part of a performance methodology for storage of high-level nuclear waste in unsaturated, welded tuff. NEFTRAN II is a successor to the NEFTRAN and NWFI/DVM computer codes (NUREG/CR-5618, 1991).

The NEFTRAN II input file was specified to match the parameters of the CHAINT simulations, including groundwater velocity, porosity, retardation factors, longitudinal dispersion, and radionuclide source masses. An input file was utilized to specify the constant flux sources for each radionuclide.

The NEFTRAN II input files and results are provided in the test report given in Section 7.2.

7.1.8 SUMMARY

Currently, it is anticipated that the CHAINT code will be used to model flow at Yucca Mountain. To meet this need, validation testing was performed to meet TOP 18 requirements for CNWRA software. Following the guidelines in TOP 18, validation testing was accomplished by designing the CHAINT simulations to match existing analytical solutions for systems having properties similar to those present at Yucca Mountain.

Background information for the CHAINT simulations and the corresponding analytical solutions were discussed and summarized in this section. Section 7.2 provides a complete presentation of the input files, plotted grids, and graphs of the results.

The validation testing was designed to ensure the CHAINT code was operational and that the CHAINT results matched analytical solutions for systems having properties similar to those at Yucca Mountain. Consequently, input parameters for the validation testing were consistent with values to be utilized in technical studies involving development of the EPA Standard for Yucca Mountain and model parameters were consistent between the different validation test cases presented in this document.

7.2 SOFTWARE VALIDATION TEST REPORT

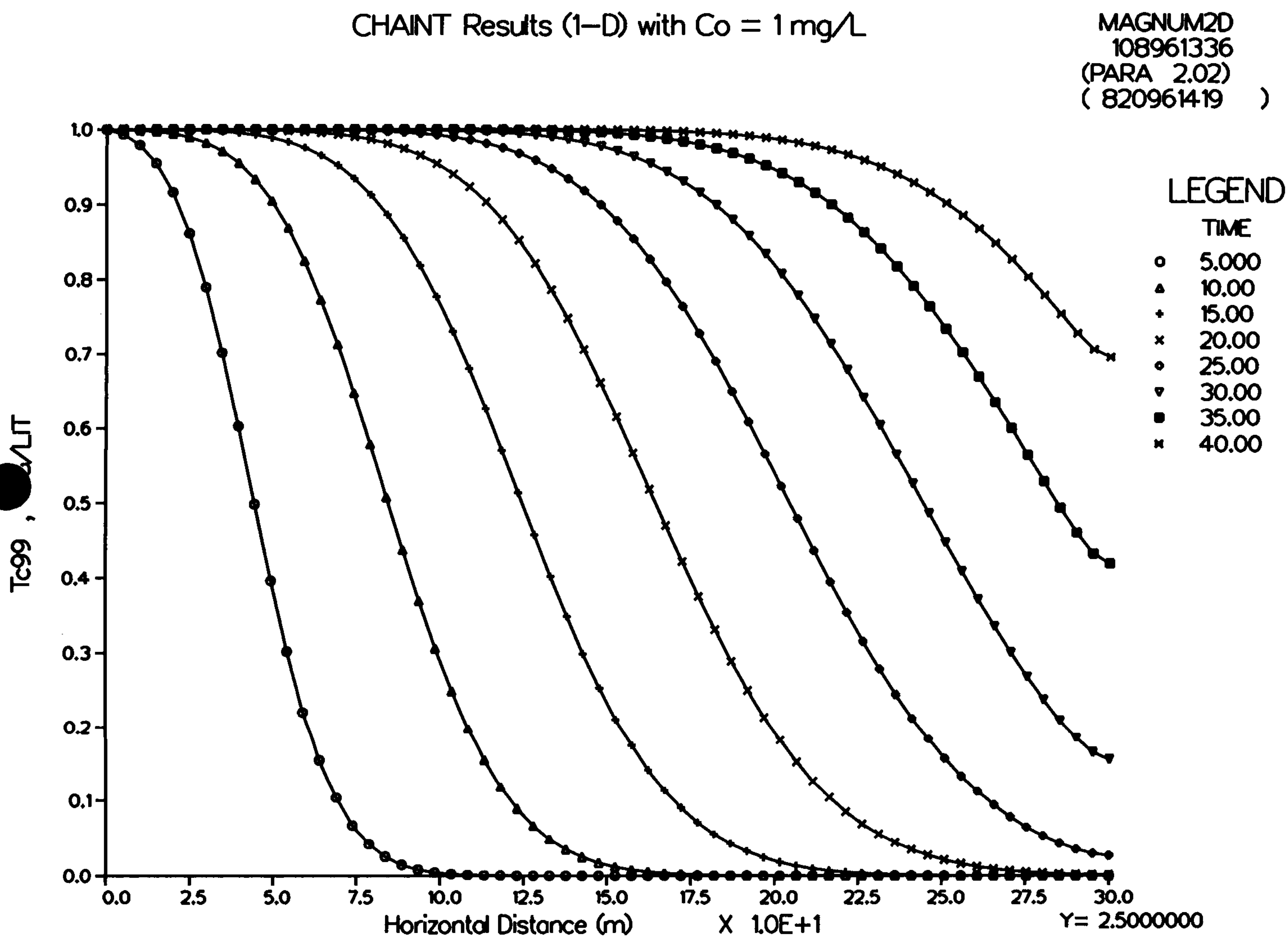
It is anticipated that CHAINT simulations will be performed for saturated zone transport of radionuclides at Yucca Mountain. Based upon this anticipated application, validation test cases with corresponding analytical solutions were designed. Steady-state MAGNUM-2D flow simulations employing hydraulic and materials properties similar to those present at Yucca Mountain were performed and the results used as CHAINT input.

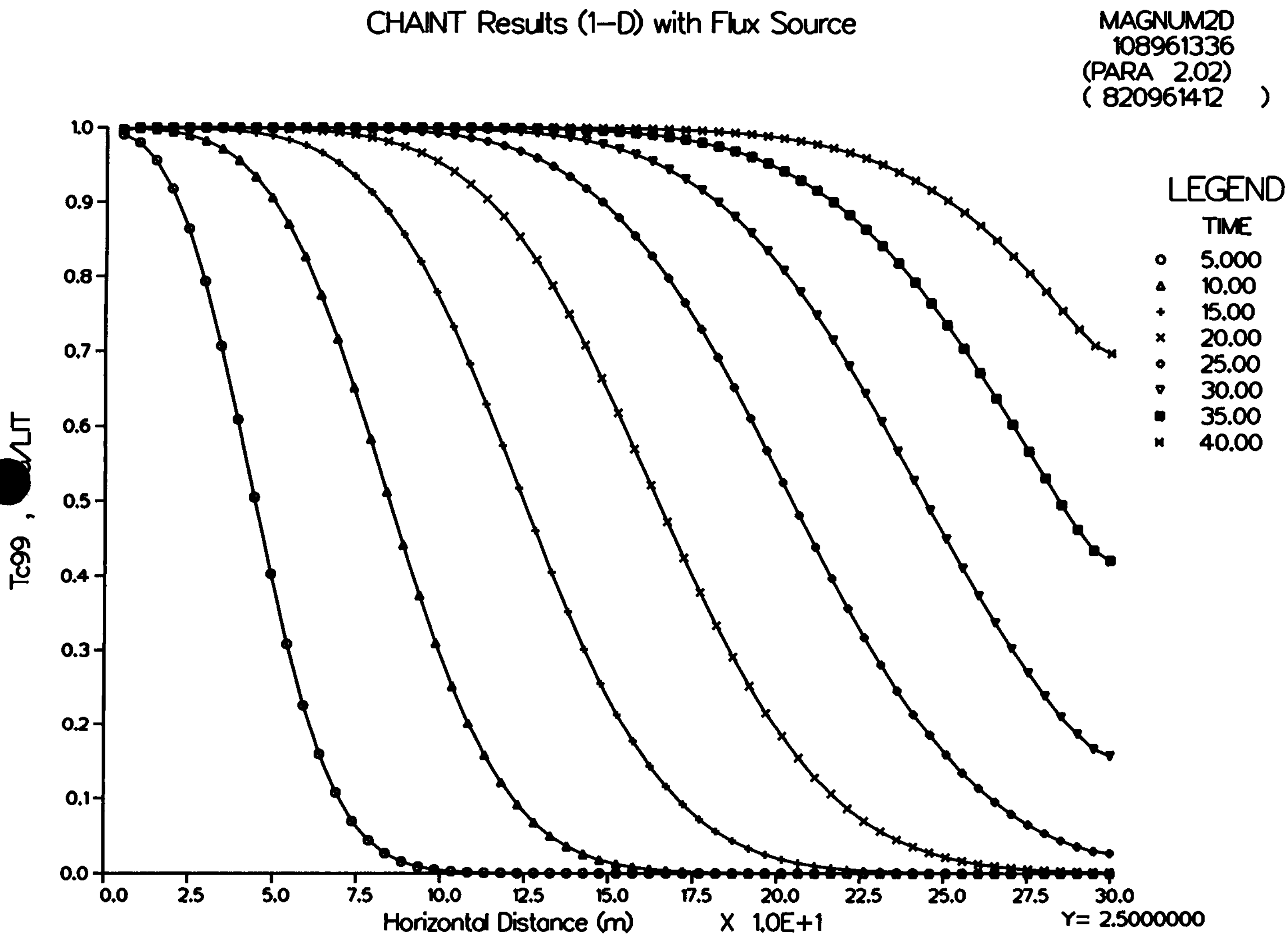
A total of seven validation test case results are presented which test the basic features and functionality of the CHAINT code for the intended applications and conditions at Yucca Mountain. The seven validation test cases included: (1) one dimensional transport; (2) two dimensional transport; (3) one dimensional transport with decay and sorption; (2) two dimensional transport with decay and sorption; (5) two dimensional transport without decay for a flux source; (6) two dimensional transport with decay for a flux source; and (7) one dimensional transport with a three member decay chain and equal and unequal sorption.

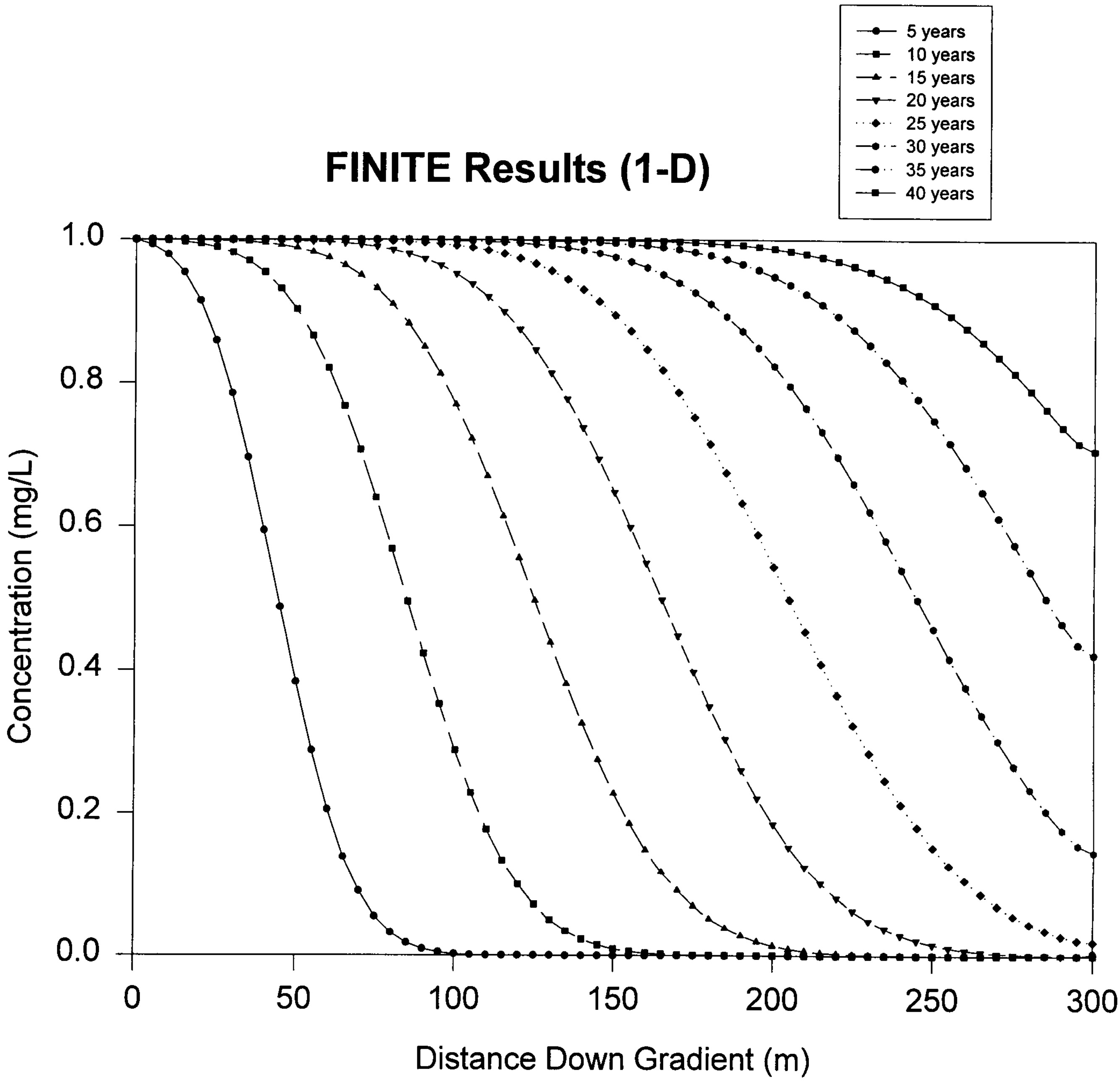
7.2.1 Validation Test Case 1 Results - One Dimensional

Results from the CHAINT simulations for constant source concentration and constant flux are presented in this section. Overlaying the figures reveals the contoured results are consistent for both CHAINT scenarios.

The results from the CHAINT simulations were compared to results from a one dimensional analytical model. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from FINITE compare favorably and overlaying the figures reveals the results from CHAINT and the analytical model are consistent.


CHAINT Results (1–D) with Co = 1 mg/L
MAGNUM2D
108961336
(PARA 2.02)
(820961419)
LEGEND
TIME
5.000
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Tc99 ,
/LIT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
Horizontal Distance (m)
X 1.0E+1
Y= 2.5000000

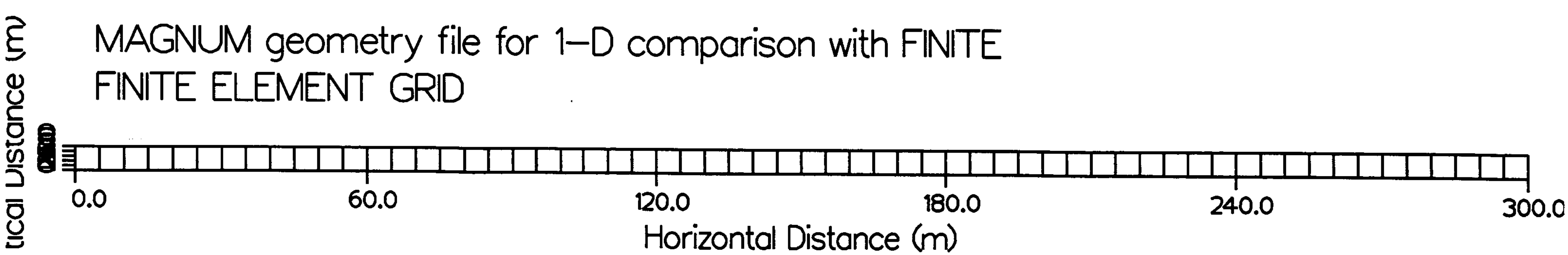

CHAINT Results (1–D) with Flux Source
MAGNUM2D
108961336
(PARA 2.02)
(820961412)
LEGEND
TIME
5.000
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Tc99 , .../LIT
Horizontal Distance (m) X 1.0E+1
Y= 2.5000000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0



FINITE Results (1-D)
5 years
10 years
15 years
20 years
25 years
30 years
35 years
40 years
Concentration (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
Distance Down Gradient (m)

(PLT 2.00)
(801961341)
(0)

MAGNUM geometry file for 1–D comparison with FINITE
FINITE ELEMENT GRID



60 303 0 BACA GEOMETRY MESHER 2.00

MAGNUM geometry file for 1-D comparison with FINITE

1	1	4	5	6	7	8	3	2	1	1
2	5	9	10	11	12	13	7	6	1	2
3	10	14	15	16	17	18	12	11	1	3
4	15	19	20	21	22	23	17	16	1	4
5	20	24	25	26	27	28	22	21	1	5
6	25	29	30	31	32	33	27	26	1	6
7	30	34	35	36	37	38	32	31	1	7
8	35	39	40	41	42	43	37	36	1	8
9	40	44	45	46	47	48	42	41	1	9
10	45	49	50	51	52	53	47	46	1	10
11	50	54	55	56	57	58	52	51	1	11
12	55	59	60	61	62	63	57	56	1	12
13	60	64	65	66	67	68	62	61	1	13
14	65	69	70	71	72	73	67	66	1	14
15	70	74	75	76	77	78	72	71	1	15
16	75	79	80	81	82	83	77	76	1	16
17	80	84	85	86	87	88	82	81	1	17
18	85	89	90	91	92	93	87	86	1	18
19	90	94	95	96	97	98	92	91	1	19
20	95	99	100	101	102	103	97	96	1	20
21	100	104	105	106	107	108	102	101	1	21
22	105	109	110	111	112	113	107	106	1	22
23	110	114	115	116	117	118	112	111	1	23
24	115	119	120	121	122	123	117	116	1	24
25	120	124	125	126	127	128	122	121	1	25
26	125	129	130	131	132	133	127	126	1	26
27	130	134	135	136	137	138	132	131	1	27
28	135	139	140	141	142	143	137	136	1	28
29	140	144	145	146	147	148	142	141	1	29
30	145	149	150	151	152	153	147	146	1	30
31	150	154	155	156	157	158	152	151	1	31
32	155	159	160	161	162	163	157	156	1	32
33	160	164	165	166	167	168	162	161	1	33
34	165	169	170	171	172	173	167	166	1	34
35	170	174	175	176	177	178	172	171	1	35
36	175	179	180	181	182	183	177	176	1	36
37	180	184	185	186	187	188	182	181	1	37
38	185	189	190	191	192	193	187	186	1	38
39	190	194	195	196	197	198	192	191	1	39
40	195	199	200	201	202	203	197	196	1	40
41	200	204	205	206	207	208	202	201	1	41
42	205	209	210	211	212	213	207	206	1	42
43	210	214	215	216	217	218	212	211	1	43
44	215	219	220	221	222	223	217	216	1	44
45	220	224	225	226	227	228	222	221	1	45
46	225	229	230	231	232	233	227	226	1	46
47	230	234	235	236	237	238	232	231	1	47
48	235	239	240	241	242	243	237	236	1	48
49	240	244	245	246	247	248	242	241	1	49
50	245	249	250	251	252	253	247	246	1	50
51	250	254	255	256	257	258	252	251	1	51
52	255	259	260	261	262	263	257	256	1	52
53	260	264	265	266	267	268	262	261	1	53
54	265	269	270	271	272	273	267	266	1	54
55	270	274	275	276	277	278	272	271	1	55
56	275	279	280	281	282	283	277	276	1	56
57	280	284	285	286	287	288	282	281	1	57
58	285	289	290	291	292	293	287	286	1	58

59	290	294	295	296	297	298	292	291	1	59
60	295	299	300	301	302	303	297	296	1	60

1	0.000	0.000	0.00	0.00
2	0.000	2.500	0.00	0.00
3	0.000	5.000	0.00	0.00
4	2.500	0.000	0.00	0.00
5	5.000	0.000	0.00	0.00
6	5.000	2.500	0.00	0.00
7	5.000	5.000	0.00	0.00
8	2.500	5.000	0.00	0.00
9	7.500	0.000	0.00	0.00
10	10.000	0.000	0.00	0.00
11	10.000	2.500	0.00	0.00
12	10.000	5.000	0.00	0.00
13	7.500	5.000	0.00	0.00
14	12.500	0.000	0.00	0.00
15	15.000	0.000	0.00	0.00
16	15.000	2.500	0.00	0.00
17	15.000	5.000	0.00	0.00
18	12.500	5.000	0.00	0.00
19	17.500	0.000	0.00	0.00
20	20.000	0.000	0.00	0.00
21	20.000	2.500	0.00	0.00
22	20.000	5.000	0.00	0.00
23	17.500	5.000	0.00	0.00
24	22.500	0.000	0.00	0.00
25	25.000	0.000	0.00	0.00
26	25.000	2.500	0.00	0.00
27	25.000	5.000	0.00	0.00
28	22.500	5.000	0.00	0.00
29	27.500	0.000	0.00	0.00
30	30.000	0.000	0.00	0.00
31	30.000	2.500	0.00	0.00
32	30.000	5.000	0.00	0.00
33	27.500	5.000	0.00	0.00
34	32.500	0.000	0.00	0.00
35	35.000	0.000	0.00	0.00
36	35.000	2.500	0.00	0.00
37	35.000	5.000	0.00	0.00
38	32.500	5.000	0.00	0.00
39	37.500	0.000	0.00	0.00
40	40.000	0.000	0.00	0.00
41	40.000	2.500	0.00	0.00
42	40.000	5.000	0.00	0.00
43	37.500	5.000	0.00	0.00
44	42.500	0.000	0.00	0.00
45	45.000	0.000	0.00	0.00
46	45.000	2.500	0.00	0.00
47	45.000	5.000	0.00	0.00
48	42.500	5.000	0.00	0.00
49	47.500	0.000	0.00	0.00
50	50.000	0.000	0.00	0.00
51	50.000	2.500	0.00	0.00
52	50.000	5.000	0.00	0.00
53	47.500	5.000	0.00	0.00
54	52.500	0.000	0.00	0.00
55	55.000	0.000	0.00	0.00
56	55.000	2.500	0.00	0.00
57	55.000	5.000	0.00	0.00
58	52.500	5.000	0.00	0.00

59	57.500	0.000	0.00	0.00
60	60.000	0.000	0.00	0.00
61	60.000	2.500	0.00	0.00
62	60.000	5.000	0.00	0.00
63	57.500	5.000	0.00	0.00
64	62.500	0.000	0.00	0.00
65	65.000	0.000	0.00	0.00
66	65.000	2.500	0.00	0.00
67	65.000	5.000	0.00	0.00
68	62.500	5.000	0.00	0.00
69	67.500	0.000	0.00	0.00
70	70.000	0.000	0.00	0.00
71	70.000	2.500	0.00	0.00
72	70.000	5.000	0.00	0.00
73	67.500	5.000	0.00	0.00
74	72.500	0.000	0.00	0.00
75	75.000	0.000	0.00	0.00
76	75.000	2.500	0.00	0.00
77	75.000	5.000	0.00	0.00
78	72.500	5.000	0.00	0.00
79	77.500	0.000	0.00	0.00
80	80.000	0.000	0.00	0.00
81	80.000	2.500	0.00	0.00
82	80.000	5.000	0.00	0.00
83	77.500	5.000	0.00	0.00
84	82.500	0.000	0.00	0.00
85	85.000	0.000	0.00	0.00
86	85.000	2.500	0.00	0.00
87	85.000	5.000	0.00	0.00
88	82.500	5.000	0.00	0.00
89	87.500	0.000	0.00	0.00
90	90.000	0.000	0.00	0.00
91	90.000	2.500	0.00	0.00
92	90.000	5.000	0.00	0.00
93	87.500	5.000	0.00	0.00
94	92.500	0.000	0.00	0.00
95	95.000	0.000	0.00	0.00
96	95.000	2.500	0.00	0.00
97	95.000	5.000	0.00	0.00
98	92.500	5.000	0.00	0.00
99	97.500	0.000	0.00	0.00
100	100.000	0.000	0.00	0.00
101	100.000	2.500	0.00	0.00
102	100.000	5.000	0.00	0.00
103	97.500	5.000	0.00	0.00
104	102.500	0.000	0.00	0.00
105	105.000	0.000	0.00	0.00
106	105.000	2.500	0.00	0.00
107	105.000	5.000	0.00	0.00
108	102.500	5.000	0.00	0.00
109	107.500	0.000	0.00	0.00
110	110.000	0.000	0.00	0.00
111	110.000	2.500	0.00	0.00
112	110.000	5.000	0.00	0.00
113	107.500	5.000	0.00	0.00
114	112.500	0.000	0.00	0.00
115	115.000	0.000	0.00	0.00
116	115.000	2.500	0.00	0.00
117	115.000	5.000	0.00	0.00
118	112.500	5.000	0.00	0.00

119	117.500	0.000	0.00	0.00
120	120.000	0.000	0.00	0.00
121	120.000	2.500	0.00	0.00
122	120.000	5.000	0.00	0.00
123	117.500	5.000	0.00	0.00
124	122.500	0.000	0.00	0.00
125	125.000	0.000	0.00	0.00
126	125.000	2.500	0.00	0.00
127	125.000	5.000	0.00	0.00
128	122.500	5.000	0.00	0.00
129	127.500	0.000	0.00	0.00
130	130.000	0.000	0.00	0.00
131	130.000	2.500	0.00	0.00
132	130.000	5.000	0.00	0.00
133	127.500	5.000	0.00	0.00
134	132.500	0.000	0.00	0.00
135	135.000	0.000	0.00	0.00
136	135.000	2.500	0.00	0.00
137	135.000	5.000	0.00	0.00
138	132.500	5.000	0.00	0.00
139	137.500	0.000	0.00	0.00
140	140.000	0.000	0.00	0.00
141	140.000	2.500	0.00	0.00
142	140.000	5.000	0.00	0.00
143	137.500	5.000	0.00	0.00
144	142.500	0.000	0.00	0.00
145	145.000	0.000	0.00	0.00
146	145.000	2.500	0.00	0.00
147	145.000	5.000	0.00	0.00
148	142.500	5.000	0.00	0.00
149	147.500	0.000	0.00	0.00
150	150.000	0.000	0.00	0.00
151	150.000	2.500	0.00	0.00
152	150.000	5.000	0.00	0.00
153	147.500	5.000	0.00	0.00
154	152.500	0.000	0.00	0.00
155	155.000	0.000	0.00	0.00
156	155.000	2.500	0.00	0.00
157	155.000	5.000	0.00	0.00
158	152.500	5.000	0.00	0.00
159	157.500	0.000	0.00	0.00
160	160.000	0.000	0.00	0.00
161	160.000	2.500	0.00	0.00
162	160.000	5.000	0.00	0.00
163	157.500	5.000	0.00	0.00
164	162.500	0.000	0.00	0.00
165	165.000	0.000	0.00	0.00
166	165.000	2.500	0.00	0.00
167	165.000	5.000	0.00	0.00
168	162.500	5.000	0.00	0.00
169	167.500	0.000	0.00	0.00
170	170.000	0.000	0.00	0.00
171	170.000	2.500	0.00	0.00
172	170.000	5.000	0.00	0.00
173	167.500	5.000	0.00	0.00
174	172.500	0.000	0.00	0.00
175	175.000	0.000	0.00	0.00
176	175.000	2.500	0.00	0.00
177	175.000	5.000	0.00	0.00
178	172.500	5.000	0.00	0.00

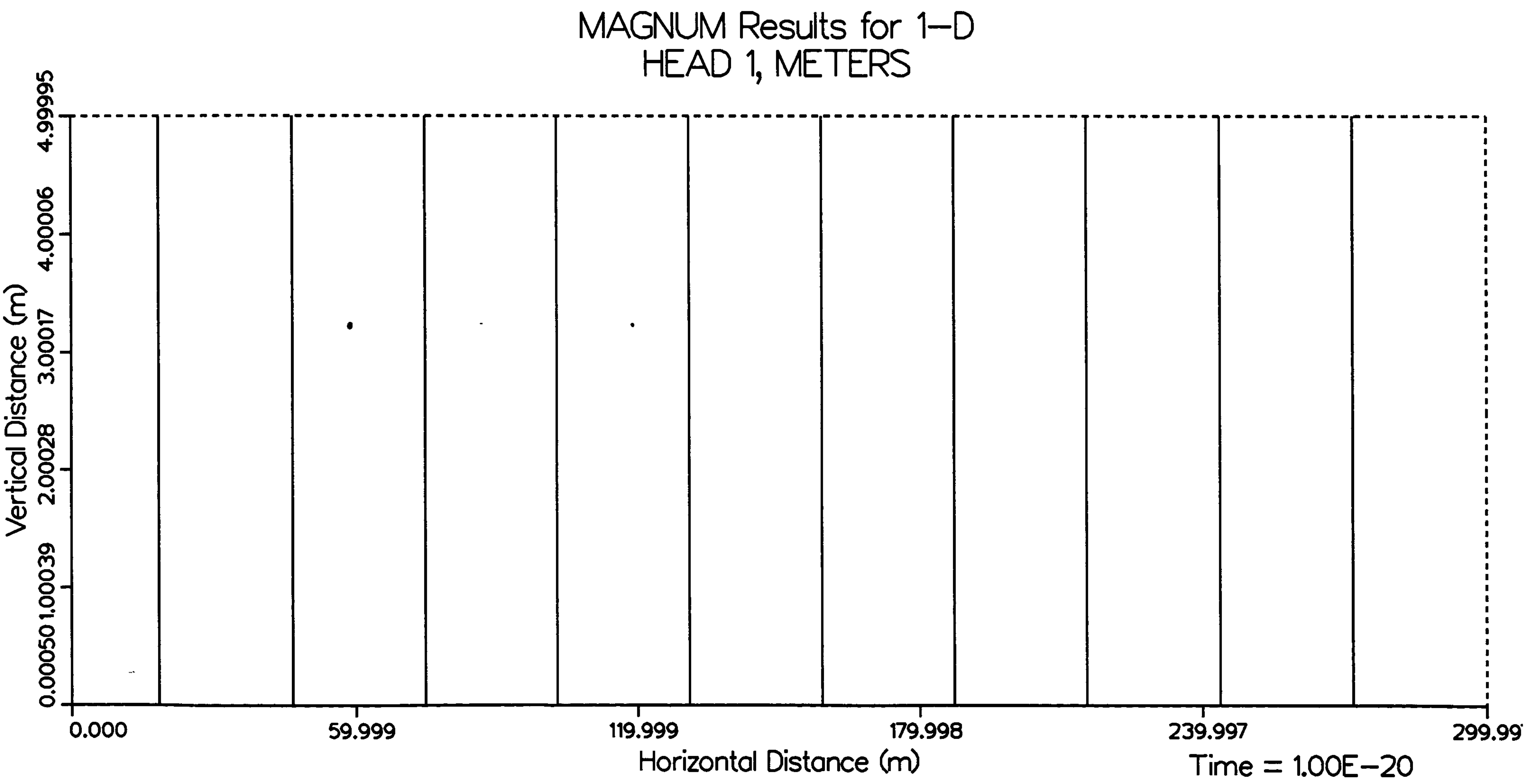
179	177.500	0.000	0.00	0.00
180	180.000	0.000	0.00	0.00
181	180.000	2.500	0.00	0.00
182	180.000	5.000	0.00	0.00
183	177.500	5.000	0.00	0.00
184	182.500	0.000	0.00	0.00
185	185.000	0.000	0.00	0.00
186	185.000	2.500	0.00	0.00
187	185.000	5.000	0.00	0.00
188	182.500	5.000	0.00	0.00
189	187.500	0.000	0.00	0.00
190	190.000	0.000	0.00	0.00
191	190.000	2.500	0.00	0.00
192	190.000	5.000	0.00	0.00
193	187.500	5.000	0.00	0.00
194	192.500	0.000	0.00	0.00
195	195.000	0.000	0.00	0.00
196	195.000	2.500	0.00	0.00
197	195.000	5.000	0.00	0.00
198	192.500	5.000	0.00	0.00
199	197.500	0.000	0.00	0.00
200	200.000	0.000	0.00	0.00
201	200.000	2.500	0.00	0.00
202	200.000	5.000	0.00	0.00
203	197.500	5.000	0.00	0.00
204	202.500	0.000	0.00	0.00
205	205.000	0.000	0.00	0.00
206	205.000	2.500	0.00	0.00
207	205.000	5.000	0.00	0.00
208	202.500	5.000	0.00	0.00
209	207.500	0.000	0.00	0.00
210	210.000	0.000	0.00	0.00
211	210.000	2.500	0.00	0.00
212	210.000	5.000	0.00	0.00
213	207.500	5.000	0.00	0.00
214	212.500	0.000	0.00	0.00
215	215.000	0.000	0.00	0.00
216	215.000	2.500	0.00	0.00
217	215.000	5.000	0.00	0.00
218	212.500	5.000	0.00	0.00
219	217.500	0.000	0.00	0.00
220	220.000	0.000	0.00	0.00
221	220.000	2.500	0.00	0.00
222	220.000	5.000	0.00	0.00
223	217.500	5.000	0.00	0.00
224	222.500	0.000	0.00	0.00
225	225.000	0.000	0.00	0.00
226	225.000	2.500	0.00	0.00
227	225.000	5.000	0.00	0.00
228	222.500	5.000	0.00	0.00
229	227.500	0.000	0.00	0.00
230	230.000	0.000	0.00	0.00
231	230.000	2.500	0.00	0.00
232	230.000	5.000	0.00	0.00
233	227.500	5.000	0.00	0.00
234	232.500	0.000	0.00	0.00
235	235.000	0.000	0.00	0.00
236	235.000	2.500	0.00	0.00
237	235.000	5.000	0.00	0.00
238	232.500	5.000	0.00	0.00

239	237.500	0.000	0.00	0.00
240	240.000	0.000	0.00	0.00
241	240.000	2.500	0.00	0.00
242	240.000	5.000	0.00	0.00
243	237.500	5.000	0.00	0.00
244	242.500	0.000	0.00	0.00
245	245.000	0.000	0.00	0.00
246	245.000	2.500	0.00	0.00
247	245.000	5.000	0.00	0.00
248	242.500	5.000	0.00	0.00
249	247.500	0.000	0.00	0.00
250	250.000	0.000	0.00	0.00
251	250.000	2.500	0.00	0.00
252	250.000	5.000	0.00	0.00
253	247.500	5.000	0.00	0.00
254	252.500	0.000	0.00	0.00
255	255.000	0.000	0.00	0.00
256	255.000	2.500	0.00	0.00
257	255.000	5.000	0.00	0.00
258	252.500	5.000	0.00	0.00
259	257.500	0.000	0.00	0.00
260	260.000	0.000	0.00	0.00
261	260.000	2.500	0.00	0.00
262	260.000	5.000	0.00	0.00
263	257.500	5.000	0.00	0.00
264	262.500	0.000	0.00	0.00
265	265.000	0.000	0.00	0.00
266	265.000	2.500	0.00	0.00
267	265.000	5.000	0.00	0.00
268	262.500	5.000	0.00	0.00
269	267.500	0.000	0.00	0.00
270	270.000	0.000	0.00	0.00
271	270.000	2.500	0.00	0.00
272	270.000	5.000	0.00	0.00
273	267.500	5.000	0.00	0.00
274	272.500	0.000	0.00	0.00
275	275.000	0.000	0.00	0.00
276	275.000	2.500	0.00	0.00
277	275.000	5.000	0.00	0.00
278	272.500	5.000	0.00	0.00
279	277.500	0.000	0.00	0.00
280	280.000	0.000	0.00	0.00
281	280.000	2.500	0.00	0.00
282	280.000	5.000	0.00	0.00
283	277.500	5.000	0.00	0.00
284	282.500	0.000	0.00	0.00
285	285.000	0.000	0.00	0.00
286	285.000	2.500	0.00	0.00
287	285.000	5.000	0.00	0.00
288	282.500	5.000	0.00	0.00
289	287.500	0.000	0.00	0.00
290	290.000	0.000	0.00	0.00
291	290.000	2.500	0.00	0.00
292	290.000	5.000	0.00	0.00
293	287.500	5.000	0.00	0.00
294	292.500	0.000	0.00	0.00
295	295.000	0.000	0.00	0.00
296	295.000	2.500	0.00	0.00
297	295.000	5.000	0.00	0.00
298	292.500	5.000	0.00	0.00

299	297.500	0.000	0.00	0.00
300	300.000	0.000	0.00	0.00
301	300.000	2.500	0.00	0.00
302	300.000	5.000	0.00	0.00
[illegible]3	297.500	5.000	0.00	0.00

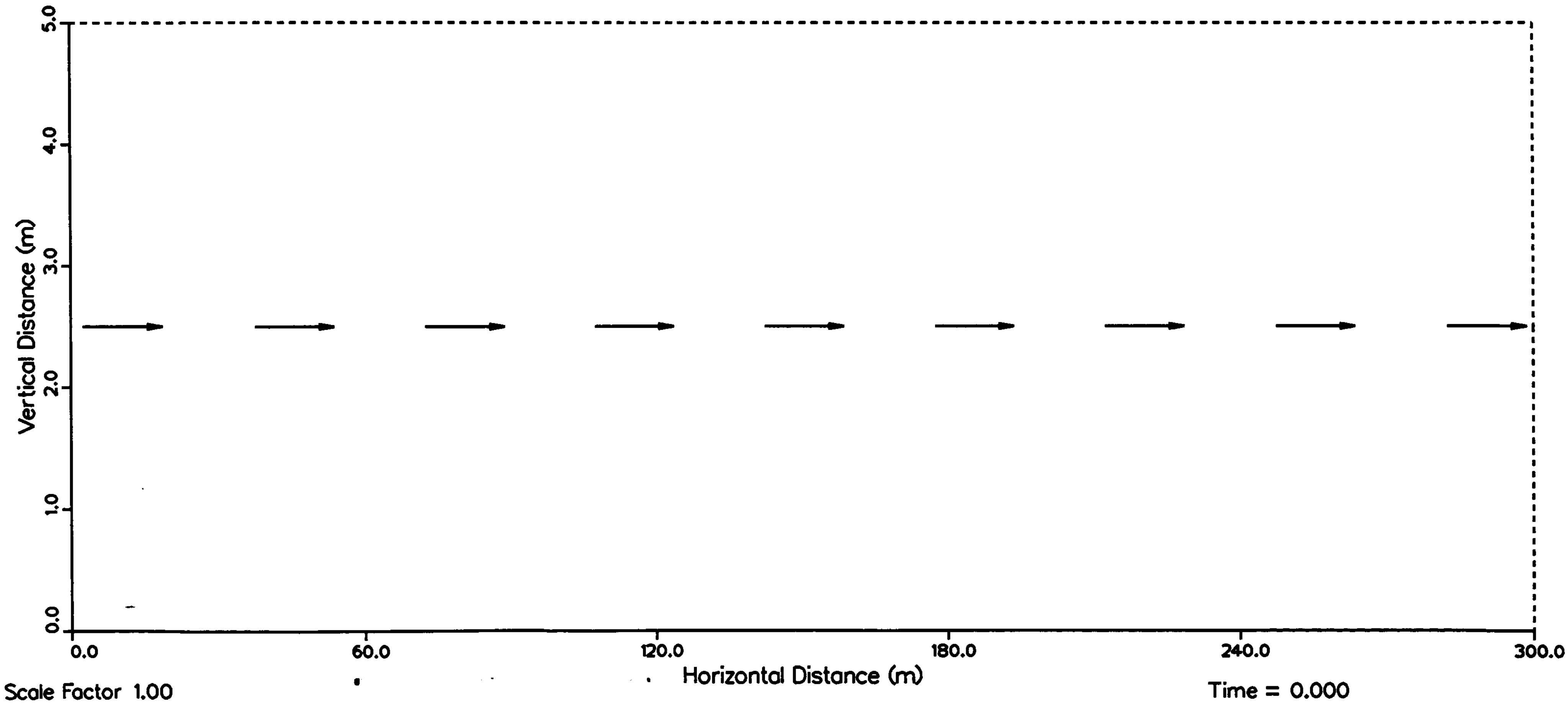
```
MAGNUM - 1-D Test case for comparison with FINITE
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
    1     0      1   303    60     1    0    0     0    1     1    0
#  irs   isv   icf  igi  ig  ivel inpt icsv
    0    13    0   10    0   12    0    0
# isf   alfa  tref
  0.0    1.8   20.0
#  nts  ntsg   dlt
   1     1     1000.
 9999    1     1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#    n      To      Ho
     1    20.000   0.5327
#  kspec
    6
#         n     n1 n2  Tbc     Hbc
        300        0   1   20.0000    0.0000
        301        0   1   20.0000    0.0000
        302        0   1   20.0000    0.0000
          3        0   1   20.0000    1.0654
          2        0   1   20.0000    1.0654
          1        0   1   20.0000    1.0654
      #   L    cvm     tkk(1)  tkk(2)  poros    hkax         hkay        nme
#         sp1      rhom    alpal   alpat    width
          1         0        0        0      0.07    5.0e-6    5.0e-6    mat1
   1.0e-6    2400          0        0         0
#  nld  nlt  scf
   0    0      0.0
```

MAGNUM2D
108961336
(CONT 2.03)
(801961338)



MAGNUM2D 3.20
****
(VELP 2.00)
(731961556)

DARCY VELOCITY VECTOR PLOT
1–D Comparison with FINITE
SCALED MAGNITUDES, TRUE DIRECTIONS



```
CHAINT 1-D Test case (with Co=1 mg/L source) for comparison with FINITE
#  nqal    ne     np    nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1      60    303     3     1      0      2     3     0      0     0
#  IS1   IS2   IS3   IS4   IS5   IS6   IS7
     0    11     0     0    14    15     0
     sf   alfa  xscale  yscale  uscale  vscale
    0.    1.8     0.      0.      0.      0.
#  nts   ntsg   dlt    zonel   zoner   zonet   zoneb
    5     5    0.02     0.       0.      0.      0.
    9     9    0.1      0.       0.      0.      0.
    8     8    0.5      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
    5     5    1.0      0.       0.      0.      0.
 9999     0     0       0        0       0       0
#   j     ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1        5.0       0.0      2400.      0.07       0.       mat1
#  islt
    1
#   L    amu     diag     isu(1)   frac(1)   isu(2)   frac(2)   cnam   eps
    1    1.0   2.13E+05     0        0.0       0        0.0     Tc99   0.0
#   i    dml(i,1..n2)  m2/yr
    1    0.0
#   i    xkdi(i,1..n2)  ml/g
    1    0.0
#   lk     Ci
           0.0
#   L      bcs
    1      1.0
    2      1.0
    3      1.0
#   nld    scf    relz
     0     1.0    0.
```

CHAINT 1-D Test case (flux source) for comparison with FINITE

```
#  nqal   ne    np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
   1      60    303   3     1     0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
   0    11   0    0    14   15   0
[illegible]f  alfa  xscale  yscale  uscale  vscale
   0.   1.8   0.      0.      0.      0.
#  nts  ntsg  dlt   zonel  zoner  zonet  zoneb
   5    5     0.02  0.     0.     0.     0.
   9    9     0.1   0.     0.     0.     0.
   8    8     0.5   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
   5    5     1.0   0.     0.     0.     0.
 9999   0     0     0      0      0      0
#  j   ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
   1     5.0       0.0       2400.     0.07      0.        mat1
#  islt
   1
#  L   amu   diag      isu(1)  frac(1)  isu(2)  frac(2)  cnam  eps
   1   1.0   2.13E+05  0       0.0      0       0.0      Tc99  0.0
#  i   dml(i,1..n2)  m2/yr
   1   0.0
#  i   xkdi(i,1..n2)  ml/g
   1   0.0
#  lk   Ci
[illegible]   0.0
#  L    bcs
   1    0.0
   2    0.0
   3    0.0
#  nld   scf   relz
   1     1.0   0.
#  NLE
   1
#  TLE      RLE(Tc99)
      0.00000E+00      0.3039883
      50.0             0.3039883
  -1.0      0.0
```

```
C
C     ***********************************************************
C     *                                                         *
C     *                    **** FINITE ****                     *
C     *                                                         *
C     * ONE-DIMENSIONAL GROUND-WATER SOLUTE-TRANSPORT MODEL     *
C     *                                                         *
C     *   FOR A FINITE SYSTEM WITH A FIRST- OR THIRD-TYPE       *
C     *                                                         *
C     *            BOUNDARY CONDITION AT X=0                    *
C     *                                                         *
C     *          VERSION CURRENT AS OF 04/01/90                 *
C     *                                                         *
C     ***********************************************************
C
C
C     Although this program has been used by the U.S. Geological
C     Survey, no warranty, expressed or implied, is made by the USGS
C     as to the accuracy and functioning of the program and related
C     program material, nor shall the fact of distribution constitute
C     any such warranty, and no responsibility is assumed by the USGS
C     in connection therewith.
C
C
C      THE FOLLOWING LINE MUST BE CHANGED IF PROBLEM DIMENSIONS ARE
C      GREATER THAN THOSE GIVEN HERE.
C        MAXX = MAXIMUM NUMBER OF X-VALUES
C        MAXT = MAXIMUM NUMBER OF TIME VALUES
C        MAXRT = MAXIMUM NUMBER OF ROOTS USED IN THE SERIES SUMMATION
      PARAMETER (MAXX=100,MAXT=20,MAXRT=1000)

      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      REAL XP(MAXX),CP(MAXX),TP,XSCLP
      CHARACTER*10 CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      CHARACTER*1 IERR(MAXX,MAXT)
      DIMENSION CXT(MAXX,MAXT),X(MAXX),T(MAXT)
      DIMENSION ROOT(MAXRT)
      COMMON /IOUNIT/ IN,IO
C
C     PROGRAM VARIABLES
C
C           NOTE:  ANY CONSISTANT SET OF UNITS MAY BE USED IN THE
C           MODEL.  NO FORMAT STATEMENTS NEED TO BE CHANGED AS
C           LABELS FOR ALL VARIABLES ARE SPECIFIED IN MODEL INPUT.
C
C     CO        SOLUTE CONCENTRATION AT THE INFLOW BOUNDARY [M/L**3]
C     DX        LONGITUDINAL DISPERSION COEFFICIENT [L**2/T]
C     VX        GROUND-WATER VELOCITY IN X-DIRECTION [L/T]
C     DK        FIRST-ORDER SOLUTE DECAY CONSTANT [1/T]
C     X         X-POSITION AT WHICH CONCENTRATION IS EVALUATED [L]
C     T         TIME AT WHICH CONCENTRATION IS EVALUATED [T]
C     CN        NORMALIZED CONCENTRATION C/CO [DIMENSIONLESS]
C     CXT       SOLUTE CONCENTRATION C(X,T) [M/L**3]
C     XL        LENGTH OF THE FLOW SYSTEM [L]
C     ROOT(N)   ROOTS OF EQ. USED IN INFINITE SERIES SUMMATION
C
C     NBC       SOURCE BOUNDARY CONDITION TYPE (1 OR 3)
C     NX        NUMBER OF X-POSITIONS AT WHICH SOLUTION IS EVALUATED
C     NT        NUMBER OF TIME VALUES AT WHICH SOLUTION IS EVALUATED
C     NROOT     NUMBER OF ROOTS USED IN INFINITE SERIES SUMMATION
```

```
C     IPLT     PLOT CONTROL. IF IPLT>0, CONCENTRATION PROFILES ARE PLOTTED
C
C       CHARACTER VARIABLES USED TO SPECIFY UNITS FOR MODEL PARAMETERS
C     CUNITS   UNITS OF CONCENTRATION (M/L**3)
C     VUNITS   UNITS OF GROUND-WATER VELOCITY (L/T)
C     DUNITS   UNITS OF DISPERSION COEFFICIENT (L**2/T)
C     KUNITS   UNITS OF SOLUTE DECAY CONSTANT  (1/T)
C     LUNITS   UNITS OF LENGTH (L)
C     TUNITS   UNITS OF TIME (T)
C
C       DEFINE INPUT/OUTPUT FILES AND PRINT TITLE PAGE
      CALL OFILE
      CALL TITLE
      WRITE(IO,201)
C
C       READ IN MODEL PARAMETERS
      READ(IN,101) NBC,NX,NT,NROOT,IPLT
      IF(NBC.EQ.1) WRITE(IO,202)
      IF(NBC.EQ.3) WRITE(IO,203)
      WRITE(IO,205) NX,NT,NROOT
      READ(IN,105) CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      READ(IN,110) CO,VX,DX,DK,XL,XSCLP
      WRITE(IO,210) CO,CUNITS,VX,VUNITS,DX,DUNITS,DK,KUNITS,XL,LUNITS,
     1 XSCLP
      READ(IN,110) (X(I),I=1,NX)
      WRITE(IO,215) LUNITS
      WRITE(IO,220) (X(I),I=1,NX)
      READ(IN,110) (T(I),I=1,NT)
      WRITE(IO,225) TUNITS
      WRITE(IO,220) (T(I),I=1,NT)
C
C       GET EIGENVALUES (BETA) USED IN SERIES SUMMATION BY SOLVING FOR
C       THE POSITIVE ROOTS OF: BETA*COTAN(BETA)+VX*XL/(2*DX)=0.0
C       FOR A FIRST-TYPE SOURCE BOUNDARY CONDITION,
C       OR: BETA*COTAN(BETA)-BETA**2*DX/(VX*XL)+VX*XL/(4*DX)=0.0
C       FOR A THIRD-TYPE SOURCE BOUNDARY CONDITION.
C
      IF (NBC.EQ.1) THEN
        C=VX*XL/(2.0D0*DX)
        CALL ROOT1(C,ROOT,NROOT)
      ELSE
        A=0.250D0*VX*XL/DX
        C=DX/(XL*VX)
        CALL ROOT3(A,C,ROOT,NROOT)
      END IF
C
C       BEGIN TIME LOOP
      DO 40 IT=1,NT
C
C       BEGIN X-COORDINATE LOOP
      DO 50 IX=1,NX
C
C       CALL ROUTINE TO CALCULATE NORMALIZED CONCENTRATION
C       BASED ON TYPE OF BOUNDARY CONDITION SPECIFIED
      IF(NBC.EQ.1) CALL CNRML1(XL,T(IT),X(IX),DX,VX,DK,ROOT,CN,NROOT,
     1 IERR(IX,IT))
      IF(NBC.EQ.3) CALL CNRML3(XL,T(IT),X(IX),DX,VX,DK,ROOT,CN,NROOT,
     1 IERR(IX,IT))
      CXT(IX,IT)=CN*CO
50    CONTINUE
```

```
C
C       CONVERT X AND C TO SINGLE PRECISION AND DIVIDE BY CO TO
C       PLOT NORMALIZED CONCENTRATION PROFILE FOR EACH TIME VALUE.
      IF(IPLT.LT.1) GO TO 40
      DO 60 I=1,NX
      XP(I)=SNGL(X(I))
60    CP(I)=SNGL(CXT(I,IT)/CO)
      TP=SNGL(T(IT))
C     CALL PLOT1D(XP,CP,NX,TP,IT,NT,TUNITS,LUNITS,XSCLP)
40    CONTINUE
C
C       PRINT OUT TABLES OF CONCENTRATION VALUES
      NPAGE=1+(NT-1)/9
      DO 80 NP=1,NPAGE
      IF(NP.EQ.1) WRITE(IO,230) TUNITS
      IF(NP.NE.1) WRITE(IO,231) TUNITS
      NP1=(NP-1)*9
      NP2=9
      IF((NP1+NP2).GT.NT) NP2=NT-NP1
      WRITE(IO,235) (T(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
      DO 70 IX=1,NX
      WRITE(IO,240) X(IX),(CXT(IX,NP1+J),IERR(IX,NP1+J),J=1,NP2)
      IF(MOD(IX,45).NE.0) GO TO 70
      WRITE(IO,231) TUNITS
      WRITE(IO,235) (T(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
70    IF(MOD(IX,5).EQ.0 .AND. MOD(IX,45).NE.0) WRITE(IO,241)
80    CONTINUE
C
      CLOSE (IN)
      CLOSE (IO)
      STOP
C
C       FORMAT STATEMENTS
101   FORMAT(20I4)
105   FORMAT(8A10)
110   FORMAT(8F10.0)
201   FORMAT(/////1H ,30X,'ANALYTICAL SOLUTION TO THE ONE-DIMENSIONAL'/
     1 1H ,28X,'ADVECTIVE-DISPERSIVE SOLUTE-TRANSPORT EQUATION'/
     2 1H ,36X,'FOR A SYSTEM OF FINITE LENGTH'///1H0,40X,'INPUT DATA'/
     3 1H ,40X,10(1H-))
202   FORMAT(1H0,25X,'FIRST-TYPE BOUNDARY CONDITION AT X = 0.0')
203   FORMAT(1H0,25X,'THIRD-TYPE BOUNDARY CONDITION AT X = 0.0')
205   FORMAT(1H0,25X,'NUMBER OF X-COORDINATES (NX) = ',I4/1H ,25X,
     1 'NUMBER OF TIME VALUES (NT) = ',I4/1H ,25X,'NUMBER OF ROOTS ',
     2 'USED IN INFINITE SERIES SUMMATION (NROOT) = ',I4)
210   FORMAT(1H0,25X,'SOLUTE CONCENTRATION ON MODEL BOUNDARY (CO) =',
     1 1P1E13.6,1X,A10/1H ,25X,
     2 'GROUND-WATER VELOCITY IN X-DIRECTION (VX) =',1P1E13.6,1X,A10/
     3 1H ,25X,'DISPERSION IN THE X-DIRECTION (DX) =',1P1E13.6,1X,A10/
     4 1H ,25X,'FIRST-ORDER SOLUTE-DECAY RATE (DK) =',1P1E13.6,1X,A10/
     5 1H ,25X,'LENGTH OF FINITE FLOW SYSTEM (XL) =',1P1E13.6,1X,A10/
     6 1H ,25X,'PLOT SCALING FACTOR (XSCLP) =',1P1E13.6)
215   FORMAT(1H0,25X,'X-COORDINATES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,78(1H-)/)
220   FORMAT(1H ,5X,8F12.4)
225   FORMAT(1H0,25X,'TIMES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,70(1H-)/)
230   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AS A FUNCTION OF TIME',
```

```
     1 15X,'*  INDICATES SOLUTION DID NOT CONVERGE'/
     2 1H0,25X,'TIME VALUES, IN ',A10)
231   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AS A FUNCTION OF TIME =',
     1 5X,'(CONTINUED)'/
     2 1H0,25X,'TIME VALUES, IN ',A10)
      FORMAT(1H ,20X,9F12.4)
236   FORMAT(1H ,19X,'*',108(1H-)/
     1 1H ,4X,'X-COORDINATE,',2X,'!',44X,'SOLUTE CONCENTRATION, IN ',
     2 A10/1H ,4X,'IN ',A10,2X,1H!/1H ,19X,'!')
240   FORMAT(1H ,5X,F12.4,2X,'! ',9(F11.5,A1))
241   FORMAT(1H ,19X,'!')
      END
      SUBROUTINE CNRML1(XL,T,X,D,V,DK,ROOT,CN,NROOT,IERR)
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
      CHARACTER*1 IERR
      DIMENSION ROOT(NROOT)
C
C       SOLUTION FOR THE ONE-DIMENSIONAL SOLUTE-TRANSPORT EQUATION
C       FOR A SYSTEM OF FINITE LENGTH WITH A FIRST-TYPE SOURCE
C       BOUNDARY CONDITION. VALUE RETURNED IS THE NORMALIZED SOLUTE
C       CONCENTRATION AT A GIVEN X-COORDINATE AND TIME VALUE.
C       FOR NO SOLUTE DECAY, A SIMPLIFIED SOLUTION IS USED.
C
      IERR=' '
      XL2=XL*XL
      V2D=V/(2.0D0*D)
      VX2D=V2D*X
      VL2D=V2D*XL
      VL2D2=VL2D*VL2D
      DKL2D=DK*XL*XL/D
      VSQT4D=V*V*T/(4.0D0*D)
      IF(DK.EQ.0.0D0) GO TO 20
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH DECAY
      SIGMA=0.0
      DO 10 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      X1=(BETA2+VL2D2)*DEXP(-BETA2*D*T/XL2)
C
C       TERM 2
      DENOM=(BETA2+VL2D2+VL2D)*(BETA2+VL2D2+DKL2D)
      X2=BETA*DSIN(BETA*X/XL)/DENOM
      SIGMA=SIGMA+X1*X2
C
C     CHECK FOR CONVERGENCE OF SERIES
      IF(N.GT.25 .AND. DABS(X1*X2).LT.1.0D-14) GO TO 15
10    CONTINUE
      IERR='*'
15    CONTINUE
C
C       TERM 3
      U=DSQRT(V*V+4.0D0*DK*D)
      VMU=V-U
      VPU=V+U
      VUPM=(U-V)/VPU
      D2=D*2.0D0
      X3=DEXP(VMU*X/D2)+VUPM*DEXP((VPU*X-2.0D0*U*XL)/D2)
```

```
      X3=X3/(1.0D0+VUPM*DEXP(-U*XL/D))
      CN=X3-2.0D0*DEXP(VX2D-VSQT4D-DK*T)*SIGMA
      RETURN
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH NO DECAY
      SIGMA=0.0
      DO 30 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      DENOM=BETA2+VL2D2+VL2D
      X1=BETA*DSIN(BETA*X/XL)*DEXP(-BETA2*D*T/XL2)
      X1=X1/DENOM
      TERM=X1
      SIGMA=SIGMA+X1
      IF(N.GT.25 .AND. DABS(X1).LT.1.0D-14) GO TO 35
30    CONTINUE
      IERR='*'
35    CONTINUE
      CN=1.0D0-2.0D0*DEXP(VX2D-VSQT4D)*SIGMA
      RETURN
      END
      SUBROUTINE CNRML3(XL,T,X,D,V,DK,ROOT,CN,NROOT,IERR)
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
      CHARACTER*1 IERR
      DIMENSION ROOT(NROOT)
C
C       SOLUTION FOR THE ONE DIMENSIONAL SOLUTE-TRANSPORT EQUATION
C       FOR A SYSTEM OF FINITE LENGTH WITH A THIRD-TYPE SOURCE
C       BOUNDARY CONDITION. VALUE RETURNED IS THE NORMALIZED SOLUTE
C       CONCENTRATION AT A GIVEN X-COORDINATE AND TIME VALUE.
C       FOR NO SOLUTE DECAY, A SIMPLIFIED SOLUTION IS USED.
C
      IERR=' '
      XL2=XL*XL
      V2D=V/(2.0D0*D)
      VLD=V*XL/D
      VX2D=V2D*X
      VL2D=V2D*XL
      VL2D2=VL2D*VL2D
      DKL2D=DK*XL*XL/D
      VSQT4D=V*V*T/(4.0D0*D)
      IF(DK.EQ.0.0D0) GO TO 20
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH DECAY
      SIGMA=0.0
      DO 10 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      BETAXL=BETA*X/XL
      X1=BETA*(BETA*DCOS(BETAXL)+VL2D*DSIN(BETAXL))
C
C       TERM 2
      DENOM=(BETA2+VL2D2+VLD)*(BETA2+VL2D2+DKL2D)
      X2=DEXP(-BETA2*D*T/XL2)/DENOM
      SIGMA=SIGMA+X1*X2
C
```

```
C     CHECK FOR CONVERGENCE OF SERIES
      IF(N.GT.25 .AND. DABS(X1*X2).LT.1.0D-14) GO TO 15
10    CONTINUE
      IERR='*'
15    CONTINUE
C
C       TERM 3
      U=DSQRT(V*V+4.0D0*DK*D)
      VMU=V-U
      VPU=V+U
      VUPM=(U-V)/VPU
      D2=D*2.0D0
      X3=DEXP(VMU*X/D2)+VUPM*DEXP((VPU*X-2.0D0*U*XL)/D2)
      X3=2.0D0*V*X3/(VPU+VMU*VUPM*DEXP(-U*XL/D))
      CN=X3-2.0D0*VLD*DEXP(VX2D-VSQT4D-DK*T)*SIGMA
      RETURN
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH NO DECAY
20    SIGMA=0.0
      DO 30 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      BETAXL=BETA*X/XL
      X1=BETA*(BETA*DCOS(BETAXL)+VL2D*DSIN(BETAXL))
C
C       TERM 2
      DENOM=(BETA2+VL2D2+VLD)*(BETA2+VL2D2)
      X2=DEXP(-BETA2*D*T/XL2)/DENOM
C
      SIGMA=SIGMA+X1*X2
      IF(N.GT.25 .AND. DABS(X1*X2).LT.1.0D-14) GO TO 35
30    CONTINUE
      IERR='*'
35    CONTINUE
C
      CN=1.0D0-2.0D0*VLD*DEXP(VX2D-VSQT4D)*SIGMA
      RETURN
      END
      SUBROUTINE ROOT1 (C,ROOT,NROOT)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION ROOT(NROOT)
      COMMON /IOUNIT/ IN,IO
      DATA MAXIT,EPS/50,1.0D-10/
C
C       THIS ROUTINE CALCULATES ROOTS OF THE EQUATION: B*COTAN(B)+C=0
C       USING NEWTON'S SECOND-ORDER METHOD.
C
C                         PROGRAM VARIABLES
C       MAXIT    MAXIMUM NUMBER OF ITERATIONS ALLOWED IN ROOT SEARCH
C       EPS      CONVERGENCE CRITERION
C       F1,F2    1ST AND 2ND DERIVATIVES OF THE EQUATION
C       H        SECOND-ORDER CORRECTION FACTOR
C
C       FIRST ROOT LIES BETWEEN PI/2 AND PI. START WITH .75*PI
      PI=3.14159265359D0
      ROOT(1)=0.750D0*PI
C
C       START LOOP FOR EACH ROOT SEARCH
```

```
      DO 10 N=1,NROOT
C
C        BEGIN ITERATIVE LOOP
      DO 20 I=1,MAXIT
      X=ROOT(N)
      SINX2=DSIN(X)*DSIN(X)
      COTX=1.0D0/DTAN(X)
      F=X*COTX+C
C        IF F IS 0.0, EXACT ROOT HAS BEEN FOUND
      IF(F.EQ.0.0) GO TO 30
      F1=COTX-X/SINX2
      F2=-1.0D0/SINX2-(SINX2-X*DSIN(X*2.0D0))/(SINX2*SINX2)
      H=(F2/2.0D0)/F1-F1/F
      H=1.0D0/H
      ROOT(N)=X+H
C
C     CHECK FOR CONVERGENCE. IF NOT ACHIEVED, RE-ITERATE
      IF(DABS(H).LT.EPS) GO TO 30
   20 CONTINUE
      WRITE(IO,201) MAXIT,N
      STOP
C
C        NEXT ROOT IS ABOUT PI GREATER THAN LAST ROOT
   30 IF(N.NE.NROOT) ROOT(N+1)=ROOT(N)+PI
   10 CONTINUE
      RETURN
C
C        FORMAT STATEMENTS
201   FORMAT(1H ,5X,'**** WARNING ****  ROOT SEARCH ROUTINE DID NOT',
     1 'CONVERGE AFTER ',I4,'ITERATIONS WHILE SEARCHING FOR ROOT',I5)
      END
      SUBROUTINE ROOT3 (A,C,ROOT,NROOT)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION ROOT(NROOT)
      COMMON /IOUNIT/ IN,IO
      DATA MAXIT,EPS/50,1.0D-10/
C
C        THIS ROUTINE CALCULATES ROOTS OF THE EQ: B*COTAN(B)-C*B**2+A=0
C        USING NEWTON'S SECOND-ORDER METHOD.
C
C                         PROGRAM VARIABLES
C        MAXIT    MAXIMUM NUMBER OF ITERATIONS ALLOWED IN ROOT SEARCH
C        EPS      CONVERGENCE CRITERION
C        F1,F2    1ST AND 2ND DERIVATIVES OF THE EQUATION
C        H        SECOND-ORDER CORRECTION FACTOR
C
C        FIRST ROOT LIES BETWEEN 0.0 AND PI. START WITH 0.5*PI
      PI=3.14159265359D0
      ROOT(1)=0.50D0*PI
C
C        START LOOP FOR EACH ROOT SEARCH
      DO 10 N=1,NROOT
C
C        BEGIN ITERATIVE LOOP
      DO 20 I=1,MAXIT
      X=ROOT(N)
      SINX2=DSIN(X)*DSIN(X)
      COTX=1.0D0/DTAN(X)
      F=X*COTX-C*X*X+A
C        IF F IS 0.0, EXACT ROOT HAS BEEN FOUND
```

```
      IF(F.EQ.0.0) GO TO 30
      F1=COTX-X/SINX2-(2.0D0*C*X)
      F2=-1.0D0/SINX2-(SINX2-X*DSIN(X*2.0D0))/(SINX2*SINX2)-2.0D0*C
      H=(F2/2.0D0)/F1-F1/F
      H=1.0D0/H
      ROOT(N)=X+H
C
C     CHECK FOR CONVERGENCE. IF NOT ACHIEVED, RE-ITERATE
      IF(DABS(H).LT.EPS) GO TO 30
   20 CONTINUE
      WRITE(IO,201) MAXIT,N
      STOP
C
C       NEXT ROOT IS ABOUT PI GREATER THAN LAST ROOT
   30 IF(N.NE.NROOT) ROOT(N+1)=ROOT(N)+PI
   10 CONTINUE
      RETURN
C
C       FORMAT STATEMENTS
201   FORMAT(1H ,5X,'**** WARNING ****  ROOT SEARCH ROUTINE DID NOT',
     1 'CONVERGE AFTER ',I4,'ITERATIONS WHILE SEARCHING FOR ROOT',I5)
      END
C       *******************************************************
C      *                                                     *
C      *                  SUBROUTINE TITLE                   *
C      *                                                     *
C      *            VERSION CURRENT AS OF 10/01/87           *
C      *                                                     *
C       *******************************************************
C
      SUBROUTINE TITLE
      CHARACTER*1 LINE1(60),EQUAL,BLANK
      CHARACTER*60 LINE
      CHARACTER*61 TITL1,T1
      COMMON /IOUNIT/ IN,IO
      COMMON /TITLES/ TITL1(4)
      DATA EQUAL/'='/,BLANK/' '/
      DATA TITL1/4*'
     1         '/
C
C        THIS ROUTINE CREATES A TITLE BOX ON THE FIRST PAGE OF
C        PROGRAM OUTPUT. THE ROUTINE READS AND PRINTS ALL DATA
C        CARDS UNTIL IT ENCOUNTERS AN '=' IN COLUMN 1. THE FIRST 4
C        LINES READ IN ARE ALSO USED AS TITLES ON PLOTS.
C
C     CALL JOBLOC (DUM,DUM,DUM,DUM,USRN)
C     USRNAM = USRN
C
      WRITE(IO,201)
      DO 10 L=1,60
      READ(IN,101,END=20) LINE
      IF (LINE(1:1).EQ.EQUAL) GOTO 60
      T1=LINE
C       STRIP OFF TRAILING BLANKS AND CENTER LINE
      DO 15 N=1,60
      NN=61-N
15    IF(LINE(NN:NN).NE.BLANK) GOTO 20
20    NN1=NN+1
      T1(NN1:NN1)='$'
      IF(L.LT.5) TITL1(L)=T1
```

```
      NS=(60-NN)/2
      IF(NS.EQ.0) GO TO 35
      DO 30 I=1,60
30    LINE1(I)=BLANK
35    NS1=NS+1
      DO 40 I=1,NN
40    LINE1(NS+I)=LINE(I:I)
10    WRITE(IO,202) (LINE1(I),I=1,60)
60    WRITE(IO,203)
      RETURN
C
C       FORMAT STATEMENTS
101   FORMAT (A60)
201   FORMAT(1H1//////////1H ,16X,68(1H*))
202   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,3X,60A1,3X,1H*)
203   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,19X,'PROGRAM AS OF  ',
     1'30 JULY 1996',20X,1H*/1H ,16X,1H*,66X,1H*/1H ,16X,68(1H*)
     2 /1H1)
      END
C
C       ********************************************************
C      *                                                        *
C      *                   SUBROUTINE OFILE                     *
C      *                                                        *
C      *             VERSION CURRENT AS OF 10/01/87             *
C      *                                                        *
C       ********************************************************
C
      SUBROUTINE OFILE
      CHARACTER*50 IFNAME,OFNAME
      CHARACTER*1 STAR
      COMMON /IOUNIT/ IN,IO
      DATA STAR/'*'/
      IN=5
      IO=6
      WRITE(*,5)
      READ(*,7) IFNAME
      WRITE(*,6)
      READ(*,7) OFNAME
      OPEN (IN,FILE=IFNAME,STATUS='OLD')
      IF(OFNAME(1:1).EQ.STAR) IO=1
      IF(OFNAME(1:1).NE.STAR) OPEN (IO,FILE=OFNAME)
      RETURN
C
C       FORMAT STATEMENTS
5     FORMAT(5X,'TYPE IN INPUT FILE NAME')
6     FORMAT(5X,'TYPE IN OUTPUT FILE NAME')
7     FORMAT(A50)
      END
```

```
FINITE Validation Problem -- 1-D Solute transport in a finite-length
soil column with a first-type boundary condition at x=0
Model Parameters:  L=300.0 m, V=8.0 m/yr, D=40.0 m**2/yr
                   K1=0.0 per yr, CO=1.0 mg/L

   1   61    8   50    1
MG/L       M/YR        M**2/YR  PER YR     METERS     YEARS
      1.0        8.0       40.0        0.0      300.0        1.2
      0.0        5.0       10.0       15.0       20.0       25.0       30.0       35.0
     40.0       45.0       50.0       55.0       60.0       65.0       70.0       75.0
     80.0       85.0       90.0       95.0      100.0      105.0      110.0      115.0
    120.0      125.0      130.0      135.0      140.0      145.0      150.0      155.0
    160.0      165.0      170.0      175.0      180.0      185.0      190.0      195.0
    200.0      205.0      210.0      215.0      220.0      225.0      230.0      235.0
    240.0      245.0      250.0      255.0      260.0      265.0      270.0      275.0
    280.0      285.0      290.0      295.0      300.0
      5.0       10.0       15.0       20.0       25.0       30.0       35.0       40.0
```

1

```
********************************************************************
*                                                                  *
*   FINITE Validation Problem -- 1-D Solute transport in a finit   *
*                                                                  *
*     soil column with a first-type boundary condition at x=0      *
*                                                                  *
*     Model Parameters:  L=300.0 m, V=8.0 m/yr, D=40.0 m**2/yr     *
*                                                                  *
*                         K1=0.0 per yr, CO=1.0 mg/L               *
*                                                                  *
*                  PROGRAM AS OF  30 JULY 1996                     *
*                                                                  *
********************************************************************
```

1

ANALYTICAL SOLUTION TO THE ONE-DIMENSIONAL
ADVECTIVE-DISPERSIVE SOLUTE-TRANSPORT EQUATION
FOR A SYSTEM OF FINITE LENGTH

0 INPUT DATA

----

0 FIRST-TYPE BOUNDARY CONDITION AT X = 0.0

0 NUMBER OF X-COORDINATES (NX) = 61

NUMBER OF TIME VALUES (NT) = 8

NUMBER OF ROOTS USED IN INFINITE SERIES SUMMATION (NROOT) = 50

0 SOLUTE CONCENTRATION ON MODEL BOUNDARY (CO) = 1.000000E+00 MG/L

GROUND-WATER VELOCITY IN X-DIRECTION (VX) = 8.000000E+00 M/YR

DISPERSION IN THE X-DIRECTION (DX) = 4.000000E+01 M**2/YR

FIRST-ORDER SOLUTE-DECAY RATE (DK) = 0.000000E+00 PER YR

LENGTH OF FINITE FLOW SYSTEM (XL) = 3.000000E+02 METERS

PLOT SCALING FACTOR (XSCLP) = 1.200000E+00

0 X-COORDINATES AT WHICH SOLUTE CONCENTRATIONS WILL BE CALCULATED, IN METERS

0.0000	5.0000	10.0000	15.0000	20.0000	25.0000	30.0000	35.0000
40.0000	45.0000	50.0000	55.0000	60.0000	65.0000	70.0000	75.0000
80.0000	85.0000	90.0000	95.0000	100.0000	105.0000	110.0000	115.0000
120.0000	125.0000	130.0000	135.0000	140.0000	145.0000	150.0000	155.0000
160.0000	165.0000	170.0000	175.0000	180.0000	185.0000	190.0000	195.0000
200.0000	205.0000	210.0000	215.0000	220.0000	225.0000	230.0000	235.0000
240.0000	245.0000	250.0000	255.0000	260.0000	265.0000	270.0000	275.0000
280.0000	285.0000	290.0000	295.0000	300.0000			

0 TIMES AT WHICH SOLUTE CONCENTRATIONS WILL BE CALCULATED, IN YEARS

5.0000 10.0000 15.0000 20.0000 25.0000 30.0000 35.0000 40.0000

1

0 SOLUTE CONCENTRATION AS A FUNCTION OF TIME * INDICATES SOLUTION DID NOT CONVERGE

0 TIME VALUES, IN YEARS

X-COORDINATE, IN METERS	5.0000	10.0000	15.0000	20.0000	25.0000	30.0000	35.0000	40.0000
	SOLUTE CONCENTRATION, IN MG/L							
0.0000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
5.0000	0.99317	0.99960	0.99997	1.00000	1.00000	1.00000	1.00000	1.00000
10.0000	0.97908	0.99874	0.99990	0.99999	1.00000	1.00000	1.00000	1.00000
15.0000	0.95420	0.99708	0.99976	0.99998	1.00000	1.00000	1.00000	1.00000
20.0000	0.91505	0.99416	0.99950	0.99995	1.00000	1.00000	1.00000	1.00000
25.0000	0.85901	0.98933	0.99906	0.99991	0.99999	1.00000	1.00000	1.00000
30.0000	0.78531	0.98175	0.99832	0.99983	0.99998	1.00000	1.00000	1.00000
35.0000	0.69567	0.97043	0.99713	0.99971	0.99997	1.00000	1.00000	1.00000
40.0000	0.59441	0.95428	0.99529	0.99950	0.99995	0.99999	1.00000	1.00000
45.0000	0.48790	0.93213	0.99253	0.99919	0.99991	0.99999	1.00000	1.00000
50.0000	0.38338	0.90297	0.98851	0.99870	0.99985	0.99998	1.00000	1.00000
55.0000	0.28752	0.86596	0.98280	0.99796	0.99976	0.99997	1.00000	1.00000
60.0000	0.20531	0.82072	0.97492	0.99688	0.99962	0.99996	0.99999	1.00000
65.0000	0.13930	0.76735	0.96433	0.99533	0.99942	0.99993	0.99999	1.00000
70.0000	0.08964	0.70655	0.95043	0.99314	0.99912	0.99989	0.99999	1.00000
75.0000	0.05465	0.63965	0.93263	0.99012	0.99868	0.99983	0.99998	1.00000
80.0000	0.03152	0.56850	0.91039	0.98602	0.99805	0.99974	0.99997	1.00000
85.0000	0.01718	0.49534	0.88324	0.98056	0.99718	0.99962	0.99995	0.99999
90.0000	0.00885	0.42259	0.85085	0.97342	0.99597	0.99943	0.99992	0.99999
95.0000	0.00430	0.35260	0.81310	0.96425	0.99432	0.99918	0.99989	0.99998
100.0000	0.00197	0.28745	0.77009	0.95268	0.99211	0.99882	0.99983	0.99998
105.0000	0.00085	0.22875	0.72218	0.93833	0.98918	0.99832	0.99976	0.99997
110.0000	0.00035	0.17756	0.66999	0.92085	0.98536	0.99764	0.99965	0.99995
115.0000	0.00013	0.13434	0.61439	0.89991	0.98045	0.99672	0.99950	0.99993
120.0000	0.00005	0.09901	0.55645	0.87525	0.97423	0.99550	0.99929	0.99989
125.0000	0.00002	0.07105	0.49738	0.84668	0.96645	0.99390	0.99900	0.99985
130.0000	0.00001	0.04962	0.43847	0.81416	0.95684	0.99180	0.99862	0.99978
135.0000	0.00000	0.03371	0.38098	0.77773	0.94516	0.98911	0.99810	0.99970
140.0000	0.00000	0.02227	0.32608	0.73761	0.93113	0.98569	0.99742	0.99957
145.0000	0.00000	0.01430	0.27478	0.69414	0.91451	0.98138	0.99652	0.99941
150.0000	0.00000	0.00893	0.22786	0.64781	0.89508	0.97603	0.99536	0.99919
155.0000	0.00000	0.00541	0.18587	0.59923	0.87268	0.96946	0.99386	0.99890
160.0000	0.00000	0.00319	0.14908	0.54912	0.84718	0.96146	0.99194	0.99851
165.0000	0.00000	0.00182	0.11753	0.49827	0.81854	0.95185	0.98953	0.99800
170.0000	0.00000	0.00101	0.09104	0.44750	0.78680	0.94042	0.98652	0.99735
175.0000	0.00000	0.00055	0.06928	0.39762	0.75206	0.92698	0.98278	0.99650
180.0000	0.00000	0.00029	0.05178	0.34941	0.71456	0.91136	0.97821	0.99542
185.0000	0.00000	0.00015	0.03800	0.30354	0.67458	0.89339	0.97265	0.99405
190.0000	0.00000	0.00007	0.02737	0.26061	0.63252	0.87294	0.96596	0.99234
195.0000	0.00000	0.00003	0.01935	0.22107	0.58884	0.84994	0.95799	0.99021
200.0000	0.00000	0.00002	0.01343	0.18522	0.54407	0.82434	0.94858	0.98757
205.0000	0.00000	0.00001	0.00914	0.15324	0.49875	0.79615	0.93757	0.98435
210.0000	0.00000	0.00000	0.00611	0.12517	0.45348	0.76545	0.92482	0.98044

215.0000	0.00000	0.00000	0.00400	0.10092	0.40884	0.73237	0.91018	0.97574
220.0000	0.00000	0.00000	0.00257	0.08029	0.36538	0.69712	0.89354	0.97012

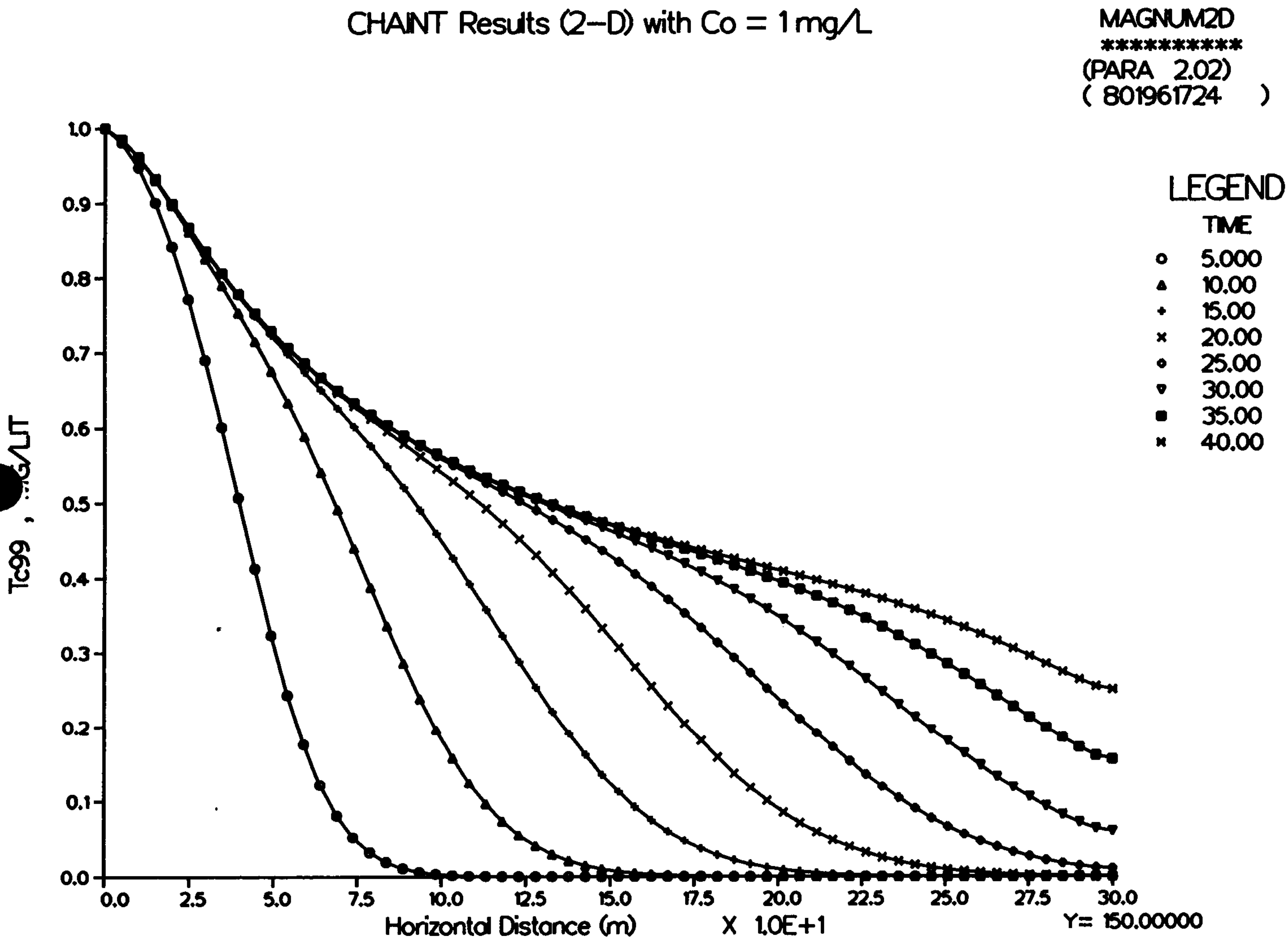
1
0
SOLUTE CONCENTRATION AS A FUNCTION OF TIME = (CONTINUED)

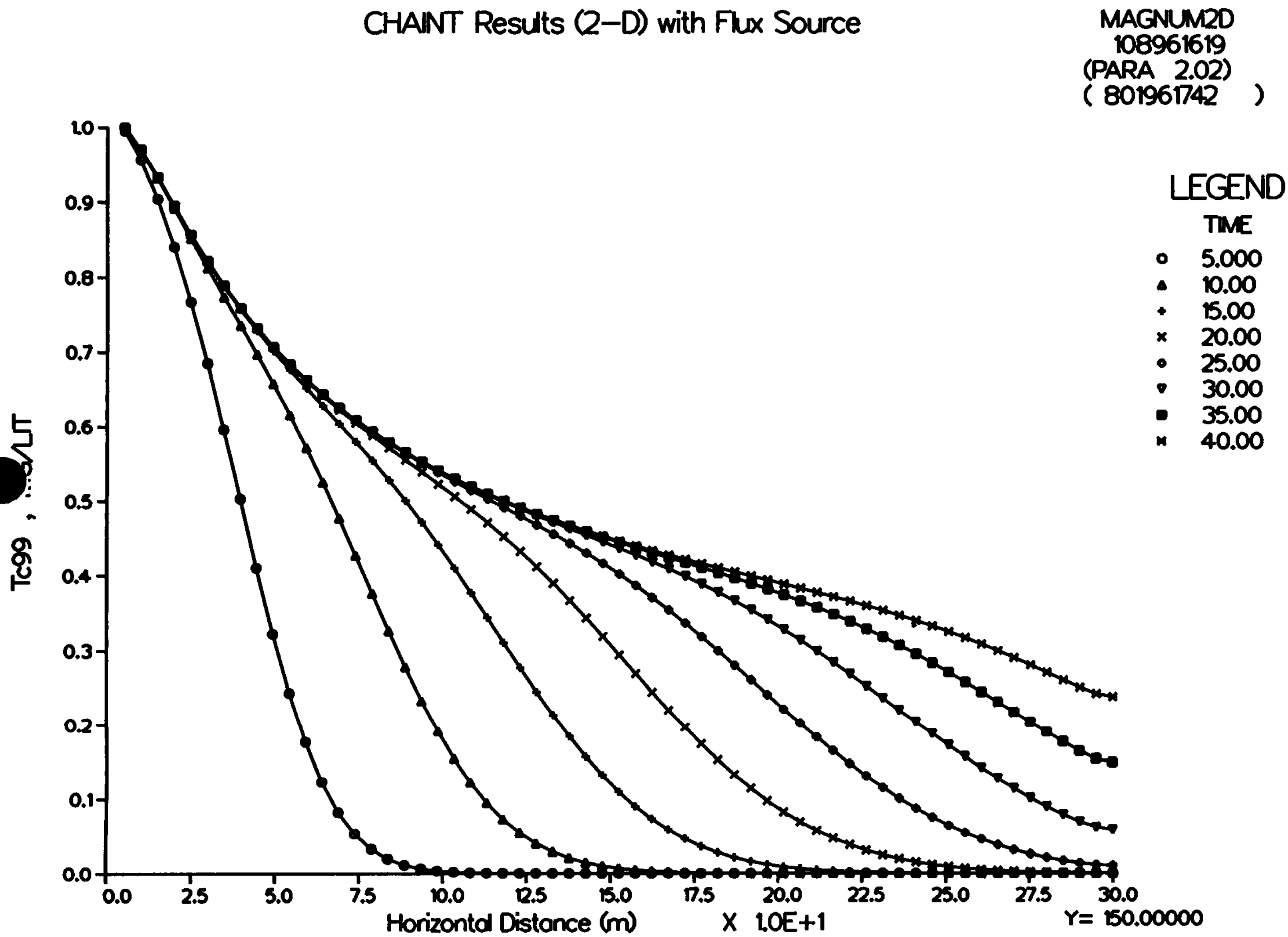
X-COORDINATE, IN METERS	TIME VALUES, IN YEARS 5.0000	10.0000	15.0000	20.0000	25.0000	30.0000	35.0000	40.0000
	SOLUTE CONCENTRATION, IN MG/L							
225.0000	0.00001	0.00000	0.00162	0.06303	0.32360	0.65994	0.87479	0.96346
230.0000	0.00000	0.00000	0.00100	0.04882	0.28395	0.62117	0.85386	0.95565
235.0000	-0.00001	0.00000	0.00061	0.03729	0.24681	0.58116	0.83071	0.94655
240.0000	-0.00001	0.00000	0.00036	0.02810	0.21245	0.54031	0.80535	0.93603
245.0000	0.00000	0.00000	0.00021	0.02087	0.18108	0.49904	0.77783	0.92398
250.0000	0.00026	0.00000	0.00012	0.01529	0.15279	0.45781	0.74821	0.91027
255.0000	-0.00001	0.00000	0.00007	0.01105	0.12761	0.41705	0.71666	0.89483
260.0000	0.00014	0.00000	0.00004	0.00786	0.10548	0.37717	0.68334	0.87755
265.0000	0.00009	0.00000	0.00002	0.00552	0.08627	0.33859	0.64848	0.85840
270.0000	0.00003	0.00000	0.00001	0.00382	0.06982	0.30165	0.61237	0.83736
275.0000	-0.00029	0.00001	0.00001	0.00260	0.05590	0.26668	0.57535	0.81447
280.0000	0.00022	0.00001	0.00000	0.00175	0.04428	0.23400	0.53789	0.78994
285.0000	0.00054	-0.00002	0.00000	0.00116	0.03474	0.20399	0.50075	0.76425
290.0000	-0.00118	-0.00003	0.00000	0.00076	0.02713	0.17740	0.46549	0.73867
295.0000	0.00023	0.00004	0.00000	0.00051	0.02157	0.15623	0.43584	0.71636
300.0000	0.00350	0.00012	0.00000	0.00041	0.01910	0.14638	0.42163	0.70546

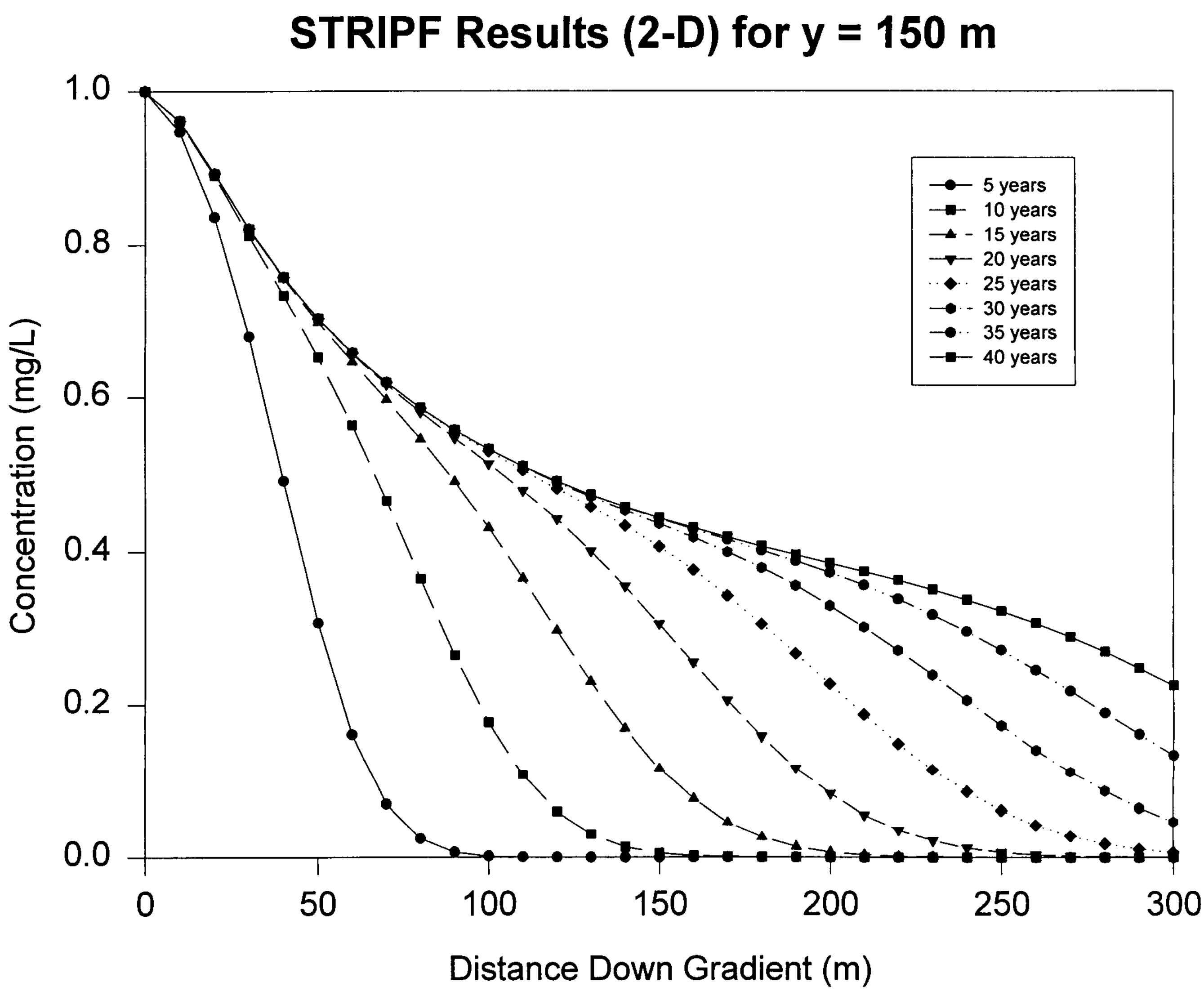
7.2.2 Validation Test Case 2 Results- Two Dimensional

Results from the CHAINT simulations for constant source concentration and constant flux are presented in this section. Overlaying the figures reveals the contoured results are consistent for both CHAINT scenarios.

The results from the CHAINT simulations were compared to results from a two dimensional analytical model. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from STRIPF compare favorably and overlaying the figures reveals the results are consistent.

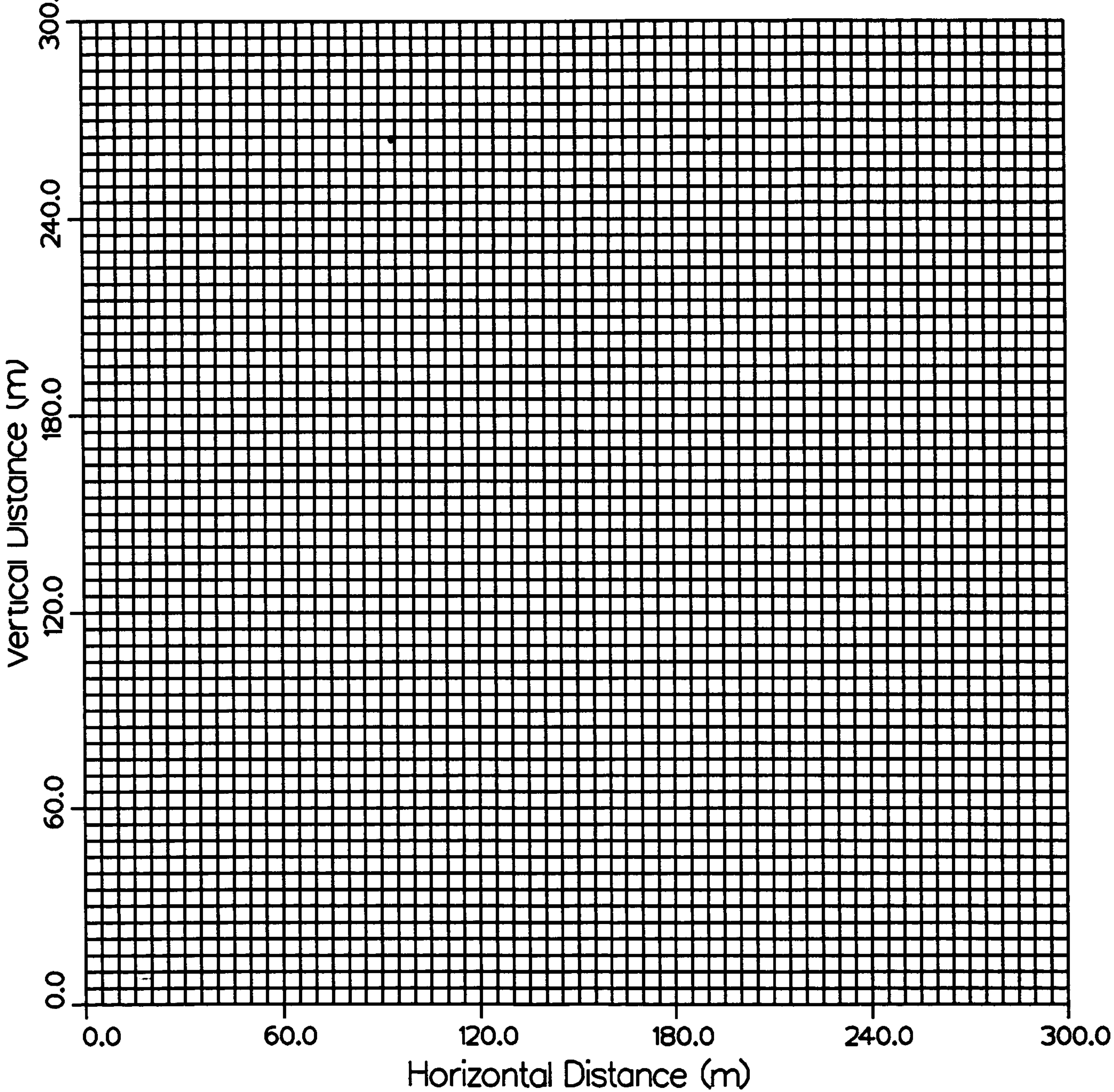

CHAINT Results (2-D) with Co = 1 mg/L
MAGNUM2D
****
(PARA 2.02)
(801961724)
LEGEND
TIME
5.000
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Tc99
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
Horizontal Distance (m)
X 1.0E+1
Y= 150.00000


CHAINT Results (2-D) with Flux Source
MAGNUM2D
108961619
(PARA 2.02)
(801961742)
LEGEND
TIME
5.000
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Tc99
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
Horizontal Distance (m)
X 1.0E+1
Y= 150.00000


STRIPF Results (2-D) for y = 150 m
Concentration (mg/L)
Distance Down Gradient (m)
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
5 years
10 years
15 years
20 years
25 years
30 years
35 years
40 years

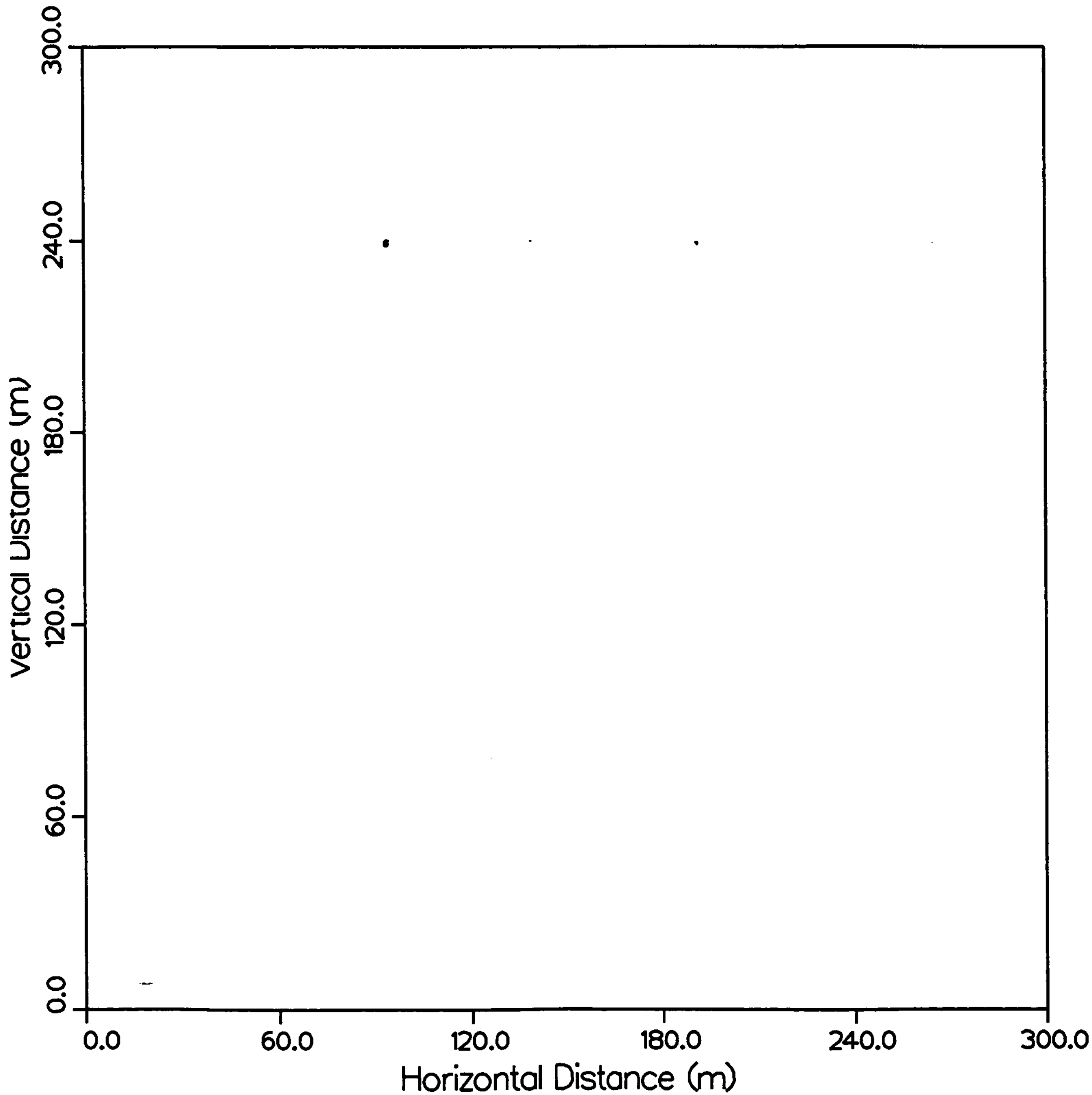
MAGNUM Geometry Grid for 2-D Comparison with STRIPF
FINITE ELEMENT GRID

(PLT 2.00)
(802960838)
(0)



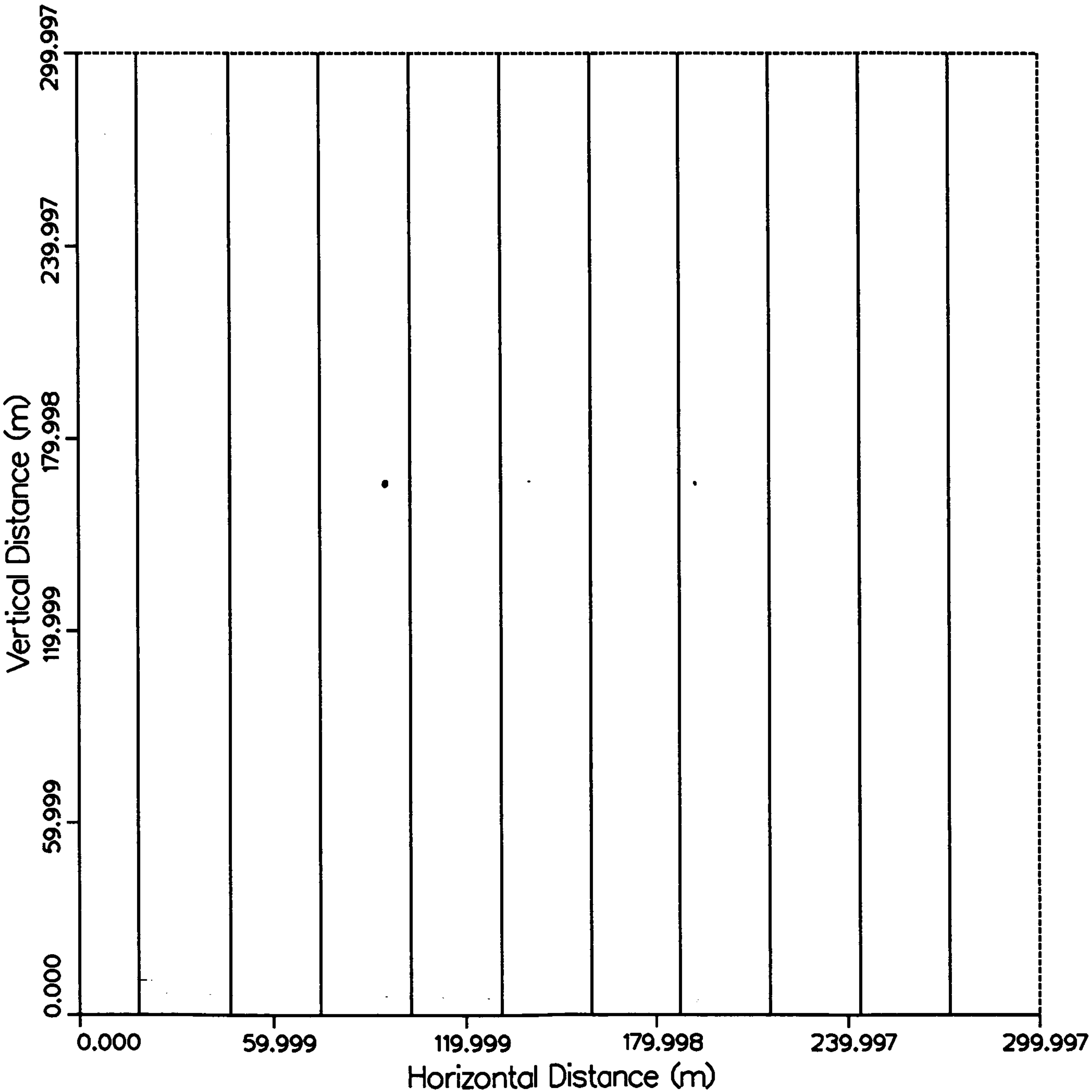
MAGNUM Geometry Grid for 2-D Comparison with STRIPF
MATERIAL TYPE BOUNDARIES

(PLT 2.00)
(802960838)
(0)

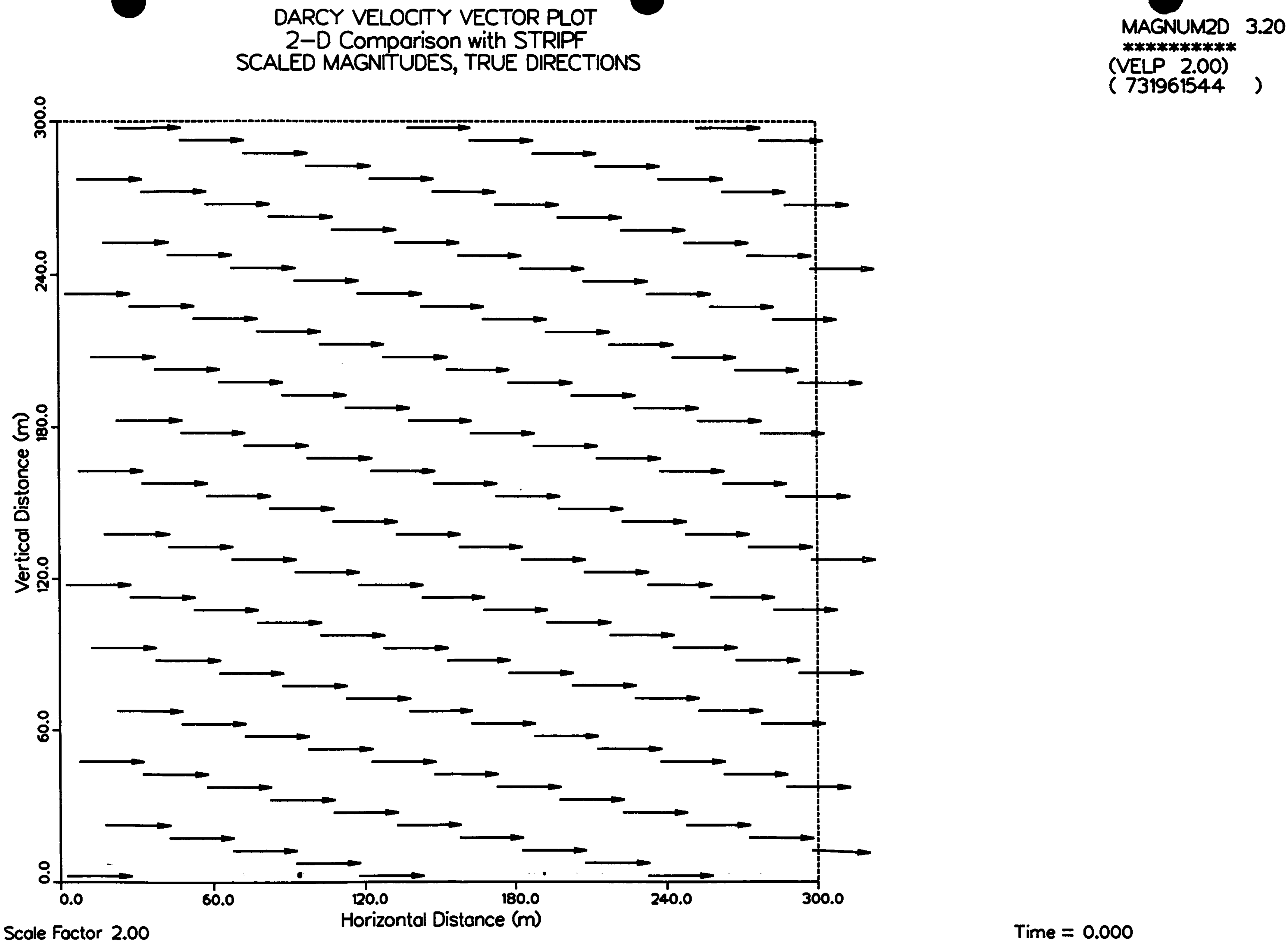


MAGNUM Results for 2-D
HEAD 1, METERS

MAGNUM2D
108961619
(CONT 2.03)
(801961623)



Time = 1.00E-20



DARCY VELOCITY VECTOR PLOT
2-D Comparison with STRIPF
SCALED MAGNITUDES, TRUE DIRECTIONS
MAGNUM2D 3.20
****
(VELP 2.00)
(731961544)
Vertical Distance (m)
0.0
60.0
120.0
180.0
240.0
300.0
Horizontal Distance (m)
Scale Factor 2.00
Time = 0.000

```
MAGNUM - 2-D Test case for comparison with STRIPF
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
    1     0      1  11041  3600    1    0    0     0    1     1    0
#  irs  isv  icf  igi  ig  ivel inpt icsv
    0   13    0   10    0   12    0    0
#  ssf   alfa  tref
   0.0    1.8   20.0
#  nts  ntsg   dlt
    1     1     1000.
 9999     1     1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#   n       To       Ho
    1    20.000    0.5327
#  kspec
   242
#         n      n1  n2  Tbc      Hbc
      10860         0   1   20.0000    0.0000
      10861         0   1   20.0000    0.0000
      10862         0   1   20.0000    0.0000
      10865         0   1   20.0000    0.0000
      10866         0   1   20.0000    0.0000
      10868         0   1   20.0000    0.0000
      10869         0   1   20.0000    0.0000
      10871         0   1   20.0000    0.0000
      10872         0   1   20.0000    0.0000
      10874         0   1   20.0000    0.0000
      10875         0   1   20.0000    0.0000
      10877         0   1   20.0000    0.0000
      10878         0   1   20.0000    0.0000
      10880         0   1   20.0000    0.0000
      10881         0   1   20.0000    0.0000
      10883         0   1   20.0000    0.0000
      10884         0   1   20.0000    0.0000
      10886         0   1   20.0000    0.0000
      10887         0   1   20.0000    0.0000
      10889         0   1   20.0000    0.0000
      10890         0   1   20.0000    0.0000
      10892         0   1   20.0000    0.0000
      10893         0   1   20.0000    0.0000
      10895         0   1   20.0000    0.0000
      10896         0   1   20.0000    0.0000
      10898         0   1   20.0000    0.0000
      10899         0   1   20.0000    0.0000
      10901         0   1   20.0000    0.0000
      10902         0   1   20.0000    0.0000
      10904         0   1   20.0000    0.0000
      10905         0   1   20.0000    0.0000
      10907         0   1   20.0000    0.0000
      10908         0   1   20.0000    0.0000
      10910         0   1   20.0000    0.0000
      10911         0   1   20.0000    0.0000
      10913         0   1   20.0000    0.0000
      10914         0   1   20.0000    0.0000
      10916         0   1   20.0000    0.0000
      10917         0   1   20.0000    0.0000
      10919         0   1   20.0000    0.0000
      10920         0   1   20.0000    0.0000
      10922         0   1   20.0000    0.0000
      10923         0   1   20.0000    0.0000
```

10925	0	1	20.0000	0.0000
10926	0	1	20.0000	0.0000
10928	0	1	20.0000	0.0000
10929	0	1	20.0000	0.0000
10931	0	1	20.0000	0.0000
10932	0	1	20.0000	0.0000
10934	0	1	20.0000	0.0000
10935	0	1	20.0000	0.0000
10937	0	1	20.0000	0.0000
10938	0	1	20.0000	0.0000
10940	0	1	20.0000	0.0000
10941	0	1	20.0000	0.0000
10943	0	1	20.0000	0.0000
10944	0	1	20.0000	0.0000
10946	0	1	20.0000	0.0000
10947	0	1	20.0000	0.0000
10949	0	1	20.0000	0.0000
10950	0	1	20.0000	0.0000
10952	0	1	20.0000	0.0000
10953	0	1	20.0000	0.0000
10955	0	1	20.0000	0.0000
10956	0	1	20.0000	0.0000
10958	0	1	20.0000	0.0000
10959	0	1	20.0000	0.0000
10961	0	1	20.0000	0.0000
10962	0	1	20.0000	0.0000
10964	0	1	20.0000	0.0000
10965	0	1	20.0000	0.0000
10967	0	1	20.0000	0.0000
10968	0	1	20.0000	0.0000
10970	0	1	20.0000	0.0000
10971	0	1	20.0000	0.0000
10973	0	1	20.0000	0.0000
10974	0	1	20.0000	0.0000
10976	0	1	20.0000	0.0000
10977	0	1	20.0000	0.0000
10979	0	1	20.0000	0.0000
10980	0	1	20.0000	0.0000
10982	0	1	20.0000	0.0000
10983	0	1	20.0000	0.0000
10985	0	1	20.0000	0.0000
10986	0	1	20.0000	0.0000
10988	0	1	20.0000	0.0000
10989	0	1	20.0000	0.0000
10991	0	1	20.0000	0.0000
10992	0	1	20.0000	0.0000
10994	0	1	20.0000	0.0000
10995	0	1	20.0000	0.0000
10997	0	1	20.0000	0.0000
10998	0	1	20.0000	0.0000
11000	0	1	20.0000	0.0000
11001	0	1	20.0000	0.0000
11003	0	1	20.0000	0.0000
11004	0	1	20.0000	0.0000
11006	0	1	20.0000	0.0000
11007	0	1	20.0000	0.0000
11009	0	1	20.0000	0.0000
11010	0	1	20.0000	0.0000
11012	0	1	20.0000	0.0000
11013	0	1	20.0000	0.0000

11015	0	1	20.0000	0.0000
11016	0	1	20.0000	0.0000
11018	0	1	20.0000	0.0000
11019	0	1	20.0000	0.0000
11021	0	1	20.0000	0.0000
11022	0	1	20.0000	0.0000
11024	0	1	20.0000	0.0000
11025	0	1	20.0000	0.0000
11027	0	1	20.0000	0.0000
11028	0	1	20.0000	0.0000
11030	0	1	20.0000	0.0000
11031	0	1	20.0000	0.0000
11033	0	1	20.0000	0.0000
11034	0	1	20.0000	0.0000
11036	0	1	20.0000	0.0000
11037	0	1	20.0000	0.0000
11039	0	1	20.0000	0.0000
11040	0	1	20.0000	0.0000
121	0	1	20.0000	1.0654
120	0	1	20.0000	1.0654
119	0	1	20.0000	1.0654
118	0	1	20.0000	1.0654
117	0	1	20.0000	1.0654
116	0	1	20.0000	1.0654
115	0	1	20.0000	1.0654
114	0	1	20.0000	1.0654
113	0	1	20.0000	1.0654
112	0	1	20.0000	1.0654
111	0	1	20.0000	1.0654
110	0	1	20.0000	1.0654
109	0	1	20.0000	1.0654
108	0	1	20.0000	1.0654
107	0	1	20.0000	1.0654
106	0	1	20.0000	1.0654
105	0	1	20.0000	1.0654
104	0	1	20.0000	1.0654
103	0	1	20.0000	1.0654
102	0	1	20.0000	1.0654
101	0	1	20.0000	1.0654
100	0	1	20.0000	1.0654
99	0	1	20.0000	1.0654
98	0	1	20.0000	1.0654
97	0	1	20.0000	1.0654
96	0	1	20.0000	1.0654
95	0	1	20.0000	1.0654
94	0	1	20.0000	1.0654
93	0	1	20.0000	1.0654
92	0	1	20.0000	1.0654
91	0	1	20.0000	1.0654
90	0	1	20.0000	1.0654
89	0	1	20.0000	1.0654
88	0	1	20.0000	1.0654
87	0	1	20.0000	1.0654
86	0	1	20.0000	1.0654
85	0	1	20.0000	1.0654
84	0	1	20.0000	1.0654
83	0	1	20.0000	1.0654
82	0	1	20.0000	1.0654
81	0	1	20.0000	1.0654
80	0	1	20.0000	1.0654

79	0	1	20.0000	1.0654
78	0	1	20.0000	1.0654
77	0	1	20.0000	1.0654
76	0	1	20.0000	1.0654
75	0	1	20.0000	1.0654
74	0	1	20.0000	1.0654
73	0	1	20.0000	1.0654
72	0	1	20.0000	1.0654
71	0	1	20.0000	1.0654
70	0	1	20.0000	1.0654
69	0	1	20.0000	1.0654
68	0	1	20.0000	1.0654
67	0	1	20.0000	1.0654
66	0	1	20.0000	1.0654
65	0	1	20.0000	1.0654
64	0	1	20.0000	1.0654
63	0	1	20.0000	1.0654
62	0	1	20.0000	1.0654
61	0	1	20.0000	1.0654
60	0	1	20.0000	1.0654
59	0	1	20.0000	1.0654
58	0	1	20.0000	1.0654
57	0	1	20.0000	1.0654
56	0	1	20.0000	1.0654
55	0	1	20.0000	1.0654
54	0	1	20.0000	1.0654
53	0	1	20.0000	1.0654
52	0	1	20.0000	1.0654
51	0	1	20.0000	1.0654
50	0	1	20.0000	1.0654
49	0	1	20.0000	1.0654
48	0	1	20.0000	1.0654
47	0	1	20.0000	1.0654
46	0	1	20.0000	1.0654
45	0	1	20.0000	1.0654
44	0	1	20.0000	1.0654
43	0	1	20.0000	1.0654
42	0	1	20.0000	1.0654
41	0	1	20.0000	1.0654
40	0	1	20.0000	1.0654
39	0	1	20.0000	1.0654
38	0	1	20.0000	1.0654
37	0	1	20.0000	1.0654
36	0	1	20.0000	1.0654
35	0	1	20.0000	1.0654
34	0	1	20.0000	1.0654
33	0	1	20.0000	1.0654
32	0	1	20.0000	1.0654
31	0	1	20.0000	1.0654
30	0	1	20.0000	1.0654
29	0	1	20.0000	1.0654
28	0	1	20.0000	1.0654
27	0	1	20.0000	1.0654
26	0	1	20.0000	1.0654
25	0	1	20.0000	1.0654
24	0	1	20.0000	1.0654
23	0	1	20.0000	1.0654
22	0	1	20.0000	1.0654
21	0	1	20.0000	1.0654
20	0	1	20.0000	1.0654

```
       19          0  1   20.0000    1.0654
       18          0  1   20.0000    1.0654
       17          0  1   20.0000    1.0654
       16          0  1   20.0000    1.0654
       15          0  1   20.0000    1.0654
       14          0  1   20.0000    1.0654
       13          0  1   20.0000    1.0654
       12          0  1   20.0000    1.0654
       11          0  1   20.0000    1.0654
       10          0  1   20.0000    1.0654
        9          0  1   20.0000    1.0654
        8          0  1   20.0000    1.0654
        7          0  1   20.0000    1.0654
        6          0  1   20.0000    1.0654
        5          0  1   20.0000    1.0654
        4          0  1   20.0000    1.0654
        3          0  1   20.0000    1.0654
        2          0  1   20.0000    1.0654
        1          0  1   20.0000    1.0654
     #  L    cvm     tkk(1)  tkk(2)  poros    hkax        hkay       nme
#       sp1      rhom    alpal   alpat    width
        1        0         0        0       0.07    5.0e-6     5.0e-6     mat1
   1.0e-6     2400         0        0        0
#  nld  nlt  scf
   0    0      0.0
```

```
CHAINT 2-D Test case (with Co=1 mg/L source) for comparison with STRIPF
#  nqal    ne     np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1    3600  11041   121    1      0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
    0   11    0    0   14   15    0
#  ssf  alfa  xscale  yscale  uscale  vscale
    0.  1.8     0.      0.      0.      0.
#  nts  ntsg   dlt    zonel  zoner  zonet  zoneb
    5    5    0.02    0.       0.    0.      0.
    9    9    0.1     0.       0.    0.      0.
    8    8    0.5     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
    5    5    1.0     0.       0.    0.      0.
 9999    0    0       0        0     0       0
#   j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1       5.       1.0      2400.      0.07       0.      mat1
#  islt
    1
#   L   amu    diag     isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1   1.0  2.13E+05    0         0.0       0         0.0    Tc99   0.0
#   i   dml(i,1..n2)  m2/yr
    1   0.0
#   i   xkdi(i,1..n2)  ml/g
    1   0.0
#   k    Ci
    1    0.0
#   L    bcs
    1    0.0
    2    0.0
    3    0.0
    4    0.0
    5    0.0
    6    0.0
    7    0.0
    8    0.0
    9    0.0
   10    0.0
   11    0.0
   12    0.0
   13    0.0
   14    0.0
   15    0.0
   16    0.0
   17    0.0
   18    0.0
   19    0.0
   20    0.0
   21    0.0
   22    0.0
   23    0.0
   24    0.0
   25    0.0
   26    0.0
   27    0.0
   28    0.0
```

29	0.0
30	0.0
31	0.0
32	0.0
33	0.0
34	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	1.0
58	1.0
59	1.0
60	1.0
61	1.0
62	1.0
63	1.0
64	1.0
65	1.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
84	0.0
85	0.0
86	0.0
87	0.0
88	0.0

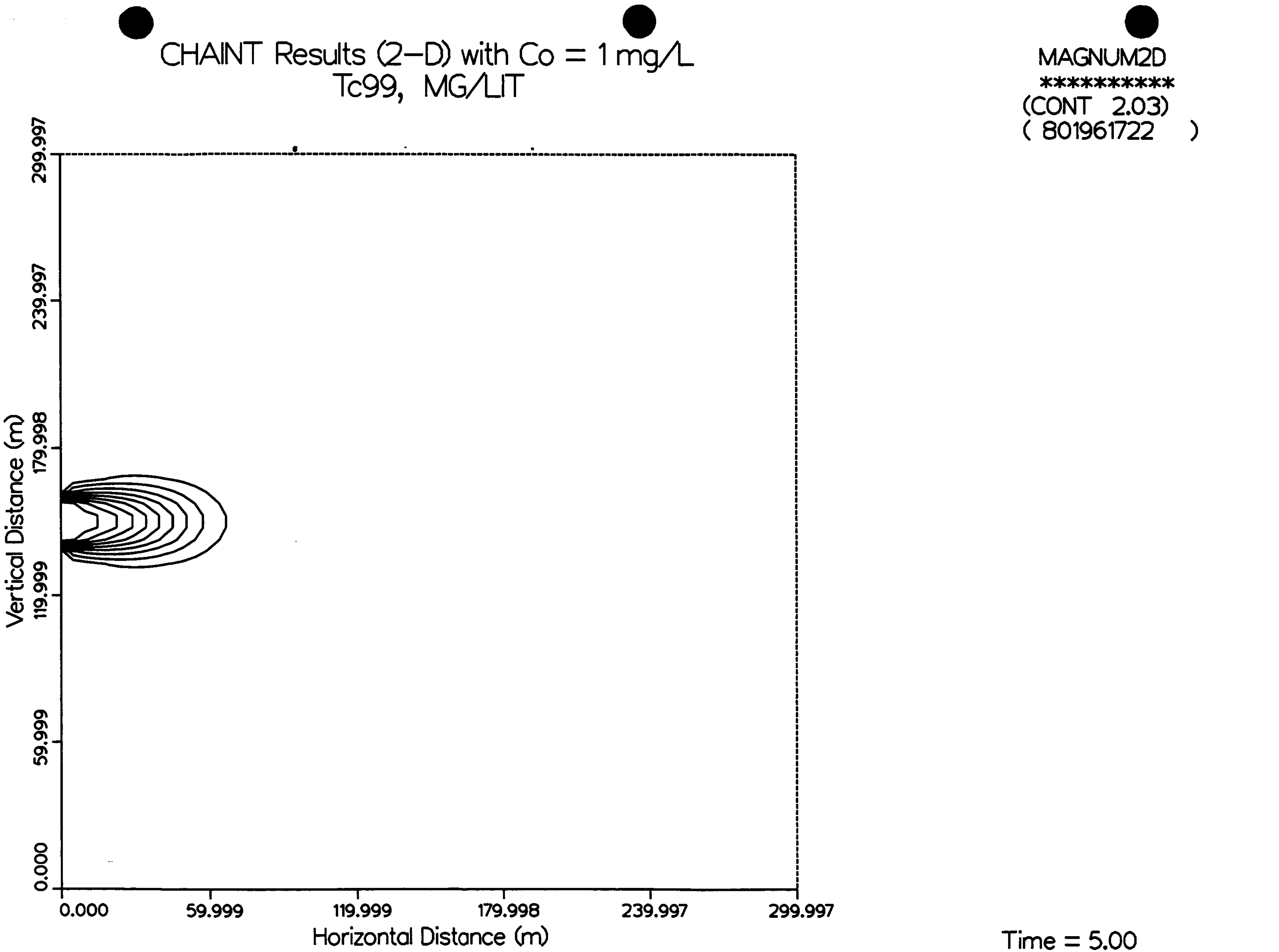
89	0.0
90	0.0
91	0.0
92	0.0
93	0.0
94	0.0
95	0.0
96	0.0
97	0.0
98	0.0
99	0.0
100	0.0
101	0.0
102	0.0
103	0.0
104	0.0
105	0.0
106	0.0
107	0.0
108	0.0
109	0.0
110	0.0
111	0.0
112	0.0
113	0.0
114	0.0
115	0.0
116	0.0
117	0.0
118	0.0
119	0.0
120	0.0
121	0.0

#	nld	scf	relz
	0	1.0	0.

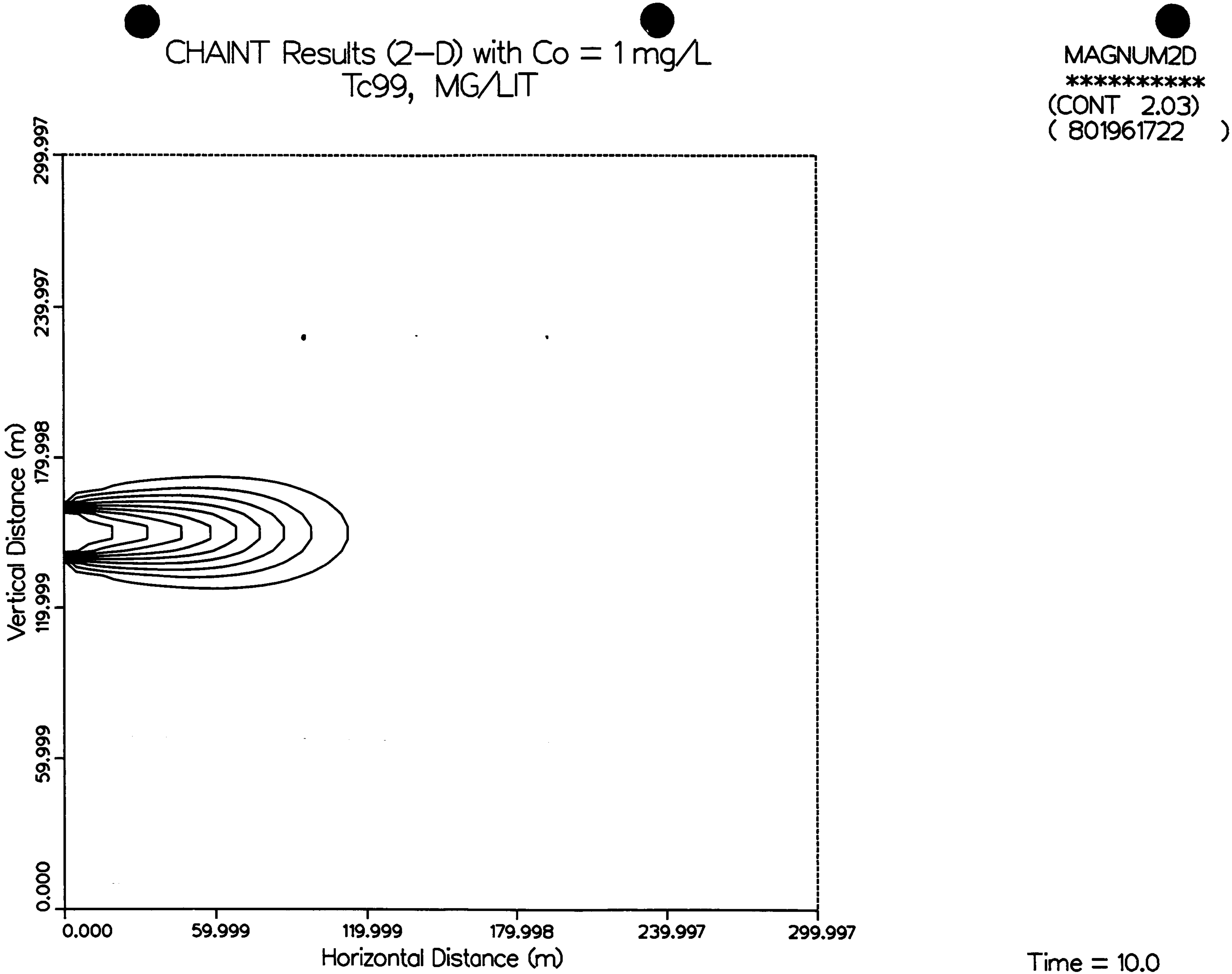
```
CHAINT 2-D Test case (with flux source) for comparison with STRIPF
#  nqal    ne     np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1    3600  11041  121    1      0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
    0   11    0    0   14   15    0
#  ssf  alfa  xscale  yscale  uscale  vscale
    0.  1.8     0.      0.      0.      0.
#  nts  ntsg   dlt    zonel  zoner  zonet  zoneb
    5    5    0.02     0.      0.     0.     0.
    9    9    0.1      0.      0.     0.     0.
    8    8    0.5      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
    5    5    1.0      0.      0.     0.     0.
 9999    0    0        0       0      0      0
#   j     ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1       5.        1.0       2400.      0.07       0.       mat1
#  islt
    1
#   L    amu    diag     isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1    1.0   2.13E+05    0        0.0       0        0.0     Tc99   0.0
#   i    dml(i,1..n2)  m2/yr
    1    0.0
#   i    xkdi(i,1..n2)  ml/g
    1    0.0
#   lk    Ci
    1     0.0
#   L     bcs
    1     0.0
    2     0.0
    3     0.0
    4     0.0
    5     0.0
    6     0.0
    7     0.0
    8     0.0
    9     0.0
   10     0.0
   11     0.0
   12     0.0
   13     0.0
   14     0.0
   15     0.0
   16     0.0
   17     0.0
   18     0.0
   19     0.0
   20     0.0
   21     0.0
   22     0.0
   23     0.0
   24     0.0
   25     0.0
   26     0.0
   27     0.0
   28     0.0
```

29	0.0
30	0.0
31	0.0
32	0.0
33	0.0
34	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	0.0
58	0.0
59	0.0
60	0.0
61	0.0
62	0.0
63	0.0
64	0.0
65	0.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
84	0.0
85	0.0
86	0.0
87	0.0
88	0.0

```
   89    0.0
   90    0.0
   91    0.0
   92    0.0
   93    0.0
   94    0.0
   95    0.0
   96    0.0
   97    0.0
   98    0.0
   99    0.0
  100    0.0
  101    0.0
  102    0.0
  103    0.0
  104    0.0
  105    0.0
  106    0.0
  107    0.0
  108    0.0
  109    0.0
  110    0.0
  111    0.0
  112    0.0
  113    0.0
  114    0.0
  115    0.0
  116    0.0
  117    0.0
  118    0.0
  119    0.0
  120    0.0
  121    0.0
#   nld   scf   relz
     4    1.0    0.
#   NLE
    29     30    31    32
#   TLE        RLE(Tc99)
         0.00000E+00      0.3102767
         50.0             0.3102767
   -1.0      0.0
```



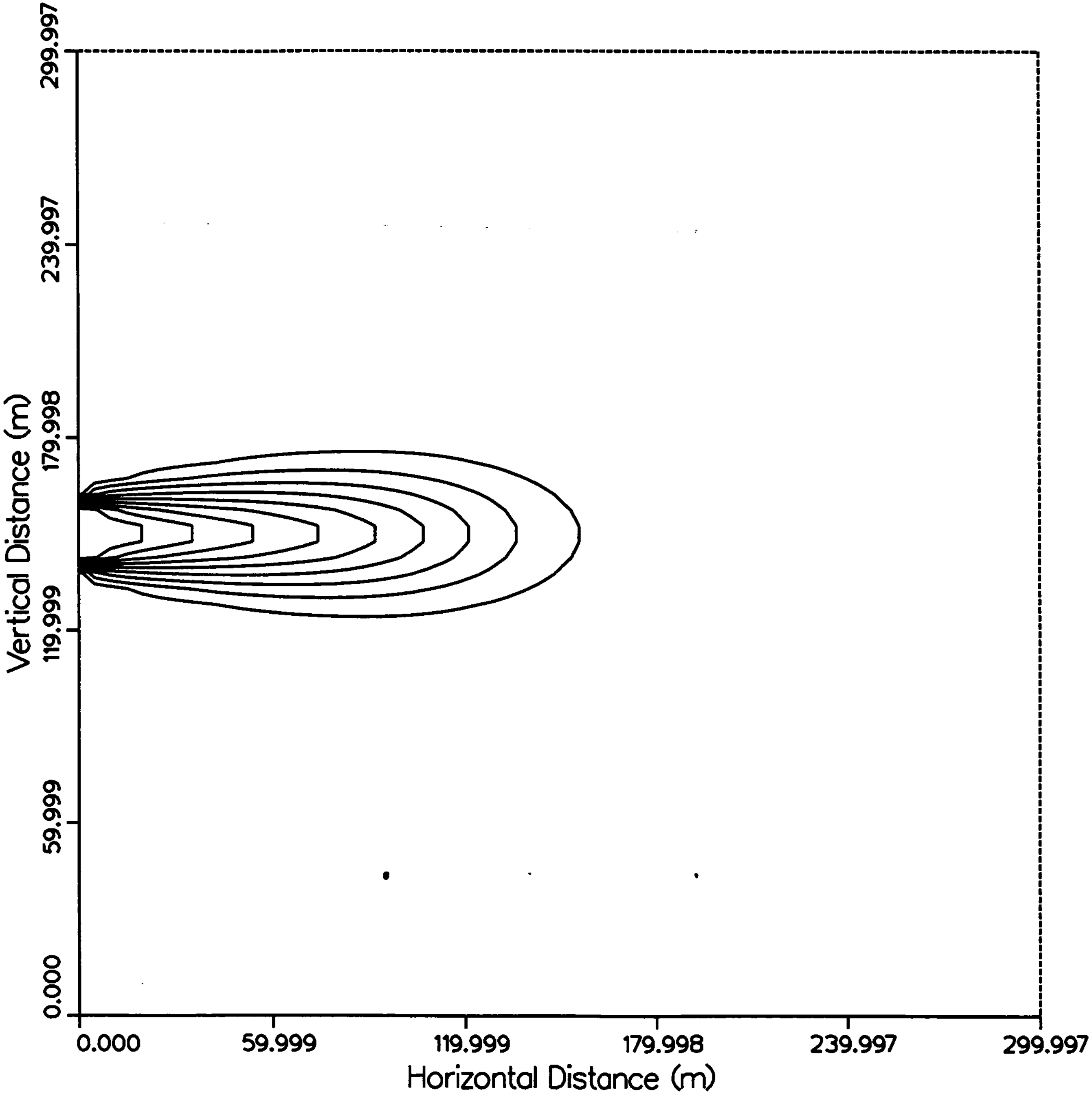
CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(801961722)
Vertical Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Time = 5.00



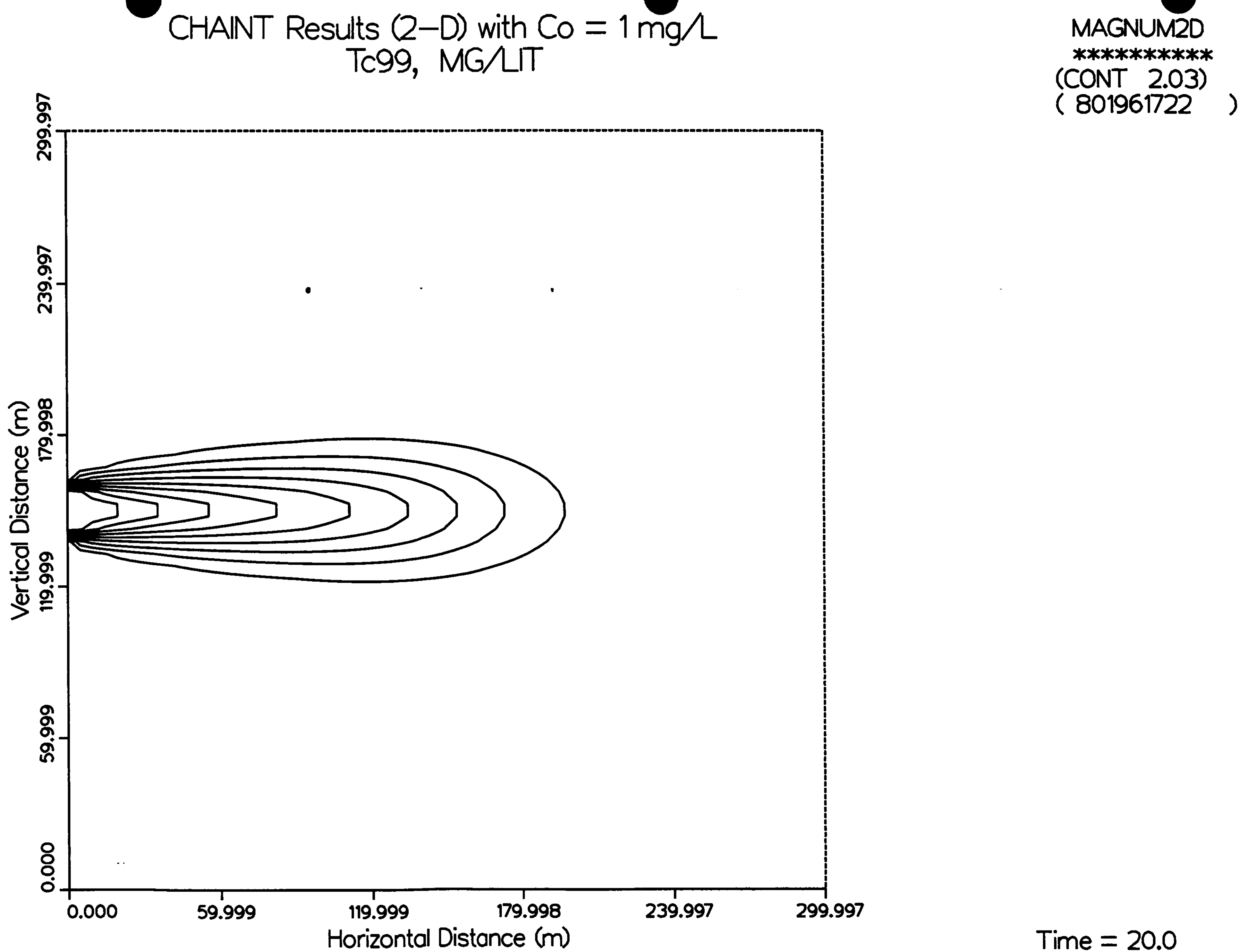
CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(801961722)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 10.0

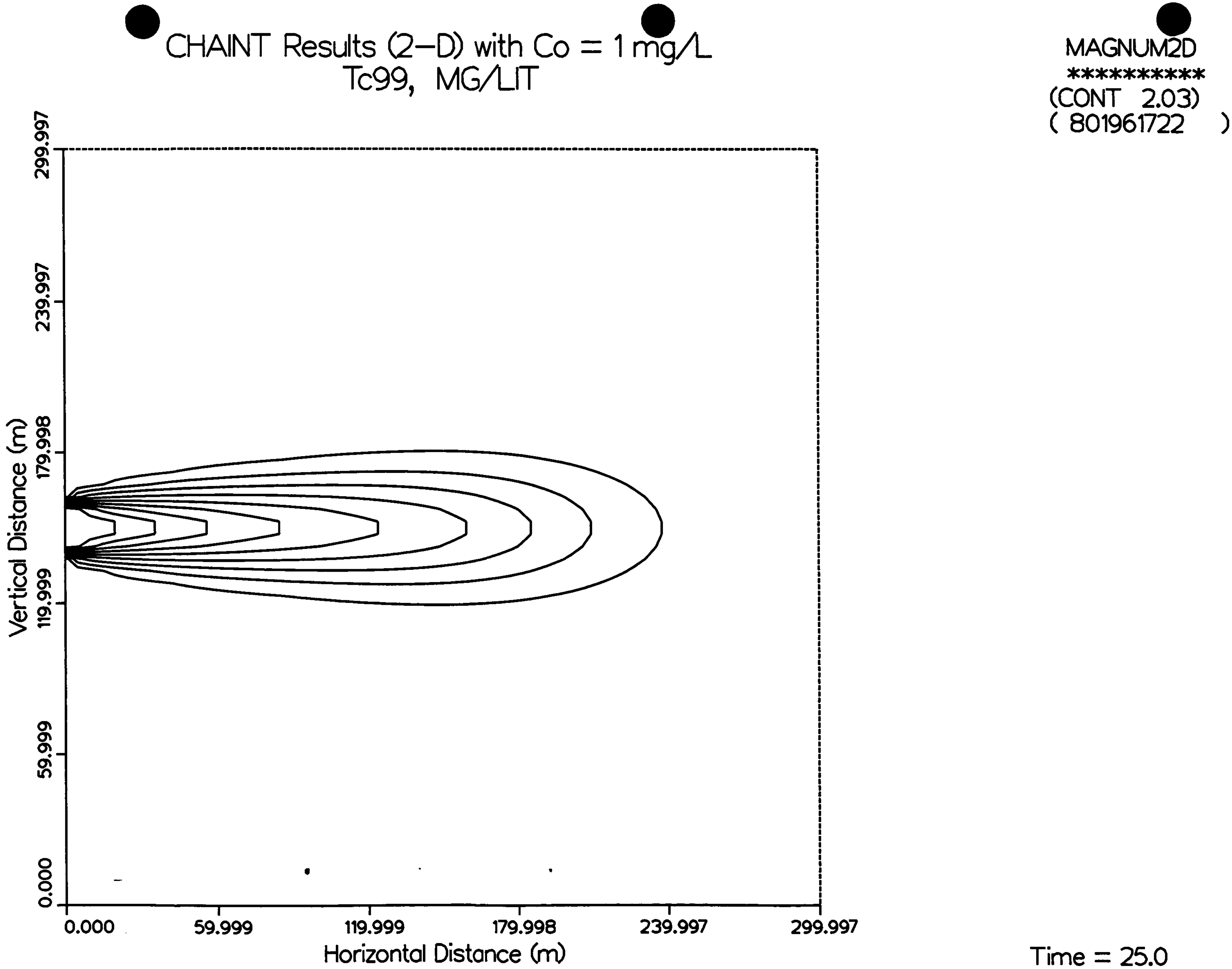
CHAINT Results (2–D) with Co = 1 mg/L
Tc99, MG/LIT

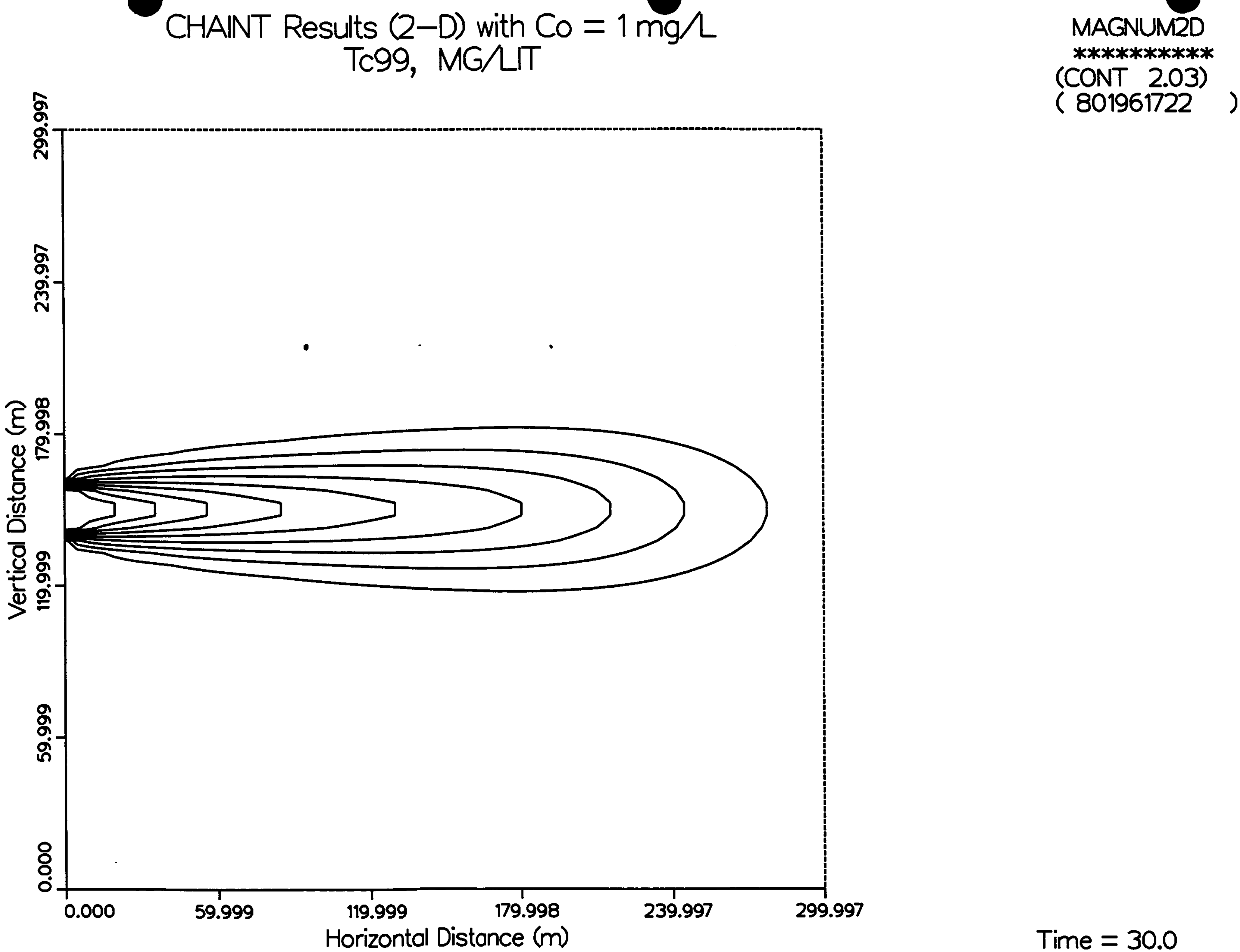
MAGNUM2D
****
(CONT 2.03)
(801961722)



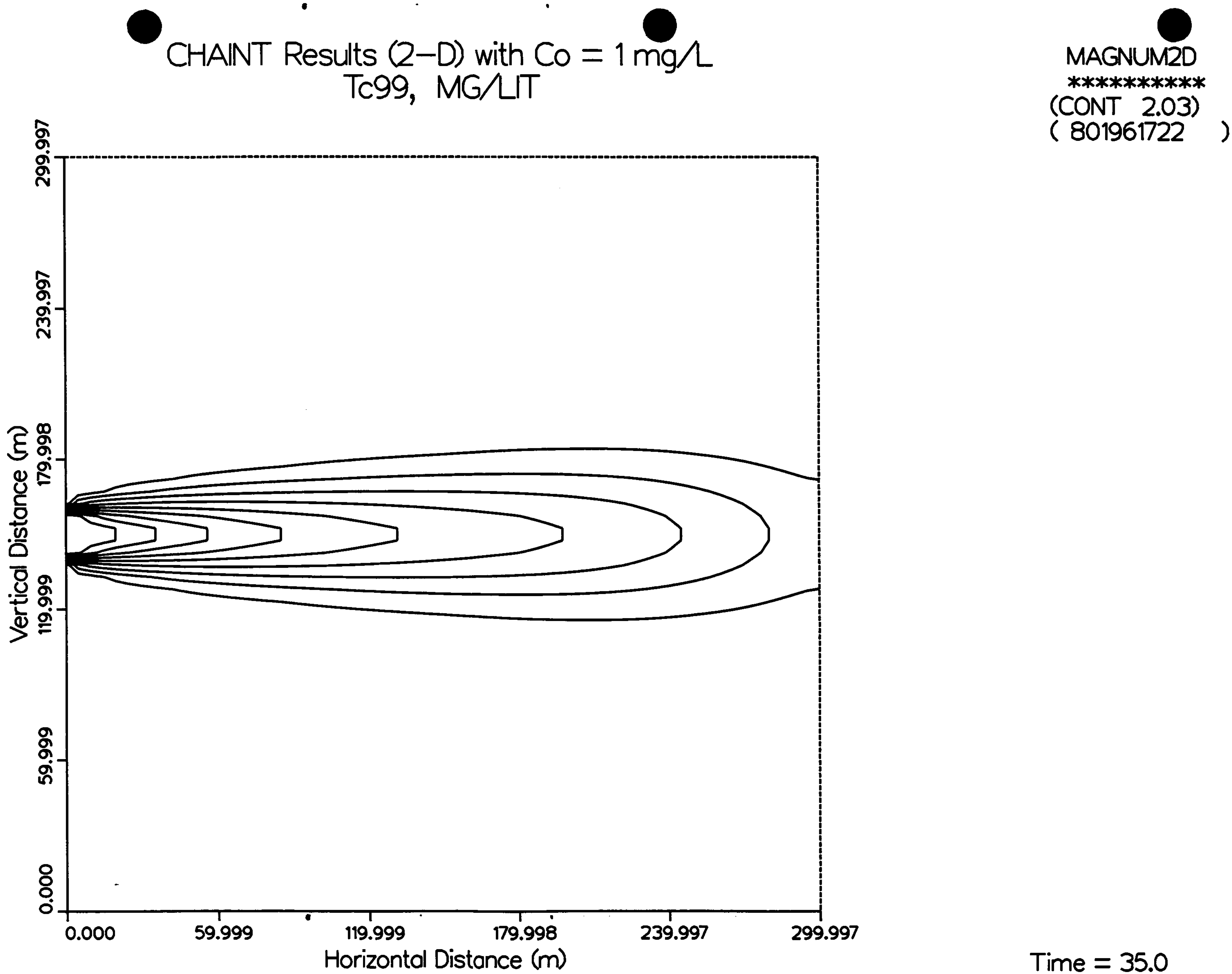
Time = 15.0


CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(801961722)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 20.0


CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(801961722)
299.997
239.997
179.998
119.999
59.999
0.000
Vertical Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 25.0



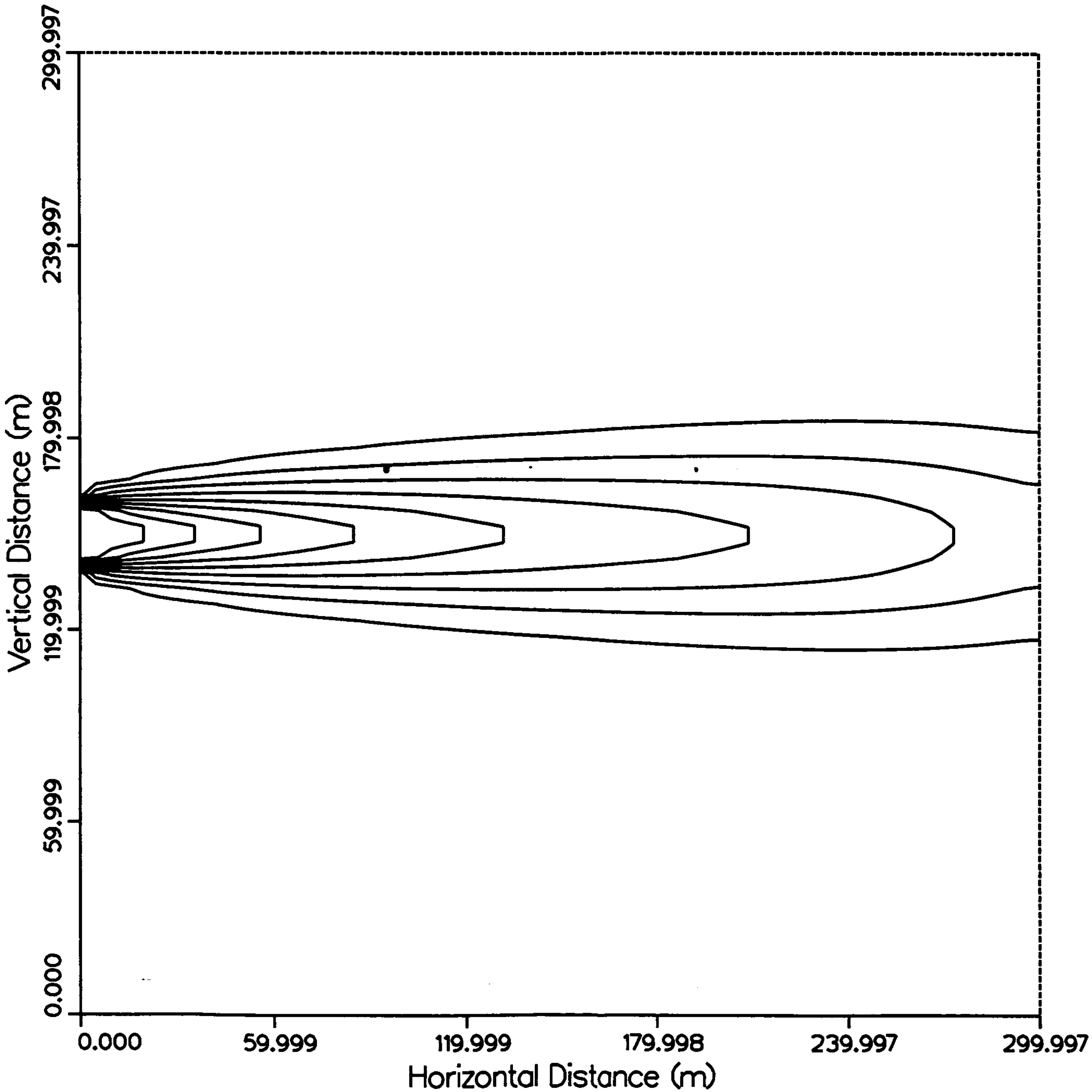
CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(801961722)
299.997
239.997
179.998
119.999
59.999
0.000
Vertical Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 30.0



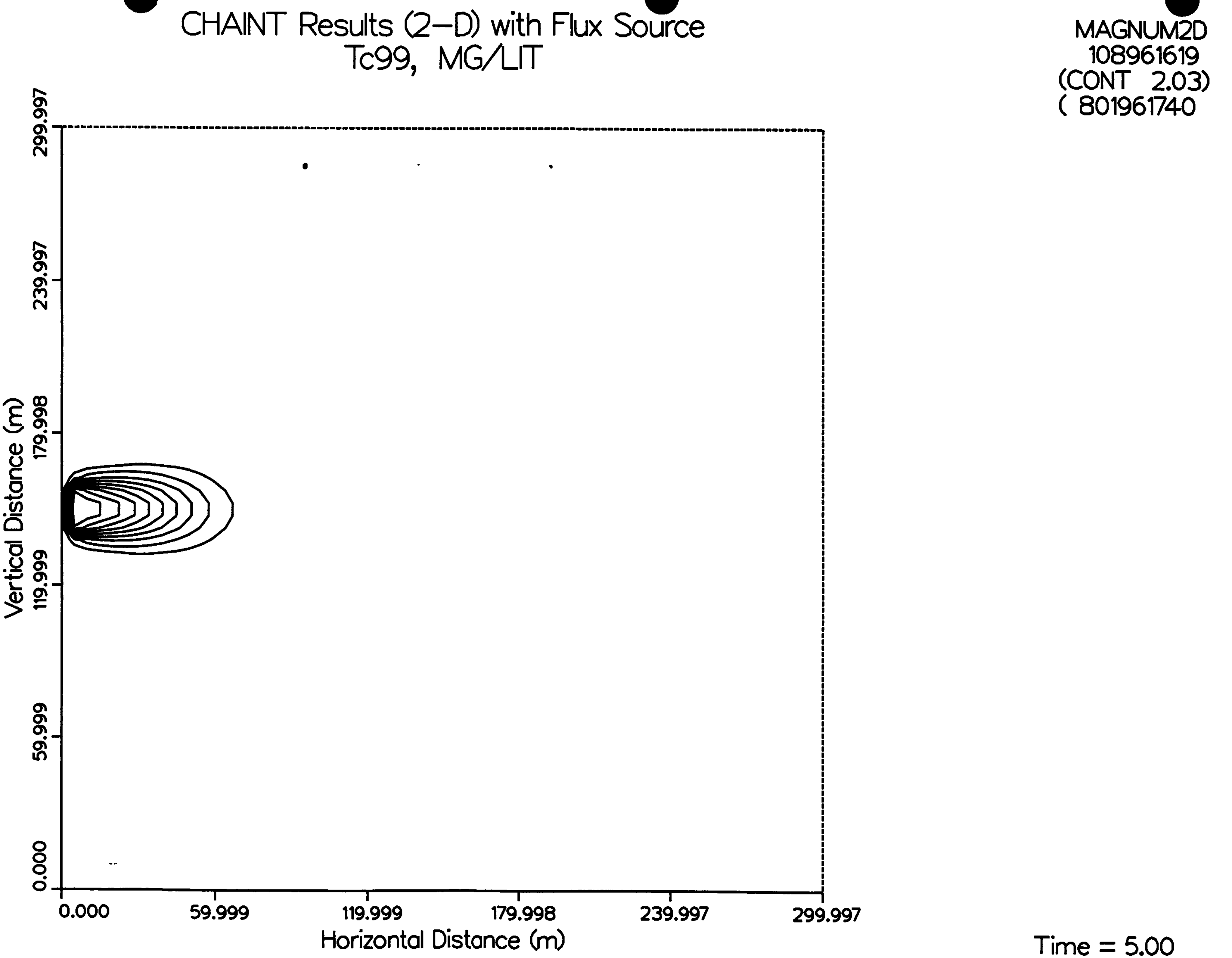
CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(801961722)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 35.0

CHAINT Results (2-D) with Co = 1 mg/L
Tc99, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(801961722)



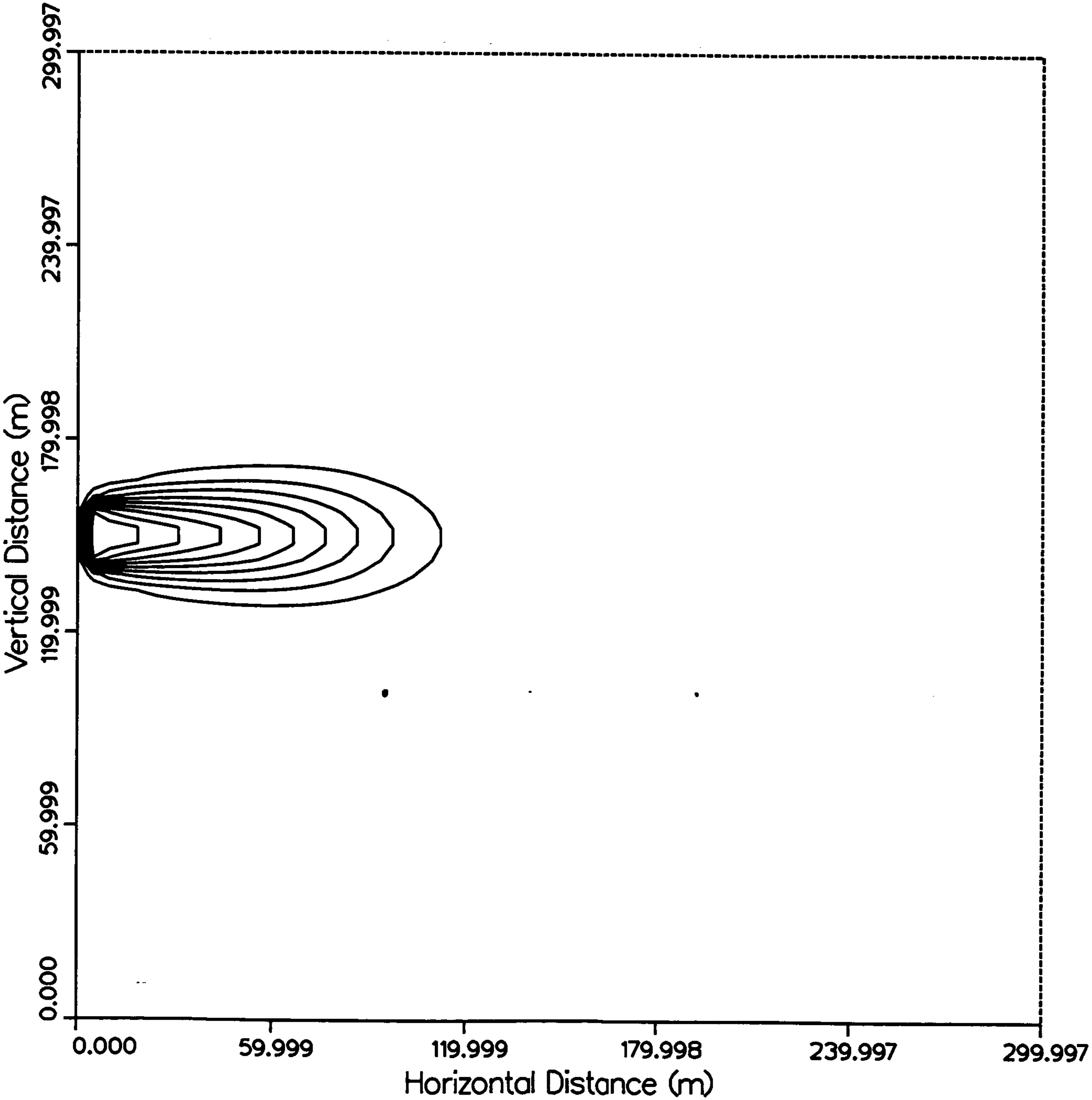
Time = 40.0



CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(801961740)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 5.00

CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT

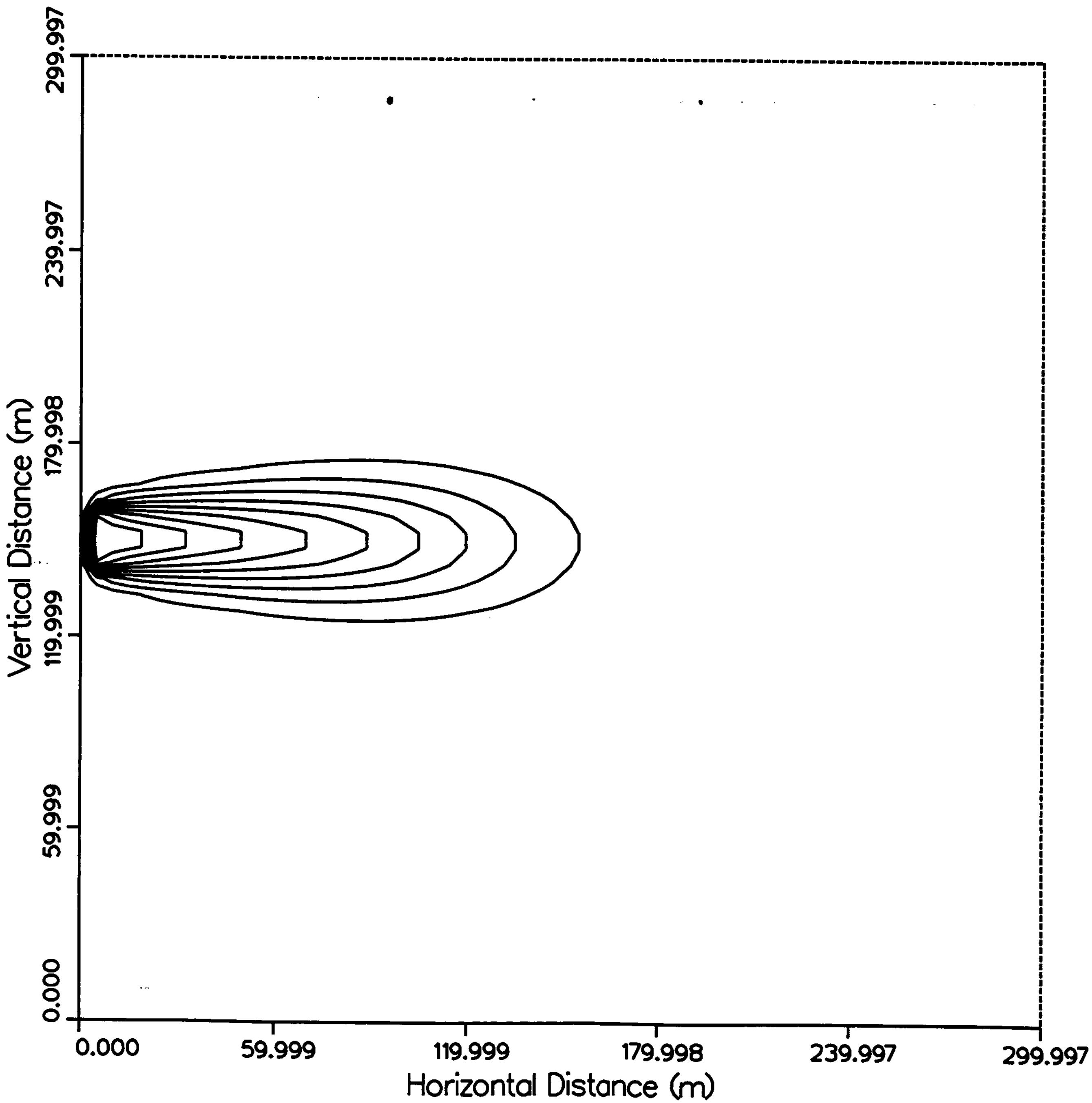
MAGNUM2D
108961619
(CONT 2.03)
(801961740)



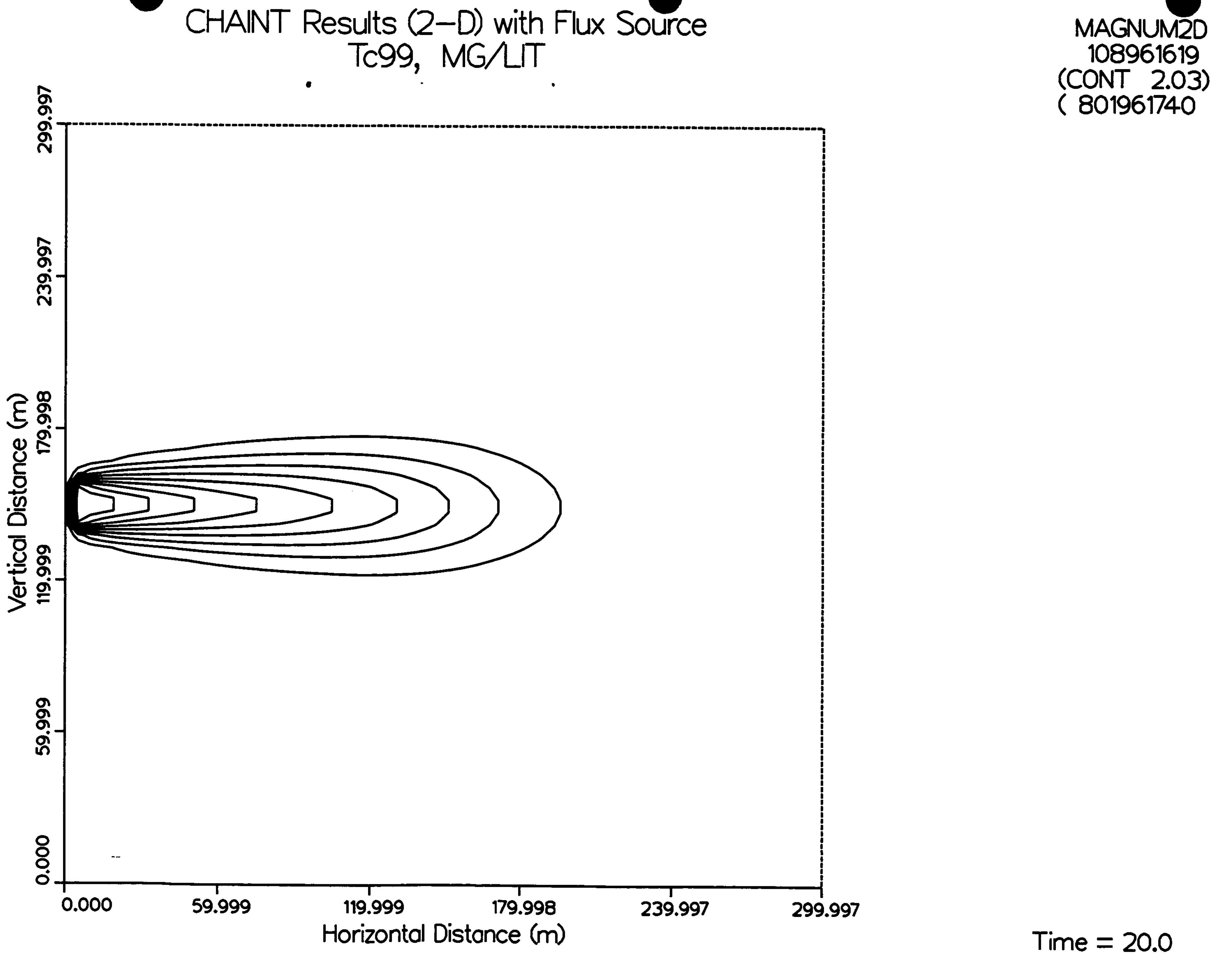
Time = 10.0

CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT

MAGNUM2D
108961619
(CONT 2.03)
(801961740)

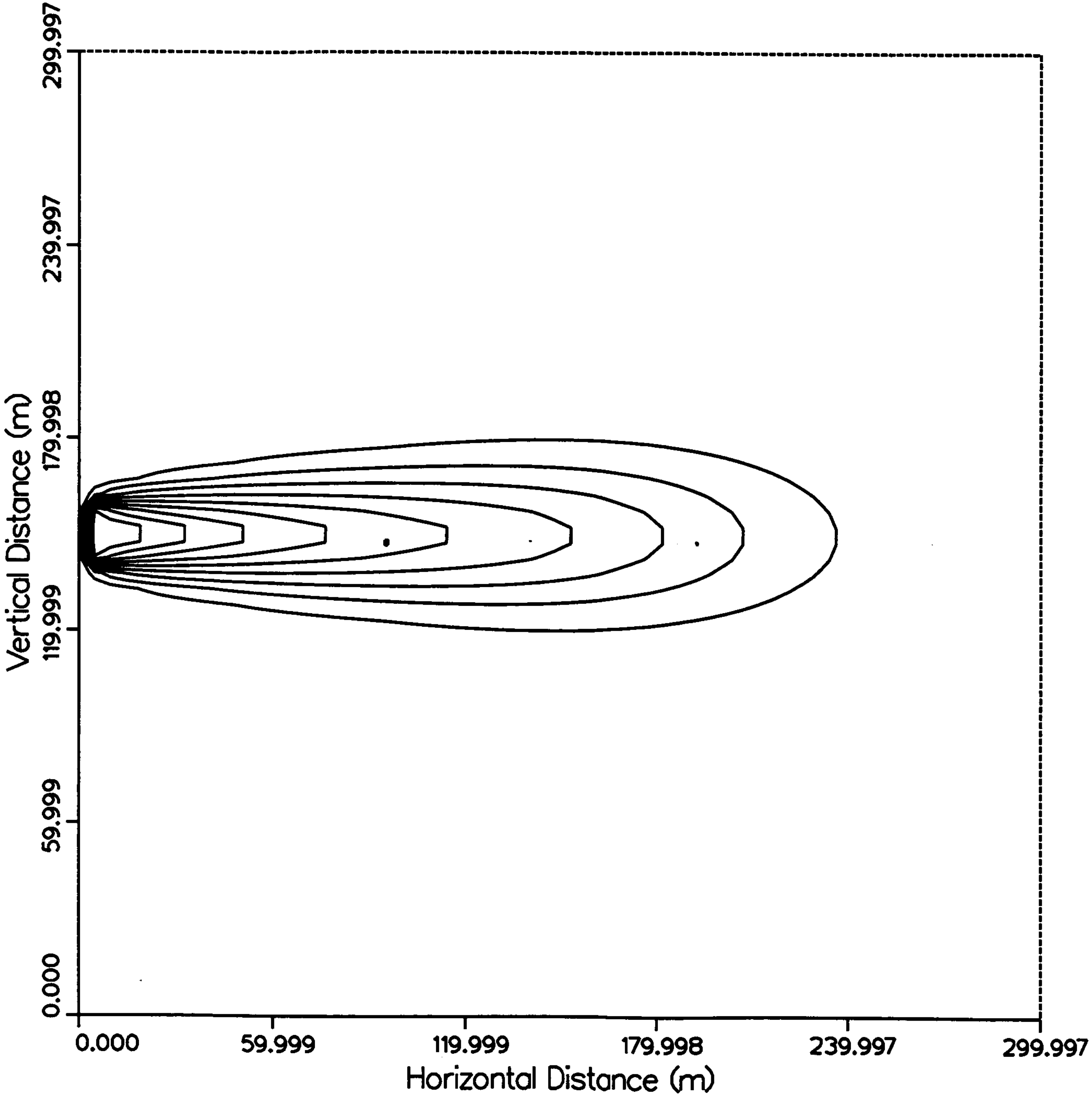


Time = 15.0

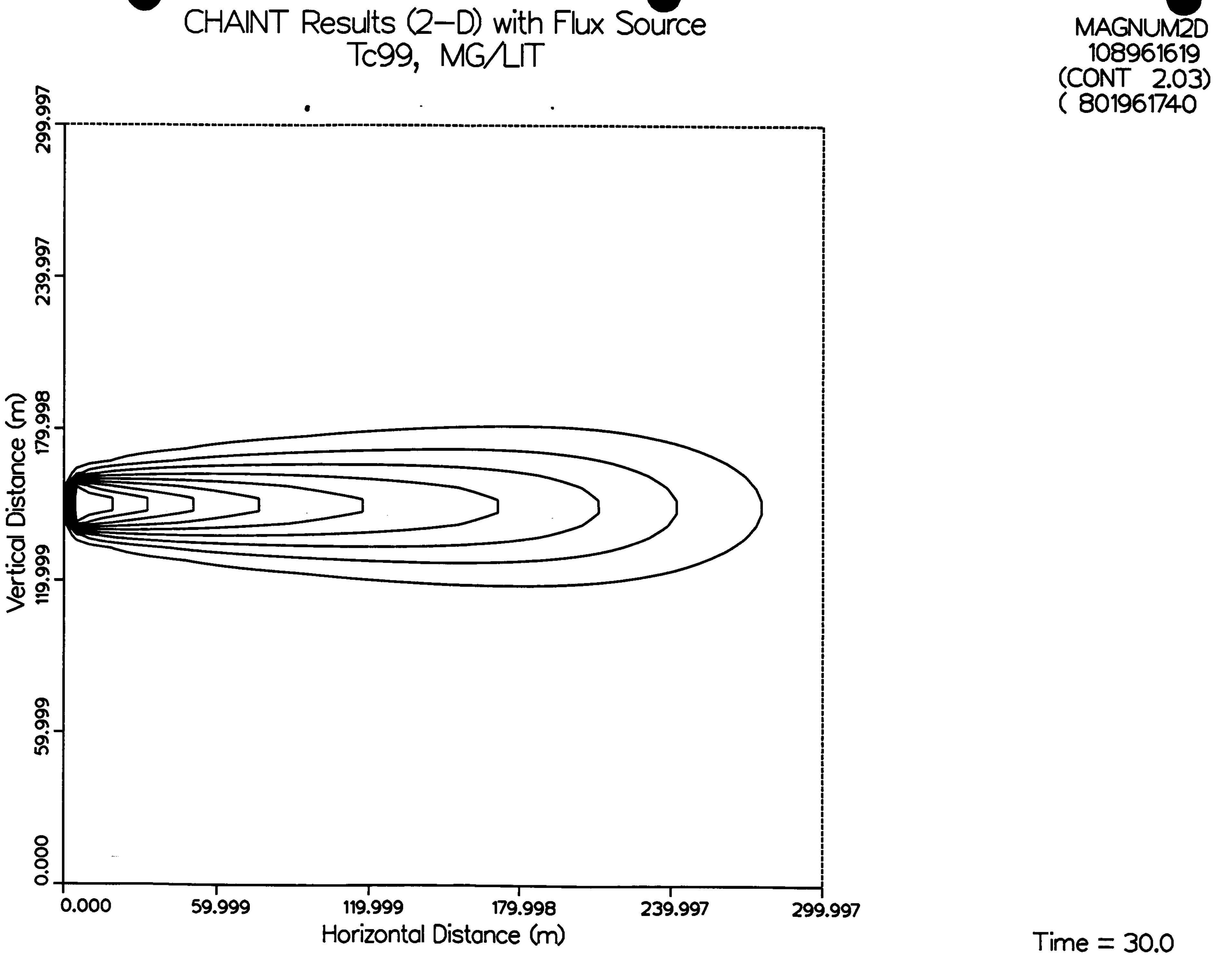

CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(801961740)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
Horizontal Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Time = 20.0

CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT

MAGNUM2D
108961619
(CONT 2.03)
(801961740)

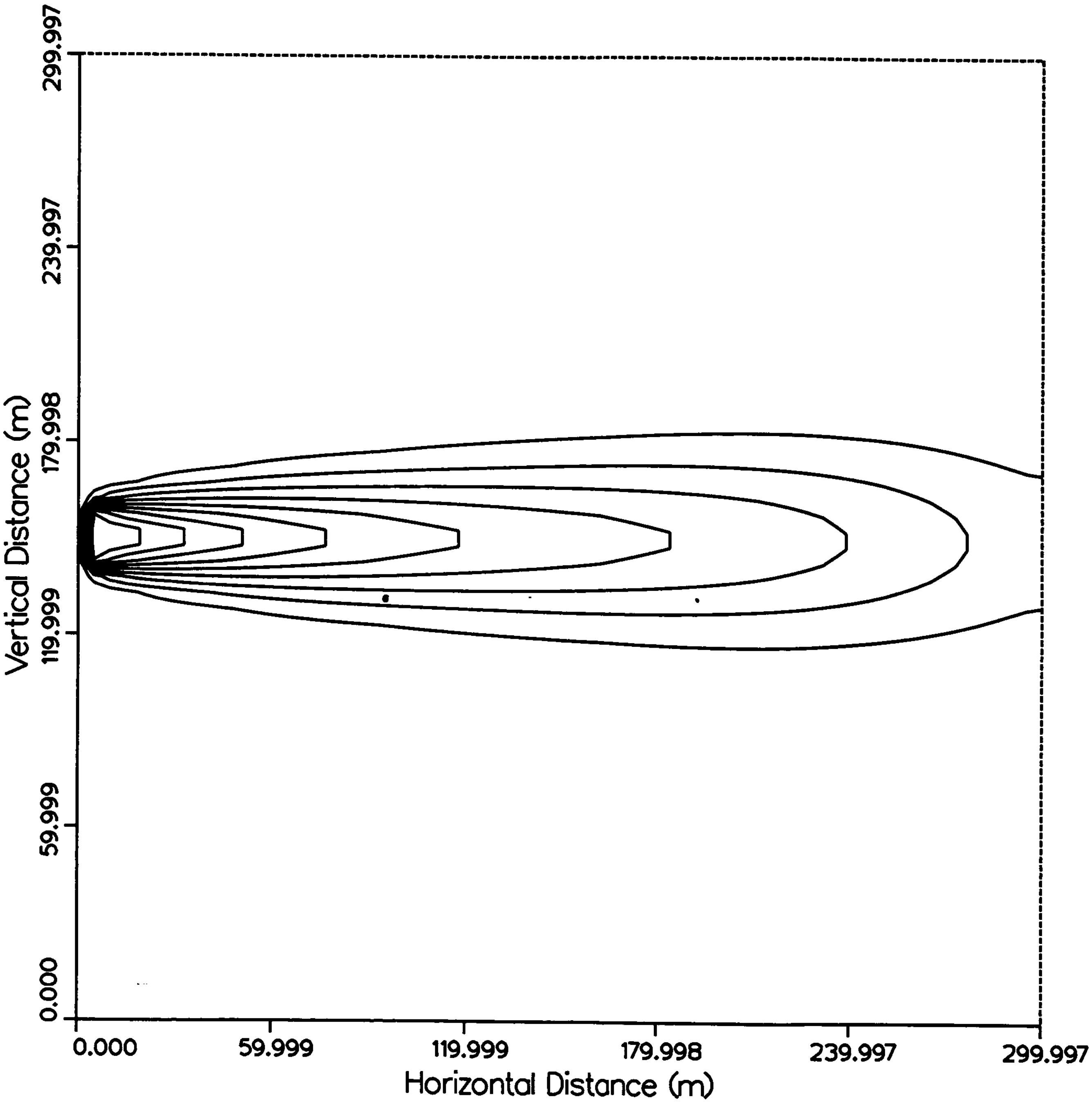


Time = 25.0


CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(801961740)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 30.0

CHAINT Results (2-D) with Flux Source
Tc99, MG/LIT

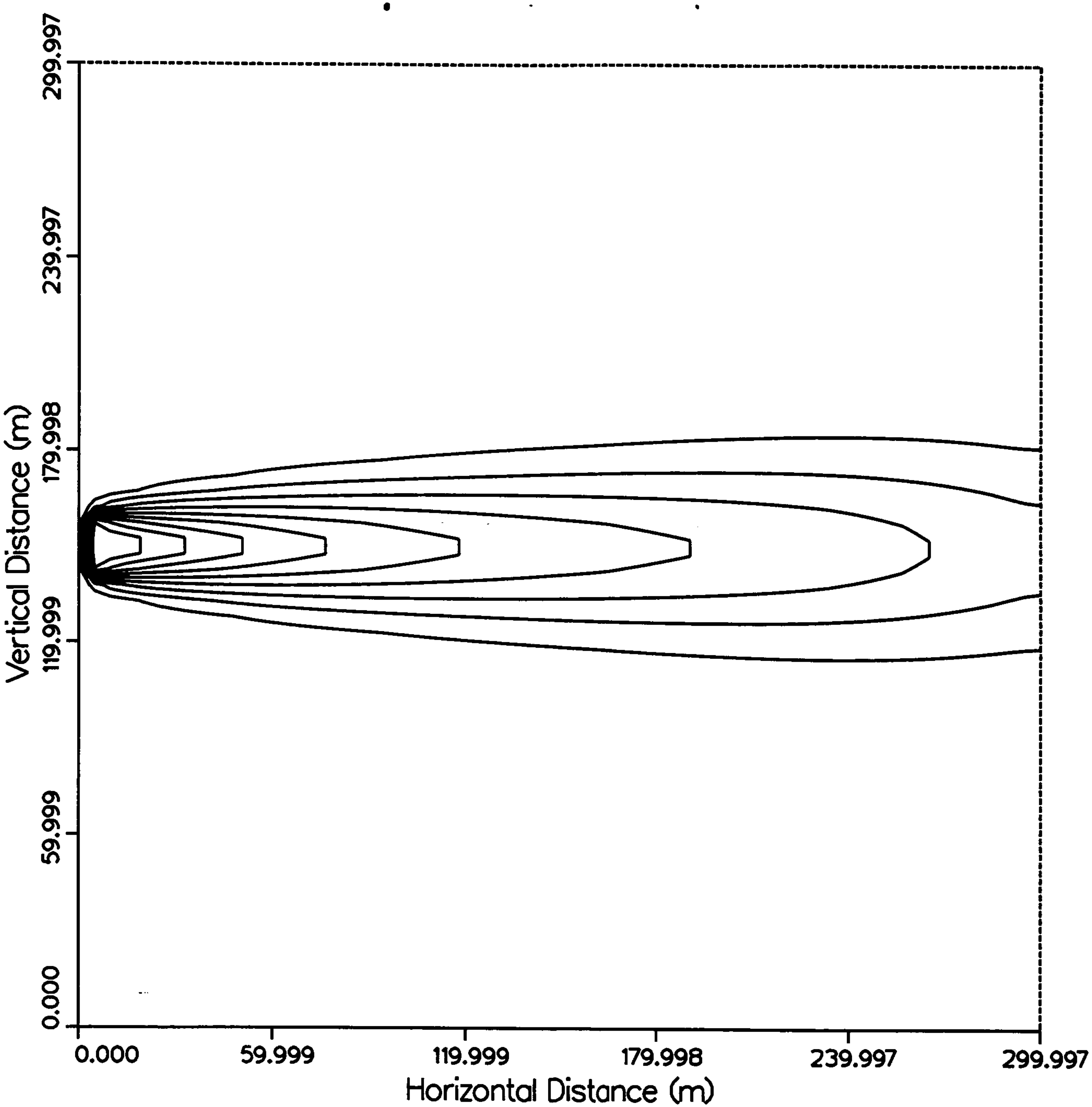
MAGNUM2D
108961619
(CONT 2.03)
(801961740)



Time = 35.0

CHAINT Results (2–D) with Flux Source
Tc99, MG/LIT

MAGNUM2D
108961619
(CONT 2.03)
(801961740)



Time = 40.0

```
C
C      ********************************************************
C      *                                                      *
C      *                    **** STRIPF ****                  *
C      *                                                      *
C      * TWO-DIMENSIONAL GROUND-WATER SOLUTE TRANSPORT MODEL  *
C      *                                                      *
C      *   FOR A SEMI-INFINITE AQUIFER WITH A FINITE WIDTH    *
C      *                                                      *
C      *     A STRIP SOURCE EXTENDS FROM Y1 TO Y2 AT X=0      *
C      *                                                      *
C      *        GROUND-WATER FLOW IN X-DIRECTION ONLY         *
C      *                                                      *
C      *            VERSION CURRENT AS OF 04/01/90            *
C      *                                                      *
C      ********************************************************
C
C
C      Although this program has been used by the U.S. Geological
C      Survey, no warranty, expressed or implied, is made by the USGS
C      as to the accuracy and functioning of the program and related
C      program material, nor shall the fact of distribution constitute
C      any such warranty, and no responsibility is assumed by the USGS
C      in connection therewith.
C
C
C       THE FOLLOWING LINE MUST BE CHANGED IF PROBLEM DIMENSIONS ARE
C       GREATER THAN THOSE GIVEN HERE.
C         MAXX = MAXIMUM NUMBER OF X-VALUES
C         MAXY = MAXIMUM NUMBER OF Y-VALUES
C         MAXT = MAXIMUM NUMBER OF TIME VALUES
C         MAXXY = MAXX * MAXY
C         MAXXY2 = 2 * MAXX * MAXY
      PARAMETER (MAXX=100,MAXY=50,MAXT=20,MAXXY=5000,MAXXY2=10000)
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      CHARACTER*1 IERR(MAXX,MAXY)
      REAL XP,YP,CP,TP,DELTA,XPC,YPC,XSCLP,YSCLP
      DIMENSION CXY(MAXX,MAXY),X(MAXX),Y(MAXY),T(MAXT)
      COMMON /PDAT/ XP(MAXX),YP(MAXY),CP(MAXXY),XPC(50),YPC(50),
     1 IFLAG(MAXXY2)
      COMMON /IOUNIT/ IN,IO
C
C     PROGRAM VARIABLES
C
C           NOTE:  ANY CONSISTANT SET OF UNITS MAY BE USED IN THE
C           MODEL.  NO FORMAT STATEMENTS NEED TO BE CHANGED AS
C           LABELS FOR ALL VARIABLES ARE SPECIFIED IN MODEL INPUT.
C
C     CO        SOLUTE CONCENTRATION AT THE INFLOW BOUNDARY [M/L**3]
C     DX        LONGITUDINAL DISPERSION COEFFICIENT [L**2/T]
C     DY        TRANSVERSE DISPERSION COEFFICIENT [L**2/T]
C     VX        GROUND-WATER VELOCITY IN X-DIRECTION [L/T]
C     DK        FIRST-ORDER SOLUTE DECAY CONSTANT [1/T]
C     X         X-POSITION AT WHICH CONCENTRATION IS EVALUATED [L]
C     Y         Y-POSITION AT WHICH CONCENTRATION IS EVALUATED [L]
C     T         TIME AT WHICH CONCENTRATION IS EVALUATED [T]
C     CN        NORMALIZED CONCENTRATION C/CO [DIMENSIONLESS]
C     CXY       SOLUTE CONCENTRATION C(X,Y,T) [M/L**3]
```

```
C     W        AQUIFER WIDTH (AQUIFER EXTENDS FROM Y=0 TO Y=W) [L]
C     Y1       Y-COORDINATE OF LOWER LIMIT OF STRIP SOLUTE SOURCE [L]
C     Y2       Y-COORDINATE OF UPPER LIMIT OF STRIP SOLUTE SOURCE [L]
C
C     NX       NUMBER OF X-POSITIONS AT WHICH SOLUTION IS EVALUATED
C     NY       NUMBER OF Y-POSITIONS AT WHICH SOLUTION IS EVALUATED
C     NT       NUMBER OF TIME VALUES AT WHICH SOLUTION IS EVALUATED
C     NMAX     NUMBER OF TERMS USED IN INFINITE SERIES SUMMATION
C
C     IPLT     PLOT CONTROL. IF IPLT>0, CONTOUR MAPS ARE PLOTTED
C     XSCLP    SCALING FACTOR TO CONVERT X TO PLOTTER INCHES
C     YSCLP    SCALING FACTOR TO CONVERT Y TO PLOTTER INCHES
C     DELTA    CONTOUR INCREMENT FOR PLOT. (VALUE BETWEEN 0 AND 1.0)
C
C       CHARACTER VARIABLES USED TO SPECIFY UNITS FOR MODEL PARAMETERS
C     CUNITS   UNITS OF CONCENTRATION (M/L**3)
C     VUNITS   UNITS OF GROUND-WATER VELOCITY (L/T)
C     DUNITS   UNITS OF DISPERSION COEFFICIENT (L**2/T)
C     KUNITS   UNITS OF SOLUTE DECAY CONSTANT  (1/T)
C     LUNITS   UNITS OF LENGTH (L)
C     TUNITS   UNITS OF TIME (T)
C
C       DEFINE INPUT/OUTPUT FILES AND PRINT TITLE PAGE
      CALL OFILE
      CALL TITLE
      WRITE(IO,201)
C
C       READ IN MODEL PARAMETERS
      READ(IN,101) NX,NY,NT,NMAX,IPLT
      WRITE(IO,205) NX,NY,NT,NMAX
      READ(IN,105) CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      READ(IN,110) CO,VX,DX,DY,DK
      WRITE(IO,210) CO,CUNITS,VX,VUNITS,DX,DUNITS,DY,DUNITS,DK,KUNITS
      READ(IN,110) W,Y1,Y2
      WRITE(IO,212) W,LUNITS,Y1,LUNITS,Y2,LUNITS
      READ(IN,110) (X(I),I=1,NX)
      WRITE(IO,215) LUNITS
      WRITE(IO,220) (X(I),I=1,NX)
      READ(IN,110) (Y(I),I=1,NY)
      WRITE(IO,216) LUNITS
      WRITE(IO,220) (Y(I),I=1,NY)
      READ(IN,110) (T(I),I=1,NT)
      WRITE(IO,225) TUNITS
      WRITE(IO,220) (T(I),I=1,NT)
      IF(IPLT.GT.0) READ(IN,110) XSCLP,YSCLP,DELTA
      IF(IPLT.GT.0) WRITE(IO,227) XSCLP,YSCLP,DELTA,CUNITS
C
C       BEGIN TIME LOOP
      DO 20 IT=1,NT
C
C       BEGIN X LOOP
      DO 40 IX=1,NX
C
C     CALCULATE NORMALIZED CONCENTRATION FOR ALL Y AT X=X(IX)
      DO 50 IY=1,NY
      CALL CNRMLF(DK,T(IT),X(IX),Y(IY),W,Y1,Y2,DX,DY,
     1 VX,CN,NMAX,IERR(IX,IY))
      CXY(IX,IY)=CO*CN
50    CONTINUE
40    CONTINUE
```

```
C
C        PRINT OUT TABLES OF CONCENTRATION VALUES
      NPAGE=1+(NY-1)/9
      DO 60 NP=1,NPAGE
      IF(NP.EQ.1) WRITE(IO,230) T(IT),TUNITS,LUNITS
      IF(NP.NE.1) WRITE(IO,231) T(IT),TUNITS,LUNITS
      NP1=(NP-1)*9
      NP2=9
      IF((NP1+NP2).GT.NY) NP2=NY-NP1
      WRITE(IO,235) (Y(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
      DO 70 IX=1,NX
      WRITE(IO,240) X(IX),(CXY(IX,NP1+J),IERR(IX,NP1+J),J=1,NP2)
      IF(MOD(IX,45).NE.0) GO TO 70
      WRITE(IO,231) T(IT),TUNITS,LUNITS
      WRITE(IO,235) (Y(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
70    IF(MOD(IX,5).EQ.0 .AND. MOD(IX,45).NE.0) WRITE(IO,241)
60    CONTINUE
C
C        CONVERT X AND Y TO SINGLE PRECISION AND DIVIDE BY THE
C        PLOT SCALING FACTORS. CONVERT C(X,Y) AND DIVIDE BY CO TO PLOT
C        CONTOUR MAPS OF NORMALIZED CONCENTRATION FOR EACH TIME VALUE.
      IF(IPLT.LT.1) GO TO 20
      NXY=NX*NY
      DO 80 I=1,NX
      IP=(I-1)*NY
      XP(I)=SNGL(X(I))
      DO 80 J=1,NY
      IF(I.EQ.1) YP(J)=SNGL(Y(J))
      CP(IP+J)=SNGL(CXY(I,J)/CO)
80    CONTINUE
      TP=SNGL(T(IT))
      NXY2=NXY*2
C     CALL PLOT2D (XP,YP,CP,TP,DELTA,NX,NY,NXY,NXY2,IT,NT,IPLT,TUNITS,
C    1 LUNITS,XSCLP,YSCLP,XPC,YPC,IFLAG)
      DO 95 IX = 1,NX
      DO 90 IY = 1,NY
       WRITE(IO,250) x(IX),Y(IY),CXY(IX,IY)
90    CONTINUE
95    CONTINUE
20    CONTINUE
      CLOSE (IN)
      CLOSE (IO)
      STOP
C
C        FORMAT STATEMENTS
101   FORMAT(20I4)
105   FORMAT(8A10)
110   FORMAT(8F10.0)
201   FORMAT(/////1H ,30X,'ANALYTICAL SOLUTION TO THE TWO-DIMENSIONAL'/
     1 1H ,28X,'ADVECTIVE-DISPERSIVE SOLUTE TRANSPORT EQUATION'/
     2 1H ,30X,'FOR A SEMI-INFINITE AQUIFER OF FINITE WIDTH'/
     3 1H ,26X,'WITH A FINITE-WIDTH (STRIP) SOLUTE SOURCE AT X=0.0'
     4 ///1H0,40X,'INPUT DATA'/1H ,40X,10(1H-))
205   FORMAT(1H0,25X,'NUMBER OF X-COORDINATES (NX) = ',I4/1H ,25X,
     1 'NUMBER OF Y-COORDINATES (NY) = ',I4/1H ,25X,
     2 'NUMBER OF TIME VALUES (NT) = ',I4/1H ,25X,
     3 'NUMBER OF TERMS IN INFINTE SERIES SUMMATION (NMAX) = ',I4)
210   FORMAT(1H0,25X,'SOLUTE CONCENTRATION ON MODEL BOUNDARY (CO) =',
```

```
     1 1P1E13.6,1X,A10/1H ,25X,
     2 'GROUND-WATER VELOCITY IN X-DIRECTION (VX) =',1P1E13.6,1X,A10/
     3 1H ,25X,'DISPERSION IN THE X-DIRECTION (DX) =',1P1E13.6,1X,A10/
     4 1H ,25X,'DISPERSION IN THE Y-DIRECTION (DY) =',1P1E13.6,1X,A10/
     5 1H ,25X,'FIRST-ORDER SOLUTE DECAY RATE (DK) =',1P1E13.6,1X,A10)
      FORMAT(1H0,25X,'AQUIFER WIDTH (W) =',1P1E13.6,1X,A10/1H ,25X,
     1 'SOLUTE SOURCE IS LOCATED BETWEEN Y1 =',1P1E13.6,1X,A10/1H ,54X,
     2 'AND Y2 =',1P1E13.6,1X,A10)
215   FORMAT(1H0,25X,'X-COORDINATES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,78(1H-)/)
216   FORMAT(1H0,25X,'Y-COORDINATES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,78(1H-)/)
220   FORMAT(1H ,5X,8F12.4)
225   FORMAT(1H0,25X,'TIMES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,70(1H-)/)
227   FORMAT(1H0,25X,'PLOT SCALING FACTOR FOR X (XSCLP) =',1P1E13.6/
     1 1H ,25X,'PLOT SCALING FACTOR FOR Y (YSCLP) =',1P1E13.6/
     2 1H ,25X,'CONTOUR INCREMENT (DELTA) =',1P1E13.6,1X,A10)
230   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AT TIME =',
     1 F12.4,1X,A10,15X,'*  INDICATES SOLUTION DID NOT CONVERGE'/
     2 1H0,25X,'Y-COORDINATE, IN ',A10)
231   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AT TIME =',
     1 F12.4,1X,A10,5X,'(CONTINUED)'/
     2 1H0,25X,'Y-COORDINATE, IN ',A10)
235   FORMAT(1H ,20X,9F12.4)
236   FORMAT(1H ,19X,'*',108(1H-)/
     1 1H ,4X,'X-COORDINATE,',2X,'!',44X,'SOLUTE CONCENTRATION, IN ',
     2 A10/1H ,4X,'IN ',A10,2X,1H!/1H ,19X,'!')
240   FORMAT(1H ,5X,F12.4,2X,'! ',9(F11.5,A1))
241   FORMAT(1H ,19X,'!')
      FORMAT(3F12.5)
      END
      SUBROUTINE CNRMLF(DK,T,X,Y,W,Y1,Y2,DX,DY,VX,CN,NMAX,IERR)
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      CHARACTER*1 IERR
      COMMON /IOUNIT/ IN,IO
C
C       THIS ROUTINE CALCULATES THE NORMALIZED CONCENTRATION AT X,Y
C       BASED ON THE ANALYTIC SOLUTION TO THE TWO-DIMENSIONAL
C       ADVECTIVE-DISPERSIVE SOLUTE TRANSPORT EQUATION FOR A SEMI-
C       INFINITE AQUIFER WITH A FINITE WIDTH.  A FINITE-WIDTH (STRIP)
C       SOLUTE SOURCE EXTENDS FROM Y=Y1 TO Y=Y2. THE SOLUTION
C       CONTAINS AN INFINITE SERIES SUMMATION WHICH MAY TAKE A LARGE
C       NUMBER OF TERMS TO CONVERGE FOR SMALL VALUES OF X.
C
      PI=3.14159265358979D0
      CN=0.0D0
      IERR=' '
C
C       FOR T=0, ALL CONCENTRATIONS EQUAL 0.0
      IF(T.LE.0.0D0) RETURN
C
C       FOR X=0.0, CONCENTRATIONS ARE SPECIFIED BY BOUNDARY CONDITIONS
      IF(X.GT.0.0D0) GO TO 10
      IF(Y.GT.Y1 .AND. Y.LT.Y2) CN=1.0D0
      IF(Y.EQ.Y1) CN=0.5D0
      IF(Y.EQ.Y2) CN=0.5D0
      RETURN
C
C       BEGIN SUMMATION OF TERMS IN INFINITE SERIES
```

```
10    RTDXT=2.0D0*DSQRT(DX*T)
      SIGMA=0.0D0
      SUBTOT=0.0D0
      NMAX1=NMAX+1
      DO 20 NN=1,NMAX1
      N=NN-1
      ETA=N*PI/W
      PN=(Y2-Y1)/(2.0D0*W)
      IF(N.NE.0) PN=(DSIN(ETA*Y2)-DSIN(ETA*Y1))/(N*PI)
      COSRY=DCOS(ETA*Y)
      ALPHA=4.0D0*DX*(ETA*ETA*DY+DK)
      BETA=DSQRT(VX*VX+ALPHA)
      BETAT=BETA*T
C
C       CALCULATE TERM 1
      A1=X*(VX-BETA)/(2.0D0*DX)
      B1=(X-BETAT)/RTDXT
      CALL EXERFC(A1,B1,C1)
C
C       CALCULATE TERM 2
      A2=X*(VX+BETA)/(2.0D0*DX)
      B2=(X+BETAT)/RTDXT
      CALL EXERFC(A2,B2,C2)
C
C       ADD TERMS TO SUMMATION
      TERM=PN*COSRY*(C1+C2)
      SIGMA=SIGMA+TERM
C
C       CHECK FOR CONVERGENCE. BECAUSE SERIES OSCILLATES, CHECK
C       SUBTOTAL OF LAST 10 TERMS.
      SUBTOT=SUBTOT+TERM
      IF(MOD(NN,10).NE.0) GO TO 20
      IF(DABS(SUBTOT).LT.1.0D-12) GO TO 30
      SUBTOT=0.0D0
20    CONTINUE
      IERR='*'
30    CN=SIGMA
      RETURN
      END
C
C       *******************************************************
C       *                                                     *
C       *                  SUBROUTINE EXERFC                  *
C       *                                                     *
C       *            VERSION CURRENT AS OF 10/01/87           *
C       *                                                     *
C       *******************************************************
C
      SUBROUTINE EXERFC (X,YY,Z)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION P1(5),Q1(5),P2(9),Q2(9),P3(6),Q3(6)
C
C       THIS ROUTINE USES RATIONAL CHEBYSHEV APPROXIMATIONS
C       FOR EVALUATING THE ERROR FUNCTION AND COMPLEMENTARY
C       ERROR FUNCTION IN ORDER TO EVALUATE THE PRODUCT OF
C       EXP(X) AND ERFC(Y)
C
      DATA P1/3.209377589138469472562D03,3.774852376853020208137D02,
     1        1.138641541510501556495D02,3.161123743870565596947D00,
     2        1.857777061846031526730D-01/
```

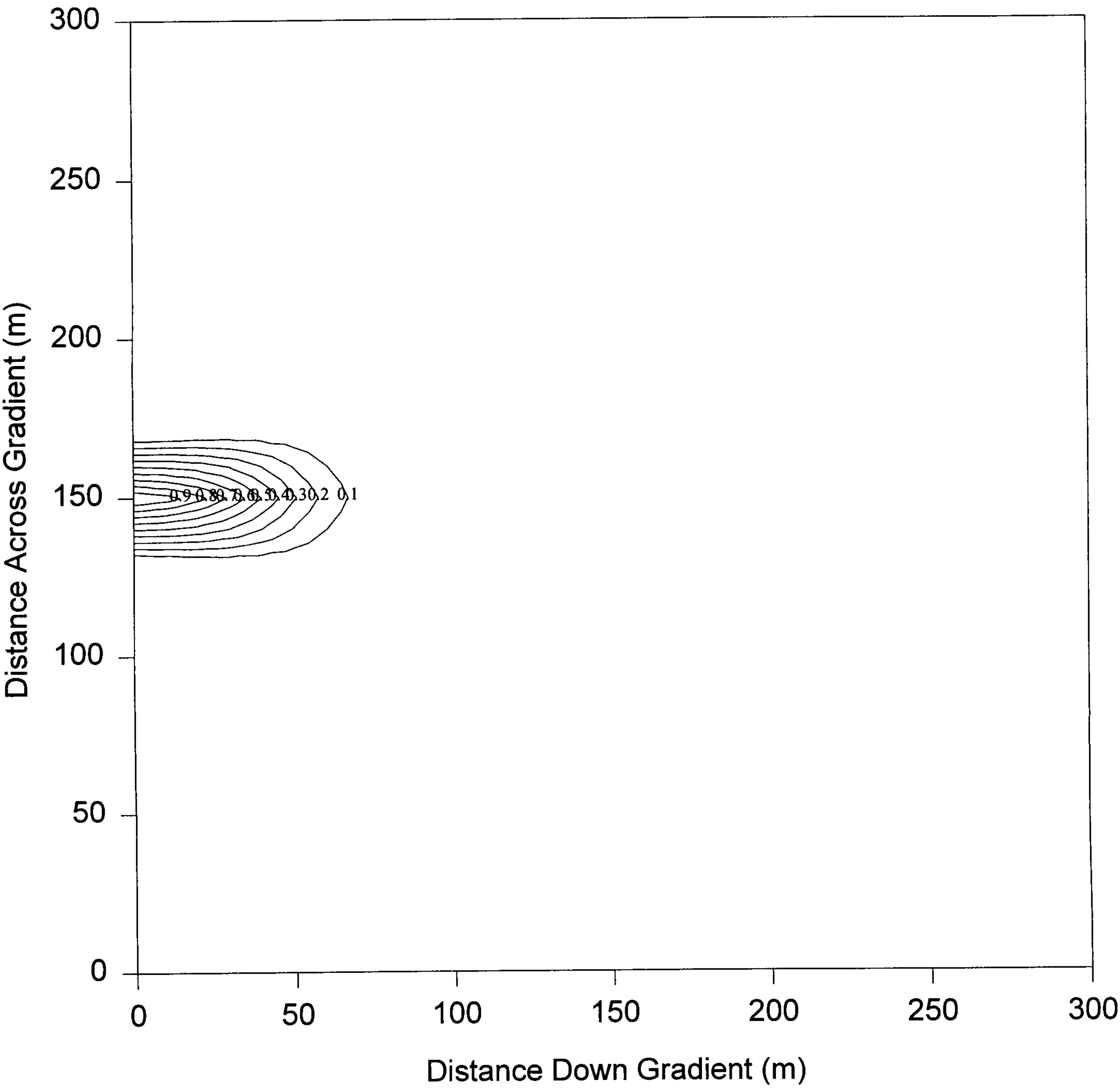
```
      DATA Q1/2.844236833439170622273D03,1.282616526077372275645D03,
     1        2.440246379344441733056D02,2.360129095234412093499D01,
     2        1.0D0 /
      DATA P2/1.230339354797997253D03,2.051078377826071465 32D03,
     1        1.712047612634070583 14D03,8.819522212417690904 11D02,
     2        2.986351381974001311 32D02,6.611919063714162947 75D01,
     3       8.883149794388375941 18D00,5.641884969886700891 80D-01,
     4       2.153115354744038463 43D-08/
      DATA Q2/1.230339354803749420 43D03,3.439367674143721636 96D03,
     1        4.362619090143247158 20D03,3.290799235733459626 78D03,
     2        1.621389574566690188 74D03,5.371811018620098575 09D02,
     3        1.176939508913124993 05D02,1.574492611070983472 53D01,
     4        1.0D0 /
      DATA P3/-6.587491615298378031 57D-04,-1.608378514874227662 78D-02,
     1        -1.257817261112292462 04D-01,-3.603448999498044394 29D-01,
     2        -3.053266349612323440 35D-01,-1.631538713730209784 98D-02/
      DATA Q3/2.335204976268691854 43D-03,6.051834131244131911 78D-02,
     1        5.279051029514284122 48D-01,1.872952849923460472 09D00,
     2        2.568520192289822420 72D00,1.0D0/
C
      IF(YY.EQ.0.0D0) Z=DEXP(X)
      IF(YY.EQ.0.0D0) RETURN
      Y=DABS(YY)
C
C        FOR 0.0 < Y < .46875
      IF (Y.GT.0.46875D0) GO TO 20
      SUMP=0.0D0
      SUMQ=0.0D0
      DO 10 I=1,5
      Y2I=Y**(2*(I-1))
      SUMP=SUMP+P1(I)*Y2I
      SUMQ=SUMQ+Q1(I)*Y2I
10    CONTINUE
      ERF=Y*SUMP/SUMQ
      IF(YY.LT.0.0) ERF=-ERF
      ERFCY=1.0D0-ERF
      Z=DEXP(X)*ERFCY
      RETURN
C
C        FOR 0.0 < Y < .46875
20    IF (Y.GT.4.0D0) GO TO 40
      SUMP=0.0D0
      SUMQ=0.0D0
      DO 30 I=1,9
      YI=Y**(I-1)
      SUMP=SUMP+P2(I)*YI
      SUMQ=SUMQ+Q2(I)*YI
30    CONTINUE
      Z=DEXP(X-Y*Y)*SUMP/SUMQ
      IF(YY.LT.0.0D0) Z=2.0D0*DEXP(X)-Z
      RETURN
40    SUMP=0.0D0
      SUMQ=0.0D0
      DO 50 I=1,6
      Y2I=Y**(-2*(I-1))
      SUMP=SUMP+P3(I)*Y2I
      SUMQ=SUMQ+Q3(I)*Y2I
50    CONTINUE
      SQRTPI=0.5641895835477562869481D0
      Z=SQRTPI+SUMP/(Y*Y*SUMQ)
```

```
      Z=DEXP(X-Y*Y)*Z/Y
      IF(YY.LT.0.0D0) Z=2.0D0*DEXP(X)-Z
      RETURN
      END
C       ******************************************************
C       *                                                    *
C       *                 SUBROUTINE TITLE                   *
C       *                                                    *
C       *          VERSION CURRENT AS OF 10/01/87            *
C       *                                                    *
C       ******************************************************
C
      SUBROUTINE TITLE
      CHARACTER*1 LINE1(60),EQUAL,BLANK
      CHARACTER*60 LINE
      CHARACTER*61 TITL1,T1
      COMMON /IOUNIT/ IN,IO
      COMMON /TITLES/ TITL1(4)
      DATA EQUAL/'='/,BLANK/' '/
      DATA TITL1/4*'
     1         '/
C
C        THIS ROUTINE CREATES A TITLE BOX ON THE FIRST PAGE OF
C        PROGRAM OUTPUT. THE ROUTINE READS AND PRINTS ALL DATA
C        CARDS UNTIL IT ENCOUNTERS AN '=' IN COLUMN 1. THE FIRST 4
C        LINES READ IN ARE ALSO USED AS TITLES ON PLOTS.
C
C     CALL JOBLOC (DUM,DUM,DUM,DUM,USRN)
C     USRNAM = USRN
C
      WRITE(IO,201)
      DO 10 L=1,60
      READ(IN,101,END=20) LINE
      IF (LINE(1:1).EQ.EQUAL) GOTO 60
      T1=LINE
C       STRIP OFF TRAILING BLANKS AND CENTER LINE
      DO 15 N=1,60
      NN=61-N
15    IF(LINE(NN:NN).NE.BLANK) GOTO 20
20    NN1=NN+1
      T1(NN1:NN1)='$'
      IF(L.LT.5) TITL1(L)=T1
      NS=(60-NN)/2
      IF(NS.EQ.0) GO TO 35
      DO 30 I=1,60
30    LINE1(I)=BLANK
35    NS1=NS+1
      DO 40 I=1,NN
40    LINE1(NS+I)=LINE(I:I)
10    WRITE(IO,202) (LINE1(I),I=1,60)
60    WRITE(IO,203)
      RETURN
C
C       FORMAT STATEMENTS
101   FORMAT (A60)
201   FORMAT(1H1//////////1H ,16X,68(1H*))
202   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,3X,60A1,3X,1H*)
203   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,19X,'PROGRAM AS OF  ',
     1'31 JULY 1996',20X,1H*/1H ,16X,1H*,66X,1H*/1H ,16X,68(1H*)
     2 /1H1)
```

```
      END
C
C       ********************************************************
C      *                                                        *
C      *                  SUBROUTINE OFILE                      *
C      *                                                        *
C      *          VERSION CURRENT AS OF 10/01/87                *
C      *                                                        *
C       ********************************************************
C
      SUBROUTINE OFILE
      CHARACTER*50 IFNAME,OFNAME
      CHARACTER*1 STAR
      COMMON /IOUNIT/ IN,IO
      DATA STAR/'*'/
      IN=5
      IO=6
      WRITE(*,5)
      READ(*,7) IFNAME
      WRITE(*,6)
      READ(*,7) OFNAME
      OPEN (IN,FILE=IFNAME,STATUS='OLD')
      IF(OFNAME(1:1).EQ.STAR) IO=1
      IF(OFNAME(1:1).NE.STAR) OPEN (IO,FILE=OFNAME)
      RETURN
C
C       FORMAT STATEMENTS
5     FORMAT(5X,'TYPE IN INPUT FILE NAME')
6     FORMAT(5X,'TYPE IN OUTPUT FILE NAME')
7     FORMAT(A50)
      END
```

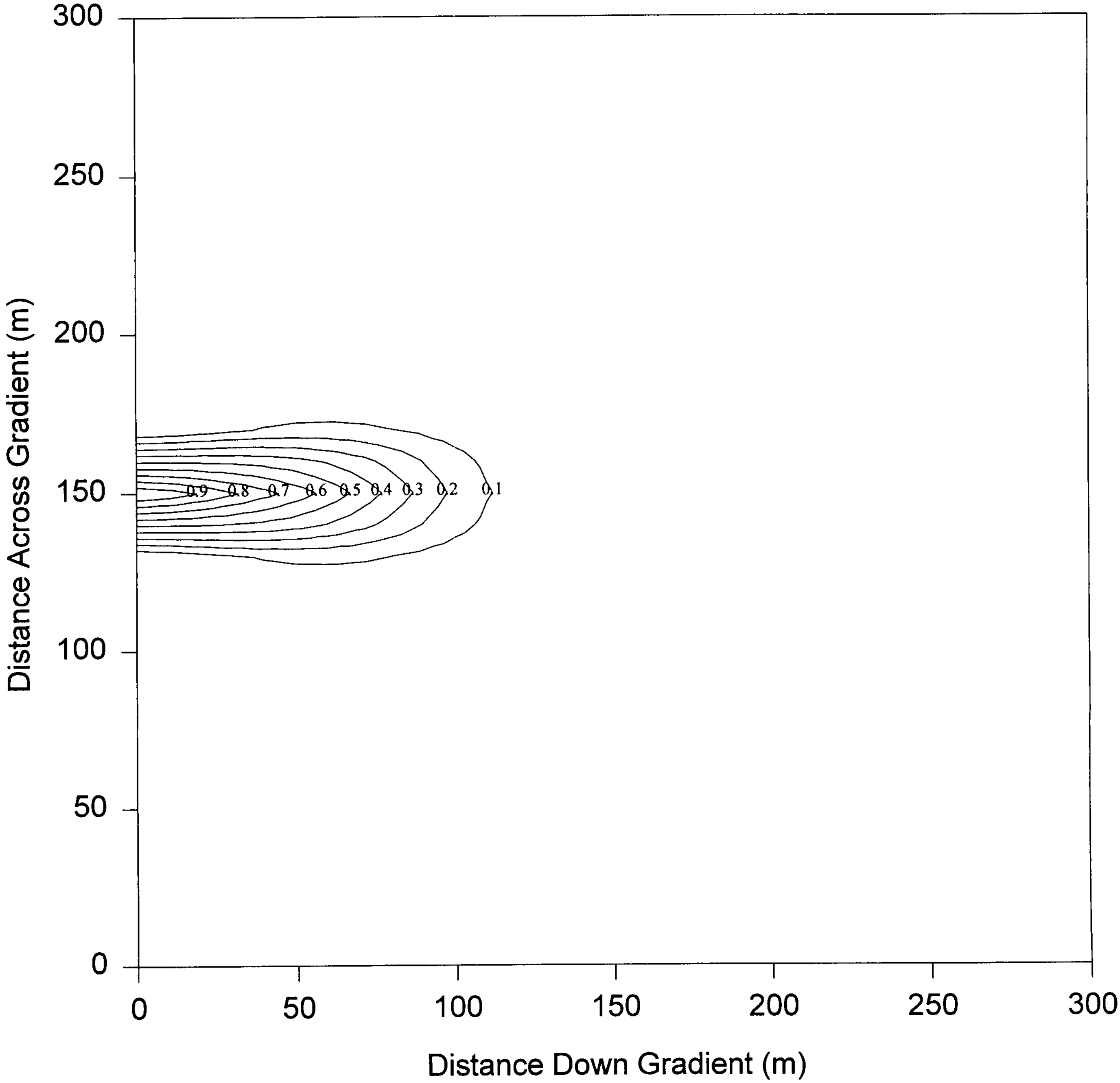
```
STRIPF Validation Problem  -- 2-D Solute transport in a semi-infinite
aquifer of infinite width with a continuous 'strip' source
Model Data:  V=8.0  m/yr, DX=40.0 m**2/yr, DY=8.0 m**2/yr,
             Y1=140 m , Y2=160 m , C0=1.0 mg/L, W=300 m

      31    8 104    1
MG/L       M/YR        M**2/YR  PER YEAR  METERS  YEARS
       1.0       8.0      40.0       8.0       0.0
     300.0     140.0     160.0
       0.0      10.0      20.0      30.0      40.0      50.0      60.0      70.0
      80.0      90.0     100.0     110.0     120.0     130.0     140.0     150.0
     160.0     170.0     180.0     190.0     200.0     210.0     220.0     230.0
     240.0     250.0     260.0     270.0     280.0     290.0     300.0
       0.0      10.0      20.0      30.0      40.0      50.0      60.0      70.0
      80.0      90.0     100.0     110.0     120.0     130.0     140.0     150.0
     160.0     170.0     180.0     190.0     200.0     210.0     220.0     230.0
     240.0     250.0     260.0     270.0     280.0     290.0     300.0
       5.0      10.0      15.0      20.0      25.0      30.0      35.0      40.0
      500.      500.       0.1
```

Time = 5 years

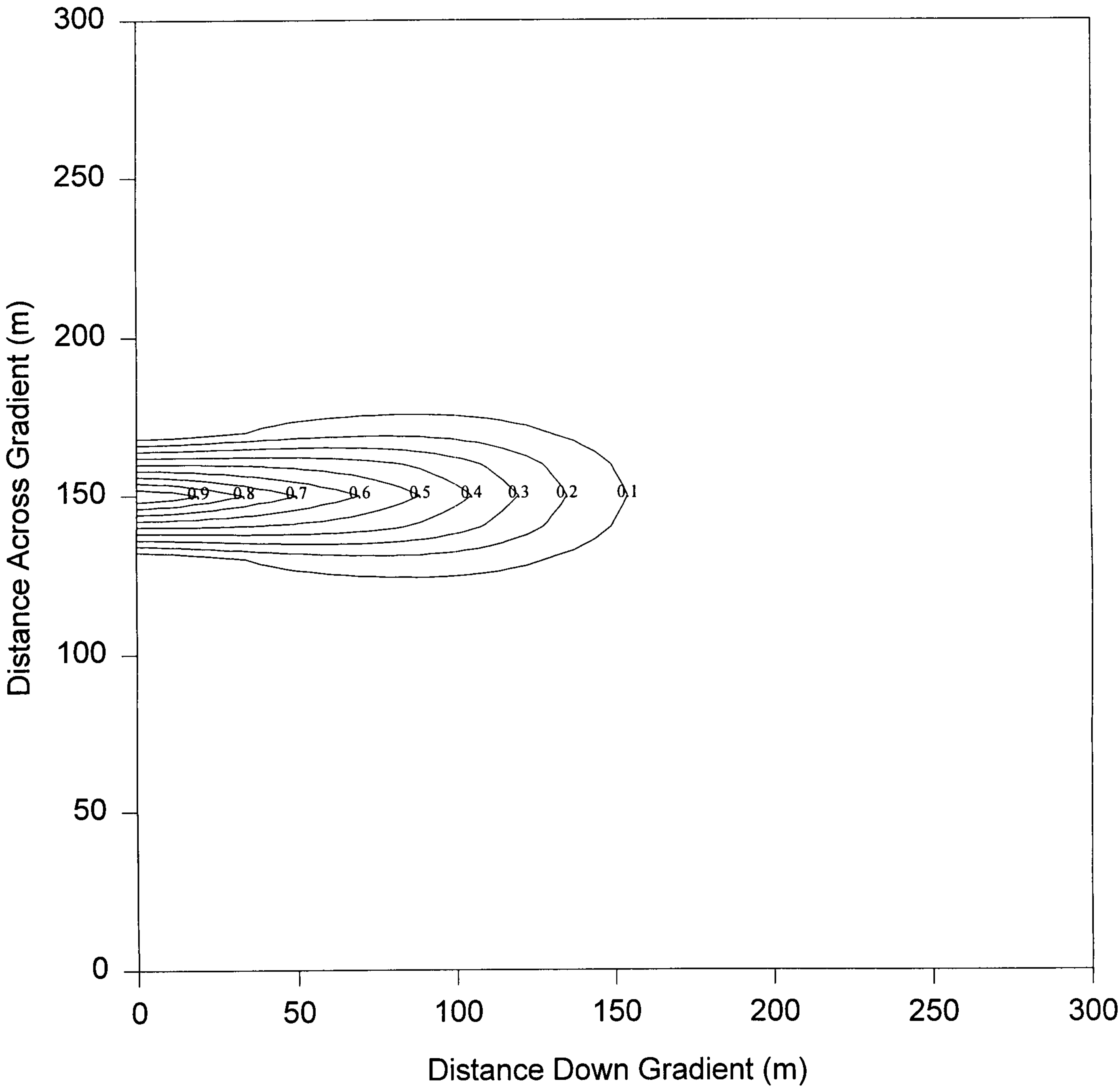


300
250
200
150
100
50
0
Distance Across Gradient (m)
0
50
100
150
200
250
300
Distance Down Gradient (m)
0.1

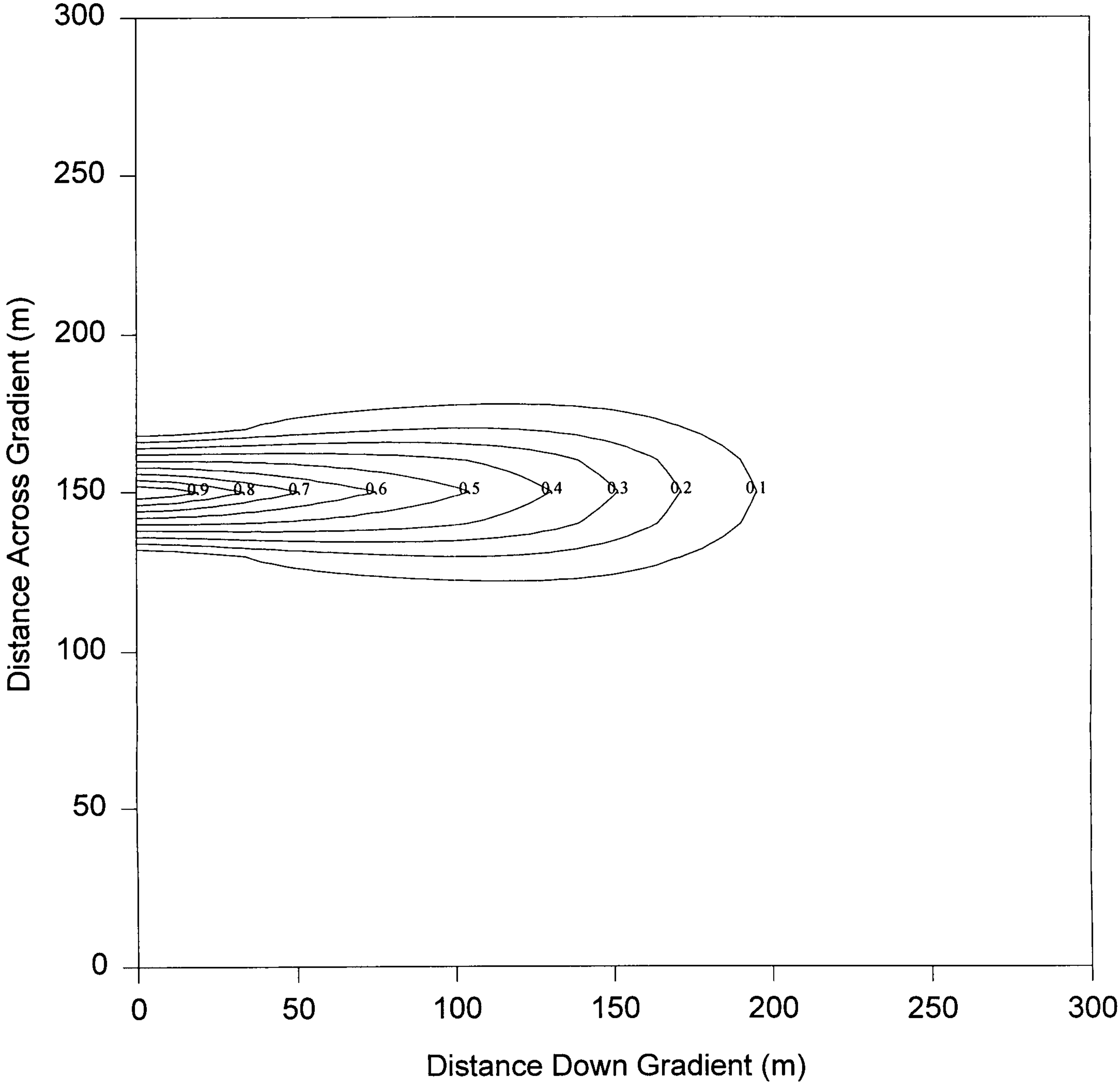
Time = 10 years



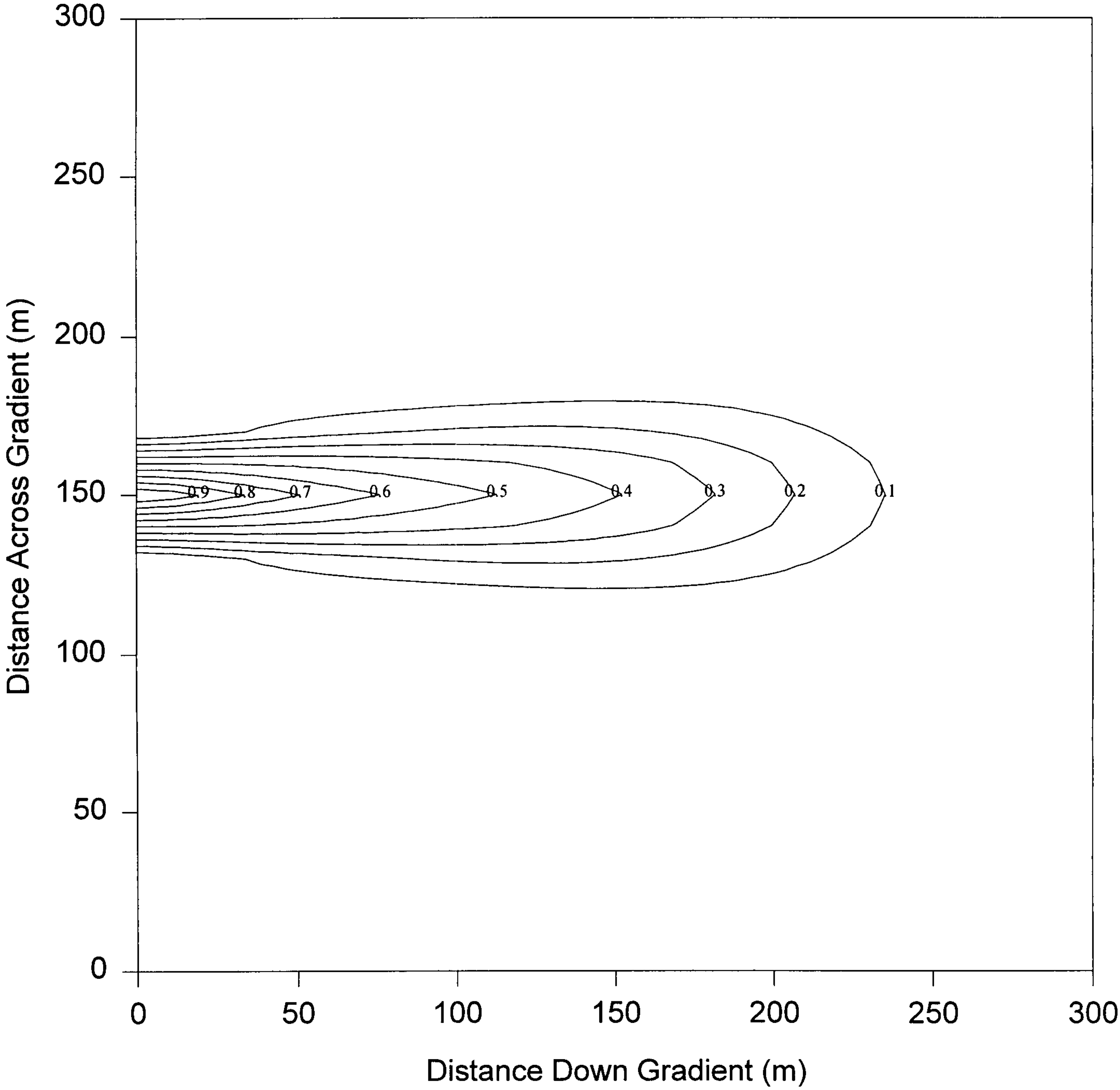
Time = 15 years



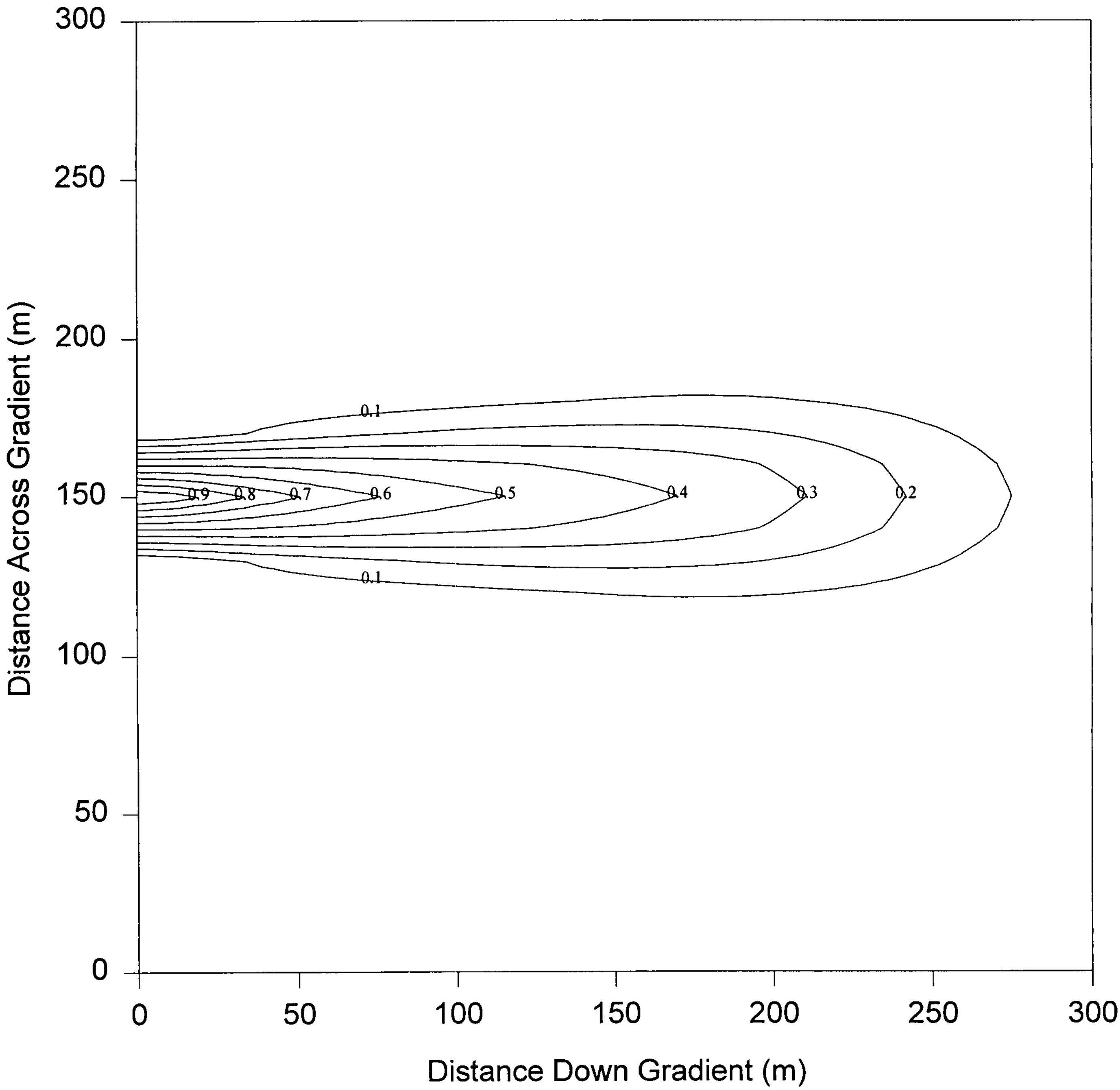
Time = 20 years



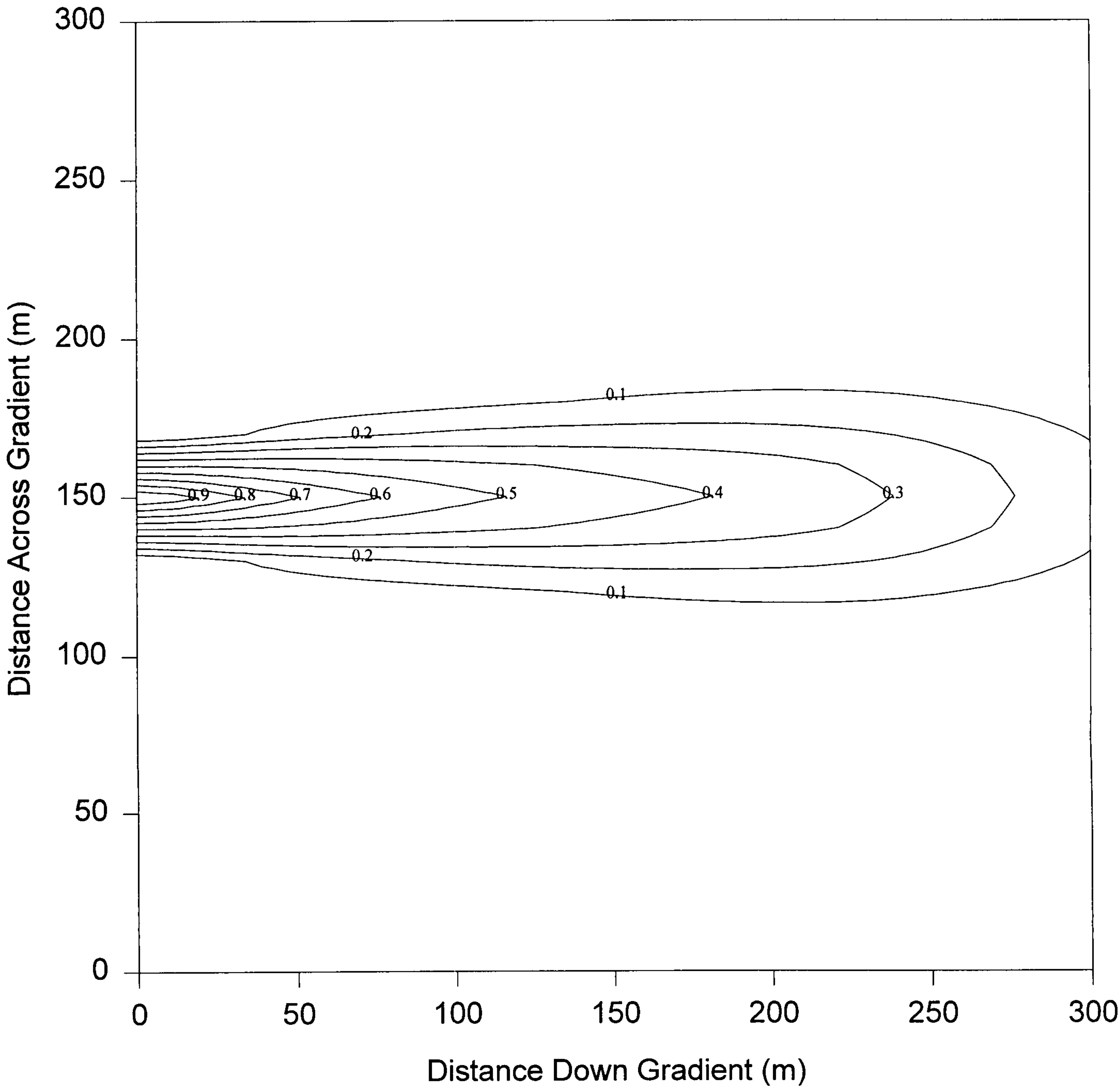
Time = 25 years



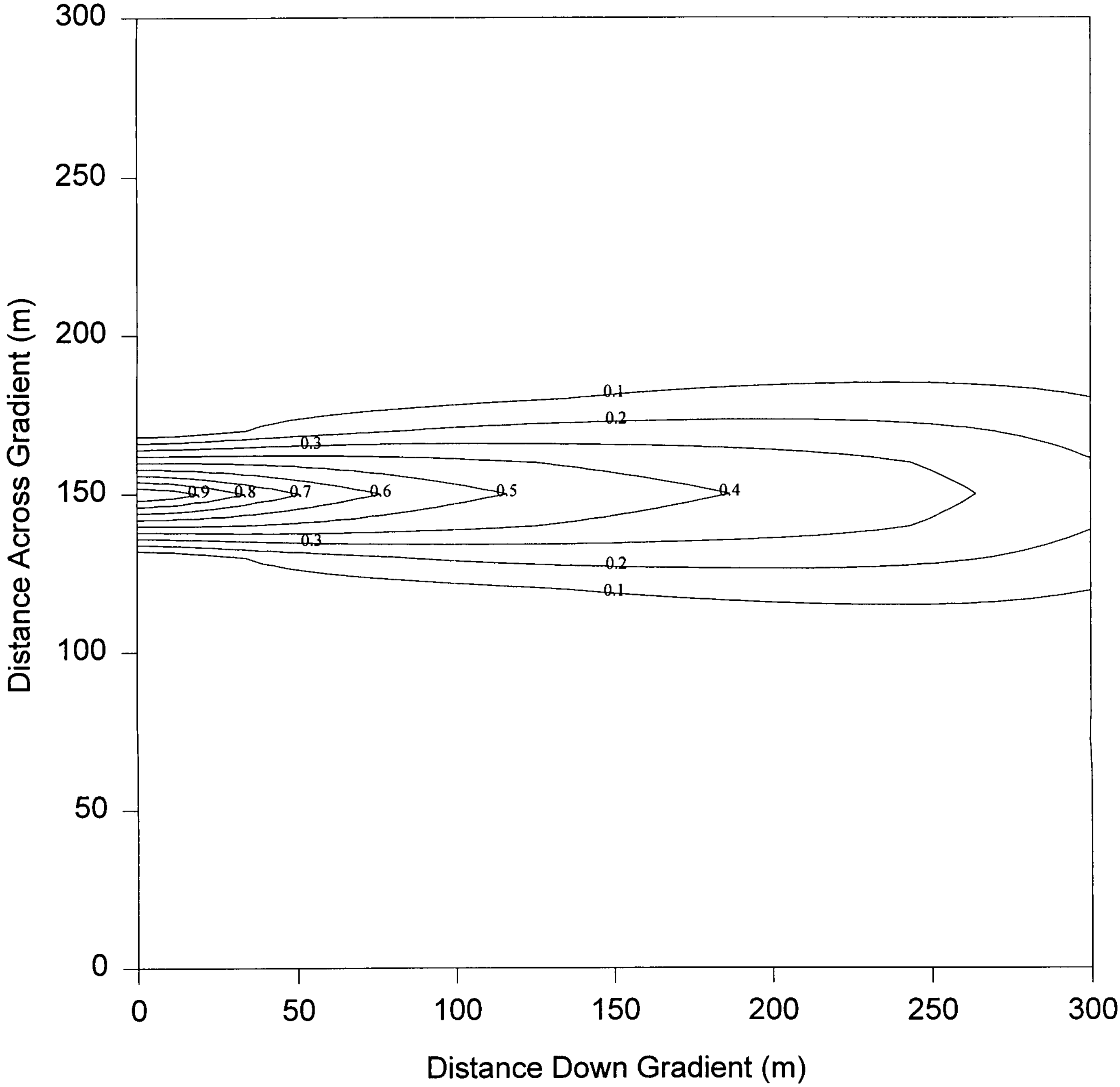
Time = 30 years



Time = 35 years



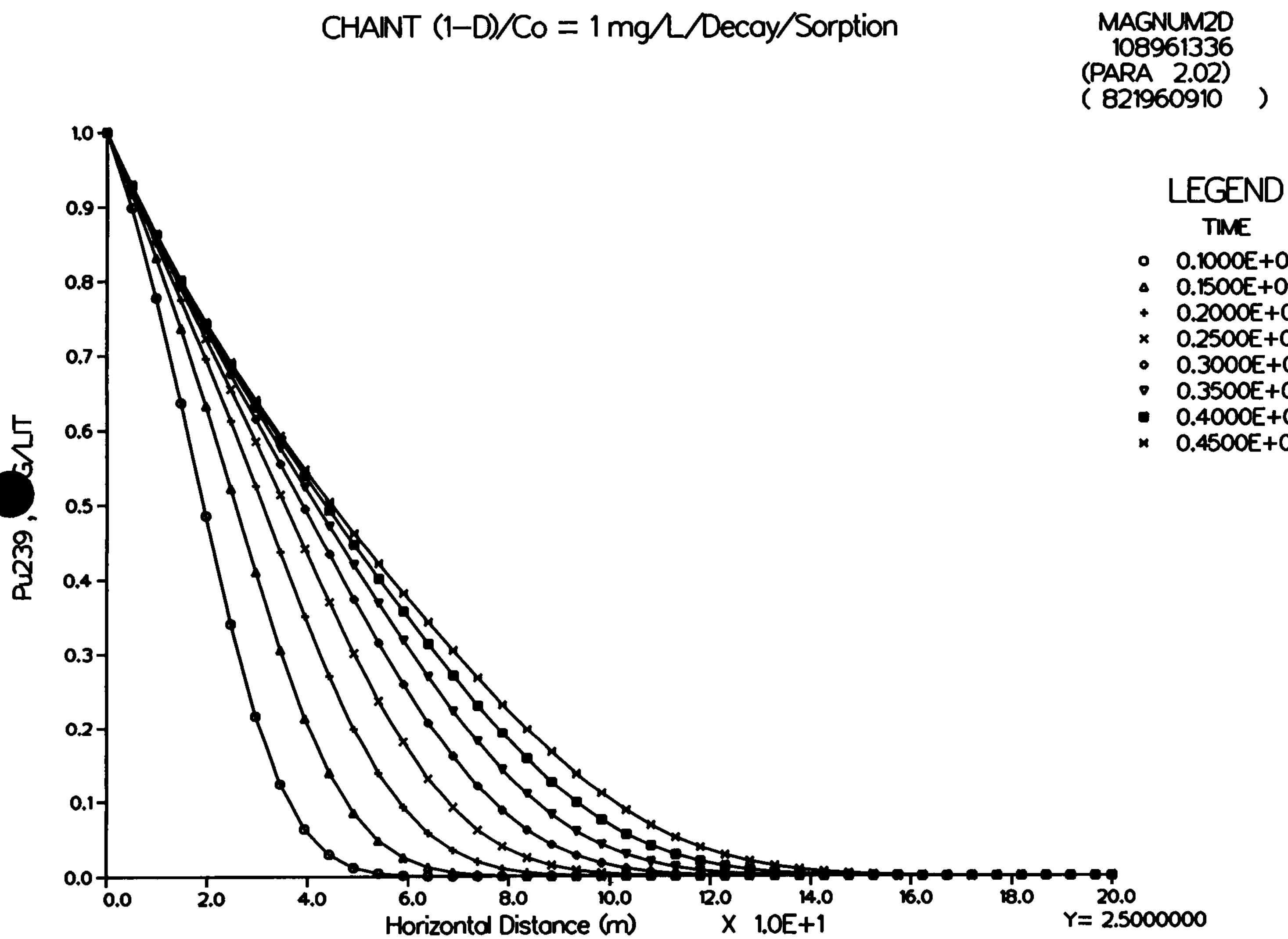
Time = 40 years

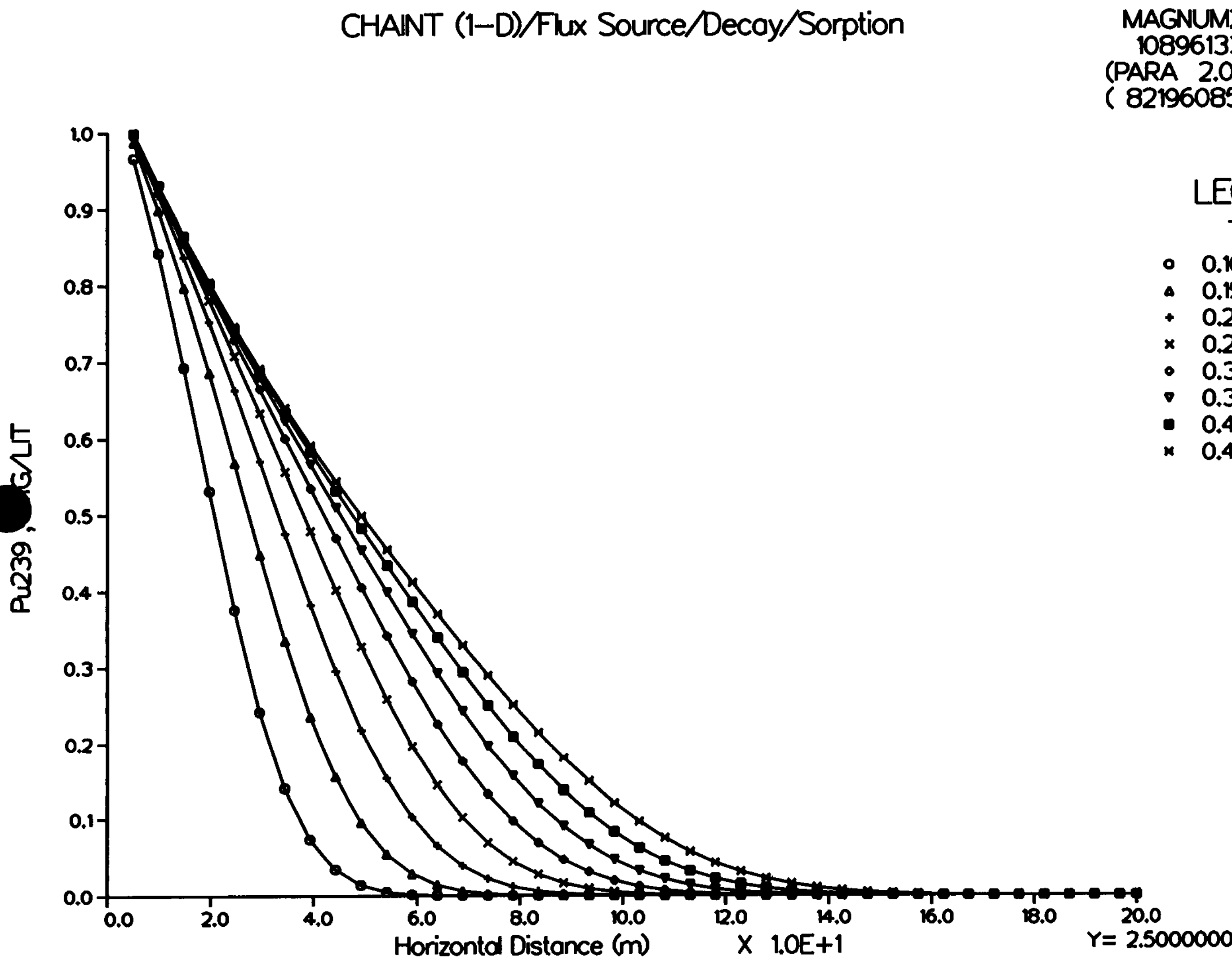


7.2.3 Validation Test Case 3 Results - One Dimensional with Decay and Sorption

Results from the CHAINT simulations for constant source concentration and constant flux are presented in this section. Overlaying the figures reveals the contoured results are consistent for both CHAINT scenarios.

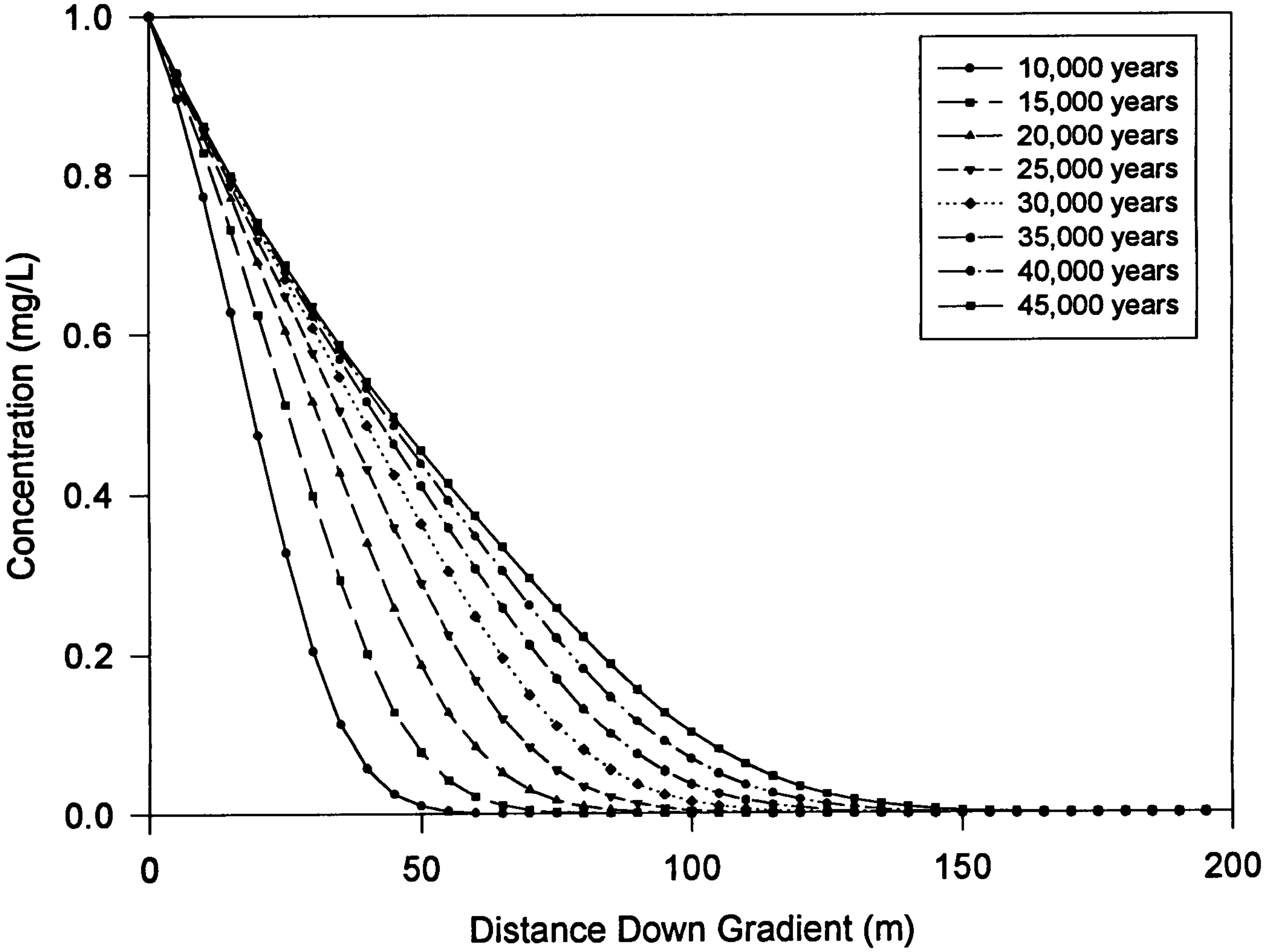
The results from the CHAINT simulations were compared to results from a two dimensional analytical model. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from FINITE compare favorably and overlaying the figures reveals the results are consistent.


CHAINT (1–D)/Co = 1 mg/L/Decay/Sorption
MAGNUM2D
108961336
(PARA 2.02)
(821960910)
LEGEND
TIME
0.1000E+05
0.1500E+05
0.2000E+05
0.2500E+05
0.3000E+05
0.3500E+05
0.4000E+05
0.4500E+05
Pu239 ,
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Horizontal Distance (m)
X 1.0E+1
Y= 2.5000000



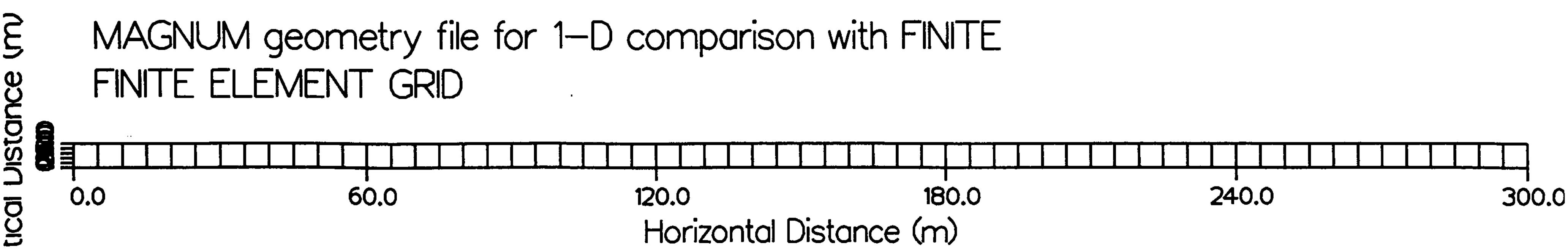
CHAINT (1–D)/Flux Source/Decay/Sorption
MAGNUM2D
108961336
(PARA 2.02)
(821960857)
LEGEND
TIME
0.1000E+05
0.1500E+05
0.2000E+05
0.2500E+05
0.3000E+05
0.3500E+05
0.4000E+05
0.4500E+05
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Horizontal Distance (m)
X 1.0E+1
Y= 2.5000000

FINITE Results (1-D) with Decay and Sorption



(PLT 2.00)
(801961341)
(0)

MAGNUM geometry file for 1-D comparison with FINITE
FINITE ELEMENT GRID



```
60  303              0  BACA      GEOMETRY     MESHER  2.00
MAGNUM geometry file for 1-D comparison with FINITE
```

1	1	4	5	6	7	8	3	2	1	1
2	5	9	10	11	12	13	7	6	1	2
3	10	14	15	16	17	18	12	11	1	3
4	15	19	20	21	22	23	17	16	1	4
5	20	24	25	26	27	28	22	21	1	5
6	25	29	30	31	32	33	27	26	1	6
7	30	34	35	36	37	38	32	31	1	7
8	35	39	40	41	42	43	37	36	1	8
9	40	44	45	46	47	48	42	41	1	9
10	45	49	50	51	52	53	47	46	1	10
11	50	54	55	56	57	58	52	51	1	11
12	55	59	60	61	62	63	57	56	1	12
13	60	64	65	66	67	68	62	61	1	13
14	65	69	70	71	72	73	67	66	1	14
15	70	74	75	76	77	78	72	71	1	15
16	75	79	80	81	82	83	77	76	1	16
17	80	84	85	86	87	88	82	81	1	17
18	85	89	90	91	92	93	87	86	1	18
19	90	94	95	96	97	98	92	91	1	19
20	95	99	100	101	102	103	97	96	1	20
21	100	104	105	106	107	108	102	101	1	21
22	105	109	110	111	112	113	107	106	1	22
23	110	114	115	116	117	118	112	111	1	23
24	115	119	120	121	122	123	117	116	1	24
25	120	124	125	126	127	128	122	121	1	25
26	125	129	130	131	132	133	127	126	1	26
27	130	134	135	136	137	138	132	131	1	27
28	135	139	140	141	142	143	137	136	1	28
29	140	144	145	146	147	148	142	141	1	29
30	145	149	150	151	152	153	147	146	1	30
31	150	154	155	156	157	158	152	151	1	31
32	155	159	160	161	162	163	157	156	1	32
33	160	164	165	166	167	168	162	161	1	33
34	165	169	170	171	172	173	167	166	1	34
35	170	174	175	176	177	178	172	171	1	35
36	175	179	180	181	182	183	177	176	1	36
37	180	184	185	186	187	188	182	181	1	37
38	185	189	190	191	192	193	187	186	1	38
39	190	194	195	196	197	198	192	191	1	39
40	195	199	200	201	202	203	197	196	1	40
41	200	204	205	206	207	208	202	201	1	41
42	205	209	210	211	212	213	207	206	1	42
43	210	214	215	216	217	218	212	211	1	43
44	215	219	220	221	222	223	217	216	1	44
45	220	224	225	226	227	228	222	221	1	45
46	225	229	230	231	232	233	227	226	1	46
47	230	234	235	236	237	238	232	231	1	47
48	235	239	240	241	242	243	237	236	1	48
49	240	244	245	246	247	248	242	241	1	49
50	245	249	250	251	252	253	247	246	1	50
51	250	254	255	256	257	258	252	251	1	51
52	255	259	260	261	262	263	257	256	1	52
53	260	264	265	266	267	268	262	261	1	53
54	265	269	270	271	272	273	267	266	1	54
55	270	274	275	276	277	278	272	271	1	55
56	275	279	280	281	282	283	277	276	1	56
57	280	284	285	286	287	288	282	281	1	57
58	285	289	290	291	292	293	287	286	1	58

59	290	294	295	296	297	298	292	291	1	59
60	295	299	300	301	302	303	297	296	1	60

1	0.000	0.000	0.00	0.00
2	0.000	2.500	0.00	0.00
3	0.000	5.000	0.00	0.00
4	2.500	0.000	0.00	0.00
5	5.000	0.000	0.00	0.00
6	5.000	2.500	0.00	0.00
7	5.000	5.000	0.00	0.00
8	2.500	5.000	0.00	0.00
9	7.500	0.000	0.00	0.00
10	10.000	0.000	0.00	0.00
11	10.000	2.500	0.00	0.00
12	10.000	5.000	0.00	0.00
13	7.500	5.000	0.00	0.00
14	12.500	0.000	0.00	0.00
15	15.000	0.000	0.00	0.00
16	15.000	2.500	0.00	0.00
17	15.000	5.000	0.00	0.00
18	12.500	5.000	0.00	0.00
19	17.500	0.000	0.00	0.00
20	20.000	0.000	0.00	0.00
21	20.000	2.500	0.00	0.00
22	20.000	5.000	0.00	0.00
23	17.500	5.000	0.00	0.00
24	22.500	0.000	0.00	0.00
25	25.000	0.000	0.00	0.00
26	25.000	2.500	0.00	0.00
27	25.000	5.000	0.00	0.00
28	22.500	5.000	0.00	0.00
29	27.500	0.000	0.00	0.00
30	30.000	0.000	0.00	0.00
31	30.000	2.500	0.00	0.00
32	30.000	5.000	0.00	0.00
33	27.500	5.000	0.00	0.00
34	32.500	0.000	0.00	0.00
35	35.000	0.000	0.00	0.00
36	35.000	2.500	0.00	0.00
37	35.000	5.000	0.00	0.00
38	32.500	5.000	0.00	0.00
39	37.500	0.000	0.00	0.00
40	40.000	0.000	0.00	0.00
41	40.000	2.500	0.00	0.00
42	40.000	5.000	0.00	0.00
43	37.500	5.000	0.00	0.00
44	42.500	0.000	0.00	0.00
45	45.000	0.000	0.00	0.00
46	45.000	2.500	0.00	0.00
47	45.000	5.000	0.00	0.00
48	42.500	5.000	0.00	0.00
49	47.500	0.000	0.00	0.00
50	50.000	0.000	0.00	0.00
51	50.000	2.500	0.00	0.00
52	50.000	5.000	0.00	0.00
53	47.500	5.000	0.00	0.00
54	52.500	0.000	0.00	0.00
55	55.000	0.000	0.00	0.00
56	55.000	2.500	0.00	0.00
57	55.000	5.000	0.00	0.00
58	52.500	5.000	0.00	0.00

59	57.500	0.000	0.00	0.00
60	60.000	0.000	0.00	0.00
61	60.000	2.500	0.00	0.00
62	60.000	5.000	0.00	0.00
[illegible]	57.500	5.000	0.00	0.00
64	62.500	0.000	0.00	0.00
65	65.000	0.000	0.00	0.00
66	65.000	2.500	0.00	0.00
67	65.000	5.000	0.00	0.00
68	62.500	5.000	0.00	0.00
69	67.500	0.000	0.00	0.00
70	70.000	0.000	0.00	0.00
71	70.000	2.500	0.00	0.00
72	70.000	5.000	0.00	0.00
73	67.500	5.000	0.00	0.00
74	72.500	0.000	0.00	0.00
75	75.000	0.000	0.00	0.00
76	75.000	2.500	0.00	0.00
77	75.000	5.000	0.00	0.00
78	72.500	5.000	0.00	0.00
79	77.500	0.000	0.00	0.00
80	80.000	0.000	0.00	0.00
81	80.000	2.500	0.00	0.00
82	80.000	5.000	0.00	0.00
83	77.500	5.000	0.00	0.00
84	82.500	0.000	0.00	0.00
85	85.000	0.000	0.00	0.00
86	85.000	2.500	0.00	0.00
87	85.000	5.000	0.00	0.00
[illegible]	82.500	5.000	0.00	0.00
89	87.500	0.000	0.00	0.00
90	90.000	0.000	0.00	0.00
91	90.000	2.500	0.00	0.00
92	90.000	5.000	0.00	0.00
93	87.500	5.000	0.00	0.00
94	92.500	0.000	0.00	0.00
95	95.000	0.000	0.00	0.00
96	95.000	2.500	0.00	0.00
97	95.000	5.000	0.00	0.00
98	92.500	5.000	0.00	0.00
99	97.500	0.000	0.00	0.00
100	100.000	0.000	0.00	0.00
101	100.000	2.500	0.00	0.00
102	100.000	5.000	0.00	0.00
103	97.500	5.000	0.00	0.00
104	102.500	0.000	0.00	0.00
105	105.000	0.000	0.00	0.00
106	105.000	2.500	0.00	0.00
107	105.000	5.000	0.00	0.00
108	102.500	5.000	0.00	0.00
109	107.500	0.000	0.00	0.00
110	110.000	0.000	0.00	0.00
111	110.000	2.500	0.00	0.00
112	110.000	5.000	0.00	0.00
[illegible]	107.500	5.000	0.00	0.00
114	112.500	0.000	0.00	0.00
115	115.000	0.000	0.00	0.00
116	115.000	2.500	0.00	0.00
117	115.000	5.000	0.00	0.00
118	112.500	5.000	0.00	0.00

119	117.500	0.000	0.00	0.00
120	120.000	0.000	0.00	0.00
121	120.000	2.500	0.00	0.00
122	120.000	5.000	0.00	0.00
123	117.500	5.000	0.00	0.00
124	122.500	0.000	0.00	0.00
125	125.000	0.000	0.00	0.00
126	125.000	2.500	0.00	0.00
127	125.000	5.000	0.00	0.00
128	122.500	5.000	0.00	0.00
129	127.500	0.000	0.00	0.00
130	130.000	0.000	0.00	0.00
131	130.000	2.500	0.00	0.00
132	130.000	5.000	0.00	0.00
133	127.500	5.000	0.00	0.00
134	132.500	0.000	0.00	0.00
135	135.000	0.000	0.00	0.00
136	135.000	2.500	0.00	0.00
137	135.000	5.000	0.00	0.00
138	132.500	5.000	0.00	0.00
139	137.500	0.000	0.00	0.00
140	140.000	0.000	0.00	0.00
141	140.000	2.500	0.00	0.00
142	140.000	5.000	0.00	0.00
143	137.500	5.000	0.00	0.00
144	142.500	0.000	0.00	0.00
145	145.000	0.000	0.00	0.00
146	145.000	2.500	0.00	0.00
147	145.000	5.000	0.00	0.00
148	142.500	5.000	0.00	0.00
149	147.500	0.000	0.00	0.00
150	150.000	0.000	0.00	0.00
151	150.000	2.500	0.00	0.00
152	150.000	5.000	0.00	0.00
153	147.500	5.000	0.00	0.00
154	152.500	0.000	0.00	0.00
155	155.000	0.000	0.00	0.00
156	155.000	2.500	0.00	0.00
157	155.000	5.000	0.00	0.00
158	152.500	5.000	0.00	0.00
159	157.500	0.000	0.00	0.00
160	160.000	0.000	0.00	0.00
161	160.000	2.500	0.00	0.00
162	160.000	5.000	0.00	0.00
163	157.500	5.000	0.00	0.00
164	162.500	0.000	0.00	0.00
165	165.000	0.000	0.00	0.00
166	165.000	2.500	0.00	0.00
167	165.000	5.000	0.00	0.00
168	162.500	5.000	0.00	0.00
169	167.500	0.000	0.00	0.00
170	170.000	0.000	0.00	0.00
171	170.000	2.500	0.00	0.00
172	170.000	5.000	0.00	0.00
173	167.500	5.000	0.00	0.00
174	172.500	0.000	0.00	0.00
175	175.000	0.000	0.00	0.00
176	175.000	2.500	0.00	0.00
177	175.000	5.000	0.00	0.00
178	172.500	5.000	0.00	0.00

179	177.500	0.000	0.00	0.00
180	180.000	0.000	0.00	0.00
181	180.000	2.500	0.00	0.00
182	180.000	5.000	0.00	0.00
183	177.500	5.000	0.00	0.00
184	182.500	0.000	0.00	0.00
185	185.000	0.000	0.00	0.00
186	185.000	2.500	0.00	0.00
187	185.000	5.000	0.00	0.00
188	182.500	5.000	0.00	0.00
189	187.500	0.000	0.00	0.00
190	190.000	0.000	0.00	0.00
191	190.000	2.500	0.00	0.00
192	190.000	5.000	0.00	0.00
193	187.500	5.000	0.00	0.00
194	192.500	0.000	0.00	0.00
195	195.000	0.000	0.00	0.00
196	195.000	2.500	0.00	0.00
197	195.000	5.000	0.00	0.00
198	192.500	5.000	0.00	0.00
199	197.500	0.000	0.00	0.00
200	200.000	0.000	0.00	0.00
201	200.000	2.500	0.00	0.00
202	200.000	5.000	0.00	0.00
203	197.500	5.000	0.00	0.00
204	202.500	0.000	0.00	0.00
205	205.000	0.000	0.00	0.00
206	205.000	2.500	0.00	0.00
207	205.000	5.000	0.00	0.00
208	202.500	5.000	0.00	0.00
209	207.500	0.000	0.00	0.00
210	210.000	0.000	0.00	0.00
211	210.000	2.500	0.00	0.00
212	210.000	5.000	0.00	0.00
213	207.500	5.000	0.00	0.00
214	212.500	0.000	0.00	0.00
215	215.000	0.000	0.00	0.00
216	215.000	2.500	0.00	0.00
217	215.000	5.000	0.00	0.00
218	212.500	5.000	0.00	0.00
219	217.500	0.000	0.00	0.00
220	220.000	0.000	0.00	0.00
221	220.000	2.500	0.00	0.00
222	220.000	5.000	0.00	0.00
223	217.500	5.000	0.00	0.00
224	222.500	0.000	0.00	0.00
225	225.000	0.000	0.00	0.00
226	225.000	2.500	0.00	0.00
227	225.000	5.000	0.00	0.00
228	222.500	5.000	0.00	0.00
229	227.500	0.000	0.00	0.00
230	230.000	0.000	0.00	0.00
231	230.000	2.500	0.00	0.00
232	230.000	5.000	0.00	0.00
233	227.500	5.000	0.00	0.00
234	232.500	0.000	0.00	0.00
235	235.000	0.000	0.00	0.00
236	235.000	2.500	0.00	0.00
237	235.000	5.000	0.00	0.00
238	232.500	5.000	0.00	0.00

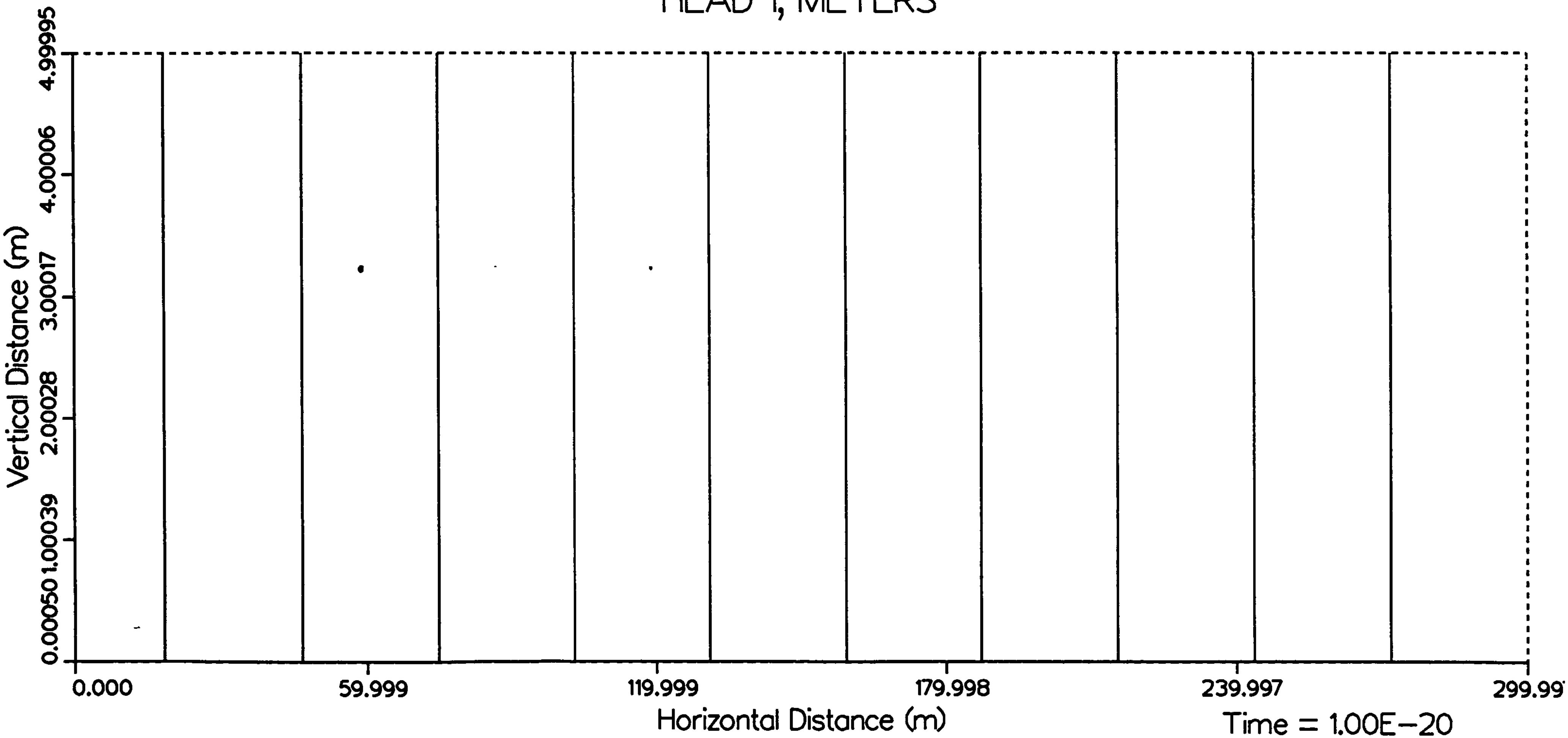
239	237.500	0.000	0.00	0.00
240	240.000	0.000	0.00	0.00
241	240.000	2.500	0.00	0.00
242	240.000	5.000	0.00	0.00
[illegible]	237.500	5.000	0.00	0.00
244	242.500	0.000	0.00	0.00
245	245.000	0.000	0.00	0.00
246	245.000	2.500	0.00	0.00
247	245.000	5.000	0.00	0.00
248	242.500	5.000	0.00	0.00
249	247.500	0.000	0.00	0.00
250	250.000	0.000	0.00	0.00
251	250.000	2.500	0.00	0.00
252	250.000	5.000	0.00	0.00
253	247.500	5.000	0.00	0.00
254	252.500	0.000	0.00	0.00
255	255.000	0.000	0.00	0.00
256	255.000	2.500	0.00	0.00
257	255.000	5.000	0.00	0.00
258	252.500	5.000	0.00	0.00
259	257.500	0.000	0.00	0.00
260	260.000	0.000	0.00	0.00
261	260.000	2.500	0.00	0.00
262	260.000	5.000	0.00	0.00
263	257.500	5.000	0.00	0.00
264	262.500	0.000	0.00	0.00
265	265.000	0.000	0.00	0.00
266	265.000	2.500	0.00	0.00
267	265.000	5.000	0.00	0.00
[illegible]	262.500	5.000	0.00	0.00
269	267.500	0.000	0.00	0.00
270	270.000	0.000	0.00	0.00
271	270.000	2.500	0.00	0.00
272	270.000	5.000	0.00	0.00
273	267.500	5.000	0.00	0.00
274	272.500	0.000	0.00	0.00
275	275.000	0.000	0.00	0.00
276	275.000	2.500	0.00	0.00
277	275.000	5.000	0.00	0.00
278	272.500	5.000	0.00	0.00
279	277.500	0.000	0.00	0.00
280	280.000	0.000	0.00	0.00
281	280.000	2.500	0.00	0.00
282	280.000	5.000	0.00	0.00
283	277.500	5.000	0.00	0.00
284	282.500	0.000	0.00	0.00
285	285.000	0.000	0.00	0.00
286	285.000	2.500	0.00	0.00
287	285.000	5.000	0.00	0.00
288	282.500	5.000	0.00	0.00
289	287.500	0.000	0.00	0.00
290	290.000	0.000	0.00	0.00
291	290.000	2.500	0.00	0.00
292	290.000	5.000	0.00	0.00
[illegible]	287.500	5.000	0.00	0.00
[illegible]	292.500	0.000	0.00	0.00
295	295.000	0.000	0.00	0.00
296	295.000	2.500	0.00	0.00
297	295.000	5.000	0.00	0.00
298	292.500	5.000	0.00	0.00

299	297.500	0.000	0.00	0.00
300	300.000	0.000	0.00	0.00
301	300.000	2.500	0.00	0.00
302	300.000	5.000	0.00	0.00
303	297.500	5.000	0.00	0.00

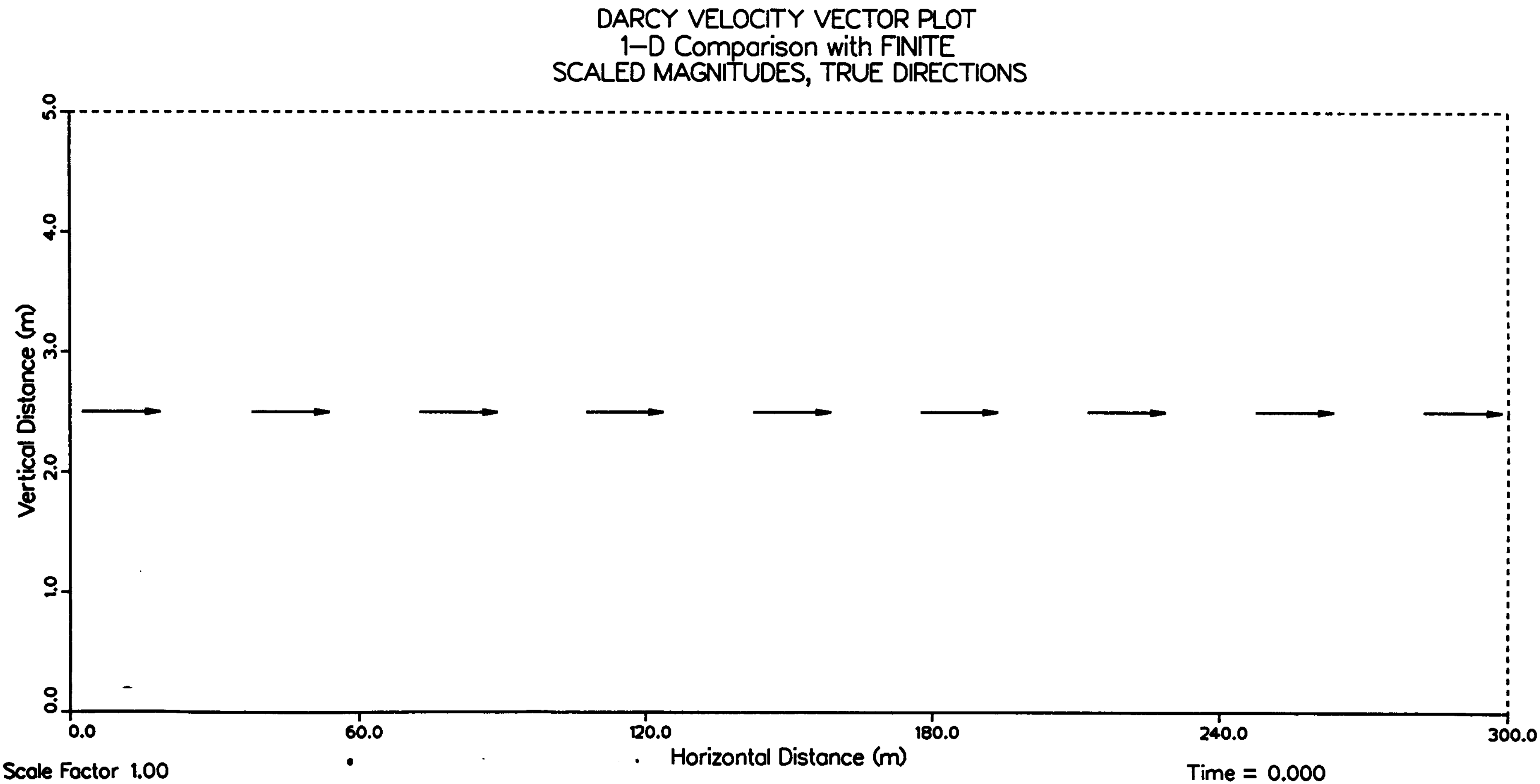
```
MAGNUM - 1-D Test case for comparison with FINITE
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
    1     0     1    303    60     1    0    0     0    1     1    0
#  irs   isv  icf  igi   ig  ivel inpt icsv
 [illegible]  13    0   10    0   12    0    0
#  …sf   alfa  tref
   0.0    1.8   20.0
#  nts  ntsg   dlt
    1    1     1000.
 9999    1     1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#   n       To      Ho
    1    20.000   0.5327
#  kspec
     6
#       n     n1 n2  Tbc      Hbc
       300        0   1   20.0000    0.0000
       301        0   1   20.0000    0.0000
       302        0   1   20.0000    0.0000
         3        0   1   20.0000    1.0654
         2        0   1   20.0000    1.0654
         1        0   1   20.0000    1.0654
      #   L     cvm     tkk(1)  tkk(2)  poros     hkax          hkay        nme
#         sp1       rhom    alpai   alpat    width
         1          0         0          0      0.07    5.0e-6    5.0e-6    mat1
    1.0e-6      2400          0          0         0
#  nld  nlt   scf
   0    0       0.0
```

MAGNUM2D
108961336
(CONT 2.03)
(801961338)

MAGNUM Results for 1-D
HEAD 1, METERS



MAGNUM2D 3.20
****
(VELP 2.00)
(731961556)



```
CHAINT 1-D Test case with decay/sorption (Co=1 mg/L) for comparison with FINITE
#  nqal   ne    np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1      60   303    3     1     0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
    0   11    0    0   14   15    0
#   f  alfa  xscale  yscale  uscale  vscale
   0.  1.8    0.      0.      0.      0.
#  nts  ntsg   dlt   zonel  zoner  zonet  zoneb
 200   200   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
 100   100   50.    0.     0.     0.     0.
9999   0     0      0      0      0      0
#    j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
     1      5.0       0.0      2400.      0.07       0.       mat1
#  islt
    1
#    L    amu    diag     isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
     1 239.0 2.411E+04     0        0.0        0        0.0   Pu239   0.0
#    i    dml(i,1..n2)  m2/yr
     1    0.0
#    i    xkdi(i,1..n2)  ml/g
     1   130.0
#   lk     Ci
     1     0.0
#    L     bcs
     1     1.0
     2     1.0
     3     1.0
#   nld   scf   relz
     0    1.0    0.
```

```
CHAINT 1-D Test case with decay/sorption (flux source) for comparison with FINITE
#  nqal   ne    np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1     60    303    3     1     0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
    0   11    0    0   14   15    0
    sf  alfa  xscale  yscale  uscale  vscale
    0.  1.8    0.      0.      0.      0.
#  nts  ntsg   dlt   zonel  zoner  zonet  zoneb
 200   200    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
 100   100    50.    0.     0.     0.     0.
9999   0     0      0      0      0      0
#   j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1      5.0       0.0      2400.     0.07       0.       mat1
#  islt
    1
#   L   amu    diag    isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1 239.0 2.411E+4     0        0.0       0        0.0    Pu239   0.0
#   i   dml(i,1..n2)  m2/yr
    1   0.0
#   i   xkdi(i,1..n2)  ml/g
    1  130.0
#  lk    Ci
    1    0.0
#   L    bcs
         0.0
    2    0.0
    3    0.0
#   nld   scf   relz
     1    1.0    0.
#   NLE
     1
#   TLE        RLE(Tc99)
        0.00000E+00       0.326161
     50000.0              0.326161
   -1.0      0.0
```

```
C
C     ********************************************************
C     *                                                      *
C     *                  **** FINITE ****                    *
C     *                                                      *
C     * ONE-DIMENSIONAL GROUND-WATER SOLUTE-TRANSPORT MODEL  *
C     *                                                      *
C     *   FOR A FINITE SYSTEM WITH A FIRST- OR THIRD-TYPE    *
C     *                                                      *
C     *             BOUNDARY CONDITION AT X=0                *
C     *                                                      *
C     *           VERSION CURRENT AS OF 04/01/90             *
C     *                                                      *
C     ********************************************************
C
C
C     Although this program has been used by the U.S. Geological
C     Survey, no warranty, expressed or implied, is made by the USGS
C     as to the accuracy and functioning of the program and related
C     program material, nor shall the fact of distribution constitute
C     any such warranty, and no responsibility is assumed by the USGS
C     in connection therewith.
C
C
C      THE FOLLOWING LINE MUST BE CHANGED IF PROBLEM DIMENSIONS ARE
C      GREATER THAN THOSE GIVEN HERE.
C        MAXX = MAXIMUM NUMBER OF X-VALUES
C        MAXT = MAXIMUM NUMBER OF TIME VALUES
C        MAXRT = MAXIMUM NUMBER OF ROOTS USED IN THE SERIES SUMMATION
      PARAMETER (MAXX=100,MAXT=20,MAXRT=1000)
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      REAL XP(MAXX),CP(MAXX),TP,XSCLP
      CHARACTER*10 CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      CHARACTER*1 IERR(MAXX,MAXT)
      DIMENSION CXT(MAXX,MAXT),X(MAXX),T(MAXT)
      DIMENSION ROOT(MAXRT)
      COMMON /IOUNIT/ IN,IO
C
C     PROGRAM VARIABLES
C
C          NOTE:  ANY CONSISTANT SET OF UNITS MAY BE USED IN THE
C          MODEL.  NO FORMAT STATEMENTS NEED TO BE CHANGED AS
C          LABELS FOR ALL VARIABLES ARE SPECIFIED IN MODEL INPUT.
C
C     CO        SOLUTE CONCENTRATION AT THE INFLOW BOUNDARY [M/L**3]
C     DX        LONGITUDINAL DISPERSION COEFFICIENT [L**2/T]
C     VX        GROUND-WATER VELOCITY IN X-DIRECTION [L/T]
C     DK        FIRST-ORDER SOLUTE DECAY CONSTANT [1/T]
C     X         X-POSITION AT WHICH CONCENTRATION IS EVALUATED [L]
C     T         TIME AT WHICH CONCENTRATION IS EVALUATED [T]
C     CN        NORMALIZED CONCENTRATION C/CO [DIMENSIONLESS]
C     CXT       SOLUTE CONCENTRATION C(X,T) [M/L**3]
C     XL        LENGTH OF THE FLOW SYSTEM [L]
C     ROOT(N)   ROOTS OF EQ. USED IN INFINITE SERIES SUMMATION
C
C     NBC       SOURCE BOUNDARY CONDITION TYPE (1 OR 3)
C     NX        NUMBER OF X-POSITIONS AT WHICH SOLUTION IS EVALUATED
C     NT        NUMBER OF TIME VALUES AT WHICH SOLUTION IS EVALUATED
C     NROOT     NUMBER OF ROOTS USED IN INFINITE SERIES SUMMATION
```

```
C     IPLT     PLOT CONTROL. IF IPLT>0, CONCENTRATION PROFILES ARE PLOTTED
C
C       CHARACTER VARIABLES USED TO SPECIFY UNITS FOR MODEL PARAMETERS
C     CUNITS   UNITS OF CONCENTRATION (M/L**3)
      VUNITS   UNITS OF GROUND-WATER VELOCITY (L/T)
      DUNITS   UNITS OF DISPERSION COEFFICIENT (L**2/T)
C     KUNITS   UNITS OF SOLUTE DECAY CONSTANT  (1/T)
C     LUNITS   UNITS OF LENGTH (L)
C     TUNITS   UNITS OF TIME (T)
C
C       DEFINE INPUT/OUTPUT FILES AND PRINT TITLE PAGE
      CALL OFILE
      CALL TITLE
      WRITE(IO,201)
C
C       READ IN MODEL PARAMETERS
      READ(IN,101) NBC,NX,NT,NROOT,IPLT
      IF(NBC.EQ.1) WRITE(IO,202)
      IF(NBC.EQ.3) WRITE(IO,203)
      WRITE(IO,205) NX,NT,NROOT
      READ(IN,105) CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      READ(IN,110) CO,VX,DX,DK,XL,XSCLP
      WRITE(IO,210) CO,CUNITS,VX,VUNITS,DX,DUNITS,DK,KUNITS,XL,LUNITS,
     1 XSCLP
      READ(IN,110) (X(I),I=1,NX)
      WRITE(IO,215) LUNITS
      WRITE(IO,220) (X(I),I=1,NX)
      READ(IN,110) (T(I),I=1,NT)
      WRITE(IO,225) TUNITS
      WRITE(IO,220) (T(I),I=1,NT)

C       GET EIGENVALUES (BETA) USED IN SERIES SUMMATION BY SOLVING FOR
C       THE POSITIVE ROOTS OF: BETA*COTAN(BETA)+VX*XL/(2*DX)=0.0
C       FOR A FIRST-TYPE SOURCE BOUNDARY CONDITION,
C       OR: BETA*COTAN(BETA)-BETA**2*DX/(VX*XL)+VX*XL/(4*DX)=0.0
C       FOR A THIRD-TYPE SOURCE BOUNDARY CONDITION.
C
      IF (NBC.EQ.1) THEN
        C=VX*XL/(2.0D0*DX)
        CALL ROOT1(C,ROOT,NROOT)
      ELSE
        A=0.250D0*VX*XL/DX
        C=DX/(XL*VX)
        CALL ROOT3(A,C,ROOT,NROOT)
      END IF
C
C       BEGIN TIME LOOP
      DO 40 IT=1,NT
C
C       BEGIN X-COORDINATE LOOP
      DO 50 IX=1,NX
C
C       CALL ROUTINE TO CALCULATE NORMALIZED CONCENTRATION
C       BASED ON TYPE OF BOUNDARY CONDITION SPECIFIED
      IF(NBC.EQ.1) CALL CNRML1(XL,T(IT),X(IX),DX,VX,DK,ROOT,CN,NROOT,
     1 IERR(IX,IT))
      IF(NBC.EQ.3) CALL CNRML3(XL,T(IT),X(IX),DX,VX,DK,ROOT,CN,NROOT,
     1 IERR(IX,IT))
      CXT(IX,IT)=CN*CO
50    CONTINUE
```

```
C
C       CONVERT X AND C TO SINGLE PRECISION AND DIVIDE BY CO TO
C       PLOT NORMALIZED CONCENTRATION PROFILE FOR EACH TIME VALUE.
      IF(IPLT.LT.1) GO TO 40
      DO 60 I=1,NX
      XP(I)=SNGL(X(I))
60    CP(I)=SNGL(CXT(I,IT)/CO)
      TP=SNGL(T(IT))
C     CALL PLOT1D(XP,CP,NX,TP,IT,NT,TUNITS,LUNITS,XSCLP)
40    CONTINUE
C
C       PRINT OUT TABLES OF CONCENTRATION VALUES
      NPAGE=1+(NT-1)/9
      DO 80 NP=1,NPAGE
      IF(NP.EQ.1) WRITE(IO,230) TUNITS
      IF(NP.NE.1) WRITE(IO,231) TUNITS
      NP1=(NP-1)*9
      NP2=9
      IF((NP1+NP2).GT.NT) NP2=NT-NP1
      WRITE(IO,235) (T(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
      DO 70 IX=1,NX
      WRITE(IO,240) X(IX),(CXT(IX,NP1+J),IERR(IX,NP1+J),J=1,NP2)
      IF(MOD(IX,45).NE.0) GO TO 70
      WRITE(IO,231) TUNITS
      WRITE(IO,235) (T(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
70    IF(MOD(IX,5).EQ.0 .AND. MOD(IX,45).NE.0) WRITE(IO,241)
80    CONTINUE
C
      CLOSE (IN)
      CLOSE (IO)
      STOP
C
C        FORMAT STATEMENTS
101   FORMAT(20I4)
105   FORMAT(8A10)
110   FORMAT(8F10.0)
201   FORMAT(/////1H ,30X,'ANALYTICAL SOLUTION TO THE ONE-DIMENSIONAL'/
     1 1H ,28X,'ADVECTIVE-DISPERSIVE SOLUTE-TRANSPORT EQUATION'/
     2 1H ,36X,'FOR A SYSTEM OF FINITE LENGTH'///1H0,40X,'INPUT DATA'/
     3 1H ,40X,10(1H-))
202   FORMAT(1H0,25X,'FIRST-TYPE BOUNDARY CONDITION AT X = 0.0')
203   FORMAT(1H0,25X,'THIRD-TYPE BOUNDARY CONDITION AT X = 0.0')
205   FORMAT(1H0,25X,'NUMBER OF X-COORDINATES (NX) = ',I4/1H ,25X,
     1 'NUMBER OF TIME VALUES (NT) = ',I4/1H ,25X,'NUMBER OF ROOTS ',
     2 'USED IN INFINITE SERIES SUMMATION (NROOT) = ',I4)
210   FORMAT(1H0,25X,'SOLUTE CONCENTRATION ON MODEL BOUNDARY (CO) =',
     1 1P1E13.6,1X,A10/1H ,25X,
     2 'GROUND-WATER VELOCITY IN X-DIRECTION (VX) =',1P1E13.6,1X,A10/
     3 1H ,25X,'DISPERSION IN THE X-DIRECTION (DX) =',1P1E13.6,1X,A10/
     4 1H ,25X,'FIRST-ORDER SOLUTE-DECAY RATE (DK) =',1P1E13.6,1X,A10/
     5 1H ,25X,'LENGTH OF FINITE FLOW SYSTEM (XL) =',1P1E13.6,1X,A10/
     6 1H ,25X,'PLOT SCALING FACTOR (XSCLP) =',1P1E13.6)
215   FORMAT(1H0,25X,'X-COORDINATES AT WHICH SOLUTE CONCENTRATIONS ',
       'WILL BE CALCULATED, IN ',A10/1H ,25X,78(1H-)/)
220   FORMAT(1H ,5X,8F12.4)
225   FORMAT(1H0,25X,'TIMES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,70(1H-)/)
230   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AS A FUNCTION OF TIME',
```

```
     1 15X,'*  INDICATES SOLUTION DID NOT CONVERGE'/
     2 1H0,25X,'TIME VALUES, IN ',A10)
231   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AS A FUNCTION OF TIME =',
     1 5X,'(CONTINUED)'/
     2 1H0,25X,'TIME VALUES, IN ',A10)
      FORMAT(1H ,20X,9F12.4)
236   FORMAT(1H ,19X,'*',108(1H-)/
     1 1H ,4X,'X-COORDINATE,',2X,'!',44X,'SOLUTE CONCENTRATION, IN ',
     2 A10/1H ,4X,'IN ',A10,2X,1H!/1H ,19X,'!')
240   FORMAT(1H ,5X,F12.4,2X,'! ',9(F11.5,A1))
241   FORMAT(1H ,19X,'!')
      END
      SUBROUTINE CNRML1(XL,T,X,D,V,DK,ROOT,CN,NROOT,IERR)
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
      CHARACTER*1 IERR
      DIMENSION ROOT(NROOT)
C
C       SOLUTION FOR THE ONE-DIMENSIONAL SOLUTE-TRANSPORT EQUATION
C       FOR A SYSTEM OF FINITE LENGTH WITH A FIRST-TYPE SOURCE
C       BOUNDARY CONDITION. VALUE RETURNED IS THE NORMALIZED SOLUTE
C       CONCENTRATION AT A GIVEN X-COORDINATE AND TIME VALUE.
C       FOR NO SOLUTE DECAY, A SIMPLIFIED SOLUTION IS USED.
C
      IERR=' '
      XL2=XL*XL
      V2D=V/(2.0D0*D)
      VX2D=V2D*X
      VL2D=V2D*XL
      VL2D2=VL2D*VL2D
      DKL2D=DK*XL*XL/D
      VSQT4D=V*V*T/(4.0D0*D)
      IF(DK.EQ.0.0D0) GO TO 20
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH DECAY
      SIGMA=0.0
      DO 10 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      X1=(BETA2+VL2D2)*DEXP(-BETA2*D*T/XL2)
C
C       TERM 2
      DENOM=(BETA2+VL2D2+VL2D)*(BETA2+VL2D2+DKL2D)
      X2=BETA*DSIN(BETA*X/XL)/DENOM
      SIGMA=SIGMA+X1*X2
C
C     CHECK FOR CONVERGENCE OF SERIES
      IF(N.GT.25 .AND. DABS(X1*X2).LT.1.0D-14) GO TO 15
10    CONTINUE
      IERR='*'
15    CONTINUE
C
C       TERM 3
      U=DSQRT(V*V+4.0D0*DK*D)
      VMU=V-U
      VPU=V+U
      VUPM=(U-V)/VPU
      D2=D*2.0D0
      X3=DEXP(VMU*X/D2)+VUPM*DEXP((VPU*X-2.0D0*U*XL)/D2)
```

```
      X3=X3/(1.0D0+VUPM*DEXP(-U*XL/D))
      CN=X3-2.0D0*DEXP(VX2D-VSQT4D-DK*T)*SIGMA
      RETURN
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH NO DECAY
      SIGMA=0.0
      DO 30 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      DENOM=BETA2+VL2D2+VL2D
      X1=BETA*DSIN(BETA*X/XL)*DEXP(-BETA2*D*T/XL2)
      X1=X1/DENOM
      TERM=X1
      SIGMA=SIGMA+X1
      IF(N.GT.25 .AND. DABS(X1).LT.1.0D-14) GO TO 35
30    CONTINUE
      IERR='*'
35    CONTINUE
      CN=1.0D0-2.0D0*DEXP(VX2D-VSQT4D)*SIGMA
      RETURN
      END
      SUBROUTINE CNRML3(XL,T,X,D,V,DK,ROOT,CN,NROOT,IERR)
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
      CHARACTER*1 IERR
      DIMENSION ROOT(NROOT)
C
C       SOLUTION FOR THE ONE DIMENSIONAL SOLUTE-TRANSPORT EQUATION
C       FOR A SYSTEM OF FINITE LENGTH WITH A THIRD-TYPE SOURCE
C       BOUNDARY CONDITION. VALUE RETURNED IS THE NORMALIZED SOLUTE
C       CONCENTRATION AT A GIVEN X-COORDINATE AND TIME VALUE.
C       FOR NO SOLUTE DECAY, A SIMPLIFIED SOLUTION IS USED.
C
      IERR=' '
      XL2=XL*XL
      V2D=V/(2.0D0*D)
      VLD=V*XL/D
      VX2D=V2D*X
      VL2D=V2D*XL
      VL2D2=VL2D*VL2D
      DKL2D=DK*XL*XL/D
      VSQT4D=V*V*T/(4.0D0*D)
      IF(DK.EQ.0.0D0) GO TO 20
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH DECAY
      SIGMA=0.0
      DO 10 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      BETAXL=BETA*X/XL
      X1=BETA*(BETA*DCOS(BETAXL)+VL2D*DSIN(BETAXL))
C
C       TERM 2
      DENOM=(BETA2+VL2D2+VLD)*(BETA2+VL2D2+DKL2D)
      X2=DEXP(-BETA2*D*T/XL2)/DENOM
      SIGMA=SIGMA+X1*X2
C
```

```
C     CHECK FOR CONVERGENCE OF SERIES
      IF(N.GT.25 .AND. DABS(X1*X2).LT.1.0D-14) GO TO 15
10    CONTINUE
      IERR='*'
15    CONTINUE
C
C       TERM 3
      U=DSQRT(V*V+4.0D0*DK*D)
      VMU=V-U
      VPU=V+U
      VUPM=(U-V)/VPU
      D2=D*2.0D0
      X3=DEXP(VMU*X/D2)+VUPM*DEXP((VPU*X-2.0D0*U*XL)/D2)
      X3=2.0D0*V*X3/(VPU+VMU*VUPM*DEXP(-U*XL/D))
      CN=X3-2.0D0*VLD*DEXP(VX2D-VSQT4D-DK*T)*SIGMA
      RETURN
C
C       BEGIN SERIES SUMMATION FOR SOLUTE WITH NO DECAY
20    SIGMA=0.0
      DO 30 N=1,NROOT
      BETA=ROOT(N)
      BETA2=BETA*BETA
C
C       TERM 1
      BETAXL=BETA*X/XL
      X1=BETA*(BETA*DCOS(BETAXL)+VL2D*DSIN(BETAXL))
C
C       TERM 2
      DENOM=(BETA2+VL2D2+VLD)*(BETA2+VL2D2)
      X2=DEXP(-BETA2*D*T/XL2)/DENOM
C
      SIGMA=SIGMA+X1*X2
      IF(N.GT.25 .AND. DABS(X1*X2).LT.1.0D-14) GO TO 35
30    CONTINUE
      IERR='*'
35    CONTINUE
C
      CN=1.0D0-2.0D0*VLD*DEXP(VX2D-VSQT4D)*SIGMA
      RETURN
      END
      SUBROUTINE ROOT1 (C,ROOT,NROOT)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION ROOT(NROOT)
      COMMON /IOUNIT/ IN,IO
      DATA MAXIT,EPS/50,1.0D-10/
C
C       THIS ROUTINE CALCULATES ROOTS OF THE EQUATION: B*COTAN(B)+C=0
C       USING NEWTON'S SECOND-ORDER METHOD.
C
C                       PROGRAM VARIABLES
C       MAXIT    MAXIMUM NUMBER OF ITERATIONS ALLOWED IN ROOT SEARCH
C       EPS      CONVERGENCE CRITERION
C       F1,F2    1ST AND 2ND DERIVATIVES OF THE EQUATION
C       H        SECOND-ORDER CORRECTION FACTOR
C
C       FIRST ROOT LIES BETWEEN PI/2 AND PI. START WITH .75*PI
      PI=3.14159265359D0
      ROOT(1)=0.750D0*PI
C
C       START LOOP FOR EACH ROOT SEARCH
```

```
      DO 10 N=1,NROOT
C
C       BEGIN ITERATIVE LOOP
      DO 20 I=1,MAXIT
      X=ROOT(N)
      SINX2=DSIN(X)*DSIN(X)
      COTX=1.0D0/DTAN(X)
      F=X*COTX+C
C       IF F IS 0.0, EXACT ROOT HAS BEEN FOUND
      IF(F.EQ.0.0) GO TO 30
      F1=COTX-X/SINX2
      F2=-1.0D0/SINX2-(SINX2-X*DSIN(X*2.0D0))/(SINX2*SINX2)
      H=(F2/2.0D0)/F1-F1/F
      H=1.0D0/H
      ROOT(N)=X+H
C
C     CHECK FOR CONVERGENCE. IF NOT ACHIEVED, RE-ITERATE
      IF(DABS(H).LT.EPS) GO TO 30
   20 CONTINUE
      WRITE(IO,201) MAXIT,N
      STOP
C
C       NEXT ROOT IS ABOUT PI GREATER THAN LAST ROOT
   30 IF(N.NE.NROOT) ROOT(N+1)=ROOT(N)+PI
   10 CONTINUE
      RETURN
C
C       FORMAT STATEMENTS
201   FORMAT(1H ,5X,'**** WARNING ****  ROOT SEARCH ROUTINE DID NOT',
     1 'CONVERGE AFTER ',I4,'ITERATIONS WHILE SEARCHING FOR ROOT',I5)
      END
      SUBROUTINE ROOT3 (A,C,ROOT,NROOT)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION ROOT(NROOT)
      COMMON /IOUNIT/ IN,IO
      DATA MAXIT,EPS/50,1.0D-10/
C
C       THIS ROUTINE CALCULATES ROOTS OF THE EQ: B*COTAN(B)-C*B**2+A=0
C       USING NEWTON'S SECOND-ORDER METHOD.
C
C                       PROGRAM VARIABLES
C       MAXIT    MAXIMUM NUMBER OF ITERATIONS ALLOWED IN ROOT SEARCH
C       EPS      CONVERGENCE CRITERION
C       F1,F2    1ST AND 2ND DERIVATIVES OF THE EQUATION
C       H        SECOND-ORDER CORRECTION FACTOR
C
C       FIRST ROOT LIES BETWEEN 0.0 AND PI. START WITH 0.5*PI
      PI=3.14159265359D0
      ROOT(1)=0.50D0*PI
C
C       START LOOP FOR EACH ROOT SEARCH
      DO 10 N=1,NROOT
C
C       BEGIN ITERATIVE LOOP
      DO 20 I=1,MAXIT
      X=ROOT(N)
      SINX2=DSIN(X)*DSIN(X)
      COTX=1.0D0/DTAN(X)
      F=X*COTX-C*X*X+A
C       IF F IS 0.0, EXACT ROOT HAS BEEN FOUND
```

```
      IF(F.EQ.0.0) GO TO 30
      F1=COTX-X/SINX2-(2.0D0*C*X)
      F2=-1.0D0/SINX2-(SINX2-X*DSIN(X*2.0D0))/(SINX2*SINX2)-2.0D0*C
      H=(F2/2.0D0)/F1-F1/F
      H=1.0D0/H
      ROOT(N)=X+H
C
C     CHECK FOR CONVERGENCE. IF NOT ACHIEVED, RE-ITERATE
      IF(DABS(H).LT.EPS) GO TO 30
   20 CONTINUE
      WRITE(IO,201) MAXIT,N
      STOP
C
C       NEXT ROOT IS ABOUT PI GREATER THAN LAST ROOT
   30 IF(N.NE.NROOT) ROOT(N+1)=ROOT(N)+PI
   10 CONTINUE
      RETURN
C
C       FORMAT STATEMENTS
201   FORMAT(1H ,5X,'**** WARNING ****  ROOT SEARCH ROUTINE DID NOT',
     1 'CONVERGE AFTER ',I4,'ITERATIONS WHILE SEARCHING FOR ROOT',I5)
      END
C       ******************************************************
C      *                                                      *
C      *                  SUBROUTINE TITLE                    *
C      *                                                      *
C      *            VERSION CURRENT AS OF 10/01/87            *
C      *                                                      *
C       ******************************************************
C
      SUBROUTINE TITLE
      CHARACTER*1 LINE1(60),EQUAL,BLANK
      CHARACTER*60 LINE
      CHARACTER*61 TITL1,T1
      COMMON /IOUNIT/ IN,IO
      COMMON /TITLES/ TITL1(4)
      DATA EQUAL/'='/,BLANK/' '/
      DATA TITL1/4*'
     1          '/
C
C        THIS ROUTINE CREATES A TITLE BOX ON THE FIRST PAGE OF
C        PROGRAM OUTPUT. THE ROUTINE READS AND PRINTS ALL DATA
C        CARDS UNTIL IT ENCOUNTERS AN '=' IN COLUMN 1. THE FIRST 4
C        LINES READ IN ARE ALSO USED AS TITLES ON PLOTS.
C
C     CALL JOBLOC (DUM,DUM,DUM,DUM,USRN)
C     USRNAM = USRN
C
      WRITE(IO,201)
      DO 10 L=1,60
      READ(IN,101,END=20) LINE
      IF (LINE(1:1).EQ.EQUAL) GOTO 60
      T1=LINE
C       STRIP OFF TRAILING BLANKS AND CENTER LINE
      DO 15 N=1,60
      NN=61-N
15    IF(LINE(NN:NN).NE.BLANK) GOTO 20
20    NN1=NN+1
      T1(NN1:NN1)='$'
      IF(L.LT.5) TITL1(L)=T1
```

```
      NS=(60-NN)/2
      IF(NS.EQ.0) GO TO 35
      DO 30 I=1,60
30    LINE1(I)=BLANK
35    NS1=NS+1
      DO 40 I=1,NN
40    LINE1(NS+I)=LINE(I:I)
10    WRITE(IO,202) (LINE1(I),I=1,60)
60    WRITE(IO,203)
      RETURN
C
C       FORMAT STATEMENTS
101   FORMAT (A60)
201   FORMAT(1H1//////////1H ,16X,68(1H*))
202   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,3X,60A1,3X,1H*)
203   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,19X,'PROGRAM AS OF   ',
     1'30 JULY 1996',20X,1H*/1H ,16X,1H*,66X,1H*/1H ,16X,68(1H*)
     2 /1H1)
      END
C
C       *******************************************************
C      *                                                       *
C      *                  SUBROUTINE OFILE                     *
C      *                                                       *
C      *            VERSION CURRENT AS OF 10/01/87             *
C      *                                                       *
C       *******************************************************
C
      SUBROUTINE OFILE
      CHARACTER*50 IFNAME,OFNAME
      CHARACTER*1 STAR
      COMMON /IOUNIT/ IN,IO
      DATA STAR/'*'/
      IN=5
      IO=6
      WRITE(*,5)
      READ(*,7) IFNAME
      WRITE(*,6)
      READ(*,7) OFNAME
      OPEN (IN,FILE=IFNAME,STATUS='OLD')
      IF(OFNAME(1:1).EQ.STAR) IO=1
      IF(OFNAME(1:1).NE.STAR) OPEN (IO,FILE=OFNAME)
      RETURN
C
C       FORMAT STATEMENTS
5     FORMAT(5X,'TYPE IN INPUT FILE NAME')
6     FORMAT(5X,'TYPE IN OUTPUT FILE NAME')
7     FORMAT(A50)
      END
```

```
FINITE Validation Problem -- 1-D Solute transport in a finite-length
soil column with a first-type boundary condition at x=0 with Pu decay
and half-life of 24110 yr and kd of 130 ml/g
Model Parameters:  L=300.0 m, V=1.7945E-3 m/yr, D=8.9723E-3 m**2/yr
                   K1=2.875E-5 per yr, CO=1.0 mg/L
====
   1  61   8  50   1
MG/L       M/YR        M**2/YR  PER YR    METERS     YEARS
      1.0 1.7945E-3 8.9723E-3  2.875E-5     300.0       1.2
      0.0       5.0      10.0      15.0      20.0      25.0      30.0      35.0
     40.0      45.0      50.0      55.0      60.0      65.0      70.0      75.0
     80.0      85.0      90.0      95.0     100.0     105.0     110.0     115.0
    120.0     125.0     130.0     135.0     140.0     145.0     150.0     155.0
    160.0     165.0     170.0     175.0     180.0     185.0     190.0     195.0
    200.0     205.0     210.0     215.0     220.0     225.0     230.0     235.0
    240.0     245.0     250.0     255.0     260.0     265.0     270.0     275.0
    280.0     285.0     290.0     295.0     300.0
      1E+4    1.5E+4      2E+4    2.5E+4      3E+4    3.5E+4      4E+4    4.5E+4
```

1

```
*******************************************************************
*                                                                 *
*   FINITE Validation Problem -- 1-D Solute transport in a finit  *
*                                                                 *
*   soil column with a first-type boundary condition at x=0 with  *
*                                                                 *
*           and half-life of 24110 yr and kd of 130 ml/g          *
*                                                                 *
*   Model Parameters:  L=300.0 m, V=1.7945E-3 m/yr, D=8.9723E-3   *
*                                                                 *
*                          K1=2.875E-5 per yr, CO=1.0 mg/L        *
*                                                                 *
*                   PROGRAM AS OF  30 JULY 1996                   *
*                                                                 *
*******************************************************************
```

1

ANALYTICAL SOLUTION TO THE ONE-DIMENSIONAL
ADVECTIVE-DISPERSIVE SOLUTE-TRANSPORT EQUATION
FOR A SYSTEM OF FINITE LENGTH

0 INPUT DATA

----

0 FIRST-TYPE BOUNDARY CONDITION AT X = 0.0

0 NUMBER OF X-COORDINATES (NX) = 61

NUMBER OF TIME VALUES (NT) = 8

NUMBER OF ROOTS USED IN INFINITE SERIES SUMMATION (NROOT) = 50

0 SOLUTE CONCENTRATION ON MODEL BOUNDARY (CO) = 1.000000E+00 MG/L

GROUND-WATER VELOCITY IN X-DIRECTION (VX) = 1.794500E-03 M/YR

DISPERSION IN THE X-DIRECTION (DX) = 8.972300E-03 M**2/YR

FIRST-ORDER SOLUTE-DECAY RATE (DK) = 2.875000E-05 PER YR

LENGTH OF FINITE FLOW SYSTEM (XL) = 3.000000E+02 METERS

PLOT SCALING FACTOR (XSCLP) = 1.200000E+00

0 X-COORDINATES AT WHICH SOLUTE CONCENTRATIONS WILL BE CALCULATED, IN METERS

0.0000	5.0000	10.0000	15.0000	20.0000	25.0000	30.0000	35.0000
40.0000	45.0000	50.0000	55.0000	60.0000	65.0000	70.0000	75.0000
80.0000	85.0000	90.0000	95.0000	100.0000	105.0000	110.0000	115.0000
120.0000	125.0000	130.0000	135.0000	140.0000	145.0000	150.0000	155.0000
160.0000	165.0000	170.0000	175.0000	180.0000	185.0000	190.0000	195.0000
200.0000	205.0000	210.0000	215.0000	220.0000	225.0000	230.0000	235.0000
240.0000	245.0000	250.0000	255.0000	260.0000	265.0000	270.0000	275.0000
280.0000	285.0000	290.0000	295.0000	300.0000			

0 TIMES AT WHICH SOLUTE CONCENTRATIONS WILL BE CALCULATED, IN YEARS

10000.0000 15000.0000 20000.0000 25000.0000 30000.0000 35000.0000 40000.0000 45000.0000

1

SOLUTE CONCENTRATION AS A FUNCTION OF TIME * INDICATES SOLUTION DID NOT CONVERGE

TIME VALUES, IN YEARS

X-COORDINATE, IN METERS	10000.0000	15000.0000	20000.0000	25000.0000	30000.0000	35000.0000	40000.0000	45000.0000
	SOLUTE CONCENTRATION, IN MG/L							
0.0000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
5.0000	0.89683*	0.91703	0.92375	0.92629	0.92734	0.92779	0.92799	0.92808
10.0000	0.77266*	0.82851	0.84810	0.85574	0.85892	0.86031	0.86093	0.86122
15.0000	0.62823*	0.73132	0.77079	0.78692	0.79385	0.79693	0.79833	0.79899
20.0000	0.47406*	0.62483	0.68998	0.71842	0.73113	0.73694	0.73966	0.74094
25.0000	0.32728*	0.51186	0.60485	0.64897	0.66976	0.67962	0.68434	0.68663
30.0000	0.20438*	0.39855	0.51610	0.57783	0.60884	0.62421	0.63182	0.63558
35.0000	0.11444*	0.29269	0.42609	0.50499	0.54772	0.57003	0.58149	0.58734
40.0000	0.05707*	0.20143	0.33849	0.43132	0.48614	0.51652	0.53282	0.54142
45.0000	0.02523*	0.12923	0.25747	0.35855	0.42434	0.46335	0.48534	0.49740
50.0000	0.00985*	0.07696	0.18671	0.28895	0.36310	0.41049	0.43872	0.45485
55.0000	0.00338*	0.04241	0.12862	0.22497	0.30363	0.35823	0.39279	0.41348
60.0000	0.00102*	0.02156	0.08392	0.16868	0.24739	0.30717	0.34761	0.37308
65.0000	0.00027*	0.01009	0.05173	0.12149	0.19589	0.25817	0.30344	0.33357
70.0000	0.00006*	0.00434	0.03007	0.08385	0.15038	0.21221	0.26076	0.29504
75.0000	0.00001*	0.00172	0.01645	0.05536	0.11168	0.17022	0.22014	0.25771
80.0000	0.00000*	0.00062	0.00846	0.03490	0.08011	0.13299	0.18225	0.22192
85.0000	0.00000*	0.00021	0.00409	0.02099	0.05540	0.10105	0.14771	0.18809
90.0000	0.00000*	0.00006	0.00185	0.01202	0.03690	0.07454	0.11702	0.15667
95.0000	0.00000*	0.00002	0.00079	0.00655	0.02364	0.05333	0.09048	0.12807
100.0000	0.00000*	0.00000	0.00031	0.00340	0.01455	0.03695	0.06821	0.10259
105.0000	0.00000	0.00000	0.00012	0.00167	0.00860	0.02478	0.05007	0.08045
110.0000	0.00000*	0.00000	0.00004	0.00078	0.00488	0.01607	0.03576	0.06170
115.0000	0.00000	0.00000	0.00001	0.00035	0.00265	0.01007	0.02482	0.04622
120.0000	0.00000*	0.00000	0.00000	0.00015	0.00138	0.00609	0.01674	0.03380
125.0000	0.00000*	0.00000	0.00000	0.00006	0.00069	0.00356	0.01096	0.02411
130.0000	0.00000*	0.00000	0.00000	0.00002	0.00033	0.00200	0.00696	0.01677
135.0000	0.00000*	0.00000	0.00000	0.00001	0.00015	0.00109	0.00429	0.01136
140.0000	0.00000*	0.00000	0.00000	0.00000	0.00007	0.00057	0.00256	0.00749
145.0000	0.00000*	0.00000	0.00000	0.00000	0.00003	0.00029	0.00148	0.00481
150.0000	0.00000*	0.00000	0.00000	0.00000	0.00001	0.00014	0.00083	0.00300
155.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00007	0.00045	0.00183
160.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00003	0.00024	0.00108
165.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00001	0.00012	0.00062
170.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00001	0.00006	0.00035
175.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00003	0.00019
180.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00010
185.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00005
190.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00003
195.0000	0.00000*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001
200.0000	-0.00001*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001

205.0000	!	0.00003*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
210.0000	!	-0.00005*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
215.0000	!	0.00006*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
220.0000	!	-0.00005*	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

SOLUTE CONCENTRATION AS A FUNCTION OF TIME = (CONTINUED)

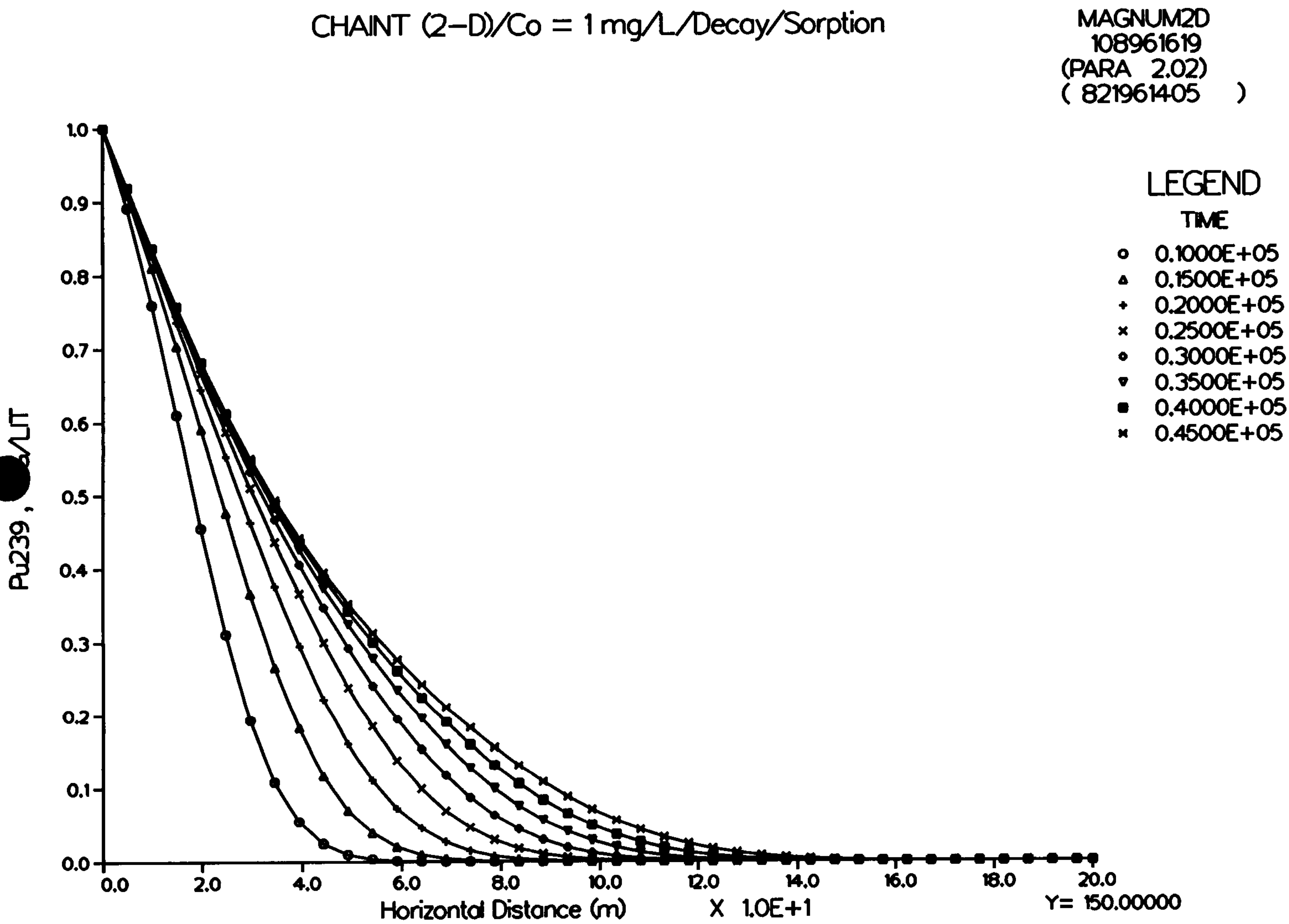
0 TIME VALUES, IN YEARS

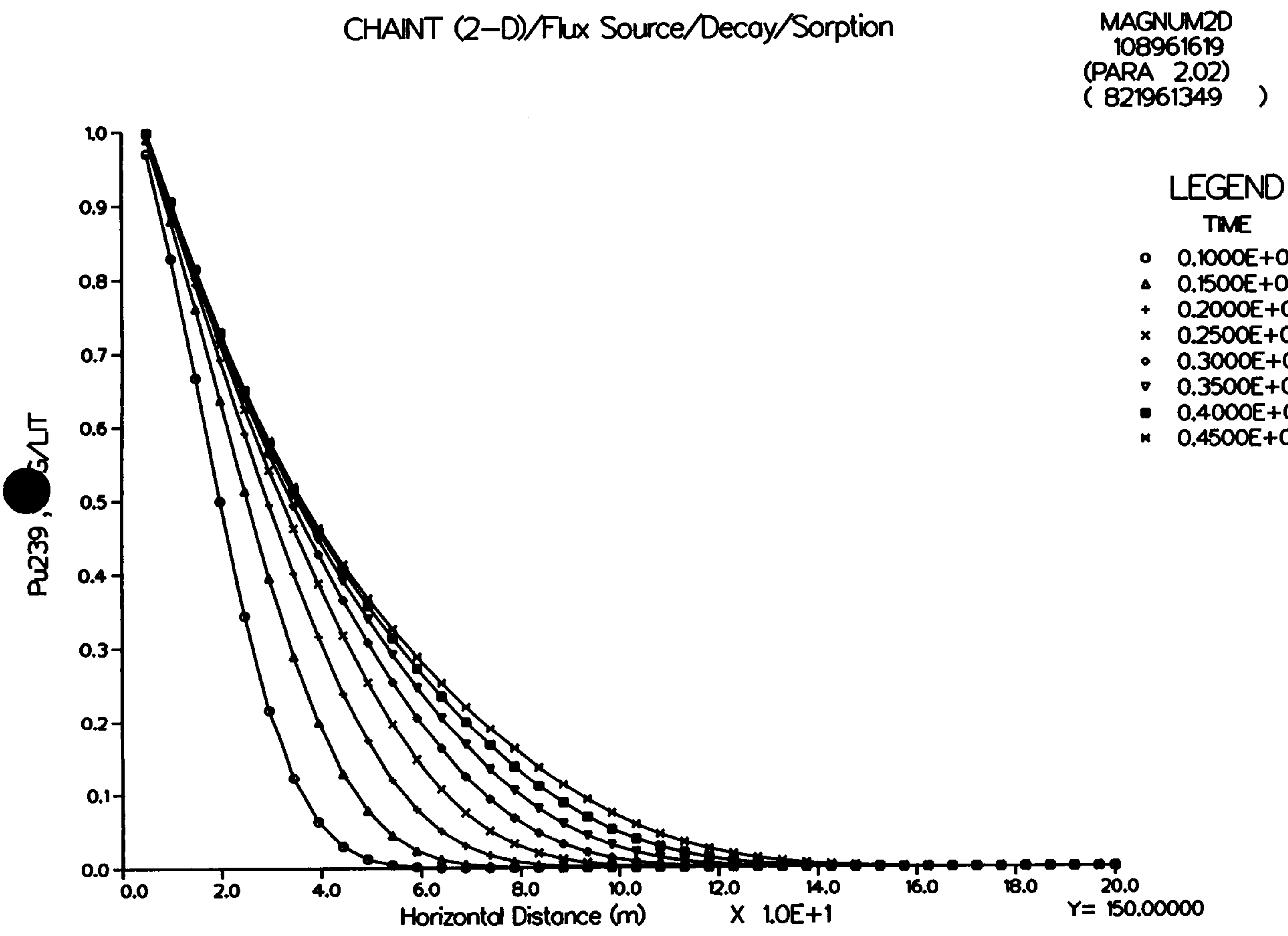
X-COORDINATE, IN METERS	!	10000.0000	15000.0000	20000.0000	25000.0000	30000.0000	35000.0000	40000.0000	45000.0000
	!	SOLUTE CONCENTRATION, IN MG/L							
225.0000	!	-0.00001*	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
230.0000	!	0.00018	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
235.0000	!	-0.00047*	-0.00046	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
240.0000	!	0.00089*	0.00001	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
245.0000	!	-0.00127*	0.00012	-0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
250.0000	!	0.00126*	-0.00001	0.00001	0.00000	0.00000	-0.00001	0.00000	0.00000
255.0000	!	-0.00019*	-0.00003	-0.00001	-0.00001	0.00000	0.00000	0.00000	0.00000
260.0000	!	-0.00285*	0.00021	-0.00004	0.00000	-0.00001	0.00002	0.00000	0.00000
265.0000	!	0.00868*	-0.00010	0.00002	0.00004	-0.00001	0.00000	0.00000	0.00000
270.0000	!	-0.01723*	0.00007	0.00043	-0.00003	0.00004	0.00001	0.00000	0.00000
275.0000	!	0.02606*	-0.00015	-0.00018	-0.00008	0.00001	-0.00001	-0.00001	0.00000
280.0000	!	-0.02831*	-0.00046	0.00002	0.00014	-0.00010	-0.00003	-0.00001	0.00000
285.0000	!	0.01080*	0.00070	0.00047	0.00077	0.00001	0.00002	0.00002	0.00000
290.0000	!	0.04549*	0.00188	-0.00070	-0.00047	0.00028	0.00008	0.00005	-0.00001
295.0000	!	-0.16034*	0.00372	-0.00226	-0.00043	-0.00010	-0.00005	-0.00004	0.00001
300.0000	!	0.33809*	0.00346	0.00232	0.00125	-0.00073	-0.00021	-0.00015	0.00002

7.2.4 Validation Test Case 4 Results - Two Dimensional with Decay and Sorption

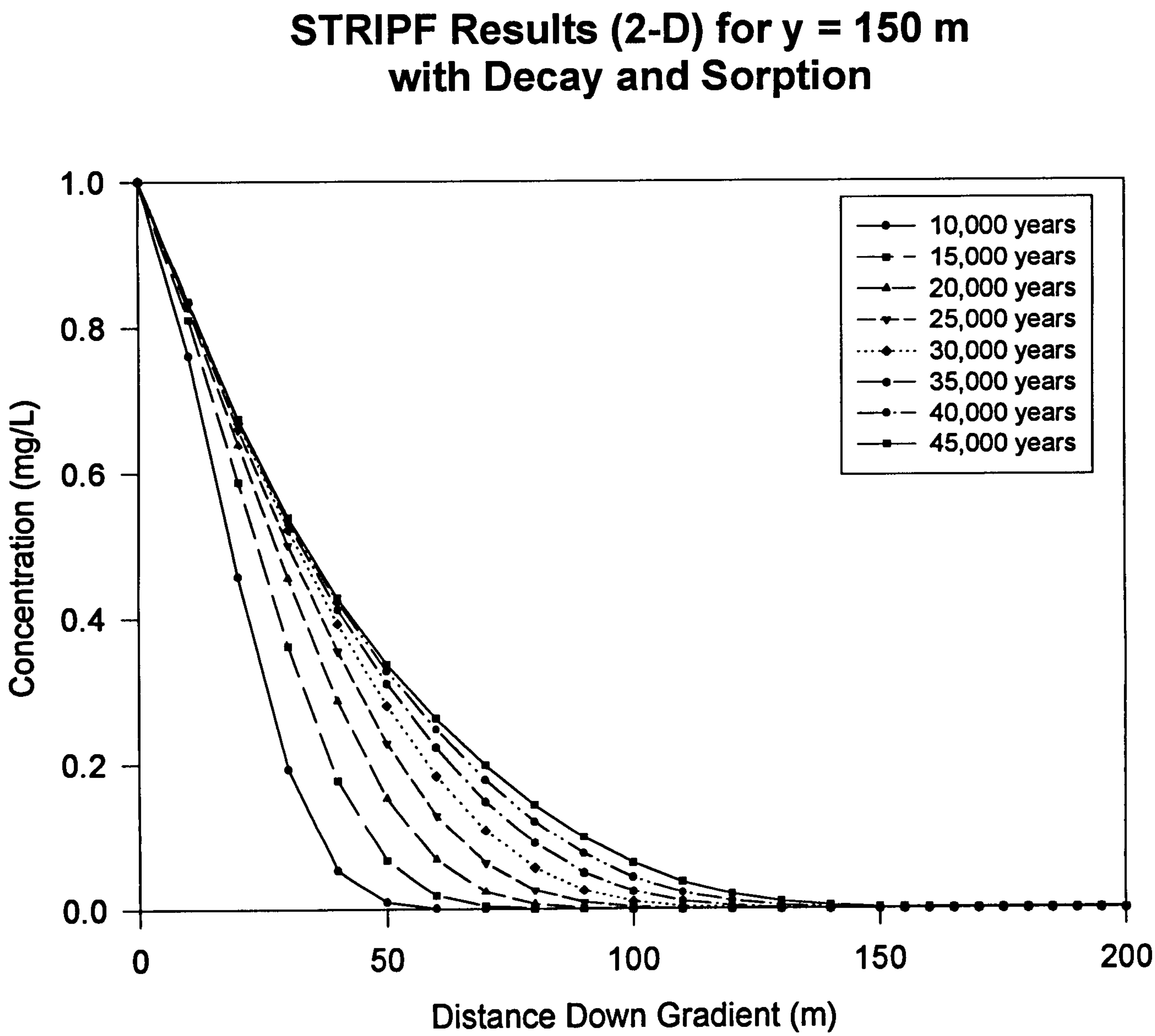
Results from the CHAINT simulations for constant source concentration and constant flux are presented in this section. Overlaying the figures reveals the contoured results are consistent for both CHAINT scenarios.

The STRIPF input file and results are provided in this section. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from STRIPF compare favorably and overlaying the figures reveals the results are consistent.


CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
MAGNUM2D
108961619
(PARA 2.02)
(821961405)
LEGEND
TIME
0.1000E+05
0.1500E+05
0.2000E+05
0.2500E+05
0.3000E+05
0.3500E+05
0.4000E+05
0.4500E+05
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Horizontal Distance (m)
X 1.0E+1
Y= 150.00000



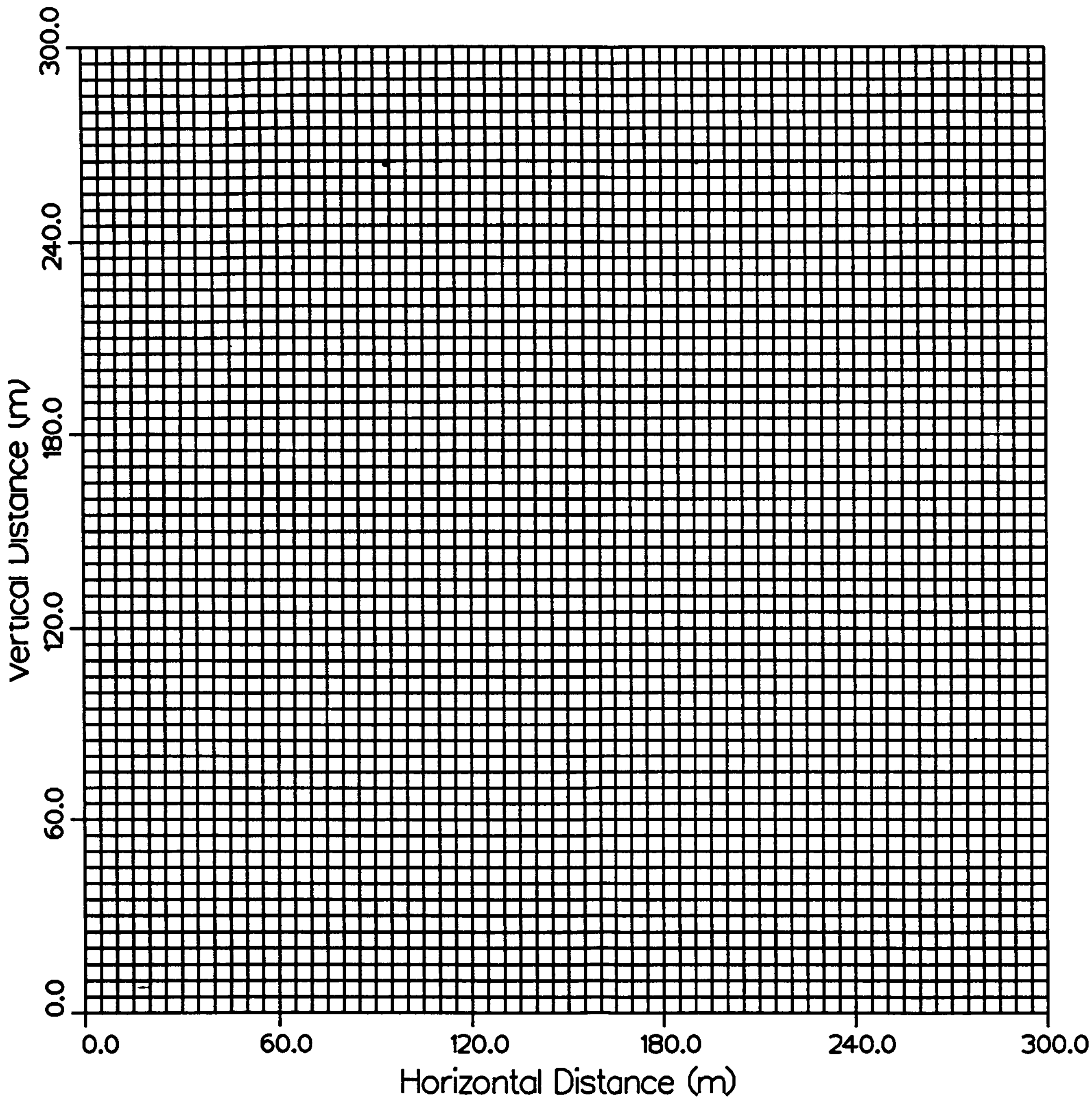
CHAINT (2-D)/Flux Source/Decay/Sorption
MAGNUM2D
108961619
(PARA 2.02)
(821961349)
LEGEND
TIME
0.1000E+05
0.1500E+05
0.2000E+05
0.2500E+05
0.3000E+05
0.3500E+05
0.4000E+05
0.4500E+05
Pu239 , G/LIT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Horizontal Distance (m)
X 1.0E+1
Y= 150.00000



STRIPF Results (2-D) for y = 150 m
with Decay and Sorption
10,000 years
15,000 years
20,000 years
25,000 years
30,000 years
35,000 years
40,000 years
45,000 years
Concentration (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
Distance Down Gradient (m)

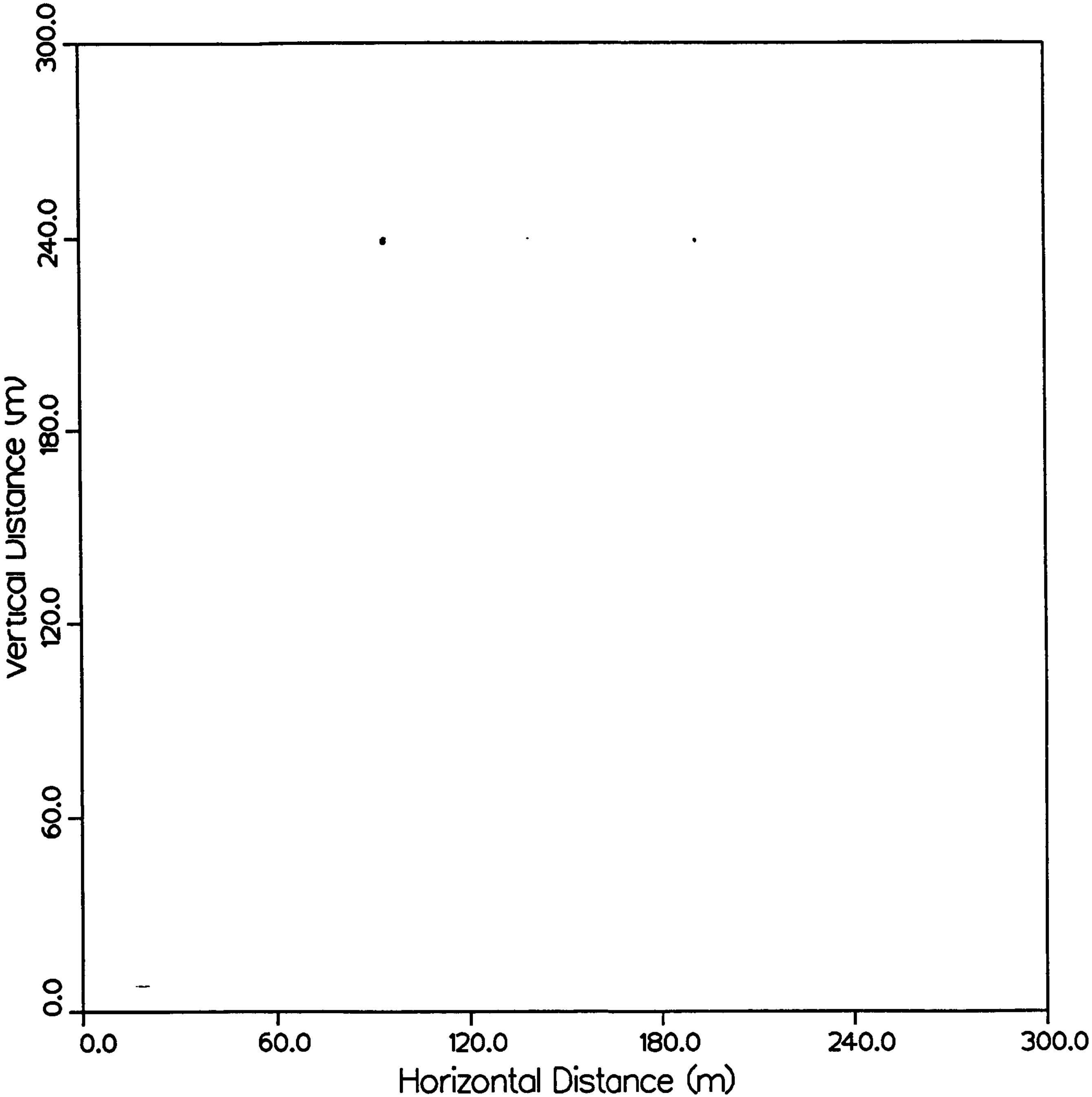
MAGNUM Geometry Grid for 2-D Comparison with STRIPF
FINITE ELEMENT GRID

(PLT 2.00)
(802960838)
(0)



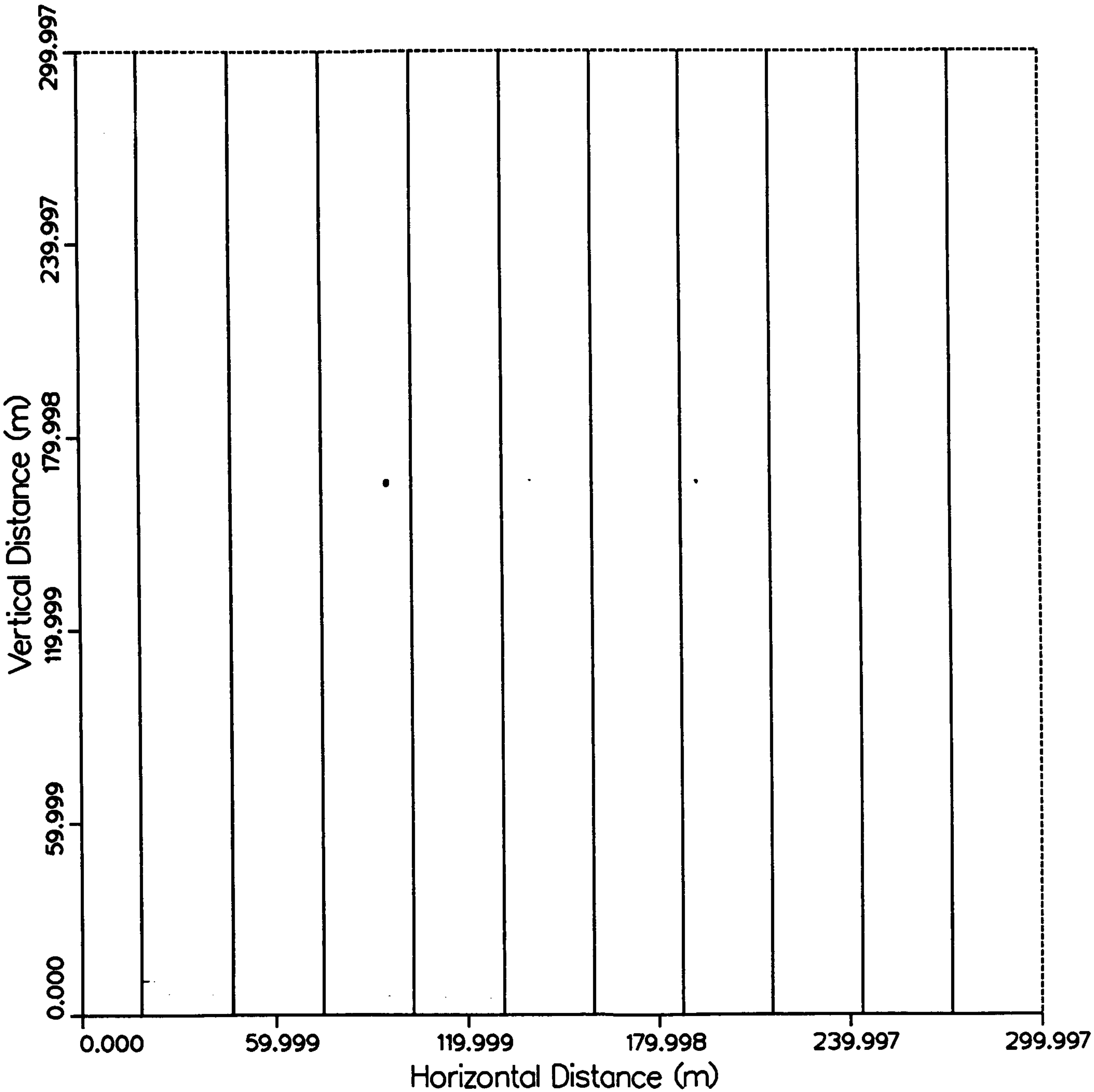
MAGNUM Geometry Grid for 2-D Comparison with STRIPF
MATERIAL TYPE BOUNDARIES

(PLT 2.00)
(802960838)
(0)



MAGNUM Results for 2-D
HEAD 1, METERS

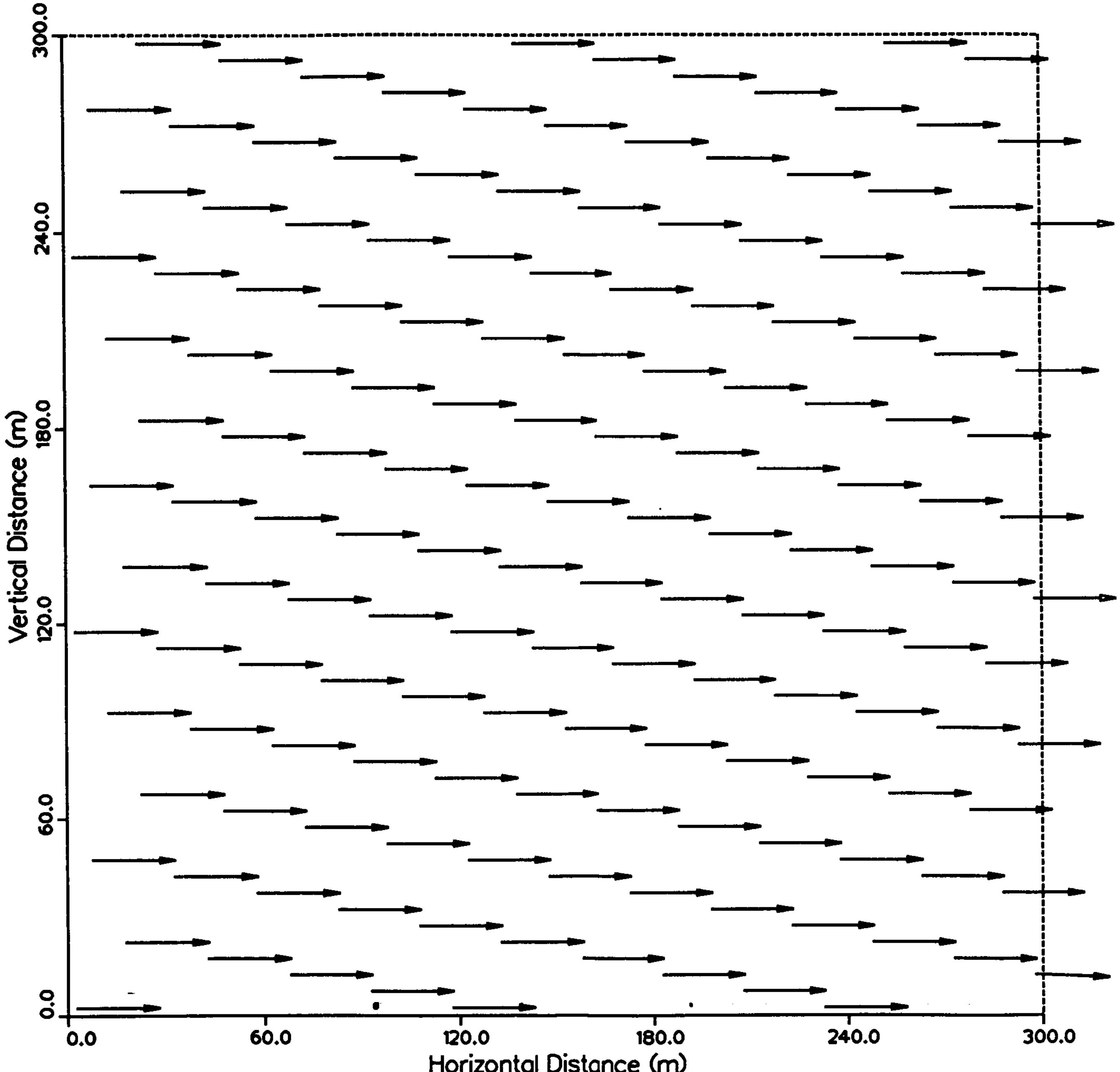
MAGNUM2D
108961619
(CONT 2.03)
(801961623)



Time = 1.00E-20

MAGNUM2D 3.20
****
(VELP 2.00)
(731961544)

DARCY VELOCITY VECTOR PLOT
2-D Comparison with STRIPF
SCALED MAGNITUDES, TRUE DIRECTIONS



Scale Factor 2.00

Time = 0.000

```
MAGNUM - 2-D Test case for comparison with STRIPF
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
    1     0      1  11041  3600    1    0    0     0    1     1    0
#  irs  isv  icf  igi  ig  ivel inpt icsv
    0   13    0   10    0   12    0    0
   ssf   alfa  tref
   0.0    1.8   20.0
#  nts  ntsg   dlt
    1     1     1000.
 9999     1     1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#   n       To       Ho
    1    20.000    0.5327
#  kspec
   242
#        n      n1 n2  Tbc      Hbc
      10860        0  1   20.0000    0.0000
      10861        0  1   20.0000    0.0000
      10862        0  1   20.0000    0.0000
      10865        0  1   20.0000    0.0000
      10866        0  1   20.0000    0.0000
      10868        0  1   20.0000    0.0000
      10869        0  1   20.0000    0.0000
      10871        0  1   20.0000    0.0000
      10872        0  1   20.0000    0.0000
      10874        0  1   20.0000    0.0000
      10875        0  1   20.0000    0.0000
      10877        0  1   20.0000    0.0000
      10878        0  1   20.0000    0.0000
      10880        0  1   20.0000    0.0000
      10881        0  1   20.0000    0.0000
      10883        0  1   20.0000    0.0000
      10884        0  1   20.0000    0.0000
      10886        0  1   20.0000    0.0000
      10887        0  1   20.0000    0.0000
      10889        0  1   20.0000    0.0000
      10890        0  1   20.0000    0.0000
      10892        0  1   20.0000    0.0000
      10893        0  1   20.0000    0.0000
      10895        0  1   20.0000    0.0000
      10896        0  1   20.0000    0.0000
      10898        0  1   20.0000    0.0000
      10899        0  1   20.0000    0.0000
      10901        0  1   20.0000    0.0000
      10902        0  1   20.0000    0.0000
      10904        0  1   20.0000    0.0000
      10905        0  1   20.0000    0.0000
      10907        0  1   20.0000    0.0000
      10908        0  1   20.0000    0.0000
      10910        0  1   20.0000    0.0000
      10911        0  1   20.0000    0.0000
      10913        0  1   20.0000    0.0000
      10914        0  1   20.0000    0.0000
      10916        0  1   20.0000    0.0000
      10917        0  1   20.0000    0.0000
      10919        0  1   20.0000    0.0000
      10920        0  1   20.0000    0.0000
      10922        0  1   20.0000    0.0000
      10923        0  1   20.0000    0.0000
```

10925	0	1	20.0000	0.0000
10926	0	1	20.0000	0.0000
10928	0	1	20.0000	0.0000
10929	0	1	20.0000	0.0000
10931	0	1	20.0000	0.0000
10932	0	1	20.0000	0.0000
10934	0	1	20.0000	0.0000
10935	0	1	20.0000	0.0000
10937	0	1	20.0000	0.0000
10938	0	1	20.0000	0.0000
10940	0	1	20.0000	0.0000
10941	0	1	20.0000	0.0000
10943	0	1	20.0000	0.0000
10944	0	1	20.0000	0.0000
10946	0	1	20.0000	0.0000
10947	0	1	20.0000	0.0000
10949	0	1	20.0000	0.0000
10950	0	1	20.0000	0.0000
10952	0	1	20.0000	0.0000
10953	0	1	20.0000	0.0000
10955	0	1	20.0000	0.0000
10956	0	1	20.0000	0.0000
10958	0	1	20.0000	0.0000
10959	0	1	20.0000	0.0000
10961	0	1	20.0000	0.0000
10962	0	1	20.0000	0.0000
10964	0	1	20.0000	0.0000
10965	0	1	20.0000	0.0000
10967	0	1	20.0000	0.0000
10968	0	1	20.0000	0.0000
10970	0	1	20.0000	0.0000
10971	0	1	20.0000	0.0000
10973	0	1	20.0000	0.0000
10974	0	1	20.0000	0.0000
10976	0	1	20.0000	0.0000
10977	0	1	20.0000	0.0000
10979	0	1	20.0000	0.0000
10980	0	1	20.0000	0.0000
10982	0	1	20.0000	0.0000
10983	0	1	20.0000	0.0000
10985	0	1	20.0000	0.0000
10986	0	1	20.0000	0.0000
10988	0	1	20.0000	0.0000
10989	0	1	20.0000	0.0000
10991	0	1	20.0000	0.0000
10992	0	1	20.0000	0.0000
10994	0	1	20.0000	0.0000
10995	0	1	20.0000	0.0000
10997	0	1	20.0000	0.0000
10998	0	1	20.0000	0.0000
11000	0	1	20.0000	0.0000
11001	0	1	20.0000	0.0000
11003	0	1	20.0000	0.0000
11004	0	1	20.0000	0.0000
11006	0	1	20.0000	0.0000
11007	0	1	20.0000	0.0000
11009	0	1	20.0000	0.0000
11010	0	1	20.0000	0.0000
11012	0	1	20.0000	0.0000
11013	0	1	20.0000	0.0000

11015	0	1	20.0000	0.0000
11016	0	1	20.0000	0.0000
11018	0	1	20.0000	0.0000
11019	0	1	20.0000	0.0000
11021	0	1	20.0000	0.0000
11022	0	1	20.0000	0.0000
11024	0	1	20.0000	0.0000
11025	0	1	20.0000	0.0000
11027	0	1	20.0000	0.0000
11028	0	1	20.0000	0.0000
11030	0	1	20.0000	0.0000
11031	0	1	20.0000	0.0000
11033	0	1	20.0000	0.0000
11034	0	1	20.0000	0.0000
11036	0	1	20.0000	0.0000
11037	0	1	20.0000	0.0000
11039	0	1	20.0000	0.0000
11040	0	1	20.0000	0.0000
121	0	1	20.0000	1.0654
120	0	1	20.0000	1.0654
119	0	1	20.0000	1.0654
118	0	1	20.0000	1.0654
117	0	1	20.0000	1.0654
116	0	1	20.0000	1.0654
115	0	1	20.0000	1.0654
114	0	1	20.0000	1.0654
113	0	1	20.0000	1.0654
112	0	1	20.0000	1.0654
111	0	1	20.0000	1.0654
110	0	1	20.0000	1.0654
109	0	1	20.0000	1.0654
108	0	1	20.0000	1.0654
107	0	1	20.0000	1.0654
106	0	1	20.0000	1.0654
105	0	1	20.0000	1.0654
104	0	1	20.0000	1.0654
103	0	1	20.0000	1.0654
102	0	1	20.0000	1.0654
101	0	1	20.0000	1.0654
100	0	1	20.0000	1.0654
99	0	1	20.0000	1.0654
98	0	1	20.0000	1.0654
97	0	1	20.0000	1.0654
96	0	1	20.0000	1.0654
95	0	1	20.0000	1.0654
94	0	1	20.0000	1.0654
93	0	1	20.0000	1.0654
92	0	1	20.0000	1.0654
91	0	1	20.0000	1.0654
90	0	1	20.0000	1.0654
89	0	1	20.0000	1.0654
88	0	1	20.0000	1.0654
87	0	1	20.0000	1.0654
86	0	1	20.0000	1.0654
85	0	1	20.0000	1.0654
84	0	1	20.0000	1.0654
83	0	1	20.0000	1.0654
82	0	1	20.0000	1.0654
81	0	1	20.0000	1.0654
80	0	1	20.0000	1.0654

79	0	1	20.0000	1.0654
78	0	1	20.0000	1.0654
77	0	1	20.0000	1.0654
76	0	1	20.0000	1.0654
75	0	1	20.0000	1.0654
74	0	1	20.0000	1.0654
73	0	1	20.0000	1.0654
72	0	1	20.0000	1.0654
71	0	1	20.0000	1.0654
70	0	1	20.0000	1.0654
69	0	1	20.0000	1.0654
68	0	1	20.0000	1.0654
67	0	1	20.0000	1.0654
66	0	1	20.0000	1.0654
65	0	1	20.0000	1.0654
64	0	1	20.0000	1.0654
63	0	1	20.0000	1.0654
62	0	1	20.0000	1.0654
61	0	1	20.0000	1.0654
60	0	1	20.0000	1.0654
59	0	1	20.0000	1.0654
58	0	1	20.0000	1.0654
57	0	1	20.0000	1.0654
56	0	1	20.0000	1.0654
55	0	1	20.0000	1.0654
54	0	1	20.0000	1.0654
53	0	1	20.0000	1.0654
52	0	1	20.0000	1.0654
51	0	1	20.0000	1.0654
50	0	1	20.0000	1.0654
49	0	1	20.0000	1.0654
48	0	1	20.0000	1.0654
47	0	1	20.0000	1.0654
46	0	1	20.0000	1.0654
45	0	1	20.0000	1.0654
44	0	1	20.0000	1.0654
43	0	1	20.0000	1.0654
42	0	1	20.0000	1.0654
41	0	1	20.0000	1.0654
40	0	1	20.0000	1.0654
39	0	1	20.0000	1.0654
38	0	1	20.0000	1.0654
37	0	1	20.0000	1.0654
36	0	1	20.0000	1.0654
35	0	1	20.0000	1.0654
34	0	1	20.0000	1.0654
33	0	1	20.0000	1.0654
32	0	1	20.0000	1.0654
31	0	1	20.0000	1.0654
30	0	1	20.0000	1.0654
29	0	1	20.0000	1.0654
28	0	1	20.0000	1.0654
27	0	1	20.0000	1.0654
26	0	1	20.0000	1.0654
25	0	1	20.0000	1.0654
24	0	1	20.0000	1.0654
23	0	1	20.0000	1.0654
22	0	1	20.0000	1.0654
21	0	1	20.0000	1.0654
20	0	1	20.0000	1.0654

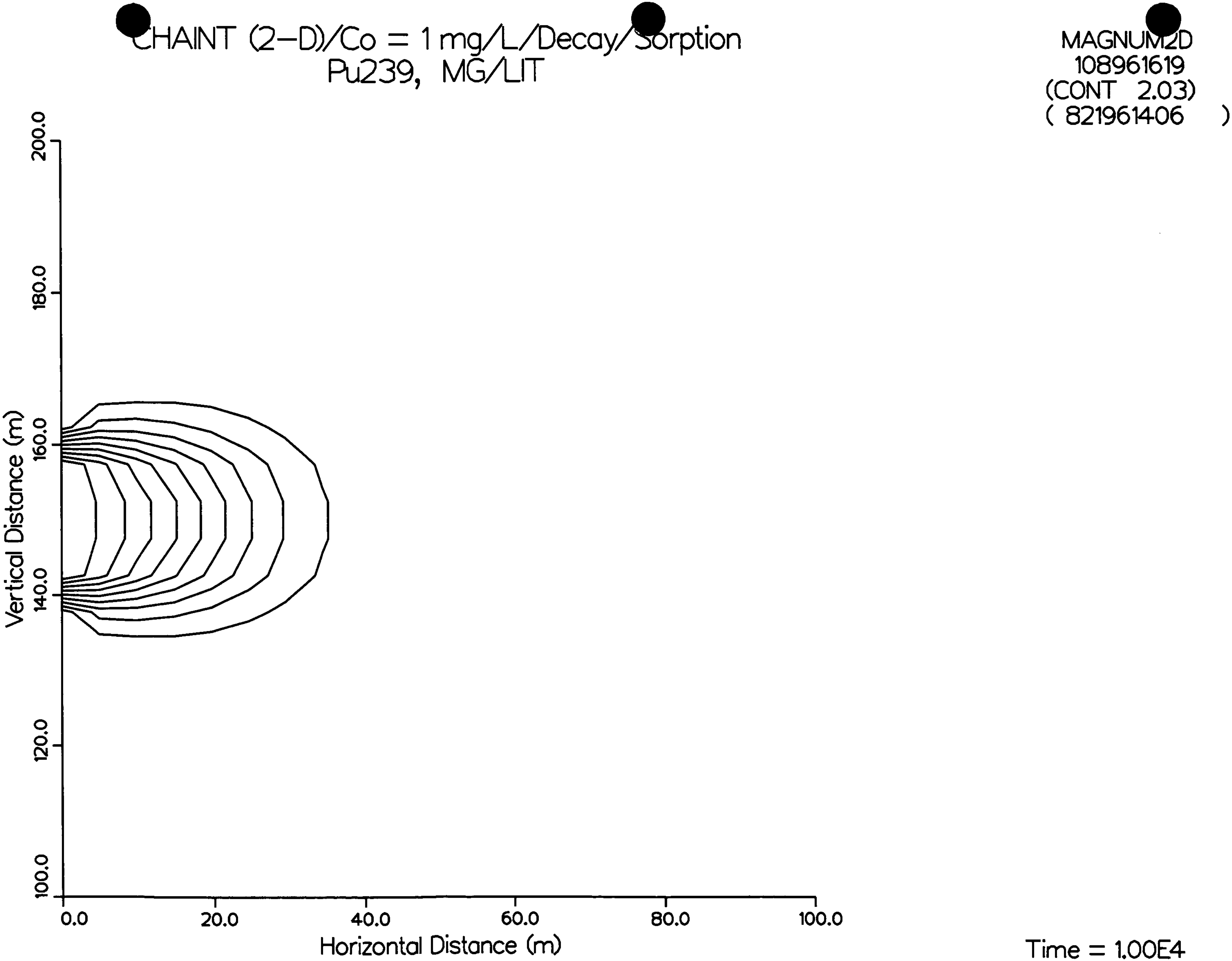
```
       19         0  1   20.0000    1.0654
       18         0  1   20.0000    1.0654
       17         0  1   20.0000    1.0654
       16         0  1   20.0000    1.0654
       15         0  1   20.0000    1.0654
       14         0  1   20.0000    1.0654
       13         0  1   20.0000    1.0654
       12         0  1   20.0000    1.0654
       11         0  1   20.0000    1.0654
       10         0  1   20.0000    1.0654
        9         0  1   20.0000    1.0654
        8         0  1   20.0000    1.0654
        7         0  1   20.0000    1.0654
        6         0  1   20.0000    1.0654
        5         0  1   20.0000    1.0654
        4         0  1   20.0000    1.0654
        3         0  1   20.0000    1.0654
        2         0  1   20.0000    1.0654
        1         0  1   20.0000    1.0654
      #   L    cvm     tkk(1)  tkk(2)  poros     hkax          hkay         nme
#         spl      rhom    alpal    alpat    width
        1         0         0         0       0.07     5.0e-6     5.0e-6     mat1
   1.0e-6     2400         0         0         0
#  nld  nlt  scf
   0    0       0.0
```

```
CHAINT 2-D Test case with decay/sorption (Co=1 mg/L) for comparison with STRIPF
# nqal  ne    np    nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
   1   3600  11041  121    1     0      2     3     0      0     0
# IS1  IS2  IS3  IS4  IS5  IS6  IS7
[illegible]0  11   0    0   14   15   0
[illegible]f  alfa  xscale  yscale  uscale  vscale
   0.  1.8    0.      0.      0.      0.
# nts  ntsg  dlt   zonel  zoner  zonet  zoneb
  200  200   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
  100  100   50.     0.     0.    0.     0.
 9999   0     0      0      0     0      0
#  j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
   1       5.       1.0      2400.      0.07       0.      mat1
# islt
   1
#  L   amu    diag    isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
   1 239.0  2.411E+04   0        0.0       0        0.0    Pu239  0.0
#  i   dml(i,1..n2)  m2/yr
   1   0.0
#  i   xkdi(i,1..n2)  ml/g
   1 130.0
# [illegible]k   Ci
  [illegible]   0.0
#  L     bcs
   1     0.0
   2     0.0
   3     0.0
   4     0.0
   5     0.0
   6     0.0
   7     0.0
   8     0.0
   9     0.0
  10     0.0
  11     0.0
  12     0.0
  13     0.0
  14     0.0
  15     0.0
  16     0.0
  17     0.0
  18     0.0
  19     0.0
  20     0.0
  21     0.0
  22     0.0
  23     0.0
  [illegible]   0.0
  25     0.0
  26     0.0
  27     0.0
  28     0.0
```

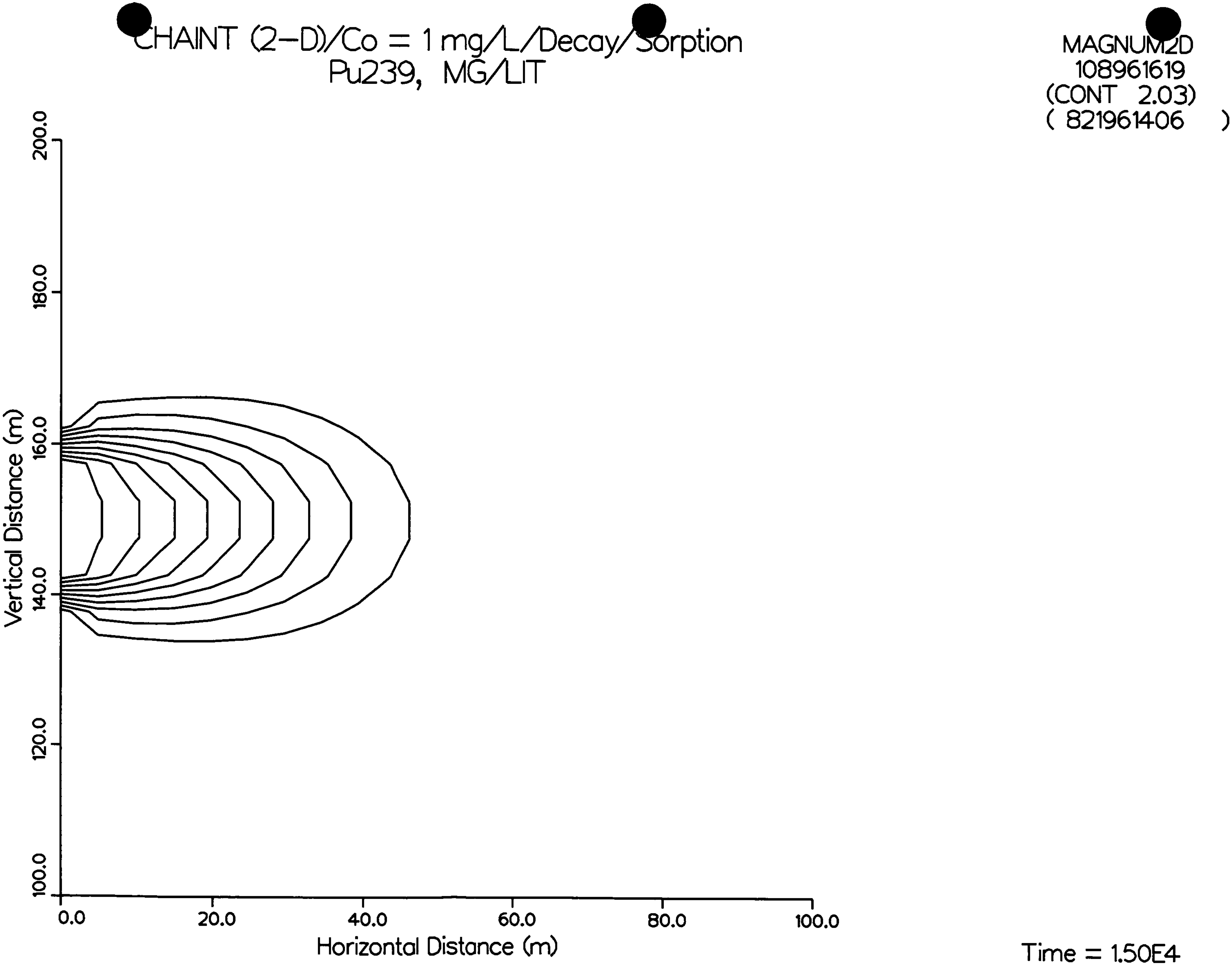
29	0.0
30	0.0
31	0.0
32	0.0
33	0.0
[illegible]	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	1.0
58	1.0
[illegible]	1.0
60	1.0
61	1.0
62	1.0
63	1.0
64	1.0
65	1.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
[illegible]	0.0
[illegible]	0.0
86	0.0
87	0.0
88	0.0

89	0.0
90	0.0
91	0.0
92	0.0
93	0.0
[illegible]	0.0
95	0.0
96	0.0
97	0.0
98	0.0
99	0.0
100	0.0
101	0.0
102	0.0
103	0.0
104	0.0
105	0.0
106	0.0
107	0.0
108	0.0
109	0.0
110	0.0
111	0.0
112	0.0
113	0.0
114	0.0
115	0.0
116	0.0
117	0.0
118	0.0
[illegible]	0.0
120	0.0
121	0.0

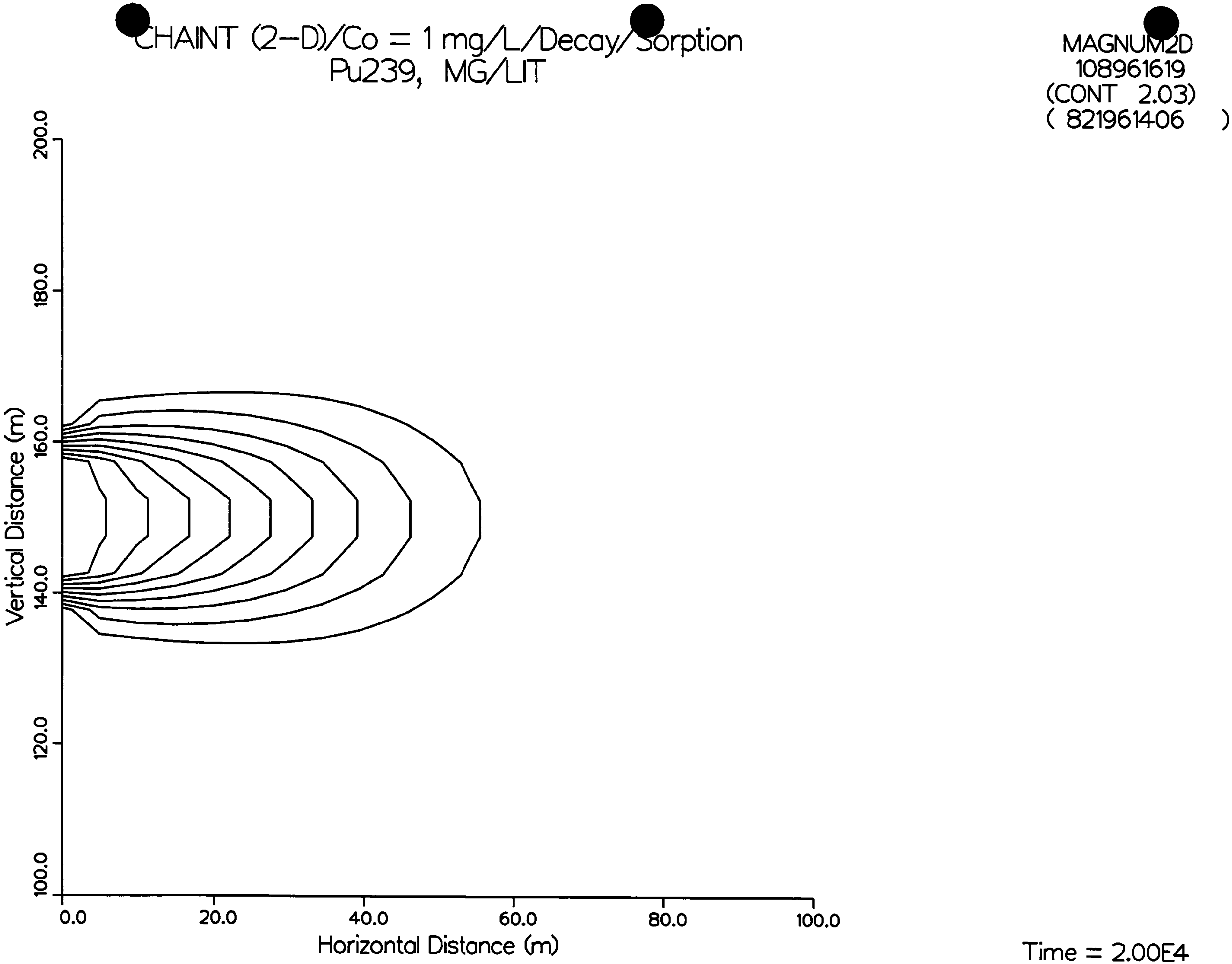
#	nld	scf	relz
	0	1.0	0.



CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961406)
200.0
180.0
160.0
140.0
120.0
100.0
Vertical Distance (m)
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 1.00E4



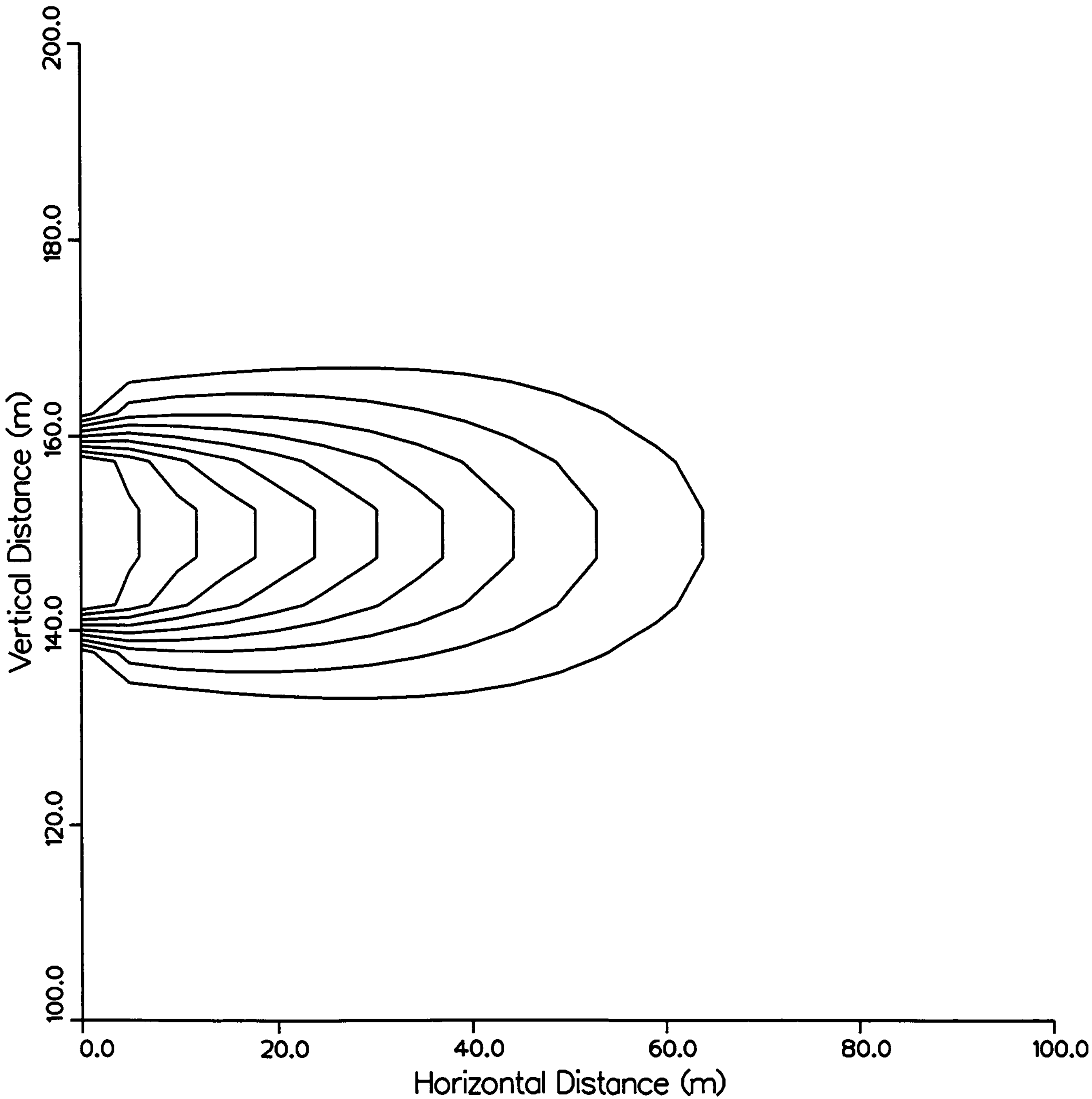
CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961406)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 1.50E4



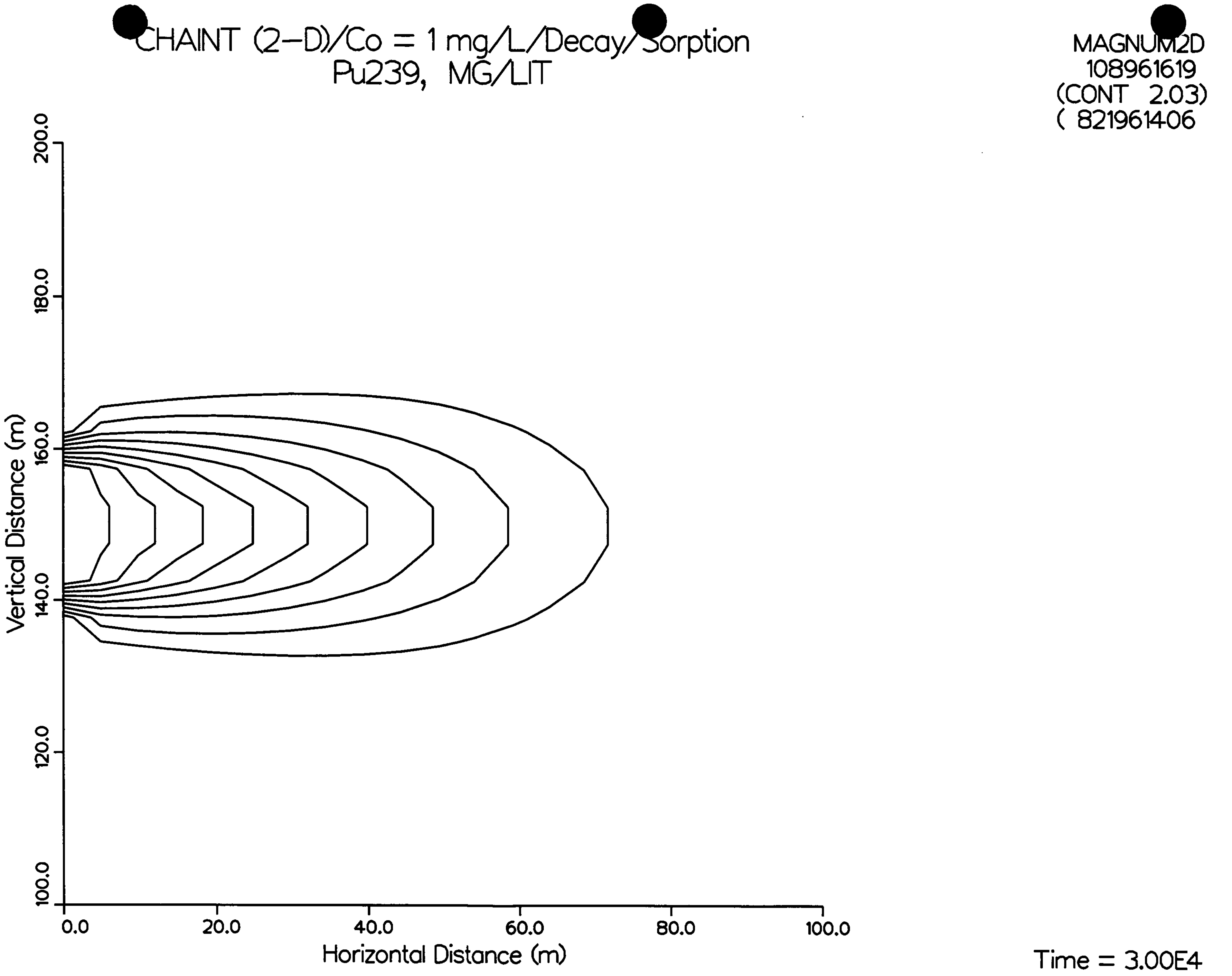
CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961406)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 2.00E4

CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT

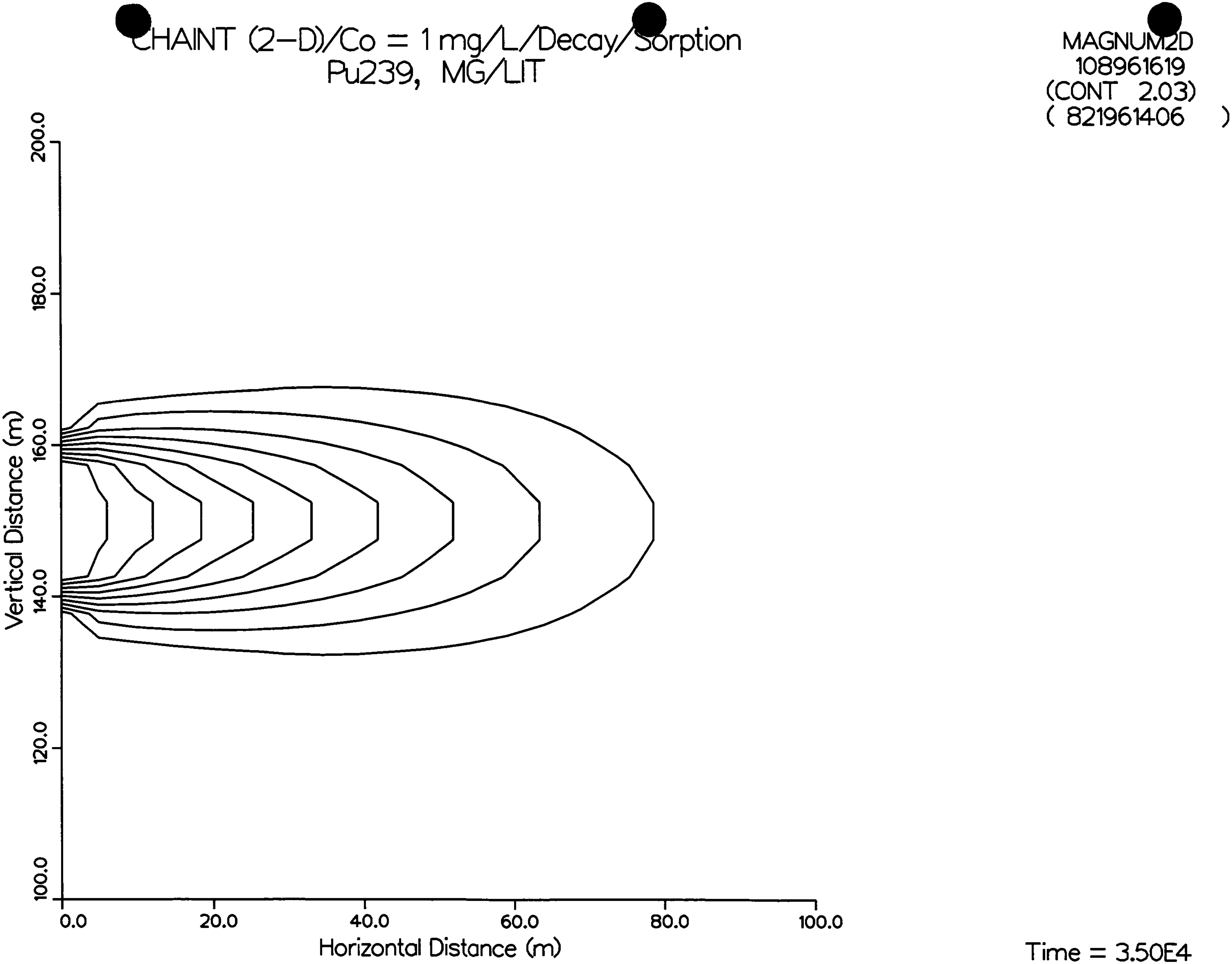
MAGNUM2D
108961619
(CONT 2.03)
(821961406)



Time = 2.50E4

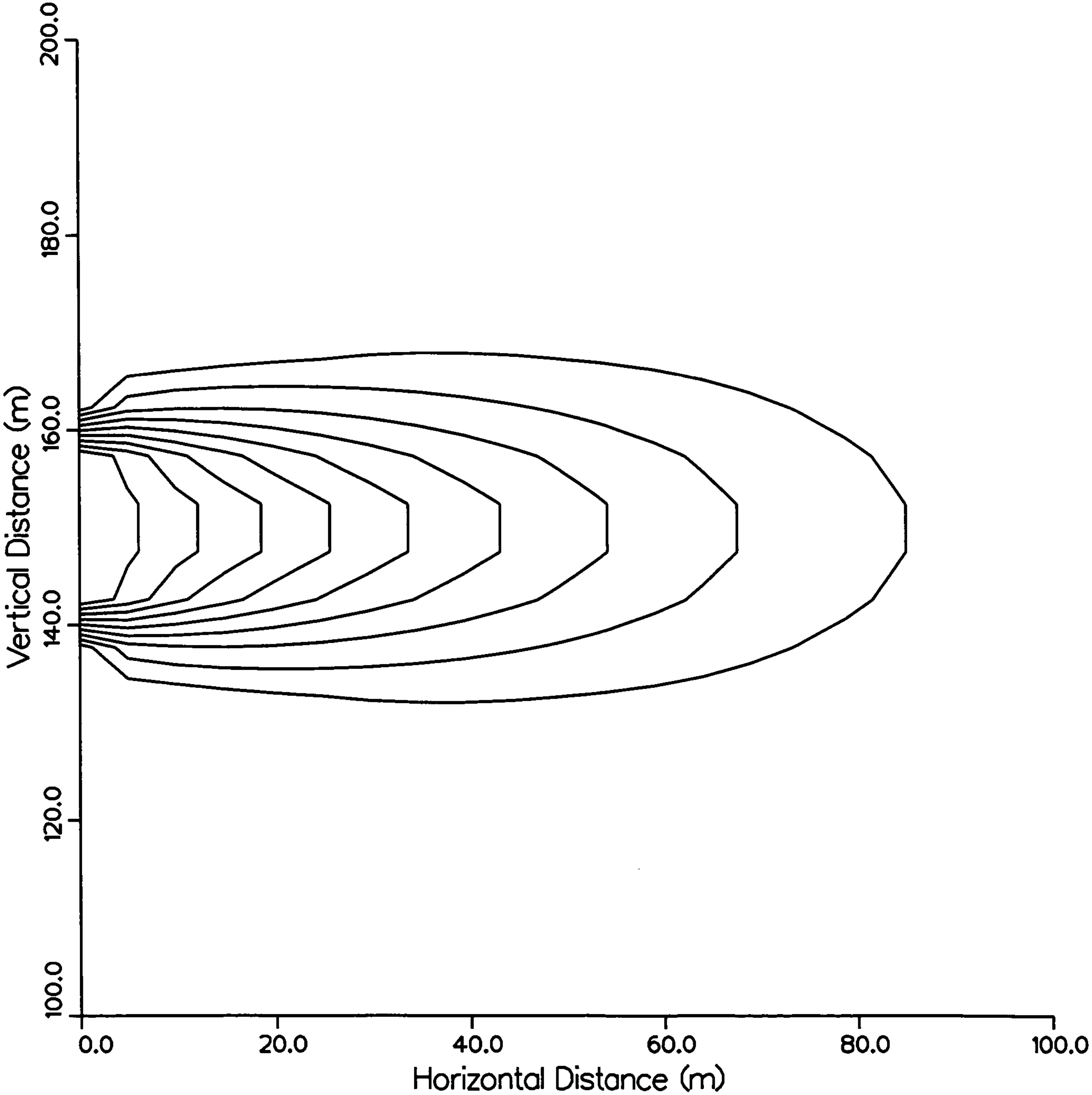


CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961406)
200.0
180.0
160.0
140.0
120.0
100.0
Vertical Distance (m)
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 3.00E4

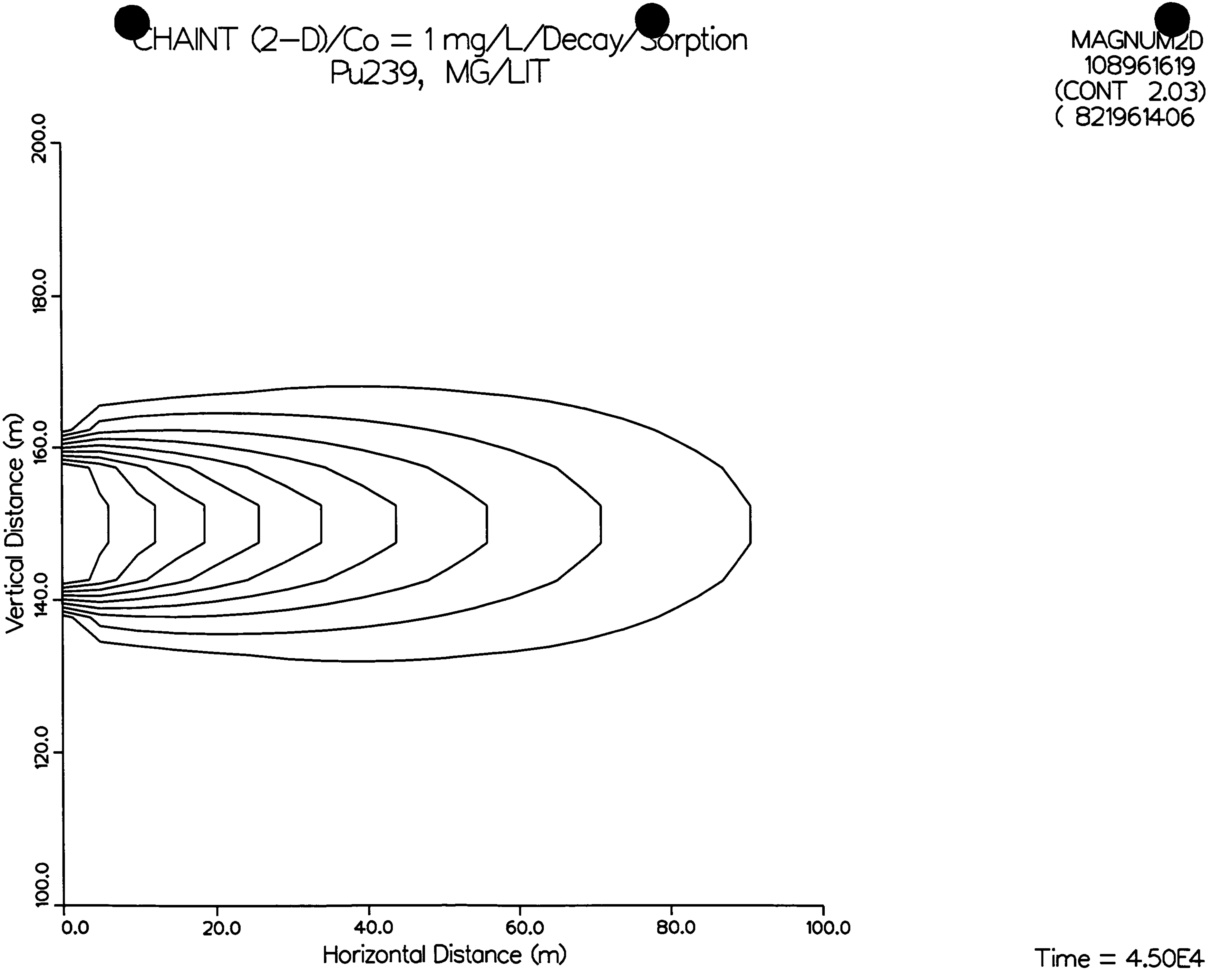

CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961406)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 3.50E4

CHAINT (2–D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT

MAGNUM2D
108961619
(CONT 2.03)
(821961406)



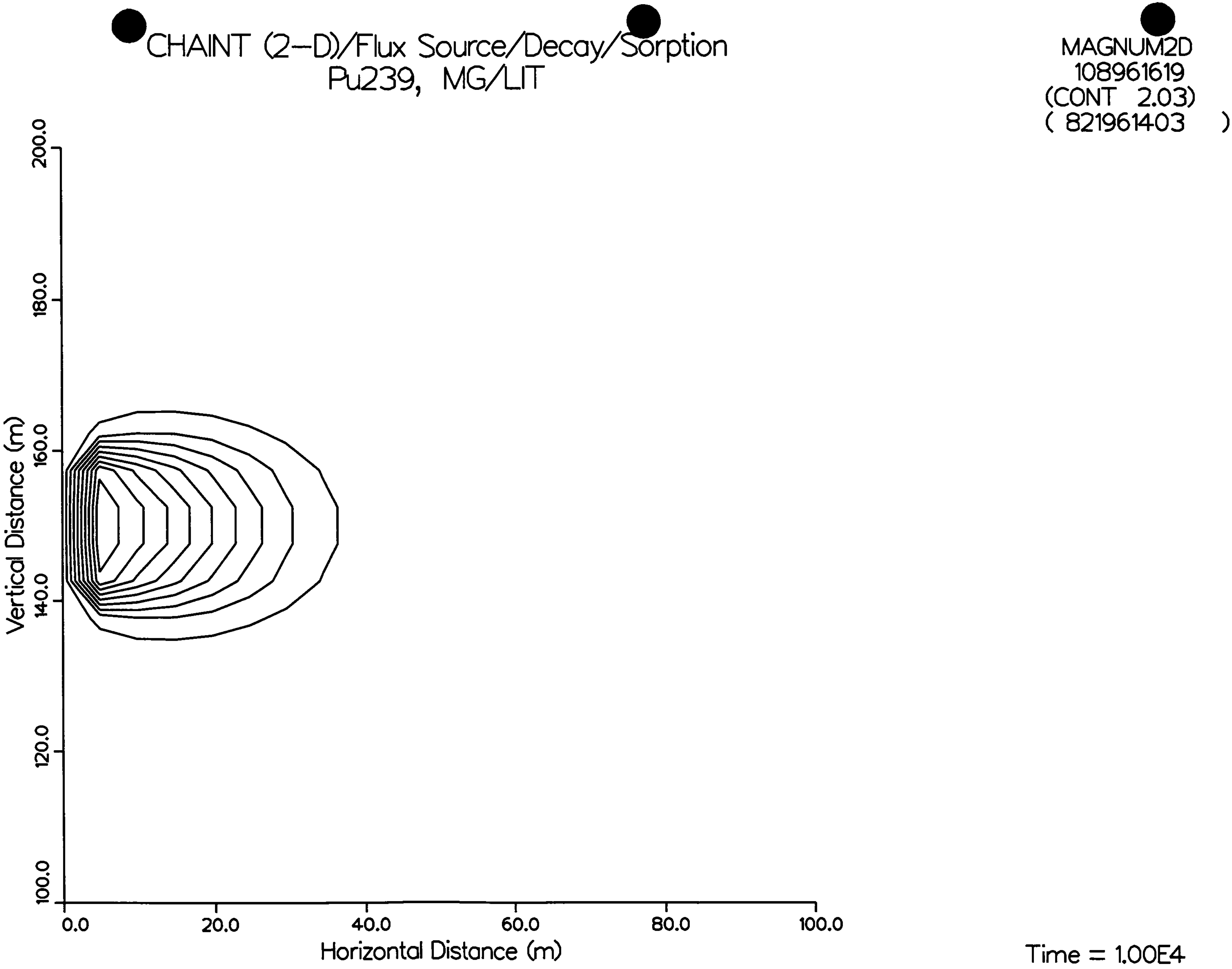
Time = 4.00E4


CHAINT (2-D)/Co = 1 mg/L/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961406)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 4.50E4

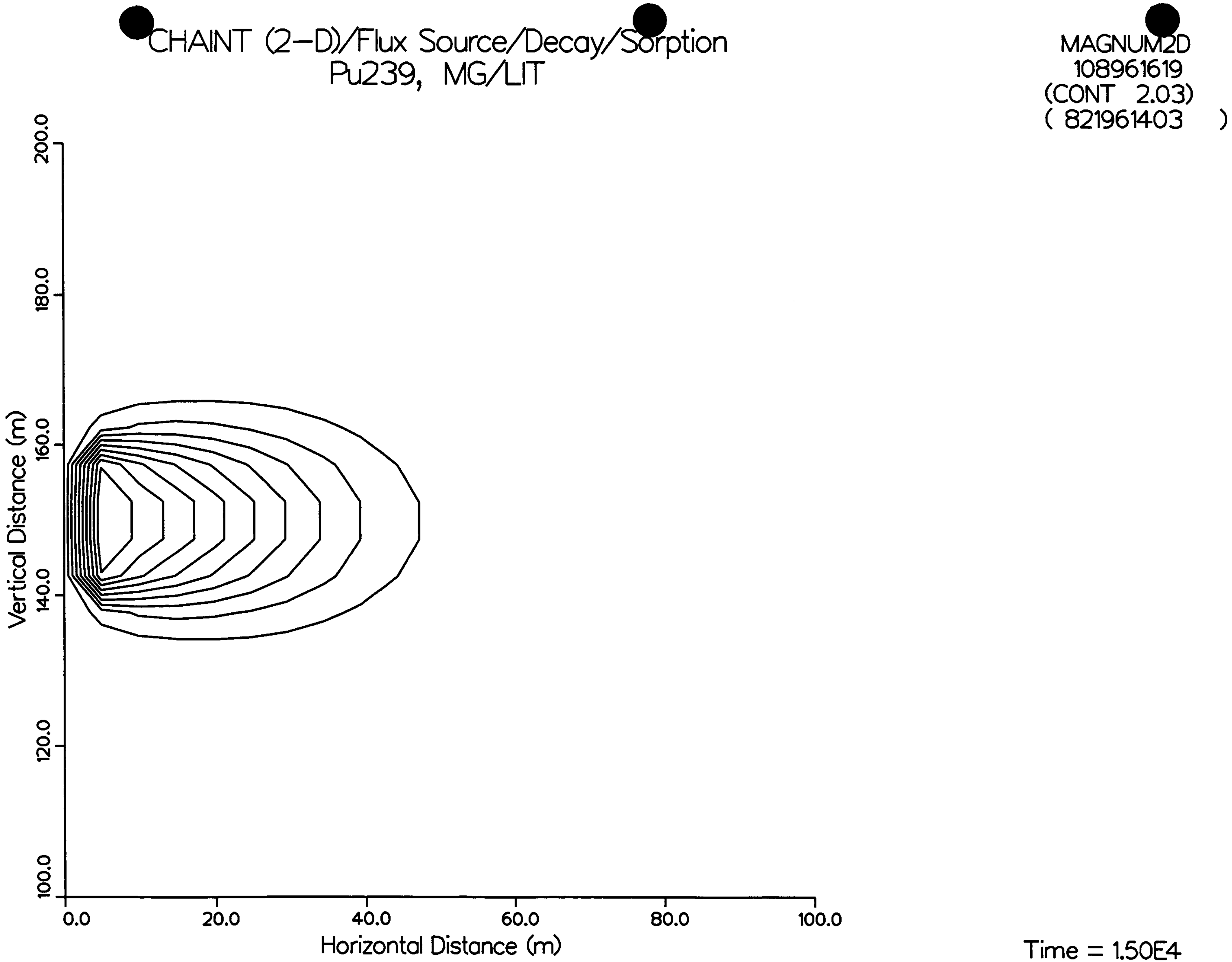
```
CHAINT 2-D Test case with decay/sorption (flux source) for comparison with STRIPF
#  nqal    ne     np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1    3600  11041  121    1      0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
    0   11    0    0   14   15    0
#   sf  alfa  xscale  yscale  uscale  vscale
    0.  1.8    0.      0.      0.      0.
#  nts  ntsg   dlt   zonel  zoner  zonet  zoneb
  20    20   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
  10    10   500.      0.      0.     0.      0.
 9999    0     0      0      0     0      0
#   j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1       5.       1.0      2400.      0.07       0.      mat1
#  islt
    1
#   L    amu    diag    isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1 239.0  2.411E+04    0        0.0        0        0.0    Pu239   0.0
#   i    dml(i,1..n2)  m2/yr
    1   0.0
#   i    xkdi(i,1..n2)  ml/g
    1 130.0
#   lk     Ci
    1     0.0
#   L     bcs
    1     0.0
    2     0.0
    3     0.0
    4     0.0
    5     0.0
    6     0.0
    7     0.0
    8     0.0
    9     0.0
   10     0.0
   11     0.0
   12     0.0
   13     0.0
   14     0.0
   15     0.0
   16     0.0
   17     0.0
   18     0.0
   19     0.0
   20     0.0
   21     0.0
   22     0.0
   23     0.0
   24     0.0
   25     0.0
   26     0.0
   27     0.0
   28     0.0
```

29	0.0
30	0.0
31	0.0
32	0.0
33	0.0
34	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	0.0
58	0.0
59	0.0
60	0.0
61	0.0
62	0.0
63	0.0
64	0.0
65	0.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
[illegible]	0.0
85	0.0
86	0.0
87	0.0
88	0.0

```
   89    0.0
   90    0.0
   91    0.0
   92    0.0
   93    0.0
   94    0.0
   95    0.0
   96    0.0
   97    0.0
   98    0.0
   99    0.0
  100    0.0
  101    0.0
  102    0.0
  103    0.0
  104    0.0
  105    0.0
  106    0.0
  107    0.0
  108    0.0
  109    0.0
  110    0.0
  111    0.0
  112    0.0
  113    0.0
  114    0.0
  115    0.0
  116    0.0
  117    0.0
  118    0.0
  119    0.0
  120    0.0
  121    0.0
#   nld   scf   relz
     4    1.0    0.
#   NLE
    29      30     31     32
#   TLE        RLE(Tc99)
         0.00000E+00      0.3304331
         50000.           0.3304331
   -1.0       0.0
```



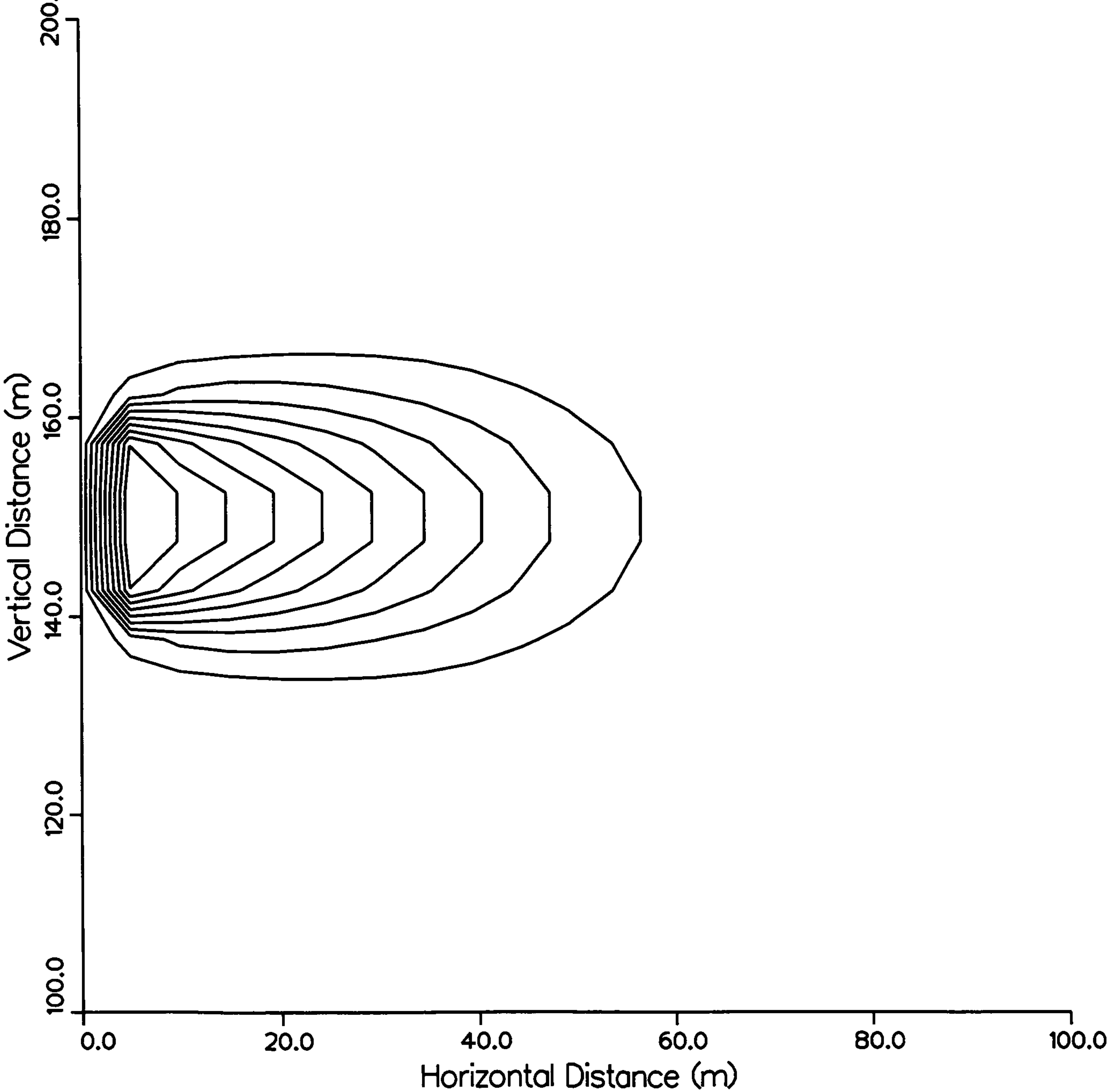
CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961403)
200.0
180.0
160.0
140.0
120.0
100.0
Vertical Distance (m)
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 1.00E4



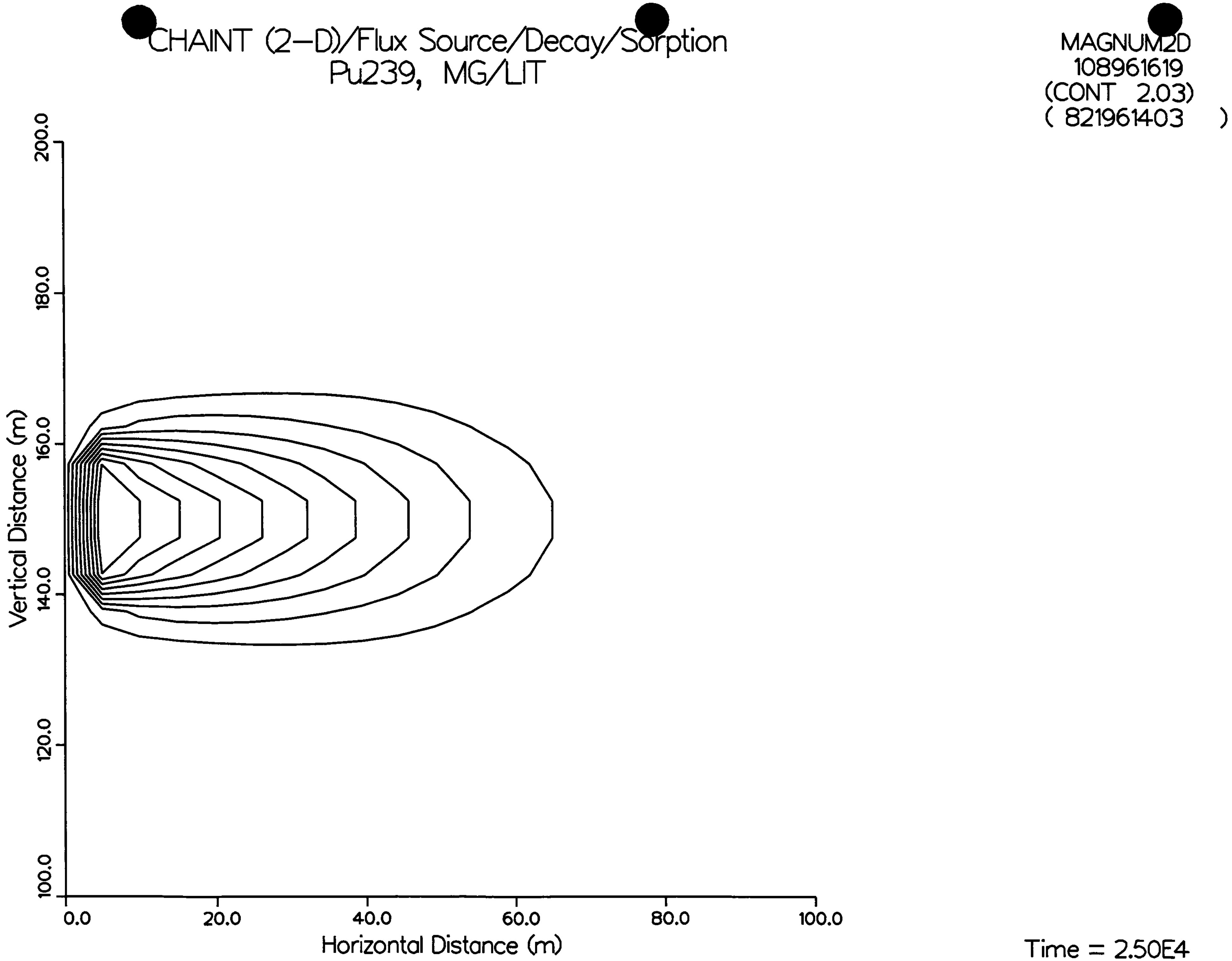
CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961403)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 1.50E4

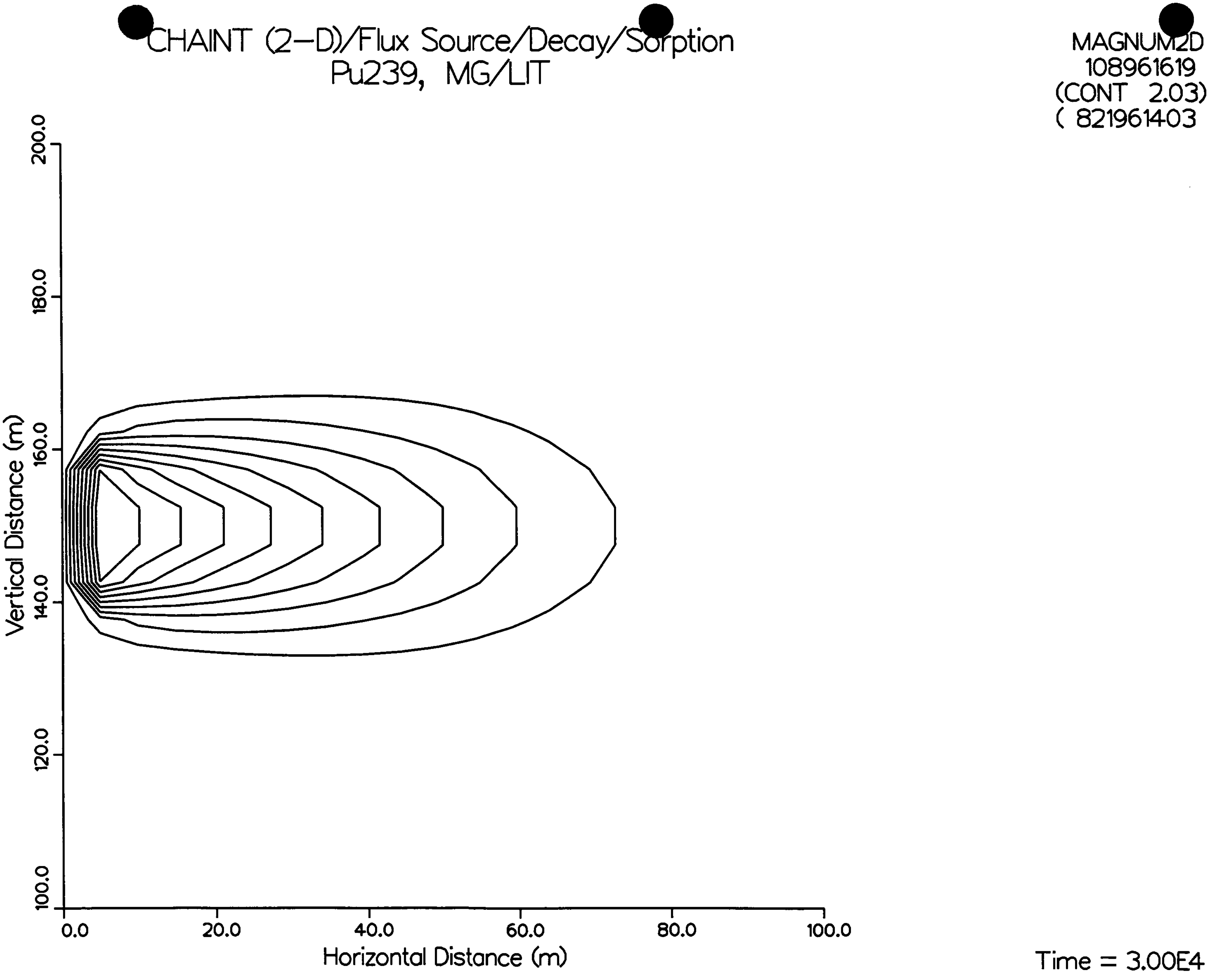
CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT

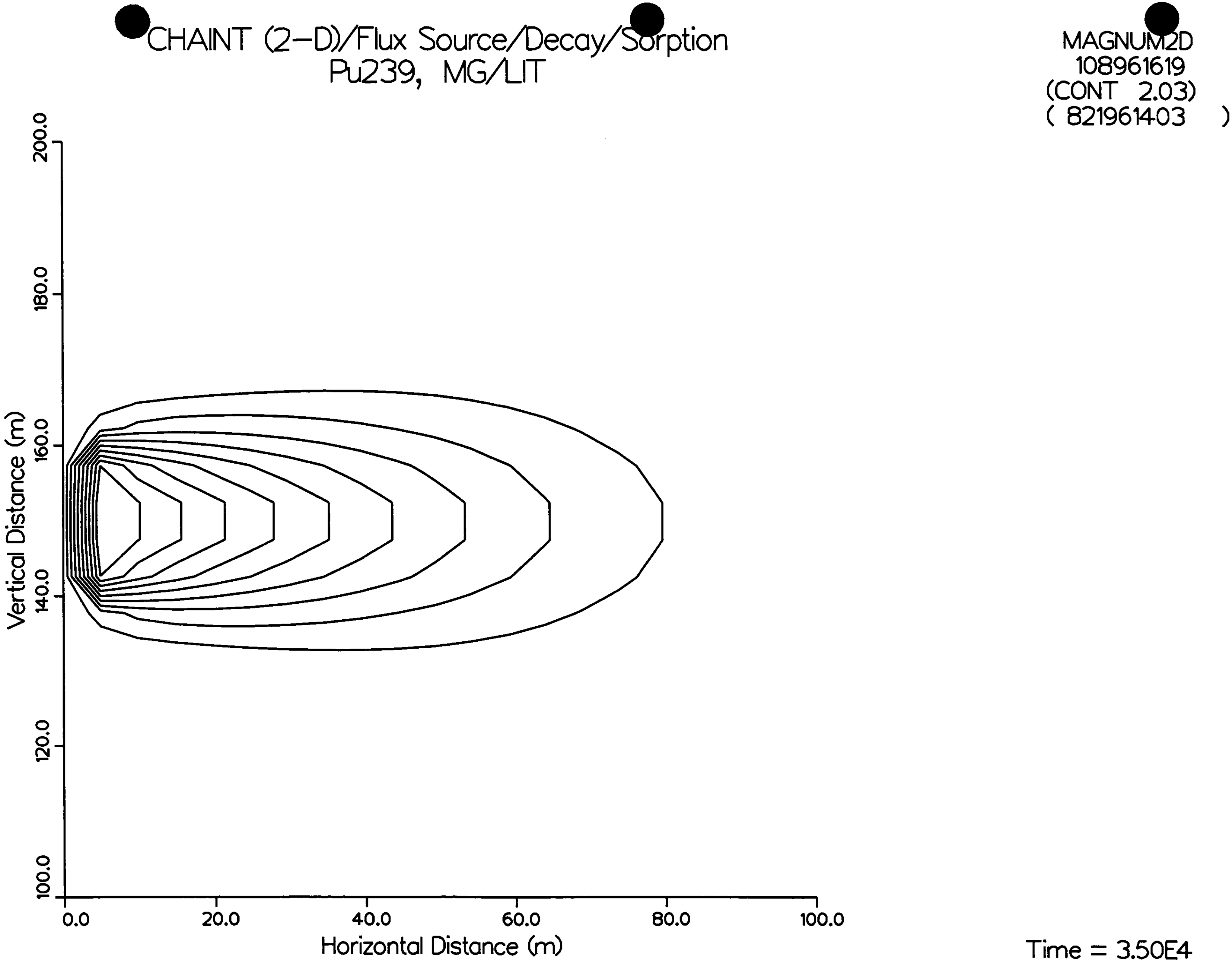
MAGNUM2D
108961619
(CONT 2.03)
(821961403)



Time = 2.00E4

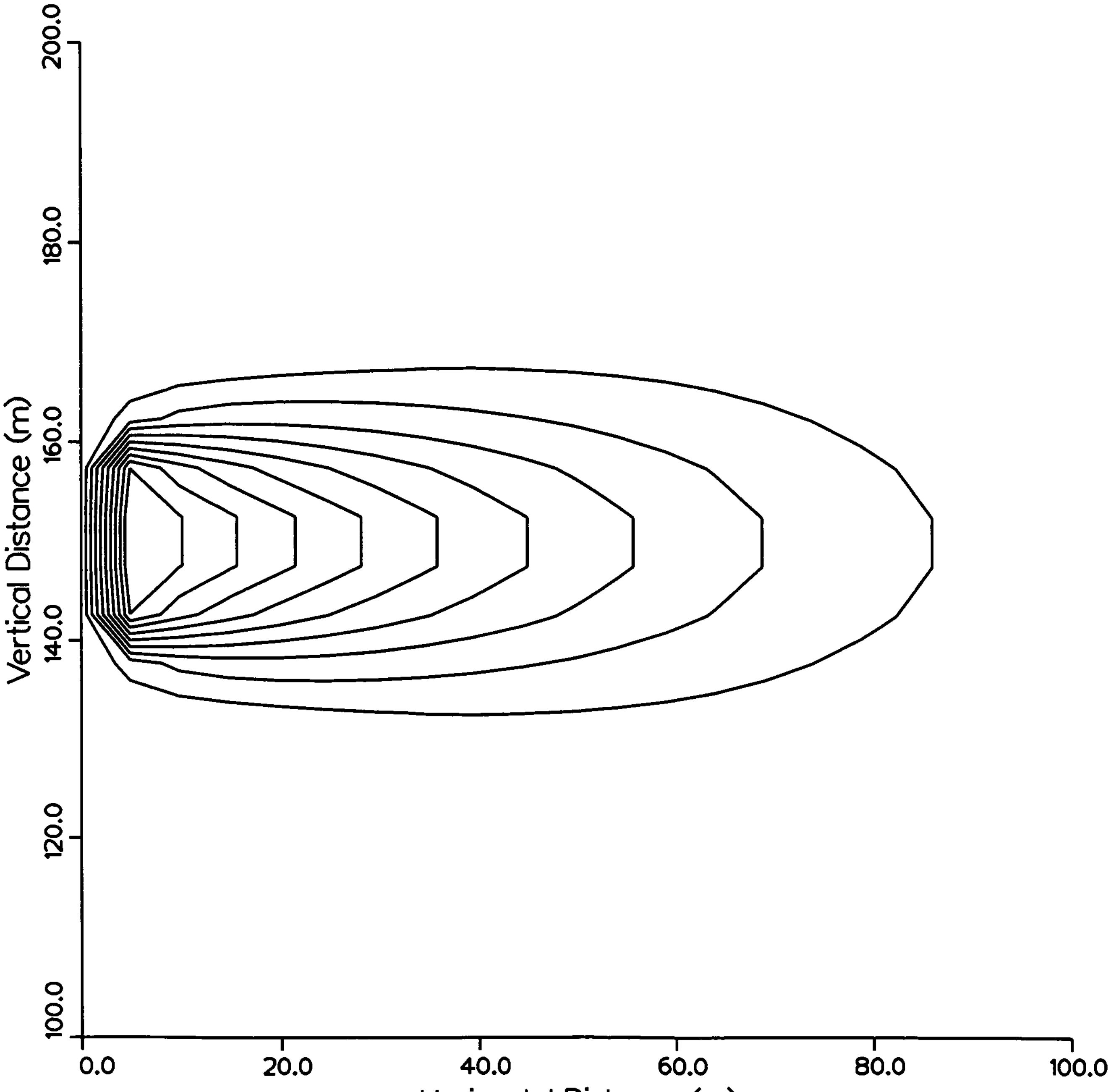

CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961403)
200.0
180.0
160.0
140.0
120.0
100.0
Vertical Distance (m)
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 2.50E4


CHAINT (2–D)/Flux Source/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961403)
200.0
180.0
160.0
140.0
120.0
100.0
Vertical Distance (m)
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 3.00E4

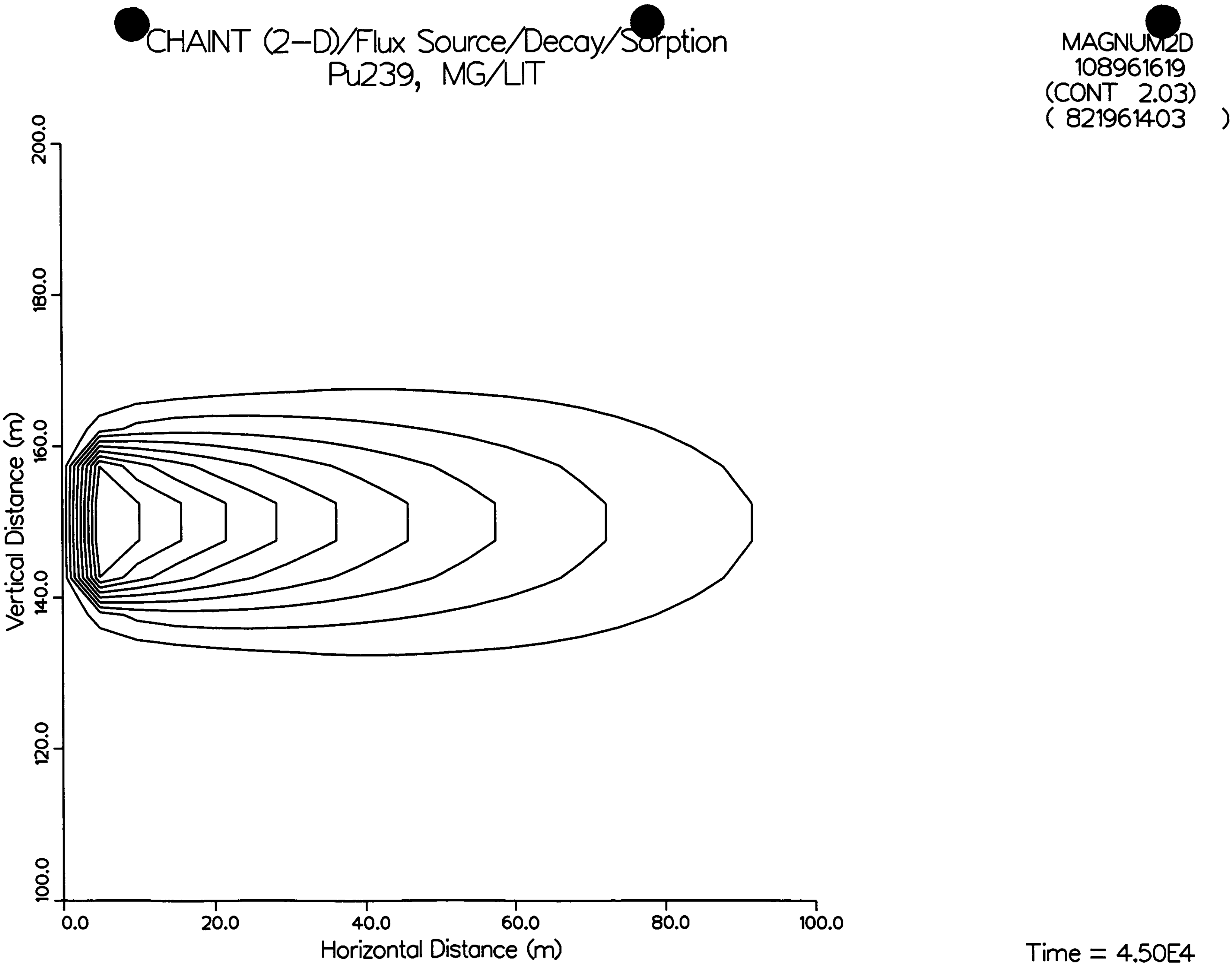

CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961403)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 3.50E4

CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT

MAGNUM2D
108961619
(CONT 2.03)
(821961403)



Time = 4.00E4


CHAINT (2-D)/Flux Source/Decay/Sorption
Pu239, MG/LIT
MAGNUM2D
108961619
(CONT 2.03)
(821961403)
Vertical Distance (m)
200.0
180.0
160.0
140.0
120.0
100.0
0.0
20.0
40.0
60.0
80.0
100.0
Horizontal Distance (m)
Time = 4.50E4

```
C
C     ******************************************************
C     *                                                    *
C     *                  **** STRIPF ****                  *
C     *                                                    *
C     * TWO-DIMENSIONAL GROUND-WATER SOLUTE TRANSPORT MODEL *
C     *                                                    *
C     *   FOR A SEMI-INFINITE AQUIFER WITH A FINITE WIDTH  *
C     *                                                    *
C     *     A STRIP SOURCE EXTENDS FROM Y1 TO Y2 AT X=0    *
C     *                                                    *
C     *        GROUND-WATER FLOW IN X-DIRECTION ONLY       *
C     *                                                    *
C     *            VERSION CURRENT AS OF 04/01/90          *
C     *                                                    *
C     ******************************************************
C
C
C     Although this program has been used by the U.S. Geological
C     Survey, no warranty, expressed or implied, is made by the USGS
C     as to the accuracy and functioning of the program and related
C     program material, nor shall the fact of distribution constitute
C     any such warranty, and no responsibility is assumed by the USGS
C     in connection therewith.
C
C
C      THE FOLLOWING LINE MUST BE CHANGED IF PROBLEM DIMENSIONS ARE
C      GREATER THAN THOSE GIVEN HERE.
C        MAXX = MAXIMUM NUMBER OF X-VALUES
C        MAXY = MAXIMUM NUMBER OF Y-VALUES
C        MAXT = MAXIMUM NUMBER OF TIME VALUES
C        MAXXY = MAXX * MAXY
C        MAXXY2 = 2 * MAXX * MAXY
      PARAMETER (MAXX=100,MAXY=50,MAXT=20,MAXXY=5000,MAXXY2=10000)
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      CHARACTER*1 IERR(MAXX,MAXY)
      REAL XP,YP,CP,TP,DELTA,XPC,YPC,XSCLP,YSCLP
      DIMENSION CXY(MAXX,MAXY),X(MAXX),Y(MAXY),T(MAXT)
      COMMON /PDAT/ XP(MAXX),YP(MAXY),CP(MAXXY),XPC(50),YPC(50),
     1 IFLAG(MAXXY2)
      COMMON /IOUNIT/ IN,IO
C
C     PROGRAM VARIABLES
C
C           NOTE:  ANY CONSISTANT SET OF UNITS MAY BE USED IN THE
C           MODEL.  NO FORMAT STATEMENTS NEED TO BE CHANGED AS
C           LABELS FOR ALL VARIABLES ARE SPECIFIED IN MODEL INPUT.
C
C     CO        SOLUTE CONCENTRATION AT THE INFLOW BOUNDARY [M/L**3]
C     DX        LONGITUDINAL DISPERSION COEFFICIENT [L**2/T]
C     DY        TRANSVERSE DISPERSION COEFFICIENT [L**2/T]
C     VX        GROUND-WATER VELOCITY IN X-DIRECTION [L/T]
C     DK        FIRST-ORDER SOLUTE DECAY CONSTANT [1/T]
C     X         X-POSITION AT WHICH CONCENTRATION IS EVALUATED [L]
C     Y         Y-POSITION AT WHICH CONCENTRATION IS EVALUATED [L]
C     T         TIME AT WHICH CONCENTRATION IS EVALUATED [T]
C     CN        NORMALIZED CONCENTRATION C/CO [DIMENSIONLESS]
C     CXY       SOLUTE CONCENTRATION C(X,Y,T) [M/L**3]
```

```
C     W        AQUIFER WIDTH (AQUIFER EXTENDS FROM Y=0 TO Y=W) [L]
C     Y1       Y-COORDINATE OF LOWER LIMIT OF STRIP SOLUTE SOURCE [L]
C     Y2       Y-COORDINATE OF UPPER LIMIT OF STRIP SOLUTE SOURCE [L]
C
C     NX       NUMBER OF X-POSITIONS AT WHICH SOLUTION IS EVALUATED
C     NY       NUMBER OF Y-POSITIONS AT WHICH SOLUTION IS EVALUATED
C     NT       NUMBER OF TIME VALUES AT WHICH SOLUTION IS EVALUATED
C     NMAX     NUMBER OF TERMS USED IN INFINITE SERIES SUMMATION
C
C     IPLT     PLOT CONTROL. IF IPLT>0, CONTOUR MAPS ARE PLOTTED
C     XSCLP    SCALING FACTOR TO CONVERT X TO PLOTTER INCHES
C     YSCLP    SCALING FACTOR TO CONVERT Y TO PLOTTER INCHES
C     DELTA    CONTOUR INCREMENT FOR PLOT. (VALUE BETWEEN 0 AND 1.0)
C
C       CHARACTER VARIABLES USED TO SPECIFY UNITS FOR MODEL PARAMETERS
C     CUNITS   UNITS OF CONCENTRATION (M/L**3)
C     VUNITS   UNITS OF GROUND-WATER VELOCITY (L/T)
C     DUNITS   UNITS OF DISPERSION COEFFICIENT (L**2/T)
C     KUNITS   UNITS OF SOLUTE DECAY CONSTANT  (1/T)
C     LUNITS   UNITS OF LENGTH (L)
C     TUNITS   UNITS OF TIME (T)
C
C       DEFINE INPUT/OUTPUT FILES AND PRINT TITLE PAGE
      CALL OFILE
      CALL TITLE
      WRITE(IO,201)
C
C       READ IN MODEL PARAMETERS
      READ(IN,101) NX,NY,NT,NMAX,IPLT
      WRITE(IO,205) NX,NY,NT,NMAX
      READ(IN,105) CUNITS,VUNITS,DUNITS,KUNITS,LUNITS,TUNITS
      READ(IN,110) C0,VX,DX,DY,DK
      WRITE(IO,210) C0,CUNITS,VX,VUNITS,DX,DUNITS,DY,DUNITS,DK,KUNITS
      READ(IN,110) W,Y1,Y2
      WRITE(IO,212) W,LUNITS,Y1,LUNITS,Y2,LUNITS
      READ(IN,110) (X(I),I=1,NX)
      WRITE(IO,215) LUNITS
      WRITE(IO,220) (X(I),I=1,NX)
      READ(IN,110) (Y(I),I=1,NY)
      WRITE(IO,216) LUNITS
      WRITE(IO,220) (Y(I),I=1,NY)
      READ(IN,110) (T(I),I=1,NT)
      WRITE(IO,225) TUNITS
      WRITE(IO,220) (T(I),I=1,NT)
      IF(IPLT.GT.0) READ(IN,110) XSCLP,YSCLP,DELTA
      IF(IPLT.GT.0) WRITE(IO,227) XSCLP,YSCLP,DELTA,CUNITS
C
C       BEGIN TIME LOOP
      DO 20 IT=1,NT
C
C       BEGIN X LOOP
      DO 40 IX=1,NX
C
C     CALCULATE NORMALIZED CONCENTRATION FOR ALL Y AT X=X(IX)
      DO 50 IY=1,NY
      CALL CNRMLF(DK,T(IT),X(IX),Y(IY),W,Y1,Y2,DX,DY,
     1 VX,CN,NMAX,IERR(IX,IY))
      CXY(IX,IY)=C0*CN
50    CONTINUE
40    CONTINUE
```

```
C
C       PRINT OUT TABLES OF CONCENTRATION VALUES
      NPAGE=1+(NY-1)/9
      DO 60 NP=1,NPAGE
      IF(NP.EQ.1) WRITE(IO,230) T(IT),TUNITS,LUNITS
      IF(NP.NE.1) WRITE(IO,231) T(IT),TUNITS,LUNITS
      NP1=(NP-1)*9
      NP2=9
      IF((NP1+NP2).GT.NY) NP2=NY-NP1
      WRITE(IO,235) (Y(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
      DO 70 IX=1,NX
      WRITE(IO,240) X(IX),(CXY(IX,NP1+J),IERR(IX,NP1+J),J=1,NP2)
      IF(MOD(IX,45).NE.0) GO TO 70
      WRITE(IO,231) T(IT),TUNITS,LUNITS
      WRITE(IO,235) (Y(NP1+J),J=1,NP2)
      WRITE(IO,236) CUNITS,LUNITS
70    IF(MOD(IX,5).EQ.0 .AND. MOD(IX,45).NE.0) WRITE(IO,241)
60    CONTINUE
C
C       CONVERT X AND Y TO SINGLE PRECISION AND DIVIDE BY THE
C       PLOT SCALING FACTORS. CONVERT C(X,Y) AND DIVIDE BY CO TO PLOT
C       CONTOUR MAPS OF NORMALIZED CONCENTRATION FOR EACH TIME VALUE.
      IF(IPLT.LT.1) GO TO 20
      NXY=NX*NY
      DO 80 I=1,NX
      IP=(I-1)*NY
      XP(I)=SNGL(X(I))
      DO 80 J=1,NY
      IF(I.EQ.1) YP(J)=SNGL(Y(J))
      CP(IP+J)=SNGL(CXY(I,J)/CO)
80    CONTINUE
      TP=SNGL(T(IT))
      NXY2=NXY*2
C     CALL PLOT2D (XP,YP,CP,TP,DELTA,NX,NY,NXY,NXY2,IT,NT,IPLT,TUNITS,
C    1 LUNITS,XSCLP,YSCLP,XPC,YPC,IFLAG)
      DO 95 IX = 1,NX
      DO 90 IY = 1,NY
       WRITE(IO,250) x(IX),Y(IY),CXY(IX,IY)
90    CONTINUE
95    CONTINUE
20    CONTINUE
      CLOSE (IN)
      CLOSE (IO)
      STOP
C
C         FORMAT STATEMENTS
101   FORMAT(20I4)
105   FORMAT(8A10)
110   FORMAT(8F10.0)
201   FORMAT(/////1H ,30X,'ANALYTICAL SOLUTION TO THE TWO-DIMENSIONAL'/
     1 1H ,28X,'ADVECTIVE-DISPERSIVE SOLUTE TRANSPORT EQUATION'/
     2 1H ,30X,'FOR A SEMI-INFINITE AQUIFER OF FINITE WIDTH'/
     3 1H ,26X,'WITH A FINITE-WIDTH (STRIP) SOLUTE SOURCE AT X=0.0'
     4 ///1H0,40X,'INPUT DATA'/1H ,40X,10(1H-))
2     FORMAT(1H0,25X,'NUMBER OF X-COORDINATES (NX) = ',I4/1H ,25X,
     1 'NUMBER OF Y-COORDINATES (NY) = ',I4/1H ,25X,
     2 'NUMBER OF TIME VALUES (NT) = ',I4/1H ,25X,
     3 'NUMBER OF TERMS IN INFINTE SERIES SUMMATION (NMAX) = ',I4)
210   FORMAT(1H0,25X,'SOLUTE CONCENTRATION ON MODEL BOUNDARY (CO) =',
```

```
     1 1P1E13.6,1X,A10/1H ,25X,
     2 'GROUND-WATER VELOCITY IN X-DIRECTION (VX) =',1P1E13.6,1X,A10/
     3 1H ,25X,'DISPERSION IN THE X-DIRECTION (DX) =',1P1E13.6,1X,A10/
     4 1H ,25X,'DISPERSION IN THE Y-DIRECTION (DY) =',1P1E13.6,1X,A10/
     5 1H ,25X,'FIRST-ORDER SOLUTE DECAY RATE (DK) =',1P1E13.6,1X,A10)
      FORMAT(1H0,25X,'AQUIFER WIDTH (W) =',1P1E13.6,1X,A10/1H ,25X,
     1 'SOLUTE SOURCE IS LOCATED BETWEEN Y1 =',1P1E13.6,1X,A10/1H ,54X,
     2 'AND Y2 =',1P1E13.6,1X,A10)
215   FORMAT(1H0,25X,'X-COORDINATES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,78(1H-)/)
216   FORMAT(1H0,25X,'Y-COORDINATES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,78(1H-)/)
220   FORMAT(1H ,5X,8F12.4)
225   FORMAT(1H0,25X,'TIMES AT WHICH SOLUTE CONCENTRATIONS ',
     1 'WILL BE CALCULATED, IN ',A10/1H ,25X,70(1H-)/)
227   FORMAT(1H0,25X,'PLOT SCALING FACTOR FOR X (XSCLP) =',1P1E13.6/
     1 1H ,25X,'PLOT SCALING FACTOR FOR Y (YSCLP) =',1P1E13.6/
     2 1H ,25X,'CONTOUR INCREMENT (DELTA) =',1P1E13.6,1X,A10)
230   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AT TIME =',
     1 F12.4,1X,A10,15X,'*  INDICATES SOLUTION DID NOT CONVERGE'/
     2 1H0,25X,'Y-COORDINATE, IN ',A10)
231   FORMAT(1H1/1H0,15X,'SOLUTE CONCENTRATION AT TIME =',
     1 F12.4,1X,A10,5X,'(CONTINUED)'/
     2 1H0,25X,'Y-COORDINATE, IN ',A10)
235   FORMAT(1H ,20X,9F12.4)
236   FORMAT(1H ,19X,'*',108(1H-)/
     1 1H ,4X,'X-COORDINATE,',2X,'!',44X,'SOLUTE CONCENTRATION, IN ',
     2 A10/1H ,4X,'IN ',A10,2X,1H!/1H ,19X,'!')
240   FORMAT(1H ,5X,F12.4,2X,'! ',9(F11.5,A1))
      FORMAT(1H ,19X,'!')
      FORMAT(3F12.5)
      END
      SUBROUTINE CNRMLF(DK,T,X,Y,W,Y1,Y2,DX,DY,VX,CN,NMAX,IERR)
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      CHARACTER*1 IERR
      COMMON /IOUNIT/ IN,IO
C
C       THIS ROUTINE CALCULATES THE NORMALIZED CONCENTRATION AT X,Y
C       BASED ON THE ANALYTIC SOLUTION TO THE TWO-DIMENSIONAL
C       ADVECTIVE-DISPERSIVE SOLUTE TRANSPORT EQUATION FOR A SEMI-
C       INFINITE AQUIFER WITH A FINITE WIDTH.  A FINITE-WIDTH (STRIP)
C       SOLUTE SOURCE EXTENDS FROM Y=Y1 TO Y=Y2. THE SOLUTION
C       CONTAINS AN INFINITE SERIES SUMMATION WHICH MAY TAKE A LARGE
C       NUMBER OF TERMS TO CONVERGE FOR SMALL VALUES OF X.
C
      PI=3.14159265358979D0
      CN=0.0D0
      IERR=' '
C
C       FOR T=0, ALL CONCENTRATIONS EQUAL 0.0
      IF(T.LE.0.0D0) RETURN
C
C       FOR X=0.0, CONCENTRATIONS ARE SPECIFIED BY BOUNDARY CONDITIONS
      IF(X.GT.0.0D0) GO TO 10
      IF(Y.GT.Y1 .AND. Y.LT.Y2) CN=1.0D0
      IF(Y.EQ.Y1) CN=0.50D0
      IF(Y.EQ.Y2) CN=0.50D0
      RETURN
C
C       BEGIN SUMMATION OF TERMS IN INFINITE SERIES
```

```
10    RTDXT=2.0D0*DSQRT(DX*T)
      SIGMA=0.0D0
      SUBTOT=0.0D0
      NMAX1=NMAX+1
      DO 20 NN=1,NMAX1
      N=NN-1
      ETA=N*PI/W
      PN=(Y2-Y1)/(2.0D0*W)
      IF(N.NE.0) PN=(DSIN(ETA*Y2)-DSIN(ETA*Y1))/(N*PI)
      COSRY=DCOS(ETA*Y)
      ALPHA=4.0D0*DX*(ETA*ETA*DY+DK)
      BETA=DSQRT(VX*VX+ALPHA)
      BETAT=BETA*T
C
C       CALCULATE TERM 1
      A1=X*(VX-BETA)/(2.0D0*DX)
      B1=(X-BETAT)/RTDXT
      CALL EXERFC(A1,B1,C1)
C
C       CALCULATE TERM 2
      A2=X*(VX+BETA)/(2.0D0*DX)
      B2=(X+BETAT)/RTDXT
      CALL EXERFC(A2,B2,C2)
C
C       ADD TERMS TO SUMMATION
      TERM=PN*COSRY*(C1+C2)
      SIGMA=SIGMA+TERM
C
C       CHECK FOR CONVERGENCE. BECAUSE SERIES OSCILLATES, CHECK
C       SUBTOTAL OF LAST 10 TERMS.
      SUBTOT=SUBTOT+TERM
      IF(MOD(NN,10).NE.0) GO TO 20
      IF(DABS(SUBTOT).LT.1.0D-12) GO TO 30
      SUBTOT=0.0D0
20    CONTINUE
      IERR='*'
30    CN=SIGMA
      RETURN
      END
C
C       **********************************************************
C      *                                                          *
C      *                  SUBROUTINE EXERFC                       *
C      *                                                          *
C      *            VERSION CURRENT AS OF 10/01/87                *
C      *                                                          *
C       **********************************************************
C
      SUBROUTINE EXERFC (X,YY,Z)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION P1(5),Q1(5),P2(9),Q2(9),P3(6),Q3(6)
C
C       THIS ROUTINE USES RATIONAL CHEBYSHEV APPROXIMATIONS
C       FOR EVALUATING THE ERROR FUNCTION AND COMPLEMENTARY
C       ERROR FUNCTION IN ORDER TO EVALUATE THE PRODUCT OF
C       EXP(X) AND ERFC(Y)
C
      DATA P1/3.209377589138469472562D03,3.774852376853020208137D02,
     1        1.138641541510501556495D02,3.161123743870565596947D0,
     2        1.857777061846031526730D-01/
```

```
      DATA Q1/2.84423683343917062227 3D03,1.28261652607737227564 5D03,
     1        2.44024637934444173305 6D02,2.36012909523441209349 9D01,
     2        1.0D0 /
      DATA P2/1.23033935479799725272D03,2.05107837782607146532D03,
     1        1.71204761263407058314D03,8.81952221241769090411D02,
     2        2.98635138197400131132D02,6.61191906371416294775D01,
     3       8.88314979438837594118D00,5.64188496988670089180D-01,
     4       2.15311535474403846343D-08/
      DATA Q2/1.23033935480374942043D03,3.43936767414372163696D03,
     1        4.36261909014324715820D03,3.29079923573345962678D03,
     2        1.62138957456669018874D03,5.37181101862009857509D02,
     3        1.17693950891312499305D02,1.57449261107098347253D01,
     4        1.0D0 /
      DATA P3/-6.58749161529837803157D-04,-1.60837851487422766278D-02,
     1        -1.25781726111229246204D-01,-3.60344899949804439429D-01,
     2        -3.05326634961232344035D-01,-1.63153871373020978498D-02/
      UATA Q3/2.33520497626869185443D-03,6.05183413124413191178D-02,
     1        5.27905102951428412248D-01,1.87295284992346047209D00,
     2        2.56852019228982242072D00,1.0D0/
C
      IF(YY.EQ.0.0D0) Z=DEXP(X)
      IF(YY.EQ.0.0D0) RETURN
      Y=DABS(YY)
C
C       FOR 0.0 < Y < .46875
      IF (Y.GT.0.46875D0) GO TO 20
      SUMP=0.0D0
      SUMQ=0.0D0
      DO 10 I=1,5
      Y2I=Y**(2*(I-1))
      SUMP=SUMP+P1(I)*Y2I
      SUMQ=SUMQ+Q1(I)*Y2I
10    CONTINUE
      ERF=Y*SUMP/SUMQ
      IF(YY.LT.0.0) ERF=-ERF
      ERFCY=1.0D0-ERF
      Z=DEXP(X)*ERFCY
      RETURN
C
C       FOR 0.0 < Y < .46875
20    IF (Y.GT.4.0D0) GO TO 40
      SUMP=0.0D0
      SUMQ=0.0D0
      DO 30 I=1,9
      YI=Y**(I-1)
      SUMP=SUMP+P2(I)*YI
      SUMQ=SUMQ+Q2(I)*YI
30    CONTINUE
      Z=DEXP(X-Y*Y)*SUMP/SUMQ
      IF(YY.LT.0.0D0) Z=2.0D0*DEXP(X)-Z
      RETURN
40    SUMP=0.0D0
      SUMQ=0.0D0
      DO 50 I=1,6
      Y2I=Y**(-2*(I-1))
      SUMP=SUMP+P3(I)*Y2I
      SUMQ=SUMQ+Q3(I)*Y2I
50    CONTINUE
      SQRTPI=0.56418958354775628695481D0
      Z=SQRTPI+SUMP/(Y*Y*SUMQ)
```

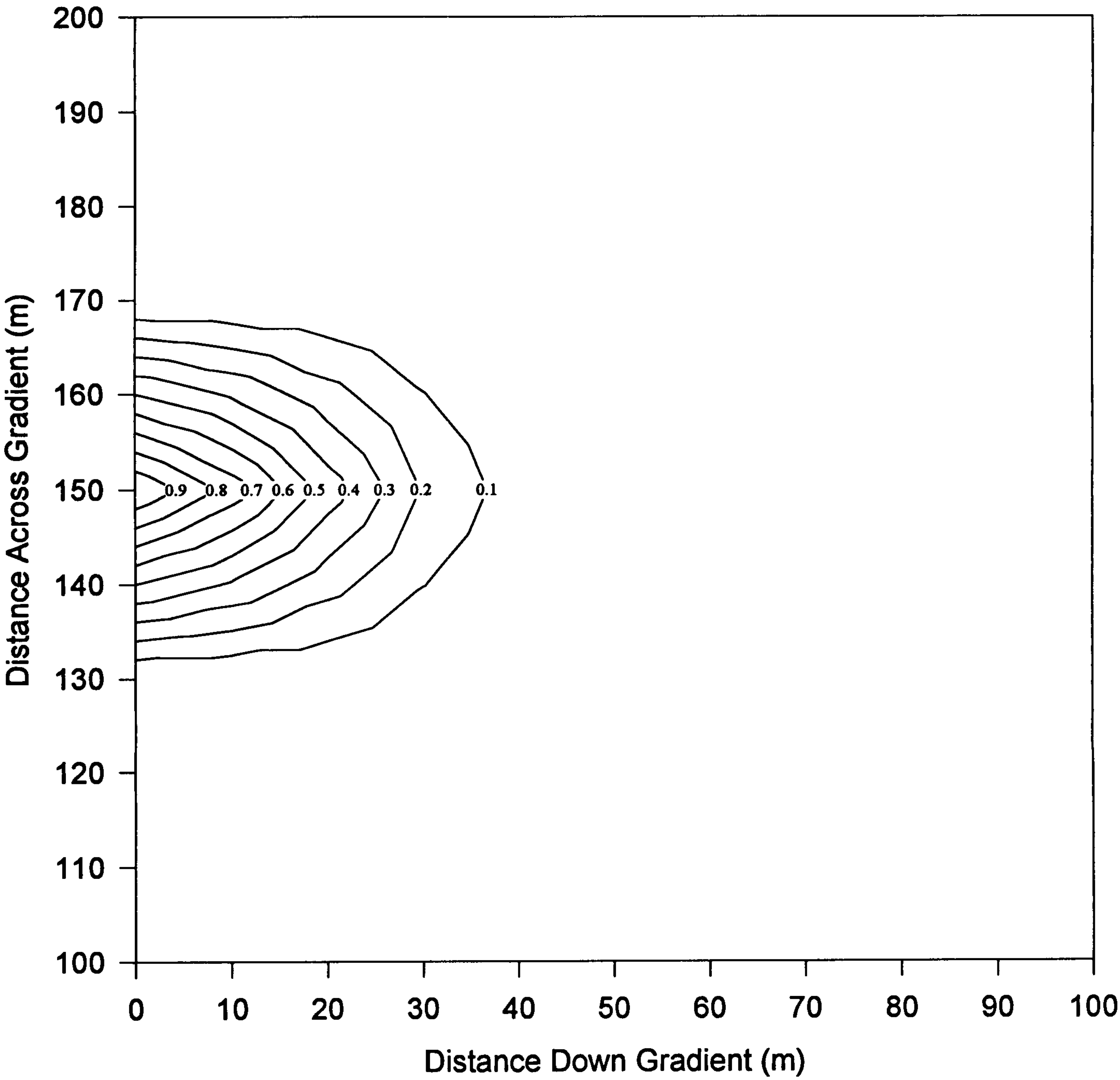
```
      Z=DEXP(X-Y*Y)*Z/Y
      IF(YY.LT.0.0D0) Z=2.0D0*DEXP(X)-Z
      RETURN
      END
C      ******************************************************
C     *                                                      *
C     *                  SUBROUTINE TITLE                    *
C     *                                                      *
C     *           VERSION CURRENT AS OF 10/01/87             *
C     *                                                      *
C      ******************************************************
C
      SUBROUTINE TITLE
      CHARACTER*1 LINE1(60),EQUAL,BLANK
      CHARACTER*60 LINE
      CHARACTER*61 TITL1,T1
      COMMON /IOUNIT/ IN,IO
      COMMON /TITLES/ TITL1(4)
      DATA EQUAL/'='/,BLANK/' '/
      DATA TITL1/4*'
     1          '/
C
C        THIS ROUTINE CREATES A TITLE BOX ON THE FIRST PAGE OF
C        PROGRAM OUTPUT. THE ROUTINE READS AND PRINTS ALL DATA
C        CARDS UNTIL IT ENCOUNTERS AN '=' IN COLUMN 1. THE FIRST 4
C        LINES READ IN ARE ALSO USED AS TITLES ON PLOTS.
C
C     CALL JOBLOC (DUM,DUM,DUM,DUM,USRN)
C     USRNAM = USRN
C
      WRITE(IO,201)
      DO 10 L=1,60
      READ(IN,101,END=20) LINE
      IF (LINE(1:1).EQ.EQUAL) GOTO 60
      T1=LINE
C       STRIP OFF TRAILING BLANKS AND CENTER LINE
      DO 15 N=1,60
      NN=61-N
15    IF(LINE(NN:NN).NE.BLANK) GOTO 20
20    NN1=NN+1
      T1(NN1:NN1)='$'
      IF(L.LT.5) TITL1(L)=T1
      NS=(60-NN)/2
      IF(NS.EQ.0) GO TO 35
      DO 30 I=1,60
30    LINE1(I)=BLANK
35    NS1=NS+1
      DO 40 I=1,NN
40    LINE1(NS+I)=LINE(I:I)
10    WRITE(IO,202) (LINE1(I),I=1,60)
60    WRITE(IO,203)
      RETURN
C
C       FORMAT STATEMENTS
101   FORMAT (A60)
201   FORMAT(1H1//////////1H ,16X,68(1H*))
202   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,3X,60A1,3X,1H*)
203   FORMAT(1H ,16X,1H*,66X,1H*/1H ,16X,1H*,19X,'PROGRAM AS OF  ',
     1'31 JULY 1996',20X,1H*/1H ,16X,1H*,66X,1H*/1H ,16X,68(1H*)
     2 /1H1)
```

```
      END
C
C      ******************************************************
C     *                                                      *
      *                 SUBROUTINE OFILE                     *
      *                                                      *
C     *           VERSION CURRENT AS OF 10/01/87             *
C     *                                                      *
C      ******************************************************
C
      SUBROUTINE OFILE
      CHARACTER*50 IFNAME,OFNAME
      CHARACTER*1 STAR
      COMMON /IOUNIT/ IN,IO
      DATA STAR/'*'/
      IN=5
      IO=6
      WRITE(*,5)
      READ(*,7) IFNAME
      WRITE(*,6)
      READ(*,7) OFNAME
      OPEN (IN,FILE=IFNAME,STATUS='OLD')
      IF(OFNAME(1:1).EQ.STAR) IO=1
      IF(OFNAME(1:1).NE.STAR) OPEN (IO,FILE=OFNAME)
      RETURN
C
C       FORMAT STATEMENTS
5     FORMAT(5X,'TYPE IN INPUT FILE NAME')
6     FORMAT(5X,'TYPE IN OUTPUT FILE NAME')
7     FORMAT(A50)
      END
```

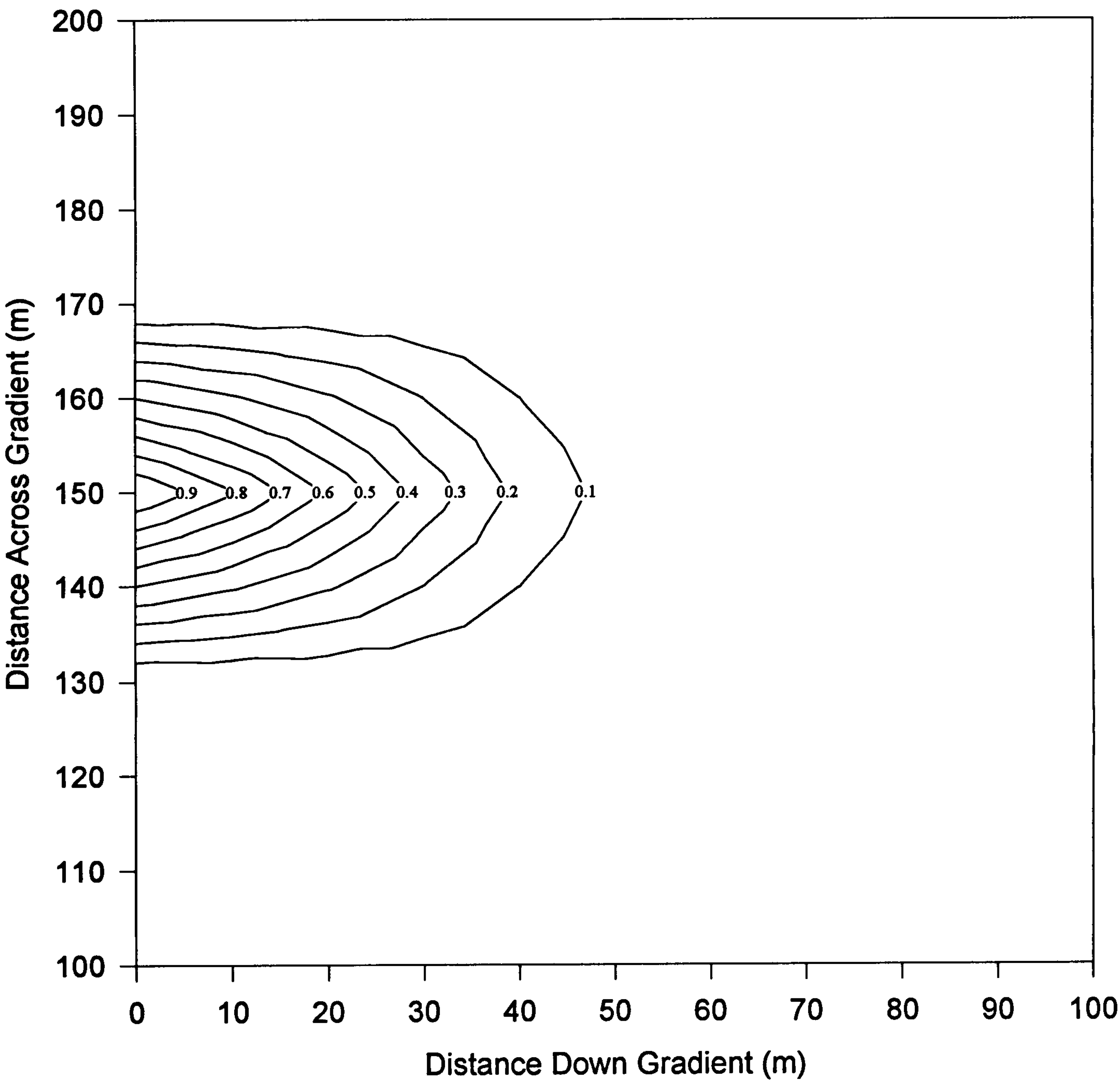
STRIPF Validation Problem -- 2-D Solute transport in a semi-infinite aquifer of infinite width with a continuous 'strip' source at x = 0 from y = 140 to 160 m also included is Pu-239 decay and a half life of 24110 yr and sorption with kd = 130 mL/g

```
Model Data:  V=1.7945E-03 m/yr, DX=8.9723-03 m**2/yr, DY=1.7945E-03 m**2/yr,
             Y1=140 m , Y2=160 m , C0=1.0 mg/L, W=300 m, K1 = 2.875E-5 per year
====
  31  31   8 104   1
MG/L      M/YR      M**2/YR  PER YEAR  METERS  YEARS
     1.0  1.7945E-3 8.9723E-3 1.7945E-3  2.875E-5
   300.0     140.0     160.0
     0.0      10.0      20.0      30.0      40.0      50.0      60.0      70.0
    80.0      90.0     100.0     110.0     120.0     130.0     140.0     150.0
   160.0     170.0     180.0     190.0     200.0     210.0     220.0     230.0
   240.0     250.0     260.0     270.0     280.0     290.0     300.0
     0.0      10.0      20.0      30.0      40.0      50.0      60.0      70.0
    80.0      90.0     100.0     110.0     120.0     130.0     140.0     150.0
   160.0     170.0     180.0     190.0     200.0     210.0     220.0     230.0
   240.0     250.0     260.0     270.0     280.0     290.0     300.0
     1E+4    1.5E+4      2E+4    2.5E+4      3E+4    3.5E+4      4E+4    4.5E+4
    500.      500.       0.1
```

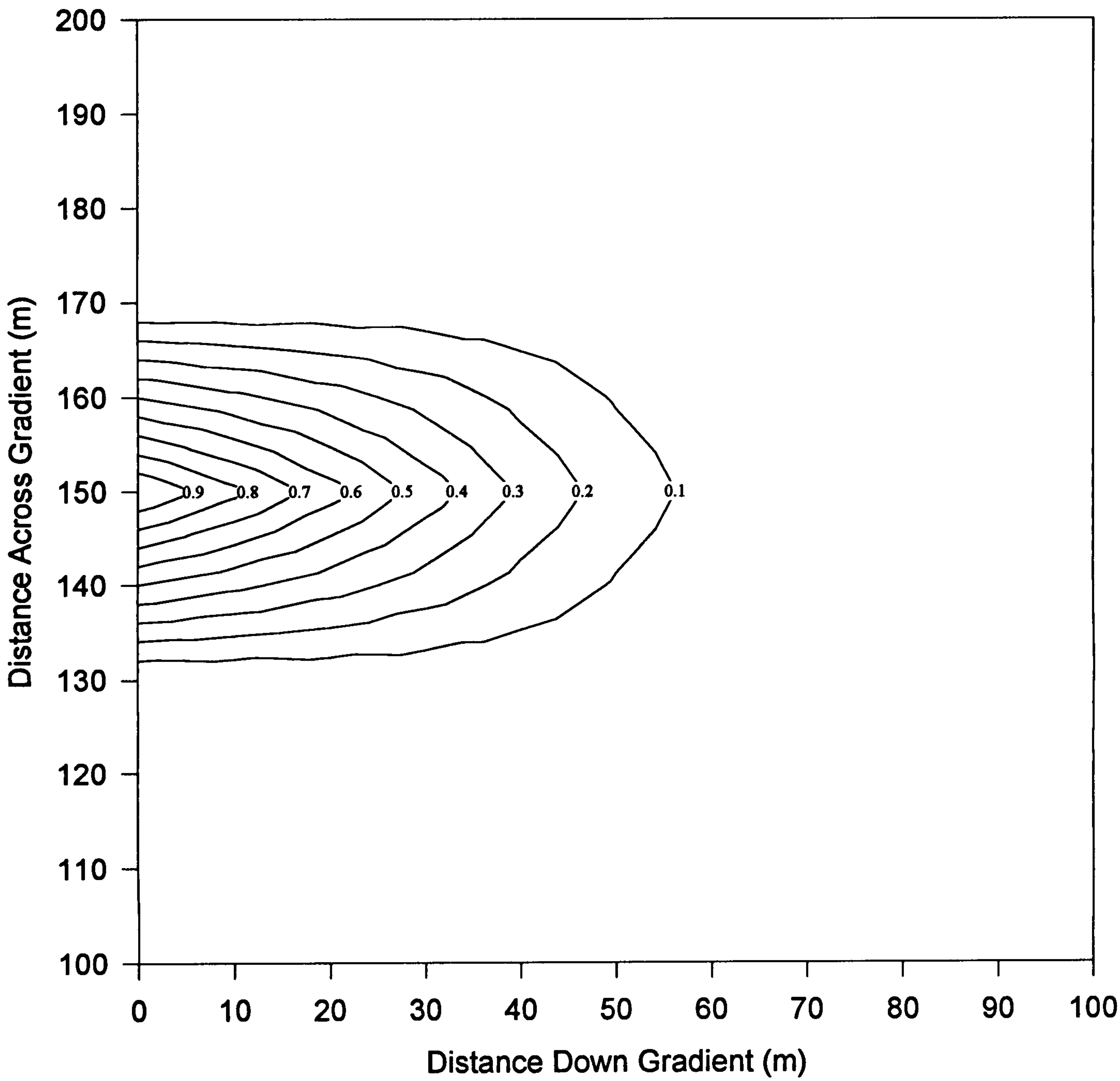
STRIPF Results (2-D) with Decay and Sorption at Time = 10,000 years



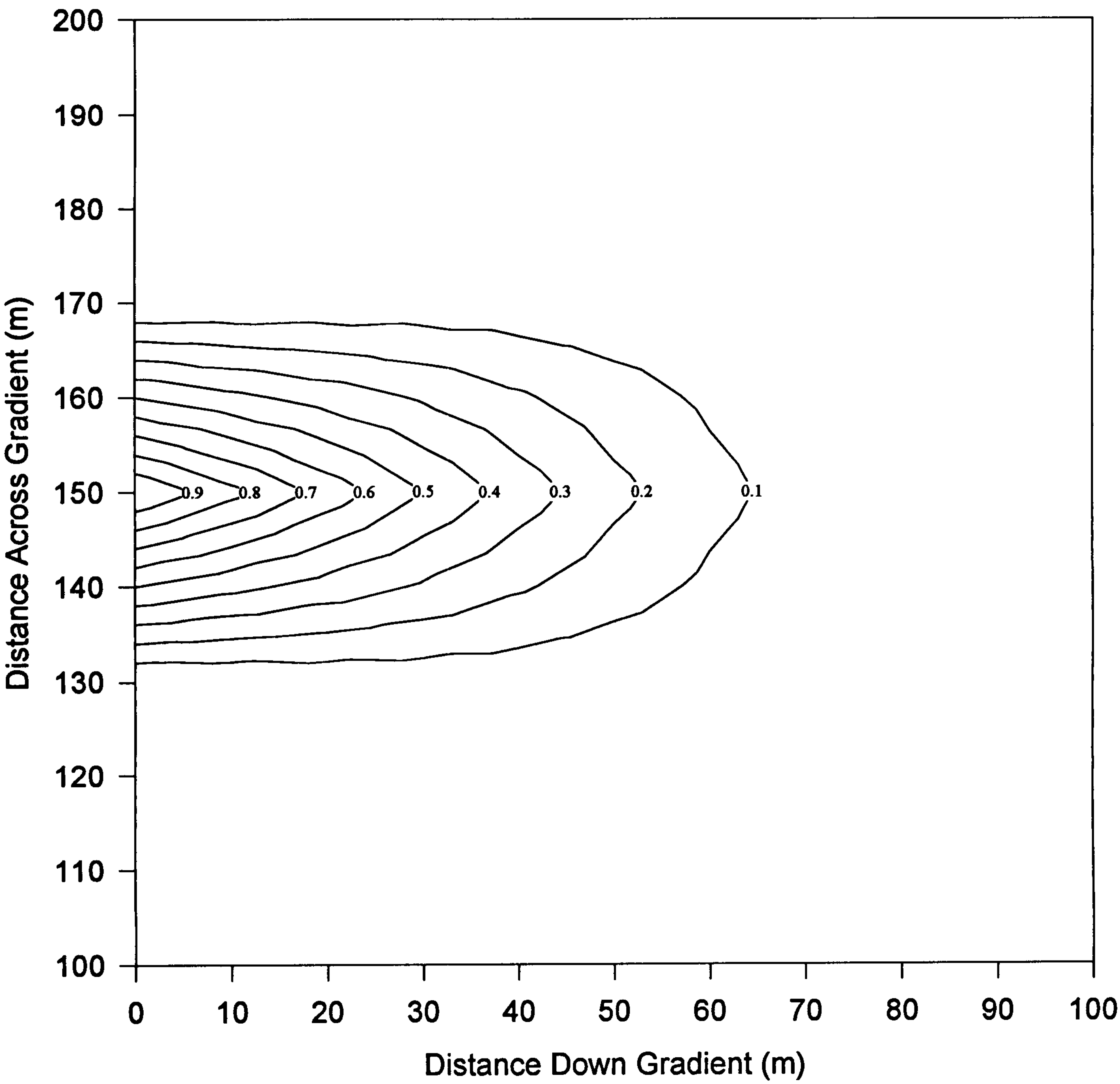
STRIPF Results (2-D) with Decay and Sorption at Time = 15,000 years



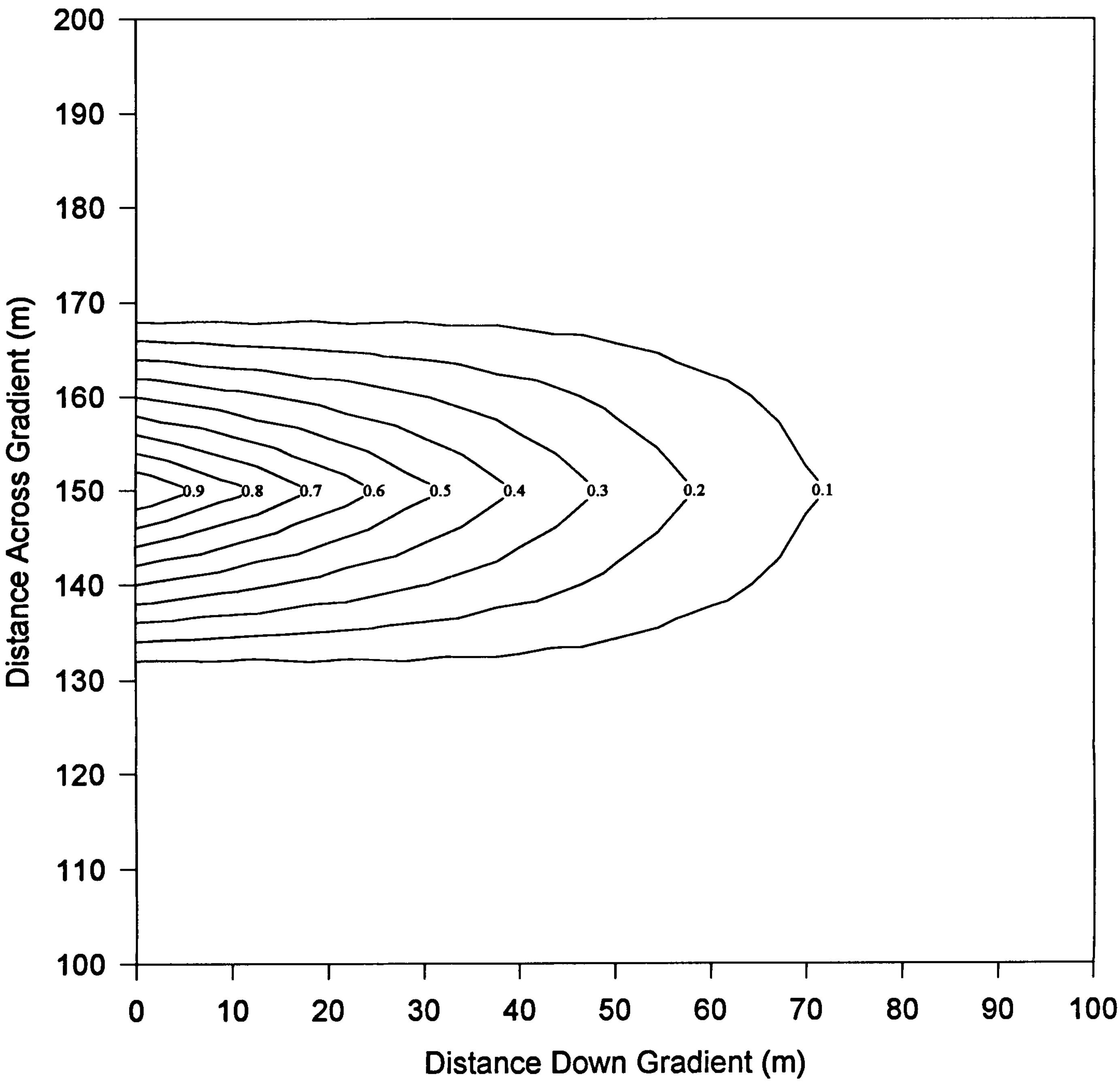
STRIPF Results (2-D) with Decay and Sorption at Time = 20,000 years



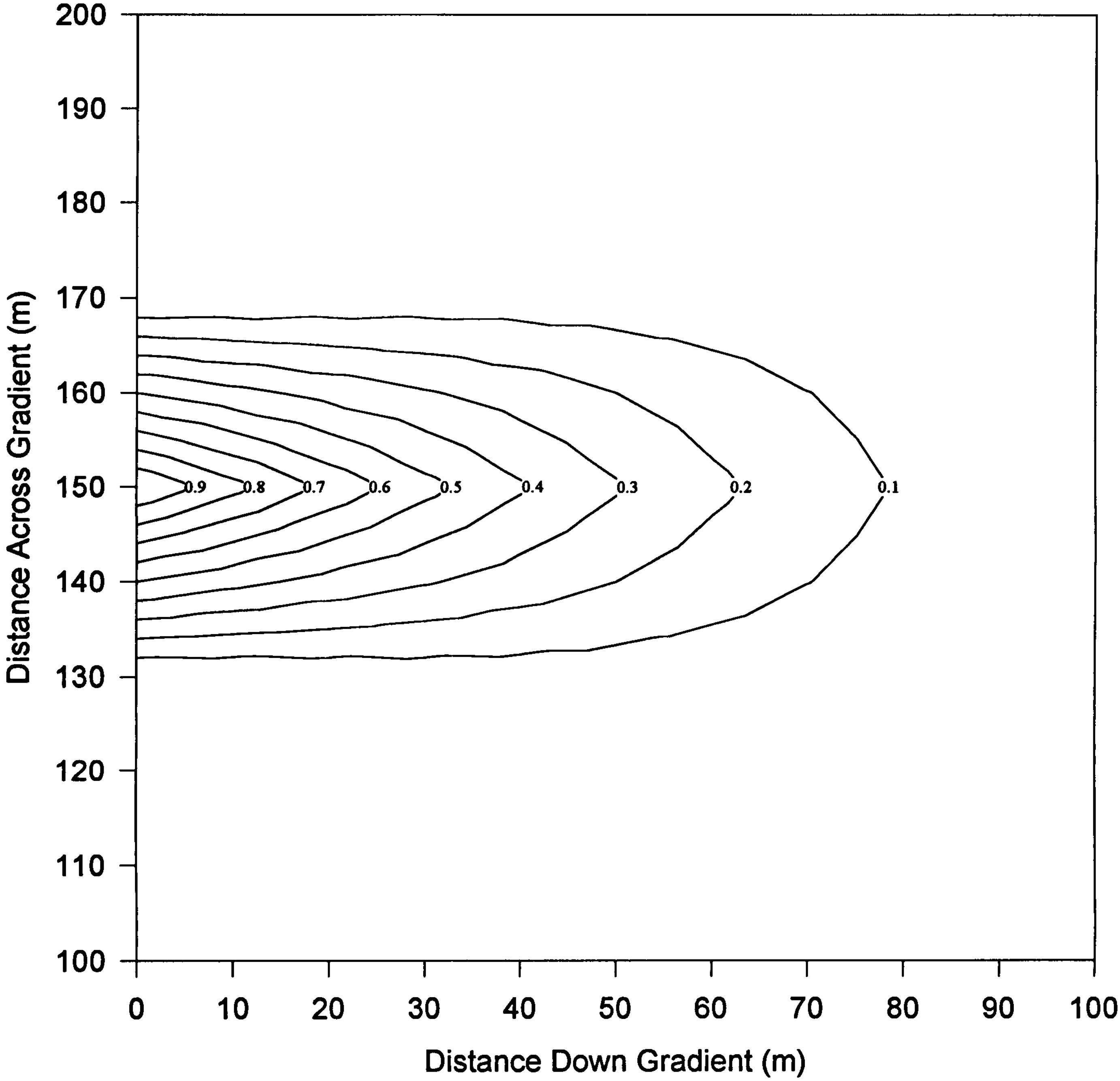
STRIPF Results (2-D) with Decay and Sorption at Time = 25,000 years



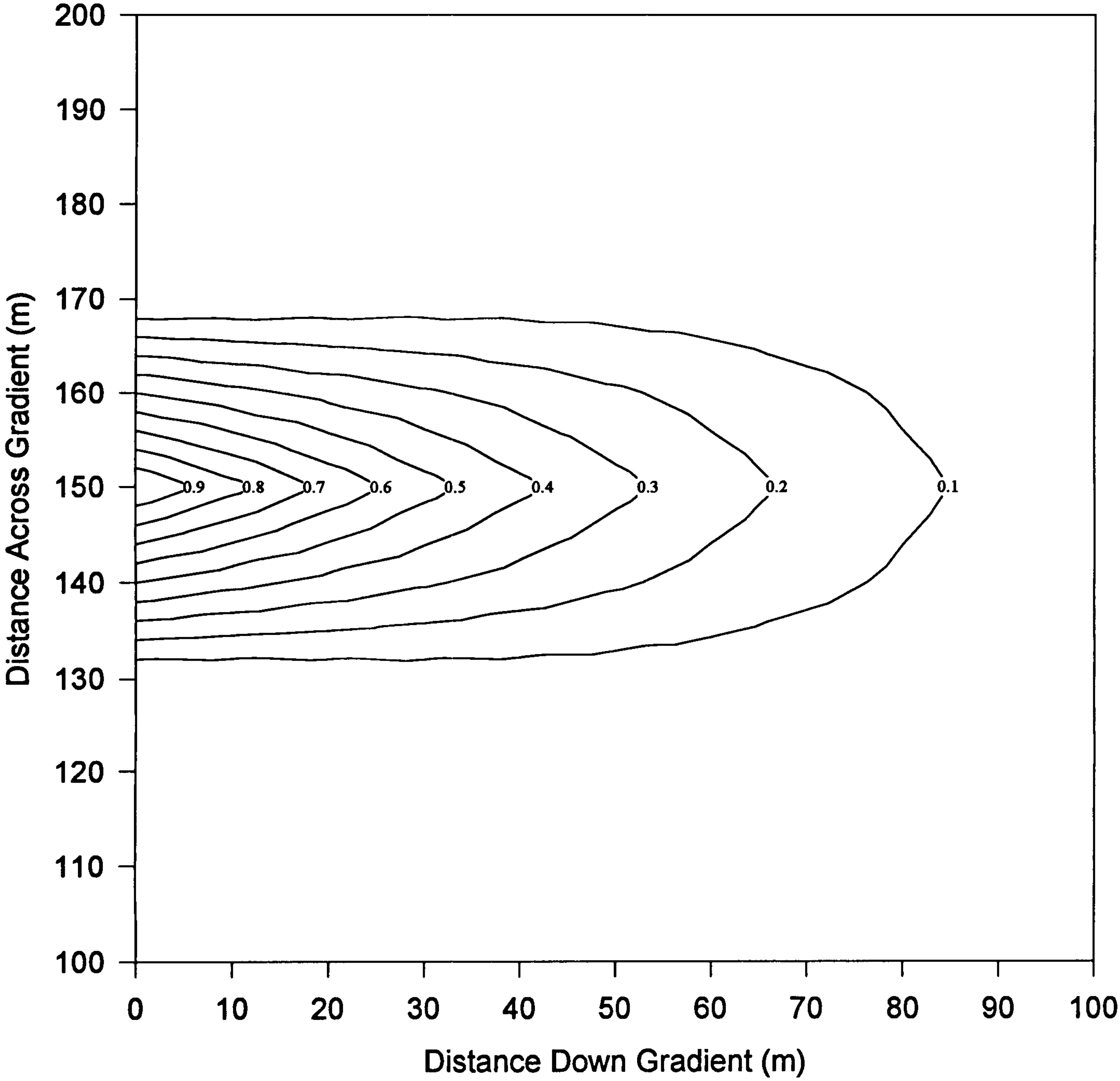
STRIPF Results (2-D) with Decay and Sorption at Time = 30,000 years



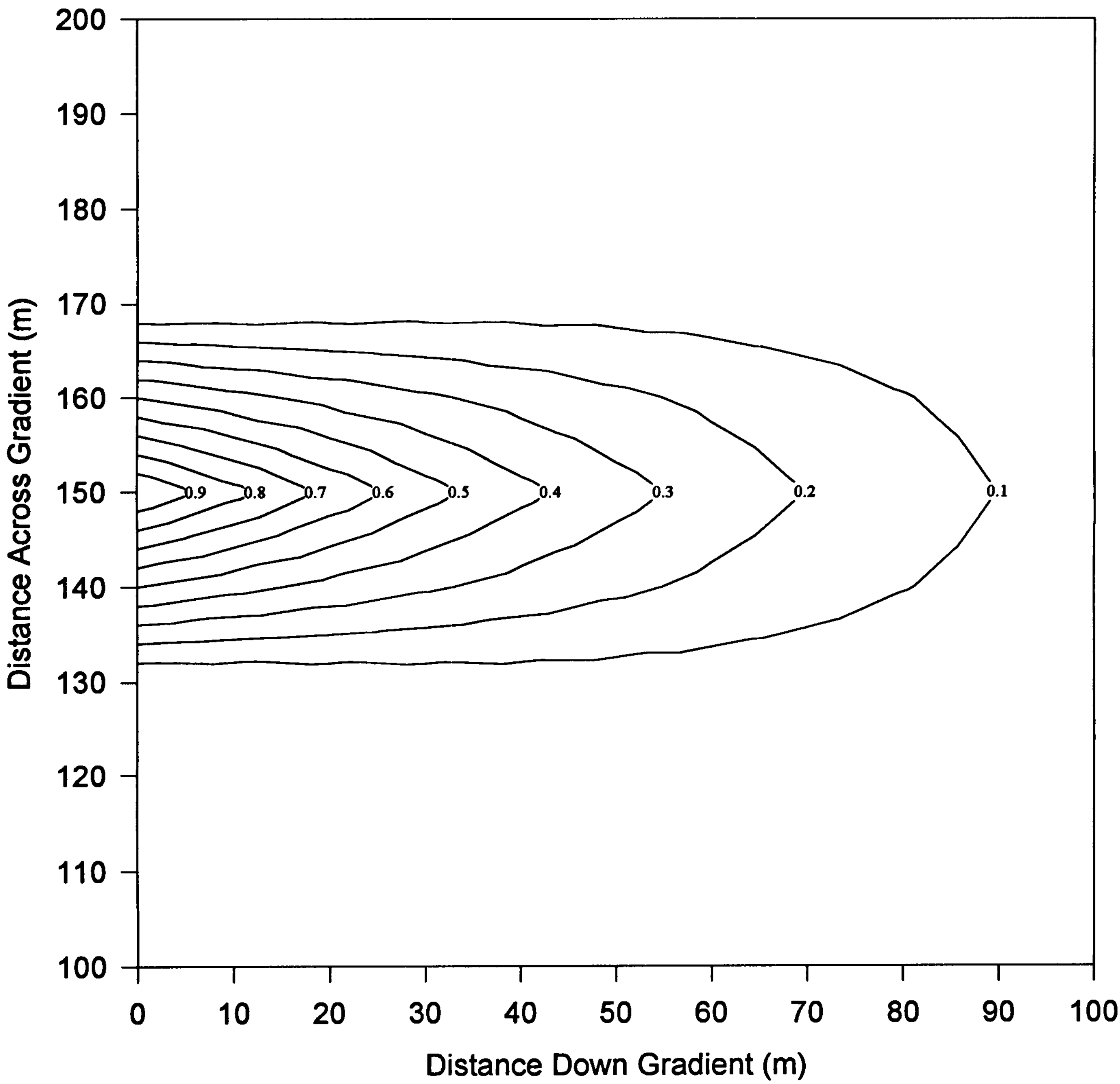
STRIPF Results (2-D) with Decay and Sorption at Time = 35,000 years



STRIPF Results (2-D) with Decay and Sorption at Time = 40,000 years



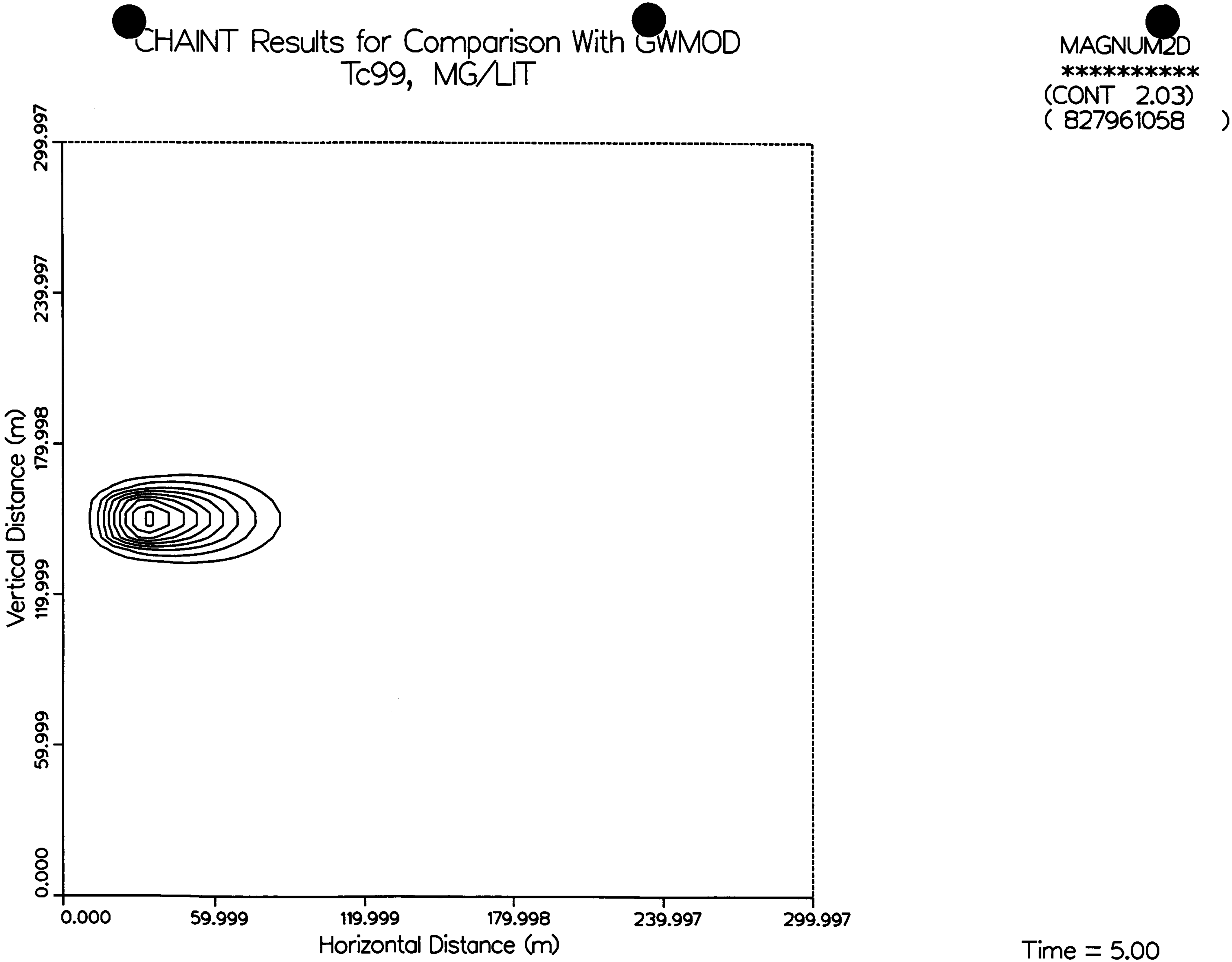
STRIPF Results (2-D) with Decay and Sorption at Time = 45,000 years

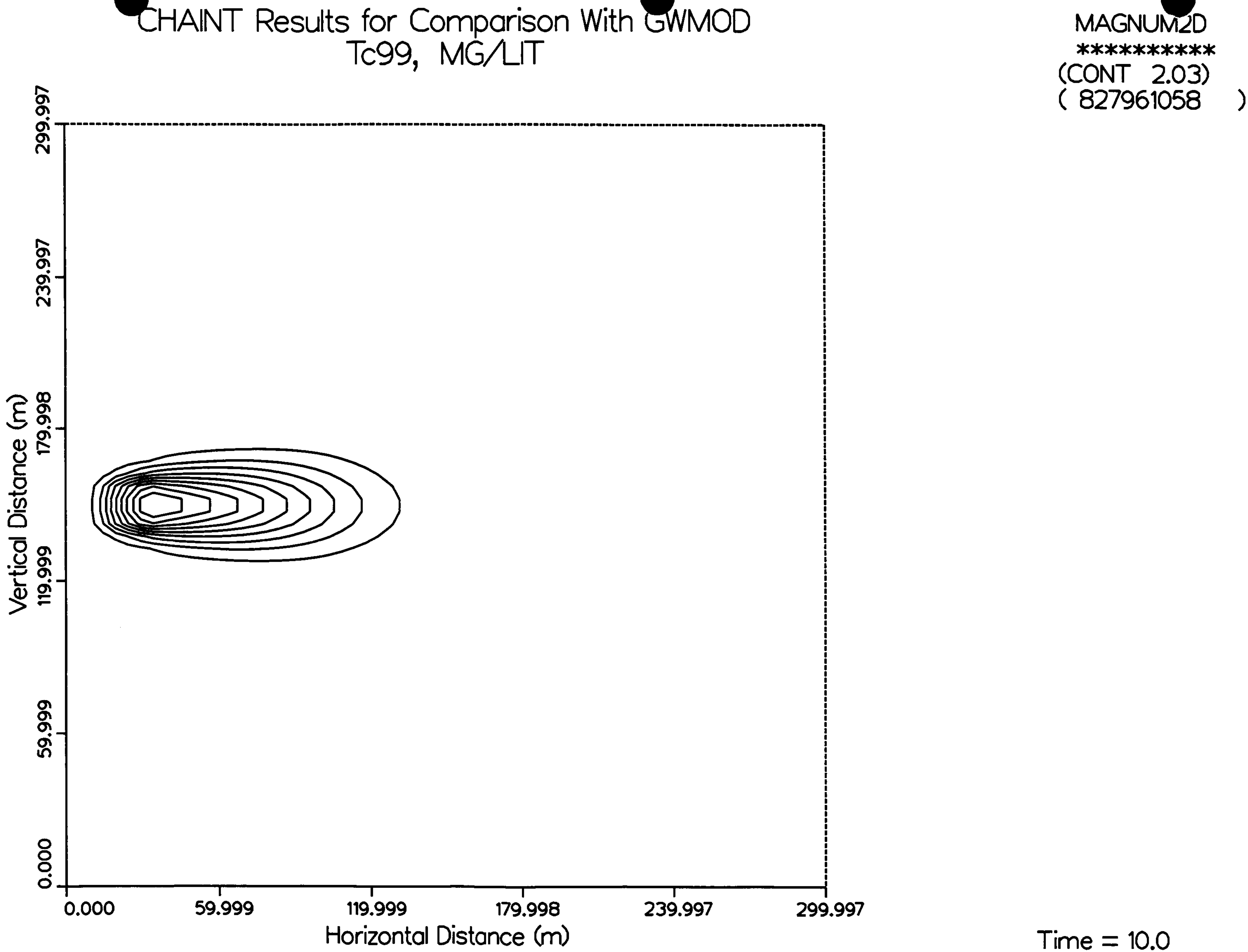


7.2.5 Validation Test Case 5 Results - Two Dimensional Transport Without Decay for a Flux Source

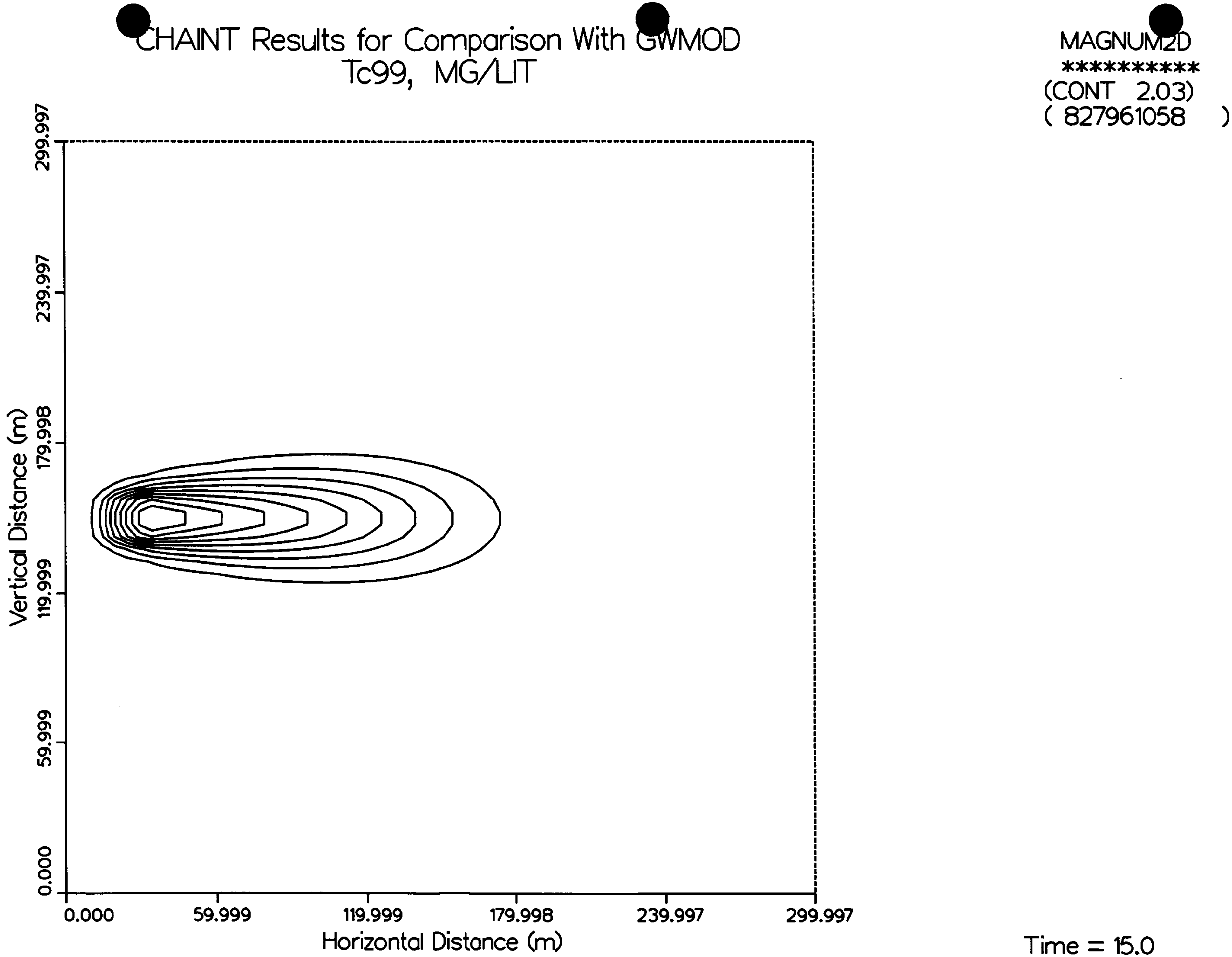
Results from the CHAINT simulations for a constant flux source are presented in this section. The CHAINT results were compared to a semi-analytical model, GWMODF2.

The GWMODF2 input file and results are provided in this section. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from GWMODF2 compare favorably and overlaying the figures reveals the results are consistent.


CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(827961058)
299.997
239.997
179.998
119.999
59.999
0.000
Vertical Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
0
Time = 5.00



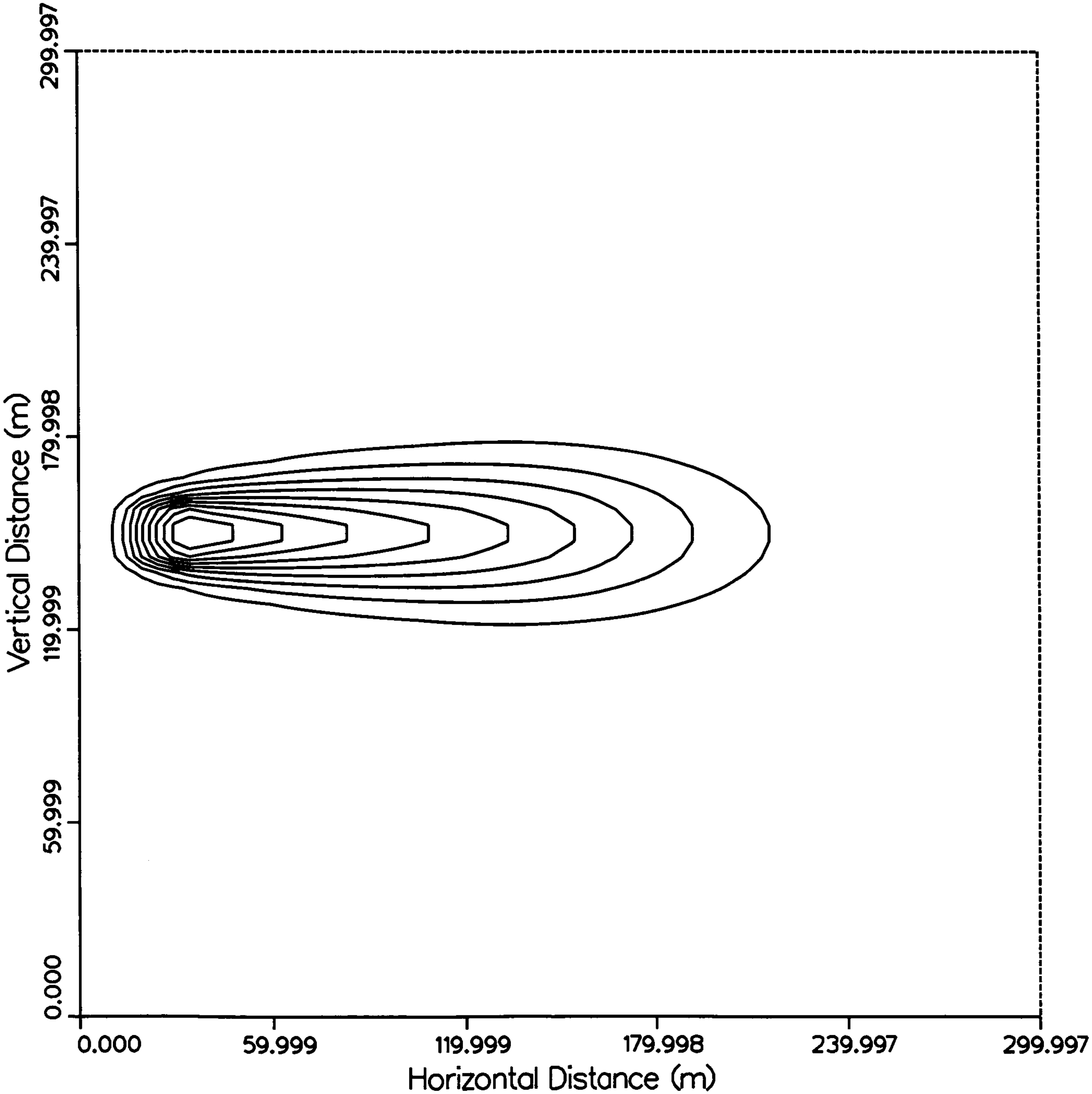
CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(827961058)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
Horizontal Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Time = 10.0



CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(827961058)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 15.0

CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT

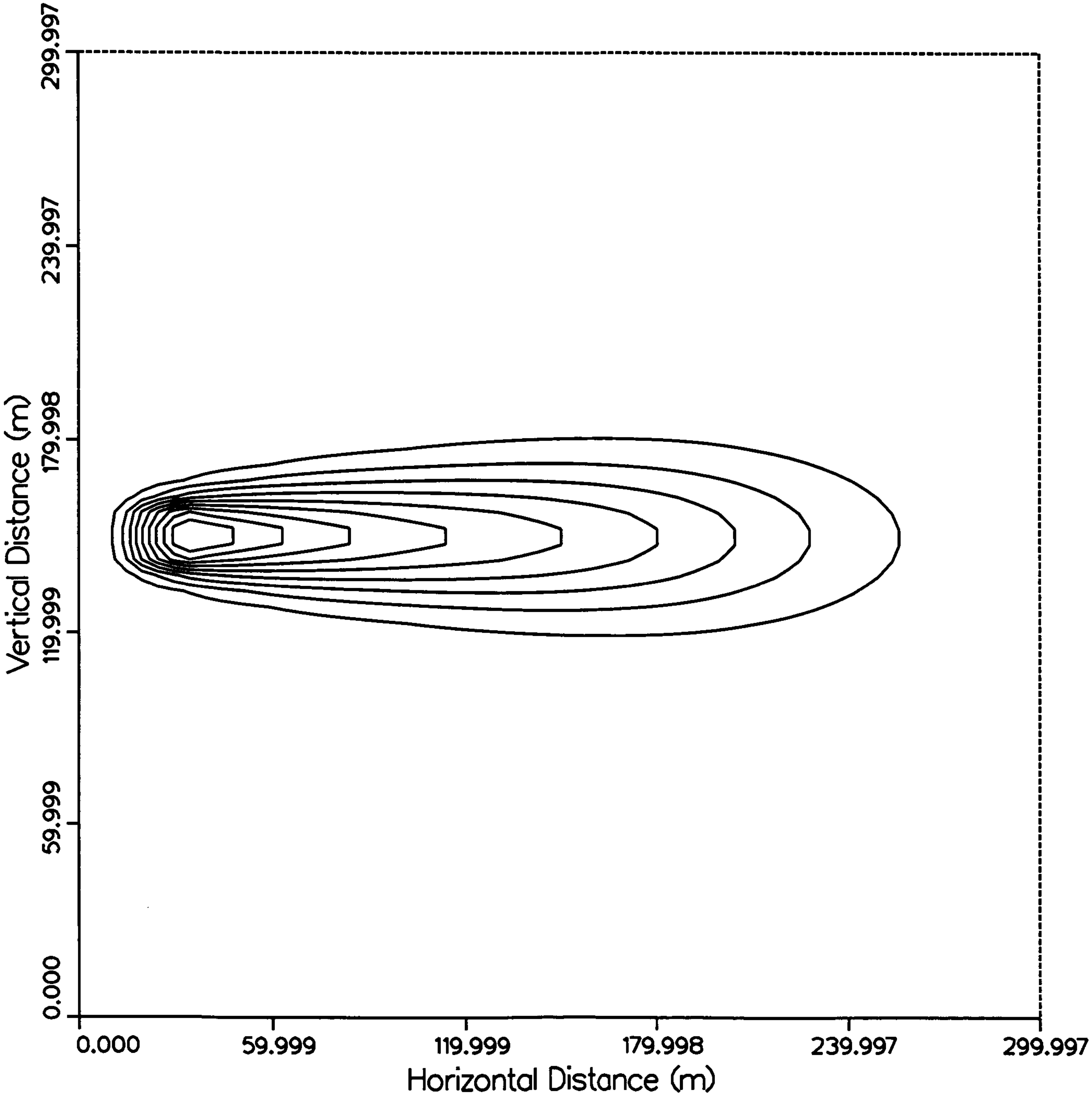
MAGNUM2D
****
(CONT 2.03)
(827961058)



Time = 20.0

CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT

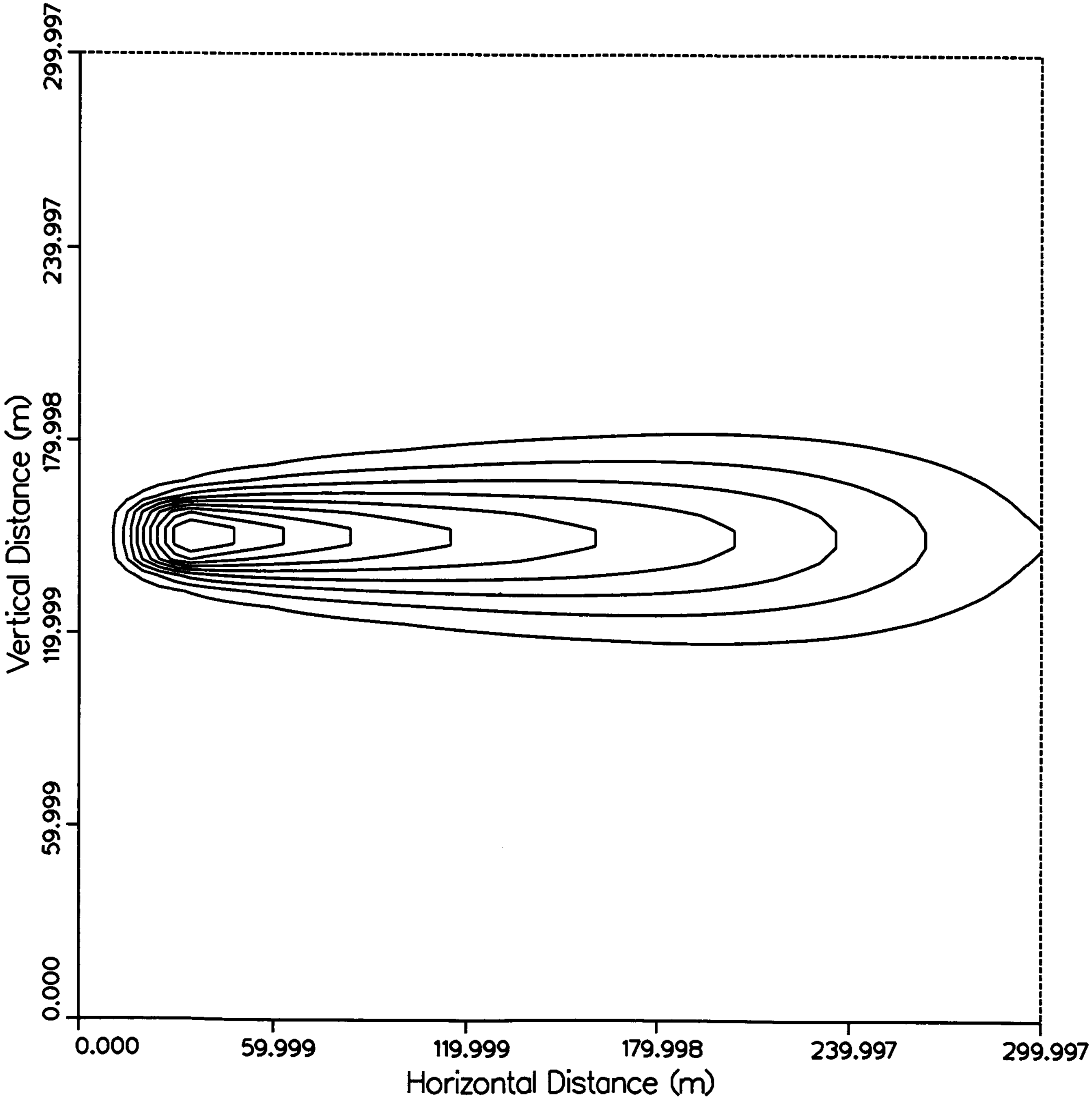
MAGNUM2D
****
(CONT 2.03)
(827961058)



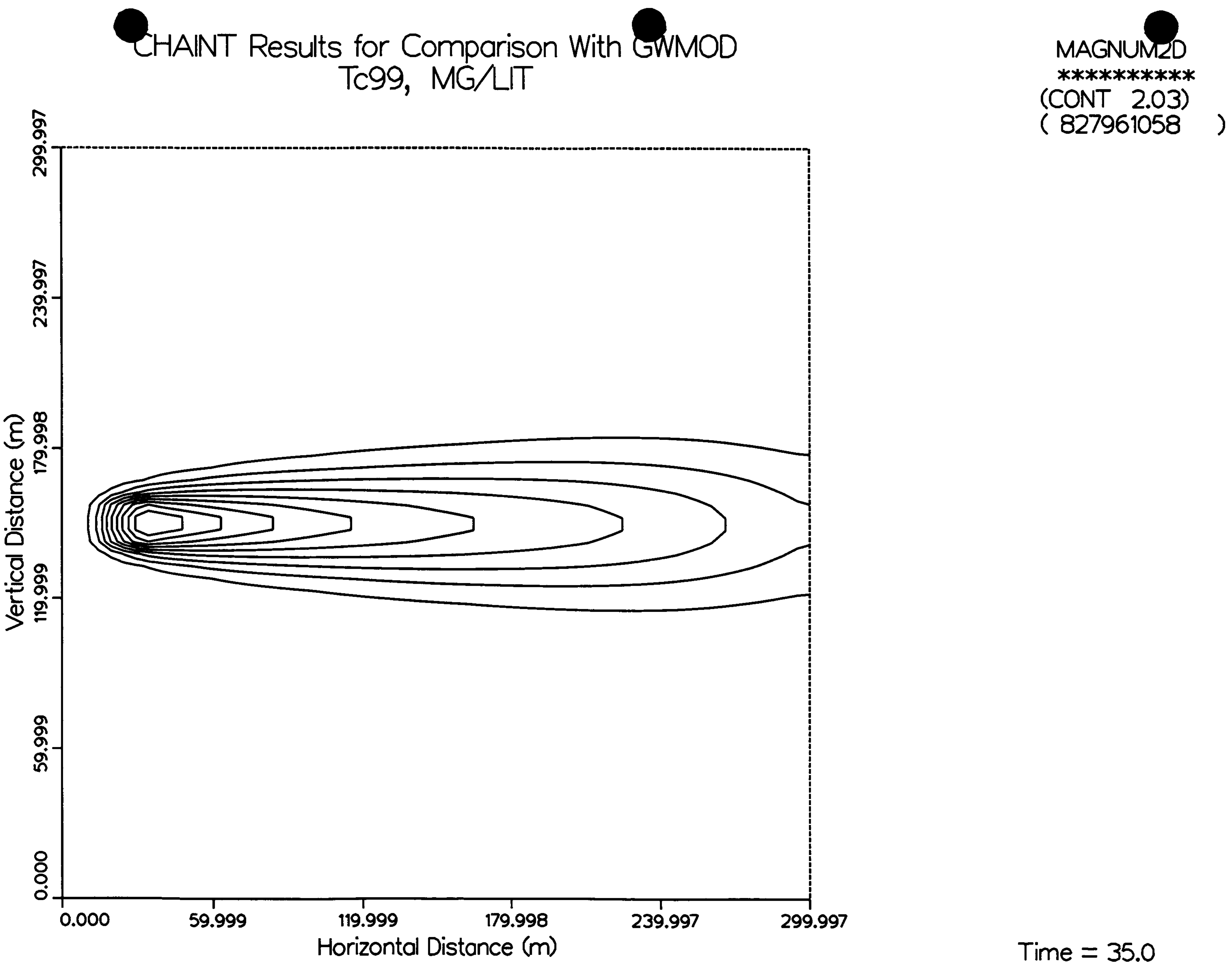
Time = 25.0

CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(827961058)

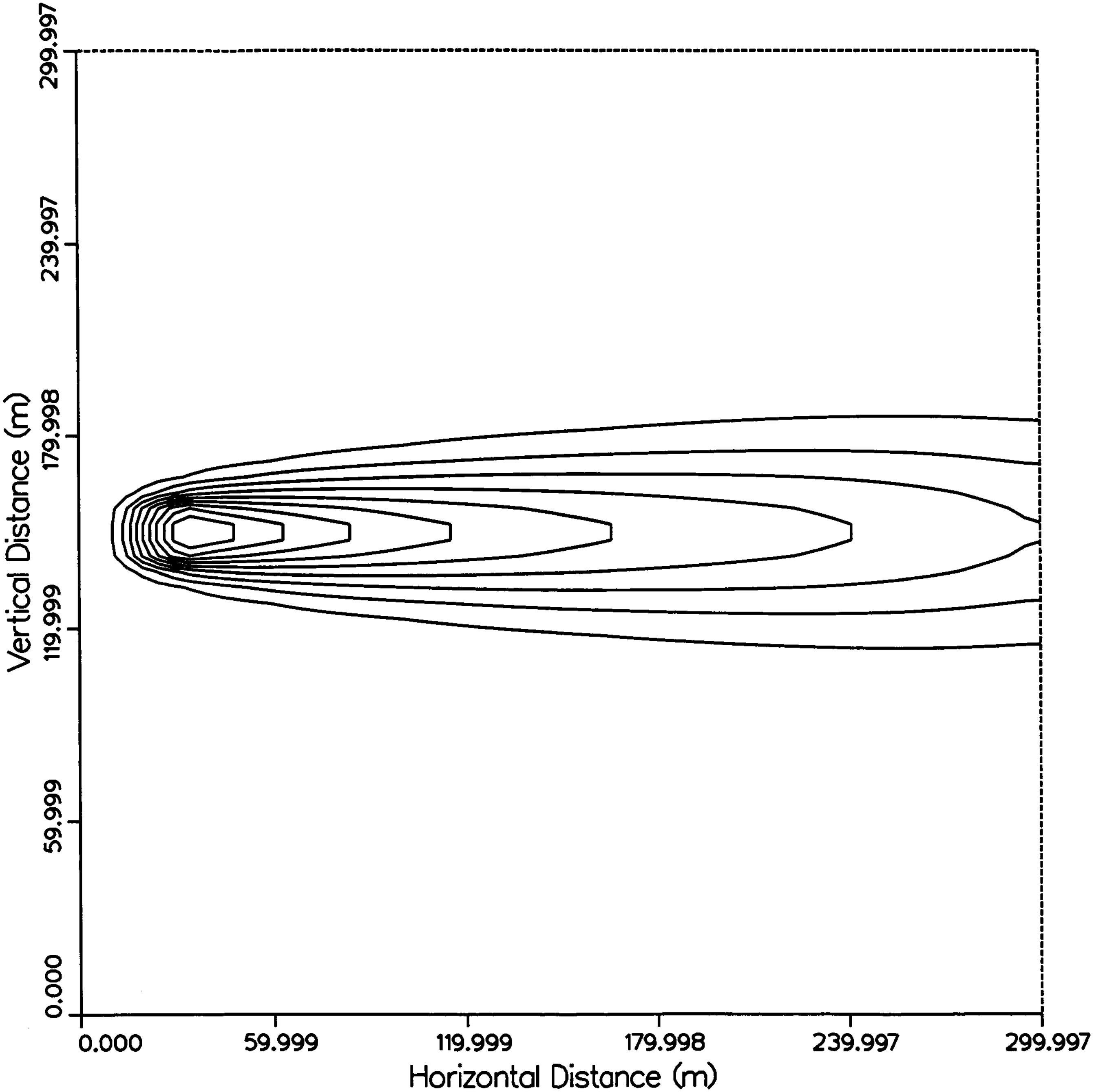


Time = 30.0


CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(827961058)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 35.0

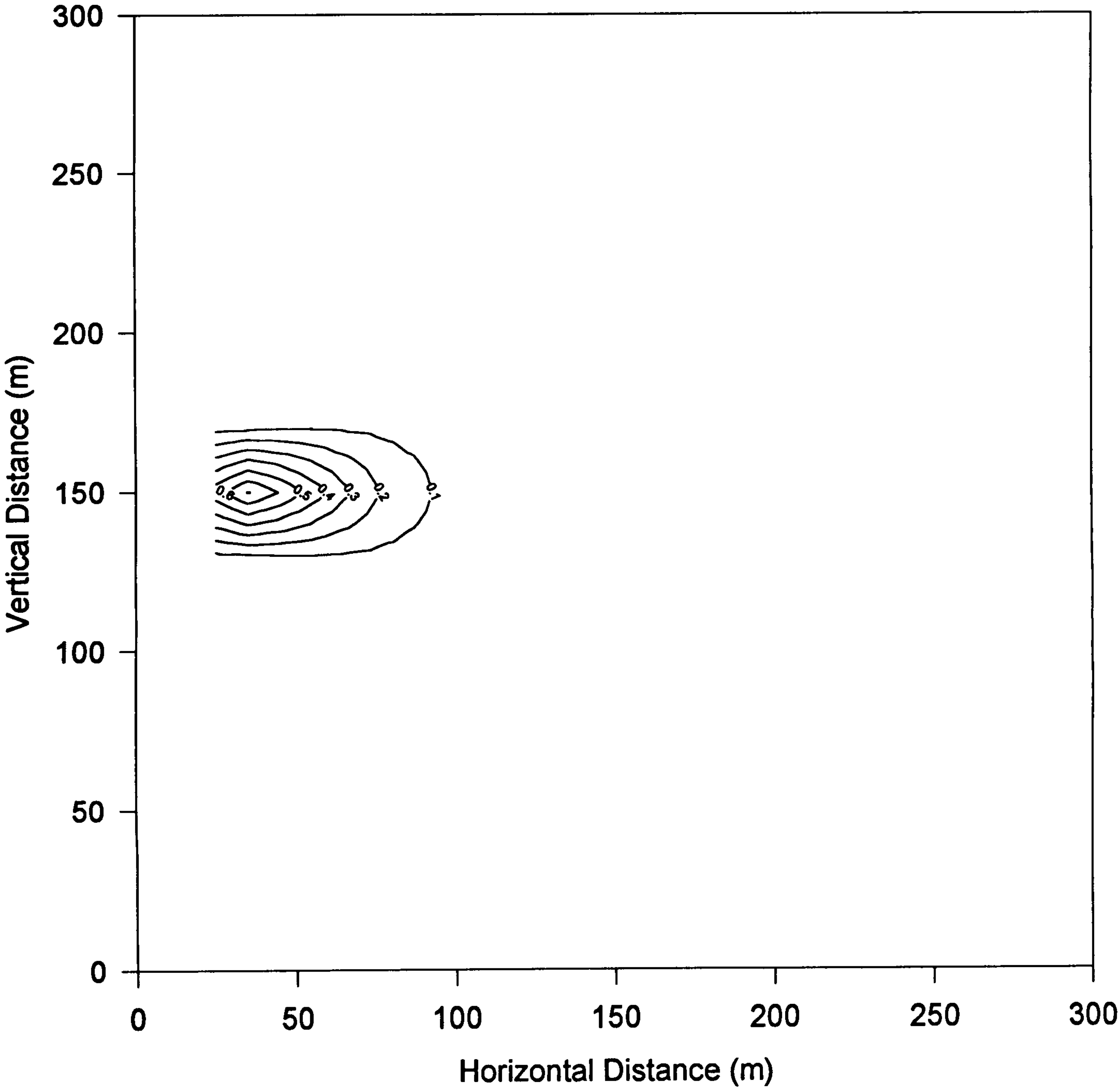
CHAINT Results for Comparison With GWMOD
Tc99, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(827961058)

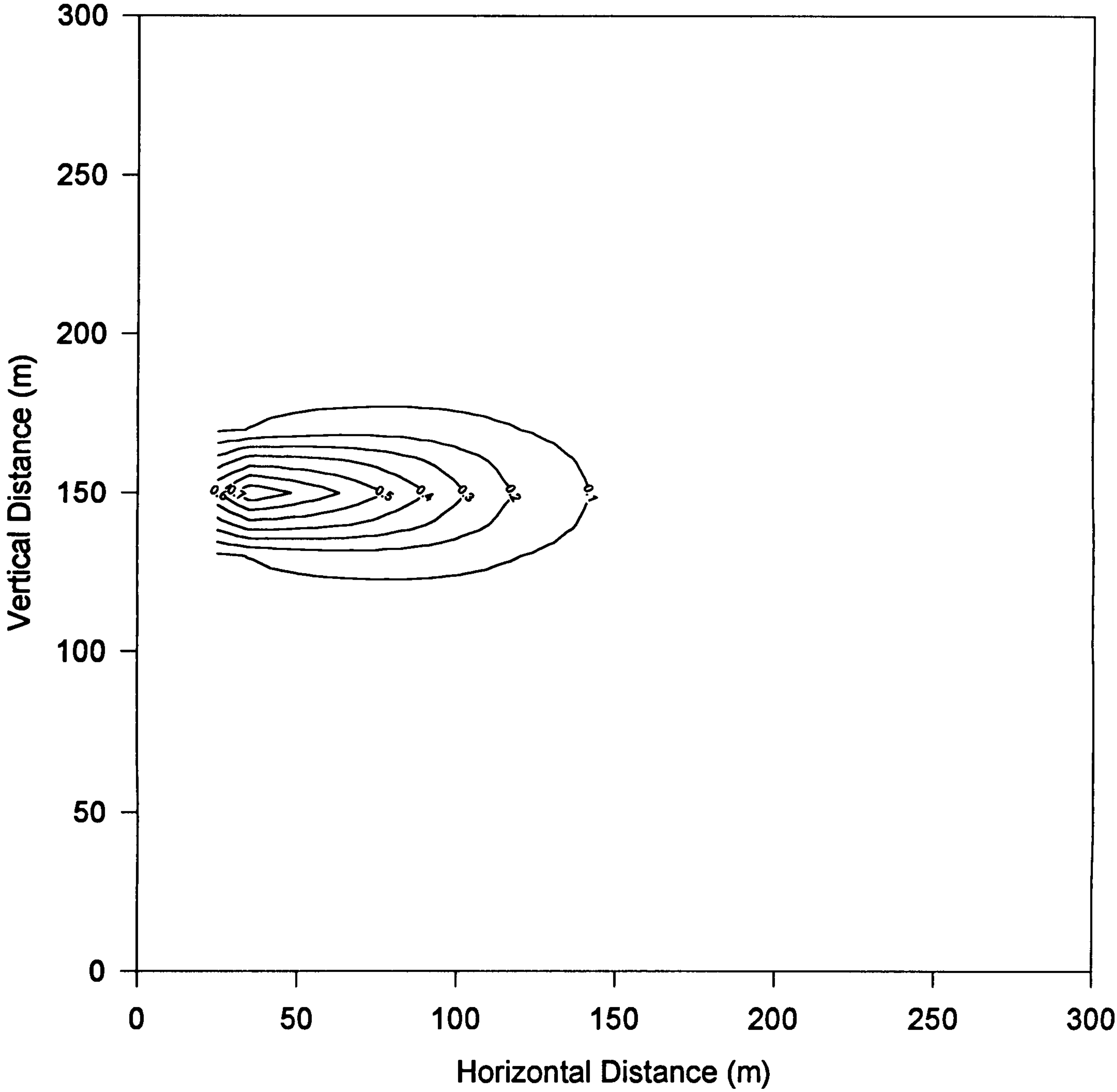


Time = 40.0

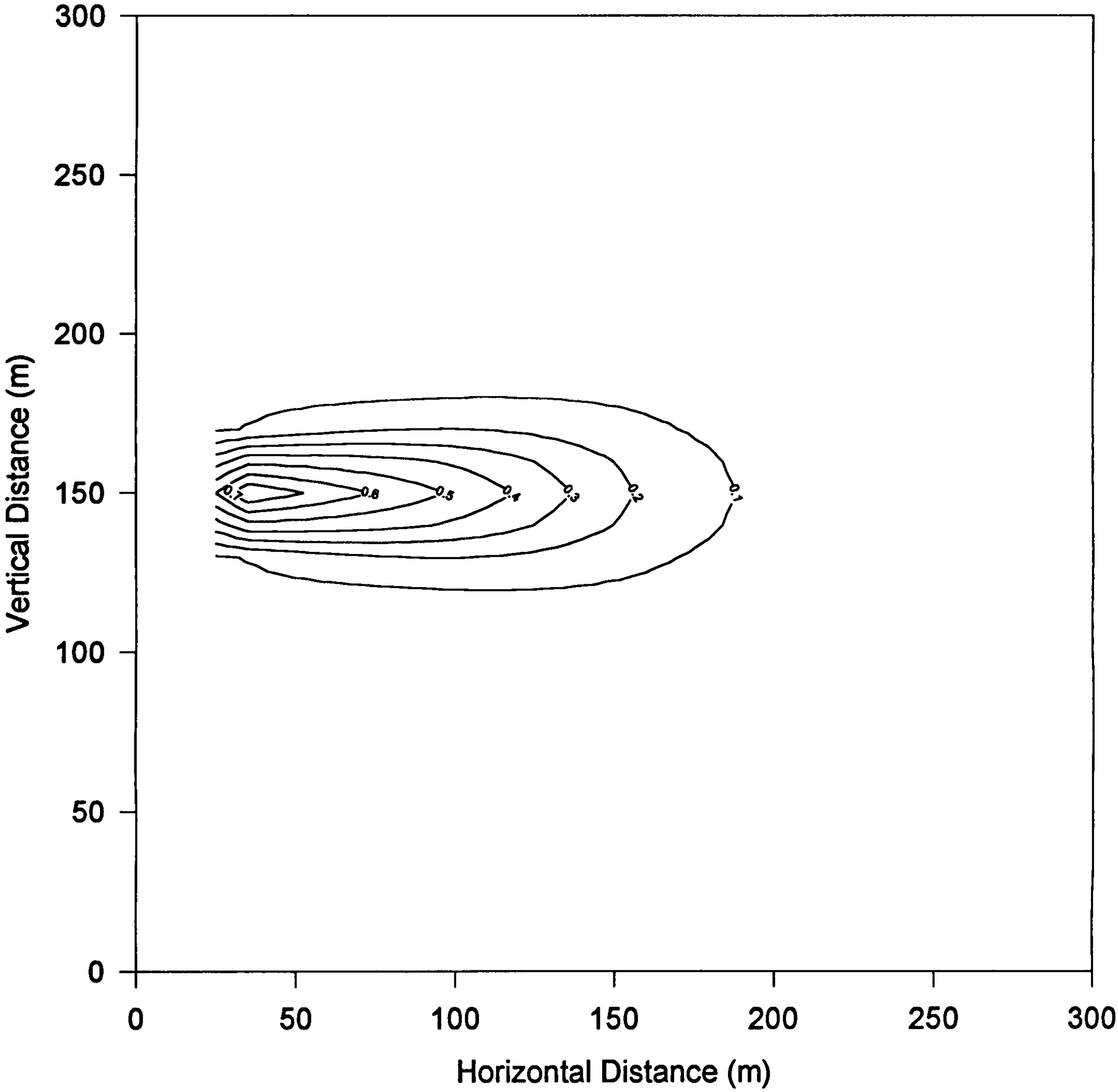
GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 5 Years



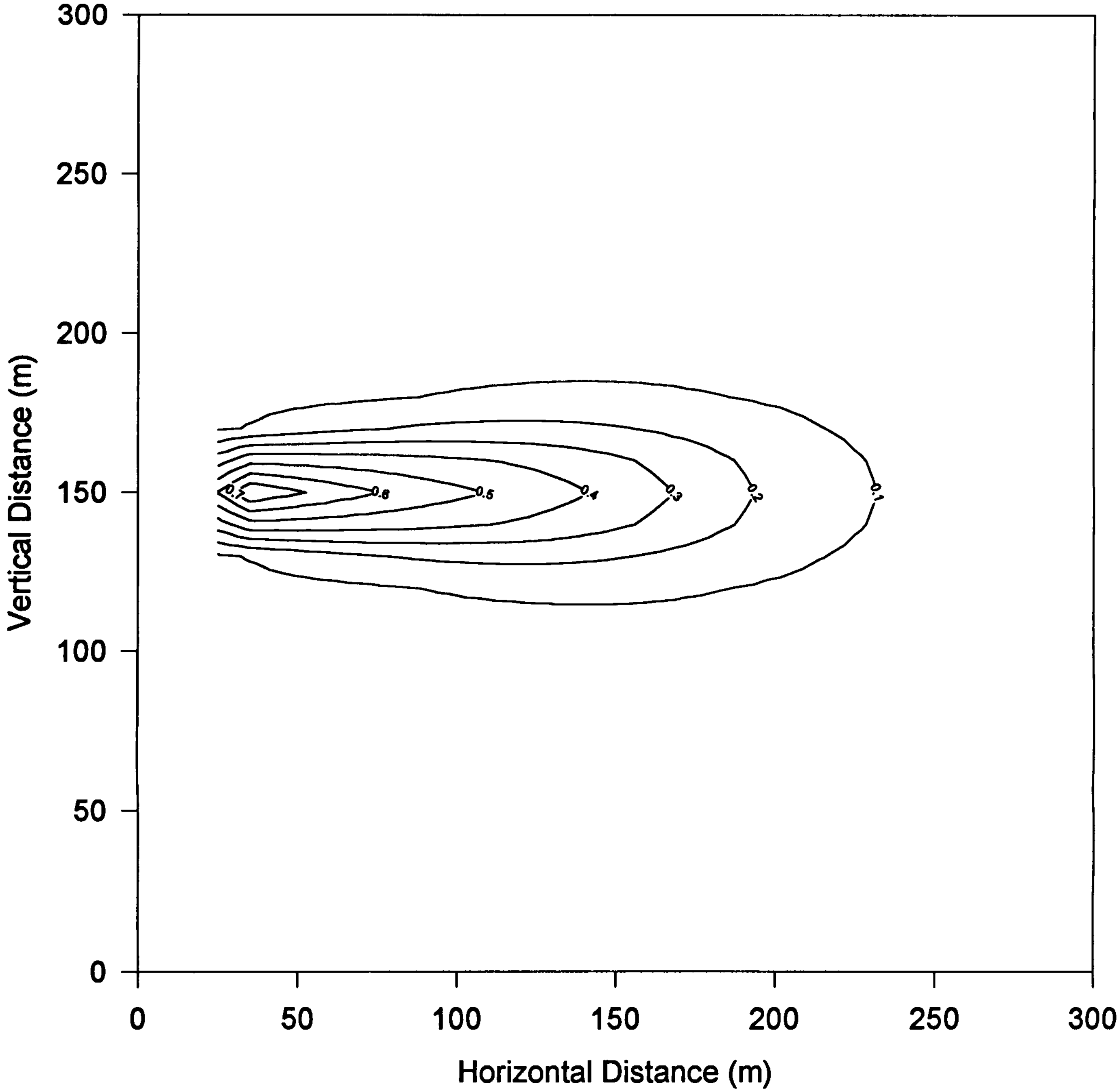
GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 10 Years



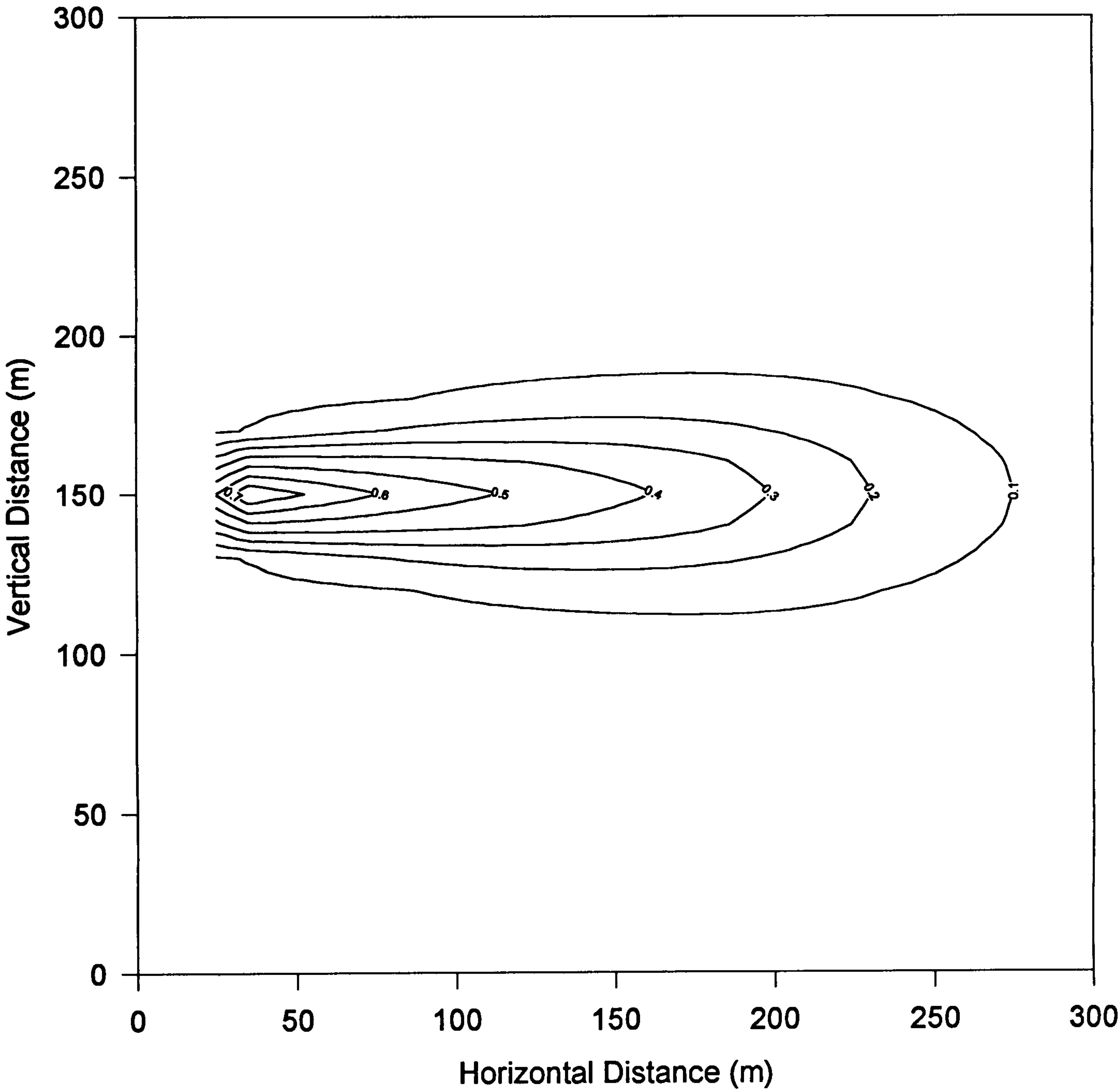
GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 15 Years



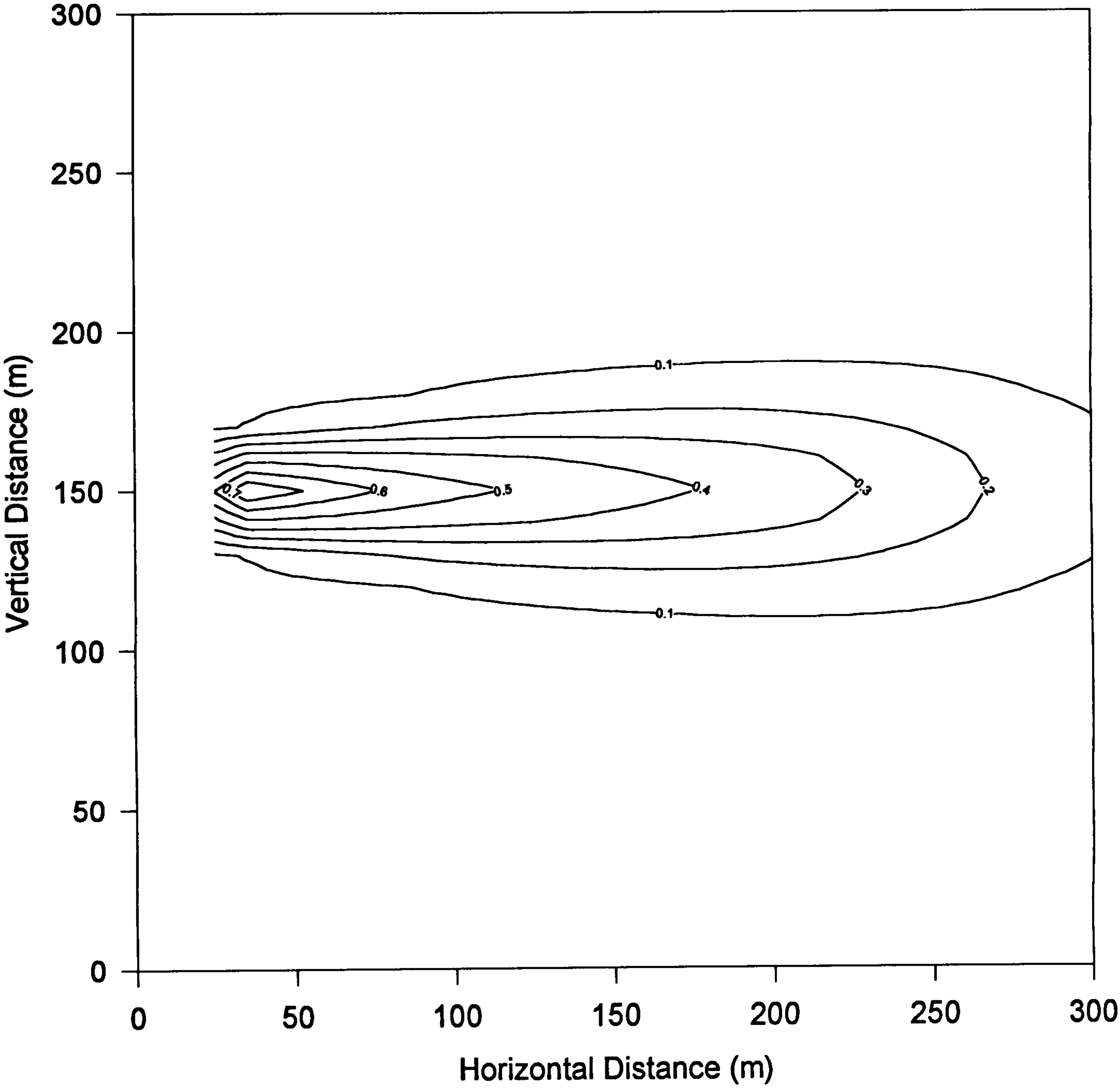
GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 20 Years



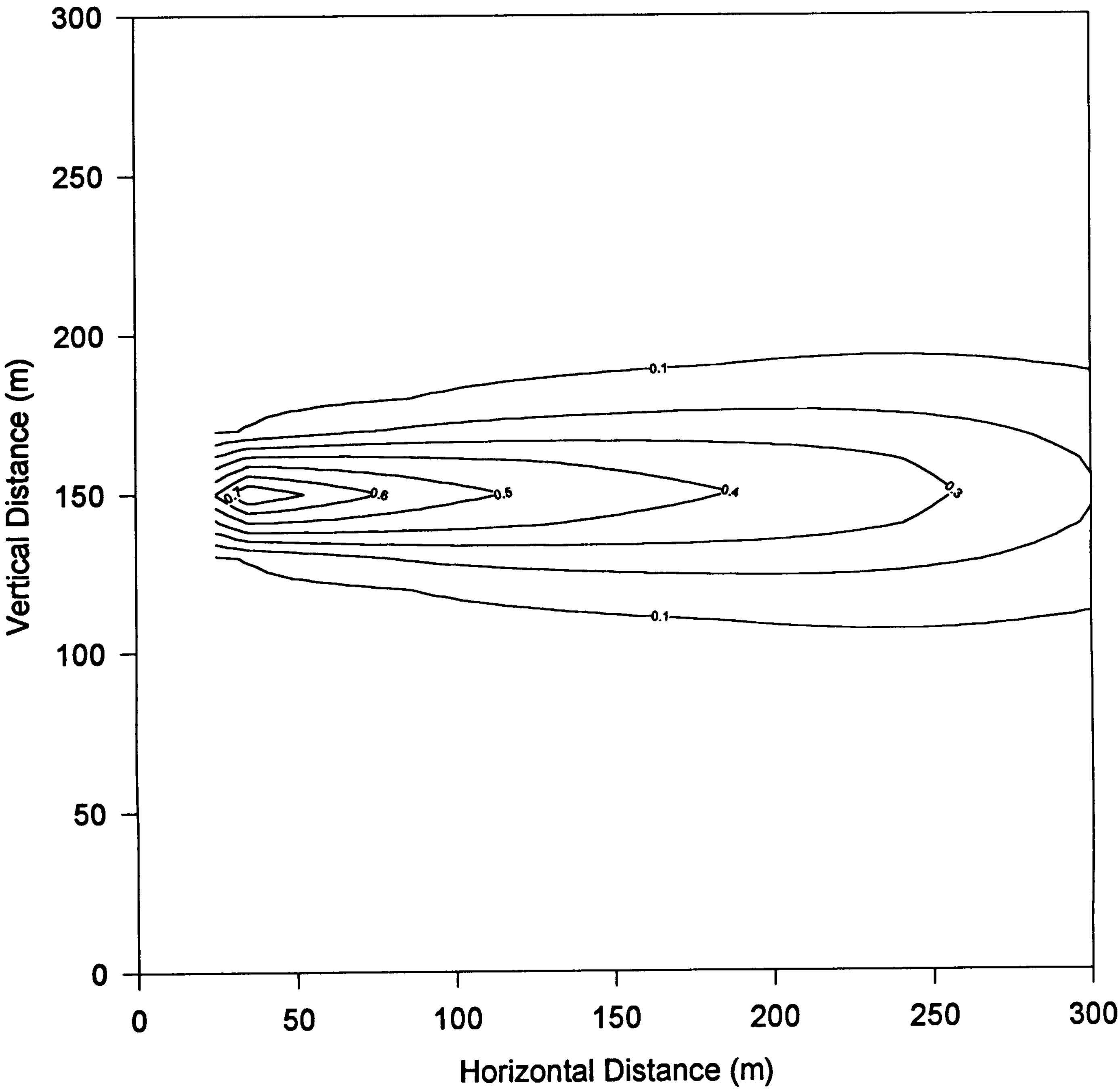
GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 25 Years



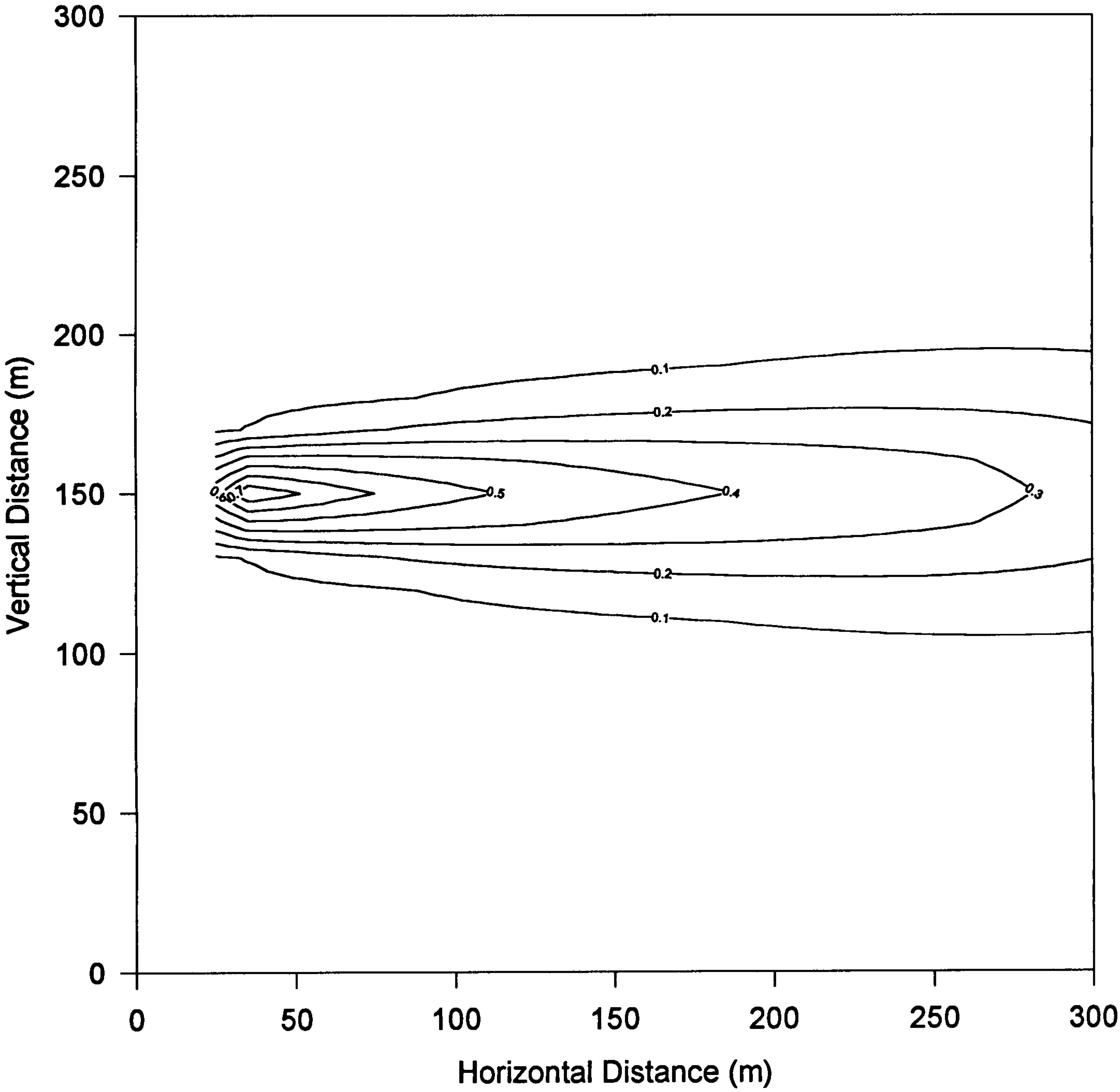
GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 30 Years



GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 35 Years

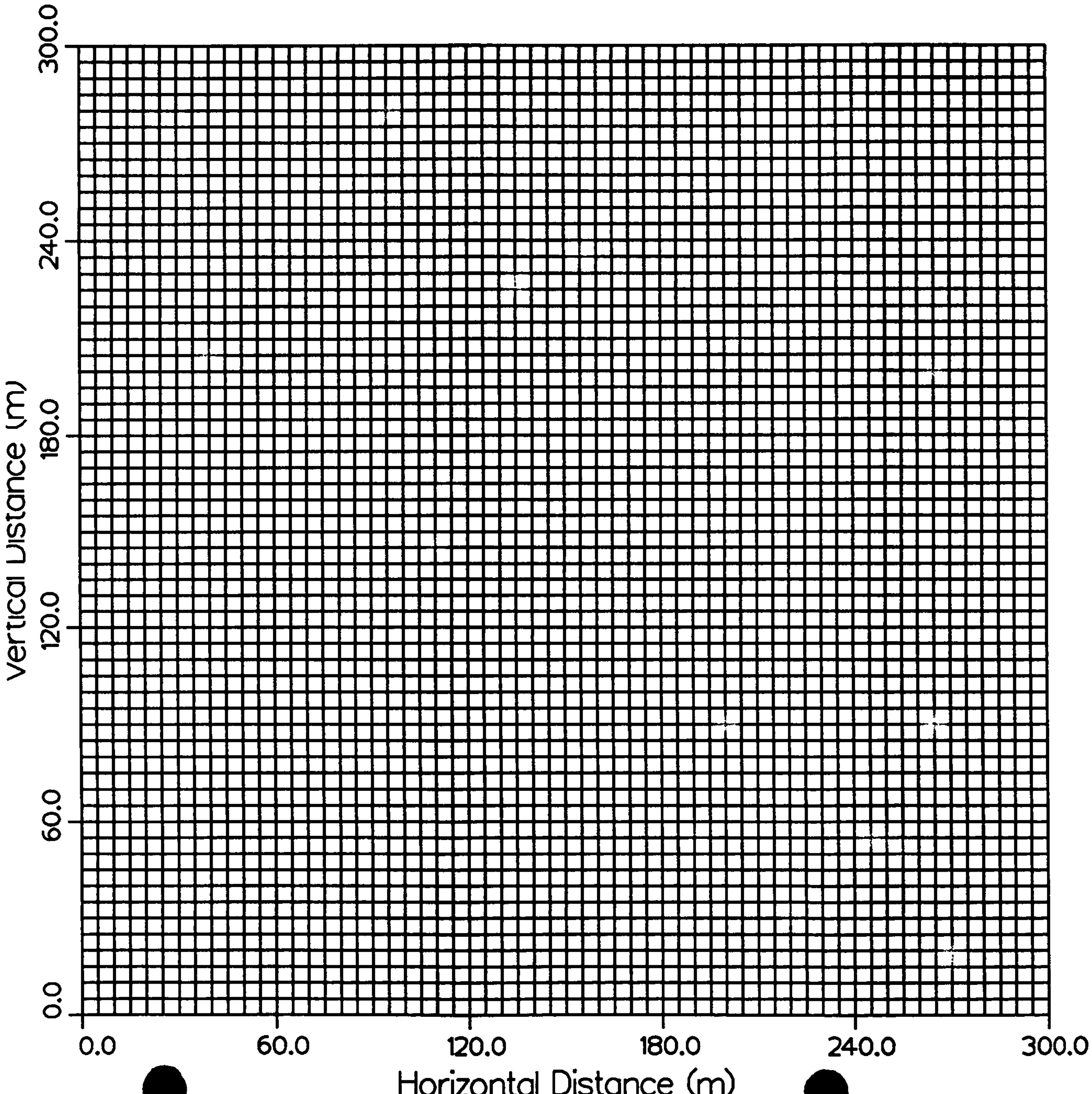


GWMOD Results for Comparison with CHAINT
Tc-99, mg/L at 40 Years



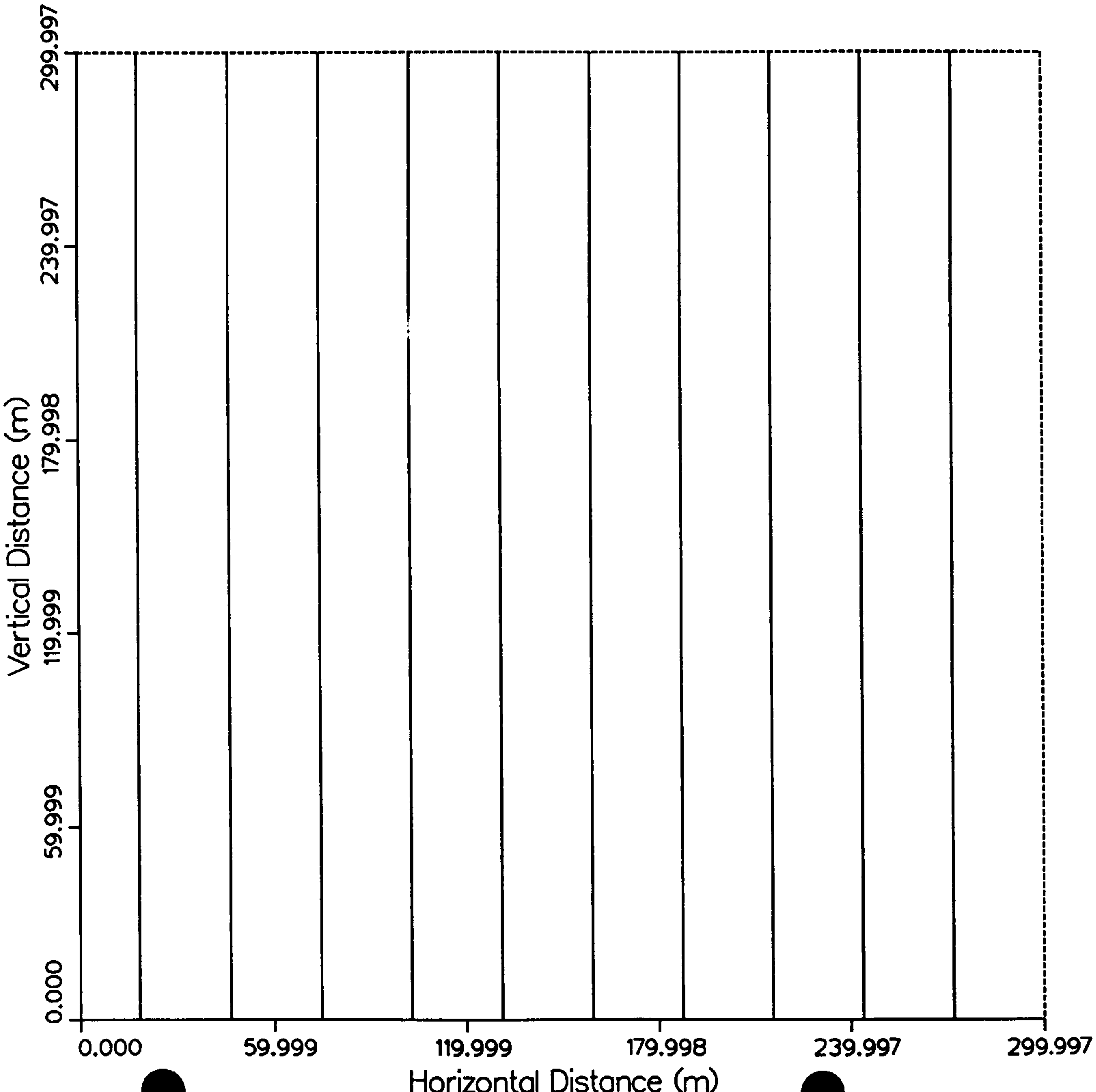
MAGNUM Geometry Grid for Comparison with GWMODF2
FINITE ELEMENT GRID

(PLT 2.00)
(830960755)
(0)



MAGNUM-2D for Comparison with GWMODF2
HEAD 1, METERS

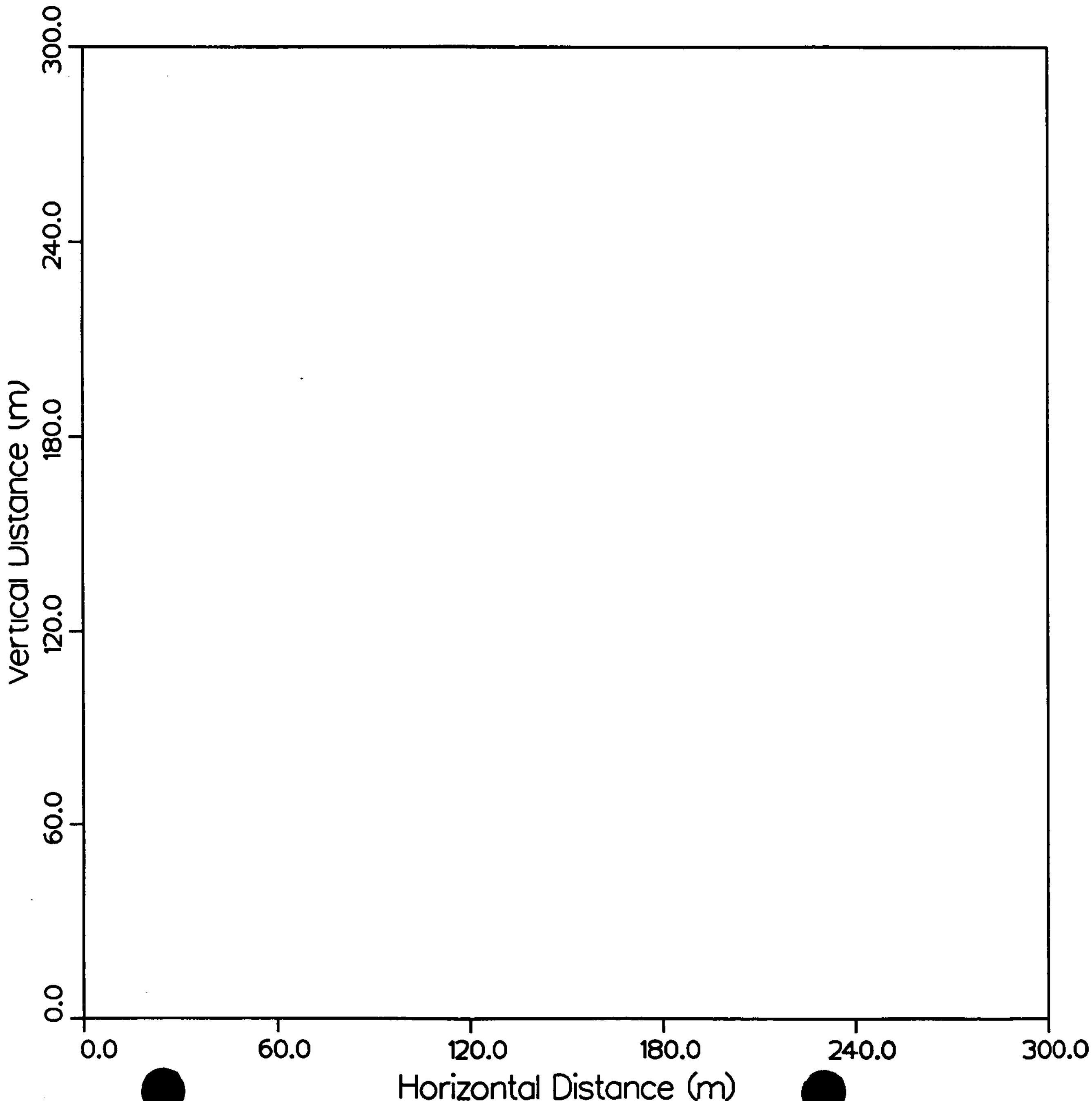
MAGNUM2D
****
(CONT 2.03)
(830960805)



Time = 1.0 -20

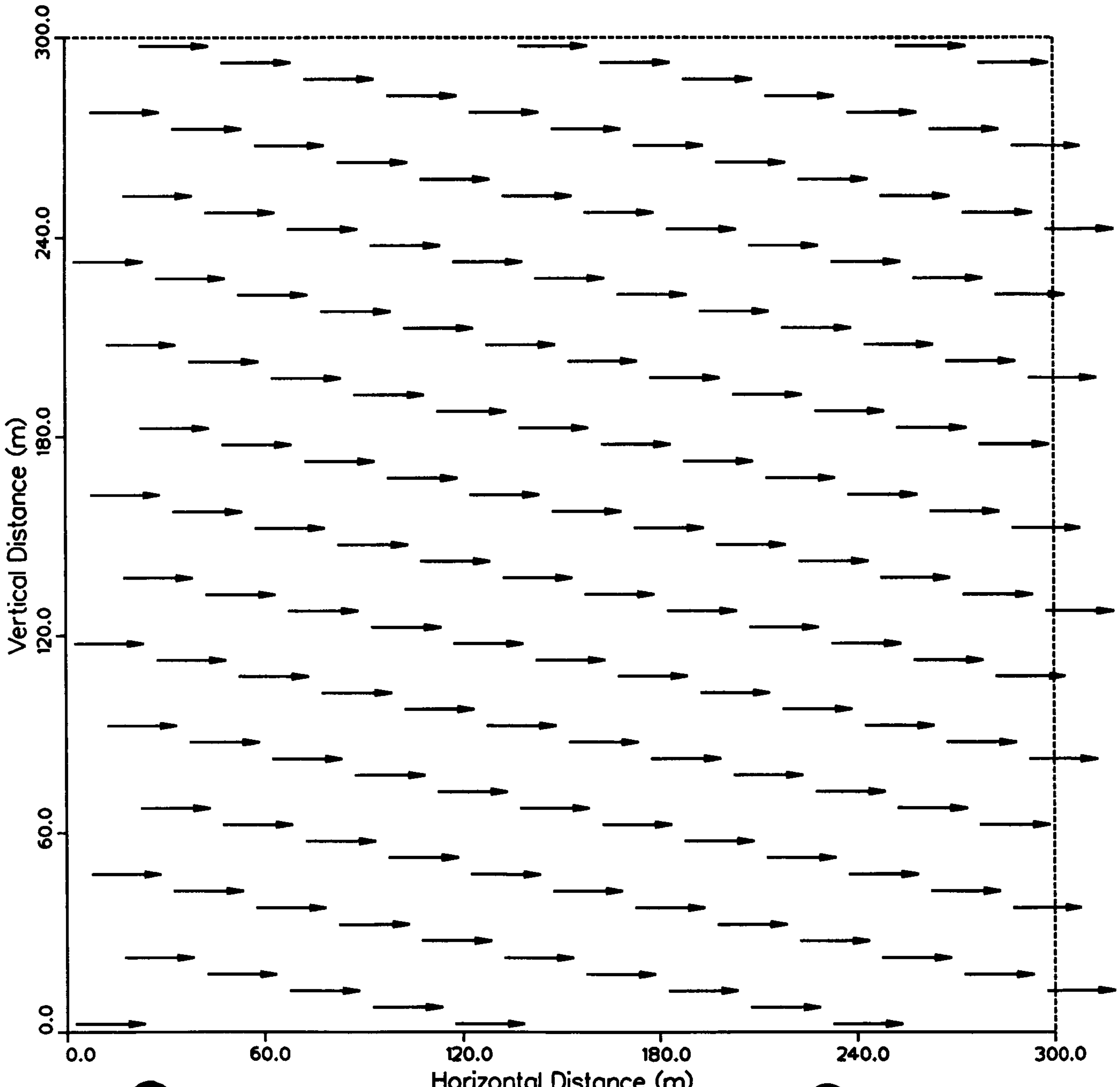
MAGNUM Geometry Grid for Comparison with GWMODF2
MATERIAL TYPE BOUNDARIES

(PLT 2.00)
(830960755)
(0)



DARCY VELOCITY VECTOR PLOT
MAGNUM – 2–D Test case for comparison with GWMODF2
SCALED MAGNITUDES, TRUE DIRECTIONS

MAGNUM2D 3.20
****
(VELP 2.00)
(830960821)



Scale Factor

Time = 0.000

```
MAGNUM - 2-D Test case for comparison with GWMODF2
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
    1     0      1  11041  3600    1    0    0     0    1     1    0
#  irs  isv  icf  igi  ig  ivel inpt icsv
 [illegible]  13   0   10   0   12   0    0
#  ssf   alfa  tref
   0.0    1.8   20.0
#  nts  ntsg   dlt
    1    1     1000.
 9999    1     1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#    n       To      Ho
    1    20.000   0.5327
#  kspec
   242
#        n     n1 n2  Tbc      Hbc
     10860        0  1   20.0000    0.0000
     10861        0  1   20.0000    0.0000
     10862        0  1   20.0000    0.0000
     10865        0  1   20.0000    0.0000
     10866        0  1   20.0000    0.0000
     10868        0  1   20.0000    0.0000
     10869        0  1   20.0000    0.0000
     10871        0  1   20.0000    0.0000
     10872        0  1   20.0000    0.0000
     10874        0  1   20.0000    0.0000
     10875        0  1   20.0000    0.0000
     10877        0  1   20.0000    0.0000
     10878        0  1   20.0000    0.0000
     10880        0  1   20.0000    0.0000
     10881        0  1   20.0000    0.0000
     10883        0  1   20.0000    0.0000
     10884        0  1   20.0000    0.0000
     10886        0  1   20.0000    0.0000
     10887        0  1   20.0000    0.0000
     10889        0  1   20.0000    0.0000
     10890        0  1   20.0000    0.0000
     10892        0  1   20.0000    0.0000
     10893        0  1   20.0000    0.0000
     10895        0  1   20.0000    0.0000
     10896        0  1   20.0000    0.0000
     10898        0  1   20.0000    0.0000
     10899        0  1   20.0000    0.0000
     10901        0  1   20.0000    0.0000
     10902        0  1   20.0000    0.0000
     10904        0  1   20.0000    0.0000
     10905        0  1   20.0000    0.0000
     10907        0  1   20.0000    0.0000
     10908        0  1   20.0000    0.0000
     10910        0  1   20.0000    0.0000
     10911        0  1   20.0000    0.0000
     10913        0  1   20.0000    0.0000
     10914        0  1   20.0000    0.0000
     10916        0  1   20.0000    0.0000
     10917        0  1   20.0000    0.0000
     10919        0  1   20.0000    0.0000
     10920        0  1   20.0000    0.0000
     10922        0  1   20.0000    0.0000
     10923        0  1   20.0000    0.0000
```

10925	0	1	20.0000	0.0000
10926	0	1	20.0000	0.0000
10928	0	1	20.0000	0.0000
10929	0	1	20.0000	0.0000
10931	0	1	20.0000	0.0000
10932	0	1	20.0000	0.0000
10934	0	1	20.0000	0.0000
10935	0	1	20.0000	0.0000
10937	0	1	20.0000	0.0000
10938	0	1	20.0000	0.0000
10940	0	1	20.0000	0.0000
10941	0	1	20.0000	0.0000
10943	0	1	20.0000	0.0000
10944	0	1	20.0000	0.0000
10946	0	1	20.0000	0.0000
10947	0	1	20.0000	0.0000
10949	0	1	20.0000	0.0000
10950	0	1	20.0000	0.0000
10952	0	1	20.0000	0.0000
10953	0	1	20.0000	0.0000
10955	0	1	20.0000	0.0000
10956	0	1	20.0000	0.0000
10958	0	1	20.0000	0.0000
10959	0	1	20.0000	0.0000
10961	0	1	20.0000	0.0000
10962	0	1	20.0000	0.0000
10964	0	1	20.0000	0.0000
10965	0	1	20.0000	0.0000
10967	0	1	20.0000	0.0000
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10970	0	1	20.0000	0.0000
10971	0	1	20.0000	0.0000
10973	0	1	20.0000	0.0000
10974	0	1	20.0000	0.0000
10976	0	1	20.0000	0.0000
10977	0	1	20.0000	0.0000
10979	0	1	20.0000	0.0000
10980	0	1	20.0000	0.0000
10982	0	1	20.0000	0.0000
10983	0	1	20.0000	0.0000
10985	0	1	20.0000	0.0000
10986	0	1	20.0000	0.0000
10988	0	1	20.0000	0.0000
10989	0	1	20.0000	0.0000
10991	0	1	20.0000	0.0000
10992	0	1	20.0000	0.0000
10994	0	1	20.0000	0.0000
10995	0	1	20.0000	0.0000
10997	0	1	20.0000	0.0000
10998	0	1	20.0000	0.0000
11000	0	1	20.0000	0.0000
11001	0	1	20.0000	0.0000
11003	0	1	20.0000	0.0000
11004	0	1	20.0000	0.0000
11006	0	1	20.0000	0.0000
11007	0	1	20.0000	0.0000
11009	0	1	20.0000	0.0000
11010	0	1	20.0000	0.0000
11012	0	1	20.0000	0.0000
11013	0	1	20.0000	0.0000

11015	0	1	20.0000	0.0000
11016	0	1	20.0000	0.0000
11018	0	1	20.0000	0.0000
11019	0	1	20.0000	0.0000
11021	0	1	20.0000	0.0000
11022	0	1	20.0000	0.0000
11024	0	1	20.0000	0.0000
11025	0	1	20.0000	0.0000
11027	0	1	20.0000	0.0000
11028	0	1	20.0000	0.0000
11030	0	1	20.0000	0.0000
11031	0	1	20.0000	0.0000
11033	0	1	20.0000	0.0000
11034	0	1	20.0000	0.0000
11036	0	1	20.0000	0.0000
11037	0	1	20.0000	0.0000
11039	0	1	20.0000	0.0000
11040	0	1	20.0000	0.0000
121	0	1	20.0000	1.0654
120	0	1	20.0000	1.0654
119	0	1	20.0000	1.0654
118	0	1	20.0000	1.0654
117	0	1	20.0000	1.0654
116	0	1	20.0000	1.0654
115	0	1	20.0000	1.0654
114	0	1	20.0000	1.0654
113	0	1	20.0000	1.0654
112	0	1	20.0000	1.0654
111	0	1	20.0000	1.0654
110	0	1	20.0000	1.0654
109	0	1	20.0000	1.0654
108	0	1	20.0000	1.0654
107	0	1	20.0000	1.0654
106	0	1	20.0000	1.0654
105	0	1	20.0000	1.0654
104	0	1	20.0000	1.0654
103	0	1	20.0000	1.0654
102	0	1	20.0000	1.0654
101	0	1	20.0000	1.0654
100	0	1	20.0000	1.0654
99	0	1	20.0000	1.0654
98	0	1	20.0000	1.0654
97	0	1	20.0000	1.0654
96	0	1	20.0000	1.0654
95	0	1	20.0000	1.0654
94	0	1	20.0000	1.0654
93	0	1	20.0000	1.0654
92	0	1	20.0000	1.0654
91	0	1	20.0000	1.0654
90	0	1	20.0000	1.0654
89	0	1	20.0000	1.0654
88	0	1	20.0000	1.0654
87	0	1	20.0000	1.0654
86	0	1	20.0000	1.0654
85	0	1	20.0000	1.0654
84	0	1	20.0000	1.0654
83	0	1	20.0000	1.0654
82	0	1	20.0000	1.0654
81	0	1	20.0000	1.0654
80	0	1	20.0000	1.0654

79	0	1	20.0000	1.0654
78	0	1	20.0000	1.0654
77	0	1	20.0000	1.0654
76	0	1	20.0000	1.0654
75	0	1	20.0000	1.0654
74	0	1	20.0000	1.0654
73	0	1	20.0000	1.0654
72	0	1	20.0000	1.0654
71	0	1	20.0000	1.0654
70	0	1	20.0000	1.0654
69	0	1	20.0000	1.0654
68	0	1	20.0000	1.0654
67	0	1	20.0000	1.0654
66	0	1	20.0000	1.0654
65	0	1	20.0000	1.0654
64	0	1	20.0000	1.0654
63	0	1	20.0000	1.0654
62	0	1	20.0000	1.0654
61	0	1	20.0000	1.0654
60	0	1	20.0000	1.0654
59	0	1	20.0000	1.0654
58	0	1	20.0000	1.0654
57	0	1	20.0000	1.0654
56	0	1	20.0000	1.0654
55	0	1	20.0000	1.0654
54	0	1	20.0000	1.0654
53	0	1	20.0000	1.0654
52	0	1	20.0000	1.0654
51	0	1	20.0000	1.0654
50	0	1	20.0000	1.0654
49	0	1	20.0000	1.0654
48	0	1	20.0000	1.0654
47	0	1	20.0000	1.0654
46	0	1	20.0000	1.0654
45	0	1	20.0000	1.0654
44	0	1	20.0000	1.0654
43	0	1	20.0000	1.0654
42	0	1	20.0000	1.0654
41	0	1	20.0000	1.0654
40	0	1	20.0000	1.0654
39	0	1	20.0000	1.0654
38	0	1	20.0000	1.0654
37	0	1	20.0000	1.0654
36	0	1	20.0000	1.0654
35	0	1	20.0000	1.0654
34	0	1	20.0000	1.0654
33	0	1	20.0000	1.0654
32	0	1	20.0000	1.0654
31	0	1	20.0000	1.0654
30	0	1	20.0000	1.0654
29	0	1	20.0000	1.0654
28	0	1	20.0000	1.0654
27	0	1	20.0000	1.0654
26	0	1	20.0000	1.0654
25	0	1	20.0000	1.0654
24	0	1	20.0000	1.0654
23	0	1	20.0000	1.0654
22	0	1	20.0000	1.0654
21	0	1	20.0000	1.0654
20	0	1	20.0000	1.0654

```
        19        0  1   20.0000    1.0654
        18        0  1   20.0000    1.0654
        17        0  1   20.0000    1.0654
        16        0  1   20.0000    1.0654
        15        0  1   20.0000    1.0654
        14        0  1   20.0000    1.0654
        13        0  1   20.0000    1.0654
        12        0  1   20.0000    1.0654
        11        0  1   20.0000    1.0654
        10        0  1   20.0000    1.0654
         9        0  1   20.0000    1.0654
         8        0  1   20.0000    1.0654
         7        0  1   20.0000    1.0654
         6        0  1   20.0000    1.0654
         5        0  1   20.0000    1.0654
         4        0  1   20.0000    1.0654
         3        0  1   20.0000    1.0654
         2        0  1   20.0000    1.0654
         1        0  1   20.0000    1.0654
     #  L    cvm     tkk(1)  tkk(2)  poros     hkax         hkay        nme
#       sp1      rhom   alpal   alpat    width
         1        0         0         0      0.07    5.0e-6    5.0e-6    mat1
   1.0e-6     2400         0         0         0
#  nld  nlt  scf
   0    0       0.0
```

```
CHAINT 2-D Test case (with flux source) for comparison with GWMODF2
#  nqal   ne     np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
    1    3600  11041  121    1      0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
   [illegible]0   11    0    0   14   15    0
#[illegible]sf  alfa  xscale  yscale  uscale  vscale
   0.  1.8    0.      0.      0.      0.
#  nts  ntsg   dlt   zonel  zoner  zonet  zoneb
    5    5    0.02    0.     0.     0.     0.
    9    9    0.1     0.     0.     0.     0.
    8    8    0.5     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
    5    5    1.0     0.     0.     0.     0.
 9999    0    0       0      0      0      0
#   j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1       5.        1.0      2400.      0.07       0.       mat1
#  islt
    1
#   L    amu    diag    isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1    1.0  2.13E+05    0        0.0       0        0.0    Tc99   0.0
#   i    dml(i,1..n2)  m2/yr
    1    0.0
#   i    xkdi(i,1..n2)  ml/g
    1    0.0
#[illegible]k    Ci
 [illegible]     0.0
#   L     bcs
    1     0.0
    2     0.0
    3     0.0
    4     0.0
    5     0.0
    6     0.0
    7     0.0
    8     0.0
    9     0.0
   10     0.0
   11     0.0
   12     0.0
   13     0.0
   14     0.0
   15     0.0
   16     0.0
   17     0.0
   18     0.0
   19     0.0
   20     0.0
   21     0.0
   22     0.0
   23     0.0
 [illegible]     0.0
 [illegible]     0.0
   26     0.0
   27     0.0
   28     0.0
```

29	0.0
30	0.0
31	0.0
32	0.0
33	0.0
34	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	0.0
58	0.0
59	0.0
60	0.0
61	0.0
62	0.0
63	0.0
64	0.0
65	0.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
84	0.0
85	0.0
86	0.0
87	0.0
88	0.0

```
  89    0.0
  90    0.0
  91    0.0
  92    0.0
  93    0.0
  94    0.0
  95    0.0
  96    0.0
  97    0.0
  98    0.0
  99    0.0
 100    0.0
 101    0.0
 102    0.0
 103    0.0
 104    0.0
 105    0.0
 106    0.0
 107    0.0
 108    0.0
 109    0.0
 110    0.0
 111    0.0
 112    0.0
 113    0.0
 114    0.0
 115    0.0
 116    0.0
 117    0.0
 118    0.0
 119    0.0
 120    0.0
 121    0.0
#   nld   scf   relz
    16    1.0    0.
#   NLE
 209  210 211  212   269  270  271  272
 329  330 331  332   389  390  391  392
#   TLE        RLE(Tc99)
        0.00000E+00     0.0322406
        50.0            0.0322406
   -1.0      0.0
```

```
1 0                 SOURCE  (0)POINT (1)AREA (2)LINE  JAVG (0)AVG (1)NOT-AVG
2                    MODE    (1) CONC VS TIME (2) XY CONTOUR (3) Z CONTOUR
1                           TYPE     (0) IMPULSE  (1) TIME VARIANT
0.07                        PHI
1.00E+00                   QIMP
1.0 1.00E-02 50. 20   FACTOR EPS ARB JMAX
1.03E-13,1.00E-20,1.00E-20,1.0E-20,1.0E-20,1.0E-20  DLR(I)
5.0,1.0,0.0,2.5368-7,0.0,1.0               AX,AY,AZ,VX,DEPTH,THICK
1.0,1.0,1.0,1.0,1.0,1.0        RD(I)
0.0,10.0,10.0                     TSTART TEND,TP
20.0,  20.0                              AL,WA
0.0,0.0,0.0                            XD,YD,ZD
1 25                                     JSPEC JSTART
'gwmod.in'                                FILEIN
'10Tc99.out'                fileout
'GWMODF2 Test Case with Tc-99 for Comparison with CHAINT'   TITLE
```

GWMODF INPUT DECK

This program is a combination of two codes: GWMOD and GROUND. The analytical solutions to the groundwater equations for a point, line and area source found in Till and Meyer Eq 4.25, 4.36 and 4.37. Soultion for time varient releases are taken from the Simpson rule integration as interpreted by Codell in the GROUND code.

VARIABLES:

SOURCE = CHOOSE TO RUN EITHER(0)POINT SOURCE(1)AREA SOURCE(3)LINE SOURCE
JAVG = (0) AVERAGED (1)NON AVERAGED
MODE = (1) CONC VS TIME (2) CONTOUR XY PLANE OR (3) CONTOUR Z SLICE
TYPE = (0) IMPULSE RELEASE (1) TIME VARIENT RELEASE
PHI = POROSITY
QIMP = IMPULSE RELEASE MASS (amount)
FACTOR = VALUE TO MULTIPLY FINAL RESULTS BY (use 1.0 if no change is desired)
JMAX = MAXIMIM NUMBER OF STEPS (assume to start at 20, increase if necessary)
EPS = Desired accuracy
ARB = ARBITRARY NUMBER TO MULITPLY TIME VALUES BY IN DETERMINING INTEGRATION
DLR = DECAY CONSTANT (s-1)
AX = DISPERSIVITY IN THE X DIRECTION (m)
AY = DISPERSIVITY IN THE Y DIRECTION (m)
AZ = DISPERSIVITY IN THE Z DIRECTION (m)
VX = PORE VELOCITY, (m/s)
DEPTH = DEPTH OF SOURCE IN AQUIFER (m)
THICK = THICKNESS OF AQUIFER (m)
RD(I) = RETARDATION FACTOR (an array of 6)
TSTART = TIME TO START SIMULATION (years)
TEND = END TIME OF SIMULATION (years)
TP = OUTPUT TIME STEP (years)
AL = LENGTH OF SOURCE (m)
WA = WIDTH OF SOURCE USED AS WIDTH FOR LINE SOURCES (m)
XD = DESIRED X DISTANCE (m)
YD = DESIRED Y DISTANCE (m)
ZD = DESIRED Z DISTANCE (m)
JSPEC = DESIRED SPECIES (1,2,3,4,5 or 6)
FILEIN = RELEASE RATE INPUT FILE (years, amount/s)
FILEOUT = OUTPUT FILE FOR CONTOUR OR CONCENTRATIONS
TITLE = TITLE OF PROJECT

```
      PROGRAM GWMODF2
C
C AUTHOR   A.S. ROOD
C ORIGINAL PROGRAM WRITTEN FEBRUARY 10, 1989
C REVISED FORTRAN VERSION 12/90
C This program is a refinement of GROUND written by D Codell.  The analytical
C solutions to the groundwater equations for a point, line and area source are
C found in Till and Meyer Eq 4.25, 4.31 and 4.37.  Solution for time variant releases
C are taken from the Simpson rule integration. Limits of integration are
C determined by Codells method in the GROUND code. Simpson rule integration
C was taken from Numerical Recipes and found in the routines SIMPSON and TRAPZD

C 3/28 89   Reduced the number of std the program looks at initially in
C subroutine  SIMPSON.
C 4/15/89 Added solution for a NON vertically averaged area source.
C Also added routines to print out date and time in output along with
C the GWMOD2.PAR file and the GW.REL file
C 4/16/89 Changed the number of std initially looked at in SIMPSON from
C DEL=STD/4 to DEL=STD/10.  This was earlier changed in 3/28/89 but was
C changed back due to under estimations of concentration using Codells
C examples.
C 4/27/89 Added character variables to allow for input and output file
C names to be input by the user.
C 06/01/89 DEL changed from STD/10 to STD/JMAX.     The was done in order
C to eliminate problems when the STD of a pulse was extremely large, such
C as the case with high RD values.  This results in high DEL values and
C a value of TNM of less than 1.
C 10/23/90 INCREASED THE VALUE OF M TO 100
C 12/11/90 REWROTE INTEGRATION ROUTINE TO BE AS CLOSE AS POSSIBLE TO
C THE SIMPSONS RULE ROUTINE IN NUMERICAL RECIPES. Changed the conversion
C from years-to-seconds to 3.1536E07
C 01/05/90 Changed TEMP2 variable in integration limit determination
C to be similar to Codell's P9 variable Added variable JAVG

      IMPLICIT REAL*8 (A-H,O-Z)

C  INPUT VARIABLES:

C SOURCE = CHOOSE TO RUN EITHER (0) POINT SOURCE (1) AREA SOURCE  (3) LINE SOURCE
C JAVG = (0) VERT AVERAGED  (1) NOT VERT AVERAGED
C MODE =  (1) CONC VS TIME (2) CONTOUR XY PLANE OR (3) CONTOUR Z SLICE
C TYPE = (0) IMPULSE RELEASE (1) TIME VARIENT RELEASE
C PHI = POROSITY
C QIMP = IMPULSE RELEASE MASS (amount)
C FACTOR = VALUE TO MULTIPLY FINAL RESULTS BY (use 1.0 if no change is desired)
C EPS = Desired accuracy
C JMAX = MAX NUMBER OF STEPS
C ARB = ARBITRARY NUMBER TO DETERMINE INTEGRATION LIMITS
C DLR = DECAY CONSTANT  (s-1)
C AX = DISPERSIVITY IN THE X DIRECTION (m)
C AY = DISPERSIVITY IN THE Y DIRECTION (m)
C AZ = DISPERSIVITY IN THE Z DIRECTION (m)
C VX = PORE VELOCITY,  (m/s)
C DEPTH = DEPTH OF SOURCE IN AQUIFER (m)
C THICK = THICKNESS OF AQUIFER (m)
C RD(I) = RETARDATION FACTOR
C TSTART = TIME TO START SIMULATION (years)
C TEND = END TIME OF SIMULATION (years)
C TP = OUTPUT TIME STEP (years)
C AL = LENGTH OF SOURCE (m)
C WA = WIDTH OF SOURCE  USED AS WIDTH FOR LINE SOURCES (m)
C XD = DESIRED X DISTANCE (m)
C YD = DESIRED Y DISTANCE (m)
C ZD = DESIRED Z DISTANCE (m)
C JSPEC = DESIRED SPECIES (1,2,3,4,5 or 6)
C JSTART=NUMBER OF INITIAL STEPS
C ATIME = TIME ARRAY FOR TIME VARIANT RELEASES [ATIME(NSTEPS)], time in years
C QREL =  RELEASE RATE ARRAY FOR TIME VARIANT RELEASES [QREL(NSTEPS,NSPEC)] release rate in
amount per sec
C X(I), Y(I), Z(I) COORDINATE MATRIX FOR CONTOURING PURPOSES INPUT DURING CONTOUR

C CALCULATED VARIABLES

C TIME = TIME COUNT VARIABLE (years in subroutine SIMPSON, sec in subroutine TRAPZD)
C TI = TIME COUNT VARIABLE CONVERTED TO SECONDS
C A = BOTTOM LIMIT OF INTEGRATION  (s) (in subroutine TRAPZD)
C B = UPPER LIMIT OF INTEGRATION   (s) (in subroutine TRAPZD)
C T1 = BOTTOM LIMIT OF INTEGRATION  (s) (in subroutine SIMPSON)
C T2 = UPPER LIMIT OF INTEGRATION   (s) (in subroutine SIMPSON)
C TC = TIME COUNT VARIABLE
C NP = NUMBER OF POINTS IN TIME VARIANT SOURCE INPUT FILE
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C TNM = NUMBER OF DIVISIONS IN INTEGRATION
C DEL = TIME INCREMENT IN INTEGRATION (DEL=B-A/TNM)
C TCAL = TIME WHICH CONC. IS CALC. FOR A RELEASE AT TI in subroutine TRAPDZ (TCAL= TI-TIME)
C QREL = SOURCE RELESES ARRAY FOR TIME VARIANT RELEASES (amount/s)
C TS = TOTAL TIME OF SOURCE INPUT (years)
C PECLET = PECLET NUMBER
C GWT = GROUND WATER TRAVEL TIME
C STD = STANDARD DEVIATION OF PULSE (no dimentions)
C STDD = STANDARD DEVIATION OF PULSE (dimentioned)
C TTIME = CHARACTER VARIABLE FOR HOLDING TIME OF RUN
C DDATE = CHARACTER VARIABLE FOR HOLDING DATA OF RUN


C PARAMETERS

C NSTEPS= PARAMETER FOR DIMENSION OF INPUT SOURCE FILE
C NSPEC = NUMBER OF CHEMICAL SPECIES TO CONSIDER

      PARAMETER(NSPEC=6,NSTEPS=2000)
      DIMENSION  RD(NSPEC),DLR(NSPEC),ATIME(NSTEPS),QREL(NSTEPS,NSPEC)
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /SOURCE/ ATIME,QREL,NP
      COMMON /FILES/ FILEIN,FILEOUT,TITLE
      WRITE(*,1000)
 1000 FORMAT(2X,' ********************  GWMODF2 *********************'
     !/,2X,' * ORIGINAL FORTRAN VERSION WRITTEN FEB 10 1988     *'
     !/,2X,' * REVISED FORTRAN VERSION WRITTEN APRIL 10 1991    *'
     !/,2X ' * DATE OF LAST PROGRAM MODIFICATION 04/10/91       *'
     !/,2X,' * This program uses equation 4.25, 4.31 and 4.37   *'
     !/,2X,' * in Till and Meyer for a source at 0,0,Zs         *'
     !/,2X,' * in an aquifer of infinite lateral extent         *'
     !/,2X,' * and finite thickness and constant pore velocity  *'
     !/,2X,' * A. S. ROOD  EG&G IDAHO                           *'
     !/,2X,' **************************************************')
C INPUT ENVIRONMENTAL PARAMETERS
      OPEN(1,FILE='GWMODF.PAR', STATUS='OLD')
      READ(1,*) SOURCE,JAVG
      READ(1,*) MODE
      READ(1,*) TYPE
      READ(1,*) PHI
      READ(1,*) QIMP
      READ(1,*) FACTOR,EPS,ARB,JMAX
      READ(1,*) (DLR(I),I=1,NSPEC)
      READ(1,*) AX,AY,AZ,VX,DEPTH,THICK
      READ(1,*) (RD(I),I=1, NSPEC)
      READ(1,*) TSTART,TEND,TP
      READ(1,*) AL,WA
      READ(1,*) XD,YD,ZD
      READ(1,*) JSPEC,JSTART
      READ(1,*) FILEIN
      READ(1,*) FILEOUT
      READ(1,*) TITLE
      CLOSE(1,STATUS='KEEP')
      WRITE(*,*) TITLE

C CALCULATE CONTAMINANT CONCENTRATIONS AS A FUNCTION OF TIME
      IF(MODE.EQ.1.) THEN
      CALL TSOURCE(XD,YD,ZD)
      ELSE
C CALCULATE CONTAMINANT CONCENTRATION WITH CONTOUR OUTPUT
      IF(MODE.GE.2.) THEN
      CALL CONTOUR
      ENDIF
      ENDIF
      END

C *******************************************************************
C     SUBROUTINE TSOURCE
C *******************************************************************
      SUBROUTINE TSOURCE(XD,YD,ZD)
      implicit real*8 (a-h,o-z)
      PARAMETER (NSPEC=6,NSTEPS=2000)
      CHARACTER*11 TTIME
```

```
      CHARACTER*8 DDATE
      CHARACTER*40 FILEIN, FILEOUT
      CHARACTER*80 TITLE
      DIMENSION RD(NSPEC),DLR(NSPEC)

      CALL TIME(TTIME)
      CALL DATE(DDATE)

C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG
      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /FILES/ FILEIN,FILEOUT,TITLE

      WRITE(*,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,XD,YD,ZD,AL,WA,QIMP,FACTOR,TSTART,TEND,TP,EPS,ARB,JMAX,
     ! JSTART

    7 FORMAT(2X,'WATER TRANSPORT PARAMETERS FOR CONC. VS TIME PLOT'
     !/,2X,'*********************************************************'
     !/,2X,'SOURCE TYPE: (0) POINT (1) AREA (2) LINE          ',I1
     !/,2X,'VERTICALLY AVERAGED: (0) YES  (1) NO              ',I1
     !/,2X,'TYPE OF RELEASE: (0) IMPULSE  (1) TIME VARIANT   ',I1
     !/,2X,'POROSITY                                         ',1PE9.2
     !/,2X,'DECAY CONSTANTS (s-1) ',1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,
     ! 1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,2X,'DISPERSIVITY X DIRECTION (m)                     ',1PE11.4
     !/,2X,'DISPERSIVITY Y DIRECTION (m)                     ',1PE11.4
     !/,2X,'DISPERSIVITY Z DIRECTION (m)                     ',1PE11.4
     !/,2X,'RETARDATION FAC.',1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1
     !PE9.2,1X,1PE9.2
     !/,2X,'PORE VELOCITY  (m/s)                             ',1PE11.4
     !/,2X,'CHEMICAL SPECIES DESIRED                         ',1PE9.2
     !/,2X,'WATER TABLE THICKNESS (m)                        ',1PE9.2
     !/,2X,'DEPTH OF SOURCE (m)                              ',1PE9.2
     !/,2X,'DESIRED X DISTANCE (m)                           ',1PE11.4
     !/,2X,'DESIRED Y DISTANCE (m)                           ',1PE11.4
     !/,2X,'DESIRED Z DISTANCE (m)                           ',1PE11.4
     !/,2X,'LENGTH OF SOURCE (for area source) (m)           ',1PE11.4
     !/,2X,'WIDTH OF SOURCE (for area source) (m)            ',1PE11.4
     !/,2X,'IMPULSE MASS INPUT (mass units)                  ',1PE11.4
     !/,2X,'OUTPUT FACTOR                                    ',1PE11.4
     !/,2X,'TIME START OF SIMULATION (years)                 ',1PE11.4
     !/,2X,'TIME END OF SIMULATION (years)                   ',1PE11.4
     !/,2X,'OUTPUT TIME STEP (years)                         ',1PE9.2
     !/,2X,'DESIRED ACCURACY                                 ',1PE9.2
     !/,2X,'ARB VALUE                                        ',I4
     !/,2X,'JMAX VALUE                                       ',I4
     !/,2X,'JSTART VALUE                                     ',I4)

      PAUSE

C  OPEN OUTPUT FILE

      OPEN(1,FILE=FILEOUT, STATUS='UNKNOWN')
      WRITE(1,1000)


 1000 FORMAT(2X,' ********************  GWMODF2 *********************'
     !/,2X,' * ORIGINAL FORTRAN VERSION WRITTEN FEB 10 1988    *'
     !/,2X,' * REVISED FORTRAN VERSION WRITTEN APRIL 10 1991   *'
     !/,2X ' * DATE OF LAST PROGRAM MODIFICATION 04/10/91      *'
     !/,2X,' * This program uses equation 4.25, 4.31 and 4.37  *'
     !/,2X,' * in Till and Meyer for a source at 0,0,Zs        *'
     !/,2X,' * in an aquifer of infinite lateral extent        *'
     !/,2X,' * and finite thickness and constant pore velocity *'
     !/,2X,' * A. S. ROOD  EG&G IDAHO                           *'
     !/,2X,' ***************************************************')


      WRITE(1,*)
      WRITE(1,*) ' TITLE: ',TITLE
      WRITE(1,*) ' FILE NAME: ',FILEOUT
      WRITE(1,*)
      WRITE(1,22)
   22 FORMAT(2X,'---------- CONCENTRATION VS TIME PLOT ----------'
     !/,7X,'TIME',4X,'CONCENTRATION'
```

```
     !/,5X,'(years)',3X,'(amount/m3) x factor')

      IF(TYPE.EQ.0) THEN

C ********************* IMPULSE RELEASE ROUTINE ***********************
      WRITE(*,*) 'TYPE OF RELEASE:  IMPULSE'
      DO 120,TC=TSTART,TEND,TP
C CONVERT TIME TO SECONDS AND CALL POINT, AREA OR LINE SOURCE EQ
      TI=TC*3.1536E7
      IF(TI.LE.0.0) THEN
      GOTO 120
      ENDIF
       IF(SOURCE.EQ.0) THEN
       CALL POINT(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.1) THEN
       CALL AREA(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.2) THEN
       CALL LINE(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
C FACTOR OUTPUT ACCORDING TO FACTOR VARIABLE
      GWCON=GWCON*FACTOR
      WRITE(*,23) TC,GWCON
      WRITE(1,23) TC,GWCON

C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      TMAX=TC
      ENDIF

  120 CONTINUE

      ELSE

C  ****************** TIME VARIENT RELEASE ROUTINE *****************

C  READ GROUND WATER RELEASE DATA INTO ARRAY FOR INPUT INTO LINT
       CALL TINPUT(TS)
C CALCULATE STD AND DETERMINE IF AN IMPULSE OR TIME VARIANT RELEASE SHOULD BE USED
C      PECLET=XD/AX
C      STD=SQRT(ABS(2/PECLET+8/PECLET**2))
C      GWT=XD/VX*RD(JSPEC)
C      STD=(STD*GWT)/3.1536E7
C      IF(TS.LT.STD)THEN
C      PAUSE 'CAUTION  Source input time is less than STD of pulse'
C      ENDIF
C  BEGIN LOOP FOR CALCULATING GWCON FOR SPECIFIED TIMES
      DO 100 TC=TSTART,TEND,TP
      CALL SIMPSON(XD,YD,ZD,TC,GWCON,TS)
C  SCALE DATA ACCORDING TO FACTOR
      GWCON=GWCON*FACTOR
C  WRITE OUTPUT
      WRITE(*,23) TC,GWCON
      WRITE(1,23) TC,GWCON
   23 FORMAT(3X,1PE11.4,1X,1PE11.4)

C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      TMAX=TC
      ENDIF

  100 CONTINUE

      ENDIF

      WRITE(1,*) '    DATE ',DDATE
      WRITE(1,*) '    TIME ',TTIME

      WRITE(1,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,XD,YD,ZD,AL,WA,QIMP,FACTOR,TSTART,TEND,TP,EPS,ARB,JMAX,
     ! JSTART

C WRITE MAXIMUM CONCENTRATION AND TIME OF MAX CONCENTRATION
      WRITE(1,8) GWMAX,TMAX
```

```
    8  FORMAT(2X,'MAXIMUM CONCENTRATION WAS ', 1PE11.4
     !/,2X,'TIME OF MAXIMUM CONCENTRATION WAS ',1PE11.4)

       IF(TYPE.EQ.1.)THEN
       CALL GWOUT
       ENDIF

      CLOSE(1,STATUS='KEEP')
      RETURN
      END
C
C ********************************************
C *    SUBROUTINE CONTOUR                     *
C ********************************************
      SUBROUTINE CONTOUR
C UNITS meters years

      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*11 TTIME
      CHARACTER*8 DDATE
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
      PARAMETER (NSPEC=6,NSTEPS=2000)

      CALL TIME(TTIME)
      CALL DATE(DDATE)

C  This routine creates a file which contains the x and y coordinates and the
C  ground water concentration at the specified depth z.

C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /FILES/FILEIN,FILEOUT,TITLE
      DIMENSION RD(NSPEC),DLR(NSPEC),X(2000),Y(2000),Z(2000)

      WRITE(*,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,AL,WA,QIMP,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,TEND,FACTOR,JMAX,ARB,EPS

    7 FORMAT(1X,'WATER TRANSPORT PARAMETERS FOR CONTOUR PLOT'
     !/,1X,'*********************************************************'
     !/,1X,'SOURCE TYPE: (0) POINT (1) AREA (2) LINE        ',I1
     !/,1X,'VERTICALLY AVERAGED: (0) YES  (1) NO            ',I1
     !/,1X,'TYPE OF RELEASE: (0) IMPULSE  (1) TIME VARIANT  ',I1
     !/,1X,'POROSITY                                        ',1PE9.2
     !/,1X,'DECAY CONSTANTS (s-1) ',1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,
     ! 1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'DISPERSIVITY X DIRECTION (m)                    ',1PE11.4
     !/,1X,'DISPERSIVITY Y DIRECTION (m)                    ',1PE11.4
     !/,1X,'DISPERSIVITY Z DIRECTION (m)                    ',1PE11.4
     !/,1X,'LENGTH OF SOURCE (for area source) (m)          ',1PE11.4
     !/,1X,'WIDTH OF SOURCE (for area source)  (m)          ',1PE11.4
     !/,1X,'IMPULSE MASS (for impulse release) (mass units) ',1PE11.4
     !/,1X,'RETARDATION FACTORS ',1PE9.2,1X,1PE9.2,1X,1PE9.2,
     ! 1X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'PORE VELOCITY  (m/s)                            ',1PE11.4
     !/,1X, 'CHEMICAL SPECIES DESIRED                       ',1PE9.2
     !/,1X, 'WATER TABLE THICKNESS (m)                      ',1PE9.2
     !/,1X, 'DEPTH OF SOURCE (m)                            ',1PE9.2
     !/,1X,'TIME OF SIMULATION (years)                      ',1PE11.4
     !/,1X,'OUTPUT FACTOR                                   ',1PE11.4
     !/,1X,'JMAX VALUE                                      ',I4
     !/,1X,'ARB VALUE                                       ',I4
     !/,1X,'DESIRED ACCURACY                                ',1PE9.2)
      PAUSE

C  READ DATA POINT COORDINATES AND CHEM SPECIES FROM CONTOUR.PAR FILE
C  AND OPEN OUTPUT FILE

      WRITE(*,*) 'READING CONTOUR.PAR FILE'
      OPEN(1,FILE='CONTOUR.PAR',STATUS='OLD')
      NPOINTS=1
   20 READ(1,*,END=22) X(NPOINTS),Y(NPOINTS),Z(NPOINTS)
      NPOINTS=NPOINTS+1
      GO TO 20
```

```
  22  CLOSE(1,STATUS='KEEP')
      NPOINTS=NPOINTS-1
      WRITE(*,*) 'NUMBER OF POINTS=',NPOINTS
      CLOSE(1,STATUS='KEEP')
C OPEN OUTPUT FILE AND WRITE INFORMATION

      OPEN(1,FILE=FILEOUT, STATUS='UNKNOWN')
      WRITE(1,1000)

 1000 FORMAT(2X,' ********************  GWMODF2 *********************'
     !/,2X,' * ORIGINAL FORTRAN VERSION WRITTEN FEB 10 1988      *'
     !/,2X,' * REVISED FORTRAN VERSION WRITTEN APRIL 10 1991     *'
     !/,2X ' * DATE OF LAST PROGRAM MODIFICATION 04/10/91        *'
     !/,2X,' * This program uses equation 4.25, 4.31 and 4.37    *'
     !/,2X,' * in Till and Meyer for a source at 0,0,Zs          *'
     !/,2X,' * in an aquifer of infinite lateral extent          *'
     !/,2X,' * and finite thickness and constant pore velocity *'
     !/,2X,' * A. S. ROOD  EG&G IDAHO                            *'
     !/,2X,' ***************************************************')

      WRITE(1,*)
      WRITE(1,*) '    TITLE: ',TITLE
      WRITE(1,*) '    FILE NAME: ',FILEOUT
      WRITE(1,*)
      WRITE(1,44)
 44   FORMAT(3X,'--------------- CONTOUR PLOT --------------',
     !/,4X,'X (m)',5X,'Y (m)',5X,'CONC (amount/m3 x factor)')

C  READ GROUND WATER RELEASE DATA INTO ARRAY FOR INPUT INTO LINT
C  FOR TIME VARIANT RELEASES

      IF(TYPE.EQ.1) THEN
      WRITE(*,*) 'TIME VARIANT RELEASE'
       CALL TINPUT(TS)
      WRITE(*,*) 'TIME OF CONTOURING  (years) =    ',TEND

      ELSE
      WRITE(*,*) 'IMPULSE RELEASE SELECTED'

      ENDIF

C ********************* IMPULSE RELEASE ROUTINE ********************

      IF(TYPE.EQ.0) THEN
      DO 120,J=1,NPOINTS

       TI=TEND*3.1536E7
       XD=X(J)
       YD=Y(J)
       ZD=Z(J)

       IF(SOURCE.EQ.0) THEN
       CALL POINT(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.1) THEN
       CALL AREA(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.2) THEN
       CALL LINE(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF

C SCALE RELEASE DATA

      GWCON=GWCON*FACTOR

C  OUTPUT DATA TO CONTOUR.DAT

      IF(MODE.EQ.2) THEN
        WRITE(*,145) X(J),Y(J),GWCON
        WRITE(1,145) X(J),Y(J),GWCON
      ELSE
      ZDOWN=-1*Z(J)
C  CALCULATE X DISTANCE FOR SLICE CONTOUR PLOT
          IF(Y(J).LE.0.0) THEN
          XLINE=X(J)
          ELSE
          XLINE=X(J)/COS(ATAN(X(J)/Y(J)))
          ENDIF
          WRITE(*,145) XLINE,ZDOWN,GWCON
          WRITE(1,145) XLINE,ZDOWN,GWCON
      ENDIF
```

```
C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      XDMAX=X(J)
      YDMAX=Y(J)
      ZDMAX=Z(J)
      ENDIF

  120 CONTINUE

      ELSE

C ******************** TIME VARIENT RELEASE ROUTINE ****************

      DO 110,J=1,NPOINTS

       XD=X(J)
       YD=Y(J)
       ZD=Z(J)
       GWCON=0.0
      CALL SIMPSON(XD,YD,ZD,TEND,GWCON,TS)

C SCALE RELEASE DATA

      GWCON=GWCON*FACTOR

C  OUTPUT DATA TO OUTPUT FILE

      IF(MODE.EQ.2) THEN
        WRITE(*,145) X(J),Y(J),GWCON
        WRITE(1,145) X(J),Y(J),GWCON
      ELSE
      ZDOWN=-1*Z(J)
C  CALCULATE X DISTANCE FOR SLICE CONTOUR PLOT
          IF(Y(J).LE.0.0) THEN
          XLINE=X(J)
          ELSE
          XLINE=X(J)/COS(ATAN(X(J)/Y(J)))
          ENDIF
          WRITE(*,145) XLINE,ZDOWN,GWCON
          WRITE(1,145) XLINE,ZDOWN,GWCON
  145 FORMAT(3X,1PE10.3,1X,1PE10.3,1X,1PE9.2)
      ENDIF

C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      XDMAX=X(J)
      YDMAX=Y(J)
      ZDMAX=Z(J)
      ENDIF

 110  CONTINUE

      ENDIF

 165  WRITE(1,*) '    DATE ',DDATE
      WRITE(1,*) '    TIME ',TTIME
      WRITE(1,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,AL,WA,QIMP,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,TEND,FACTOR,JMAX,ARB,EPS

C WRITE TIME AND LOCATION OF MAX CONC

      WRITE(1,8) GWMAX,XDMAX,YDMAX,ZDMAX

    8 FORMAT(2X,'MAXIMUM CONCENTRATION WAS ', 1PE11.4
     !/,2X,'THE X,Y,Z COORDINATES WERE ',1PE11.4,1X,1PE11.4,1X,1PE11.4)

       IF(TYPE.EQ.1.)THEN
       CALL GWOUT
       ENDIF

      CLOSE(1,STATUS='KEEP')
      RETURN
      END
```

```
      SUBROUTINE SIMPSON(XD,YD,ZD,TIME,GWCON,TS)
C ************************************************
C *    SUBROUTINE SIMPSON                        *
C ************************************************
C UNITS: XD YD ZD in meters TIME in years GWCON in g/m3 x FACTOR
C        TS in years
       IMPLICIT REAL*8(A-H,O-Z)

C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG
      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      PARAMETER (NSPEC=6)
      DIMENSION DLR(NSPEC),RD(NSPEC)

C INITIALIZE GWCON VARIABLES CONVERT TIME TO SECONDS IF TIME=0.0 RETURN
C TO START
        IF(TIME.EQ.0) THEN
        GWCON=0.0
        RETURN
        ENDIF
        TI=TIME*3.1536E7

C DETERMINE LIMITS FOR INTEGRATION
C T1= LOWER LIMIT T2 = UPPER LIMIT
C INTEGRATION LIMITS ARE SELECTED BY CODELL'S METHOD.  THE LIMITS ARE
C BASED ON THE VALUE OF ARB WHEN EXP(-ARB) APPROACHES ZERO.  DEPENDING
C ON THE MACHINE USED, ARB MAY BE -50 TO -200
C XC1 AND XC2 = THE X DISTANCE USED IN CALCULATION OF THE INTEGRATION LIMITS.
C XC1=XC2=XD IF A POINT OR LINE SOURCE GEOMETRY IS SELECTED.  XC1=XD+AL/2 AND
C XC2=XD-AL/2 IF HORZ AREA SOURCE IS SELECTED. THE TEMP VARIABLES STORE THE
C INTERMEDIATE VALUES

      DX=ABS(AX*VX)

      IF(SOURCE.EQ.1.)THEN
            XC1=XD+AL/2
            XC2=XD-AL/2
      ELSE
          XC1=XD
          XC2=XD
      ENDIF

C  TEMP 1 CORRECTED 11/29/90

      TEMP1=(2*VX*XC1/RD(JSPEC)+4*DX*ARB/RD(JSPEC))/((VX/RD(JSPEC))**2
     !+4*DX*DLR(JSPEC)/RD(JSPEC))

      TEMP2=TEMP1**2 - (2*XC2)**2/((VX/RD(JSPEC))**2
     !+4*DX*DLR(JSPEC)/RD(JSPEC))

C IF TEMP2 IS LESS THAN ZERO THEN DO NOT PROCEED WITH INTEGRATION

      IF(TEMP2.LE.0.0)THEN
      GWCON=0
      RETURN
      ENDIF

      TEMP3=(2*VX*XC2/RD(JSPEC)+4
     !*DX*ARB/RD(JSPEC))/((VX/RD(JSPEC))**2
     !+4*DX*DLR(JSPEC)/RD(JSPEC))

      T2=TI-(TEMP3-SQRT(TEMP2))/2

      T1=TI-(TEMP1+SQRT(TEMP2))/2

C CONDITIONAL STATEMENTS
C     IF THE UPPER LIMIT IS EQ TO 0 THEN GWCON EQ 0
       IF(T2.LE.0.) THEN
        GWCON=0.0
        RETURN
      ENDIF
C     CHECK LOWER LIMIT OF INTEGRATION TO MAKE SURE IS NOT LESS THAN 0
      IF(T1.LE.0.) THEN
       T1=0.0
      ENDIF
C     CHECK TO SEE IF UPPER LIMIT IS GREATER THAN DESIERD TIME
      IF(T2.GE.TI) THEN
       T2=TI
```

```
      ENDIF
C     CHECK TO SEE IF UPPER LIMIT IS GREATER SOURCE INPUT TIME (in years)
      IF(T2.GE.TS*3.1536E7) THEN
       T2=TS*3.15E+07
      ENDIF
C     CHECK TO SEE IF T1 IS GREATER THAN T2
      IF(T1.GE.T2) THEN
       GWCON=0.0
       RETURN
      ENDIF

C INTEGRATION IS NOW PERFORMED BY SIMPSONS RULE.  ROUTINE IS ADAPTED FROM
C CODELL'S GRDFLX WITH AN ADDITIONAL ROUTINE TO CHECK FOR CONVERGENCE
C VARIABLE OST IS A DUMMY VARIABLE THAT IS USED TO CHECK
C THE ACCURACY OF THE SOLUTION.
C JFLAG IS USED TO START THE INITIAL STEPS

C INITIALIZE VARIABLES

      ST=0.
      GWCON=0.0
      OST=-1.0E38
      JFLAG=1

         DO 11,J=1,JMAX
      CALL TRAPZD(XD,YD,ZD,T1,T2,ST,TI,JFLAG)

C check for convergance

         IF(ABS(ST-OST).LE.EPS*ABS(ST)) THEN
         GWCON=ST
         RETURN
         ENDIF
         OST=ST

  11  CONTINUE
c gwcon given the last value of s
      gwcon=ST
      WRITE(*,*) 'Convergence not Achievied'
  999 RETURN
      END


      SUBROUTINE TRAPZD(XD,YD,ZD,A,B,C,T2,JFLAG)
      IMPLICIT REAL*8(A-H,O-Z)
C ***************************************************************
C *    SUBROUTINE TRAPZD                                         *
C ***************************************************************
C UNITS:XD YD ZD in meters C in g/m3
C       A  B  T2 in seconds

C This subroutine has been adapted from Codell's GRDFLX. Instead
C of Function FUN,  subroutines POINT AREA or LINE are called.
C In addition, the source mass is determined prior to the call statements
C The variable TYEAR is the time of pulse release converted to years for the
C interpolation routine.  F is the temporary storage variable and the conc.
C is returned in the variable C.  N1 is the number of division to be used
C in integration. Integration limits are set to T3 and T9 on each call



      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      PARAMETER(NSPEC=6)
      DIMENSION  RD(NSPEC),DLR(NSPEC)
      T3=A
      T9=B
      C=0.

      IF(JFLAG.EQ.1) THEN
           N1=JSTART
           D1=(T9-T3)
           JFLAG=2
      ENDIF
      T10=T3
      D3=D1/6/FLOAT(N1)
      TYEAR=T3/3.1536E7
```

```
      T4=T2-T3+1.0E-10*3.1536E+07

C FIRST CALL OF FUN
       CALL LINT(TYEAR,Q)
       IF(SOURCE.EQ.0) THEN
         CALL POINT(T4,Q,F3,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.1.) THEN
         CALL AREA(T4,Q,F3,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.2.) THEN
         CALL LINE(T4,Q,F3,XD,YD,ZD)
       ENDIF

 9     DO 11,N2=1,N1
          F1=F3
          T3=T10+(FLOAT(N2)-0.5)/FLOAT(N1)*D1
          TYEAR=T3/3.1536E7
          T4=T2-T3+1.0E-10*3.1536E7

          CALL LINT(TYEAR,Q)
          IF(SOURCE.EQ.0) THEN
            CALL POINT(T4,Q,F2,XD,YD,ZD)
          ENDIF
          IF(SOURCE.EQ.1.) THEN
            CALL AREA(T4,Q,F2,XD,YD,ZD)
          ENDIF
          IF(SOURCE.EQ.2.) THEN
            CALL LINE(T4,Q,F2,XD,YD,ZD)
          ENDIF

          T3=T10+FLOAT(N2)/FLOAT(N1)*D1
          TYEAR=T3/3.1536E7
          T4=T2-T3+1.0E-10*3.1536E7

          CALL LINT(TYEAR,Q)
          IF(SOURCE.EQ.0) THEN
           CALL POINT(T4,Q,F3,XD,YD,ZD)
          ENDIF
          IF(SOURCE.EQ.1.) THEN
           CALL AREA(T4,Q,F3,XD,YD,ZD)
          ENDIF
          IF(SOURCE.EQ.2.) THEN
           CALL LINE(T4,Q,F3,XD,YD,ZD)
          ENDIF

          D4=(F1+4*F2+F3)*D3
          C=C+D4

  11   CONTINUE
         N1=N1*2
         RETURN
         END

C ********************************************
C *   SUBROUTINE LINT                         *
C ********************************************
      SUBROUTINE LINT(X,Y)
C UNITS:X in years Y in g/s
c
c  subroutine for linear interpolation
c
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (NSPEC=6)

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /SOURCE/ ATIME,QREL,NP
      DIMENSION ATIME(2000),QREL(2000,NSPEC),DLR(NSPEC),RD(NSPEC)
      N=NP
      KLO=1
      KHI=N
1     IF (KHI-KLO.GT.1) THEN
        K=(KHI+KLO)/2
        IF(ATIME(K).GT.X)THEN
          KHI=K
        ELSE
          KLO=K
        ENDIF
```

```
      GOTO 1
      ENDIF
      H=ATIME(KHI)-ATIME(KLO)
      IF (H.EQ.0.) PAUSE 'Bad XA input.'
      y = QREL(klo,JSPEC)+(x-ATIME(klo))/h * (QREL(khi,JSPEC)-
     ! QREL(KLO,JSPEC))
      RETURN
      END

C ******************************
C *  SUBROUTINE POINT          *
C ******************************
      SUBROUTINE POINT(TI,Q,GWCON,XD,YD,ZD)
C UNITS:XD YD ZD in meters GWCON in g/m3/s Q in g/s TI in seconds


C This subroutine calculates the ground water concentration from a
C point source


      IMPLICIT REAL*8 (A-H,O-Z)

C COMMON STATEMENTS

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      PARAMETER(NSPEC=6)
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DX=ABS(AX*VX)
      DY=ABS(AY*VX)

C   X ARGUMENTS

      ARG=(-((XD-VX*TI/RD(JSPEC))**2)/(4*DX*TI/RD(JSPEC))-
     ! DLR(JSPEC)*TI)
      IF (ARG.LE.-300.) THEN
      ARG=-300.0
      ENDIF
      X1=EXP(ARG)/SQRT(12.68*DX*TI/RD(JSPEC))

C  Y ARGUMENTS

      ARG=(-(YD**2))/(4*DY*TI/RD(JSPEC))
      IF (ARG.LE.-300.) THEN
      ARG=-300.0
      ENDIF
      Y1=EXP(ARG)/SQRT(12.68*DY*TI/RD(JSPEC))
C  Z ARGUMENTS

C CALCULATE Z PARAMETER FOR AVG SOLUTION IF JAVG=0

      IF(JAVG.EQ.1)THEN
      CALL Z1ARG(Z1,ZD,TI)
      ELSE
      Z1=1/THICK
      ZD=1*ZD
      ENDIF

      GWCON=(Q*X1*Y1*Z1)/(PHI*RD(JSPEC))
      RETURN
      END

      SUBROUTINE AREA(TI,Q,GWCON,XD,YD,ZD)
      IMPLICIT REAL*8 (A-H,O-Z)
C *********************************
C *      SUBROUTINE AREA          *
C *********************************
C UNITS:XD YD ZD in meters GWCON in g/m3/s Q in g/s TI in seconds
C This subroutine calculates the ground water concentration for an area source

C COMMON STATEMENTS

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG
      PARAMETER(NSPEC=6)
```

```
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DX=ABS(AX*VX)
      DY=ABS(AY*VX)

C   X ARGUMENTS

      ARG1=((XD+AL/2)-VX*TI/RD(JSPEC))/SQRT(4*DX*TI/RD(JSPEC))
      ARG2=((XD-AL/2)-VX*TI/RD(JSPEC))/SQRT(4*DX*TI/RD(JSPEC))

      IF(ARG1.GE.25.) THEN
      ARG1=1.0
      ELSE
      IF(ARG1.LE.-25.) THEN
      ARG1=-1.0
      ELSE
      CALL ERRORD(ARG1,ERX)
      ARG1=ERX
      ENDIF
      ENDIF

      IF(ARG2.GE.25.) THEN
      ARG2=1.0
      ELSE
      IF(ARG2.LE.-25.) THEN
      ARG2=-1.0
      ELSE
      CALL ERRORD(ARG2,ERX)
      ARG2=ERX
      ENDIF
      ENDIF

      X2=(ARG1-ARG2)*EXP(-DLR(JSPEC)*TI)/(2*AL)
C  Y ARGUMENTS

      ARG1=(WA/2+YD)/SQRT(4*DY*TI/RD(JSPEC))
      IF(ARG1.GE.25.) THEN
      ARG1=1.0
      ELSE
      IF(ARG1.LE.-25.) THEN
      ARG1=-1.0
      ELSE
      CALL ERRORD(ARG1,ERX)
      ARG1=ERX
      ENDIF
      ENDIF
      ARG2=(WA/2-YD)/SQRT(4*DY*TI/RD(JSPEC))

      IF(ARG2.GE.25.) THEN
      ARG2=1.0
      ELSE
      IF(ARG2.LE.-25.) THEN
      ARG2=-1.0
      ELSE
      CALL ERRORD(ARG2,ERX)
      ARG2=ERX
      ENDIF
      ENDIF
      Y2=(ARG1+ARG2)/(2*WA)

C CALCULATE Z PARAMETER FOR AVG SOLUTION IF JAVG=0

      IF(JAVG.EQ.1)THEN
      CALL Z1ARG(Z1,ZD,TI)
      ELSE
      Z1=1/THICK
      ZD=1*ZD
      ENDIF


C  CALCULATE GROUND WATER CONCENTRATION
      GWCON=(Q*X2*Y2*Z1)/(PHI*RD(JSPEC))
      RETURN
      END

C *****************************
C *  SUBROUTINE LINE          *
C *****************************
C UNITS:XD YD ZD in meters GWCON in g/m3/s Q in g/s TI in seconds
C This subroutine calculates the ground water concentration from a
```

```
C line source in an aquifer of infinite lateral extent and finite thickness

      SUBROUTINE LINE(TI,Q,GWCON,XD,YD,ZD)
      IMPLICIT REAL*8 (A-H,O-Z)

C COMMON STATEMENTS

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      PARAMETER(NSPEC=6)
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DX=ABS(AX*VX)
      DY=ABS(AY*VX)

C   X ARGUMENTS

      ARG=(-((XD-VX*TI/RD(JSPEC))**2)/(4*DX*TI/RD(JSPEC))-
     ! DLR(JSPEC)*TI)
      IF (ARG.LE.-300.) THEN
      ARG=-300.0
      ENDIF
      X1=EXP(ARG)/SQRT(12.68*DX*TI/RD(JSPEC))

C  Y ARGUMENTS

      ARG1=(WA/2+YD)/SQRT(4*DY*TI/RD(JSPEC))
      IF(ARG1.GE.25.) THEN
      ARG1=1.0
      ELSE
      IF(ARG1.LE.-25.) THEN
      ARG1=-1.0
      ELSE
      CALL ERRORD(ARG1,ERX)
      ARG1=ERX
      ENDIF
      ENDIF
      ARG2=(WA/2-YD)/SQRT(4*DY*TI/RD(JSPEC))
      IF(ARG2.GE.25.) THEN
      ARG2=1.0
      ELSE
      IF(ARG2.LE.-25.) THEN
      ARG2=-1.0
      ELSE
      CALL ERRORD(ARG2,ERX)
      ARG2=ERX
      ENDIF
      ENDIF
      Y2=(ARG1+ARG2)/(2*WA)

      IF(JAVG.EQ.1)THEN
      CALL Z1ARG(Z1,ZD,TI)
      ELSE
      Z1=1/THICK
      ZD=1*ZD
      ENDIF

      GWCON=(Q*X1*Y2*Z1)/(PHI*RD(JSPEC))
      RETURN
      END

C *********************
C * SUBROUTINE Z1ARG  *
C *********************
C UNITS:ZD in meters TI in seconds

C This subroutine calculates the non vertically averaged Z value

      SUBROUTINE Z1ARG(Z1,ZD,TI)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      PARAMETER(NSPEC=6)
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DZ=ABS(AZ*VX)
```

```
C  Z ARGUMENTS

      M=1
      ZARG=0.0

C  ADDED CODE TO REMOVE POSSIBILTY OF NEGATIVE RELEASES  11/23/88

      if(zd.lt.0.0) then
      write(*,*) 'desired concentration depth is invalid'
      pause
      ENDIF

C MAXIMUM NUMBER OF TERMS ALLOWED IS 100 SUCH THAT WHEN M=100, EXP(ARG)=0
C NUMBER OF TERMS EXPANDED 10-23-90

   55 ARG=(-(M**2)*9.869*DZ*TI)/(RD(JSPEC)*THICK**2)
      IF(M.GE.100.)THEN
      ARG=-10000
      ENDIF
      IF (ARG.GE.-300.) THEN
      ZARG=ZARG+EXP(ARG)*COS(M*3.14152*DEPTH/THICK)*
     !COS(M*3.14152*ZD/THICK)
      M=M+1
      GO TO 55
      ELSE
      Z1=(1+2*ZARG)/THICK
      ENDIF
      RETURN
      END


      SUBROUTINE ERRORD(X,ERX)
C *********************************************
C *       SUBROUTINE ERRORD                   *
C *********************************************
C  This subroutine calculates the error function for an argument, X
C  Adapted from Press et al, Numerical RECIPES: modified by A. Rood for
C  use with double precision variables
C
      IMPLICIT REAL*8 (A-H,O-Z)
      ERX =ERF(X)
      END
C
C ****************************************************************
C
      REAL*8 FUNCTION ERF(X)
      IMPLICIT REAL*8 (A-H,O-Z)
      A=0.50
      IF(X.LT.0.)THEN
          ERF=-GAMMP(A,X**2)
      ELSE
          ERF=GAMMP(A,X**2)
      ENDIF
      RETURN
      END
C
C *****************************************************************
C
      REAL*8 FUNCTION GAMMP(A,X)
      IMPLICIT REAL*8 (A-H,O-Z)
      IF (X.LT.0..OR.A.LE.0.)PAUSE
      IF(X.LT.A+1.)THEN
         CALL GSER(GAMSER,A,X,GLN)
         GAMMP=GAMSER
      ELSE
C      WRITE(*,*) 'A, X, GLN ',A,X,GLN
         CALL GCF(GAMMCF,A,X,GLN)
         GAMMP=1.-GAMMCF
      ENDIF
      RETURN
      END
C
C******************************************************************
C
      SUBROUTINE GSER(GAMSER,A,X,GLN)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (ITMAX=100,EPS=3.E-3)
      GLN=GAMMLN(A)
C      WRITE(*,*) 'A=',A
      IF(X.LE.0.)THEN
        IF(X.LT.0.)PAUSE
```

```
         GAMSER=0.
         RETURN
       ENDIF
       AP=A
       SUM=1./A
       DEL=SUM
       DO 11 N=1,ITMAX
         AP=AP+1.
         DEL=DEL*X/AP
         SUM=SUM+DEL
         IF(ABS(DEL).LT.ABS(SUM)*EPS)GO TO 1
11     CONTINUE
       PAUSE 'A too large, ITMAX too small'
1      GAMSER=SUM*EXP(-X+A*LOG(X)-GLN)
       RETURN
       END
C
C ****************************************************************
C
       SUBROUTINE GCF(GAMMCF,A,X,GLN)
       IMPLICIT REAL*8 (A-H,O-Z)
       PARAMETER (ITMAX=100,EPS=3.E-7)
C       WRITE(*,*) 'GAMMCF, A, X, GLN =',GAMMCF,A,X,GLN
       GLN=GAMMLN(A)
       GOLD=0.
       A0=1.
       A1=X
       B0=0.
       B1=1.
       FAC=1.
       DO 11 N=1,ITMAX
         AN=FLOAT(N)
         ANA=AN-A
         A0=(A1+A0*ANA)*FAC
         B0=(B1+B0*ANA)*FAC
         ANF=AN*FAC
         A1=X*A0+ANF*A1
         B1=X*B0+ANF*B1
         IF(A1.NE.0.)THEN
           FAC=1./A1
           G=B1*FAC
           IF(ABS((G-GOLD)/G).LT.EPS)GO TO 1
           GOLD=G
         ENDIF
11     CONTINUE
       PAUSE 'A too large, ITMAX too small'
1      GAMMCF=EXP(-X+A*ALOG(X)-GLN)*G
       RETURN
       END
C
       REAL*8 FUNCTION GAMMLN(XX)
C ******************************************
C *          FUNCTION GAMMLN              *
C ******************************************
       REAL*8 COF(6),STP,HALF,ONE,FPF,X,TMP,SER,XX
       DATA COF,STP/76.18009173D0,-86.50532033D0,24.01409822D0,
     *     -1.231739516D0,.120858003D-2,-.536382D-5,2.50662827465D0/
       DATA HALF,ONE,FPF/0.5D0,1.0D0,5.5D0/
C       WRITE(*,*) 'XX=',XX
       X=XX-ONE
C       WRITE(*,*) 'X=',X
       TMP=X+FPF
       TMP=(X+HALF)*LOG(TMP)-TMP
       SER=ONE
       DO 11 J=1,6
         X=X+ONE
C         WRITE(*,*) X
         SER=SER+COF(J)/X
11     CONTINUE
       GAMMLN=TMP+LOG(STP*SER)
       RETURN
       END

       SUBROUTINE TINPUT(TS)
C ***********************************************
C *    SUBROUTINE TINPUT                        *
C ***********************************************
C UNITS: TS in years
C This routine inputs time variant source date into array ATIME and QREL
       IMPLICIT REAL*8(A-H,O-Z)
       PARAMETER (NSPEC=6,NSTEPS=2000)
```

```
      COMMON /SOURCE/ ATIME,QREL,NP
      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      DIMENSION ATIME(NSTEPS),QREL(NSTEPS,NSPEC),RD(NSPEC),DLR(NSPEC)
      COMMON /FILES/ FILEIN,FILEOUT,TITLE
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
       NP=1
C NP IS A COUNT VARIABLE WHICH COUNTS THE NUMBER OF POINTS IN THE RELEASE FILE
      OPEN(2,FILE=FILEIN,STATUS='OLD')
  08  READ(2,*,END=09) ATIME(NP),(QREL(NP,J),J=1,NSPEC)
      NP=NP+1
      GO TO 08
  09  CLOSE(2,STATUS='KEEP')
      TS=ATIME(NP-1)
      WRITE(*,101) NP,TS
  101 FORMAT(1X,'NUMBER OF POINTS READ ',I4
     !/1X,'TOTAL TIME OF SOURCE INPUT (years)',1PE9.2)

      PAUSE
      RETURN
      END

      SUBROUTINE GWOUT
C ************************************************
C *    SUBROUTINE GWOUT                          *
C ************************************************

C This routine prints time variant source date into files CONTOUR or GWCON
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (NSPEC=6,NSTEPS=2000)
      COMMON /SOURCE/ ATIME,QREL,NP

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /FILES/FILEIN,FILEOUT,TITLE
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
      DIMENSION ATIME(NSTEPS),QREL(NSTEPS,NSPEC),RD(NSPEC),DLR(NSPEC)
      WRITE(1,*) '    RELEASE RATE INPUT FILE = ',FILEIN
      WRITE(1,99)
      DO 200 I=1,NP
      WRITE(1,100) ATIME(I),QREL(I,JSPEC)
 200  CONTINUE
 99    FORMAT(3X,'TIME (years)  RELEASE (amount/s)')
 100  FORMAT(3X,1PE10.3,6X,1PE11.4)
      RETURN
      END
```

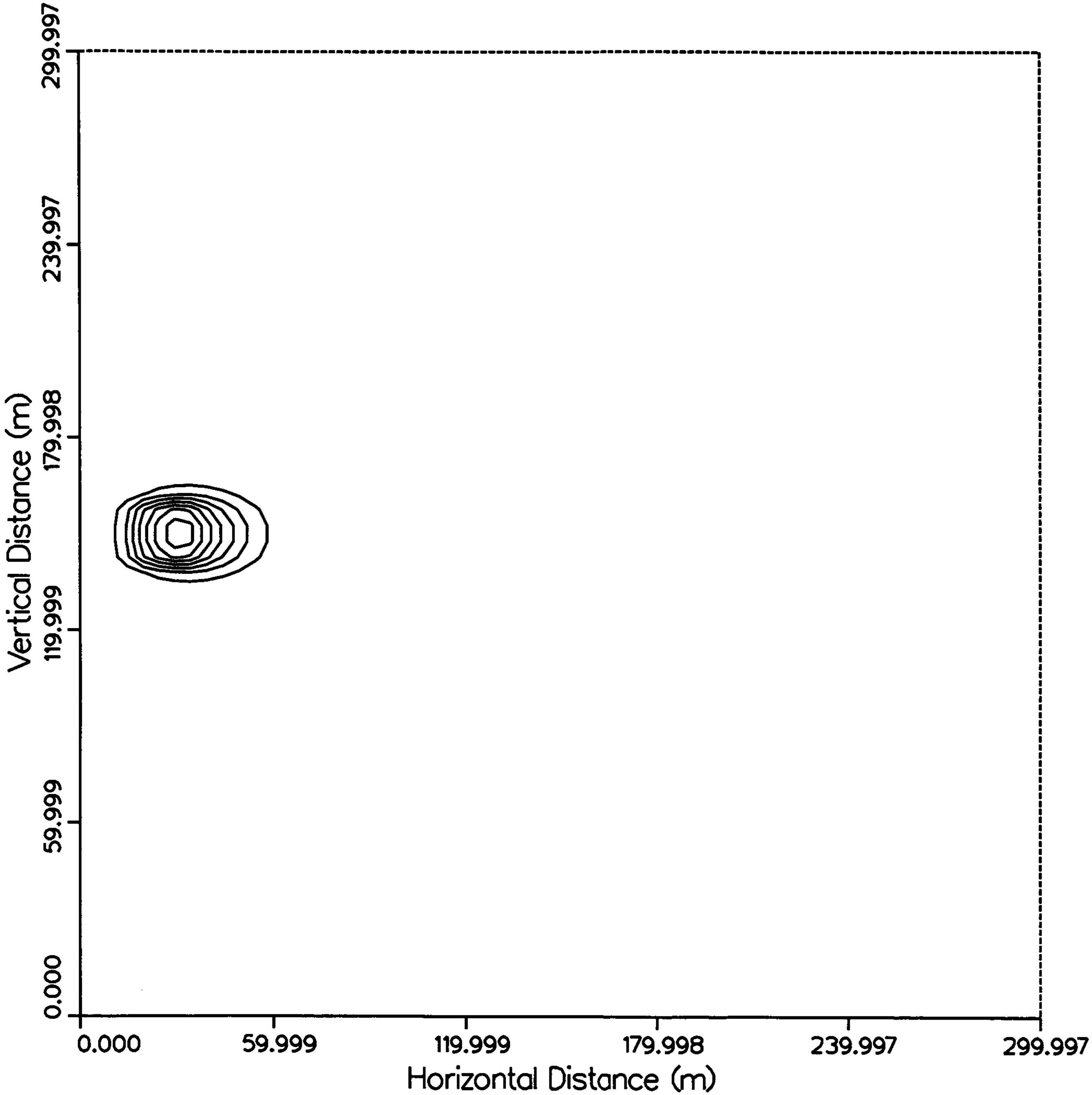
7.2.6 Validation Test Case 6 Results - Two Dimensional Transport With Decay for a Flux Source

Results from the CHAINT simulations for a constant flux source are presented in this section. The CHAINT results were compared to a semi-analytical model, GWMODF2.

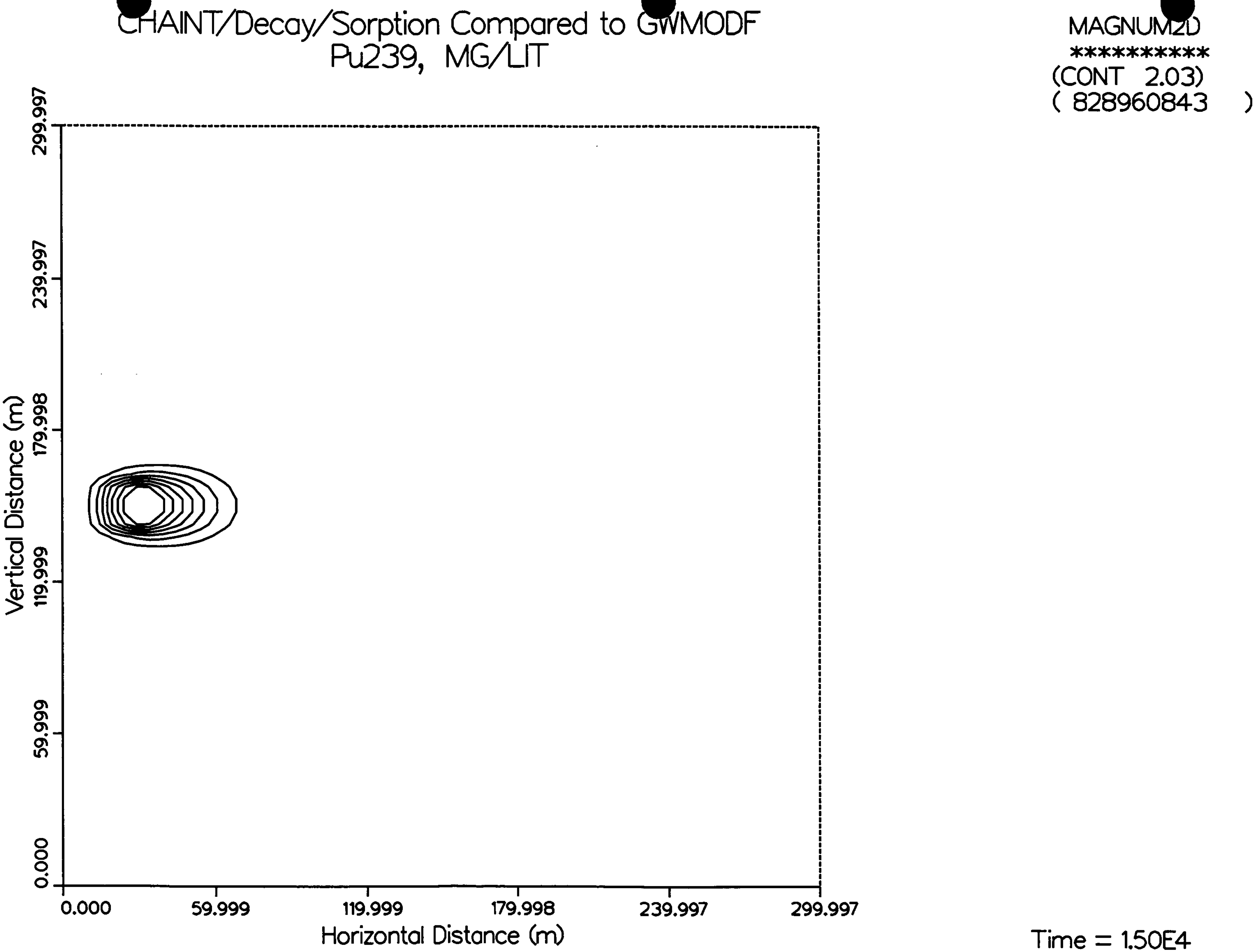
The GWMODF2 input file and results are provided in this section. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from GWMODF2 compare favorably and overlaying the figures reveals the results are consistent.

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(828960843)

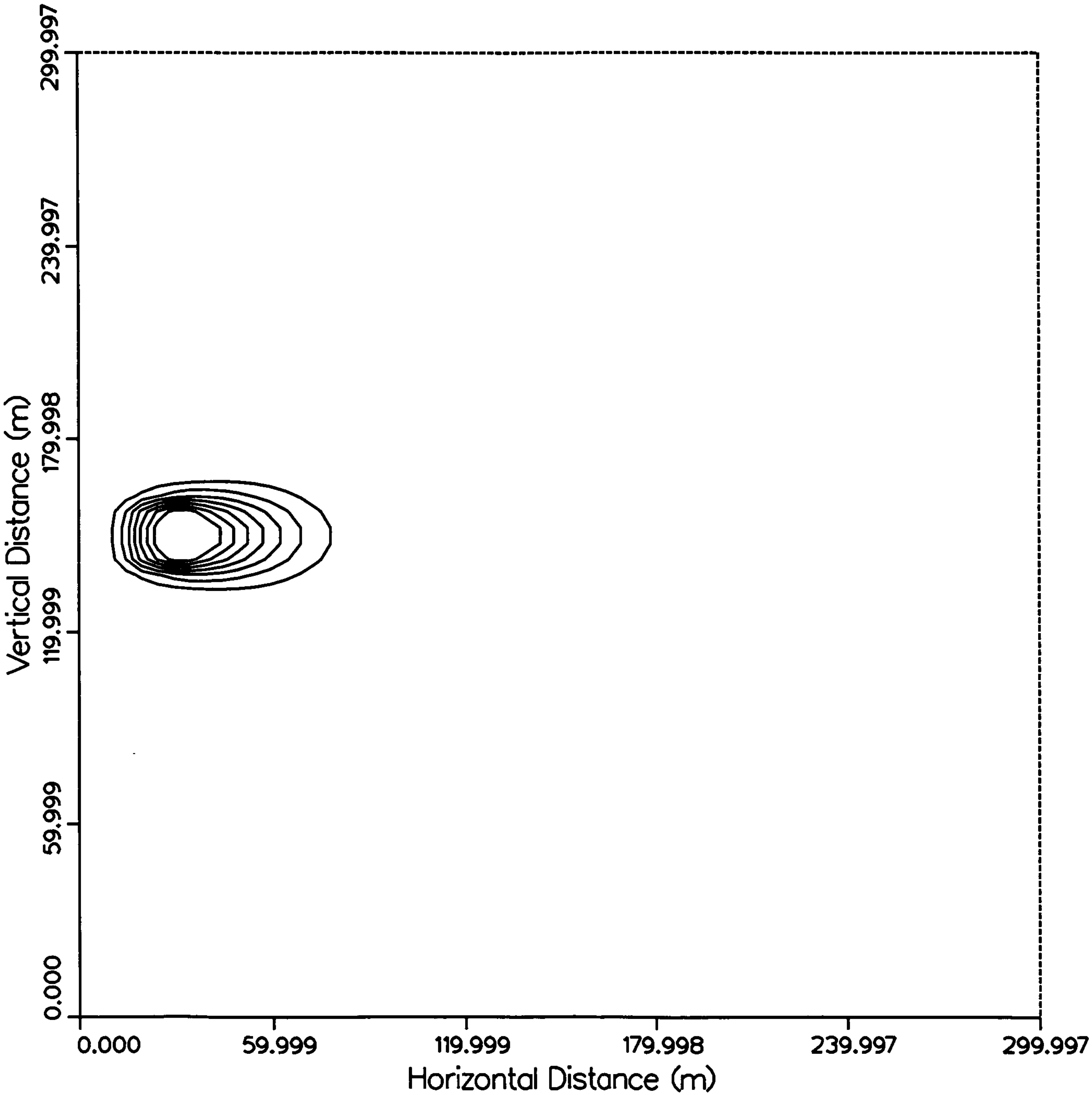


Time = 1.00E4

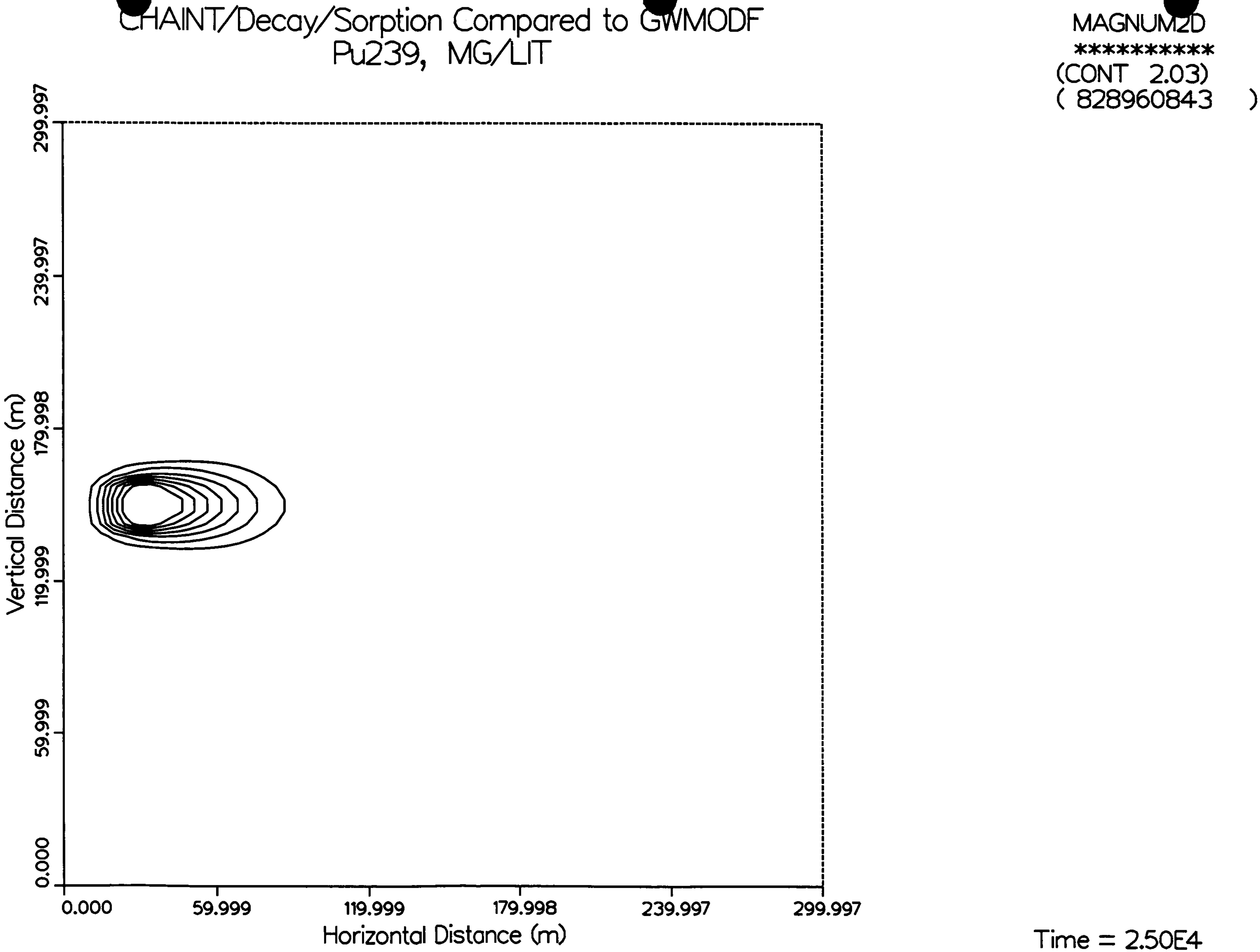

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(828960843)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
Horizontal Distance (m)
0.000
59.999
119.999
179.998
239.997
299.997
Time = 1.50E4

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(828960843)

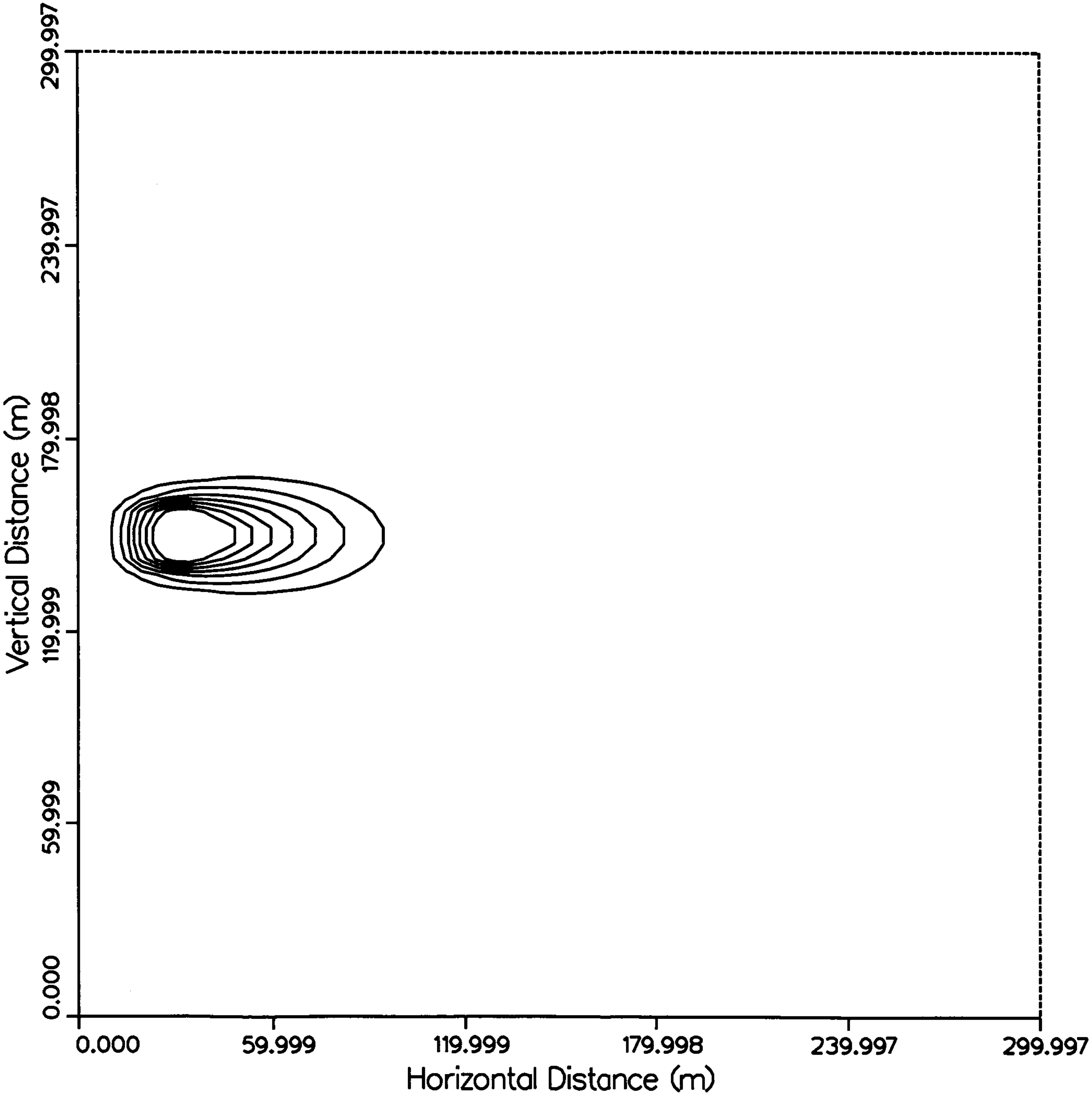


Time = 2.00E4


CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(828960843)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
0.000
59.999
119.999
179.998
239.997
299.997
Horizontal Distance (m)
Time = 2.50E4

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT

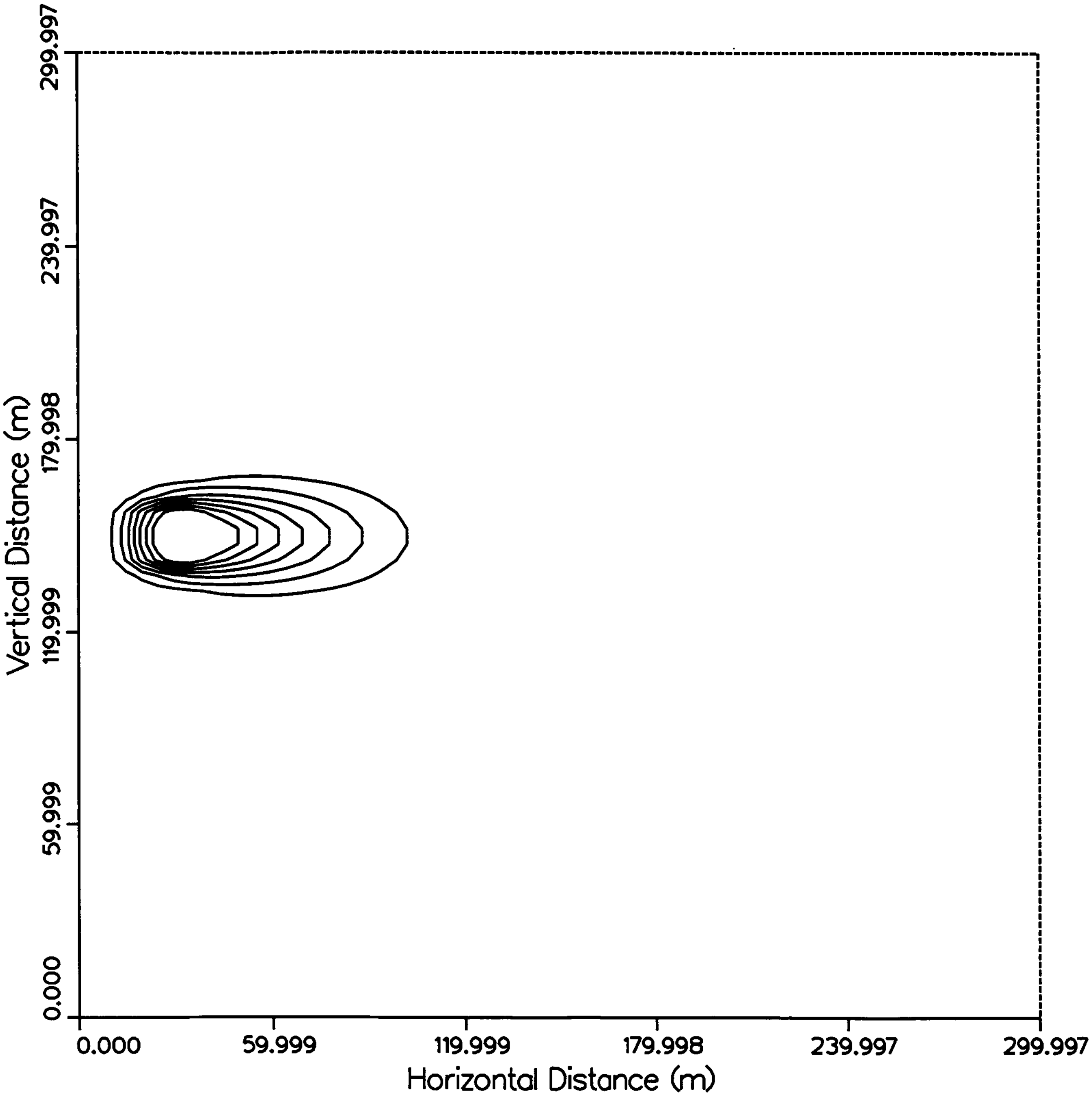
MAGNUM2D
****
(CONT 2.03)
(828960843)



Time = 3.00E4

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT

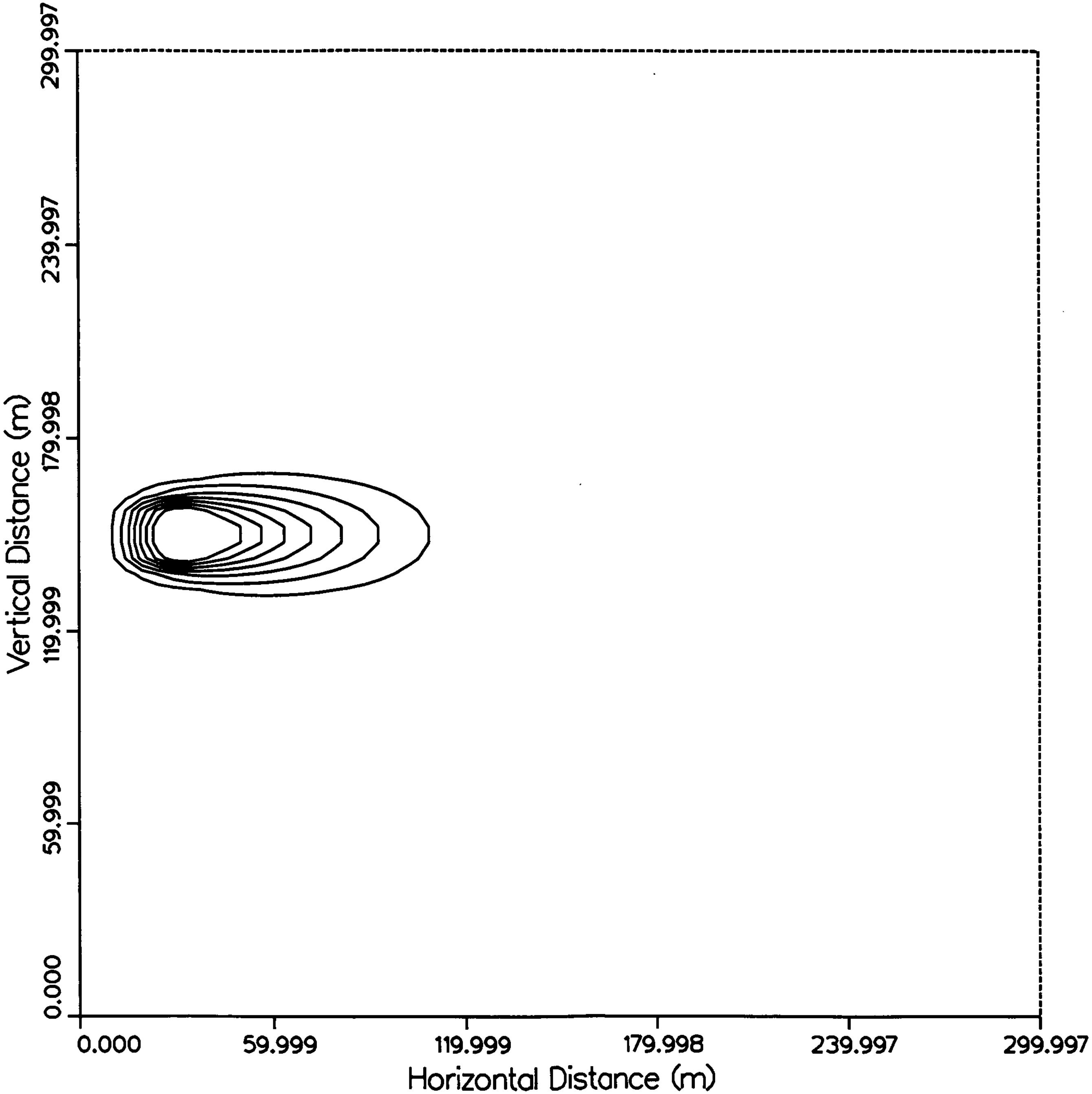
MAGNUM2D
****
(CONT 2.03)
(828960843)



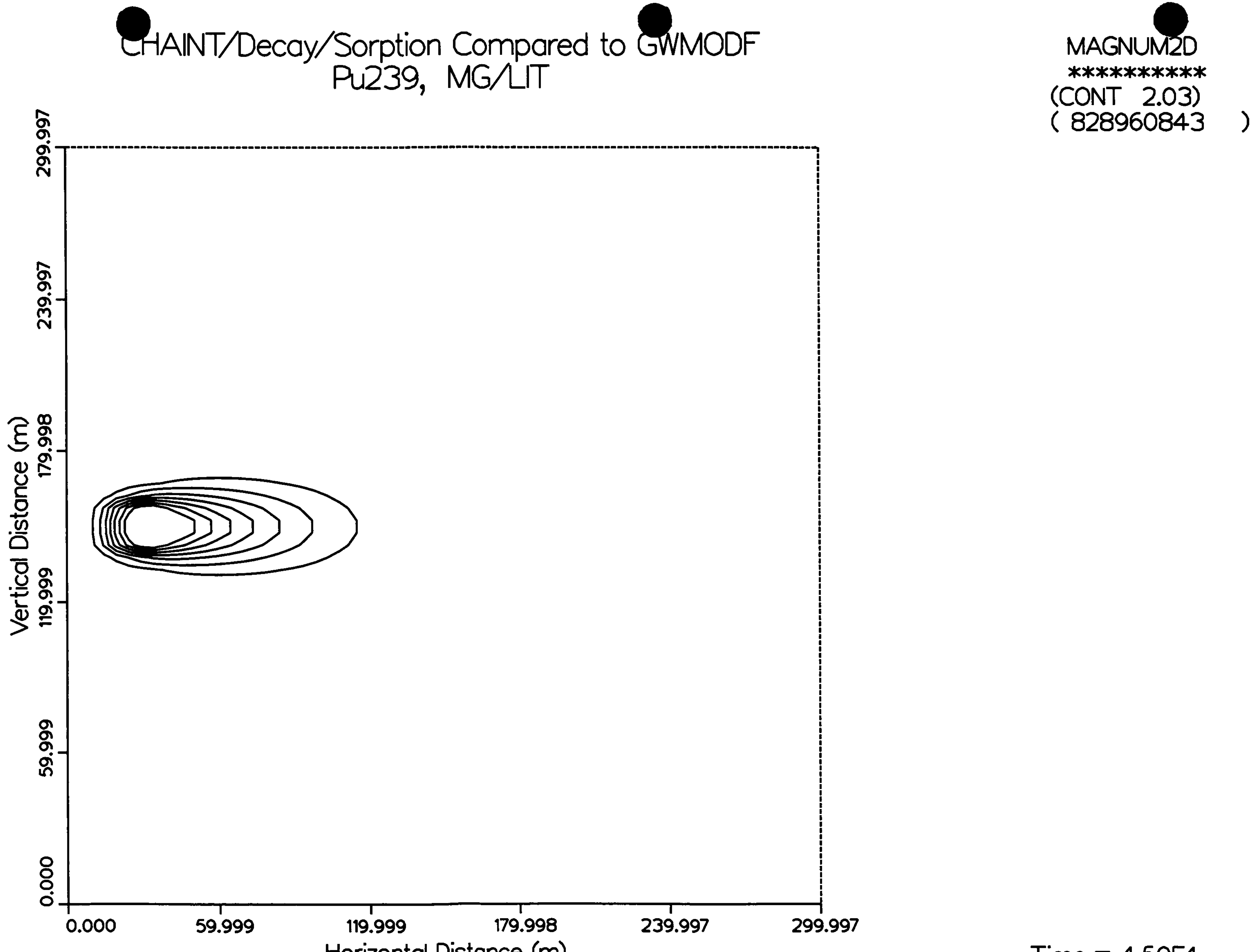
Time = 3.50E4

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(828960843)



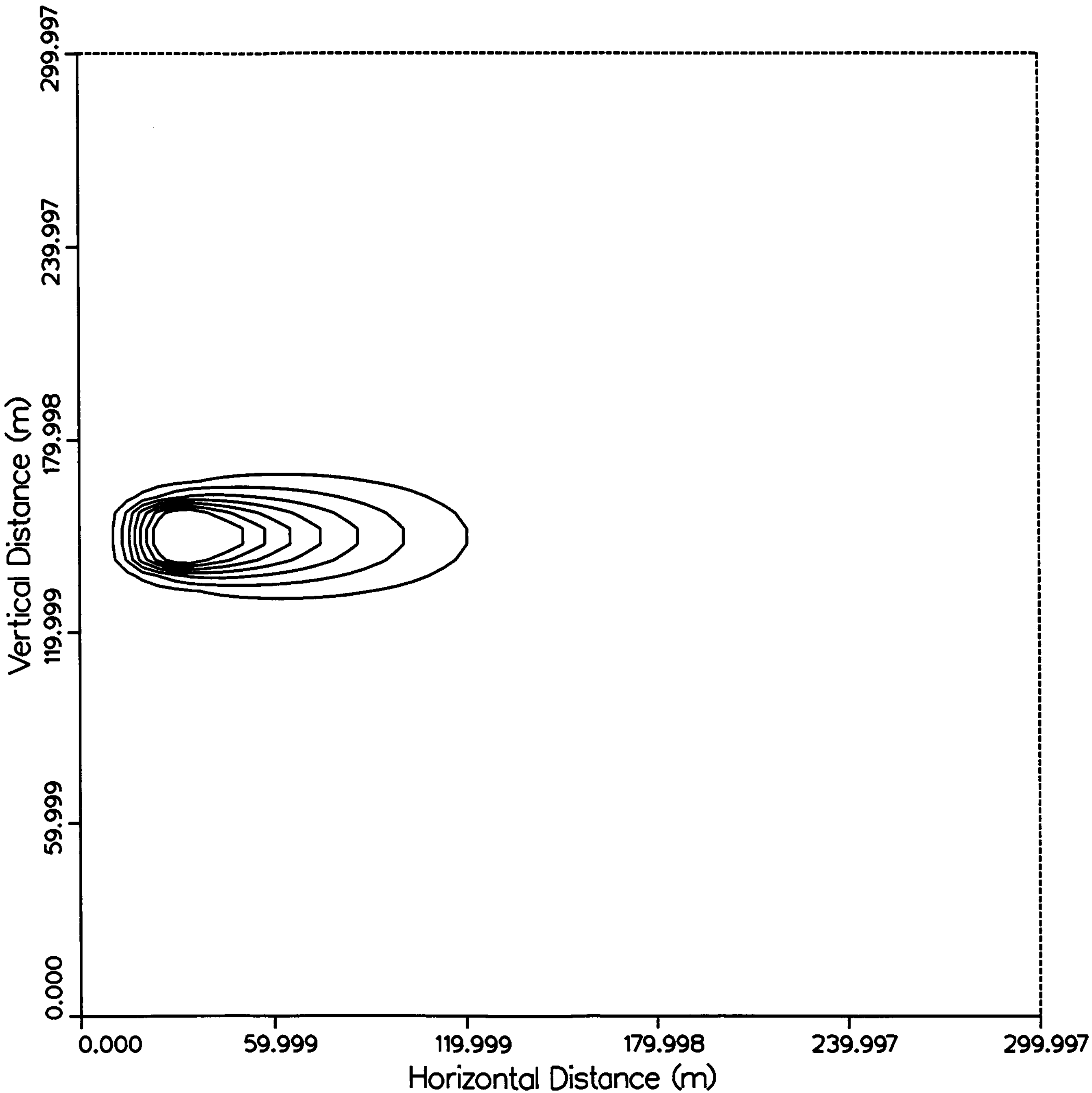
Time = 4.00E4



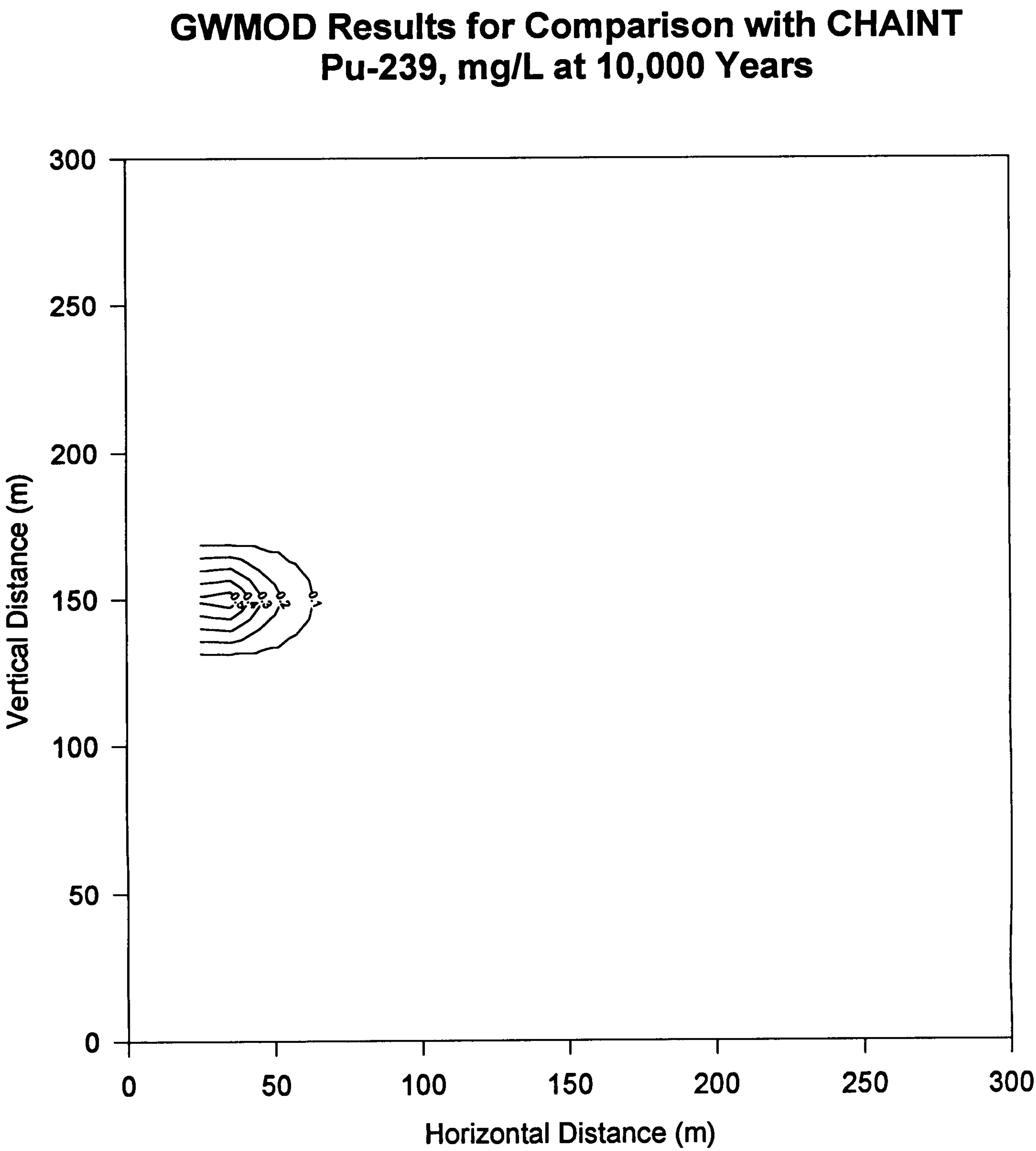
CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT
MAGNUM2D
****
(CONT 2.03)
(828960843)
Vertical Distance (m)
299.997
239.997
179.998
119.999
59.999
0.000
Horizontal Distance (m)
Time = 4.50E4

CHAINT/Decay/Sorption Compared to GWMODF
Pu239, MG/LIT

MAGNUM2D
****
(CONT 2.03)
(828960843)

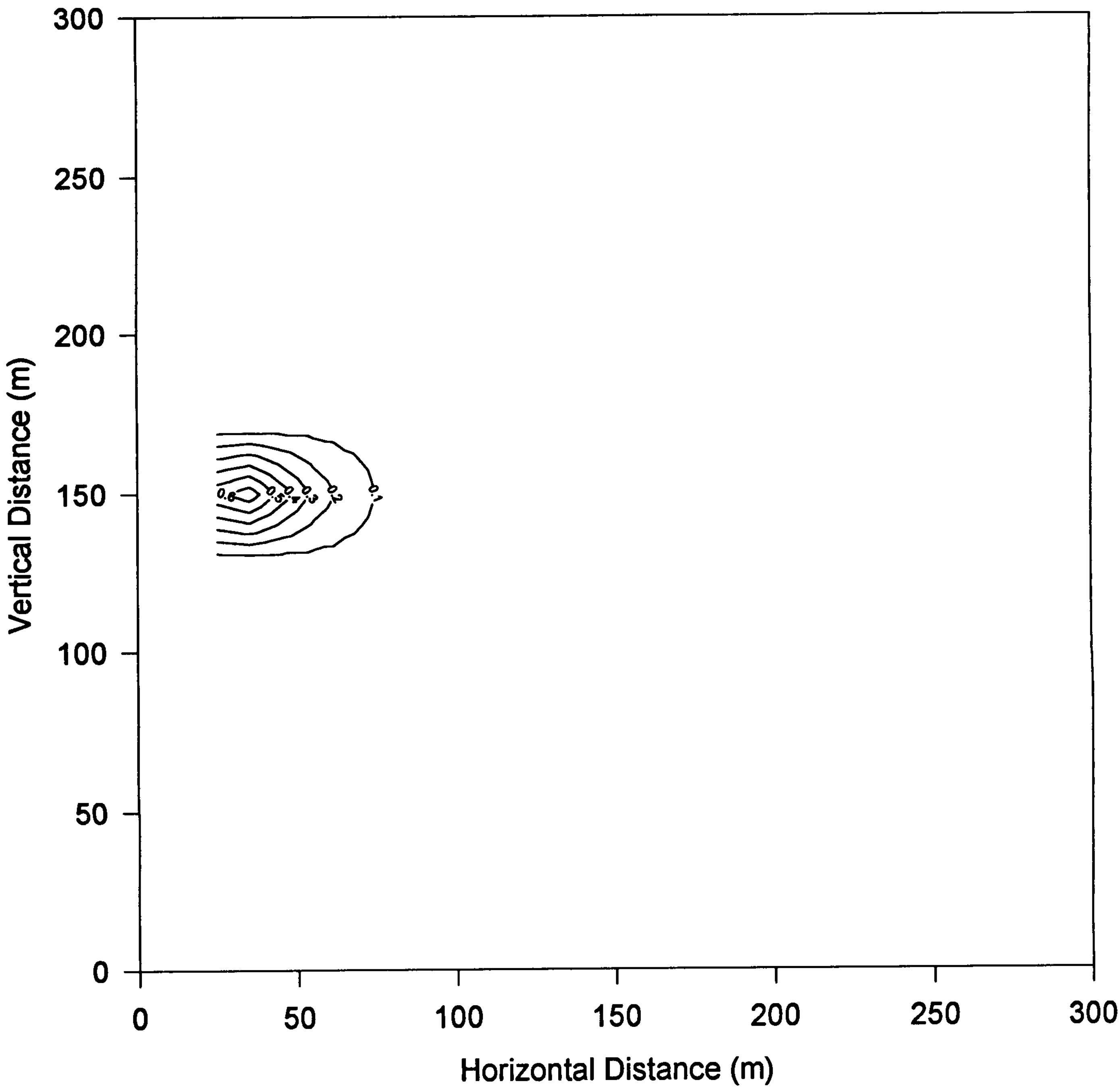


Time = 5.00E4

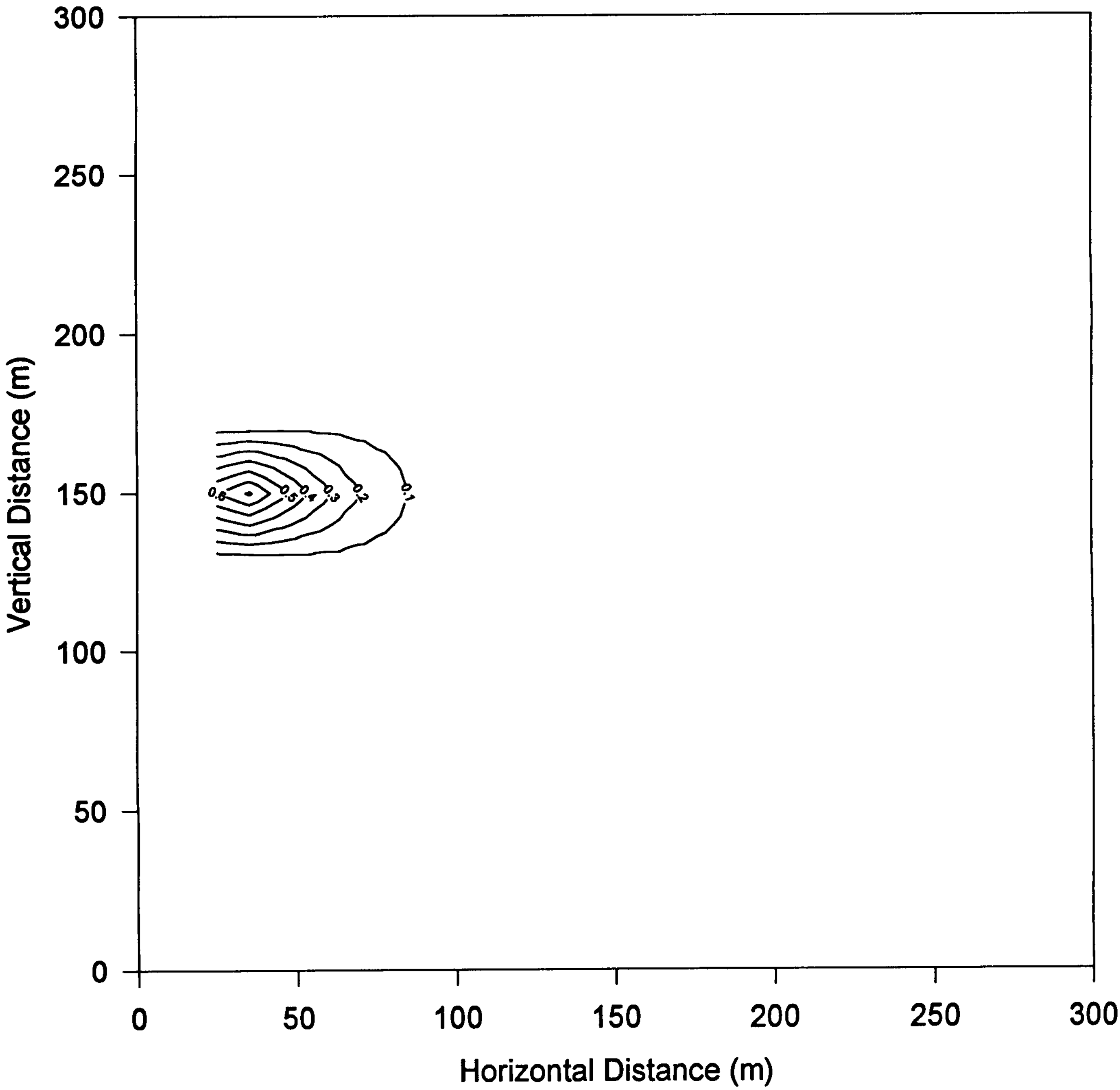


GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 10,000 Years
Vertical Distance (m)
Horizontal Distance (m)
0
50
100
150
200
250
300
0.1
0.2
0.3

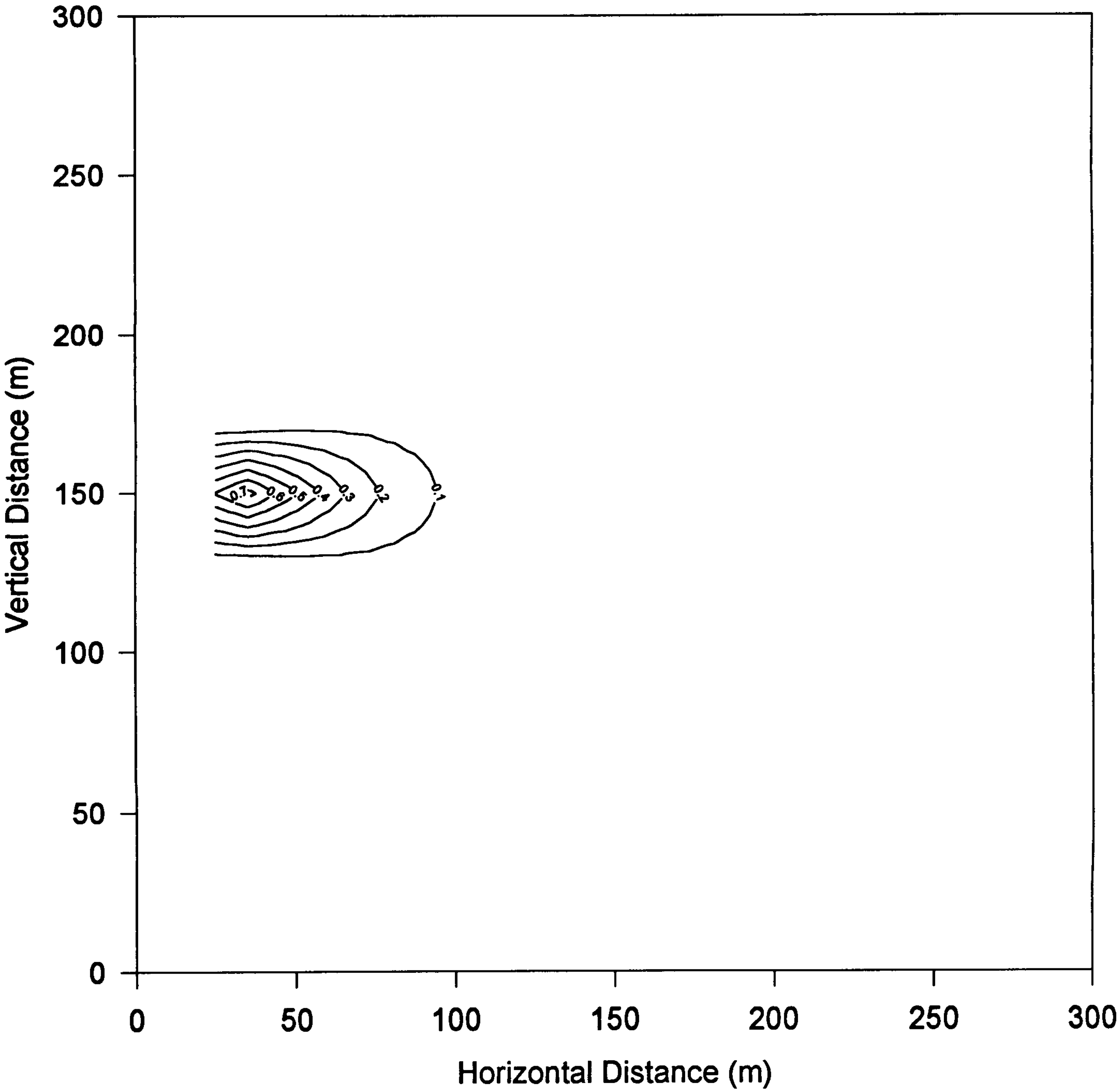
GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 15,000 Years



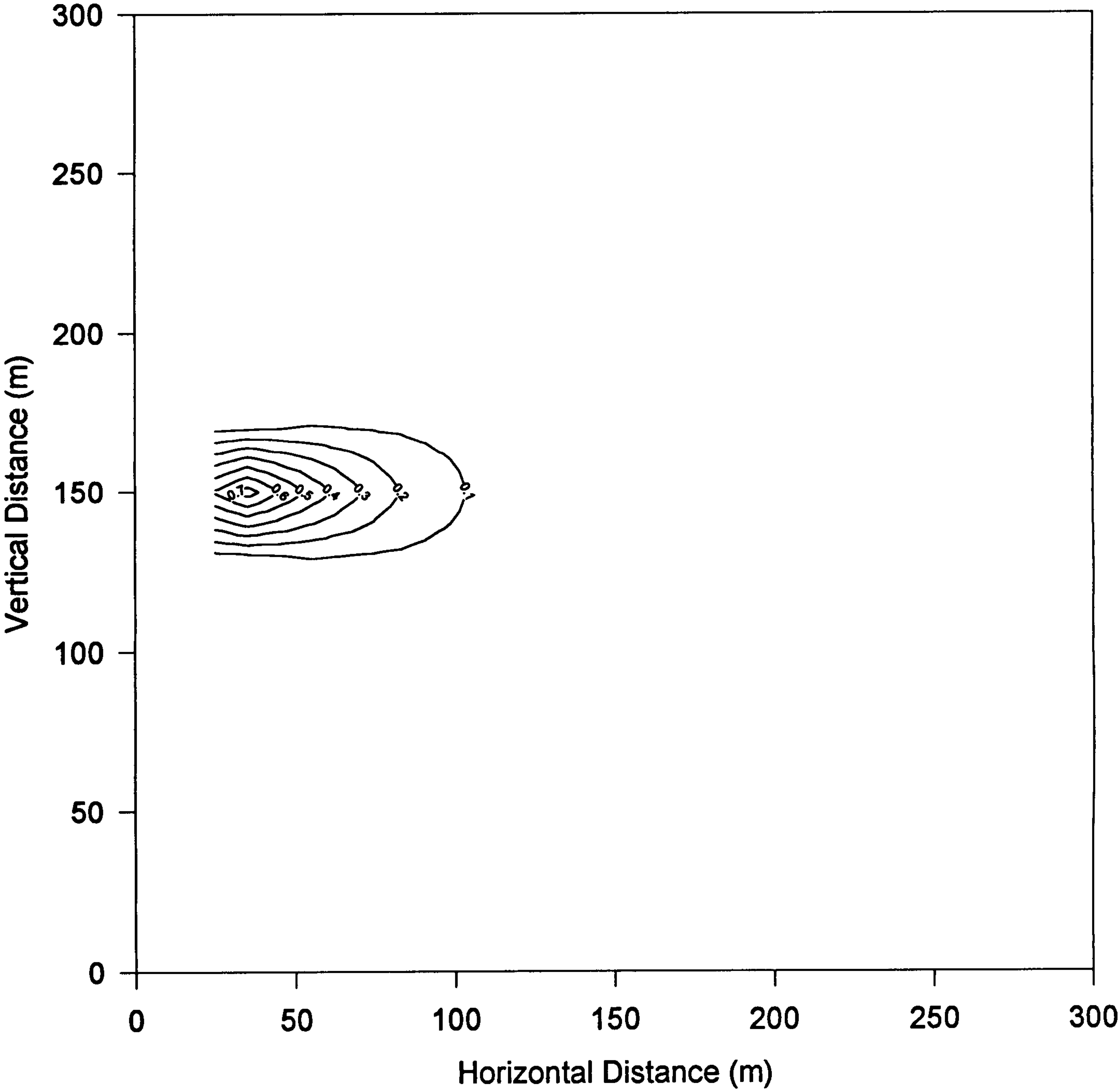
GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 20,000 Years



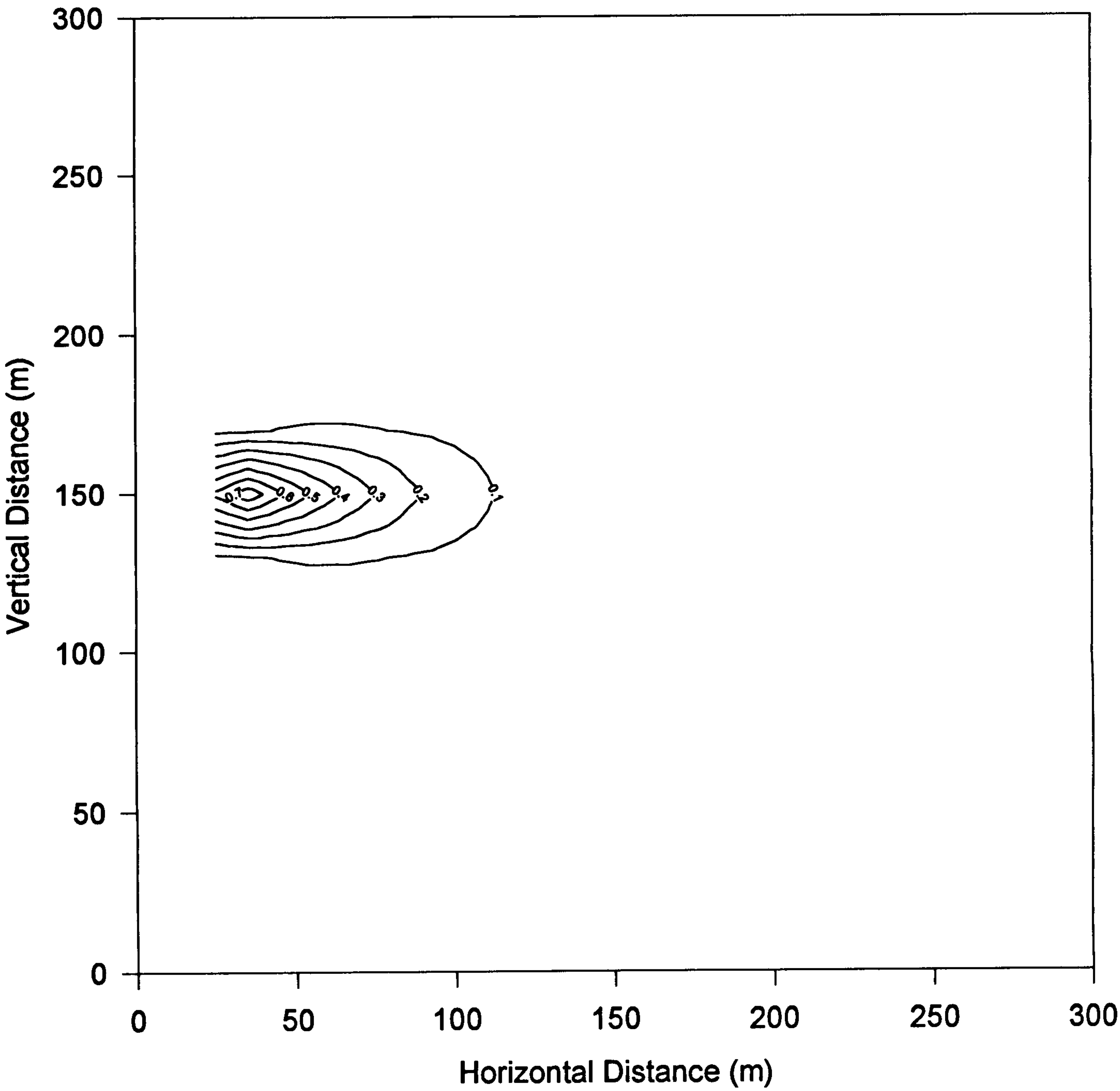
GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 25,000 Years



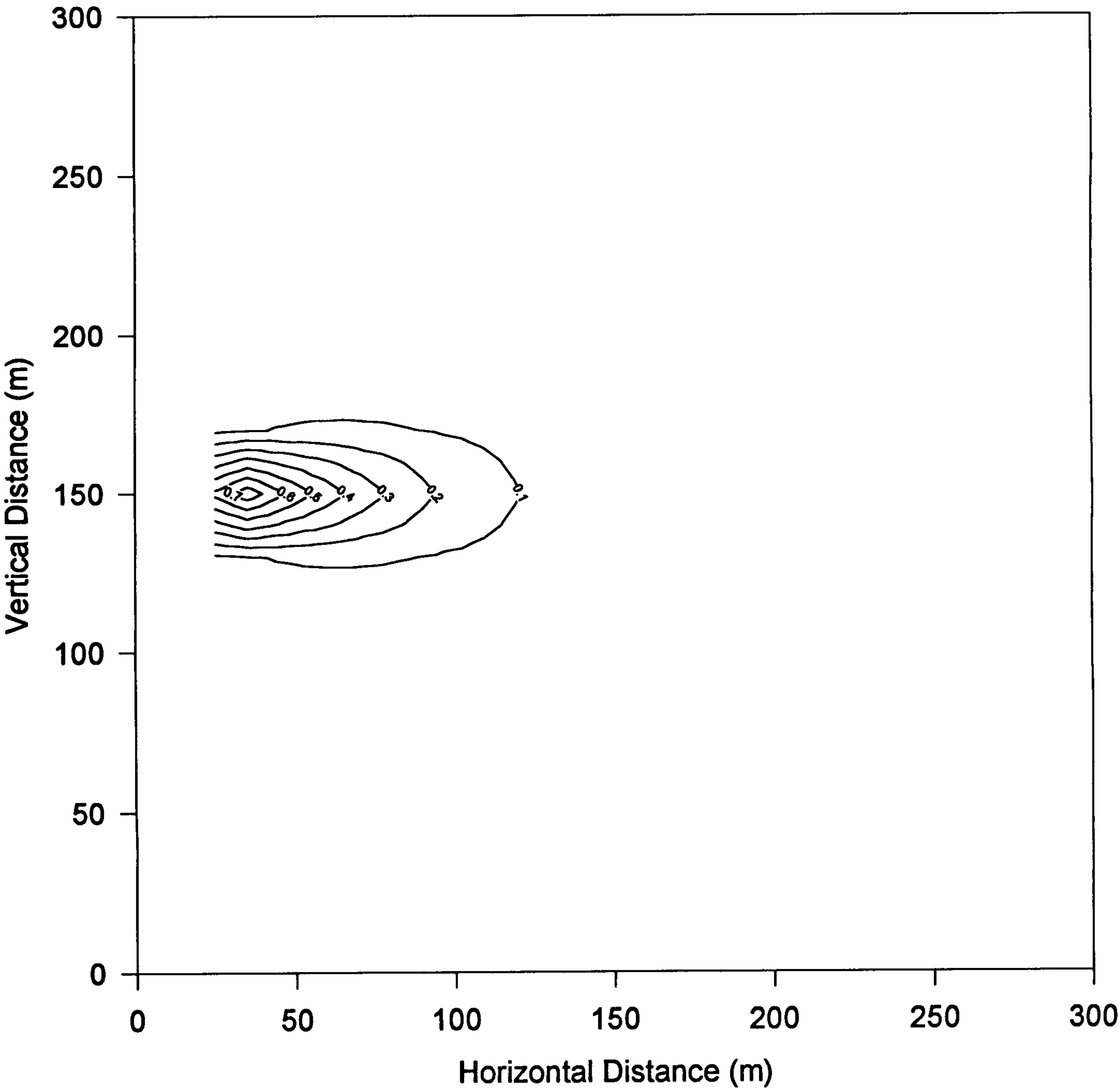
GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 30,000 Years



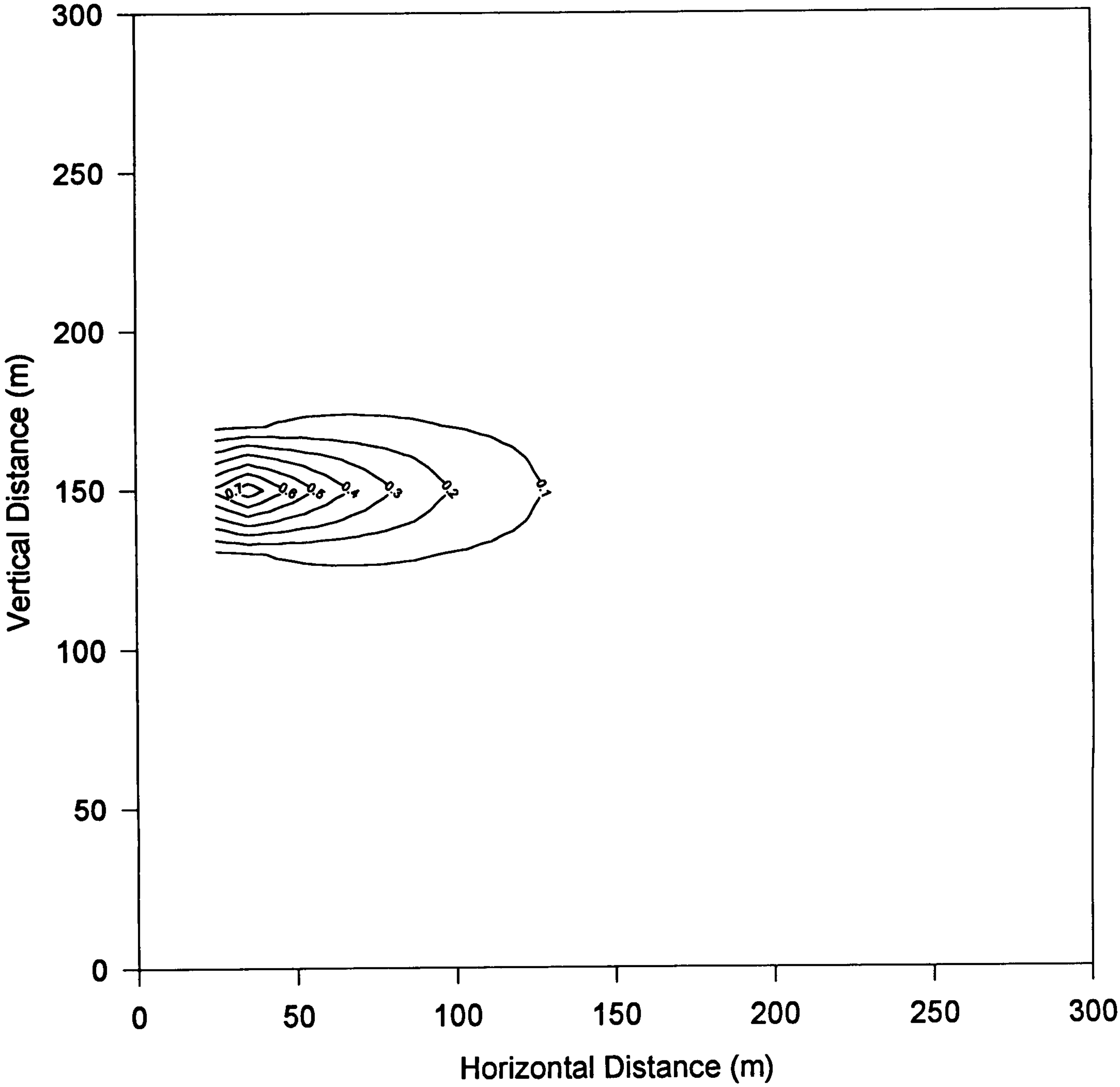
GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 35,000 Years



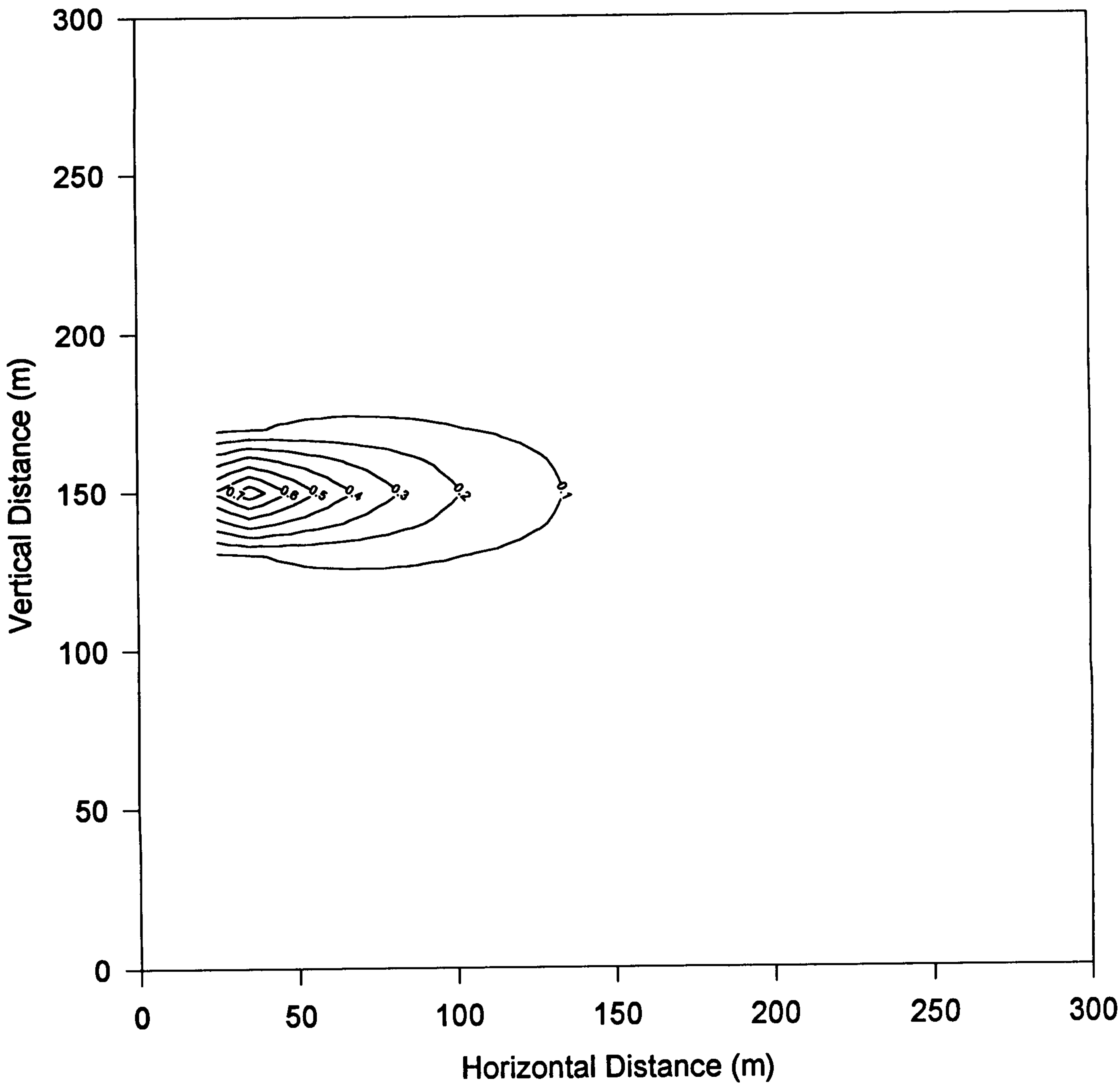
GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 40,000 Years



GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 45,000 Years

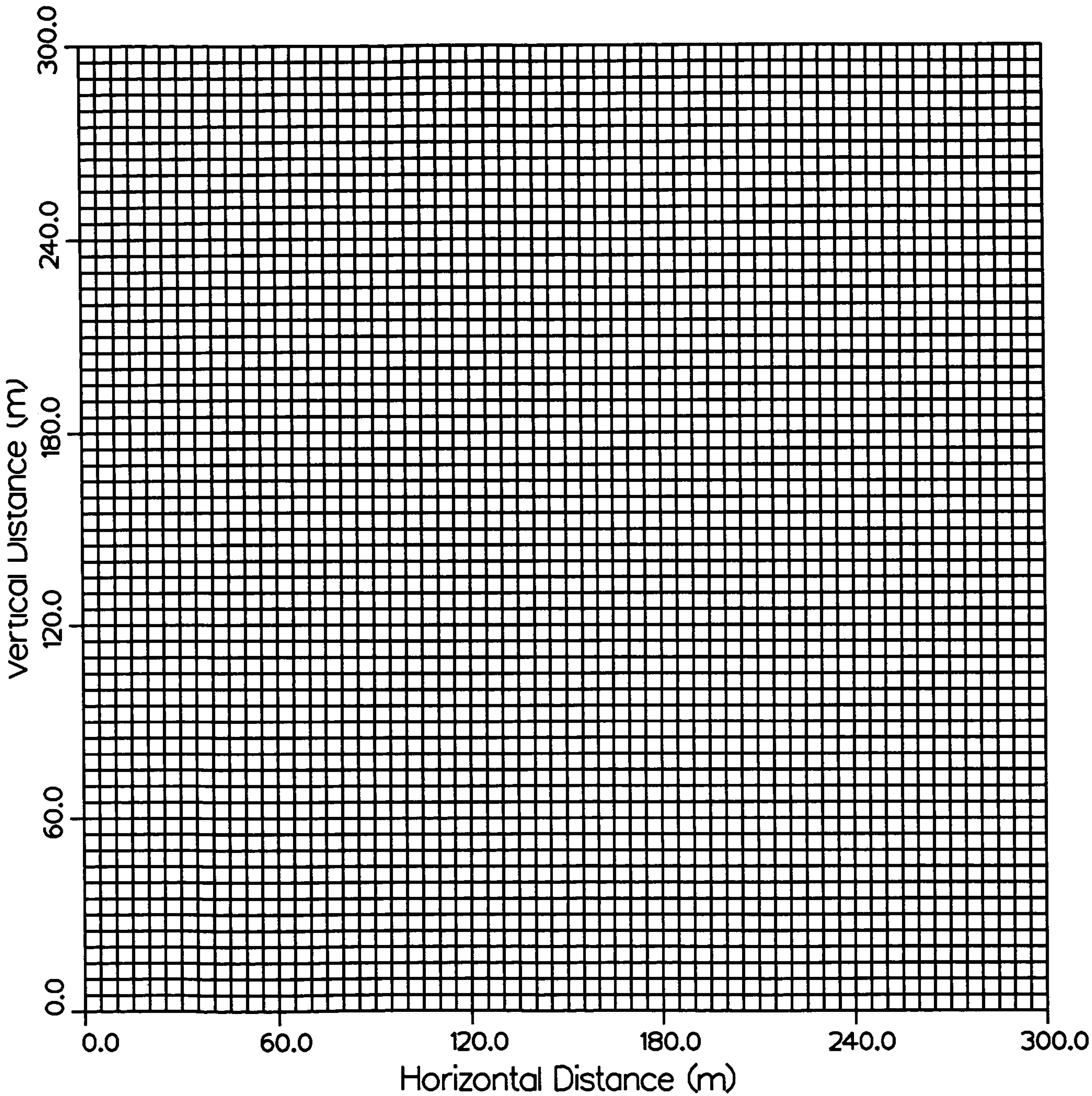


GWMOD Results for Comparison with CHAINT
Pu-239, mg/L at 50,000 Years



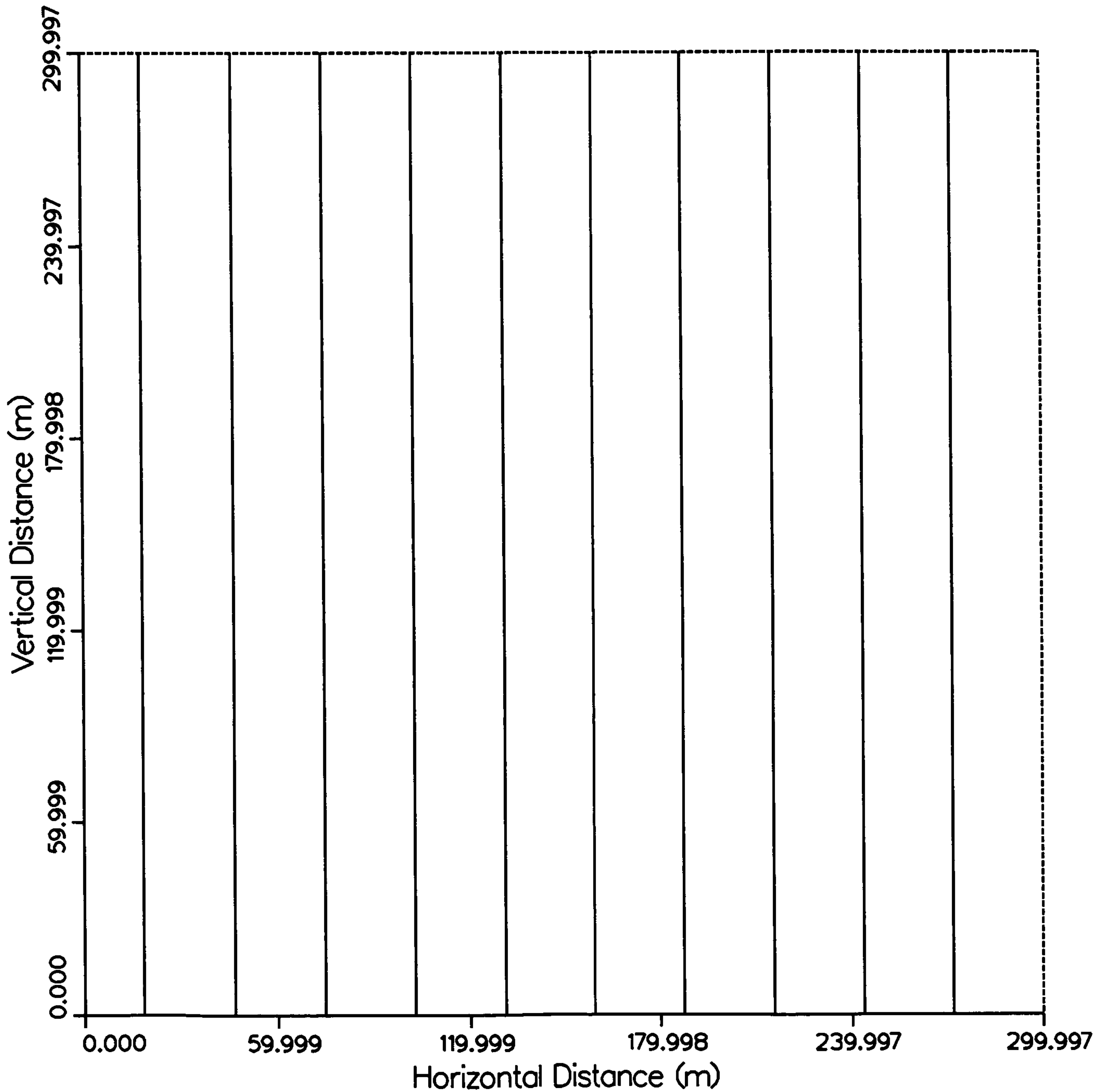
MAGNUM Geometry Grid for Comparison with GWMODF2
FINITE ELEMENT GRID

(PLT 2.00)
(830960755)
(0)



MAGNUM–2D for Comparison with GWMODF2
HEAD 1, METERS

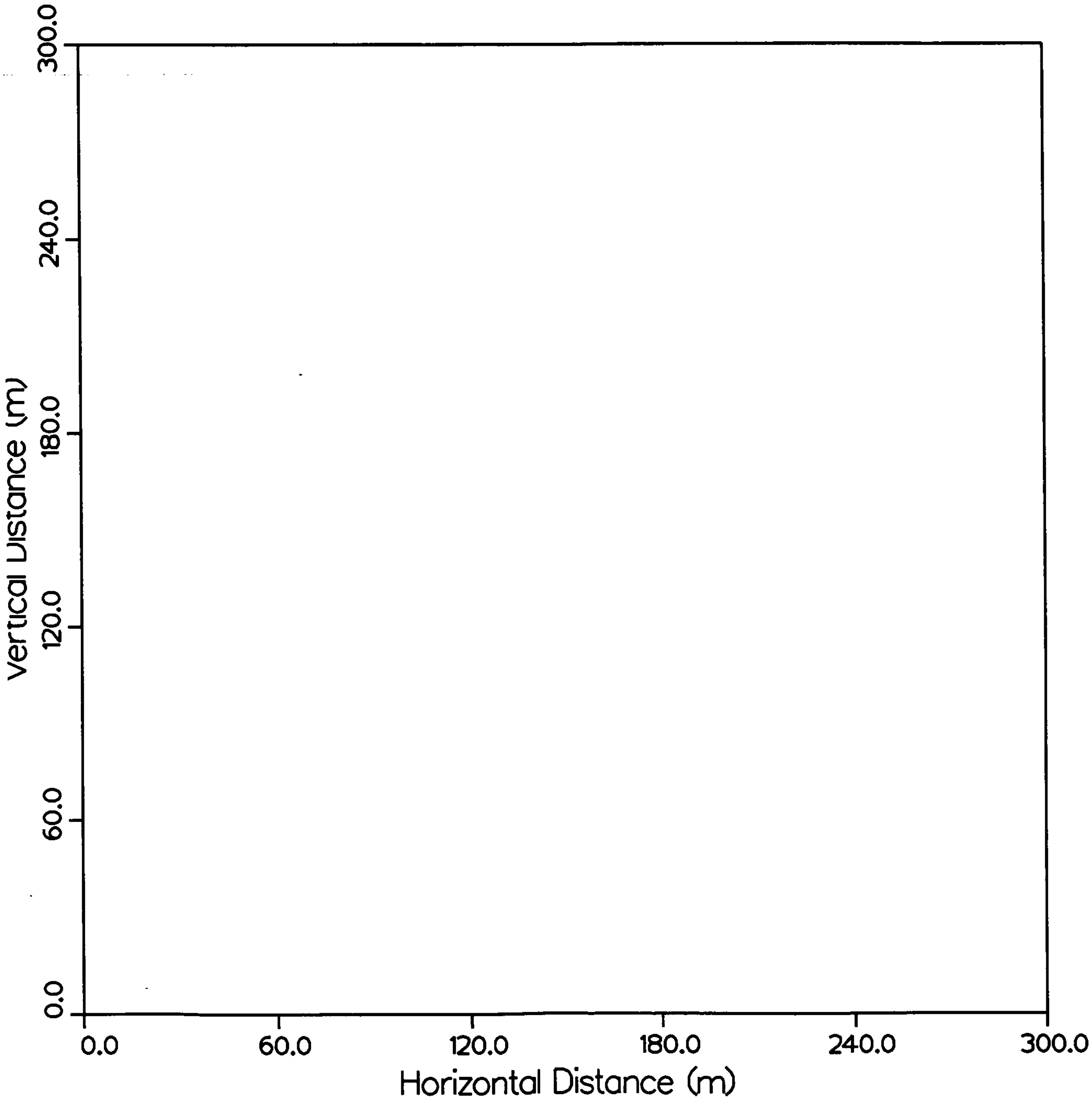
MAGNUM2D
****
(CONT 2.03)
(830960805)



Time = 1.00E–20

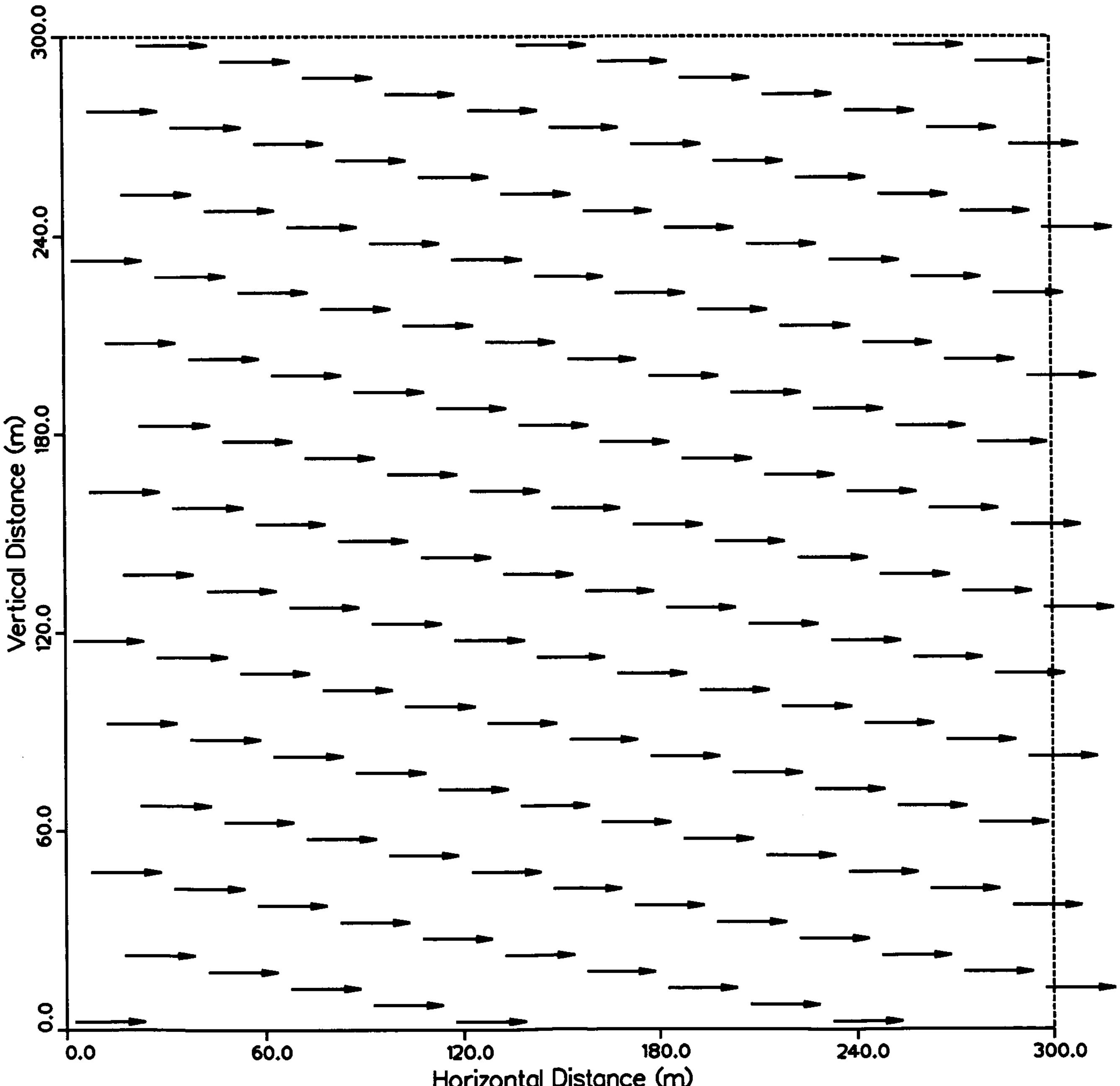
MAGNUM Geometry Grid for Comparison with GWMODF2
MATERIAL TYPE BOUNDARIES

(PLT 2.00)
(830960755)
(0)



DARCY VELOCITY VECTOR PLOT
MAGNUM – 2–D Test case for comparison with GWMODF2
SCALED MAGNITUDES, TRUE DIRECTIONS

MAGNUM2D 3.20
****
(VELP 2.00)
(830960821)



Scale Factor 1.00

Time = 0.000

```
MAGNUM - 2-D Test case for comparison with GWMODF2
# imode itemp imoist  np     ne   nmat icnd iech  iall ivelp iprt nsys
   1     0      1  11041  3600    1    0    0     0    1     1    0
#  irs  isv  icf  igi  ig  ivel inpt icsv
         13    0   10    0   12    0    0
#  ssf   alfa  tref
  0.0    1.8   20.0
#  nts  ntsg   dlt
   1     1     1000.
 9999    1     1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#   n      To      Ho
    1   20.000    0.5327
#  kspec
   242
#       n     n1 n2  Tbc      Hbc
     10860       0  1   20.0000    0.0000
     10861       0  1   20.0000    0.0000
     10862       0  1   20.0000    0.0000
     10865       0  1   20.0000    0.0000
     10866       0  1   20.0000    0.0000
     10868       0  1   20.0000    0.0000
     10869       0  1   20.0000    0.0000
     10871       0  1   20.0000    0.0000
     10872       0  1   20.0000    0.0000
     10874       0  1   20.0000    0.0000
     10875       0  1   20.0000    0.0000
     10877       0  1   20.0000    0.0000
     10878       0  1   20.0000    0.0000
     10880       0  1   20.0000    0.0000
     10881       0  1   20.0000    0.0000
     10883       0  1   20.0000    0.0000
     10884       0  1   20.0000    0.0000
     10886       0  1   20.0000    0.0000
     10887       0  1   20.0000    0.0000
     10889       0  1   20.0000    0.0000
     10890       0  1   20.0000    0.0000
     10892       0  1   20.0000    0.0000
     10893       0  1   20.0000    0.0000
     10895       0  1   20.0000    0.0000
     10896       0  1   20.0000    0.0000
     10898       0  1   20.0000    0.0000
     10899       0  1   20.0000    0.0000
     10901       0  1   20.0000    0.0000
     10902       0  1   20.0000    0.0000
     10904       0  1   20.0000    0.0000
     10905       0  1   20.0000    0.0000
     10907       0  1   20.0000    0.0000
     10908       0  1   20.0000    0.0000
     10910       0  1   20.0000    0.0000
     10911       0  1   20.0000    0.0000
     10913       0  1   20.0000    0.0000
     10914       0  1   20.0000    0.0000
     10916       0  1   20.0000    0.0000
     10917       0  1   20.0000    0.0000
     10919       0  1   20.0000    0.0000
     10920       0  1   20.0000    0.0000
     10922       0  1   20.0000    0.0000
     10923       0  1   20.0000    0.0000
```

10925	0	1	20.0000	0.0000
10926	0	1	20.0000	0.0000
10928	0	1	20.0000	0.0000
10929	0	1	20.0000	0.0000
10931	0	1	20.0000	0.0000
10932	0	1	20.0000	0.0000
10934	0	1	20.0000	0.0000
10935	0	1	20.0000	0.0000
10937	0	1	20.0000	0.0000
10938	0	1	20.0000	0.0000
10940	0	1	20.0000	0.0000
10941	0	1	20.0000	0.0000
10943	0	1	20.0000	0.0000
10944	0	1	20.0000	0.0000
10946	0	1	20.0000	0.0000
10947	0	1	20.0000	0.0000
10949	0	1	20.0000	0.0000
10950	0	1	20.0000	0.0000
10952	0	1	20.0000	0.0000
10953	0	1	20.0000	0.0000
10955	0	1	20.0000	0.0000
10956	0	1	20.0000	0.0000
10958	0	1	20.0000	0.0000
10959	0	1	20.0000	0.0000
10961	0	1	20.0000	0.0000
10962	0	1	20.0000	0.0000
10964	0	1	20.0000	0.0000
10965	0	1	20.0000	0.0000
10967	0	1	20.0000	0.0000
10968	0	1	20.0000	0.0000
10970	0	1	20.0000	0.0000
10971	0	1	20.0000	0.0000
10973	0	1	20.0000	0.0000
10974	0	1	20.0000	0.0000
10976	0	1	20.0000	0.0000
10977	0	1	20.0000	0.0000
10979	0	1	20.0000	0.0000
10980	0	1	20.0000	0.0000
10982	0	1	20.0000	0.0000
10983	0	1	20.0000	0.0000
10985	0	1	20.0000	0.0000
10986	0	1	20.0000	0.0000
10988	0	1	20.0000	0.0000
10989	0	1	20.0000	0.0000
10991	0	1	20.0000	0.0000
10992	0	1	20.0000	0.0000
10994	0	1	20.0000	0.0000
10995	0	1	20.0000	0.0000
10997	0	1	20.0000	0.0000
10998	0	1	20.0000	0.0000
11000	0	1	20.0000	0.0000
11001	0	1	20.0000	0.0000
11003	0	1	20.0000	0.0000
11004	0	1	20.0000	0.0000
11006	0	1	20.0000	0.0000
11007	0	1	20.0000	0.0000
11009	0	1	20.0000	0.0000
11010	0	1	20.0000	0.0000
11012	0	1	20.0000	0.0000
11013	0	1	20.0000	0.0000

11015	0	1	20.0000	0.0000
11016	0	1	20.0000	0.0000
11018	0	1	20.0000	0.0000
11019	0	1	20.0000	0.0000
11021	0	1	20.0000	0.0000
11022	0	1	20.0000	0.0000
11024	0	1	20.0000	0.0000
11025	0	1	20.0000	0.0000
11027	0	1	20.0000	0.0000
11028	0	1	20.0000	0.0000
11030	0	1	20.0000	0.0000
11031	0	1	20.0000	0.0000
11033	0	1	20.0000	0.0000
11034	0	1	20.0000	0.0000
11036	0	1	20.0000	0.0000
11037	0	1	20.0000	0.0000
11039	0	1	20.0000	0.0000
11040	0	1	20.0000	0.0000
121	0	1	20.0000	1.0654
120	0	1	20.0000	1.0654
119	0	1	20.0000	1.0654
118	0	1	20.0000	1.0654
117	0	1	20.0000	1.0654
116	0	1	20.0000	1.0654
115	0	1	20.0000	1.0654
114	0	1	20.0000	1.0654
113	0	1	20.0000	1.0654
112	0	1	20.0000	1.0654
111	0	1	20.0000	1.0654
110	0	1	20.0000	1.0654
109	0	1	20.0000	1.0654
108	0	1	20.0000	1.0654
107	0	1	20.0000	1.0654
106	0	1	20.0000	1.0654
105	0	1	20.0000	1.0654
104	0	1	20.0000	1.0654
103	0	1	20.0000	1.0654
102	0	1	20.0000	1.0654
101	0	1	20.0000	1.0654
100	0	1	20.0000	1.0654
99	0	1	20.0000	1.0654
98	0	1	20.0000	1.0654
97	0	1	20.0000	1.0654
96	0	1	20.0000	1.0654
95	0	1	20.0000	1.0654
94	0	1	20.0000	1.0654
93	0	1	20.0000	1.0654
92	0	1	20.0000	1.0654
91	0	1	20.0000	1.0654
90	0	1	20.0000	1.0654
89	0	1	20.0000	1.0654
88	0	1	20.0000	1.0654
87	0	1	20.0000	1.0654
86	0	1	20.0000	1.0654
85	0	1	20.0000	1.0654
84	0	1	20.0000	1.0654
83	0	1	20.0000	1.0654
82	0	1	20.0000	1.0654
81	0	1	20.0000	1.0654
80	0	1	20.0000	1.0654

79	0	1	20.0000	1.0654
78	0	1	20.0000	1.0654
77	0	1	20.0000	1.0654
76	0	1	20.0000	1.0654
75	0	1	20.0000	1.0654
74	0	1	20.0000	1.0654
73	0	1	20.0000	1.0654
72	0	1	20.0000	1.0654
71	0	1	20.0000	1.0654
70	0	1	20.0000	1.0654
69	0	1	20.0000	1.0654
68	0	1	20.0000	1.0654
67	0	1	20.0000	1.0654
66	0	1	20.0000	1.0654
65	0	1	20.0000	1.0654
64	0	1	20.0000	1.0654
63	0	1	20.0000	1.0654
62	0	1	20.0000	1.0654
61	0	1	20.0000	1.0654
60	0	1	20.0000	1.0654
59	0	1	20.0000	1.0654
58	0	1	20.0000	1.0654
57	0	1	20.0000	1.0654
56	0	1	20.0000	1.0654
55	0	1	20.0000	1.0654
54	0	1	20.0000	1.0654
53	0	1	20.0000	1.0654
52	0	1	20.0000	1.0654
51	0	1	20.0000	1.0654
50	0	1	20.0000	1.0654
49	0	1	20.0000	1.0654
48	0	1	20.0000	1.0654
47	0	1	20.0000	1.0654
46	0	1	20.0000	1.0654
45	0	1	20.0000	1.0654
44	0	1	20.0000	1.0654
43	0	1	20.0000	1.0654
42	0	1	20.0000	1.0654
41	0	1	20.0000	1.0654
40	0	1	20.0000	1.0654
39	0	1	20.0000	1.0654
38	0	1	20.0000	1.0654
37	0	1	20.0000	1.0654
36	0	1	20.0000	1.0654
35	0	1	20.0000	1.0654
34	0	1	20.0000	1.0654
33	0	1	20.0000	1.0654
32	0	1	20.0000	1.0654
31	0	1	20.0000	1.0654
30	0	1	20.0000	1.0654
29	0	1	20.0000	1.0654
28	0	1	20.0000	1.0654
27	0	1	20.0000	1.0654
26	0	1	20.0000	1.0654
25	0	1	20.0000	1.0654
24	0	1	20.0000	1.0654
23	0	1	20.0000	1.0654
22	0	1	20.0000	1.0654
21	0	1	20.0000	1.0654
20	0	1	20.0000	1.0654

```
       19        0  1   20.0000    1.0654
       18        0  1   20.0000    1.0654
       17        0  1   20.0000    1.0654
       16        0  1   20.0000    1.0654
       15        0  1   20.0000    1.0654
       14        0  1   20.0000    1.0654
       13        0  1   20.0000    1.0654
       12        0  1   20.0000    1.0654
       11        0  1   20.0000    1.0654
       10        0  1   20.0000    1.0654
        9        0  1   20.0000    1.0654
        8        0  1   20.0000    1.0654
        7        0  1   20.0000    1.0654
        6        0  1   20.0000    1.0654
        5        0  1   20.0000    1.0654
        4        0  1   20.0000    1.0654
        3        0  1   20.0000    1.0654
        2        0  1   20.0000    1.0654
        1        0  1   20.0000    1.0654
     #   L    cvm    tkk(1)  tkk(2)  poros    hkax       hkay      nme
#       spl      rhom   alpal   alpat   width
        1        0       0        0      0.07    5.0e-6    5.0e-6    mat1
   1.0e-6     2400       0        0        0
#  nld  nlt  scf
   0    0       0.0
```

```
CHAINT 2-D Test case (with flux source/decay/sorption) for comparison with GWMODF2
# nqal   ne     np    nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
   1    3600  11041   121    1     0      2     3     0      0     0
# IS1  IS2  IS3  IS4  IS5  IS6  IS7
  [illegible]  11    0    0   14   15    0
# ssf   alfa  xscale  yscale  uscale  vscale
   0.   1.8    0.      0.      0.      0.
# nts  ntsg  dlt    zonel  zoner  zonet  zoneb
   20   20   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
   10   10   500.     0.     0.     0.     0.
 9999    0     0      0      0      0      0
#  j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
   1       5.       1.0      2400.      0.07       0.      mat1
# islt
   1
#  L   amu    diag     isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
   1   1.0  2.411E+04    0        0.0       0        0.0    Pu239   0.0
#  i   dml(i,1..n2)  m2/yr
   1   0.0
#  i   xkdi(i,1..n2)  ml/g
   1 130.0
# [illegible]   Ci
  [illegible]   0.0
#  L    bcs
   1    0.0
   2    0.0
   3    0.0
   4    0.0
   5    0.0
   6    0.0
   7    0.0
   8    0.0
   9    0.0
  10    0.0
  11    0.0
  12    0.0
  13    0.0
  14    0.0
  15    0.0
  16    0.0
  17    0.0
  18    0.0
  19    0.0
  20    0.0
  21    0.0
  22    0.0
  23    0.0
  [illegible]    0.0
  25    0.0
  26    0.0
  27    0.0
  28    0.0
```

29	0.0
30	0.0
31	0.0
32	0.0
[illegible]	0.0
34	0.0
35	0.0
36	0.0
37	0.0
38	0.0
39	0.0
40	0.0
41	0.0
42	0.0
43	0.0
44	0.0
45	0.0
46	0.0
47	0.0
48	0.0
49	0.0
50	0.0
51	0.0
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	0.0
[illegible]	0.0
[illegible]	0.0
60	0.0
61	0.0
62	0.0
63	0.0
64	0.0
65	0.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
[illegible]	0.0
85	0.0
86	0.0
87	0.0
88	0.0

```
    89    0.0
    90    0.0
    91    0.0
    92    0.0
    93    0.0
    94    0.0
    95    0.0
    96    0.0
    97    0.0
    98    0.0
    99    0.0
   100    0.0
   101    0.0
   102    0.0
   103    0.0
   104    0.0
   105    0.0
   106    0.0
   107    0.0
   108    0.0
   109    0.0
   110    0.0
   111    0.0
   112    0.0
   113    0.0
   114    0.0
   115    0.0
   116    0.0
   117    0.0
   118    0.0
   119    0.0
   120    0.0
   121    0.0
#   nld   scf   relz
    16    1.0    0.
#   NLE
  209  210 211  212   269  270  271  272
  329  330 331  332   389  390  391  392
#   TLE        RLE(Tc99)
        0.00000E+00      0.041118
     50000.0             0.041118
   -1.0       0.0
```

```
1 0                 SOURCE  (0)POINT (1)AREA (2)LINE  JAVG (0)AVG (1)NOT-AVG
2                    MODE    (1) CONC VS TIME (2) XY CONTOUR (3) Z CONTOUR
1                           TYPE     (0) IMPULSE  (1) TIME VARIANT
0.07                        PHI
1.00E+00                    QIMP
1.0 1.00E-02 50. 20   FACTOR EPS ARB JMAX
9.12E-13,1.00E-20,1.00E-20,1.0E-20,1.0E-20,1.0E-20  DLR(I)
5.0,1.0,0.0,2.54E-7,0.0,1.0             AX,AY,AZ,VX,DEPTH,THICK
4458.0,1.0,1.0,1.0,1.0,1.0         RD(I)
0.0,15000.0,5000.0                      TSTART TEND,TP
20.0,  20.0                              AL,WA
0.0,0.0,0.0                             XD,YD,ZD
1 25                                       JSPEC JSTART
'gwmod.in'                                  FILEIN
'15Pu239.out'         fileout
'GWMODF2 Test Case with Pu239 for Comparison with CHAINT'   TITLE
```

GWMODF INPUT DECK

This program is a combination of two codes: GWMOD and GROUND. The analytical solutions to the groundwater equations for a point, line and area source found in Till and Meyer Eq 4.25, 4.36 and 4.37. Soultion for time varient releases are taken from the Simpson rule integration as interpreted by Codell in the GROUND code.

VARIABLES:

SOURCE = CHOOSE TO RUN EITHER(0)POINT SOURCE(1)AREA SOURCE(3)LINE SOURCE
JAVG = (0) AVERAGED (1)NON AVERAGED
MODE = (1) CONC VS TIME (2) CONTOUR XY PLANE OR (3) CONTOUR Z SLICE
TYPE = (0) IMPULSE RELEASE (1) TIME VARIENT RELEASE
PHI = POROSITY
QIMP = IMPULSE RELEASE MASS (amount)
FACTOR = VALUE TO MULTIPLY FINAL RESULTS BY (use 1.0 if no change is desired)
JMAX = MAXIMIM NUMBER OF STEPS (assume to start at 20, increase if necessary)
EPS = Desired accuracy
ARB = ARBITRARY NUMBER TO MULITPLY TIME VALUES BY IN DETERMINING INTEGRATION
DLR = DECAY CONSTANT (s-1)
AX = DISPERSIVITY IN THE X DIRECTION (m)
AY = DISPERSIVITY IN THE Y DIRECTION (m)
AZ = DISPERSIVITY IN THE Z DIRECTION (m)
VX = PORE VELOCITY, (m/s)
DEPTH = DEPTH OF SOURCE IN AQUIFER (m)
THICK = THICKNESS OF AQUIFER (m)
RD(I) = RETARDATION FACTOR (an array of 6)
TSTART = TIME TO START SIMULATION (years)
TEND = END TIME OF SIMULATION (years)
TP = OUTPUT TIME STEP (years)
AL = LENGTH OF SOURCE (m)
WA = WIDTH OF SOURCE USED AS WIDTH FOR LINE SOURCES (m)
XD = DESIRED X DISTANCE (m)
YD = DESIRED Y DISTANCE (m)
ZD = DESIRED Z DISTANCE (m)
JSPEC = DESIRED SPECIES (1,2,3,4,5 or 6)
FILEIN = RELEASE RATE INPUT FILE (years, amount/s)
FILEOUT = OUTPUT FILE FOR CONTOUR OR CONCENTRATIONS
TITLE = TITLE OF PROJECT

```
      PROGRAM GWMODF2
C
C AUTHOR   A.S. ROOD
C ORIGINAL PROGRAM WRITTEN FEBRUARY 10, 1989
C REVISED FORTRAN VERSION 12/90
C This program is a refinement of GROUND written by D Codell.  The analytical
C solutions to the groundwater equations for a point, line and area source are
C found in Till and Meyer Eq 4.25, 4.31 and 4.37.  Solution for time variant releases
C are taken from the Simpson rule integration. Limits of integration are
C determined by Codells method in the GROUND code. Simpson rule integration
C was taken from Numerical Recipes and found in the routines SIMPSON and TRAPZD

C 3/28 89   Reduced the number of std the program looks at initially in
C subroutine  SIMPSON.
C 4/15/89 Added solution for a NON vertically averaged area source.
C Also added routines to print out date and time in output along with
C the GWMOD2.PAR file and the GW.REL file
C 4/16/89 Changed the number of std initially looked at in SIMPSON from
C DEL=STD/4 to DEL=STD/10.  This was earlier changed in 3/28/89 but was
C changed back due to under estimations of concentration using Codells
C examples.
C 4/27/89 Added character variables to allow for input and output file
C names to be input by the user.
C 06/01/89 DEL changed from STD/10 to STD/JMAX.     The was done in order
C to eliminate problems when the STD of a pulse was extremely large, such
C as the case with high RD values.  This results in high DEL values and
C a value of TNM of less than 1.
C 10/23/90 INCREASED THE VALUE OF M TO 100
C 12/11/90 REWROTE INTEGRATION ROUTINE TO BE AS CLOSE AS POSSIBLE TO
C THE SIMPSONS RULE ROUTINE IN NUMERICAL RECIPES. Changed the conversion
C from years-to-seconds to 3.1536E07
C 01/05/90 Changed TEMP2 variable in integration limit determination
C to be similar to Codell's P9 variable Added variable JAVG

      IMPLICIT REAL*8 (A-H,O-Z)

C  INPUT VARIABLES:

C SOURCE = CHOOSE TO RUN EITHER (0) POINT SOURCE (1) AREA SOURCE  (3) LINE SOURCE
C JAVG = (0) VERT AVERAGED  (1) NOT VERT AVERAGED
C MODE =  (1) CONC VS TIME (2) CONTOUR XY PLANE OR (3) CONTOUR Z SLICE
C TYPE = (0) IMPULSE RELEASE (1) TIME VARIENT RELEASE
C PHI = POROSITY
C QIMP = IMPULSE RELEASE MASS (amount)
C FACTOR = VALUE TO MULTIPLY FINAL RESULTS BY (use 1.0 if no change is desired)
C EPS = Desired accuracy
C JMAX = MAX NUMBER OF STEPS
C ARB = ARBITRARY NUMBER TO DETERMINE INTEGRATION LIMITS
C DLR = DECAY CONSTANT  (s-1)
C AX = DISPERSIVITY IN THE X DIRECTION (m)
C AY = DISPERSIVITY IN THE Y DIRECTION (m)
C AZ = DISPERSIVITY IN THE Z DIRECTION (m)
C VX = PORE VELOCITY,  (m/s)
C DEPTH = DEPTH OF SOURCE IN AQUIFER (m)
C THICK = THICKNESS OF AQUIFER (m)
C RD(I) = RETARDATION FACTOR
C TSTART = TIME TO START SIMULATION (years)
C TEND = END TIME OF SIMULATION (years)
C TP = OUTPUT TIME STEP (years)
C AL = LENGTH OF SOURCE (m)
C WA = WIDTH OF SOURCE  USED AS WIDTH FOR LINE SOURCES (m)
C XD = DESIRED X DISTANCE (m)
C YD = DESIRED Y DISTANCE (m)
C ZD = DESIRED Z DISTANCE (m)
C JSPEC = DESIRED SPECIES (1,2,3,4,5 or 6)
C JSTART=NUMBER OF INITIAL STEPS
C ATIME = TIME ARRAY FOR TIME VARIANT RELEASES [ATIME(NSTEPS)], time in years
C QREL =  RELEASE RATE ARRAY FOR TIME VARIANT RELEASES [QREL(NSTEPS,NSPEC)] release rate in
amount per sec
C X(I), Y(I), Z(I) COORDINATE MATRIX FOR CONTOURING PURPOSES INPUT DURING CONTOUR

C CALCULATED VARIABLES

C TIME = TIME COUNT VARIABLE (years in subroutine SIMPSON, sec in subroutine TRAPZD)
C TI = TIME COUNT VARIABLE CONVERTED TO SECONDS
C A = BOTTOM LIMIT OF INTEGRATION  (s) (in subroutine TRAPZD)
C B = UPPER LIMIT OF INTEGRATION   (s) (in subroutine TRAPZD)
C T1 = BOTTOM LIMIT OF INTEGRATION  (s) (in subroutine SIMPSON)
C T2 = UPPER LIMIT OF INTEGRATION   (s) (in subroutine SIMPSON)
C TC = TIME COUNT VARIABLE
C NP = NUMBER OF POINTS IN TIME VARIANT SOURCE INPUT FILE
```

```
C TNM = NUMBER OF DIVISIONS IN INTEGRATION
C DEL = TIME INCREMENT IN INTEGRATION (DEL=B-A/TNM)
C TCAL = TIME WHICH CONC. IS CALC. FOR A RELEASE AT TI in subroutine TRAPDZ (TCAL= TI-TIME)
C QREL = SOURCE RELESES ARRAY FOR TIME VARIANT RELEASES (amount/s)
C TS = TOTAL TIME OF SOURCE INPUT (years)
C PECLET = PECLET NUMBER
C GWT = GROUND WATER TRAVEL TIME
C STD = STANDARD DEVIATION OF PULSE (no dimentions)
C STDD = STANDARD DEVIATION OF PULSE (dimentioned)
C TTIME = CHARACTER VARIABLE FOR HOLDING TIME OF RUN
C DDATE = CHARACTER VARIABLE FOR HOLDING DATA OF RUN


C PARAMETERS

C NSTEPS= PARAMETER FOR DIMENSION OF INPUT SOURCE FILE
C NSPEC = NUMBER OF CHEMICAL SPECIES TO CONSIDER

      PARAMETER(NSPEC=6,NSTEPS=2000)
      DIMENSION  RD(NSPEC),DLR(NSPEC),ATIME(NSTEPS),QREL(NSTEPS,NSPEC)
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /SOURCE/ ATIME,QREL,NP
      COMMON /FILES/ FILEIN,FILEOUT,TITLE
      WRITE(*,1000)
 1000 FORMAT(2X,' *********************  GWMODF2 *********************'
     !/,2X,' * ORIGINAL FORTRAN VERSION WRITTEN FEB 10 1988       *'
     !/,2X,' * REVISED FORTRAN VERSION WRITTEN APRIL 10 1991      *'
     !/,2X ' * DATE OF LAST PROGRAM MODIFICATION 04/10/91         *'
     !/,2X,' * This program uses equation 4.25, 4.31 and 4.37     *'
     !/,2X,' * in Till and Meyer for a source at 0,0,Zs           *'
     !/,2X,' * in an aquifer of infinite lateral extent           *'
     !/,2X,' * and finite thickness and constant pore velocity    *'
     !/,2X,' * A. S. ROOD  EG&G IDAHO                             *'
     !/,2X,' ****************************************************')
C INPUT ENVIRONMENTAL PARAMETERS
      OPEN(1,FILE='GWMODF.PAR', STATUS='OLD')
      READ(1,*) SOURCE,JAVG
      READ(1,*) MODE
      READ(1,*) TYPE
      READ(1,*) PHI
      READ(1,*) QIMP
      READ(1,*) FACTOR,EPS,ARB,JMAX
      READ(1,*) (DLR(I),I=1,NSPEC)
      READ(1,*) AX,AY,AZ,VX,DEPTH,THICK
      READ(1,*) (RD(I),I=1, NSPEC)
      READ(1,*) TSTART,TEND,TP
      READ(1,*) AL,WA
      READ(1,*) XD,YD,ZD
      READ(1,*) JSPEC,JSTART
      READ(1,*) FILEIN
      READ(1,*) FILEOUT
      READ(1,*) TITLE
      CLOSE(1,STATUS='KEEP')
      WRITE(*,*) TITLE

C CALCULATE CONTAMINANT CONCENTRATIONS AS A FUNCTION OF TIME
      IF(MODE.EQ.1.) THEN
      CALL TSOURCE(XD,YD,ZD)
      ELSE
C CALCULATE CONTAMINANT CONCENTRATION WITH CONTOUR OUTPUT
      IF(MODE.GE.2.) THEN
      CALL CONTOUR
      ENDIF
      ENDIF
      END

C *******************************************************************
C     SUBROUTINE TSOURCE
C *******************************************************************
      SUBROUTINE TSOURCE(XD,YD,ZD)
      implicit real*8 (a-h,o-z)
      PARAMETER (NSPEC=6,NSTEPS=2000)
      CHARACTER*11 TTIME
```

```fortran
      CHARACTER*8 DDATE
      CHARACTER*40 FILEIN, FILEOUT
      CHARACTER*80 TITLE
      DIMENSION RD(NSPEC),DLR(NSPEC)

      CALL TIME(TTIME)
      CALL DATE(DDATE)

C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG
      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /FILES/ FILEIN,FILEOUT,TITLE

      WRITE(*,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,XD,YD,ZD,AL,WA,QIMP,FACTOR,TSTART,TEND,TP,EPS,ARB,JMAX,
     ! JSTART

    7 FORMAT(2X,'WATER TRANSPORT PARAMETERS FOR CONC. VS TIME PLOT'
     !/,2X,'*********************************************************'
     !/,2X,'SOURCE TYPE: (0) POINT (1) AREA (2) LINE        ',I1
     !/,2X,'VERTICALLY AVERAGED: (0) YES  (1) NO            ',I1
     !/,2X,'TYPE OF RELEASE: (0) IMPULSE  (1) TIME VARIANT  ',I1
     !/,2X,'POROSITY                                        ',1PE9.2
     !/,2X,'DECAY CONSTANTS (s-1) ',1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,
     ! 1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,2X,'DISPERSIVITY X DIRECTION (m)                    ',1PE11.4
     !/,2X,'DISPERSIVITY Y DIRECTION (m)                    ',1PE11.4
     !/,2X,'DISPERSIVITY Z DIRECTION (m)                    ',1PE11.4
     !/,2X,'RETARDATION FAC.',1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1
     !PE9.2,1X,1PE9.2
     !/,2X,'PORE VELOCITY  (m/s)                            ',1PE11.4
     !/,2X,'CHEMICAL SPECIES DESIRED                        ',1PE9.2
     !/,2X,'WATER TABLE THICKNESS (m)                       ',1PE9.2
     !/,2X,'DEPTH OF SOURCE (m)                             ',1PE9.2
     !/,2X,'DESIRED X DISTANCE (m)                          ',1PE11.4
     !/,2X,'DESIRED Y DISTANCE (m)                          ',1PE11.4
     !/,2X,'DESIRED Z DISTANCE (m)                          ',1PE11.4
     !/,2X,'LENGTH OF SOURCE (for area source) (m)          ',1PE11.4
     !/,2X,'WIDTH OF SOURCE (for area source) (m)           ',1PE11.4
     !/,2X,'IMPULSE MASS INPUT (mass units)                 ',1PE11.4
     !/,2X,'OUTPUT FACTOR                                   ',1PE11.4
     !/,2X,'TIME START OF SIMULATION (years)                ',1PE11.4
     !/,2X,'TIME END OF SIMULATION (years)                  ',1PE11.4
     !/,2X,'OUTPUT TIME STEP (years)                        ',1PE9.2
     !/,2X,'DESIRED ACCURACY                                ',1PE9.2
     !/,2X,'ARB VALUE                                       ',I4
     !/,2X,'JMAX VALUE                                      ',I4
     !/,2X,'JSTART VALUE                                    ',I4)

      PAUSE

C  OPEN OUTPUT FILE

      OPEN(1,FILE=FILEOUT, STATUS='UNKNOWN')
      WRITE(1,1000)


 1000 FORMAT(2X,' ********************  GWMODF2 *********************'
     !/,2X,' * ORIGINAL FORTRAN VERSION WRITTEN FEB 10 1988      *'
     !/,2X,' * REVISED FORTRAN VERSION WRITTEN APRIL 10 1991     *'
     !/,2X ' * DATE OF LAST PROGRAM MODIFICATION 04/10/91        *'
     !/,2X,' * This program uses equation 4.25, 4.31 and 4.37    *'
     !/,2X,' * in Till and Meyer for a source at 0,0,Zs          *'
     !/,2X,' * in an aquifer of infinite lateral extent          *'
     !/,2X,' * and finite thickness and constant pore velocity   *'
     !/,2X,' * A. S. ROOD  EG&G IDAHO                             *'
     !/,2X,' *****************************************************')


      WRITE(1,*)
      WRITE(1,*) ' TITLE: ',TITLE
      WRITE(1,*) ' FILE NAME: ',FILEOUT
      WRITE(1,*)
      WRITE(1,22)
   22 FORMAT(2X,'---------- CONCENTRATION VS TIME PLOT ----------'
     !/,7X,'TIME',4X,'CONCENTRATION'
```

```
     !/,5X,'(years)',3X,'(amount/m3) x factor')

      IF(TYPE.EQ.0) THEN

C ********************** IMPULSE RELEASE ROUTINE ************************
      WRITE(*,*) 'TYPE OF RELEASE:  IMPULSE'
      DO 120,TC=TSTART,TEND,TP
C CONVERT TIME TO SECONDS AND CALL POINT, AREA OR LINE SOURCE EQ
      TI=TC*3.1536E7
      IF(TI.LE.0.0) THEN
      GOTO 120
      ENDIF
       IF(SOURCE.EQ.0) THEN
       CALL POINT(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.1) THEN
       CALL AREA(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
       IF(SOURCE.EQ.2) THEN
       CALL LINE(TI,QIMP,GWCON,XD,YD,ZD)
       ENDIF
C FACTOR OUTPUT ACCORDING TO FACTOR VARIABLE
      GWCON=GWCON*FACTOR
      WRITE(*,23) TC,GWCON
      WRITE(1,23) TC,GWCON

C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      TMAX=TC
      ENDIF

  120 CONTINUE

      ELSE

C  ****************** TIME VARIENT RELEASE ROUTINE *****************

C  READ GROUND WATER RELEASE DATA INTO ARRAY FOR INPUT INTO LINT
       CALL TINPUT(TS)
C CALCULATE STD AND DETERMINE IF AN IMPULSE OR TIME VARIANT RELEASE SHOULD BE USED
C      PECLET=XD/AX
C      STD=SQRT(ABS(2/PECLET+8/PECLET**2))
C      GWT=XD/VX*RD(JSPEC)
C      STD=(STD*GWT)/3.1536E7
C      IF(TS.LT.STD)THEN
C      PAUSE 'CAUTION  Source input time is less than STD of pulse'
C      ENDIF
C  BEGIN LOOP FOR CALCULATING GWCON FOR SPECIFIED TIMES
      DO 100 TC=TSTART,TEND,TP
      CALL SIMPSON(XD,YD,ZD,TC,GWCON,TS)
C  SCALE DATA ACCORDING TO FACTOR
      GWCON=GWCON*FACTOR
C  WRITE OUTPUT
      WRITE(*,23) TC,GWCON
      WRITE(1,23) TC,GWCON
   23 FORMAT(3X,1PE11.4,1X,1PE11.4)

C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      TMAX=TC
      ENDIF

  100 CONTINUE

      ENDIF

      WRITE(1,*) '   DATE ',DDATE
      WRITE(1,*) '   TIME ',TTIME

      WRITE(1,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,XD,YD,ZD,AL,WA,QIMP,FACTOR,TSTART,TEND,TP,EPS,ARB,JMAX,
     ! JSTART

C WRITE MAXIMUM CONCENTRATION AND TIME OF MAX CONCENTRATION
      WRITE(1,8) GWMAX,TMAX
```

```
    8  FORMAT(2X,'MAXIMUM CONCENTRATION WAS ', 1PE11.4
     !/,2X,'TIME OF MAXIMUM CONCENTRATION WAS ',1PE11.4)

       IF(TYPE.EQ.1.)THEN
       CALL GWOUT
       ENDIF

      CLOSE(1,STATUS='KEEP')
      RETURN
      END
C
C *********************************************
C *    SUBROUTINE CONTOUR                       *
C *********************************************
      SUBROUTINE CONTOUR
C UNITS meters years

      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*11 TTIME
      CHARACTER*8 DDATE
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
      PARAMETER (NSPEC=6,NSTEPS=2000)

      CALL TIME(TTIME)
      CALL DATE(DDATE)

C  This routine creates a file which contains the x and y coordinates and the
C  ground water concentration at the specified depth z.

C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /FILES/FILEIN,FILEOUT,TITLE
      DIMENSION RD(NSPEC),DLR(NSPEC),X(2000),Y(2000),Z(2000)

      WRITE(*,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,AL,WA,QIMP,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,TEND,FACTOR,JMAX,ARB,EPS

    7  FORMAT(1X,'WATER TRANSPORT PARAMETERS FOR CONTOUR PLOT'
     !/,1X,'*********************************************************'
     !/,1X,'SOURCE TYPE: (0) POINT (1) AREA (2) LINE        ',I1
     !/,1X,'VERTICALLY AVERAGED: (0) YES  (1) NO           ',I1
     !/,1X,'TYPE OF RELEASE: (0) IMPULSE  (1) TIME VARIANT  ',I1
     !/,1X,'POROSITY                                        ',1PE9.2
     !/,1X,'DECAY CONSTANTS (s-1) ',1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,
     ! 1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'DISPERSIVITY X DIRECTION (m)                    ',1PE11.4
     !/,1X,'DISPERSIVITY Y DIRECTION (m)                    ',1PE11.4
     !/,1X,'DISPERSIVITY Z DIRECTION (m)                    ',1PE11.4
     !/,1X,'LENGTH OF SOURCE (for area source) (m)          ',1PE11.4
     !/,1X,'WIDTH OF SOURCE (for area source) (m)           ',1PE11.4
     !/,1X,'IMPULSE MASS (for impulse release) (mass units) ',1PE11.4
     !/,1X,'RETARDATION FACTORS ',1PE9.2,1X,1PE9.2,1X,1PE9.2,
     ! 1X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'PORE VELOCITY  (m/s)                            ',1PE11.4
     !/,1X, 'CHEMICAL SPECIES DESIRED                       ',1PE9.2
     !/,1X, 'WATER TABLE THICKNESS (m)                      ',1PE9.2
     !/,1X, 'DEPTH OF SOURCE (m)                            ',1PE9.2
     !/,1X,'TIME OF SIMULATION (years)                      ',1PE11.4
     !/,1X,'OUTPUT FACTOR                                   ',1PE11.4
     !/,1X,'JMAX VALUE                                      ',I4
     !/,1X,'ARB VALUE                                       ',I4
     !/,1X,'DESIRED ACCURACY                                ',1PE9.2)
      PAUSE

C  READ DATA POINT COORDINATES AND CHEM SPECIES FROM CONTOUR.PAR FILE
C  AND OPEN OUTPUT FILE

      WRITE(*,*) 'READING CONTOUR.PAR FILE'
      OPEN(1,FILE='CONTOUR.PAR',STATUS='OLD')
      NPOINTS=1
   20 READ(1,*,END=22) X(NPOINTS),Y(NPOINTS),Z(NPOINTS)
      NPOINTS=NPOINTS+1
      GO TO 20
```

```
 22  CLOSE(1,STATUS='KEEP')
     NPOINTS=NPOINTS-1
     WRITE(*,*) 'NUMBER OF POINTS=',NPOINTS
     CLOSE(1,STATUS='KEEP')
C OPEN OUTPUT FILE AND WRITE INFORMATION

     OPEN(1,FILE=FILEOUT, STATUS='UNKNOWN')
     WRITE(1,1000)

1000 FORMAT(2X,' ******************** GWMODF2 ********************'
    !/,2X,' * ORIGINAL FORTRAN VERSION WRITTEN FEB 10 1988      *'
    !/,2X,' * REVISED FORTRAN VERSION WRITTEN APRIL 10 1991     *'
    !/,2X ' * DATE OF LAST PROGRAM MODIFICATION 04/10/91        *'
    !/,2X,' * This program uses equation 4.25, 4.31 and 4.37    *'
    !/,2X,' * in Till and Meyer for a source at 0,0,Zs          *'
    !/,2X,' * in an aquifer of infinite lateral extent          *'
    !/,2X,' * and finite thickness and constant pore velocity *'
    !/,2X,' * A. S. ROOD  EG&G IDAHO                            *'
    !/,2X,' ****************************************************')

     WRITE(1,*)
     WRITE(1,*) '    TITLE: ',TITLE
     WRITE(1,*) '    FILE NAME: ',FILEOUT
     WRITE(1,*)
     WRITE(1,44)
 44  FORMAT(3X,'--------------- CONTOUR PLOT --------------',
    !/,4X,'X (m)',5X,'Y (m)',5X,'CONC (amount/m3 x factor)')

C  READ GROUND WATER RELEASE DATA INTO ARRAY FOR INPUT INTO LINT
C  FOR TIME VARIANT RELEASES

     IF(TYPE.EQ.1) THEN
     WRITE(*,*) 'TIME VARIANT RELEASE'
      CALL TINPUT(TS)
     WRITE(*,*) 'TIME OF CONTOURING  (years) =   ',TEND

     ELSE
     WRITE(*,*) 'IMPULSE RELEASE SELECTED'

     ENDIF

C ********************* IMPULSE RELEASE ROUTINE ********************

     IF(TYPE.EQ.0) THEN
     DO 120,J=1,NPOINTS

      TI=TEND*3.1536E7
      XD=X(J)
      YD=Y(J)
      ZD=Z(J)

      IF(SOURCE.EQ.0) THEN
      CALL POINT(TI,QIMP,GWCON,XD,YD,ZD)
      ENDIF
      IF(SOURCE.EQ.1) THEN
      CALL AREA(TI,QIMP,GWCON,XD,YD,ZD)
      ENDIF
      IF(SOURCE.EQ.2) THEN
      CALL LINE(TI,QIMP,GWCON,XD,YD,ZD)
      ENDIF

C SCALE RELEASE DATA

     GWCON=GWCON*FACTOR

C  OUTPUT DATA TO CONTOUR.DAT

     IF(MODE.EQ.2) THEN
       WRITE(*,145) X(J),Y(J),GWCON
       WRITE(1,145) X(J),Y(J),GWCON
     ELSE
     ZDOWN=-1*Z(J)
C  CALCULATE X DISTANCE FOR SLICE CONTOUR PLOT
         IF(Y(J).LE.0.0) THEN
         XLINE=X(J)
         ELSE
         XLINE=X(J)/COS(ATAN(X(J)/Y(J)))
         ENDIF
         WRITE(*,145) XLINE,ZDOWN,GWCON
         WRITE(1,145) XLINE,ZDOWN,GWCON
     ENDIF
```

```
C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      XDMAX=X(J)
      YDMAX=Y(J)
      ZDMAX=Z(J)
      ENDIF

  120 CONTINUE

      ELSE

C ******************** TIME VARIENT RELEASE ROUTINE ****************

      DO 110,J=1,NPOINTS

       XD=X(J)
       YD=Y(J)
       ZD=Z(J)
       GWCON=0.0
      CALL SIMPSON(XD,YD,ZD,TEND,GWCON,TS)

C SCALE RELEASE DATA

      GWCON=GWCON*FACTOR

C  OUTPUT DATA TO OUTPUT FILE

      IF(MODE.EQ.2) THEN
        WRITE(*,145) X(J),Y(J),GWCON
        WRITE(1,145) X(J),Y(J),GWCON
      ELSE
      ZDOWN=-1*Z(J)
C  CALCULATE X DISTANCE FOR SLICE CONTOUR PLOT
          IF(Y(J).LE.0.0) THEN
          XLINE=X(J)
          ELSE
          XLINE=X(J)/COS(ATAN(X(J)/Y(J)))
          ENDIF
          WRITE(*,145) XLINE,ZDOWN,GWCON
          WRITE(1,145) XLINE,ZDOWN,GWCON
  145 FORMAT(3X,1PE10.3,1X,1PE10.3,1X,1PE9.2)
      ENDIF

C CHECK FOR MAX VALUE OF GWCON

      IF(GWCON.GT.GWMAX)THEN
      GWMAX=GWCON
      XDMAX=X(J)
      YDMAX=Y(J)
      ZDMAX=Z(J)
      ENDIF

 110  CONTINUE

      ENDIF

 165  WRITE(1,*) '    DATE ',DDATE
      WRITE(1,*) '    TIME ',TTIME
      WRITE(1,7) SOURCE,JAVG,TYPE,PHI,DLR(1),DLR(2),DLR(3),DLR(4)
     ! ,DLR(5),DLR(6),AX,AY,AZ,AL,WA,QIMP,
     ! RD(1),RD(2),RD(3),RD(4),RD(5),RD(6),VX,JSPEC,THICK,
     ! DEPTH,TEND,FACTOR,JMAX,ARB,EPS

C WRITE TIME AND LOCATION OF MAX CONC

      WRITE(1,8) GWMAX,XDMAX,YDMAX,ZDMAX

    8 FORMAT(2X,'MAXIMUM CONCENTRATION WAS ', 1PE11.4
     !/,2X,'THE X,Y,Z COORDINATES WERE ',1PE11.4,1X,1PE11.4,1X,1PE11.4)

       IF(TYPE.EQ.1.)THEN
       CALL GWOUT
       ENDIF

      CLOSE(1,STATUS='KEEP')
      RETURN
      END
```

```
      SUBROUTINE SIMPSON(XD,YD,ZD,TIME,GWCON,TS)
C *****************************************************
C *    SUBROUTINE SIMPSON                             *
C *****************************************************
C UNITS: XD YD ZD in meters TIME in years GWCON in g/m3 x FACTOR
C        TS in years
       IMPLICIT REAL*8(A-H,O-Z)

C COMMON STATEMENTS

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG
      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      PARAMETER (NSPEC=6)
      DIMENSION DLR(NSPEC),RD(NSPEC)

C INITIALIZE GWCON VARIABLES CONVERT TIME TO SECONDS IF TIME=0.0 RETURN
C TO START
        IF(TIME.EQ.0) THEN
        GWCON=0.0
        RETURN
        ENDIF
        TI=TIME*3.1536E7

C DETERMINE LIMITS FOR INTEGRATION
C T1= LOWER LIMIT T2 = UPPER LIMIT
C INTEGRATION LIMITS ARE SELECTED BY CODELL'S METHOD.  THE LIMITS ARE
C BASED ON THE VALUE OF ARB WHEN EXP(-ARB) APPROACHES ZERO.  DEPENDING
C ON THE MACHINE USED, ARB MAY BE -50 TO -200
C XC1 AND XC2 = THE X DISTANCE USED IN CALCULATION OF THE INTEGRATION LIMITS.
C XC1=XC2=XD IF A POINT OR LINE SOURCE GEOMETRY IS SELECTED.  XC1=XD+AL/2 AND
C XC2=XD-AL/2 IF HORZ AREA SOURCE IS SELECTED. THE TEMP VARIABLES STORE THE
C INTERMEDIATE VALUES

      DX=ABS(AX*VX)

      IF(SOURCE.EQ.1.)THEN
            XC1=XD+AL/2
            XC2=XD-AL/2
      ELSE
          XC1=XD
          XC2=XD
      ENDIF

C  TEMP 1 CORRECTED 11/29/90

      TEMP1=(2*VX*XC1/RD(JSPEC)+4*DX*ARB/RD(JSPEC))/((VX/RD(JSPEC))**2
     !+4*DX*DLR(JSPEC)/RD(JSPEC))

      TEMP2=TEMP1**2 - (2*XC2)**2/((VX/RD(JSPEC))**2
     !+4*DX*DLR(JSPEC)/RD(JSPEC))

C IF TEMP2 IS LESS THAN ZERO THEN DO NOT PROCEED WITH INTEGRATION

      IF(TEMP2.LE.0.0)THEN
      GWCON=0
      RETURN
      ENDIF

      TEMP3=(2*VX*XC2/RD(JSPEC)+4
     !*DX*ARB/RD(JSPEC))/((VX/RD(JSPEC))**2
     !+4*DX*DLR(JSPEC)/RD(JSPEC))

      T2=TI-(TEMP3-SQRT(TEMP2))/2

      T1=TI-(TEMP1+SQRT(TEMP2))/2

C CONDITIONAL STATEMENTS
C     IF THE UPPER LIMIT IS EQ TO 0 THEN GWCON EQ 0
       IF(T2.LE.0.) THEN
        GWCON=0.0
        RETURN
      ENDIF
C     CHECK LOWER LIMIT OF INTEGRATION TO MAKE SURE IS NOT LESS THAN 0
      IF(T1.LE.0.) THEN
       T1=0.0
      ENDIF
C     CHECK TO SEE IF UPPER LIMIT IS GREATER THAN DESIERD TIME
      IF(T2.GE.TI) THEN
       T2=TI
```

```
      ENDIF
C     CHECK TO SEE IF UPPER LIMIT IS GREATER SOURCE INPUT TIME (in years)
      IF(T2.GE.TS*3.1536E7) THEN
       T2=TS*3.15E+07
      ENDIF
C     CHECK TO SEE IF T1 IS GREATER THAN T2
      IF(T1.GE.T2) THEN
       GWCON=0.0
       RETURN
      ENDIF

C INTEGRATION IS NOW PERFORMED BY SIMPSONS RULE.  ROUTINE IS ADAPTED FROM
C CODELL'S GRDFLX WITH AN ADDITIONAL ROUTINE TO CHECK FOR CONVERGENCE
C VARIABLE OST IS A DUMMY VARIABLE THAT IS USED TO CHECK
C THE ACCURACY OF THE SOLUTION.
C JFLAG IS USED TO START THE INITIAL STEPS

C INITIALIZE VARIABLES

      ST=0.
      GWCON=0.0
      OST=-1.0E38
      JFLAG=1

         DO 11,J=1,JMAX
      CALL TRAPZD(XD,YD,ZD,T1,T2,ST,TI,JFLAG)

C check for convergance

         IF(ABS(ST-OST).LE.EPS*ABS(ST)) THEN
         GWCON=ST
         RETURN
         ENDIF
         OST=ST

  11  CONTINUE
c gwcon given the last value of s
      gwcon=ST
      WRITE(*,*) 'Convergence not Achievied'
  999 RETURN
      END


      SUBROUTINE TRAPZD(XD,YD,ZD,A,B,C,T2,JFLAG)
      IMPLICIT REAL*8(A-H,O-Z)
C ****************************************************************
C *    SUBROUTINE TRAPZD                                          *
C ****************************************************************
C UNITS:XD YD ZD in meters C in g/m3
C       A  B  T2 in seconds

C This subroutine has been adapted from Codell's GRDFLX. Instead
C of Function FUN,  subroutines POINT AREA or LINE are called.
C In addition, the source mass is determined prior to the call statements
C The variable TYEAR is the time of pulse release converted to years for the
C interpolation routine.  F is the temporary storage variable and the conc.
C is returned in the variable C.  N1 is the number of division to be used
C in integration. Integration limits are set to T3 and T9 on each call



      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      PARAMETER(NSPEC=6)
      DIMENSION  RD(NSPEC),DLR(NSPEC)
      T3=A
      T9=B
      C=0.

      IF(JFLAG.EQ.1) THEN
           N1=JSTART
           D1=(T9-T3)
           JFLAG=2
      ENDIF
      T10=T3
      D3=D1/6/FLOAT(N1)
      TYEAR=T3/3.1536E7
```

```
      T4=T2-T3+1.0E-10*3.1536E+07

C FIRST CALL OF FUN
      CALL LINT(TYEAR,Q)
      IF(SOURCE.EQ.0) THEN
        CALL POINT(T4,Q,F3,XD,YD,ZD)
      ENDIF
      IF(SOURCE.EQ.1.) THEN
        CALL AREA(T4,Q,F3,XD,YD,ZD)
      ENDIF
      IF(SOURCE.EQ.2.) THEN
        CALL LINE(T4,Q,F3,XD,YD,ZD)
      ENDIF

 9    DO 11,N2=1,N1
         F1=F3
         T3=T10+(FLOAT(N2)-0.5)/FLOAT(N1)*D1
         TYEAR=T3/3.1536E7
         T4=T2-T3+1.0E-10*3.1536E7

         CALL LINT(TYEAR,Q)
         IF(SOURCE.EQ.0) THEN
           CALL POINT(T4,Q,F2,XD,YD,ZD)
         ENDIF
         IF(SOURCE.EQ.1.) THEN
           CALL AREA(T4,Q,F2,XD,YD,ZD)
         ENDIF
         IF(SOURCE.EQ.2.) THEN
           CALL LINE(T4,Q,F2,XD,YD,ZD)
         ENDIF

         T3=T10+FLOAT(N2)/FLOAT(N1)*D1
         TYEAR=T3/3.1536E7
         T4=T2-T3+1.0E-10*3.1536E7

         CALL LINT(TYEAR,Q)
         IF(SOURCE.EQ.0) THEN
          CALL POINT(T4,Q,F3,XD,YD,ZD)
         ENDIF
         IF(SOURCE.EQ.1.) THEN
          CALL AREA(T4,Q,F3,XD,YD,ZD)
         ENDIF
         IF(SOURCE.EQ.2.) THEN
          CALL LINE(T4,Q,F3,XD,YD,ZD)
         ENDIF

         D4=(F1+4*F2+F3)*D3
         C=C+D4

 11   CONTINUE
        N1=N1*2
        RETURN
        END

C ***********************************************
C *   SUBROUTINE LINT                           *
C ***********************************************
      SUBROUTINE LINT(X,Y)
C UNITS:X in years Y in g/s
c
c  subroutine for linear interpolation
c
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (NSPEC=6)

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /SOURCE/ ATIME,QREL,NP
      DIMENSION ATIME(2000),QREL(2000,NSPEC),DLR(NSPEC),RD(NSPEC)
      N=NP
      KLO=1
      KHI=N
1     IF (KHI-KLO.GT.1) THEN
        K=(KHI+KLO)/2
        IF(ATIME(K).GT.X)THEN
          KHI=K
        ELSE
          KLO=K
        ENDIF
```

```
      GOTO 1
      ENDIF
      H=ATIME(KHI)-ATIME(KLO)
      IF (H.EQ.0.) PAUSE 'Bad XA input.'
      y = QREL(klo,JSPEC)+(x-ATIME(klo))/h * (QREL(khi,JSPEC)-
     ! QREL(KLO,JSPEC))
      RETURN
      END

C ********************************
C *  SUBROUTINE POINT            *
C ********************************
      SUBROUTINE POINT(TI,Q,GWCON,XD,YD,ZD)
C UNITS:XD YD ZD in meters GWCON in g/m3/s Q in g/s TI in seconds


C This subroutine calculates the ground water concentration from a
C point source


      IMPLICIT REAL*8 (A-H,O-Z)

C COMMON STATEMENTS

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      PARAMETER(NSPEC=6)
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DX=ABS(AX*VX)
      DY=ABS(AY*VX)

C    X ARGUMENTS

      ARG=(-((XD-VX*TI/RD(JSPEC))**2)/(4*DX*TI/RD(JSPEC))-
     ! DLR(JSPEC)*TI)
      IF (ARG.LE.-300.) THEN
      ARG=-300.0
      ENDIF
      X1=EXP(ARG)/SQRT(12.68*DX*TI/RD(JSPEC))

C   Y ARGUMENTS

      ARG=(-(YD**2))/(4*DY*TI/RD(JSPEC))
      IF (ARG.LE.-300.) THEN
      ARG=-300.0
      ENDIF
      Y1=EXP(ARG)/SQRT(12.68*DY*TI/RD(JSPEC))
C   Z ARGUMENTS

C CALCULATE Z PARAMETER FOR AVG SOLUTION IF JAVG=0

      IF(JAVG.EQ.1)THEN
      CALL Z1ARG(Z1,ZD,TI)
      ELSE
      Z1=1/THICK
      ZD=1*ZD
      ENDIF

      GWCON=(Q*X1*Y1*Z1)/(PHI*RD(JSPEC))
      RETURN
      END

      SUBROUTINE AREA(TI,Q,GWCON,XD,YD,ZD)
      IMPLICIT REAL*8 (A-H,O-Z)
C *********************************
C *      SUBROUTINE AREA          *
C *********************************
C UNITS:XD YD ZD in meters GWCON in g/m3/s Q in g/s TI in seconds
C This subroutine calculates the ground water concentration for an area source

C COMMON STATEMENTS

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG
      PARAMETER(NSPEC=6)
```

```
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DX=ABS(AX*VX)
      DY=ABS(AY*VX)

C   X ARGUMENTS

      ARG1=((XD+AL/2)-VX*TI/RD(JSPEC))/SQRT(4*DX*TI/RD(JSPEC))
      ARG2=((XD-AL/2)-VX*TI/RD(JSPEC))/SQRT(4*DX*TI/RD(JSPEC))

      IF(ARG1.GE.25.) THEN
      ARG1=1.0
      ELSE
      IF(ARG1.LE.-25.) THEN
      ARG1=-1.0
      ELSE
      CALL ERRORD(ARG1,ERX)
      ARG1=ERX
      ENDIF
      ENDIF

      IF(ARG2.GE.25.) THEN
      ARG2=1.0
      ELSE
      IF(ARG2.LE.-25.) THEN
      ARG2=-1.0
      ELSE
      CALL ERRORD(ARG2,ERX)
      ARG2=ERX
      ENDIF
      ENDIF

      X2=(ARG1-ARG2)*EXP(-DLR(JSPEC)*TI)/(2*AL)
C  Y ARGUMENTS

      ARG1=(WA/2+YD)/SQRT(4*DY*TI/RD(JSPEC))
      IF(ARG1.GE.25.) THEN
      ARG1=1.0
      ELSE
      IF(ARG1.LE.-25.) THEN
      ARG1=-1.0
      ELSE
      CALL ERRORD(ARG1,ERX)
      ARG1=ERX
      ENDIF
      ENDIF
      ARG2=(WA/2-YD)/SQRT(4*DY*TI/RD(JSPEC))

      IF(ARG2.GE.25.) THEN
      ARG2=1.0
      ELSE
      IF(ARG2.LE.-25.) THEN
      ARG2=-1.0
      ELSE
      CALL ERRORD(ARG2,ERX)
      ARG2=ERX
      ENDIF
      ENDIF
      Y2=(ARG1+ARG2)/(2*WA)

C CALCULATE Z PARAMETER FOR AVG SOLUTION IF JAVG=0

      IF(JAVG.EQ.1)THEN
      CALL Z1ARG(Z1,ZD,TI)
      ELSE
      Z1=1/THICK
      ZD=1*ZD
      ENDIF


C  CALCULATE GROUND WATER CONCENTRATION
      GWCON=(Q*X2*Y2*Z1)/(PHI*RD(JSPEC))
      RETURN
      END

C *******************************
C *  SUBROUTINE LINE            *
C *******************************
C UNITS:XD YD ZD in meters GWCON in g/m3/s Q in g/s TI in seconds
C This subroutine calculates the ground water concentration from a
```

```
C line source in an aquifer of infinite lateral extent and finite thickness

      SUBROUTINE LINE(TI,Q,GWCON,XD,YD,ZD)
      IMPLICIT REAL*8 (A-H,O-Z)

C COMMON STATEMENTS

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      PARAMETER(NSPEC=6)
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DX=ABS(AX*VX)
      DY=ABS(AY*VX)

C   X ARGUMENTS

      ARG=(-((XD-VX*TI/RD(JSPEC))**2)/(4*DX*TI/RD(JSPEC))-
     ! DLR(JSPEC)*TI)
      IF (ARG.LE.-300.) THEN
      ARG=-300.0
      ENDIF
      X1=EXP(ARG)/SQRT(12.68*DX*TI/RD(JSPEC))

C  Y ARGUMENTS

      ARG1=(WA/2+YD)/SQRT(4*DY*TI/RD(JSPEC))
      IF(ARG1.GE.25.) THEN
      ARG1=1.0
      ELSE
      IF(ARG1.LE.-25.) THEN
      ARG1=-1.0
      ELSE
      CALL ERRORD(ARG1,ERX)
      ARG1=ERX
      ENDIF
      ENDIF
      ARG2=(WA/2-YD)/SQRT(4*DY*TI/RD(JSPEC))
      IF(ARG2.GE.25.) THEN
      ARG2=1.0
      ELSE
      IF(ARG2.LE.-25.) THEN
      ARG2=-1.0
      ELSE
      CALL ERRORD(ARG2,ERX)
      ARG2=ERX
      ENDIF
      ENDIF
      Y2=(ARG1+ARG2)/(2*WA)

      IF(JAVG.EQ.1)THEN
      CALL Z1ARG(Z1,ZD,TI)
      ELSE
      Z1=1/THICK
      ZD=1*ZD
      ENDIF

      GWCON=(Q*X1*Y2*Z1)/(PHI*RD(JSPEC))
      RETURN
      END

C **********************
C * SUBROUTINE Z1ARG  *
C **********************
C UNITS:ZD in meters TI in seconds

C This subroutine calculates the non vertically averaged Z value

      SUBROUTINE Z1ARG(Z1,ZD,TI)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      PARAMETER(NSPEC=6)
      DIMENSION DLR(NSPEC), RD(NSPEC)

      DZ=ABS(AZ*VX)
```

```
C  Z ARGUMENTS

      M=1
      ZARG=0.0

C  ADDED CODE TO REMOVE POSSIBILTY OF NEGATIVE RELEASES  11/23/88

      if(zd.lt.0.0) then
      write(*,*) 'desired concentration depth is invalid'
      pause
      ENDIF

C MAXIMUM NUMBER OF TERMS ALLOWED IS 100 SUCH THAT WHEN M=100, EXP(ARG)=0
C NUMBER OF TERMS EXPANDED 10-23-90

   55 ARG=(-(M**2)*9.869*DZ*TI)/(RD(JSPEC)*THICK**2)
      IF(M.GE.100.)THEN
      ARG=-10000
      ENDIF
      IF (ARG.GE.-300.) THEN
      ZARG=ZARG+EXP(ARG)*COS(M*3.14152*DEPTH/THICK)*
     !COS(M*3.14152*ZD/THICK)
      M=M+1
      GO TO 55
      ELSE
      Z1=(1+2*ZARG)/THICK
      ENDIF
      RETURN
      END


      SUBROUTINE ERRORD(X,ERX)
C **********************************************
C *       SUBROUTINE ERRORD                    *
C **********************************************
C  This subroutine calculates the error function for an argument, X
C  Adapted from Press et al, Numerical RECIPES: modified by A. Rood for
C  use with double precision variables
C
      IMPLICIT REAL*8 (A-H,O-Z)
      ERX =ERF(X)
      END
C
C ****************************************************************
C
      REAL*8 FUNCTION ERF(X)
      IMPLICIT REAL*8 (A-H,O-Z)
      A=0.50
      IF(X.LT.0.)THEN
          ERF=-GAMMP(A,X**2)
      ELSE
          ERF=GAMMP(A,X**2)
      ENDIF
      RETURN
      END
C
C *****************************************************************
C
      REAL*8 FUNCTION GAMMP(A,X)
      IMPLICIT REAL*8 (A-H,O-Z)
      IF (X.LT.0..OR.A.LE.0.)PAUSE
      IF(X.LT.A+1.)THEN
         CALL GSER(GAMSER,A,X,GLN)
         GAMMP=GAMSER
      ELSE
C      WRITE(*,*) 'A, X, GLN ',A,X,GLN
         CALL GCF(GAMMCF,A,X,GLN)
         GAMMP=1.-GAMMCF
      ENDIF
      RETURN
      END
C
C******************************************************************
C
      SUBROUTINE GSER(GAMSER,A,X,GLN)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (ITMAX=100,EPS=3.E-3)
      GLN=GAMMLN(A)
C      WRITE(*,*) 'A=',A
      IF(X.LE.0.)THEN
        IF(X.LT.0.)PAUSE
```

```
          GAMSER=0.
          RETURN
        ENDIF
        AP=A
        SUM=1./A
        DEL=SUM
        DO 11 N=1,ITMAX
          AP=AP+1.
          DEL=DEL*X/AP
          SUM=SUM+DEL
          IF(ABS(DEL).LT.ABS(SUM)*EPS)GO TO 1
11      CONTINUE
        PAUSE 'A too large, ITMAX too small'
1       GAMSER=SUM*EXP(-X+A*LOG(X)-GLN)
        RETURN
        END
C
C *********************************************************************
C
        SUBROUTINE GCF(GAMMCF,A,X,GLN)
        IMPLICIT REAL*8 (A-H,O-Z)
        PARAMETER (ITMAX=100,EPS=3.E-7)
C        WRITE(*,*) 'GAMMCF, A, X, GLN =',GAMMCF,A,X,GLN
        GLN=GAMMLN(A)
        GOLD=0.
        A0=1.
        A1=X
        B0=0.
        B1=1.
        FAC=1.
        DO 11 N=1,ITMAX
          AN=FLOAT(N)
          ANA=AN-A
          A0=(A1+A0*ANA)*FAC
          B0=(B1+B0*ANA)*FAC
          ANF=AN*FAC
          A1=X*A0+ANF*A1
          B1=X*B0+ANF*B1
          IF(A1.NE.0.)THEN
            FAC=1./A1
            G=B1*FAC
            IF(ABS((G-GOLD)/G).LT.EPS)GO TO 1
            GOLD=G
          ENDIF
11      CONTINUE
        PAUSE 'A too large, ITMAX too small'
1       GAMMCF=EXP(-X+A*ALOG(X)-GLN)*G
        RETURN
        END
C
        REAL*8 FUNCTION GAMMLN(XX)
C *******************************************
C *          FUNCTION GAMMLN                *
C *******************************************
        REAL*8 COF(6),STP,HALF,ONE,FPF,X,TMP,SER,XX
        DATA COF,STP/76.18009173D0,-86.50532033D0,24.01409822D0,
     *      -1.231739516D0,.120858003D-2,-.536382D-5,2.50662827465D0/
        DATA HALF,ONE,FPF/0.5D0,1.0D0,5.5D0/
C        WRITE(*,*) 'XX=',XX
        X=XX-ONE
C        WRITE(*,*) 'X=',X
        TMP=X+FPF
        TMP=(X+HALF)*LOG(TMP)-TMP
        SER=ONE
        DO 11 J=1,6
          X=X+ONE
C           WRITE(*,*) X
          SER=SER+COF(J)/X
11      CONTINUE
        GAMMLN=TMP+LOG(STP*SER)
        RETURN
        END

        SUBROUTINE TINPUT(TS)
C ************************************************
C *    SUBROUTINE TINPUT                         *
C ************************************************
C UNITS: TS in years
C This routine inputs time variant source date into array ATIME and QREL
        IMPLICIT REAL*8(A-H,O-Z)
        PARAMETER (NSPEC=6,NSTEPS=2000)
```

```
      COMMON /SOURCE/ ATIME,QREL,NP
      COMMON /CHOICE/ SOURCE,MODE,TYPE,JAVG

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      DIMENSION ATIME(NSTEPS),QREL(NSTEPS,NSPEC),RD(NSPEC),DLR(NSPEC)
      COMMON /FILES/ FILEIN,FILEOUT,TITLE
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
       NP=1
C NP IS A COUNT VARIABLE WHICH COUNTS THE NUMBER OF POINTS IN THE RELEASE FILE
      OPEN(2,FILE=FILEIN,STATUS='OLD')
  08  READ(2,*,END=09) ATIME(NP),(QREL(NP,J),J=1,NSPEC)
      NP=NP+1
      GO TO 08
  09  CLOSE(2,STATUS='KEEP')
      TS=ATIME(NP-1)
      WRITE(*,101) NP,TS
  101 FORMAT(1X,'NUMBER OF POINTS READ ',I4
     !/1X,'TOTAL TIME OF SOURCE INPUT (years)',1PE9.2)

      PAUSE
      RETURN
      END

      SUBROUTINE GWOUT
C ***********************************************
C *    SUBROUTINE GWOUT                         *
C ***********************************************

C This routine prints time variant source date into files CONTOUR or GWCON
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (NSPEC=6,NSTEPS=2000)
      COMMON /SOURCE/ ATIME,QREL,NP

      COMMON /BULK/ PHI,AX,AY,AZ,VX,QIMP,FACTOR,ARB,JMAX,
     ! TSTART,TEND,TP,RD,DLR,WA,AL,DEPTH,THICK,JSPEC,EPS,JSTART

      COMMON /FILES/FILEIN,FILEOUT,TITLE
      CHARACTER*40 FILEIN,FILEOUT
      CHARACTER*80 TITLE
      DIMENSION ATIME(NSTEPS),QREL(NSTEPS,NSPEC),RD(NSPEC),DLR(NSPEC)
      WRITE(1,*) '    RELEASE RATE INPUT FILE = ',FILEIN
      WRITE(1,99)
      DO 200 I=1,NP
      WRITE(1,100) ATIME(I),QREL(I,JSPEC)
  200 CONTINUE
  99   FORMAT(3X,'TIME (years)  RELEASE (amount/s)')
 100  FORMAT(3X,1PE10.3,6X,1PE11.4)
      RETURN
      END
```

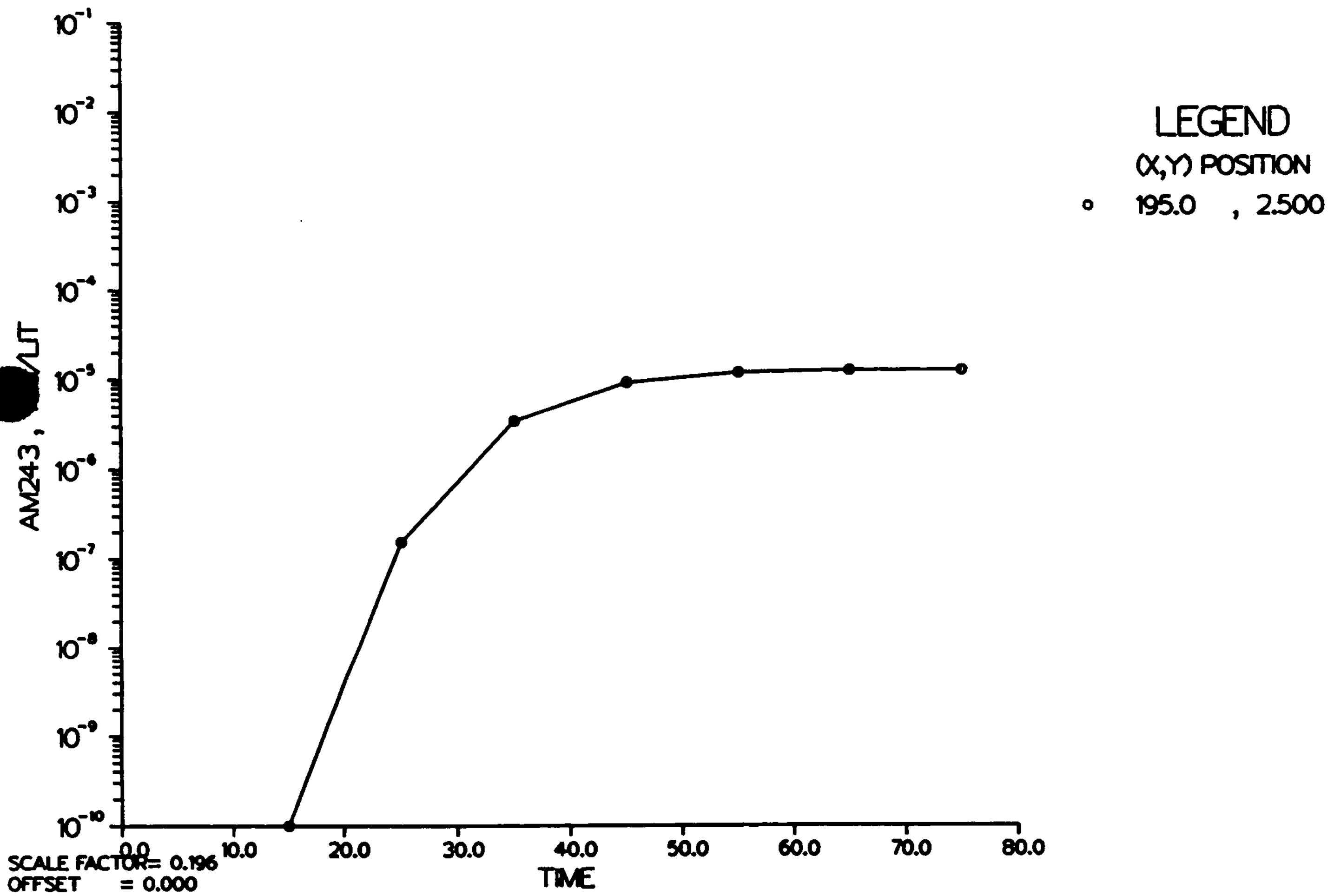
7.2.7 Validation Test Case 7 Results - One Dimensional Transport with Three Member Decay Chain

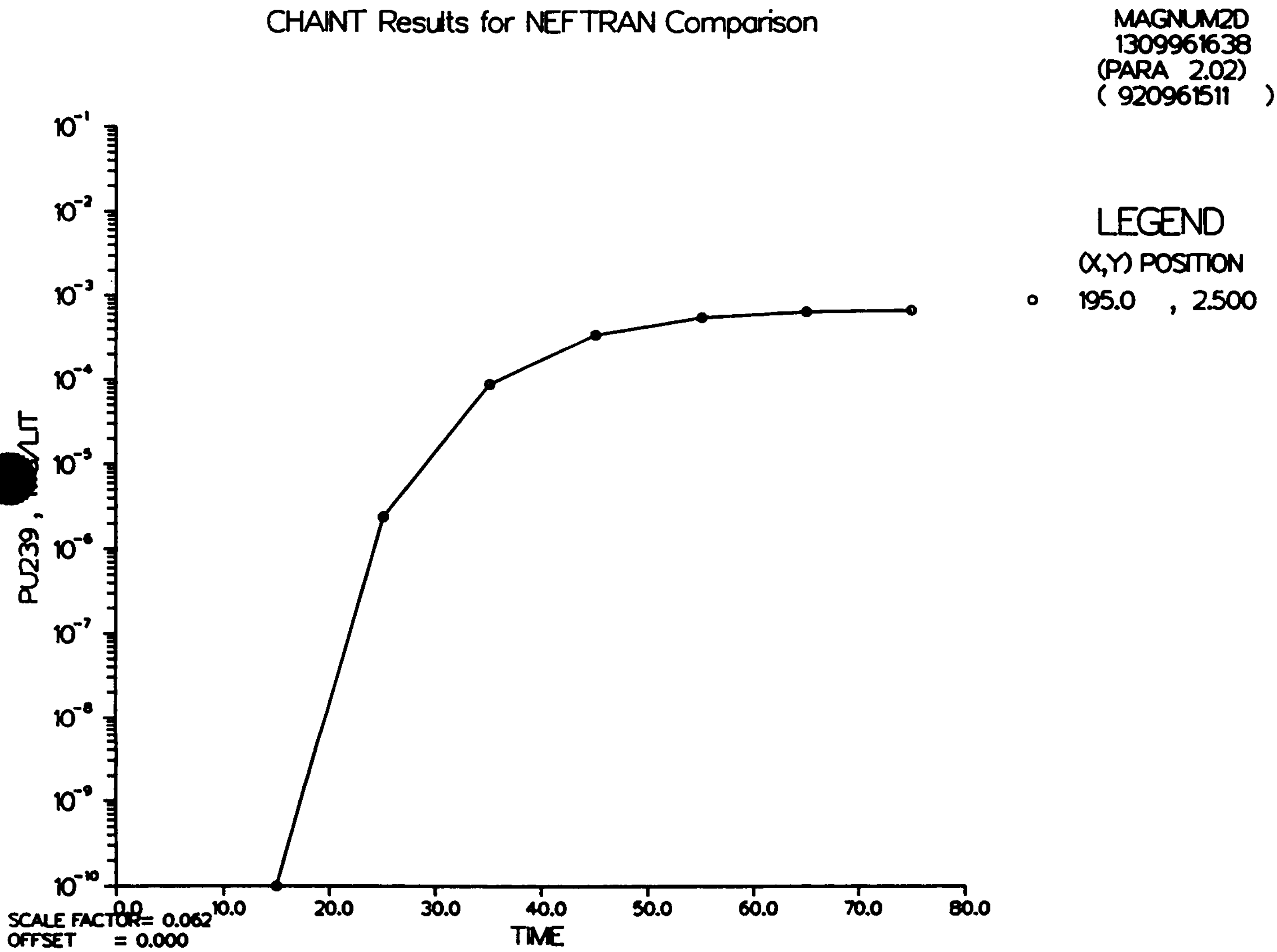
Results from CHAINT simulations of one dimensional transport with equal and unequal sorption coefficients for a three member decay chain and a constant source are presented in this section. The CHAINT results were compared to results from a one dimensional model, NEFTRAN II.

The NEFTRAN II input file and results are provided in this section. Results were plotted using SigmaPlot and are presented in this section. The results from CHAINT and from NEFTRAN II compare favorably and overlaying the figures reveals the results are consistent. The steady-state concentrations from CHAINT and NEFTRAN II match, while the CHAINT arrival times are slightly less than those for NEFTRAN II.

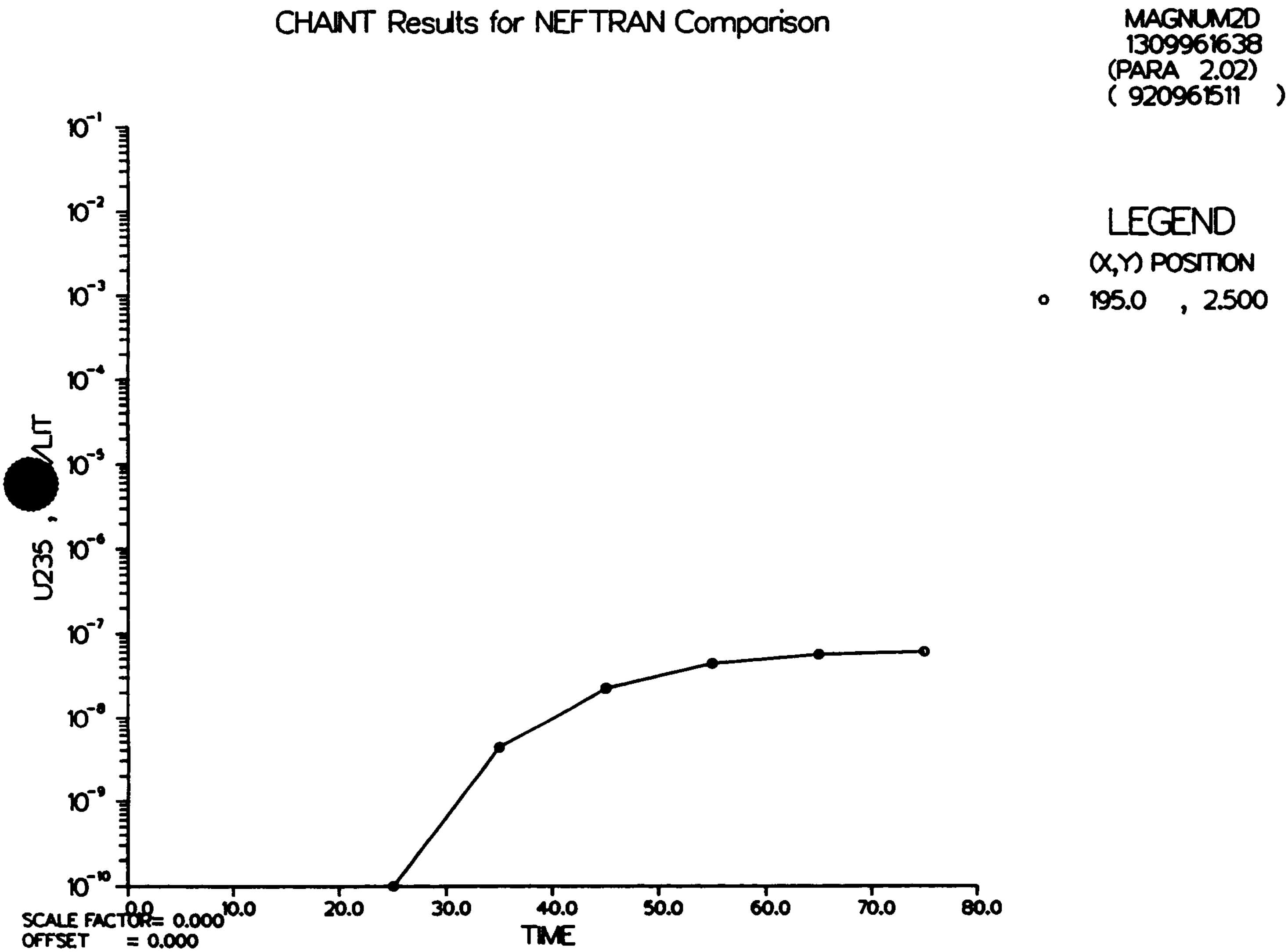
CHAINT Results for NEFTRAN Comparison

MAGNUM2D
1309961638
(PARA 2.02)
(920961511)

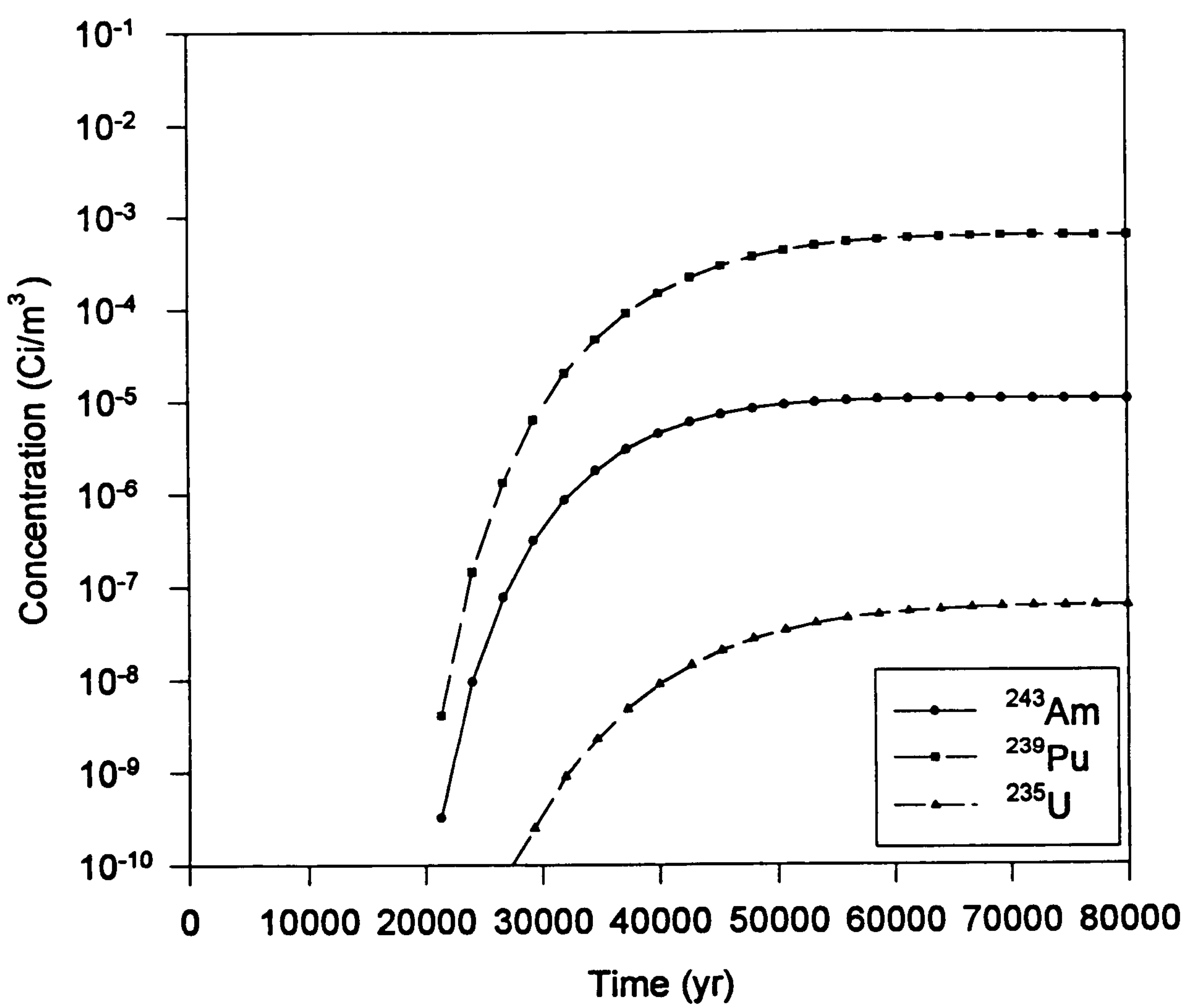



CHAINT Results for NEFTRAN Comparison
MAGNUM2D
1309961638
(PARA 2.02)
(920961511)
LEGEND
(X,Y) POSITION
195.0 , 2.500
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
PU239 ,
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
TIME
SCALE FACTOR= 0.062
OFFSET = 0.000

CHAINT Results for NEFTRAN Comparison

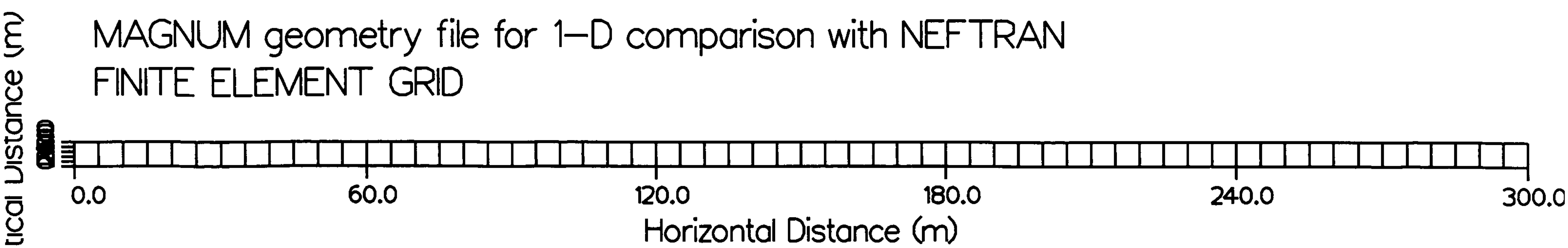


NEFTRAN Results for Three Member Decay Chain



(PLT 2.00)
(1028961021)
(0)

MAGNUM geometry file for 1-D comparison with NEFTRAN
FINITE ELEMENT GRID



60 303 0 BACA GEOMETRY MESHER 2.00

MAGNUM geometry file for 1-D comparison with NEFTRAN

1	1	4	5	6	7	8	3	2	1	1
2	5	9	10	11	12	13	7	6	1	2
3	10	14	15	16	17	18	12	11	1	3
4	15	19	20	21	22	23	17	16	1	4
5	20	24	25	26	27	28	22	21	1	5
6	25	29	30	31	32	33	27	26	1	6
7	30	34	35	36	37	38	32	31	1	7
8	35	39	40	41	42	43	37	36	1	8
9	40	44	45	46	47	48	42	41	1	9
10	45	49	50	51	52	53	47	46	1	10
11	50	54	55	56	57	58	52	51	1	11
12	55	59	60	61	62	63	57	56	1	12
13	60	64	65	66	67	68	62	61	1	13
14	65	69	70	71	72	73	67	66	1	14
15	70	74	75	76	77	78	72	71	1	15
16	75	79	80	81	82	83	77	76	1	16
17	80	84	85	86	87	88	82	81	1	17
18	85	89	90	91	92	93	87	86	1	18
19	90	94	95	96	97	98	92	91	1	19
20	95	99	100	101	102	103	97	96	1	20
21	100	104	105	106	107	108	102	101	1	21
22	105	109	110	111	112	113	107	106	1	22
23	110	114	115	116	117	118	112	111	1	23
24	115	119	120	121	122	123	117	116	1	24
25	120	124	125	126	127	128	122	121	1	25
26	125	129	130	131	132	133	127	126	1	26
27	130	134	135	136	137	138	132	131	1	27
28	135	139	140	141	142	143	137	136	1	28
29	140	144	145	146	147	148	142	141	1	29
30	145	149	150	151	152	153	147	146	1	30
31	150	154	155	156	157	158	152	151	1	31
32	155	159	160	161	162	163	157	156	1	32
33	160	164	165	166	167	168	162	161	1	33
34	165	169	170	171	172	173	167	166	1	34
35	170	174	175	176	177	178	172	171	1	35
36	175	179	180	181	182	183	177	176	1	36
37	180	184	185	186	187	188	182	181	1	37
38	185	189	190	191	192	193	187	186	1	38
39	190	194	195	196	197	198	192	191	1	39
40	195	199	200	201	202	203	197	196	1	40
41	200	204	205	206	207	208	202	201	1	41
42	205	209	210	211	212	213	207	206	1	42
43	210	214	215	216	217	218	212	211	1	43
44	215	219	220	221	222	223	217	216	1	44
45	220	224	225	226	227	228	222	221	1	45
46	225	229	230	231	232	233	227	226	1	46
47	230	234	235	236	237	238	232	231	1	47
48	235	239	240	241	242	243	237	236	1	48
49	240	244	245	246	247	248	242	241	1	49
50	245	249	250	251	252	253	247	246	1	50
51	250	254	255	256	257	258	252	251	1	51
52	255	259	260	261	262	263	257	256	1	52
53	260	264	265	266	267	268	262	261	1	53
54	265	269	270	271	272	273	267	266	1	54
55	270	274	275	276	277	278	272	271	1	55
56	275	279	280	281	282	283	277	276	1	56
57	280	284	285	286	287	288	282	281	1	57
58	285	289	290	291	292	293	287	286	1	58

59	290	294	295	296	297	298	292	291	1	59
60	295	299	300	301	302	303	297	296	1	60

1	0.000	0.000	0.00	0.00
2	0.000	2.500	0.00	0.00
3	0.000	5.000	0.00	0.00
4	2.500	0.000	0.00	0.00
5	5.000	0.000	0.00	0.00
6	5.000	2.500	0.00	0.00
7	5.000	5.000	0.00	0.00
8	2.500	5.000	0.00	0.00
9	7.500	0.000	0.00	0.00
10	10.000	0.000	0.00	0.00
11	10.000	2.500	0.00	0.00
12	10.000	5.000	0.00	0.00
13	7.500	5.000	0.00	0.00
14	12.500	0.000	0.00	0.00
15	15.000	0.000	0.00	0.00
16	15.000	2.500	0.00	0.00
17	15.000	5.000	0.00	0.00
18	12.500	5.000	0.00	0.00
19	17.500	0.000	0.00	0.00
20	20.000	0.000	0.00	0.00
21	20.000	2.500	0.00	0.00
22	20.000	5.000	0.00	0.00
23	17.500	5.000	0.00	0.00
24	22.500	0.000	0.00	0.00
25	25.000	0.000	0.00	0.00
26	25.000	2.500	0.00	0.00
27	25.000	5.000	0.00	0.00
28	22.500	5.000	0.00	0.00
29	27.500	0.000	0.00	0.00
30	30.000	0.000	0.00	0.00
31	30.000	2.500	0.00	0.00
32	30.000	5.000	0.00	0.00
33	27.500	5.000	0.00	0.00
34	32.500	0.000	0.00	0.00
35	35.000	0.000	0.00	0.00
36	35.000	2.500	0.00	0.00
37	35.000	5.000	0.00	0.00
38	32.500	5.000	0.00	0.00
39	37.500	0.000	0.00	0.00
40	40.000	0.000	0.00	0.00
41	40.000	2.500	0.00	0.00
42	40.000	5.000	0.00	0.00
43	37.500	5.000	0.00	0.00
44	42.500	0.000	0.00	0.00
45	45.000	0.000	0.00	0.00
46	45.000	2.500	0.00	0.00
47	45.000	5.000	0.00	0.00
48	42.500	5.000	0.00	0.00
49	47.500	0.000	0.00	0.00
50	50.000	0.000	0.00	0.00
51	50.000	2.500	0.00	0.00
52	50.000	5.000	0.00	0.00
53	47.500	5.000	0.00	0.00
54	52.500	0.000	0.00	0.00
55	55.000	0.000	0.00	0.00
56	55.000	2.500	0.00	0.00
57	55.000	5.000	0.00	0.00
58	52.500	5.000	0.00	0.00

59	57.500	0.000	0.00	0.00
60	60.000	0.000	0.00	0.00
61	60.000	2.500	0.00	0.00
62	60.000	5.000	0.00	0.00
63	57.500	5.000	0.00	0.00
64	62.500	0.000	0.00	0.00
65	65.000	0.000	0.00	0.00
66	65.000	2.500	0.00	0.00
67	65.000	5.000	0.00	0.00
68	62.500	5.000	0.00	0.00
69	67.500	0.000	0.00	0.00
70	70.000	0.000	0.00	0.00
71	70.000	2.500	0.00	0.00
72	70.000	5.000	0.00	0.00
73	67.500	5.000	0.00	0.00
74	72.500	0.000	0.00	0.00
75	75.000	0.000	0.00	0.00
76	75.000	2.500	0.00	0.00
77	75.000	5.000	0.00	0.00
78	72.500	5.000	0.00	0.00
79	77.500	0.000	0.00	0.00
80	80.000	0.000	0.00	0.00
81	80.000	2.500	0.00	0.00
82	80.000	5.000	0.00	0.00
83	77.500	5.000	0.00	0.00
84	82.500	0.000	0.00	0.00
85	85.000	0.000	0.00	0.00
86	85.000	2.500	0.00	0.00
87	85.000	5.000	0.00	0.00
88	82.500	5.000	0.00	0.00
89	87.500	0.000	0.00	0.00
90	90.000	0.000	0.00	0.00
91	90.000	2.500	0.00	0.00
92	90.000	5.000	0.00	0.00
93	87.500	5.000	0.00	0.00
94	92.500	0.000	0.00	0.00
95	95.000	0.000	0.00	0.00
96	95.000	2.500	0.00	0.00
97	95.000	5.000	0.00	0.00
98	92.500	5.000	0.00	0.00
99	97.500	0.000	0.00	0.00
100	100.000	0.000	0.00	0.00
101	100.000	2.500	0.00	0.00
102	100.000	5.000	0.00	0.00
103	97.500	5.000	0.00	0.00
104	102.500	0.000	0.00	0.00
105	105.000	0.000	0.00	0.00
106	105.000	2.500	0.00	0.00
107	105.000	5.000	0.00	0.00
108	102.500	5.000	0.00	0.00
109	107.500	0.000	0.00	0.00
110	110.000	0.000	0.00	0.00
111	110.000	2.500	0.00	0.00
112	110.000	5.000	0.00	0.00
113	107.500	5.000	0.00	0.00
114	112.500	0.000	0.00	0.00
115	115.000	0.000	0.00	0.00
116	115.000	2.500	0.00	0.00
117	115.000	5.000	0.00	0.00
118	112.500	5.000	0.00	0.00

119	117.500	0.000	0.00	0.00
120	120.000	0.000	0.00	0.00
121	120.000	2.500	0.00	0.00
122	120.000	5.000	0.00	0.00
123	117.500	5.000	0.00	0.00
124	122.500	0.000	0.00	0.00
125	125.000	0.000	0.00	0.00
126	125.000	2.500	0.00	0.00
127	125.000	5.000	0.00	0.00
128	122.500	5.000	0.00	0.00
129	127.500	0.000	0.00	0.00
130	130.000	0.000	0.00	0.00
131	130.000	2.500	0.00	0.00
132	130.000	5.000	0.00	0.00
133	127.500	5.000	0.00	0.00
134	132.500	0.000	0.00	0.00
135	135.000	0.000	0.00	0.00
136	135.000	2.500	0.00	0.00
137	135.000	5.000	0.00	0.00
138	132.500	5.000	0.00	0.00
139	137.500	0.000	0.00	0.00
140	140.000	0.000	0.00	0.00
141	140.000	2.500	0.00	0.00
142	140.000	5.000	0.00	0.00
143	137.500	5.000	0.00	0.00
144	142.500	0.000	0.00	0.00
145	145.000	0.000	0.00	0.00
146	145.000	2.500	0.00	0.00
147	145.000	5.000	0.00	0.00
148	142.500	5.000	0.00	0.00
149	147.500	0.000	0.00	0.00
150	150.000	0.000	0.00	0.00
151	150.000	2.500	0.00	0.00
152	150.000	5.000	0.00	0.00
153	147.500	5.000	0.00	0.00
154	152.500	0.000	0.00	0.00
155	155.000	0.000	0.00	0.00
156	155.000	2.500	0.00	0.00
157	155.000	5.000	0.00	0.00
158	152.500	5.000	0.00	0.00
159	157.500	0.000	0.00	0.00
160	160.000	0.000	0.00	0.00
161	160.000	2.500	0.00	0.00
162	160.000	5.000	0.00	0.00
163	157.500	5.000	0.00	0.00
164	162.500	0.000	0.00	0.00
165	165.000	0.000	0.00	0.00
166	165.000	2.500	0.00	0.00
167	165.000	5.000	0.00	0.00
168	162.500	5.000	0.00	0.00
169	167.500	0.000	0.00	0.00
170	170.000	0.000	0.00	0.00
171	170.000	2.500	0.00	0.00
172	170.000	5.000	0.00	0.00
173	167.500	5.000	0.00	0.00
[illegible]	172.500	0.000	0.00	0.00
175	175.000	0.000	0.00	0.00
176	175.000	2.500	0.00	0.00
177	175.000	5.000	0.00	0.00
178	172.500	5.000	0.00	0.00

179	177.500	0.000	0.00	0.00
180	180.000	0.000	0.00	0.00
181	180.000	2.500	0.00	0.00
182	180.000	5.000	0.00	0.00
183	177.500	5.000	0.00	0.00
184	182.500	0.000	0.00	0.00
185	185.000	0.000	0.00	0.00
186	185.000	2.500	0.00	0.00
187	185.000	5.000	0.00	0.00
188	182.500	5.000	0.00	0.00
189	187.500	0.000	0.00	0.00
190	190.000	0.000	0.00	0.00
191	190.000	2.500	0.00	0.00
192	190.000	5.000	0.00	0.00
193	187.500	5.000	0.00	0.00
194	192.500	0.000	0.00	0.00
195	195.000	0.000	0.00	0.00
196	195.000	2.500	0.00	0.00
197	195.000	5.000	0.00	0.00
198	192.500	5.000	0.00	0.00
199	197.500	0.000	0.00	0.00
200	200.000	0.000	0.00	0.00
201	200.000	2.500	0.00	0.00
202	200.000	5.000	0.00	0.00
203	197.500	5.000	0.00	0.00
204	202.500	0.000	0.00	0.00
205	205.000	0.000	0.00	0.00
206	205.000	2.500	0.00	0.00
207	205.000	5.000	0.00	0.00
208	202.500	5.000	0.00	0.00
209	207.500	0.000	0.00	0.00
210	210.000	0.000	0.00	0.00
211	210.000	2.500	0.00	0.00
212	210.000	5.000	0.00	0.00
213	207.500	5.000	0.00	0.00
214	212.500	0.000	0.00	0.00
215	215.000	0.000	0.00	0.00
216	215.000	2.500	0.00	0.00
217	215.000	5.000	0.00	0.00
218	212.500	5.000	0.00	0.00
219	217.500	0.000	0.00	0.00
220	220.000	0.000	0.00	0.00
221	220.000	2.500	0.00	0.00
222	220.000	5.000	0.00	0.00
223	217.500	5.000	0.00	0.00
224	222.500	0.000	0.00	0.00
225	225.000	0.000	0.00	0.00
226	225.000	2.500	0.00	0.00
227	225.000	5.000	0.00	0.00
228	222.500	5.000	0.00	0.00
229	227.500	0.000	0.00	0.00
230	230.000	0.000	0.00	0.00
231	230.000	2.500	0.00	0.00
232	230.000	5.000	0.00	0.00
233	227.500	5.000	0.00	0.00
234	232.500	0.000	0.00	0.00
235	235.000	0.000	0.00	0.00
236	235.000	2.500	0.00	0.00
237	235.000	5.000	0.00	0.00
238	232.500	5.000	0.00	0.00

239	237.500	0.000	0.00	0.00
240	240.000	0.000	0.00	0.00
241	240.000	2.500	0.00	0.00
242	240.000	5.000	0.00	0.00
[illegible]	237.500	5.000	0.00	0.00
244	242.500	0.000	0.00	0.00
245	245.000	0.000	0.00	0.00
246	245.000	2.500	0.00	0.00
247	245.000	5.000	0.00	0.00
248	242.500	5.000	0.00	0.00
249	247.500	0.000	0.00	0.00
250	250.000	0.000	0.00	0.00
251	250.000	2.500	0.00	0.00
252	250.000	5.000	0.00	0.00
253	247.500	5.000	0.00	0.00
254	252.500	0.000	0.00	0.00
255	255.000	0.000	0.00	0.00
256	255.000	2.500	0.00	0.00
257	255.000	5.000	0.00	0.00
258	252.500	5.000	0.00	0.00
259	257.500	0.000	0.00	0.00
260	260.000	0.000	0.00	0.00
261	260.000	2.500	0.00	0.00
262	260.000	5.000	0.00	0.00
263	257.500	5.000	0.00	0.00
264	262.500	0.000	0.00	0.00
265	265.000	0.000	0.00	0.00
266	265.000	2.500	0.00	0.00
267	265.000	5.000	0.00	0.00
[illegible]	262.500	5.000	0.00	0.00
[illegible]	267.500	0.000	0.00	0.00
270	270.000	0.000	0.00	0.00
271	270.000	2.500	0.00	0.00
272	270.000	5.000	0.00	0.00
273	267.500	5.000	0.00	0.00
274	272.500	0.000	0.00	0.00
275	275.000	0.000	0.00	0.00
276	275.000	2.500	0.00	0.00
277	275.000	5.000	0.00	0.00
278	272.500	5.000	0.00	0.00
279	277.500	0.000	0.00	0.00
280	280.000	0.000	0.00	0.00
281	280.000	2.500	0.00	0.00
282	280.000	5.000	0.00	0.00
283	277.500	5.000	0.00	0.00
284	282.500	0.000	0.00	0.00
285	285.000	0.000	0.00	0.00
286	285.000	2.500	0.00	0.00
287	285.000	5.000	0.00	0.00
288	282.500	5.000	0.00	0.00
289	287.500	0.000	0.00	0.00
290	290.000	0.000	0.00	0.00
291	290.000	2.500	0.00	0.00
292	290.000	5.000	0.00	0.00
293	287.500	5.000	0.00	0.00
[illegible]	292.500	0.000	0.00	0.00
295	295.000	0.000	0.00	0.00
296	295.000	2.500	0.00	0.00
297	295.000	5.000	0.00	0.00
298	292.500	5.000	0.00	0.00

299	297.500	0.000	0.00	0.00
300	300.000	0.000	0.00	0.00
301	300.000	2.500	0.00	0.00
302	300.000	5.000	0.00	0.00
303	297.500	5.000	0.00	0.00

```
MAGNUM - 1-D Test case for comparison with NEFTRAN
# imode itemp imoist  np    ne   nmat icnd iech  iall ivelp iprt nsys
    1     0      1   303    60     1    0    0     0    1     1    0
#  irs  isv  icf  igi  ig  ivel inpt icsv
    0   13    0   10    0   12    0    0
#  ssf   alfa  tref
   0.0    1.8   20.0
#  nts  ntsg   dlt
    1    1      1000.
 9999    1      1000.
#  scalex  scaley  zonel  zoner  zonet  zoneb
    1.0     1.0     0.0    0.0    0.0    0.0
#   n       To       Ho
    1    20.000    0.5327
#  kspec
     6
#        n     n1 n2  Tbc      Hbc
       300         0   1   20.0000    0.0000
       301         0   1   20.0000    0.0000
       302         0   1   20.0000    0.0000
         3         0   1   20.0000    1.0654
         2         0   1   20.0000    1.0654
         1         0   1   20.0000    1.0654
      #   L     cvm     tkk(1)  tkk(2)  poros     hkax           hkay         nme
#        sp1       rhom    alpal   alpat    width
         1          0          0          0       0.07     5.0e-6     5.0e-6    mat1
    1.0e-6      2400          0          0          0
#  nld  nlt  scf
    0    0       0.0
```

```
CHAINT 1-D Test case (decay chain) for NEFTRAN comparison
#  nqal    ne      np   nent  nmat  iecho  isko  nvel  ncflx  nsys  nsums
   3      60     303    3     1      0      2     3     0      0     0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
 [illegible]  11    0    0   14   15    0
#  ssf  alfa  xscale  yscale  uscale  vscale
   0.  1.8    0.      0.      0.      0.
#  nts  ntsg   dlt    zonel  zoner  zonet  zoneb
   500 500     .2      0.      0.     0.     0.
   900 900    1.0      0.      0.     0.     0.
   800 800    5.0      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
   500 500    20.      0.      0.     0.     0.
  9999   0     0       0       0      0      0
#   j    ort(j,1)  ort(j,2)  rod(j,1)  por(j,1)  width(j)  nme(j)
    1      5.0       0.0      2400.      0.07      0.       mat1
#  islt
 1 1 1
#   L   amu     diag     isu(1)   frac(1)   isu(2)   frac(2)  cnam   eps
    1 243.0   7.593E+3     2        1.0       0        0.0    AM243   0.0
    2 239.0   2.44E+4      3        1.0       0        0.0    PU239   0.0
    3 235.0   7.10E+8      0        0.0       0        0.0     U235   0.0
#   i    dml(i,1..n2)  m2/yr
    1    0.0
    2    0.0
    3    0.0
#   i    xkdi(i,1..n2)  ml/g
    1   58.304167
    2   58.304167
    3   58.304167
#  lk     Ci
    1     0.0
    2     0.0
    3     0.0
#   L     bcs
    1     3.57e-3  3.57e-2  3.57e-4
    2     3.57e-3  3.57e-2  3.57e-4
    3     3.57e-3  3.57e-2  3.57e-4
#   nld   scf   relz
     0    1.0    0.
```

```
AREA & PATH #S  1, 120  INFIL. =  0.0  MASS FRC.=  1.0E+00
    GROUP 1 - OPTIONS, STANDARD PRINT, 0=NO PRINT
   1      LIST IF ALL THE  PARAMETERS
   1      THE NETWORK LEG PROPERTIES
[illegible] THE NETWORK JUNCTION PROPERTIES
   1      THE MIGRATION PATH PROPERTIES ARRAY
   1      THE DECAY CHAIN PROPERTIES ARRAY
   1      THE ELEMENT PROPERTIES ARRRAY
   1      FLUID VELOCITIES & SOURCE/DISCH FLOWS
   1      SUBCHAINS, PRODUCTION & VELOCITIES
   1      SPACE & TIME STEPS AND SOURCE TYPE
  -1      TIME INDEPENDENT OUTPUT, IF +-N, RATES/CONCS EVERY NTH TIME STEP
   1      DISCHARGE SUMMARY
    EXTERNAL FILES, NONZERO => FILE WRITTEN/READ
   1      SRATE.DAT, SOURCE RATES (CI/Y) - WRITTEN TO UNIT 25
   1      DRATE.DAT, DISCHARGE RATES (CI/Y) - WRITTTEN TO UNIT 30
   1      EXTERNAL SOURCE FLAG (=1 =>READ UNIT 14)
   0      SAMP.DAT, SAMPLED DATA FOR REPEATED TRIALS - READ FROM UNIT 10
   0      VFIELD.DAT, UNIT 11, TIME-DEPENDENT VELOCITIES READ FROM
   0      SFLOW.DAT, UNIT 12, TIME-DEPENDENT SOURCE FLOW RATES READ FROM
                    RUN CONTROLS
   0      USE DVM (0) OR ANALYTIC SOLN (NONZERO)
   1      SOLVE NETWORK (0) OR INPUT VELOCITIES (NONZERO)
   0      LEACH (0), SOLUBILITIES (1), OR BOTH (2) FOR SOURCE RATES
   0      FLOWTHRU (0), MIXCELL (1), OR CHOOSE (2) FOR SOURCE RATES
   0      CONSTANT (0) OR EXPONENTIAL (1) LEACH RATE MODEL
   0      FORCE (NONZERO) USE OF LEG-TO-LEG TRANSFER ALGORITHM
                    DEBUG PRINTS, NONZERO => PRINT
   0      DVM MULTIPLIERS FOR TRANSPORT, DISCHARGE, AND SOURCE
[illegible] DIAGNOSTIC INFO FOR SUBROUTINE BAND
[illegible] DIAGNOSTIC INFO FOR FUNCTION GIT
   0      MATRIX/VECTOR SYSTEM SOLVED FOR FLOW
   0      THE DATA READ FROM UNIT 10, SAMP.DAT
   1      CONC. FLAG (=1 => WRITE TO UNIT 29 IN CI/M**3)
   0      INVENTORY AT RELEASE TIME
   0      RESTRICTIONS PLACED ON THE TIME STEPS
   0      LEG/JUNCTION & JUNCTION/LEG CONNECTIONS
   0      VELOCITY FIELDS FROM UNIT 11
   0      THE ATOM COUNT SUMMAARY
   0      JUNCTION PRESSURES & LEG FLOWRATES
   0      LEG-TO-LEG TRANSFER FRACTIONS
   0      TIME SPENT AS EACH ISOTOPE IN A SUBCHAIN
   0      TIME DEPENDENT FLOWRATES THROUGH SOURCE REGIME
                    GROUP 2  -  PROBLEM SIZE
   2      NUMBER OF NETWORK LEGS
   0      NUMBER OF NETWORK JUNCTIONS
   2      NUMBER OF MIGRATION PATH LEGS
   1      NUMBER OF DECAY CHAINS INPUT
   3      NUMBER OF ELEMENTS INPUT
  CHN1  CHN2  CHN3  CHN4  CHN5   - # PER CHAIN
   3
  CHN1  CHN2  CHN3  CHN4  CHN5  - TRANSPORT-0, SOURCE-1, NEITHER-2
   0
                    GROUP 3 - SOURCE/FLOW PARAMETERS
 1.0            FRACTION OF INVENTORY ACCESSED
 [illegible]0E+00   PORE VOLUME CONTAINING SOURCE (M**3) USED FOR MIXING CELL
 0.350E+00      PORE AREA OF SOURCE  (M**2)
 1.000E-05      LEACH RATE (1/Y) IF LEACH LTD
 1.000E+03      DENSITY OF SOURCE FLUID (KG/M**3)
 0.350E+00      PORE AREA AT DISCHARGE (M**2)
```

GROUP 4 - TIME PARAMETERS

8.000E+04	TIME TO END OF SIMULATION (Y)
0.000E+00	TIME OF ONSET OF MIGRATION (Y)
0.000E+00	TIME OF ONSET OF LEACHING (Y)
[illegible]0E+00	TIME STEP FOR SOURCE (Y)

CHAIN1 CHAIN2 CHAIN3 CHAIN4 CHAIN5 TIME STEPS BY CHAIN (Y)

0.0 0.0 0.0

GROUP 5 - INCREMENT DETERMNATION

0 USE DEFAULTS (0) OR SUPPLY ALL 16 VALUES

NETWORK LEG PROPERTIES ARRAY

LEG #	INLET JCT	OUTLET JCT	LENGTH (M)	AREA (M**2)	HYDRAULIC K (M/YR)	BRINE CONC.
1	1	2	5.0E+00	5.0E+00	0.0	0.0
2	2	3	1.95E+02	5.0E+00	0.0	0.0

MIGRATION PATH PROPERTIES ARRAY

LEG #	DISPERS. (M)	SPA. STEP (M)	DIFFUS N/Y=0/1	MOBILE POROS.	IMMOB POROS.	MASS XFER COEF(1/Y)	VELOCITY (M/YR)
1	5.0	0.0	0	7.0E-02	0.000E+00	0.0E+00	8.0
2	0.0	0.0	0	7.0E-02	0.000E+00	0.0E+00	8.0

DECAY CHAIN ARRAY

NAME A6	ATM# (AMU)	ELE- MENT	LOC NDX	PAR #1	PAR #2	FRAC FROM1	FRAC FROM2	INVEN (CI)	HALF LIFE (Y)	WEIGH FAC
'AM243'	243.	1	1	0	0	0.000	0.000	0.000E+00	7.593E+03	1.00
'PU239'	239.	2	2	1	0	1.000	0.000	0.000E+00	2.44E+04	1.00
'U235'	235.	3	3	2	0	1.000	0.000	0.000E+00	7.10E+08	1.00

ELEMENT PROPERTIES ARRAY

ELEM. INDEX	SOLUBILITY (KG/KG)	LEG #	MOBIL RD	IMMOBILE RD
1	0.000E+00	1	2.0E+03	0.000E+00
		2	2.0E+03	0.000E+00
2	0.000E+00	1	2.0E+03	0.000E+00
		2	2.0E+03	0.000E+00
3	0.000E+00	1	2.0E+03	0.000E+00
		2	2.0E+03	0.000E+00

```
TITLE: Release rates from SOTEC to NEFTRAN.
         1  is the cell number
         3          2  num nucs, num bins
AM243
      0.0000000   1.9572000E-03
   0000.0000000   1.9572000E-03
PU239
      0.0000000   6.1982000E-03
 100000.0000000   6.1982000E-03
U235
      0.0000000   2.1663000E-09
 100000.0000000   2.1663000E-09
```

```
Output file = nefrep.out
1

    ***********************************************************************
    *                                                                     *
    *         NEFTRAN II - VAX MKS VERSION RELEASED JANUARY 1991          *
    *                                                                     *
    *    AREA & PATH #S  1, 120  INFIL. =  0.0  MASS FRC.=  1.0E+00       *
    *             EXECUTION DATE  Sep 20   AND TIME  15:33:5              *
    *                                                                     *
    ***********************************************************************


                              PARAMETERS

                           GROUP1 - OPTIONS
                           ----------------

    STANDARD PRINT, NONZERO => PRINT
 OPTION  VALUE  OUTPUT-DESCRIPTION
    1      1    LIST OF ALL PARAMETERS
    2      1    THE NETWORK LEG PROPERTIES ARRAY
    3      1    THE NETWORK JUNCTION PROPERTIES ARRAY
    4      1    THE MIGRATION PATH PROPERTIES ARRAY
    5      1    THE DECAY CHAIN PROPERTIES ARRAY
    6      1    THE ELEMENT PROPERTIES ARRAY
    7      1    FLUID VELOCITIES & SOURCE/DISCH FLOWRATES
    8      1    SUBCHAINS- DECAY, PRODUCTION, & VELOCITIES
    9      1    SPACE & TIME STEPS AND SOURCE TYPE
 [illegible]  -1    TIME DEPENDENT OUTPUT
                  - IF +N, DISCHARGE RATES EVERY NTH TIME STEP
                  - IF -N, CONCENTRATIONS EVERY NTH TIME STEP
   11      1    DISCHARGE SUMMARY

    EXTERNAL FILES, NONZERO => FILE WRITTEN/READ
 OPTION  VALUE  CORRESPONDING FILE
   12      1    WRITE SRATE.DAT, SOURCE RATES (Ci/y)
   13      1    WRITE DRATE.DAT, DISCHARGE RATES (Ci/y)
   14      1    NOT CURRENTLY USED
   15      0    READ SAMP.DAT, SAMPLED DATA NORMALLY FOR REPEATED TRIALS
   16      0    READ VFIELD.DAT, TIME-DEPENDENT VELOCITIES
   17      0    READ SFLOW.DAT, TIME-DEPENDENT FLOWRATES

    RUN CONTROLS
 OPTION  VALUE  DESCRIPTION
   18      0    USE DVM(0) OR ANALYTIC SOLN(1)
   19      1    SOLVE NETWORK(0) OR INPUT VELOCITIES(1)
   20      0    LEACH(0), SOLUBILITIES(1), OR BOTH(2)
   21      0    FLOWTHRU(0), MIXCELL(1), OR CHOOSE(2)
   22      0    CONSTANT(0) OR EXPONENTIAL(1) LEACH RATE
   23      0    FORCE(1) USE OF LEG-TO-LEG TRANSFER ALGORITHM

    DEBUG PRINTS, NONZERO => PRINT
 OPTION  VALUE  OUTPUT-DESCRIPTION
   24      0    DVM MULTIPLIERS FOR TRANSPORT, DISCHARGE, AND SOURCE
   25      0    DIAGNOSTIC INFO FOR SUBROUTINE BAND
   26      0    DIAGNOSTIC INFO FOR FUNCTION GIT
   27      0    MATRIX/VECTOR SYSTEM TO BE SOLVED FOR FLOW
   28      0    THE DATA FROM UNIT 10, SAMP.DAT
   29      1    NOT CURRENTLY USED
```

```
  30       0   INVENTORY AT RELEASE TIME
  31       0   RESTRICTIONS PLACED ON THE TIME STEPS
  32       0   LEG/JUNCTION & JUNCTION/LEG CONNECTIONS
  33       0   VELOCITIES FROM THE EXTERNAL FILE, UNIT 11
  34       0   THE ATOM COUNT SUMMARY
  35       0   JUNCTION PRESSURES & LEG FLOWRATES
  36       0   LEG-TO-LEG TRANSFER FRACTIONS
  37       0   TIME SPENT AS EACH ISOTOPE IN A SUBCHAIN
  38       0   TIME-DEPENDENT SOURCE FLOWRATES

***WARNING*** SINCE NETWORK NOT SOLVED, OPTION 29 NOT AVAILABLE AND IS SET TO 0
Source output file = nefrep.src
Discharge output file = nefrep.dis

                        GROUP2 - PROBLEM SIZES
                        ----------------------
VALUE  DESCRIPTION
  2    NUMBER OF NETWORK LEGS
  0    NUMBER OF NETWORK JUNCTIONS
  2    NUMBER OF MIGRATION PATH LEGS
  1    NUMBER OF DECAY CHAINS INPUT
  3    NUMBER OF ELEMENTS INPUT
                             DECAY CHAINS
                          NUMBER   INCLUSION
                          MEMBERS    INDEX
                             3         0


                    GROUP3 - SOURCE/FLOW PARAMETERS
                    -------------------------------
   VALUE      DESCRIPTION
 1.0000E+00  FRACTION OF SOURCE ACCESSED
 0.0000E+00  PORE VOLUME CONTAINING SOURCE (m**3)
 3.5000E-01  PORE-AREA FOR SOURCE REGIME (m**2)
 1.0000E-05  LEACH RATE (1/y)
 1.0000E+03  DENSITY OF SOURCE FLUID (kg/m**3)
 3.5000E-01  PORE-AREA AT DISCHARGE (m**2)
***WARNING*** "PORE-AREA FOR SOURCE REGIME" NOT USED
***WARNING*** "DENSITY OF SOURCE FLUID" NOT USED

                        GROUP4 - TIME PARAMETERS
                        ------------------------
   VALUE      DESCRIPTION
 8.0000E+04  TIME TO END OF SIMULATION (y)
 0.0000E+00  TIME OF ONSET OF MIGRATION (y)
 0.0000E+00  TIME OF ONSET OF LEACHING (y)
 0.0000E+00  TIME STEP FOR SOURCE (y)
                    TRANSPORT TIME STEPS FOR EACH CHAIN
                          CHAIN#  TIME STEP(y)
                            1       0.000E+00


                    GROUP5 - INCREMENT DETERMINATION
                    --------------------------------
DEFAULT values utilized


                 Network Properties Array
Leg  Inlet  Outlet   Length      Area   Hydraulic     Brine
 #    jct    jct      (m)      (sq-m)   K   (m/y)     Conc.
```

1	1	2	5.000E+00	5.000E+00	0.000E+00	0.000E+00
2	2	3	1.950E+02	5.000E+00	0.000E+00	0.000E+00

WARNING SINCE THE FLOW NETWORK IS NOT SOLVED, CROSS-SECTIONAL AREAS ARE NOT USED

Migration Path Properties Array

Leg #	Dispersivity (m)	Space Step (m)	Diffusion? No/Yes=0/1	Mobile Porosity	Immobile Porosity	Mass Xfer Coef (1/y)	Velocity (m/y)
1	5.000E+00	0.000E+00	0	7.000E-02	0.000E+00	0.000E+00	8.000E+00
2	0.000E+00	0.000E+00	0	7.000E-02	0.000E+00	0.000E+00	8.000E+00

WARNING MOBILE PHASE POROSITIES NOT USED SINCE DIFFUSION NOT TREATED AND NETWORK NOT SOLVED

Decay Chain Array

Name A6	Atomic Mass	Elem. Index	Local Index	Parent # 1	Parent # 2	Fraction From # 1	Fraction From # 2	Inventory (Ci)	Half-Life (y)	Weighting Factor
DECAY CHAIN # 1										
AM243	243.0	1	1	0	0	0.000E+00	0.000E+00	0.000E+00	7.593E+03	1.000E+00
PU239	239.0	2	2	1	0	1.000E+00	0.000E+00	0.000E+00	2.440E+04	1.000E+00
U235	235.0	3	3	2	0	1.000E+00	0.000E+00	0.000E+00	7.100E+08	1.000E+00

Element Properties Array

Elem. Index	Solubility (kg/kg)	Leg #	Mobil Rd	Immobile Rd
1	0.000E+00	1	2.000E+03	0.000E+00
		2	2.000E+03	0.000E+00
2	0.000E+00	1	2.000E+03	0.000E+00
		2	2.000E+03	0.000E+00
3	0.000E+00	1	2.000E+03	0.000E+00
		2	2.000E+03	0.000E+00

FOR STEADY-STATE FLOW

LEG NO.	PORE VELOCITY m/y
1	8.0000E+00
2	8.0000E+00

PATH LENGTH FROM SOURCE BOUNDARY (m) = 1.9500E+02

AVERAGE FLUID VELOCITY (m/y) = 8.0000E+00

FLOW RATE THROUGH SOURCE = 2.8000E+00 m**3/y

FLOW RATE AT DISCHARGE = 2.8000E+00 m**3/y

DECAY/PRODUCTION FACTORS AND VELOCITIES FOR EACH SUBCHAIN TRANSPORTED

SUBCHAIN #	DESCRIPTION	DECAY/PRODUCTION
1	(DECAY) AM243	7.83931E-01
2	(DECAY) PU239	9.27044E-01
3	AM243 >PU239	2.07768E-01
4	(DECAY) U235	9.99997E-01
5	PU239 >U235	7.29555E-02

6	AM243 >PU239 >U235	8.30053E-03

VELOCITY INFORMATION FOR EACH SUBCHAIN

SINGLE LEG OPTION

#	MIN VELOCITY	MEAN VELOCITY	MAX. VELOCITY	MEAN COURANT NO.
1	-5.49842E-03	1.31234E-02	3.17451E-02	2.73504E+00
2	-5.49842E-03	1.31234E-02	3.17451E-02	2.73504E+00
3	-5.49842E-03	1.31234E-02	3.17451E-02	2.73504E+00
4	-5.49842E-03	1.31234E-02	3.17451E-02	2.73504E+00
5	-5.49842E-03	1.31234E-02	3.17451E-02	2.73504E+00
6	-5.49842E-03	1.31234E-02	3.17451E-02	2.73504E+00

THE SPACE STEP--------------- DX = 3.90000E+00 m
TOTAL NUMBER OF GRID BLOCKS-- NTX = 53
WITH TOTAL CATCHER BLOCKS---- NEX = 2
THE TIME STEP---------------- DT = 2.66667E+03 Y
FLOWTHRU SOURCE MODEL WITH 1 SOURCE BLOCKS

SETUP COMPLETE, TRANSPORT CHAIN 1

1

RADIONUCLIDE CONCENTRATIONS (Ci/m**3)

YEAR	AM243	PU239	U235
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.6667E+03	0.0000E+00	0.0000E+00	0.0000E+00
[illegible]333E+03	0.0000E+00	0.0000E+00	0.0000E+00
[illegible]000E+03	0.0000E+00	0.0000E+00	0.0000E+00
1.0667E+04	0.0000E+00	0.0000E+00	0.0000E+00
1.3333E+04	0.0000E+00	0.0000E+00	0.0000E+00
1.6000E+04	0.0000E+00	0.0000E+00	0.0000E+00
1.8667E+04	0.0000E+00	0.0000E+00	0.0000E+00
2.1333E+04	3.2392E-10	4.2134E-09	1.1092E-13
2.4000E+04	9.6104E-09	1.4547E-07	4.4798E-12
2.6667E+04	7.6639E-08	1.3431E-06	4.7365E-11
2.9333E+04	3.1546E-07	6.3693E-06	2.5379E-10
3.2000E+04	8.6315E-07	1.9969E-05	8.8967E-10
3.4667E+04	1.7903E-06	4.7155E-05	2.3279E-09
3.7333E+04	3.0467E-06	9.0681E-05	4.9200E-09
4.0000E+04	4.4829E-06	1.4948E-04	8.8439E-09
4.2667E+04	5.9182E-06	2.1895E-04	1.4019E-08
4.5333E+04	7.2053E-06	2.9259E-04	2.0122E-08
4.8000E+04	8.2607E-06	3.6398E-04	2.6685E-08
5.0667E+04	9.0638E-06	4.2821E-04	3.3217E-08
5.3333E+04	9.6373E-06	4.8244E-04	3.9304E-08
5.6000E+04	1.0025E-05	5.2580E-04	4.4666E-08
5.8667E+04	1.0276E-05	5.5889E-04	4.9164E-08
6.1333E+04	1.0431E-05	5.8311E-04	5.2778E-08
6.4000E+04	1.0523E-05	6.0022E-04	5.5576E-08
6.6667E+04	1.0577E-05	6.1192E-04	5.7671E-08
6.9333E+04	1.0607E-05	6.1971E-04	5.9194E-08
7.2000E+04	1.0623E-05	6.2475E-04	6.0271E-08
[illegible]667E+04	1.0632E-05	6.2795E-04	6.1016E-08
[illegible].7333E+04	1.0637E-05	6.2993E-04	6.1520E-08
8.0000E+04	1.0639E-05	6.3114E-04	6.1854E-08
8.2667E+04	1.0640E-05	6.3186E-04	6.2072E-08

DISCHARGE SUMMARY FOR ALL 3 ISOTOPES

(To convert from curie(Ci) to becquerel(Bq) multiply by 3.7e+10)

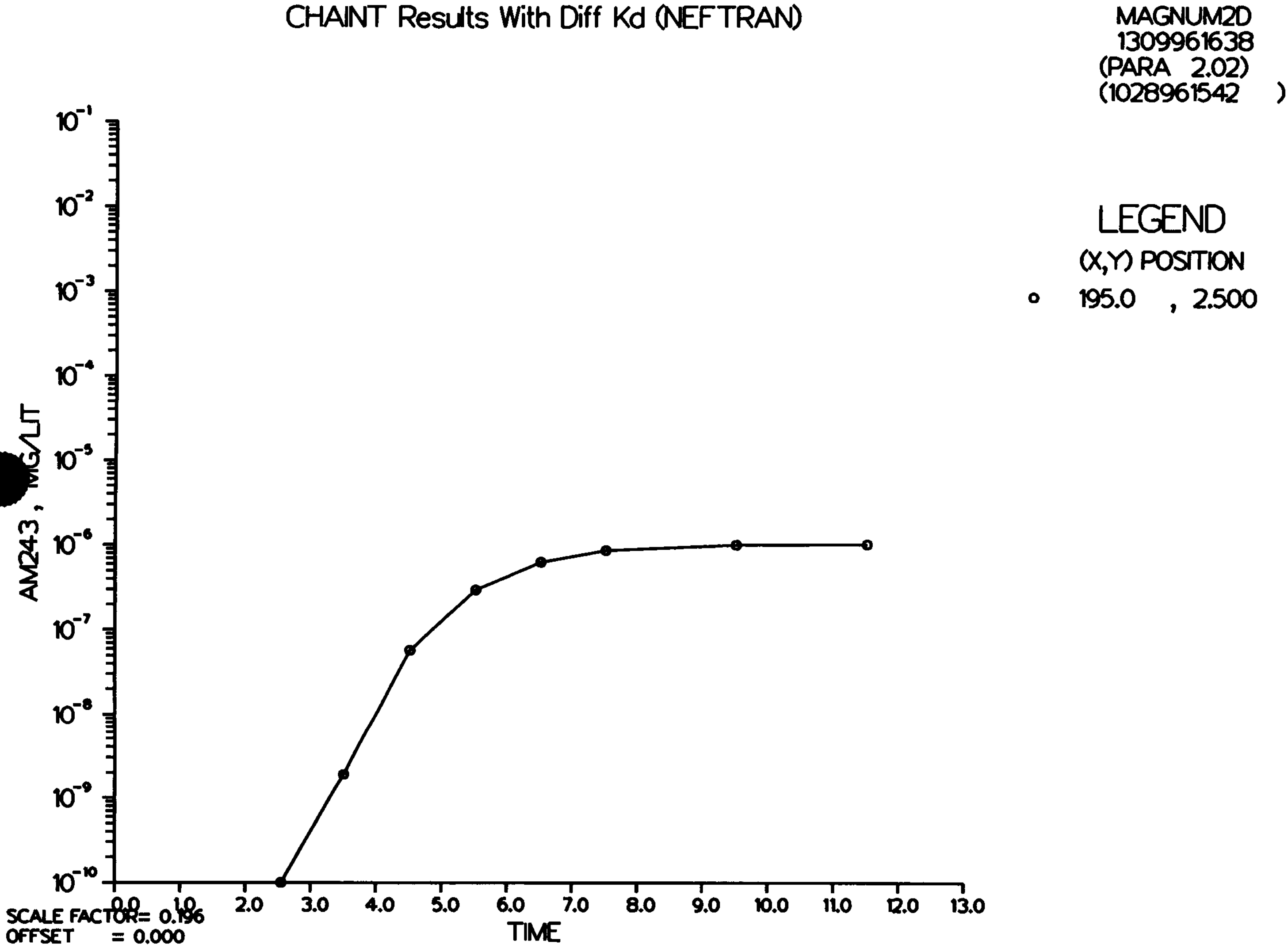
ISOTOPE	PEAK-RATE	PEAK-TIME	TOTAL(Ci)	TOTAL(WEIGHTED)
CHAIN 1				
AM243	2.9793E-05	8.2667E+04	1.1224E+00	1.1224E+00
PU239	1.7692E-03	8.2667E+04	5.8234E+01	5.8234E+01
U235	1.7380E-07	8.2667E+04	5.1029E-03	5.1029E-03

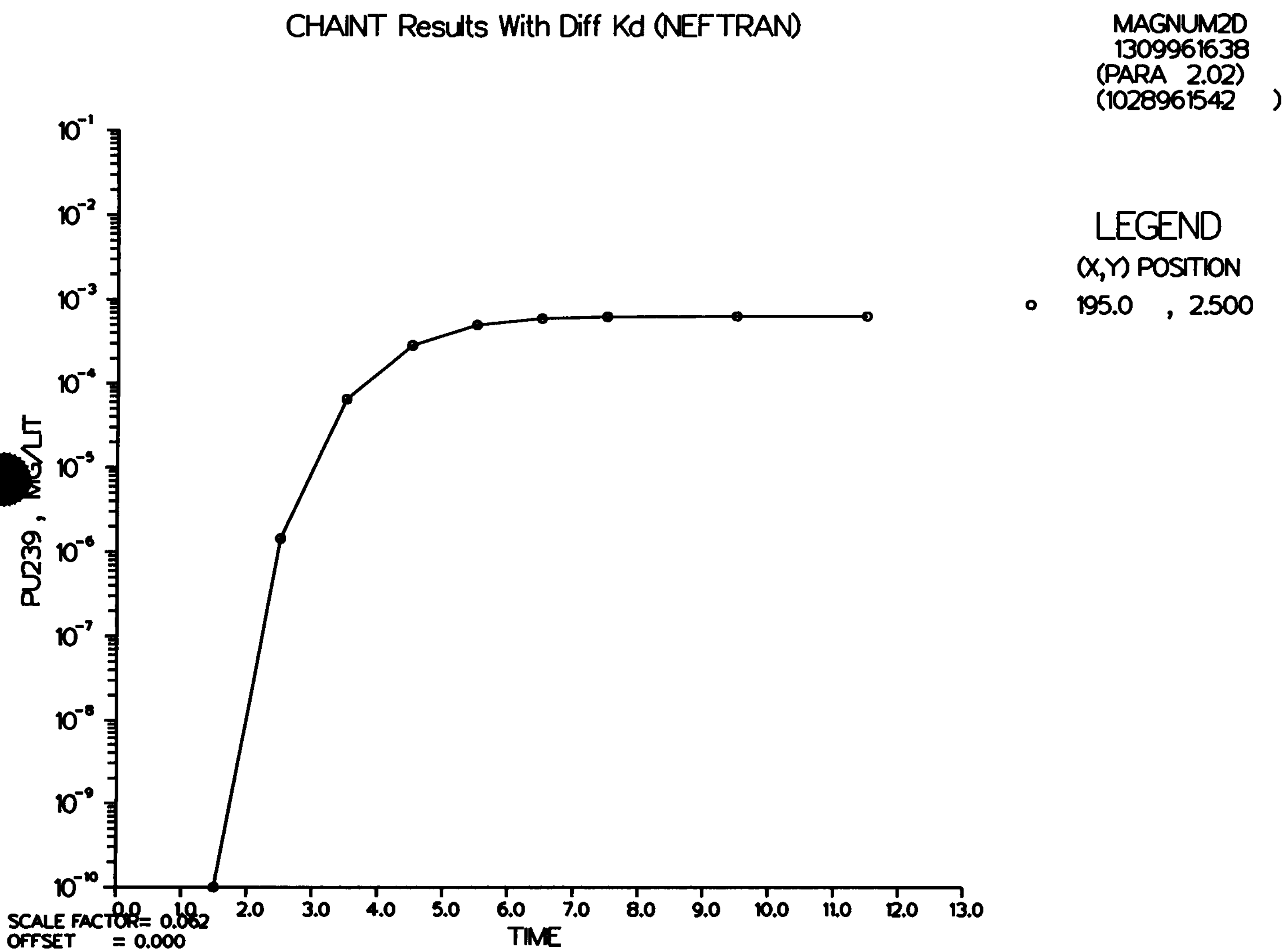
TOTAL(WEIGHTED) = 5.9361E+01

**** NORMAL TERMINATION ****

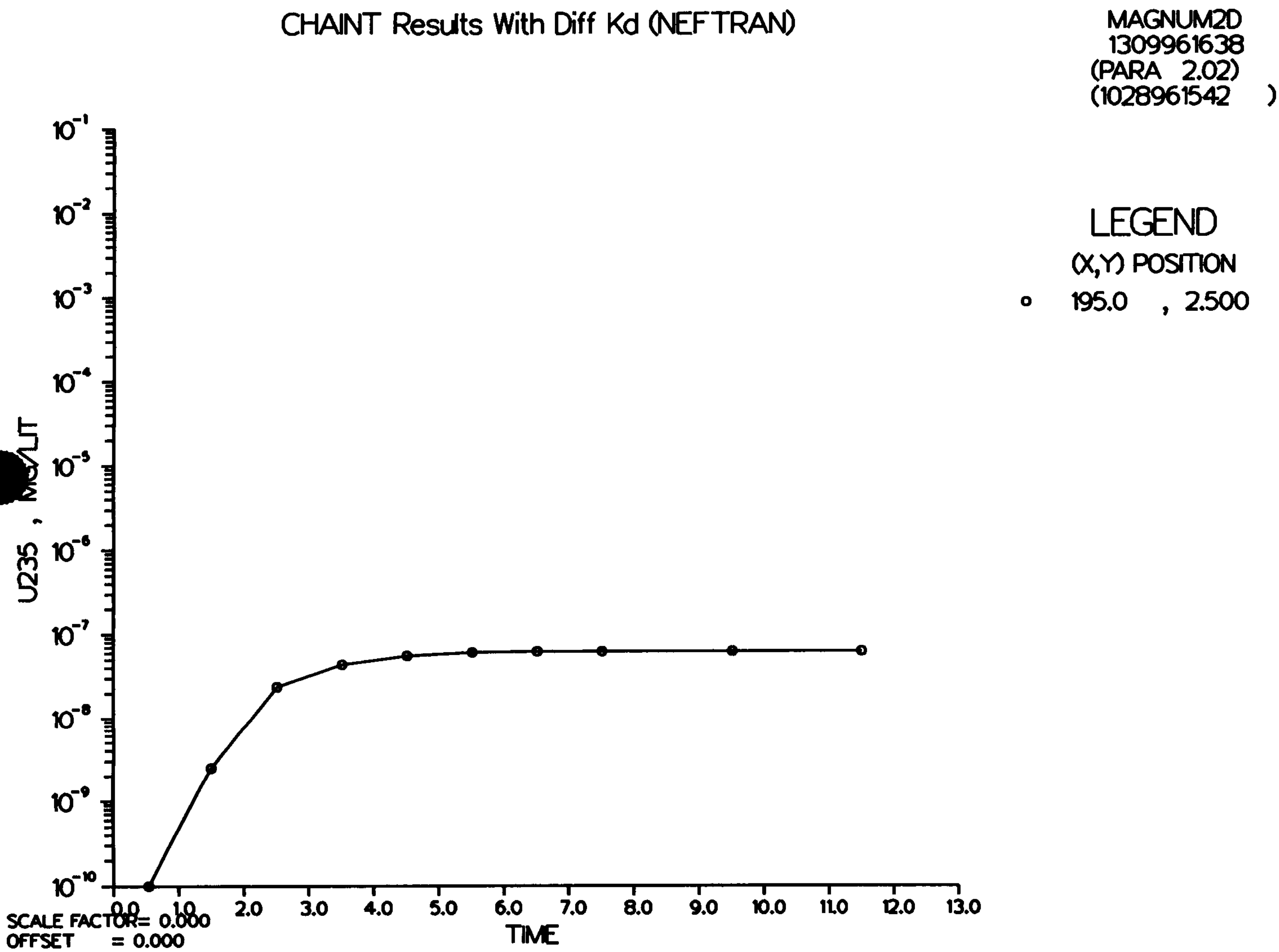
**** NORMAL TERMINATION ****

CHAINT Results With Diff Kd (NEFTRAN)

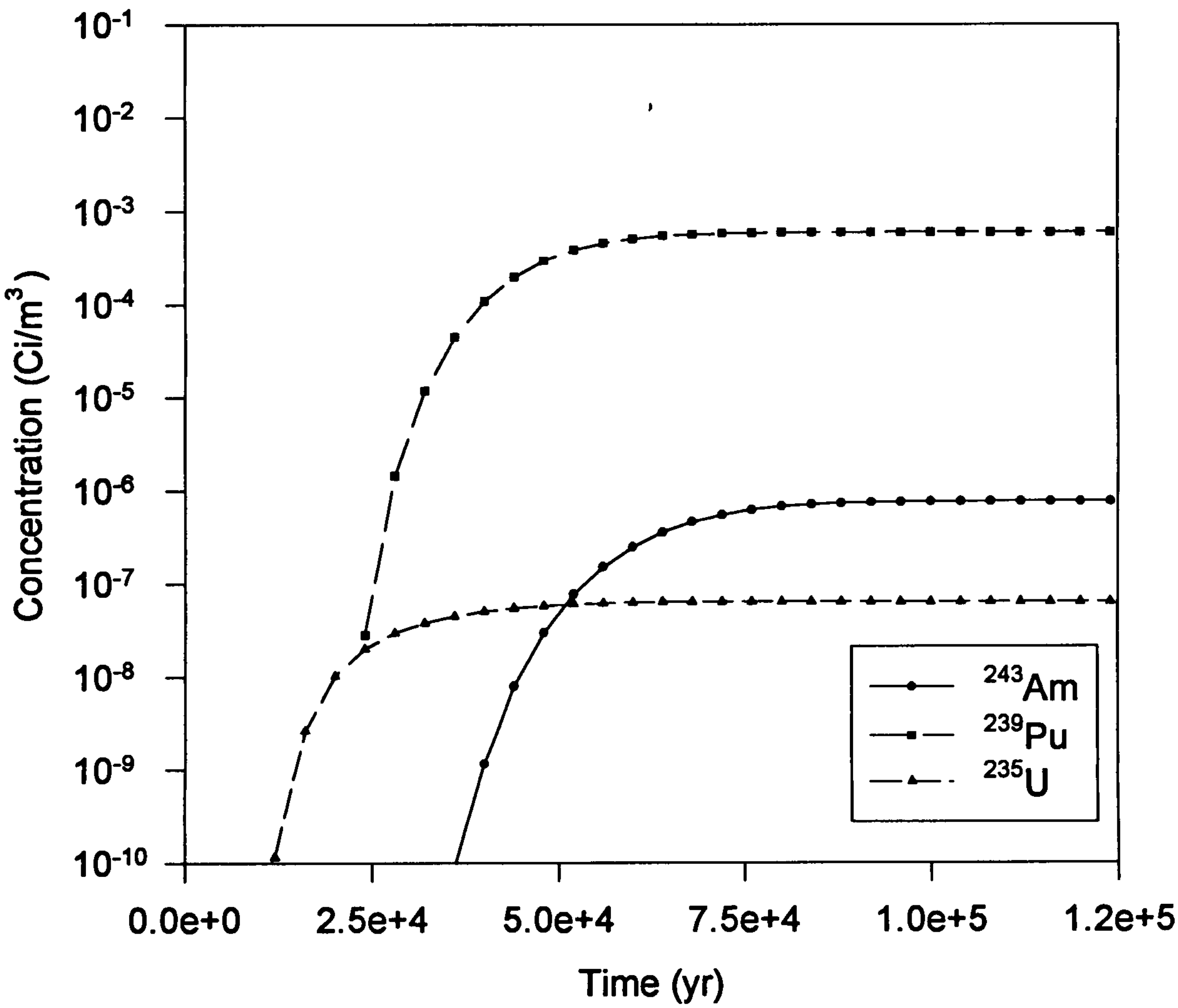



CHAINT Results With Diff Kd (NEFTRAN)
MAGNUM2D
1309961638
(PARA 2.02)
(1028961542)
LEGEND
(X,Y) POSITION
195.0 , 2.500
PU239 , MG/LIT
TIME
SCALE FACTOR= 0.062
OFFSET = 0.000

CHAINT Results With Diff Kd (NEFTRAN)



NEFTRAN Results for Three Member Decay Chain (with Different Kd)



```
CHAINT 1-D Test case (decay chain) for NEFTRAN comparison
#  nqal    ne     np    nent   nmat   iecho   isko   nvel   ncflx   nsys   nsums
    3      60     303    3      1       0       2      3      0       0      0
#  IS1  IS2  IS3  IS4  IS5  IS6  IS7
[illegible]   11    0    0   14   15    0
#  ssf   alfa   xscale   yscale   uscale   vscale
    0.   1.8     0.        0.        0.        0.
#  nts  ntsg    dlt    zonel    zoner   zonet   zoneb
   500 500      .2      0.        0.     0.       0.
   900 900     1.0      0.        0.     0.       0.
   800 800     5.0      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
   500 500     20.      0.        0.     0.       0.
  1000 1000    20.      0.        0.     0.       0.
  1000 1000    20.      0.        0.     0.       0.
 9999    0      0       0         0      0        0
#    j     ort(j,1)   ort(j,2)   rod(j,1)   por(j,1)   width(j)   nme(j)
     1        5.0        0.0       2400.       0.07        0.        mat1
#  islt
 1 1 1
#    L    amu     diag    isu(1)    frac(1)    isu(2)    frac(2)   cnam    eps
     1  243.0   7.593E+3    2         1.0        0          0.0    AM243    0.0
     2  239.0   2.44E+4     3         1.0        0          0.0    PU239    0.0
     3  235.0   7.10E+8     0         0.0        0          0.0     U235    0.0
#    i     dml(i,1..n2)   m2/yr
     1     0.0
     2     0.0
     3     0.0
#    i     xkdi(i,1..n2)   ml/g
     1     100.0
     2     60.0
     3     20.0
#   lk      Ci
     1      0.0
     2      0.0
     3      0.0
#    L      bcs
     1      3.57e-3   3.57e-2   3.57e-4
     2      3.57e-3   3.57e-2   3.57e-4
     3      3.57e-3   3.57e-2   3.57e-4
#    nld    scf    relz
      0     1.0     0.
```

```
AREA & PATH #S  1, 120  INFIL. =  0.0  MASS FRC.=  1.0E+00
    GROUP 1 - OPTIONS, STANDARD PRINT, 0=NO PRINT
   1     LIST IF ALL THE  PARAMETERS
   1     THE NETWORK LEG PROPERTIES
   1     THE NETWORK JUNCTION PROPERTIES
   1     THE MIGRATION PATH PROPERTIES ARRAY
   1     THE DECAY CHAIN PROPERTIES ARRAY
   1     THE ELEMENT PROPERTIES ARRRAY
   1     FLUID VELOCITIES & SOURCE/DISCH FLOWS
   1     SUBCHAINS, PRODUCTION & VELOCITIES
   1     SPACE & TIME STEPS AND SOURCE TYPE
  -1     TIME INDEPENDENT OUTPUT, IF +-N, RATES/CONCS EVERY NTH TIME STEP
   1     DISCHARGE SUMMARY
    EXTERNAL FILES, NONZERO => FILE WRITTEN/READ
   1     SRATE.DAT, SOURCE RATES (CI/Y) - WRITTEN TO UNIT 25
   1     DRATE.DAT, DISCHARGE RATES (CI/Y) - WRITTTEN TO UNIT 30
   1     EXTERNAL SOURCE FLAG (=1 =>READ UNIT 14)
   0     SAMP.DAT, SAMPLED DATA FOR REPEATED TRIALS - READ FROM UNIT 10
   0     VFIELD.DAT, UNIT 11, TIME-DEPENDENT VELOCITIES READ FROM
   0     SFLOW.DAT, UNIT 12, TIME-DEPENDENT SOURCE FLOW RATES READ FROM
                   RUN CONTROLS
   0     USE DVM (0) OR ANALYTIC SOLN (NONZERO)
   1     SOLVE NETWORK (0) OR INPUT VELOCITIES (NONZERO)
   0     LEACH (0), SOLUBILITIES (1), OR BOTH (2) FOR SOURCE RATES
   0     FLOWTHRU (0), MIXCELL (1), OR CHOOSE (2) FOR SOURCE RATES
   0     CONSTANT (0) OR EXPONENTIAL (1) LEACH RATE MODEL
   0     FORCE (NONZERO) USE OF LEG-TO-LEG TRANSFER ALGORITHM
                   DEBUG PRINTS, NONZERO => PRINT
   0     DVM MULTIPLIERS FOR TRANSPORT, DISCHARGE, AND SOURCE
   0     DIAGNOSTIC INFO FOR SUBROUTINE BAND
   [illegible]     DIAGNOSTIC INFO FOR FUNCTION GIT
   0     MATRIX/VECTOR SYSTEM SOLVED FOR FLOW
   0     THE DATA READ FROM UNIT 10, SAMP.DAT
   1     CONC. FLAG (=1 => WRITE TO UNIT 29 IN CI/M**3)
   0     INVENTORY AT RELEASE TIME
   0     RESTRICTIONS PLACED ON THE TIME STEPS
   0     LEG/JUNCTION & JUNCTION/LEG CONNECTIONS
   0     VELOCITY FIELDS FROM UNIT 11
   0     THE ATOM COUNT SUMMAARY
   0     JUNCTION PRESSURES & LEG FLOWRATES
   0     LEG-TO-LEG TRANSFER FRACTIONS
   0     TIME SPENT AS EACH ISOTOPE IN A SUBCHAIN
   0     TIME DEPENDENT FLOWRATES THROUGH SOURCE REGIME
                   GROUP 2  -  PROBLEM SIZE
   2     NUMBER OF NETWORK LEGS
   0     NUMBER OF NETWORK JUNCTIONS
   2     NUMBER OF MIGRATION PATH LEGS
   1     NUMBER OF DECAY CHAINS INPUT
   3     NUMBER OF ELEMENTS INPUT
  CHN1  CHN2  CHN3  CHN4  CHN5  - # PER CHAIN
   3
  CHN1  CHN2  CHN3  CHN4  CHN5 - TRANSPORT-0, SOURCE-1, NEITHER-2
   0
                   GROUP 3 - SOURCE/FLOW PARAMETERS
1.0          FRACTION OF INVENTORY ACCESSED
    0E+00    PORE VOLUME CONTAINING SOURCE (M**3) USED FOR MIXING CELL
    0E+00    PORE AREA OF SOURCE  (M**2)
1.000E-05    LEACH RATE (1/Y) IF LEACH LTD
1.000E+03    DENSITY OF SOURCE FLUID (KG/M**3)
0.350E+00    PORE AREA AT DISCHARGE (M**2)
```

GROUP 4 - TIME PARAMETERS

1.200E+05	TIME TO END OF SIMULATION (Y)
0.000E+00	TIME OF ONSET OF MIGRATION (Y)
0.000E+00	TIME OF ONSET OF LEACHING (Y)
[illegible]00E+00	TIME STEP FOR SOURCE (Y)

[illegible]N1 CHAIN2 CHAIN3 CHAIN4 CHAIN5 TIME STEPS BY CHAIN (Y)

0.0 0.0 0.0

GROUP 5 - INCREMENT DETERMNATION

0 USE DEFAULTS (0) OR SUPPLY ALL 16 VALUES

NETWORK LEG PROPERTIES ARRAY

LEG #	INLET JCT	OUTLET JCT	LENGTH (M)	AREA (M**2)	HYDRAULIC K (M/YR)	BRINE CONC.
1	1	2	5.0E+00	5.0E+00	0.0	0.0
2	2	3	1.95E+02	5.0E+00	0.0	0.0

MIGRATION PATH PROPERTIES ARRAY

LEG #	DISPERS. (M)	SPA. STEP (M)	DIFFUS N/Y=0/1	MOBILE POROS.	IMMOB POROS.	MASS XFER COEF(1/Y)	VELOCITY (M/YR)
1	5.0	0.0	0	7.0E-02	0.000E+00	0.0E+00	8.0
2	0.0	0.0	0	7.0E-02	0.000E+00	0.0E+00	8.0

DECAY CHAIN ARRAY

NAME A6	ATM# (AMU)	ELE- MENT	LOC NDX	PAR #1	PAR #2	FRAC FROM1	FRAC FROM2	INVEN (CI)	HALF LIFE (Y)	WEIGH FAC
'AM243'	243.	1	1	0	0	0.000	0.000	0.000E+00	7.593E+03	1.00
'PU239'	239.	2	2	1	0	1.000	0.000	0.000E+00	2.44E+04	1.00
'U235'	235.	3	3	2	0	1.000	0.000	0.000E+00	7.10E+08	1.00

ELEMENT PROPERTIES ARRAY

ELEM. INDEX	SOLUBILITY (KG/KG)	LEG #	MOBIL RD	IMMOBILE RD
1	0.000E+00	1	3430.0	0.000E+00
		2	3430.0	0.000E+00
[illegible]	0.000E+00	1	2058.0	0.000E+00
		2	2058.0	0.000E+00
3	0.000E+00	1	687.0	0.000E+00
		2	687.0	0.000E+00

7.2.8 Summary

Comparison of the concentration contours from CHAINT and the analytical solutions for Validation Test Cases 1, 2, 3, 4, 5, 6, and 7 shows the values are consistent for modeled systems similar to Yucca Mountain. Consequently, the CHAINT computer code meets the validation testing requirements of TOP 18.

Input files of the seven validation test cases are provided in this section on a 3.5" diskette. The diskette contains seven sub-directories called V_CASE1, V_CASE2, V_CASE3, V_CASE4, V_CASE5, V_CASE6, and V_CASE7 corresponding to the seven validation test cases presented in this document. Each sub-directory has the MAGNUM-2D and CHAINT input files (i.e., files with the .crd extension), a zipped MAGNUM-2D geometry file (i.e., a file with the .zip extension), and the PKZIP.EXE and PKUNZIP.EXE executable files which may be used to compress and uncompress files, respectively. Additionally, each sub-directory has the FORTRAN source code for the validation test case analytical solution (i.e., FINITE, STRIPF, or GWMODF2) and the accompanying input file.

8.0 SOFTWARE RETIREMENT

8.1 SOFTWARE RELEASE NOTICE

A Software Release Notice shall be issue to communicate the retirement of this software, and the software shall be removed from active software listings when the software is so identified for retirement according to TOP 18.

9.0 REFERENCES

Kline, N. W., England, R. L.,,and R. G. Baca, "CHAINT Computer Code: Users Guide," Rockwell Hanford Operations, RHO-BW-CR-144P, December 1985.

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Nuclear Regulatory Commission, "User's Manual for the NEFTRAN II Computer Code," NUREG/CR-5618, SAND90-2089, RW, February 1991.

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Rood, A.S., "GWSCREEN: A Semi-Analytical Model for Assessment of the Ground Water Pathway from Surface or Buried Contamination: Theory and User's Manual," EGG-GEO-10158, Rev. 1, November 1992.

Technical Operating Procedure 18, "The Development and Control of Scientific and Engineering Software," Center of Nuclear Waste Regulatory Analyses, Revision 4, June 9, 1995.

Wexler, E. J., "Analytical Solutions for One-, Two-, and Three-Dimensional Solute Transport in Ground-Water Systems with Uniform Flow," Book 3 Applications of Hydraulics, Chapter B7, Techniques of Water-Resources Investigations of the United States Geologic Survey, 1992.