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USER'S MANUAL FOR A MATERIAL TRANSPORT CODE ON THE OCTOPUS COMPUTER NETWORK

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FOREWORD

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TABLE OF CONTENTS

Foreword	iii
Abstract	vii
Introduction	1
Data File Preparation	2
Running the Transport Code from TTY	9
Running the Code from Order Batch Processing System	10
Files Generated by Transport Code	11
Example Problem	12
TRANPP-A Postprocessor for the MATTRAN Code	15
Definition of Terms	18
Acknowledgments	19
References	20
Appendix A: Input For The Example Problem	21
Appendix B: Graphics From The Example Problem	57

ABSTRACT

A code to simulate material transport through porous media was developed at Oak Ridge National Laboratory. This code has been modified and adapted for use at Lawrence Livermore Laboratory. This manual, in conjunction with report ORNL-4928, explains the input, output, and execution of the code on the Octopus Computer Network.

INTRODUCTION

A transport code developed by Duguid and Reeves¹ has been adapted to the Octopus Computer Network. The code calculates two-dimensional (vertical section) transport of a dissolved constituent by ground water. The code has been used to calculate transport in regional ground-water systems.² These studies were carried out (under contract to the Nuclear Regulatory Commission) to investigate geohydrological criteria important in the geological disposal of nuclear waste. However, the code can be applied to other ground-water transport problems. This manual is designed to guide the user in the input and output operations of the code and in the execution procedures required for use at a remote terminal. Duguid and Reeves¹ is well documented and should be used in conjunction with this manual.

This code is designed to calculate the concentrations of a material within porous media. Among its capabilities, it considers transient or steady-state flow, saturated or unsaturated conditions, advective transport, hydrodynamic dispersion, and radioactive decay. The theoretical development of the governing equations and numerical implementation are found in Duguid and Reeves.¹

DATA FILE PREPARATION

Construction of the finite element mesh and generation of a ground-water flow field^{3,4} precedes preparation of the data file, but the flexibility in this procedure puts it beyond the scope of this manual. What follows is a list of data requirements. This list should be used in conjunction with ORNL-4928.¹

(1) PROBLEM NUMBER AND IDENTIFICATION LINE

VARIABLE NAME	IDENTIFICATION	FORMAT(15,9A8)
NPROB -	Number of the problem	
TITLE -	Title of the problem	

(2) CONTROL LINE

VARIABLE NAME	IDENTIFICATION	FORMAT(14I6)
NNP -	Number of nodal points	
NEL -	Number of elements	
NMAT -	Number of materials	
NICM -	Number of elements with corrected material properties	
NTI -	Number of time increments (iterations)	
NBC -	Number of constant Dirichlet boundary conditions	
NST -	Number of element sides on which flux-type Neumann boundary conditions are applied.	
NTST -	Number of elements having seepage surfaces	
KVI -	Darcy velocity input control	
KSTR -	Control parameter for storage of output	
KSS -	Steady state control	
ISSENT -	If ISSENT=0, TSFXXXXX is calculated. If ISSENT=1, TSFXXXXX exists from a preceding calculation and is automatically read.	

(3) TIME CONTROL LINE

VARIABLE NAME	IDENTIFICATION	FORMAT(I5,5F10.0)
IPL0T -	Control parameter for saving concentration for postprocessing	
DELT -	Time increment	
CHNG -	Multiplier for increasing the time increment	
DELMAX -	Maximum value of DELT	
TMAX -	Maximum simulation time	
W -	Time-integration parameter	

If IPL0T<0, the code will save concentration values at 20 equally spaced values of TMAX. If IPL0T=0, the user must provide the times where the code is to save concentrations. The maximum number of times entered cannot exceed 20. These numbers are read with 5F10.0 format. If IPL0T>0, concentration values will be saved at TIME=IPL0T and at TIME=TIME+IPL0T with a maximum of 20 sets of time saved.

(4) OUTPUT CONTROL PARAMETER LINE

VARIABLE NAME	IDENTIFICATION	FORMAT(I1)
KPRO -	Printer control for steady state and initial conditions	

(5) SOURCE NODE LINE

VARIABLE NAME	IDENTIFICATION	FORMAT(I1)
II -	Number of source nodes that can be turned off during simulation.	

If the value of II is zero, no source nodes will be turned off and the source node control line (next input line) should not be entered. Also, the code will adjust all source nodes or none at all.

(6) SOURCE NODE CONTROL LINE

VARIABLE NAME	IDENTIFICATION	FORMAT(2F10.0)
TIMESOURCE -	This variable is the simulation time when source nodes can be turned off or diminished.	
SOURCE -	This variable is the value (strength) of the source node after it is adjusted to the new source value.	

In the most general case, the number of cards needed here is equal to the number of source nodes. No cards are needed if none of the source nodes are adjusted.

(7) MATERIAL PROPERTIES LINES

In the most general case, NMAT sets of parameters are required.

VARIABLE NAME	IDENTIFICATION	FORMAT(8F10.0) - first line FORMAT(F10.0) - second line
KD -	Distribution coefficient of an element	
RHOB -	Bulk density	
AL -	Longitudinal dispersivity of material	
AT -	Transverse dispersivity of material	
LAMBDA -	Radioactive decay constant	
POR -	Porosity of an element	
ALP -	Modified coefficient of compressibility	
AM -	Molecular diffusivity	
TAU -	Tortuosity	

The above material properties values are read into the array PROP, then stored as the variable names listed above. Because of this they must be entered in floating point form.

(8) LINES DEFINING NODAL POSITION AND DIRICHLET CONCENTRATION-TYPE BOUNDARY CONDITIONS

In the most general case, NNP lines are required.

VARIABLE NAME	IDENTIFICATION	FORMAT(15,I2,I3,3F10.0)
M(temporary)	- Number of the nodal points	
IM -	Variable for automatic generation of Dirichlet concentration boundary	
NP -	Contains node number where constant Dirichlet boundary conditions occur	
X -	X coordinate of node	
Z -	Z coordinate of node	
BB -	Constant material concentration for Dirichlet boundary condition	

(9) ELEMENT DEFINITION LINES

VARIABLE NAME	IDENTIFICATION	—	FORMAT(6I5)
M(temporary)	- Element number		
IE(1,M)	- Node I		
IE(2,M)	- Node J		
IE(3,M)	- Node K		
IE(4,M)	- Node L		
IE(5,M)	- Material identification		

NEL lines are usually required. Element cards must be in element sequence. If element cards are omitted, the program automatically generates the omitted information by increasing the node values of the preceding element by one. The material identification is the same as the preceding element. The last element card must always be supplied. Nodal sequencing I,J,K,L is counterclockwise around the element, starting at lower left corner of element.

(10) MATERIAL CORRECTION LINES

VARIABLE NAME	IDENTIFICATION	FORMAT(14I6)
MI -	Element number	
MTYP -	Material type	
MK -	Element number	
MINC -	Increment in element number	

(11) INITIAL CONDITIONS LINES

In the most general case there is one card per node, i.e., a total of NNP cards.

VARIABLE NAME	IDENTIFICATION	FORMAT(15,5X,F10.0)
NJ -	nodal point number	
RP(NJ) -	Pressure head at current time step	

If groups of adjacent nodal points NJ have identical values RP(NJ), a data omission can be used for automatic generation of these values. The initial concentration of each succeeding node will have the same concentration value until a new value is encountered.

(12) NEUMANN FLUX-TYPE BOUNDARY CONDITIONS LINES

VARIABLE NAME	IDENTIFICATION	FORMAT(3I5,5X,2F10.0)
NI -	Nodal point number	
NJ -	Nodal point number	
KINC -	Increment control used for automatic generation of boundary conditions	
EI -	Flux at NI normal to the surface (NI,NJ)	
EJ -	Flux at NJ normal to the surface (NI,NJ)	

If KINC>0, then the nodal-point increment is formed from NI and NJ of the immediately preceding card:

$$NPINC = NJ - NI$$

Two sequences are formed:

$$NI + NPINC, NI + 2*NPINC...$$

$$NJ + NPINC, NJ + 2*NPINC...$$

Both are terminated when the largest integer is reached that is less than both current values of NI and NJ. Corresponding nodal points for these two sequences define a surface. Quantity EI is the dot product of the flux at NI with an outwardly directed unit vector normal to the element side (NI,NJ). A similar definition holds for EJ.¹

(13) SEEPAGE SURFACE ELEMENT LINES

VARIABLE NAME	IDENTIFICATION	FORMAT(14I6)
NTSE(MP)	- Element having seepage surfaces	
IS(MP,1)	- Surface identification array for seepage elements	
IS(MP,2)	- Surface identification array for seepage elements	
KINC	- Increment control used for automatic generation of boundary conditions. If KINC is greater than 0, automatic generation is employed.	

(14) INPUT LINES OF DARCY VELOCITY AT TIME = 0.

The Darcy velocities may be entered in the user's data deck or by reading the binary format file VELOUT generated by the TAYLOR ground-water code (GWFLOW).

The method used to enter the velocities is determined by the value of variable KVI entered on line (2) of data deck.

If KVI<0, NEL velocity cards are required

If KVI=0, no Darcy velocities are read

If KVI>0, Darcy velocities are read from file VELOUT generated by TAYLOR flow code (GWFLOW).

The Darcy velocity data deck is read in the following form: JQ is an index from 1 to 4 and M is the element number: (VX(JQ,M),JQ=1,4, VZ(JQ,M),JQ=1,4).

VX(1,M) Velocity in X-direction of node I, element M
VX(2,M) Velocity in X-direction of node J, element M
VX(3,M) Velocity in X-direction of node K, element M
VX(4,M) Velocity in X-direction of node L, element M
VZ(1,M) Velocity in Z-direction of node I, element M
VZ(2,M) Velocity in Z-direction of node J, element M
VZ(3,M) Velocity in Z-direction of node K, element M
VZ(4,M) Velocity in Z-direction of node L, element M

Nodes I,J,K,L run counterclockwise starting with node I at the lower left corner of the element. If velocity values are read from cards, format(8E12.4) is used.

PRESSURE HEAD (H(I)) and TOTAL HEAD (HT(I)) at TIME=0 are set to zero internally by the code. If the type of problem desired to be run dictates that the TOTAL HEAD and PRESSURE HEAD have some value other than zero, the code will have to be modified accordingly. The two dimensional array TH(1,1) to TH(4,NEL) contains the water content. At present, the water content is set (by the code) equal to the porosity of the material.

RUNNING THE TRANSPORT CODE FROM TTY

The transport code is a public file (MATTRAN) on the CDC 7600 computers of the LTSS computer network. The following describes the teletype interactions.

```
USER:          MATTRAN / t v
TTY:           BOX NUMBER AND INPUT FILE NAME
USER:          AXX FILENAME                      Format(A3,1X,A10)
TTY:           PROBLEM INFORMATION INPUT
USER:          XXXXX J                          Format(A5,1X,A1)
```

The code now echos the user's input.

```
INPUT FILE . . . . . FILENAME
BOX NUMBER . . . . . AXX
RESTART DUMP FILE . . . . . XXXXX
HSP SENTINEL . . . . . J
```

If all is o.k., type yes; if not, hit return and retype.

USER : YES (or carriage-return)

TTY : ALL DONE

In the above example, the terms used are defined as follows:

- (1) MATTRAN - The transport controllee; a public file
- (2) AXX - The user's box number
- (3) FILENAME - The name of the user's input data deck
- (4) XXXXX - The name of the restart dump file. The user may specify any five character name.
- (5) J - HSP sentinel to determine HSP disposition.
 - K - Keep HSP files under user's I. D. number
 - H - Send HSP files to NIPS printer.

The transport code will automatically edit to TTY every 1/20 of TMAX (total simulation time) unless edit times are specified in the input. The variables edited are DELT, TIME, and NTI (number of time increments).

RUNNING CODE FROM ORDER BATCH PROCESSING SYSTEM

If the user wishes to run the MATTRAN code under the ORDER batch processing system, the following control cards are required:

- (1) *ID ACCOUNT NUMBER NAME BOX AXX
- (2) *RDFILES HL524 VELOUT
- (3) *ADT *AANNN TPPXXXXX TRMXXXXX XXXXX TFPXXXXX TSFXXXXX
- (4) *XEQ MATTRAN
- (5) *DATA
- (6) *AXX FILENAME
- (7) XXXXX J
- (8) special instruction card; blank if not a restart Format(4F12.4,I5)

In the above example, tape HL524 contains a file required by the transport code; in this case, it is file VELOUT. This file contains the Darcy velocities generated by the TAYLOR ground-water code(GWFLOW). Tape AANNN line(3) is the user's private tape. Files generated by the transport code will be written to this tape. The * before the tape name instructs the computer operator to hang a blank tape and label it accordingly. Under the ORDER system mode, it is imperative that the HSP sentinel on line (7) be set to H and not to K. Sentinel H will send HSP files to the NIPS printer. Option K will keep the files under the I. D. number and this may result in loss of HSP output if the job is being run by computer operations. Special instruction card, line (8), contains provisions for changing the values of DELT, CHNG, DELMAX, TMAX, and NTI on restarts. They are entered in the above order; enter a zero for those values that do not have to be changed. The preceding set of control cards are added to the front of the MATTRAN data deck and submitted to production. Contact Miriam Lohmann for further details on K-Division production job procedure.

FILES GENERATED BY TRANSPORT CODE

The *ADT order control card (line 3) will write the following files to magnetic tape. A short description of each file is added.

- (1) TPPXXXXX - This file contains concentration values generated by the MATTRAN code. This file is later postprocessed and contour plots are generated.
- (2) TRMXXXXX - This file contains special messages from the transport code. If running from ORDER, a problem edit 1/20 of TMAX will be included unless edit times are specified in the input.
- (3) XXXXX - Restart dump file generated by code.
- (4) TFPXXXXX - Contains variables FRATE(3), FLOW(3), TFLOW(3), FRATE(6), FLOW(6), TFLOW(6) and TIME at each iteration. These variables can be plotted against TIME by the system plot routine PLOTPK upon completion of the run.
- (5) TSFXXXXX - Contains variable arrays generated in the subroutine SURF. If in a preceding run the boundary conditions are identical to the problem to be run, this file can be read by MATTRAN to eliminate access to subroutine SURF. On a very large problem, as much as 3 minutes may be saved.

EXAMPLE PROBLEM EXECUTED FROM A REMOTE TERMINAL

To complete this run of the transport code, 6 files are needed: (1) MATTRAN, the executable code, (2) UXTV, (3) UXRJ, (4) TRANPP, the postprocessing code, (5) VELOUT, the velocity input file and, (6) the data file. MATTRAN, UXTV,⁵ UXRJ⁵ and TRANPP are public files. VELOUT is a velocity file created by GWFLOW^{4,6} and functions as an input file to MATTRAN. Because of this, an identical mesh description must be used as input to both GWFLOW and MATTRAN. VELOUT is a binary file that is compatible with MATTRAN. An example problem taken from a material transport study² is presented to demonstrate the creation of the data file.

Figure 1 illustrates the finite element mesh of the example problem. Node numbering proceeds along vertical mesh lines from bottom left to top right. Element numbering is similar. The problem configuration contained 1562 elements whose shapes were prescribed by the coordinates of the 1656 nodes that formed the corners.

FIG. 1. Finite element mesh of example problem.

The data file of the problem is found in Appendix A. The first line contains the problem identification number and title. The second line is the control line. The control line indicates 1656 nodes, 1562 elements, 22 different materials, a lack of elements with corrected material properties, 10,000 as the maximum number of time increments, one Dirichlet boundary condition (the source node), 176 element sides on which flux-type boundary conditions are applied (zero flux boundaries), 10 elements having seepage surfaces (surfaces through which material is released from the system). Also, velocity input control equals one (which means read the VELOUT file), storage control equals zero (this control has been retained for possible future use and the code has been modified to automatically store the output on disk), KSS equals one (to obtain a transient solution), and ISSENT is set to 0 (in order for the SURF subroutine to calculate TSFXXXXX).

Line 3 is the simulation time control line. The control parameter for saving concentrations for the postprocessor (TRANPP) is included as the first variable in line 3. It was set at 0 to produce concentration contour plots at the times (years) entered in lines 4 and 5. The second variable in line 3, the time increment (DELT), is 0.2 years; the multiplier for increasing DELT is 0.1 years; the maximum value of DELT is 65 years; the maximum simulation time (TMAX) of the problem is 1000 years; and the time integration parameter is one. Lines 4 and 5 list the years at which concentration values are saved on disk. Line 6 contains output control information. The number 4 is a flag commanding the initial conditions to be printed. The number 2 commands fluxes and concentrations to be printed at the simulation times listed in lines 4 and 5. Line 7 indicates one Dirichlet boundary node and line 8 indicates that this boundary will be changed to a new value at 100 years. Lines 9 through 52 define the properties of the 22 materials. Although the capability of 22 materials exist, these data describe a 5-layer system.²

For example, lines 9 and 10 describe material 1: the distribution coefficient equals 0, the bulk density is 1.75, the longitudinal dispersivity is 50 m, the transverse dispersivity is 5 m, there is no radioactive decay, porosity equals 0.1, the modified coefficient of compressibility is zero, molecular

diffusivity is 1 m, and (on line 10) tortuosity is 1.1. Lines 53 through 321 describe the nodal position and Dirichlet concentration-type boundary conditions. Some of these data are formatted and some are comma delimited because data generators and text editors were used when convenient. For example, line 53 describes node 1 by: node number equals 1 and a lack of Dirichlet boundary generation. The second 0 means this is not a Dirichlet boundary node (1 means it is a boundary node, e.g., node 586), the x coordinate position is 0.0 m, the y coordinate position is 1000 m (Fig. 1), the Dirichlet boundary value is 0.0 (the concentration at the source node 586 is 1000.0).

Lines 322 through 1883 define the elements. Line 322 describes element one as: element number equals 1, the lower left node of the element is 1, the lower right node is 24, the upper right node is 25, the upper left node is 2, the element properties are those of material 1. Lines 1884 and 1885 set the initial concentration values at all nodes equal to zero. Lines 1886 through 2061 define the Neumann flux-type boundaries. The example problem (Fig. 1) was designed to release material only at the downgradient end via seepage surfaces. Therefore, zero flux-type boundaries surround the remainder of the model. These boundaries (element sides) are defined by two nodal points. One such boundary is defined in line 1886 as being between nodes 1 and 2. A zero follows (indicating a lack of automatic generation); the final zero in the line defines the outward flux as zero. The seepage surfaces (element sides) are designated in lines 2062 through 2071. In line 2062 the element 1562 has a seepage surface between nodes 1556 and 1633. The zero indicates lack of automatic generation.

After execution, the high speed files (the printed output) contained the input data from the data file, VELOUT. This is followed by the material flux concentrations and a systems flow table printed for the years in lines 4 and 5. The graphics output file (in this problem called TPPTG031) was used to produce the concentration contour plots in Appendix B. TRANPP was the postprocessor used to produce the plots in Appendix B.

TRANPP--A POST PROCESSOR FOR THE MATTRAN CODE

INTRODUCTION

TRANPP is a LRLTRAN code written to generate graphics from the concentration file written by the MATTRAN main code. The TRANPP code uses system libraries ORDERLIB, TV80LIB, and UX80LIB to generate contour plots. A modified version of ORDERLIB routine, CONTUR, is used for contouring. The MATTRAN main code writes to disk at the specified simulation times. The TRANPP postprocessing code reads the sets of concentration values and generates the plots.

HOW TO RUN THE TRANPP CODE

The following files are needed to generate contour plots:

- (1) TRANPP - Executable controllee
- (2) TPPXXXXX - A file written by the MATTRAN code containing concentration values and other required variables.

One of the following UXDD80 system files is required and the other two are optional:

- (1) UXTV - A routine that is a member of the UXDD80 graphics system; it is used to view plots on TMD5 screens.
- (2) UXRJ - Also a member of the UXDD80 graphic system. This routine is used to send the UXDD80 plot file to the RJET printer.
- (3) UXFR - A UXDD80 system file that can be used to send the file to other output devices.

I.D. onto a teletype and proceed in the following manner (the following parameter values were used to produce Appendix B that contains the graphics of the example problem):

```

USER:      TRANPP / 1 .39
TTY:      TYPE CONCFIL NAME
USER:      TPPTGB31
TTY:      TYPE-NLEV,GRID OPT,XMIN,XMAX,ZMIN,ZMAX,CONC-MIN,CONC-MAX...
          FORMAT(2I5,6F10.4)
USER:      11,0,27490.,31400.,0.,1000.,1.9,1000.

TTY:      DISK FILE NAME . . . . . TPPXXXXX
          # OF CONTOUR LEVELS . . . . . 11
          GRID OPTION . . . . . 0
          XMIN . . . . . 2.7490E+04
          XMAX . . . . . 3.1400E+04
          ZMIN . . . . . 0.
          ZMAX . . . . . 1.0000E+03
          MIN CONCENTRATION . . . . . 1.9000E+00
          MAX CONCENTRATION . . . . . 1.0000E+03

TTY:      IF ALL TTY INPUT OK TYPE Y OR HIT RETURN TO REPEAT
USER:      Y
TTY:      TYPE FIRST SET OF LEVEL NUMBERS..10F8.4
USER:      900.,500.,100.,50.,20.,10.,8.,6.,4.,3.
TTY:      TYPE SECOND SET OF LEVEL NUMBERS..10F8.4
USER:      2.,
TTY:      THE 20 LEVELS OF CONC VALUES ARE
          900.00  500.00  100.00  50.00  20.00  10.00  8.00
            6.00   4.00   3.00

          2.00  -0.   -0.   -0.   -0.   -0.   -0.
          -0.   -0.   -0.

TTY:      ALL GOOD DATA PLOTTED....PROBLEM DONE
TTY:      ALL DONE

```

Having completed execution of the postprocessing controllee, TRANPP, the user will have a file or family of files starting with the name UATV80DD80. The plot file (UATV80DD80) contains contour plots. At each specified time, the code will generate a contour plot with nodes, and a contour plot without nodes. A maximum of 40 contour plots are possible. The user may now view the plots in file UATV80DD80 on TMDS with routine UXTV or send the file to the desired output device with routines UXRJ or UXFR. Refer to Blair's report⁵ for more information about UXTV, UXJR, and UXFR.

DEFINITION OF TERMS

- o CONCFIL - A file written by the MATTRAN code. It contains concentration values plus other variables needed to generate contour plots. The file will be of the form TPPXXXXX.
- o NLEV - Number of contour levels. This is an integer greater than or equal to one, and less than or equal to 20.
- o GRID OPTION - An integer with value of 0 or 1.
 - 0 - This option will generate a 1 page plot.
 - 1 - This option will generate a plot which is dimensioned one-to-one in X-direction vs Z-direction.
- o XMIN,XMAX - The user's minimum and maximum Cartesian coordinates, X-axis.
- o ZMIN,ZMAX - The user's minimum and maximum Cartesian coordinates, Z-axis.
- o CONC-MIN - The minimum concentration value the user wishes to contour. All values less than this number will be set to zero internally by the TRANPP code.
- o CONC-MAX - The maximum concentration value the user wishes to contour. All concentration values greater than this value will be set to zero internally by the code.

ACKNOWLEDGMENTS

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References

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APPENDIX A:
INPUT FOR THE EXAMPLE PROBLEM

This appendix contains data used as input for the example problem described in the text of the attached report.

001.INPUT FILE FOR EXAMPLE IN TRANSPORT CODE USER'S MANUAL

1856.1562.22.0.1000.1.178.10.1.0.1.0.

0..2..1.05..1000..1.

100..210..510..410..510.

550..770..900..1000..0.

42

1

100..0.

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..10..0..01.0..1.

1..1

0..1.75.30..10..0..01.0..1.

1..1

0..1.75.30..10..0..01.0..1.

1..1

0..1.75.30..10..0..01.0..1.

1..1

0..1.75.30..10..0..01.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.30..5..0..05.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

0..1.75.50..5..0..1.0..1.

1..1

1 0 00..1000..0.

2 0 00..1014..0.

23 0 00..1308..0.

24 0 02000..940..0.

25 0 02000..954..0.

46 0 02000..1248..0.

47 0 04000..080..0.

48 0 04000..094..0.

69 0 04000..1188..0.
 70 0 05000..820..0.
 71 0 06000..834..0.
 92 0 08000..1128..0.
 93 0 09000..760..0.
 94 0 08000..775..0.
 115 0 08000..1100..0.
 116 0 09000..730..0.
 117 0 09000..746..0.
 126 0 09000..890..0.
 127 0 09000..906..0.
 128 0 09000..920..0.
 130 0 09000..1082..0.
 132 0 010000..700..0.
 145 0 010000..717..0.
 161 0 010000..1074..0.
 162 0 011000..670..0.
 163 0 011000..688..0.
 164 0 011000..705..0.
 165 0 011000..724..0.
 165 0 011000..742..0.
 84 0 011000..885..0.
 135 0 012000..640..0.
 165 0 012000..659..0.
 187 0 012000..678..0.
 188 0 012000..697..0.
 189 0 012000..716..0.
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3013	3036	0	0.	0.
3036	3059	0	0.	0.
3059	3082	0	0.	0.
3082	3105	0	0.	0.
3105	3128	0	0.	0.
3128	3151	0	0.	0.
3151	3174	0	0.	0.
3174	3197	0	0.	0.
3197	3220	0	0.	0.
3220	3243	0	0.	0.
3243	3266	0	0.	0.
3266	3289	0	0.	0.
3289	3312	0	0.	0.
3312	3335	0	0.	0.
3335	3358	0	0.	0.
3358	3381	0	0.	0.
3381	3404	0	0.	0.
3404	3427	0	0.	0.
3427	3450	0	0.	0.
3450	3473	0	0.	0.
3473	3496	0	0.	0.
3496	3519	0	0.	0.
3519	3542	0	0.	0.
3542	3565	0	0.	0.
3565	3588	0	0.	0.
3588	3611	0	0.	0.
3611	3634	0	0.	0.
3634	3657	0	0.	0.
3657	3680	0	0.	0.
3680	3703	0	0.	0.
3703	3726	0	0.	0.
3726	3749	0	0.	0.
3749	3772	0	0.	0.
3772	3795	0	0.	0.
3795	3818	0	0.	0.
3818	3841	0	0.	0.
3841	3864	0	0.	0.
3864	3887	0	0.	0.
3887	3910	0	0.	0.
3910	3933	0	0.	0.
3933	3956	0	0.	0.
3956	3979	0	0.	0.
3979	4002	0	0.	0.
4002	4025	0	0.	0.
4025	4048	0	0.	0.
4048	4071	0	0.	0.
4071	4094	0	0.	0.
4094	4117	0	0.	0.
4117	4140	0	0.	0.
4140	4163	0	0.	0.
4163	4186	0	0.	0.
4186	4209	0	0.	0.
4209	4232	0	0.	0.
4232	4255	0	0.	0.
4255	4278	0	0.	0.
4278	4301	0	0.	0.
4301	4324	0	0.	0.
4324	4347	0	0.	0.
4347	4370	0	0.	0.
4370	4393	0	0.	0.
4393	4416	0	0.	0.
4416	4439	0	0.	0.
4439	4462	0	0.	0.
4462	4485	0	0.	0.
4485	4508	0	0.	0.
4508	4531	0	0.	0.
4531	4554	0	0.	0.
4554	4577	0	0.	0.
4577	4600	0	0.	0.
4600	4623	0	0.	0.
4623	4646	0	0.	0.
4646	4669	0	0.	0.
4669	4692	0	0.	0.
4692	4715	0	0.	0.
4715	4738	0	0.	0.
4738	4761	0	0.	0.
4761	4784	0	0.	0.
4784	4807	0	0.	0.
4807	4830	0	0.	0.
4830	4853	0	0.	0.
4853	4876	0	0.	0.
4876	4899	0	0.	0.
4899	4922	0	0.	0.
4922	4945	0	0.	0.
4945	4968	0	0.	0.
4968	4991	0	0.	0.
4991	5014	0	0.	0.
5014	5037	0	0.	0.
5037	5060	0	0.	0.
5060	5083	0	0.	0.
5083	5106	0	0.	0.
5106	5129	0	0.	0.
5129	5152	0	0.	0.
5152	5175	0	0.	0.
5175	5198	0	0.	0.
5198	5221	0	0.	0.
5221	5244	0	0.	0.
5244	5267	0	0.	0.
5267	5290	0	0.	0.
5290	5313	0	0.	0.
5313	5336	0	0.	0.
5336	5359	0	0.	0.
5359	5382	0	0.	0.
5382	5405	0	0.	0.
5405	5428	0	0.	0.
5428	5451	0	0.	0.
5451	5474	0	0.	0.
5474	5497	0	0.	0.
5497	5520	0	0.	0.
5520	5543	0	0.	0.
5543	5566	0	0.	0.
5566	5589	0	0.	0.
5589	5612	0	0.	0.
5612	5635	0	0.	0.
5635	5658	0	0.	0.
5658	5681	0	0.	0.
5681	5704	0	0.	0.
5704	5727	0	0.	0.
5727	5750	0	0.	0.
5750	5773	0	0.	0.
5773	5796	0	0.	0.
5796	5819	0	0.	0.
5819	5842	0	0.	0.
5842	5865	0	0.	0.
5865	5888	0	0.	0.
5888	5911	0	0.	0.
5911	5934	0	0.	0.
5934	5957	0	0.	0.
5957	5980	0	0.	0.
5980	6003	0	0.	0.
6003	6026	0	0.	0.
6026	6049	0	0.	0.
6049	6072	0	0.	0.
6072	6095	0	0.	0.
6095	6118	0	0.	0.
6118	6141	0	0.	0.
6141	6164	0	0.	0.
6164	6187	0	0.	0.
6187	6210	0	0.	0.
6210	6233	0	0.	0.
6233	6256	0	0.	0.
6256	6279	0	0.	0.
6279	6302	0	0.	0.
6302	6325	0	0.	0.
6325	6348	0	0.	0.
6348	6371	0	0.	0.
6371	6394	0	0.	0.
6394	6417	0	0.	0.
6417	6440	0	0.	0.
6440	6463	0	0.	0.
6463	6486	0	0.	0.
6486	6509	0	0.	0.
6509	6532	0	0.	0.
6532	6555	0	0.	0.
6555	6578	0	0.	0.
6578	6601	0	0.	0.
6601	6624	0	0.	0.
6624	6647	0	0.	0.
6647	6670	0	0.	0.
6670	6693	0	0.	0.
6693	6716	0	0.	0.
6716	6739	0	0.	0.
6739	6762	0	0.	0.
6762	6785	0	0.	0.
6785	6808	0	0.	0.
6808	6831	0	0.	0.
6831	6854	0	0.	0.
6854	6877	0	0.	0.
6877	6900	0	0.	0.
6900	6923	0	0.	0.
6923	6946	0	0.	0.
6946	6969	0	0.	0.
6969	6992	0	0.	0.
6992	7015	0	0.	0.
7015	7038	0	0.	0.
7038	7061	0	0.	0.
7061	7084	0	0.	0.
7084	7107	0	0.	0.
7107	7130	0	0.	0.
7130	7153	0	0.	0.
7153	7176	0	0.	0.
7176	7199	0	0.	0.
7199	7222	0	0.	0.
7222	7245	0	0.	0.
7245	7268	0	0.	0.
7268	7291	0	0.</	

1644	1643	0	0.	0.
1643	1642	0	0.	0.
1642	1641	0	0.	0.
1641	1640	0	0.	0.
1640	1639	0	0.	0.
1639	1638	0	0.	0.
1638	1637	0	0.	0.
1637	1636	0	0.	0.
1636	1635	0	0.	0.
1635	1634	0	0.	0.
1	24	0	0.	0.
24	47	0	0.	0.
47	70	0	0.	0.
70	93	0	0.	0.
93	116	0	0.	0.
116	139	0	0.	0.
139	162	0	0.	0.
162	185	?	0.	0.
185	208	?	0.	0.
208	231	0	0.	0.
231	254	0	0.	0.
254	277	0	0.	0.
277	300	0	0.	0.
300	323	0	0.	0.
323	346	0	0.	0.
346	369	0	0.	0.
369	392	0	0.	0.
392	415	0	0.	0.
415	438	0	0.	0.
438	461	0	0.	0.
461	484	0	0.	0.
484	507	0	0.	0.
507	530	0	0.	0.
530	553	0	0.	0.
553	576	0	0.	0.
576	599	0	0.	0.
599	622	0	0.	0.
622	645	0	0.	0.
645	668	0	0.	0.
668	691	0	0.	0.
691	714	0	0.	0.
714	737	0	0.	0.
737	760	0	0.	0.
760	783	0	0.	0.
783	806	0	0.	0.
806	829	0	0.	0.
829	852	0	0.	0.
852	875	0	0.	0.
875	898	0	0.	0.
898	921	0	0.	0.
921	944	0	0.	0.
944	967	0	0.	0.
967	990	0	0.	0.
990	1013	0	0.	0.
1013	1036	0	0.	0.
1036	1059	0	0.	0.
1059	1082	0	0.	0.
1082	1105	0	0.	0.
1105	1128	0	0.	0.
1128	1151	0	0.	0.

1151	1174	0	0.	0.
1174	1197	0	0.	0.
1197	1220	0	0.	0.
1220	1243	0	0.	0.
1243	1266	0	0.	0.
1266	1289	0	0.	0.
1289	1312	0	0.	0.
1312	1335	0	0.	0.
1335	1358	0	0.	0.
1358	1381	0	0.	0.
1381	1404	0	0.	0.
1404	1427	0	0.	0.
1427	1450	0	0.	0.
1450	1473	0	0.	0.
1473	1496	0	0.	0.
1496	1519	0	0.	0.
1519	1542	0	0.	0.
1542	1565	?	0.	0.
1565	1588	?	0.	0.
1588	1611	0	0.	0.
1611	1634	0	0.	0.
1562.	1626.	1633.0		
1540.	1633.	1610.0		
1518.	1610.	1587.0		
1496.	1587.	1564.0		
1474.	1564.	1541.0		
1452.	1541.	1518.0		
1430.	1518.	1495.0		
1408.	1495.	1472.0		
1386.	1472.	1449.0		
1364.	1449.	1426.0		

APPENDIX B:
GRAPHICS FROM THE EXAMPLE PROBLEM

This appendix contains the graphics generated by the example problem described in the text of the attached report.

CONCENTRATION CONTOUR W/OUT NODES. TIME= 1.0E+02

CONCENTRATION CONTOUR W/OUT NODES. TIME= 2.1E+02

CONCENTRATION CONTOUR WITH NODE'S.TIME= 3.1E+02

CONCENTRATION CONTOUR W/OUT NODES, TIME= 3.1E+02

CONCENTRATION CONTOUR WITH NODES, TIME= 4.1E+02

CONCENTRATION CONTOUR W/OUT NODES. TIME = 4.1E+02

CONCENTRATION CONTOUR W/OUT NODES. TIME= 5.1E+02

CONCENTRATION CONTOUR WITH NODES, TIME= 6.5E+02

CONCENTRATION CONTOUR W/OUT NODES. TIME= 6.5E+02

CONCENTRATION CONTOUR WITH NODES. TIME= 7.7E+02

CONCENTRATION CONTOUR W/OUT NODES. TIME= 7.7E+02

CONCENTRATION CONTOUR WITH NODES, TIME= 9.0E+02

CONCENTRATION CONTOUR W/OUT NODES, TIME = $9.0E+02$

CONCENTRATION CONTOUR WITH NODES. TIME = 1.0E+03

CONCENTRATION CONTOUR W/OUT NODES. TIME= 9.0E+01

CONCENTRATION CONTOUR W/OUT NODES.TIME= 1.0E+03