User's Guide

for

R-LINE Model Version 1.2

A Research LINE source model for near-surface releases

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TABLE OF CONTENTS

1 Introduction

The R-LINE model is a research dispersion modeling tool under development by the US EPA's Office of Research and Development. While this User Guide focuses on the mechanics of using the model, information on the model formulation and evaluation can be found in Snyder et al (2013) and Venkatram et al. (2013). In addition, a model inter-comparison study was also published in Heist et al. (2013).

The model is based on a steady-state Gaussian formulation and is designed to simulate line-type source emissions (e.g. mobile sources along roadways) by numerically integrating point source emissions. R-LINE is currently formulated for near-surface releases, contains new (field study and wind tunnel based) formulations for the vertical and lateral dispersion rates, simulates low wind meander conditions, includes Monin-Obukhov similarity profiling of winds near the surface and selects plume-weighted winds for transport and dispersion calculations. The model uses the hourly surface meteorology provided by the AERMET model (the meteorological preprocessor for AERMOD; Cimorelli, 2005) and simplified road-link specifications. The model uses error analysis to determine the number of points needed in the integration to represent each source. R-LINE is not designed for volume, area or point sources. R-LINE as it is currently formulated is a flat-terrain model and therefore does not account for variations in terrain elevation.

Several features in R-LINE are currently under development and are offered as beta-options. An analytical solution to the problem of integrating source contributions along a line source is incorporated as the first beta-option. This "analytical solution" runs more quickly for some source-receptor combinations than the numerical integration approach while producing comparable, though slightly different, results. The second beta-option enables algorithms that account for two types of roadway configurations: roadside barriers (e.g., noise barriers) and depressed roadways. Finally, a third beta-option adds an amount of initial horizontal spread to the plume to simulate the width of the roadway and may be especially useful when wide multilane roadways are simulated as a single source. These beta-options are not yet fully evaluated and documented and are undergoing further development. It is expected that they will become standard options in a future release.

2 File structure & descriptions

In setting up the R-LINE model, the user defines the arrangement of road links by specifying line source endpoints and defines the locations where concentrations estimates are required as receptor locations. In defining these locations, the *X*-, *Y*-coordinates (given in meters) are specified relative to an origin of the user's choosing. For example, the user can choose to use Universal Transverse Mercator coordinates or a local coordinate system centered on a source of interest. The heights (*Z*) of the sources and receptors must be specified relative to local ground level (terrain variations are not considered). R-LINE uses four input files to provide the necessary parameters (see Table 1, below). Concentrations are generated at each receptor location for each hour modeled.

2.1 User Modified Input Files

Text files are used to control the sources, meteorology, receptors and program run options. The main user-edited file is *Line_Source_Inputs.txt*, within which the user specifies the file names for the source, receptor and meteorological data, as well as the run options and output file name.

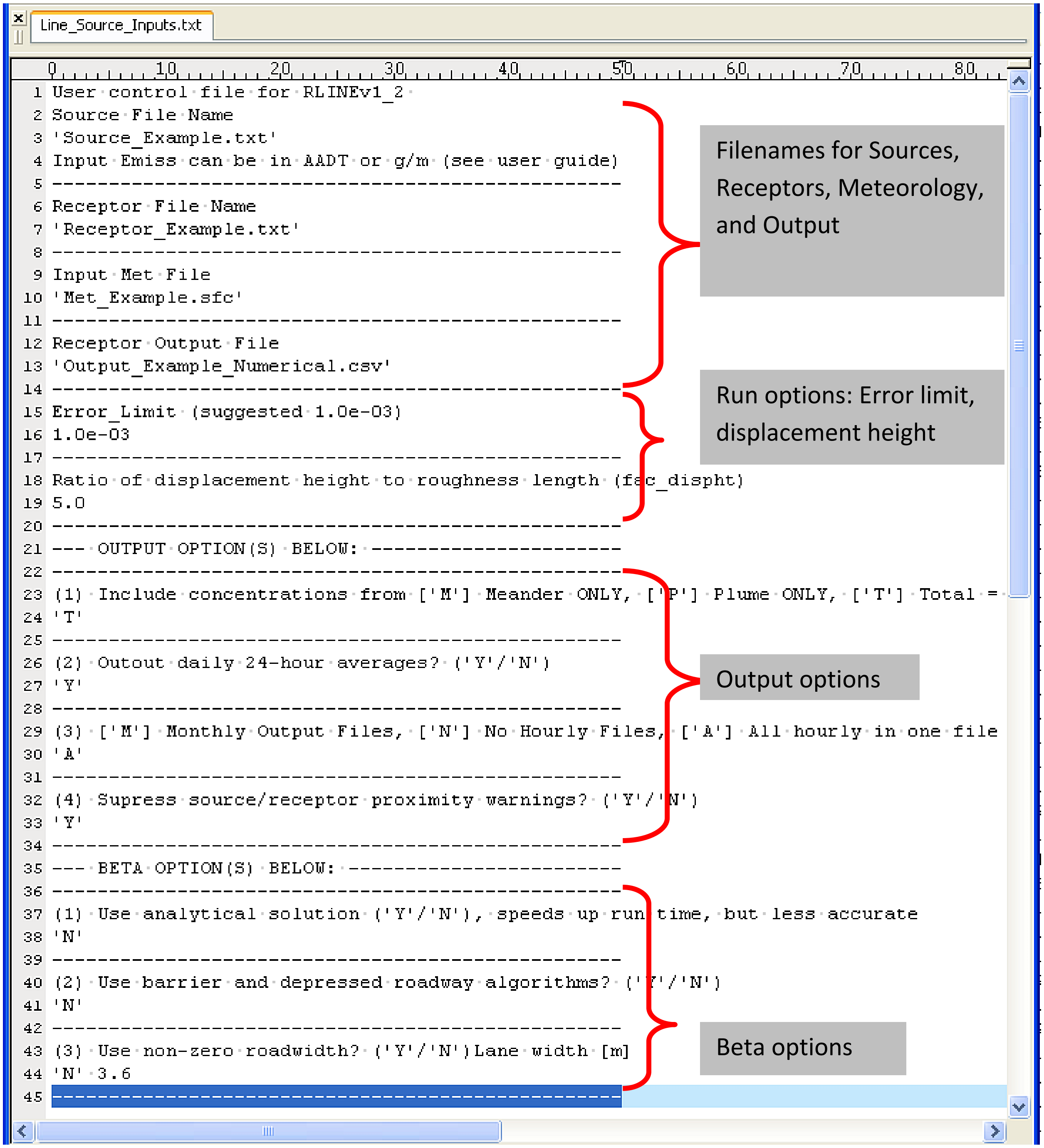
Table 1. Descriptions and names for user modified files in R-LINE code.

File Name	Type	Description
Line_Source_Inputs.txt	Text	Specify names of other files and options used in model run.
*Source_Example.txt**	Text	Contains descriptive headers, specify one line source per line.
*Receptor_Example.txt**	Text	Contains the *X, Y, Z* location of each receptor on separate lines.
*Met_Example.scf**	Surface	A surface meteorology file of the same form provided by the AERMET model (the meteorological preprocessor for AERMOD).

* *file names specified by user in the* Line_Source_Inputs.txt *file*

2.1.1 Main Input File (*Line_Source_Inputs.txt*)

Of the four input files, this is the only one whose name the user cannot change. An example of this 45-line input file is shown in Figure 1. In this file, the user specifies the names of the other three input files and the root name for the output file(s). The user also specifies: the convergence error limit criterion (a value of 0.001 is recommend) and a factor (*f*) to be multiplied by the surface roughness length (z_0) to estimate the displacement height (*d*) (i.e., $d = f z_0$). For a displacement height of zero, set *f* equal to zero. Table 2 provides some guidance on values of surface roughness and displacement height for a range of urban classifications (adapted from Grimmond and Oke, 1999).



```
User control file for RLINEv1_2
Source File Name
'Source_Example.txt'
Input Emiss can be in AADT or g/m (see user guide)
--------------------------------------------------
Receptor File Name
'Receptor_Example.txt'
--------------------------------------------------
Input Met File
'Met_Example.sfc'
--------------------------------------------------
Receptor Output File
'Output_Example_Numerical.csv'
--------------------------------------------------
Error_Limit (suggested 1.0e-03)
1.0e-03
--------------------------------------------------
Ratio of displacement height to roughness length (fac_dispht)
5.0
--------------------------------------------------
--- OUTPUT OPTION(S) BELOW: ----------------------
--------------------------------------------------
(1) Include concentrations from ['M'] Meander ONLY, ['P'] Plume ONLY, ['T'] Total =
'T'
--------------------------------------------------
(2) Outout daily 24-hour averages? ('Y'/'N')
'Y'
--------------------------------------------------
(3) ['M'] Monthly Output Files, ['N'] No Hourly Files, ['A'] All hourly in one file
'A'
--------------------------------------------------
(4) Supress source/receptor proximity warnings? ('Y'/'N')
'Y'
--------------------------------------------------
--- BETA OPTION(S) BELOW: ------------------------
--------------------------------------------------
(1) Use analytical solution ('Y'/'N'), speeds up run time, but less accurate
'N'
--------------------------------------------------
(2) Use barrier and depressed roadway algorithms? ('Y'/'N')
'N'
--------------------------------------------------
(3) Use non-zero roadwidth? ('Y'/'N')Lane width [m]
'N' 3.6
--------------------------------------------------
```


Figure 1. *Line_Source_Inputs.txt*, where the user specifies other input filenames and the options for the model run.

Table 2. Typical urban boundary layer parameters (adapted from Grimmond and Oke, 1999).

Urban surface form	Mean building height (m)	Displacement height, d (m)	Surface roughness length, z_0 (m)
Low height and density	5 — 8	2 — 4	0.3 — 0.8
Medium height and density	7 — 14	3.5 — 8.0	0.7 — 1.5
Tall height and density	11 — 20	7 — 15	0.8 — 1.5
High rise	> 20	> 12	> 2.0

There are four options that control the output of the program.

In the first option (1), the user specifies whether the output concentrations is due to the direct plume ('P'), due to low wind speed meander ('M') or the combination of both components, i.e. the total plume ('T').

The second option (2) gives the user the ability to report concentrations averaged over a 24-hour period (all 24 hours from the same calendar day).

The third option (3) directs the hourly output into either a single file ('A') of multiple files divided by month ('M'), or allows the user to specify no hourly output ('N'). The user should take care with options (2) and (3) to be sure that some form of output is chosen, since it is possible to select 'N' for both and have no output.

The fourth option (4) allows the user to suppress warnings regarding source-receptor proximity. R-LINE enforces a one meter minimum distance between source and receptor and will assume that distance if any source-receptor pairs are closer than that limit. This may speed up the model run slightly by eliminating the need to write warnings during program execution.

There are three beta options available in R-LINEv1_2 that can be selected in the input file. The first option (1) is for an analytical solution instead of the default numerical solution. The derivation of this solution includes some simplifying assumptions that lead to slightly different results than the numerical solution, especially for receptors close to the source, or for sources and/or receptors significantly off the ground. The analytical solution is significantly faster than the numerical solution. The limitations of this solution and comparison to the numerical solution are still being evaluated and a journal article documenting the discrepancies is planned. Some initial analysis has been documented in the appendix of this document. The second option (2) activates algorithms that take into account two types of roadway configurations: roadside barriers (e.g., noise barriers) and depressed roadways. Parameters describing the geometry of these configurations are specified in the Source Input File (see section 2 below). The third option (3) activates an enhanced initial lateral dispersion (σ_{y0}) to spread emissions over the width of the roadway. This may be important for multilane roads simulated with one road link. The user defines the lane width at this point.

2.1.2 Source Input File (e.g., *Source_Example.txt*)

The source filename is specified in the *Line_Source_Inputs.txt* file. The user is required to include three lines of header text though these lines are not processed by R-LINE.

Source grouping is available in R-LINE. Sources can be grouped together and given a group ID (an alphanumeric string of less than or equal to 40 characters). Concentrations resulting from each group of sources will be reported separately in the output file. A source's group ID is the first item on the source input line. Sources with the same group ID do not need to be grouped together in the input file. For example, if the user wanted to group highways with annual average daily traffic (AADT) greater than 100,000 together for the purpose of reporting results, a group ID 'HW1E5' could be used. The user could still arrange the sources within Source Input File according to a different scheme (e.g., according to the geographical region within a city).

In R-LINE, a roadway can be represented as one source or as multiple sources to represent different lanes of traffic individually. Each source is listed on a different line in the Source Input File. The endpoints of the source can be specified in one of two ways: the end points of each source (x, y, and z) are given individually or the endpoints of the center of a group of sources are given with an offset distance (*dCL*) for each source relative to the centerline. Compare figures 2a and 2b where the same set of sources is created in each version of the input file, but in one the endpoints of each individual lane of traffic are given and in the other the centerline and offset method is used.

Each line in the Source Input File contains 18 columns. The header shows what is expected in each column. Column 1 is the group ID. Columns 2 through 7 are the coordinates of the beginning and end points of a line (in meters), respectively: (*X_b, Y_b, Z_b*) and (*X_e, Y_e, Z_e*). Column 8 is the offset distance from the road centerline, if using that method ('0', otherwise). When using an offset distance, positive values of *dCL* represent an eastward shift parallel to the centerline, while negative values represent a westward shift parallel to the centerline. If the source is oriented exactly east-west, a positive *dCL* represents an offset north of the centerline, and a negative *dCL* represents an offset south of the centerline.

The next two columns (9 and 10) are initial vertical dispersion (σ_{z0}, in meters) and the number of lanes for the specified roadlink. Lane width is defined in the *Line_Source_Inputs.txt* file. The number of lanes does not have to be specified in integer numbers allowing the user greater control of the roadway width. The road width (number of lanes multiplied by road width) is used to calculate the initial horizontal dispersion (σ_{y0}).

Column 11 is the emission rate (*Emis*). If the user gives the emission rate in g/(m s), the resulting concentrations are in $\mu g/m^3$. Alternatively, the user can specify the emission rate in AADT - annual average daily traffic with units of vehicles/day. In this case the results would be in $\mu g/m^3$ x [veh day^{-1} / g/(m s)]. An emission factor (*EF*) relating g/(m s) to veh day^{-1}, could then be used in post-processing to calculate concentration in $\mu g/m^3$. This method might be useful, for example, if the user wished to apply different temporal allocation factors to different groups of roadways.

The final columns (12 through 18) are for roadway configurations other than flat terrain. To use these options, which are still in the beta-testing stage as they undergo further evaluation, the user must indicate 'Y' in the *Line_Source_Inputs.txt* file under "Beta Option 2." Two types of roadway configurations are allowed: roadside barriers and depressed roadways. When using these options, the user must specify the location of the centerline of the roadway using the centerline and offset method.

To use the roadside barrier algorithm, the user must supply geometric information about the location and height of the barrier in columns 12 through 13. At this time only a single downwind barrier is used by R-LINE, though a placeholder has been reserved in the input file (i.e., columns 14 and 15) for future development for a second barrier. If the barrier is upwind of the roadway, R-LINE will ignore it. The user indicates the distance (*dw*, in meters) between the center of the roadway and the location of the barrier in column 12. The sign of *dw* follows the same convention as *dCL*, described above. Column 13 is for the height (*Hw*) of the barrier (in meters). The barrier is assumed to run the length of the road link. See Figure 3.

The depressed roadway algorithm requires three parameters, the depth of the depression (*Depth*, column 16), the width of the opening at the top of the depression (*Wtop*, column 17), and the width of the roadway at the bottom of the depression (*Wbottom*, column 18) (see Figure 4). All three parameters are in meters.

Note: Columns 10 (σ_{y0}), and 12 through 18 (roadway configurations) relate to beta-options. Even if the option is not selected, the user must still populate these columns with a numerical value (e.g., "0.0").

Comment lines (indicated with an initial '!') and blank lines are permitted. The '!' must appear in the first column of the comment line or an error will occur.

a)

Source_Example.txt

```
Source input file
Group  X_b    Y_b   Z_b    X_e    Y_e   Z_e  dCL  sigmaz0 #lanes  Emis  Hw1  dw1  Hw2  dw2 Depth  Wtop  Wbottom
----------------------------------------------
! Group 1 (G1) sources running north-south:
G1    -8.5 -500.0   1.0   -8.5  500.0   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
G1    -5.0 -500.0   1.0   -5.0  500.0   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
G1     5.0 -500.0   1.0    5.0  500.0   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
G1     8.5 -500.0   1.0    8.5  500.0   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0

! Group 2 (G2) sources running north-south:
G2  -500.0   -8.5   1.0  500.0   -8.5   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
G2  -500.0   -5.0   1.0  500.0   -5.0   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
G2  -500.0    5.0   1.0  500.0    5.0   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
G2  -500.0    8.5   1.0  500.0    8.5   1.0    0      2.0    1.0   1.0    0    0    0    0      0    0        0
```

b)

Source_Example_dCL.txt

```
Source input file
Group  X_b    Y_b   Z_b    X_e    Y_e   Z_e  dCL  sigmaz0 #lanes  Emis  Hw1  dw1  Hw2  dw2 Depth  Wtop  Wbottom
----------------------------------------------
! Group 1 (G1) sources running north-south:
G1     0.0 -500.0   1.0    0.0  500.0   1.0 -8.5      2.0    1.0   1.0    0    0    0    0      0    0        0
G1     0.0 -500.0   1.0    0.0  500.0   1.0 -5.0      2.0    1.0   1.0    0    0    0    0      0    0        0
G1     0.0 -500.0   1.0    0.0  500.0   1.0  5.0      2.0    1.0   1.0    0    0    0    0      0    0        0
G1     0.0 -500.0   1.0    0.0  500.0   1.0  8.5      2.0    1.0   1.0    0    0    0    0      0    0        0

! Group 2 (G2) sources running north-south:
G2  -500.0    0.0   1.0  500.0    0.0   1.0 -8.5      2.0    1.0   1.0    0    0    0    0      0    0        0
G2  -500.0    0.0   1.0  500.0    0.0   1.0 -5.0      2.0    1.0   1.0    0    0    0    0      0    0        0
G2  -500.0    0.0   1.0  500.0    0.0   1.0  5.0      2.0    1.0   1.0    0    0    0    0      0    0        0
G2  -500.0    0.0   1.0  500.0    0.0   1.0  8.5      2.0    1.0   1.0    0    0    0    0      0    0        0
```

Figure 2. Example line sources used in R-LINE calculation. The two files specify the same sources using (a) individual lane endpoints and (b) centerline endpoints and offsets.

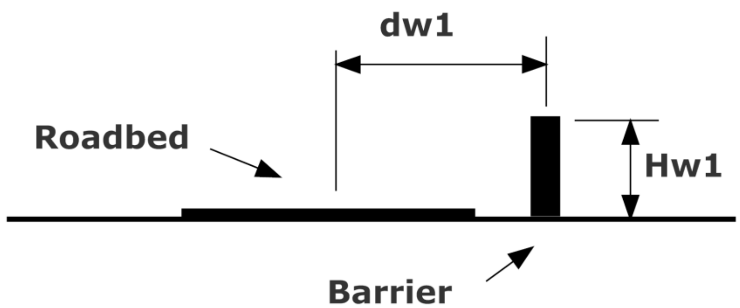


Figure 3. Parameters required to specify noise barrier.

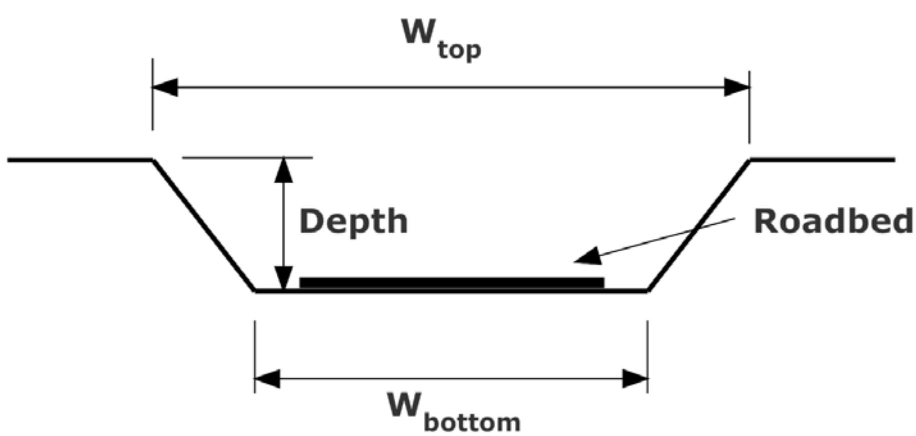


Figure 4. Parameters required to specify depressed roadway.

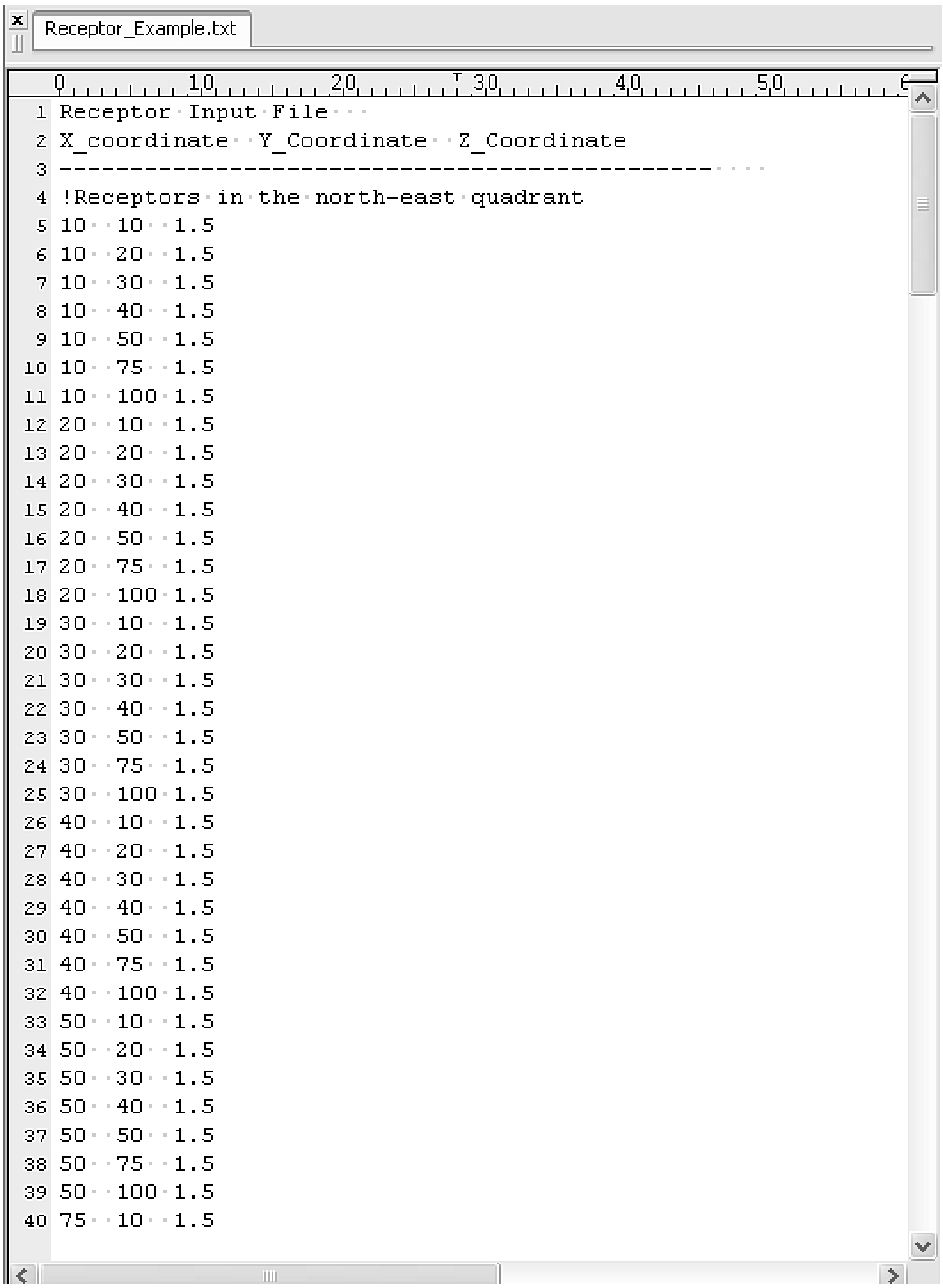
Table 3. Abbreviations and variables used in the source file.

Name	Parameter	Description	Notes
Group	Group ID	Identifier indicating to which group the source belongs.	Sources in the same group need not be listed sequentially.
X_b, Y_b, Z_b	Beginning coordinates of the road link		
X_e, Y_e, Z_e	Ending coordinates of the road link		
dCL	Distance from the roadway centerline to the lane of traffic	The distance is specified as an offset from the roadway centerline.	Can be set to zero. *dCL* > 0 indicates lanes east of the centerline (or north if the roadway runs directly east- west). *dCL* < 0 indicates lanes west of the centerline (or south if the roadway runs directly east- west).
sigmaz0	Initial σ_z	The initial dispersion of the plume created from the line source.	While R-LINE is not a recommended regulatory model, EPA's PM hotspot guidance recommends setting initial σ_z to the average vehicle height x 1.7/2.15 (see Guidance Appendix J.3.3, EPA-420-B-10-040)
#lanes	Number of lanes	Indicates the number of lanes, each 3.5m wide. This does not need to be an integer.	The number of lanes is used to compute the road width (assuming a 3.5 m wide lane). Road width is used to calculate the initial horizontal dispersion (σ_{y0}).
Emis	Emission rate in g/m/s or AADT	The source emission rate per unit length.	Must be greater than zero
dw1	Distance from roadway centerline to barrier	The distance is specified as an offset from the roadway centerline.	*dCL* > 0 indicates barriers east of the centerline (or north if the roadway runs directly east- west). *dCL* < 0 indicates barriers west of the centerline (or south if the roadway runs directly east-west).
Hw1	Height of the barrier (m)		
dw2 and Hw2	Unused		Placeholders for future development.
Depth	Depth of roadway depression (m)	Depth relative to the surround terrain of the roadway cut.	
wTop	Width at top (m)	Width of opening for depressed roadway.	
wBottom	Width at bottom (m)	Width of depression at the bottom of the cut.	This value can be larger than the width of the actual roadway if shoulders or other areas are within the depression.

2.1.3 Receptor Input File (e.g., *Receptor_Example.txt*)

The receptor filename is specified in the *Line_Source_Inputs.txt* file.

The user is required to include three lines of header text though these lines are not processed by R-LINE. Each line thereafter specifies the *X*, *Y*, and *Z* location of a receptor. Comment lines (indicated with an initial ‘!’) and blank lines are permitted. The ‘!’ must appear in the first column of the comment line or an error will occur.



```
Receptor Input File
X_coordinate  Y_Coordinate  Z_Coordinate
---------------------------------------------
!Receptors in the north-east quadrant
10  10  1.5
10  20  1.5
10  30  1.5
10  40  1.5
10  50  1.5
10  75  1.5
10  100 1.5
20  10  1.5
20  20  1.5
20  30  1.5
20  40  1.5
20  50  1.5
20  75  1.5
20  100 1.5
30  10  1.5
30  20  1.5
30  30  1.5
30  40  1.5
30  50  1.5
30  75  1.5
30  100 1.5
40  10  1.5
40  20  1.5
40  30  1.5
40  40  1.5
40  50  1.5
40  75  1.5
40  100 1.5
50  10  1.5
50  20  1.5
50  30  1.5
50  40  1.5
50  50  1.5
50  75  1.5
50  100 1.5
75  10  1.5
```

Figure 5. An example receptor file, where one receptor is on each line and the receptors are each specified with their *X*, *Y*, and *Z* coordinate in the user defined coordinate system.

2.1.4 Surface Meteorology File (e.g., *Met_Example.sfc*)

The surface meteorology file name is specified in the *Line_Source_Inputs.txt* file.

The model uses surface meteorology provided by the AERMET model (the meteorological preprocessor for AERMOD). Alternatively, user-supplied meteorology is acceptable providing the parameters are in the same order as in the AERMET surface file. The R-LINE model can read a more free-form surface file than AERMOD will, so the example file provided (*Met_Example.sfc*) does not have all of the proper formatting for use with AERMOD (e.g., spacing, tabs, etc.). From the AERMET surface file, R-LINE uses the surface friction velocity (u_*, m s^{-1}), the convective velocity scale (w_*, m s^{-1}), the heights of both the convectively-generated and mechanically-generated boundary layer (m), the Monin-Obhukov length (L_{mo}, m), the surface roughness length (z_0, m), the wind speed (m s^{-1}) and direction (degrees) at reference height, and that reference height (m). The reference height should be within the surface layer without being in the immediate influence of nearby obstacles. The date/time information is transferred to the output file, but is not used by the model. Each line in the surface meteorology file is assumed to represent hourly averaged values.

2.2 Program Files

Table 4 lists the R-LINE FORTRAN source code files. The main program file is RLINE_Main.f90.

Table 4. R-LINE code listing.

File Name	Description
Main program and modules	
RLINE_Main.f90	The MAIN program that calls all subroutines
Data_Structures.f90	Module defining variable types for meteorological, receptor and source variables
Line_source_data.f90	Module declaring global variables used by the program
Subprograms for reading inputs and setting up look-up table	
Read_Line_Source_Inputs.f90	Reads inputs from *Line_Source_Inputs.txt*
Read_Met_Inputs.f90	Reads inputs from surface meteorological file
Read_Receptors.f90	Reads inputs from receptor file
Read_Sources.f90	Reads inputs from source file
Compute_File_Size.f90	Determines the number of entries in an input file
Create_Exp_Table.f90	Creates a look-up table based on arguments of the built-in exponential function to improve computation time
Expx.f90	Looks up the value of exp(x) in a look-up table created by Create_Exp_Table.f90
Subprograms for calculating concentrations and integrating point sources	

Fill_Met.f90	Assigns meteorological values in the surface meteorology file to global variables
Compute_Met.f90	Calculates σ_v using u_* and w_*
Translate_Rotate.f90	Translates and rotates the sources and receptors based on the hourly wind direction; adds displacements for source configurations
Numerical_Line_Source.f90	Calculates the contribution to concentration at a receptor due to a line source using Romberg integration of a series of point sources
Point_conc.f90	Calculates the direct plume contribution of a point source using Gaussian dispersion
Meander.f90	Calculates the meander contribution of a point source assuming that the material spreads out radially in all directions
Polyinterp.f90	Interpolation scheme used in Romberg integration
Sigmay.f90	Calculates the horizontal plume spread
Sigmaz.f90	Calculates the vertical plume spread including source configuration effects
MOST_Wind.f90	Calculates the wind speed from similarity theory
Effective_Wind.f90	Calculates the mean plume height and calls MOST_Wind to get the wind speed at that height

Subprograms for calculating concentrations using an analytical solution	
Anlaytical_Line_Source.f90	Computes concentrations using an analytical solution (instead of using Numerical_Line_Source)
Analytical_Line_Parallel.f90	Computes concentrations with wind parallel to the line source using an analytical solution

Subprograms for calculating source displacements due to roadway features	
Barrier_Displacement.f90	Calculates a vertical displacement of the source to account for the effect of a roadside barrier
Depressed_Displacement.f90	Calculates a horizontal displacement of the source to account for the effect of a depressed roadway

Subprograms for writing output files and deallocating arrays	
Write_Hourly_All.f90	Writes the calculated hourly concentrations for each receptor location and each hour of meteorology (all in one file)
Write_Hourly_by_Month.f90	Writes the calculated hourly concentrations for each receptor location and each hour of meteorology (in files organized by month).
Write_Daily_Ave.f90	Writes the calculated 24-hr average (calendar day) concentrations for each receptor location
Deallocate_arrays.f90	Deallocates arrays at end of program

2.3 Output Files

The user has both hourly and daily-average output file options. All output filenames are built off the filename supplied by the user in the *Line_Source_Inputs.txt* file (see Table 5).

Table 5. Output files created by R-LINE.

File Name	Description
*Output_Example.csv** (Output option 3: 'A')	Computed hourly concentration at each receptor location for each time period in the surface meteorology file.
Output_Example_MM-YY.csv (Output option 3: 'M')	Computed hourly concentration at each receptor location for each time period in the surface meteorology file during the year, YY, and month, MM (where YY and MM are two digit numbers).
Output_Example_Dailyave.csv (Output option 2: 'Y')	Computed daily average concentrations at each receptor location for each calendar day in the surface meteorology file.
**file name specified by the user in the* Line_Source_Inputs.txt *file*	

Output_Example.csv. This filename is specified in the *Line_Source_Inputs.txt* file. The header lines report the R-LINE version number, input source, receptor and surface files used, the input error limit and displacement height, and a summary of the options used. Columns headings are given. Results are reported for all receptors for a given hour before advancing to the next hour. All output is in one file.

Output_Example_MM-YY.csv. This filename is built off the filename specified in the *Line_Source_Inputs.txt* file. The header lines report the R-LINE version number, input source, receptor and surface files used, the input error limit and displacement height, and a summary of the options used. Columns headings are given. Results are reported for all receptors for a given hour before advancing to the next hour. Results are arranged according to month and year to manage the file sizes.

Output_Example_ Dailyave.csv. This filename is built off the filename specified in the *Line_Source_Inputs.txt* file. The header lines report the R-LINE version number, input source, receptor and surface files used, the input error limit and displacement height, and a summary of the options used. Columns headings are given. Daily average results are reported for all receptors for a given calendar before advancing to the next day. All output is in one file.

If information is missing from the surface meteorology file (i.e., values reported as -999), the concentration output for that hour will be -99 for all receptors.

	A	B	C	D	E	F	G	H
1	RLINEv1_2							
2	SOURCE FILE: Source_Example.txt (8 Sources)							
3	RECEPTOR FILE: Receptor_Example.txt (196 Receptors)							
4	SURFACE FILE: Met_Example.sfc							
5	Error Limit: 1.000E-03							
6	Displacement Height: 5.000*z0							
7	Concentrations from: Plume and Meander							
8	Roadway configurations used: N							
9	Roadway #Lanes Option : N							
10	Integraton option: Numerical							
11								
12	Year	Julian_Day	Hour	X-Coordinate	Y-Coordinate	Z-Coordinate	C_G1	C_G2
13	12	264	1	10	10	1.5	1.70E+06	6.78E+05
14	12	264	1	10	20	1.5	1.70E+06	4.22E+05
15	12	264	1	10	30	1.5	1.70E+06	3.13E+05
16	12	264	1	10	40	1.5	1.70E+06	2.46E+05
17	12	264	1	10	50	1.5	1.69E+06	2.00E+05
18	12	264	1	10	75	1.5	1.69E+06	1.32E+05
19	12	264	1	10	100	1.5	1.68E+06	9.59E+04
20	12	264	1	20	10	1.5	6.25E+05	6.78E+05
21	12	264	1	20	20	1.5	6.24E+05	4.22E+05
22	12	264	1	20	30	1.5	6.23E+05	3.13E+05
23	12	264	1	20	40	1.5	6.21E+05	2.45E+05
24	12	264	1	20	50	1.5	6.20E+05	2.00E+05
25	12	264	1	20	75	1.5	6.16E+05	1.32E+05
26	12	264	1	20	100	1.5	6.12E+05	9.58E+04
27	12	264	1	30	10	1.5	3.78E+05	6.78E+05
28	12	264	1	30	20	1.5	3.77E+05	4.22E+05
29	12	264	1	30	30	1.5	3.77E+05	3.13E+05
30	12	264	1	30	40	1.5	3.76E+05	2.45E+05
31	12	264	1	30	50	1.5	3.75E+05	2.00E+05
32	12	264	1	30	75	1.5	3.72E+05	1.32E+05
33	12	264	1	30	100	1.5	3.69E+05	9.56E+04
34	12	264	1	40	10	1.5	2.69E+05	6.78E+05
35	12	264	1	40	20	1.5	2.68E+05	4.22E+05
36	12	264	1	40	30	1.5	2.67E+05	3.13E+05

Figure 6. An example hourly output file. The first three columns report the year, Julian day, and hour of day from the surface meteorology file. The next three columns are the x-, y-, and z-coordinates from the receptor file (in m). The final columns are the computed concentrations for each source group (in µg m^{-3} if the source emission rates was in g $(m\ s)^{-1}$).

	A	B	C	D	E	F	G	H
1	RLINEv1_2							
2	SOURCE FILE: Source_Example.txt (8 Sources)							
3	RECEPTOR FILE: Receptor_Example.txt (196 Receptors)							
4	SURFACE FILE: Met_Example.sfc							
5	Error Limit: 1.000E-03							
6	Displacement Height: 5.000*z0							
7	Concentrations from: Plume and Meander							
8	Roadway configurations used: N							
9	Roadway #Lanes Option : N							
10	Integraton option: Numerical							
11								
12	Year	Julian_Day	# Hours	X-Coordinate	Y-Coordinate	Z-Coordinate	C_G1	C_G2
13	12	264	10	10	10	1.5	1.42E+06	1.45E+06
14	12	264	10	10	20	1.5	1.42E+06	9.24E+05
15	12	264	10	10	30	1.5	1.42E+06	7.06E+05
16	12	264	10	10	40	1.5	1.42E+06	5.69E+05
17	12	264	10	10	50	1.5	1.42E+06	4.74E+05
18	12	264	10	10	75	1.5	1.42E+06	3.30E+05
19	12	264	10	10	100	1.5	1.42E+06	2.49E+05
20	12	264	10	20	10	1.5	9.43E+05	1.45E+06
21	12	264	10	20	20	1.5	9.44E+05	9.24E+05
22	12	264	10	20	30	1.5	9.44E+05	7.06E+05
23	12	264	10	20	40	1.5	9.45E+05	5.69E+05
24	12	264	10	20	50	1.5	9.45E+05	4.74E+05
25	12	264	10	20	75	1.5	9.45E+05	3.29E+05
26	12	264	10	20	100	1.5	9.46E+05	2.48E+05
27	12	264	10	30	10	1.5	7.32E+05	1.45E+06
28	12	264	10	30	20	1.5	7.32E+05	9.24E+05
29	12	264	10	30	30	1.5	7.32E+05	7.06E+05
30	12	264	10	30	40	1.5	7.33E+05	5.69E+05
31	12	264	10	30	50	1.5	7.33E+05	4.74E+05
32	12	264	10	30	75	1.5	7.34E+05	3.29E+05
33	12	264	10	30	100	1.5	7.35E+05	2.48E+05
34	12	264	10	40	10	1.5	5.92E+05	1.45E+06
35	12	264	10	40	20	1.5	5.93E+05	9.24E+05
36	12	264	10	40	30	1.5	5.94E+05	7.06E+05

Figure 7. An example daily average output file. The first two columns report the year and Julian day. The third column reports the number of hours used in the daily average. The next three columns are the x-, y-, and z-coordinates from the receptor file (in m). The final columns are the computed concentrations for each source group (in µg m^{-3} if the source emission rates was in g $(m\ s)^{-1}$).

3 Examples

3.1 Example 1 - Crossed roadways

A set of example input files are provided to demonstrate the use of R-LINE. The files are:

- *Line_Source_Inputs.txt*
- *Source_Example.txt* and *Source_ Example_dCL.txt*
- *Receptor_Example.txt*
- *Met_Example.sfc*

The line sources are set up EAST-WEST or NORTH-SOUTH and have equal emission rates of 1 g $(m\ s)^{-1}$. The two source example files specify the same set of sources in two different ways. One, *Source_Example.txt*, specifies the end points of each lane of traffic with *dCL* = 0 (*dCL* is the lane offset from the road centerline). The other, *Source_ Example_dCL.txt*, specifies the endpoints of the centerline of the roadway and uses *dCL* to indicate the distance of each lane from that centerline. Both source files produce the same results. The concentrations shown in Figures 9 & 10 are from the first two hours in the surface meteorology file, when the atmospheric conditions are stable. The concentrations shown are in $\mu g\ m^{-3}$.

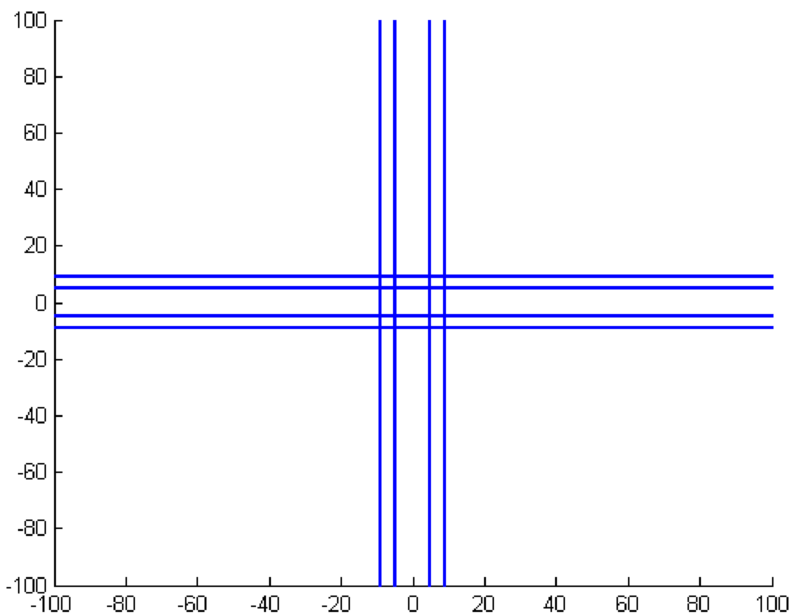


Figure 8. Example sources, units (m).

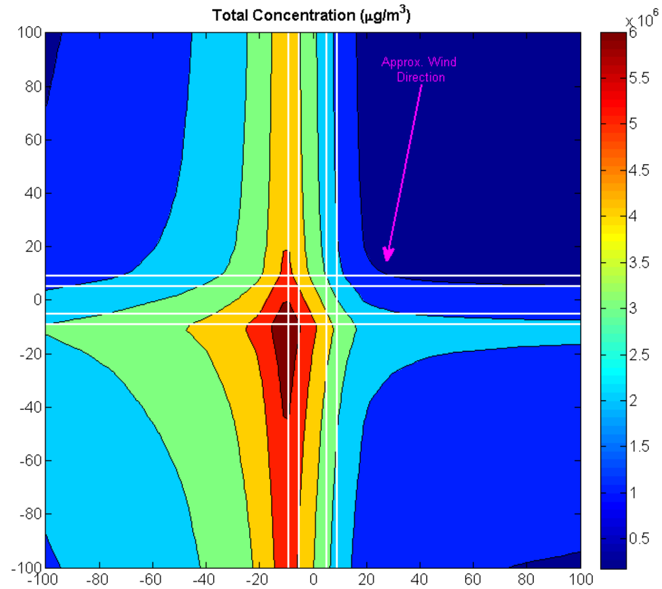


Figure 9. Plot of concentrations (μg m^{-3}) for the first hour of meteorology for the provided example. Wind direction is 17° (shown by pink arrow).

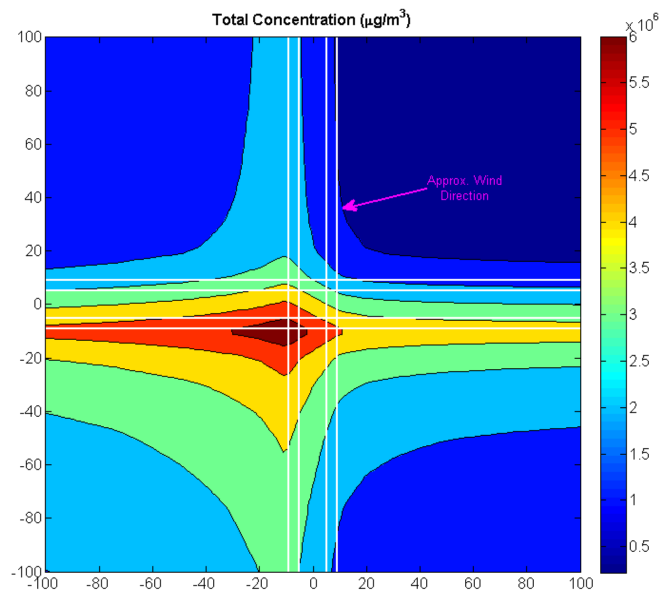


Figure 10. Plot of concentrations (μg m^{-3}) for the second hour of meteorology for the provided example. Wind direction is 68° (shown by pink arrow).

3.2 Example 2 - Curved roadways

Curved roadways can be modeled as a series of straight-line road links to capture the effect of the curvature. The number of links to use depends on the proximity of the receptors of interest to the roadway and is a matter of judgement by the user. Figure 11 shows a curved roadway simulated with six, two and one road links (with constant emissions) to demonstrate the effect. In this example, the wind direction is 17°. Sample input files for this example are not included in the release documentation.

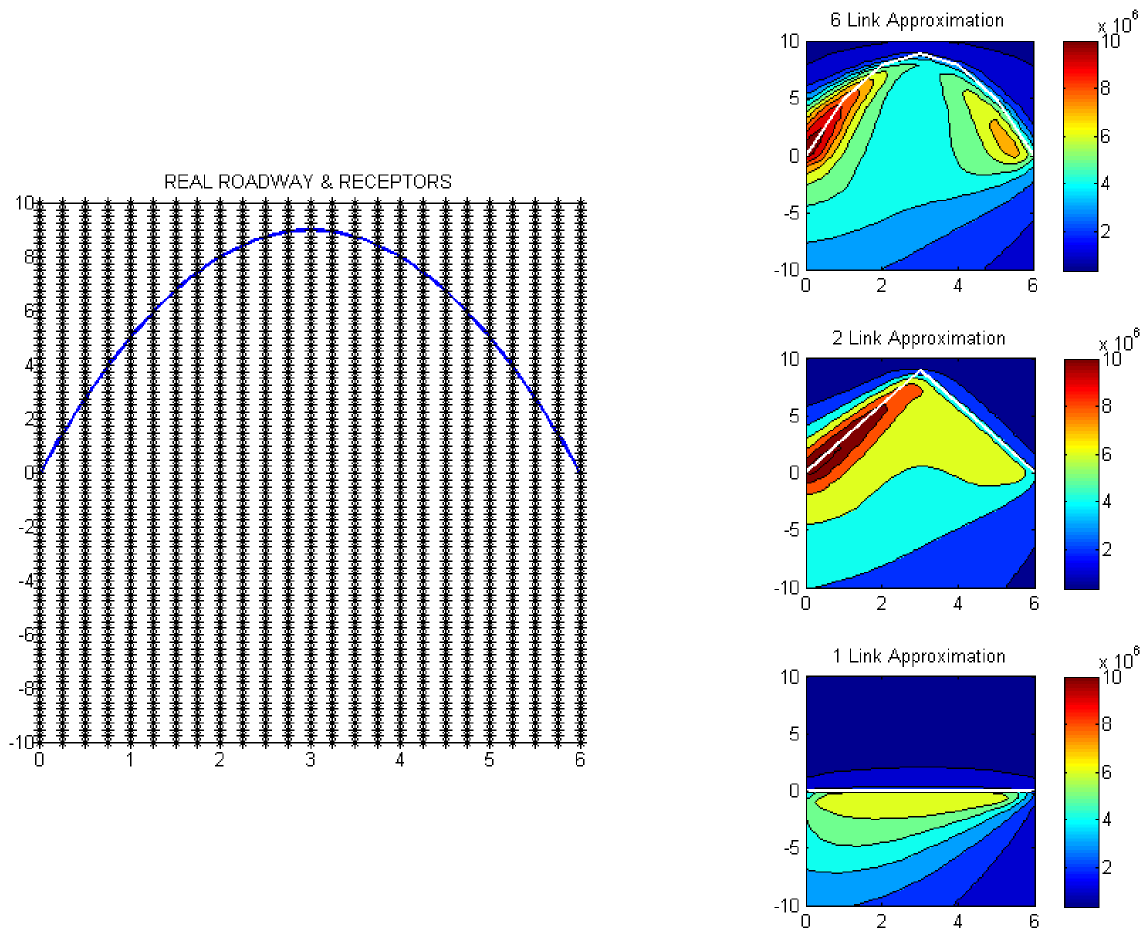


Figure 11 Curved roadway example demonstrating modeling a roadway with 6, 2, and 1 straight-line links.

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Venkatram, A., Snyder, M.G., Heist, D.K., Perry, S.G., Petersen, W. B., Isakov, V., 2013. Re-formulation of Plume Spread for Near-Surface Dispersion. *Atmos. Environ*. 77, 846-855.

Appendix - Analytical Option

Included in this release of R-LINE is an algorithm that uses an analytical solution to estimate direct plume dispersion from a finite line source. The meander component of the solution uses a five-point Gaussian quadrature estimate.

This option can be considerably faster to run than the numerical option in some cases. In this appendix, the performance of the analytical algorithm is compared to that of the numerical algorithm for a few selected conditions. A thorough evaluation of the analytical option has not yet been completed, but the analytical algorithm is included in R-LINE as a beta option to give users a chance to explore its use.

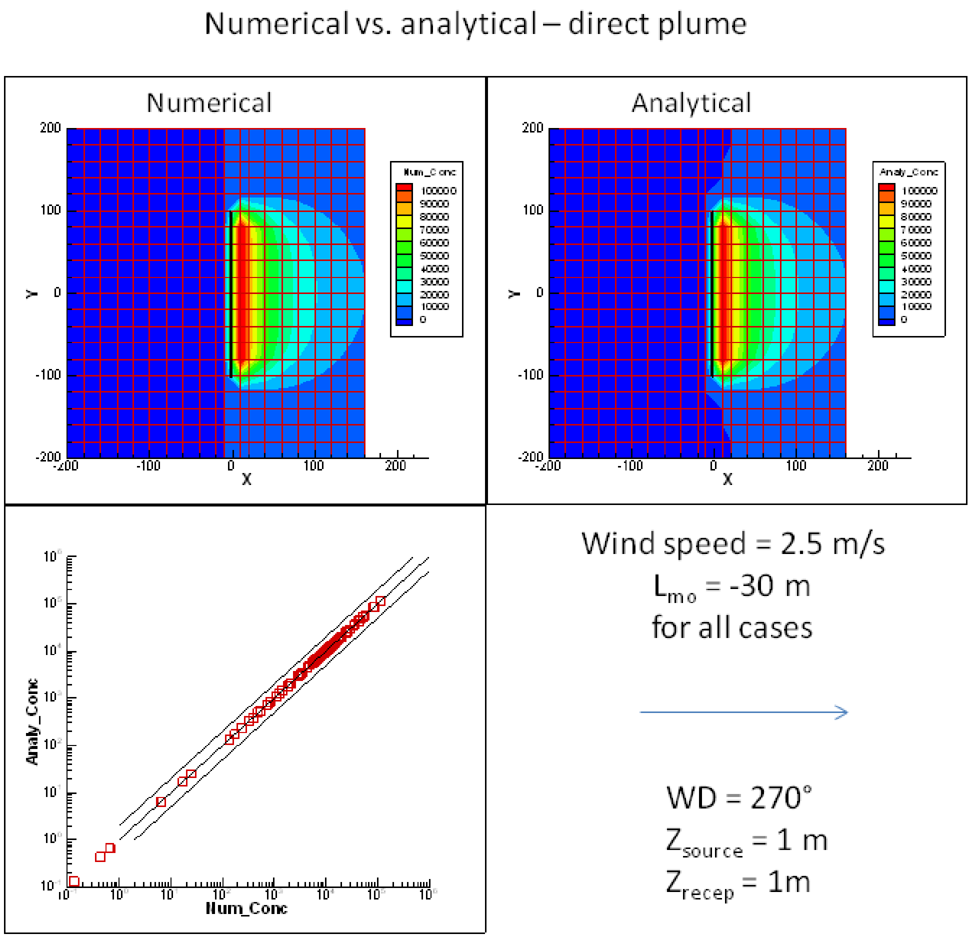

Figure A-1. Comparison of Analytical and Numerical algorithms -direct plume. Wind speed = 2.5 m s^{-1}; Wind direction = 270°; source height = 1m, receptor heights = 1m.

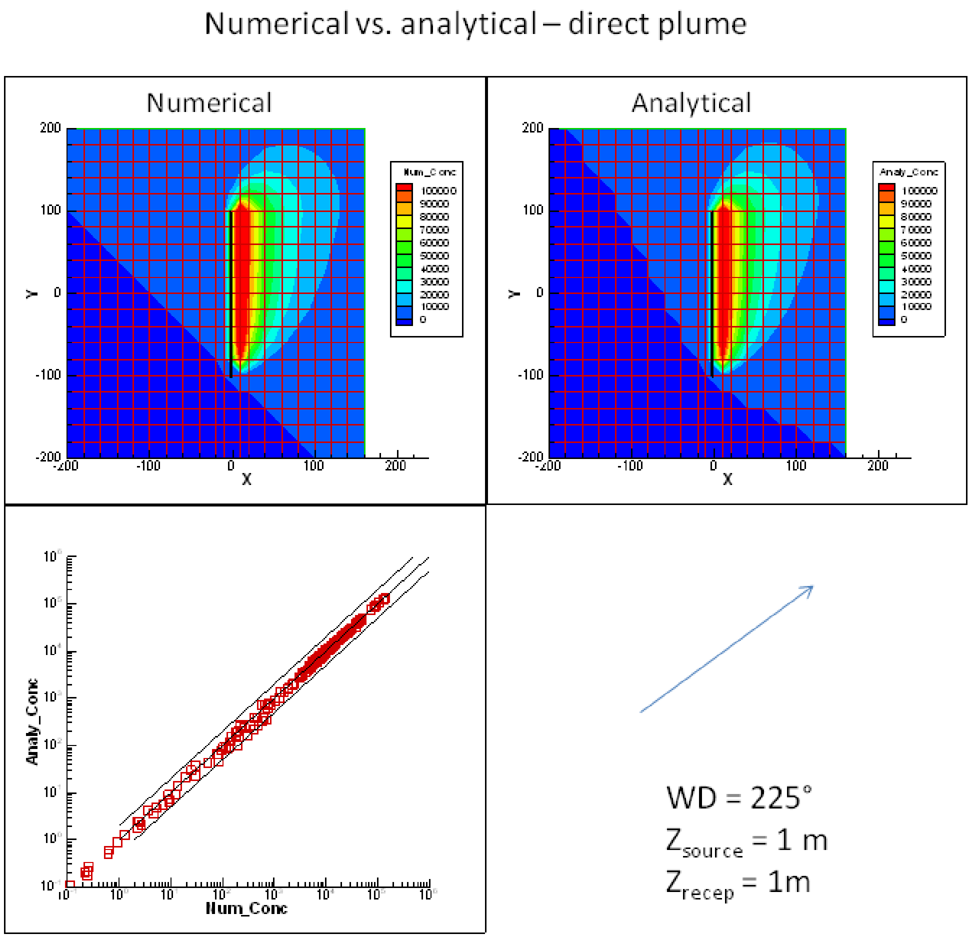

Figure A-2. Comparison of Analytical and Numerical algorithms -direct plume. Wind speed = 2.5 m s^{-1}; Wind direction = 225°; source height = 1m, receptor heights = 1m.

Numerical vs. analytical – direct plume

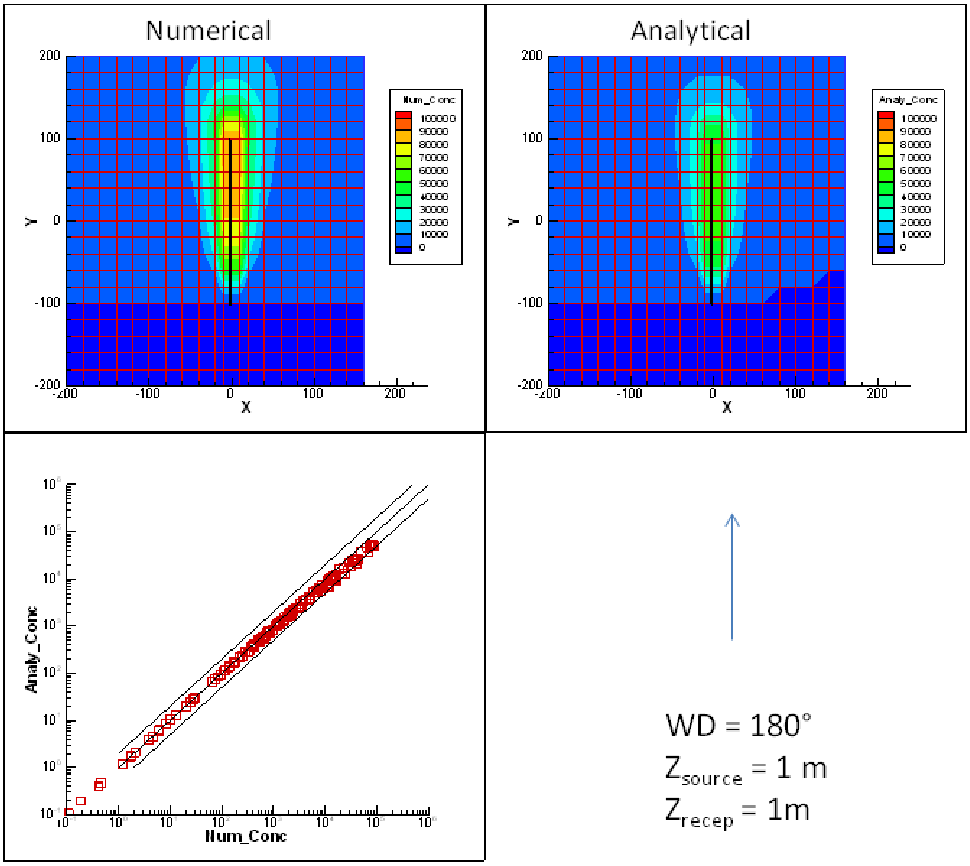

Figure A-3. Comparison of Analytical and Numerical algorithms -direct plume. Wind speed = 2.5 m s^{-1}; Wind direction = 180°; source height = 1m, receptor heights = 1m.

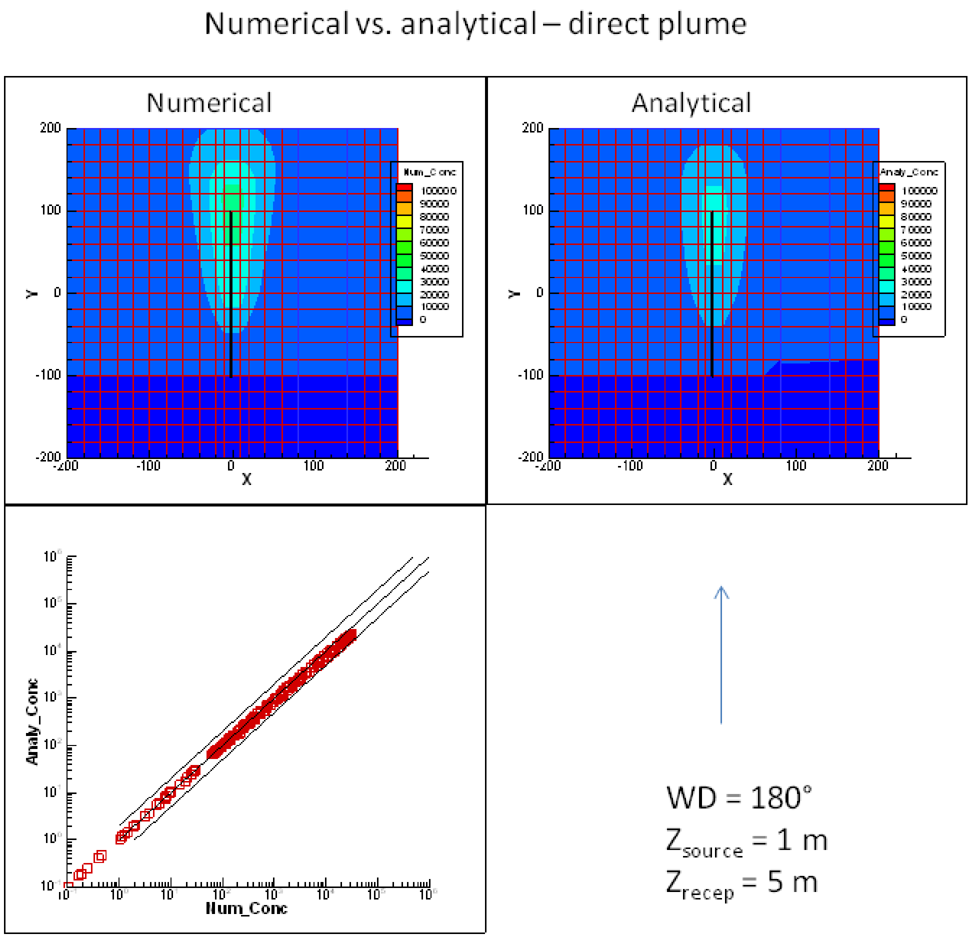

Figure A-4. Comparison of Analytical and Numerical algorithms -direct plume. Wind speed = 2.5 m s^{-1}; Wind direction = 270°; source height = 1m, receptor heights = 5m.

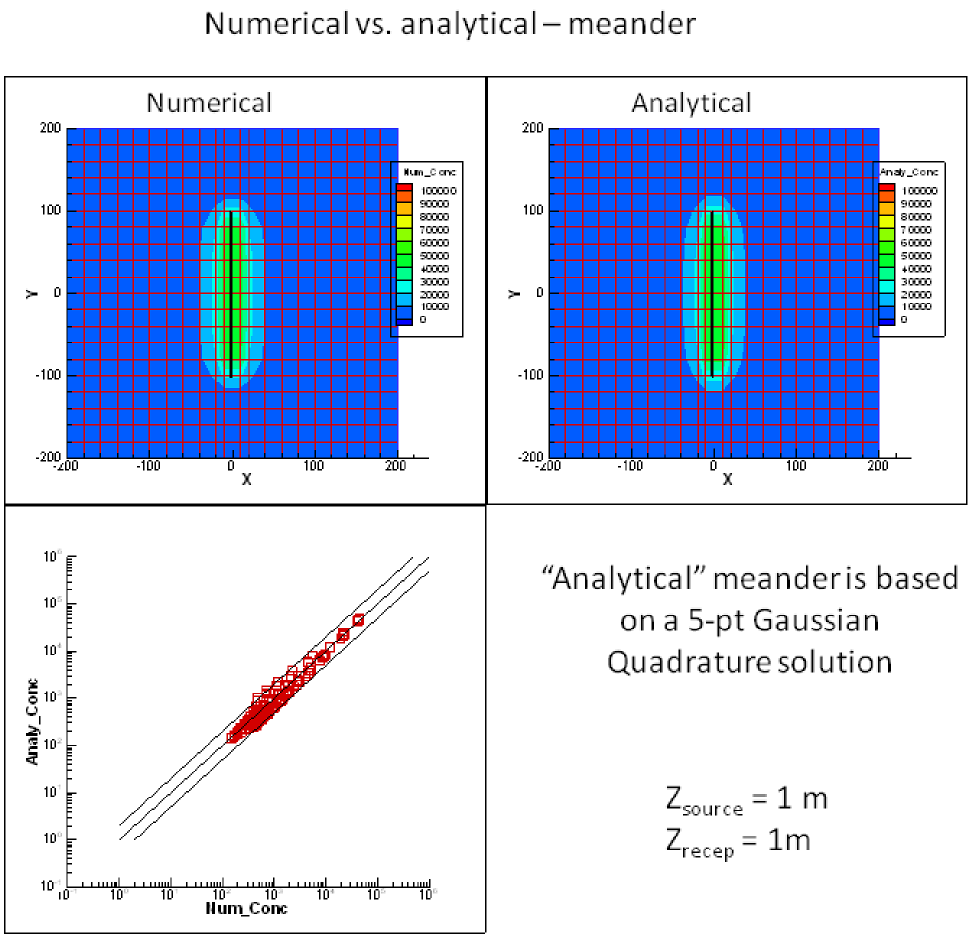

Figure A-5. Comparison of Analytical and Numerical algorithms -meander. Wind speed = 2.5 m s^{-1}; Wind direction = 270°; source height = 1m, receptor heights = 1m.

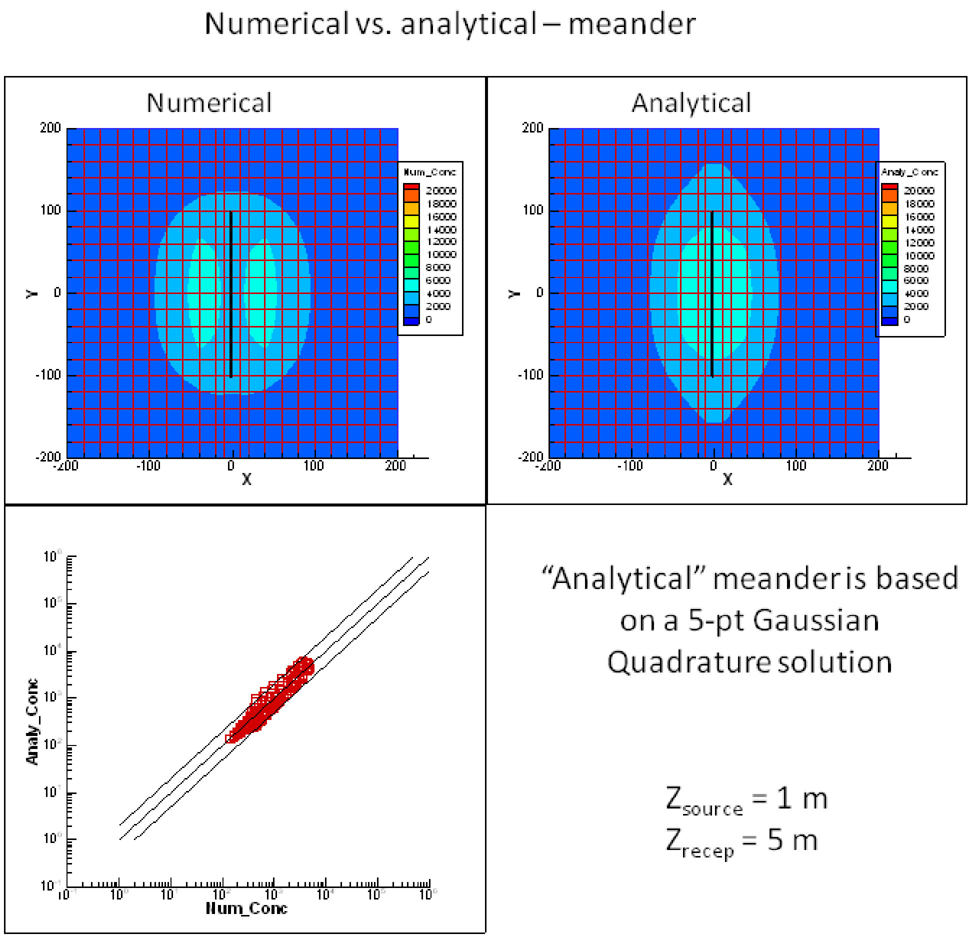

Figure A-6. Comparison of Analytical and Numerical algorithms -meander. Wind speed = 2.5 m s^{-1}; Wind direction = 270°; source height = 1m, receptor heights = 5m.

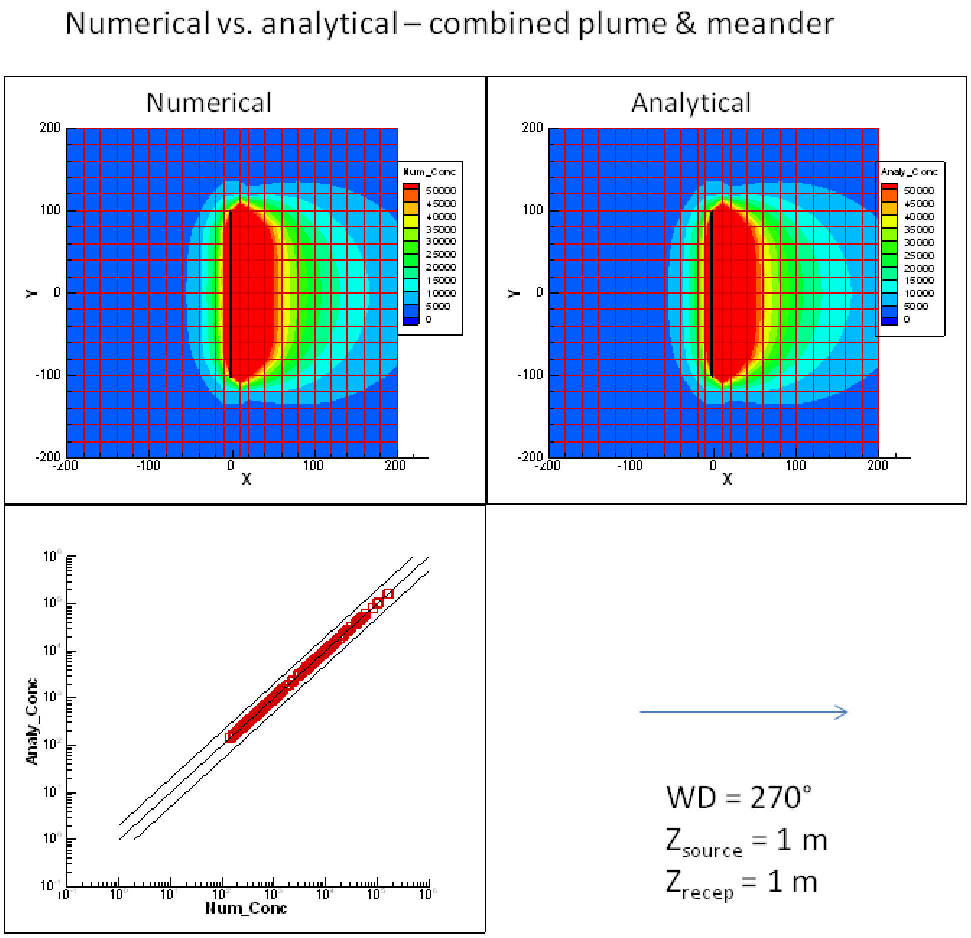

Figure A-7. Comparison of Analytical and Numerical algorithms -plume + meander. Wind speed = 2.5 m s^{-1}; Wind direction = 270°; source height = 1m, receptor heights = 1m.

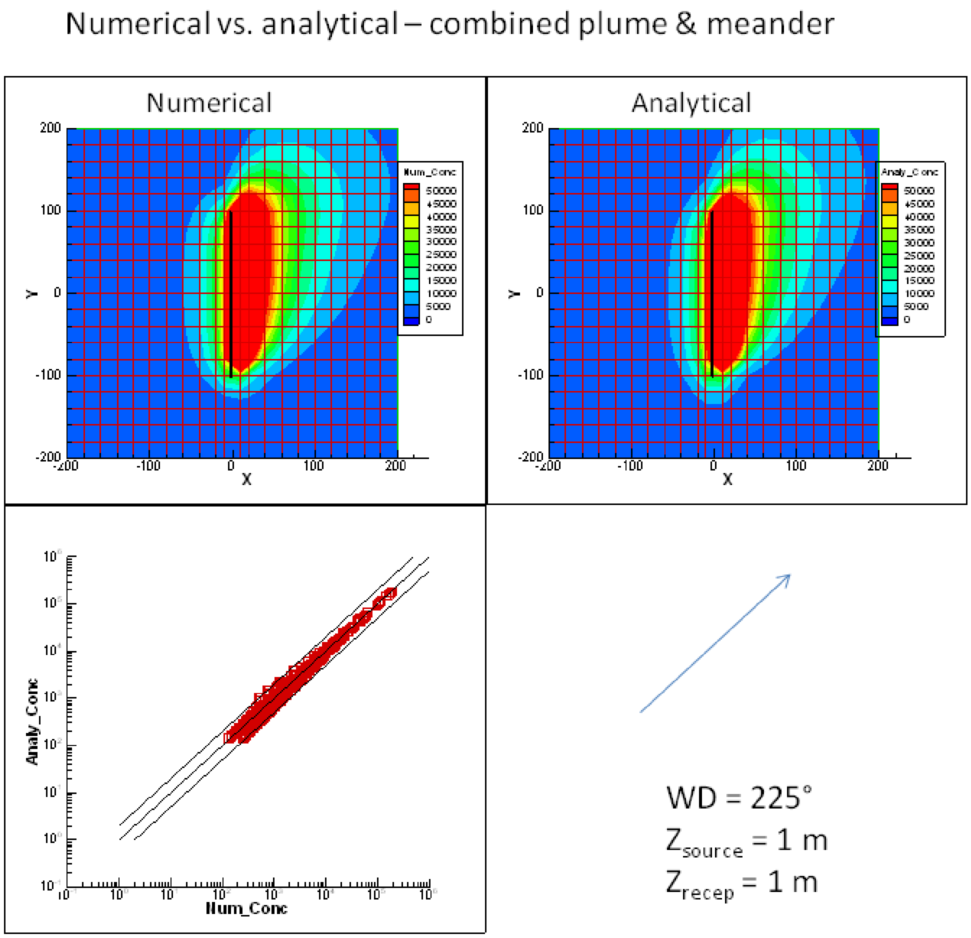

Figure A-8. Comparison of Analytical and Numerical algorithms -plume + meander. Wind speed = 2.5 m s^{-1}; Wind direction = 225°; source height = 1m, receptor heights = 1m.

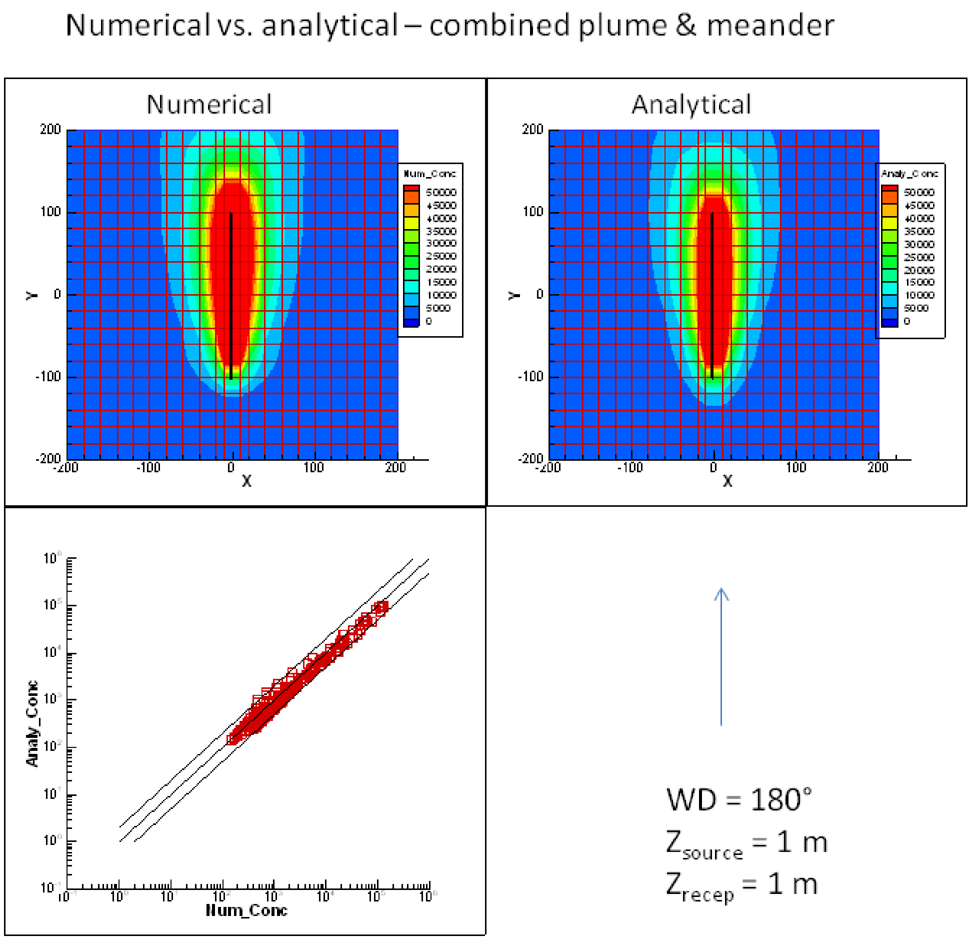

Figure A-9. Comparison of Analytical and Numerical algorithms -plume + meander. Wind speed = 2.5 m s^{-1}; Wind direction = 180°; source height = 1m, receptor heights = 1m.

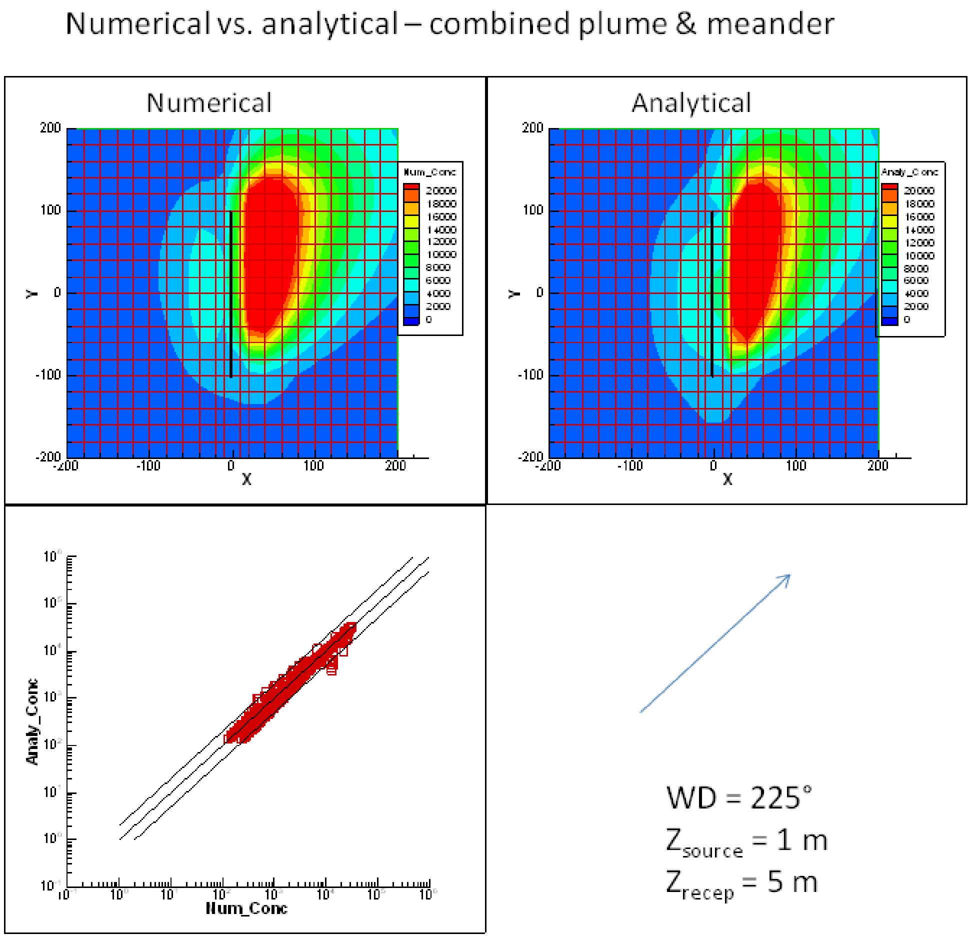

Figure A-10. Comparison of Analytical and Numerical algorithms -plume + meander. Wind speed = 2.5 m s^{-1}; Wind direction = 225°; source height = 1m, receptor heights = 5m.