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16. Abstract

Data from essentially all previous experimental programs were used to develop and verify an improved roadway dispersion model. The development of the TRAPS series of models is given here, along with a computer program employing the latest, or TRAPS II, version. The program is written as a subroutine in order to allow maximum compatibility with a large variety of computers. A listing of the subroutine and of a sample main program designed to use it are included. All input/output functions are handled by the main program. All required input values are listed along with an explanation of each term. The output terms are likewise listed and explained. In addition, the error and warning codes returned by the program as a result of invalid input parameters are explained.

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Research Report

on

TRAPS II USER'S GUIDE: ANALYTICAL AND EXPERIMENTAL ASSESSMENT OF HIGHWAY IMPACT ON AIR QUALITY

by

J. A. Bullin
J. C. Polasek

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Implementation

A study of the dispersion of pollutants from roadways is under way. Early results in the model development portion of the project indicate that existing models should be used with caution. The TRAPS pollution dispersion model was developed from the data of previous experimental programs outside Texas. An improved version of that model, called TRAPS II, is presented here along with a computer program to implement it. The new version is approximately twice as fast as its predecessor and is at least 10 times faster than any model prior to the original TRAPS model.

Disclaimer

This work was sponsored by the Texas State Department of Highways and Public Transportation in cooperation with the United States Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Please be advised that no warranty is made by the Texas State Department of Highways and Public Transportation, the Federal Highway Administration, or the Texas Transportation Institute as to the accuracy, completeness, reliability, usability, or suitability of the computer program and its associated data documentation. No responsibility is assumed by the above parties for incorrect results or damages resulting from the use of the program.

Summary

Data from essentially all previous experimental programs were used to develop and verify an improved roadway dispersion model. The development of the TRAPS series of models is given here, along with a computer program employing the latest, or TRAPS II, version. The program is written as a subroutine in order to allow maximum compatability with a large variety of computers. A listing of the subroutine and of a sample main program designed to use it are included. The subroutine itself performs no input/output functions, rather all I/O is handled by the main program. All required input values are listed along with an explanation of each term. The output terms are likewise listed and explained. In addition, the error and warning codes returned by the program as a result of invalid input parameters are discussed.

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Introduction

The TRAPS series of highway dispersion models are used to predict the carbon monoxide concentration downwind of "at grade" roadways given the site's meteorology, geometry, and traffic conditions. The associated computer programs were verified using experimental data from Virginia (Carpenter, et al., 1975), North Carolina (Noll, et al., 1973), Tennessee (Noll, et al., 1975), and California (Ranzieri, 1975). Data collected in Texas for this project were not used in verifying either the original TRAPS model or the improved TRAPS II model presented here. The original model was improved by substituting a polynomial equation for an iterative step in the program. In addition, the virtual origin is now calculated by direct iteration rather the secant method used in the original TRAPS model. This greatly reduces the required computational time. The model is presented in subroutine form to increase its utility on the many different computer systems. A sample main program calling the subroutine is also included for convenience.

The subprogram is designed to have maximum compatibility with all Fortran compilers. It does no input/output operations. It calls only three very common library functions and no external user functions. All IF statements are arithmetic. All integers fit within 16 bits. The subprogram is protected against division by zero and exponent underflow. The verification was carried out on the WATFIV compiler of an AMDAHL 470/V6 and cross checked for compatibility on a FORTRAN IV compiler of a META-4 and a Stand Alone NOVA 1200 for several cases. The subprogram is also flexible. It accepts values in either common English system units or in metric units or in a combination of both systems. It returns the most important intermediate values in English units and the carbon monoxide levels in parts per million by volume. It can calculate the concentrations for up to 100 downwind receptors.

Theory of Operation

The TRAPS series of models are somewhat unusual from a user point of view because they use a different version of the diffusion equation to calculate the dispersion downwind of a roadway as opposed to such models as Caline 2, Hiway, and Airpol 4. These other models all employ a Fickian solution to the anisotropic diffusion equation, imposing two highly restrictive boundary conditions on the system. First, the solution is based on a completely smooth site. Obstacles on the terrain must be ignored. Second, the wind shear due to velocity changes with altitude is assumed nonexistant.

The development of the TRAPS models is reported by Maldonado in his master's thesis (1976), and in papers by Maldonado and Bullin (1977), and Polasek and Bullin (1976). This series avoids these two major restrictions by using the non-Fickian solution to the diffusion equation proposed by Sutton (Pasquill, 1974).

$$\psi_{(X,Z)} = \frac{Qr}{u_1\ \Gamma(s)} \left[\frac{u_1}{r^2 K_1 X}\right]^s \exp\left[\frac{u_1 Z^r}{r^2 K_1 X}\right] \qquad (1)$$

where

- X = distance downwind of source
- Z = vertical distance above source
- $\psi_{(X,Z)}$ = CO concentration at X,Z
- Q = source strength
- u_1 = windspeed at 1 meter
- K_1 = diffusion constant
- $r = \alpha - \beta + 2 \qquad r > 0$
- $s = (\alpha + 1)/r$
- $\Gamma(s)$ = Gamma function of s
- α = constant from the power law wind equation $0 < \alpha < 1$
- β = stability constant $0.5 < \beta < 1.5$

Sensitivity analyses run on early versions of TRAPS prototypes showed that changes in the stability constant β had very little effect on the answers generated. This constant was then "fixed" at 1.0 to increase computational speed. This forces s and $\Gamma(s)$ to 1.0 as well, making the form used in the TRAPS models

$$\psi_{(X,Z)} = \frac{Q}{rK_1X} \exp\left[\frac{u_1Z^r}{r^2K_1X}\right] \qquad (2)$$

with $r = \alpha + 1$.

In order to use this equation, three meteorological parameters, u_1, K_1, α, must be calculated.

<u>Calculation of u_1, K_1, and α</u>

It has been well documented that windspeed is not constant with height, (Project Prairie Grass, 1958). The shape of the windspeed profile with height is mainly dependent on the surface roughness. One of the best equations for predicting this profile is the log law equation:

$$u_Z = \frac{u_*}{K} \ln\left(\frac{Z}{Z_o}\right) \qquad (3)$$

u_Z = windspeed at height $Z > Z_o$

u_* = friction velocity

K = von Karmon's Constant

Z_o = roughness height (0.15 times average obstacle height)

Given a wind velocity at a particular height, and an estimate of Z_o, this equation can generate the value of u_1 and u_*.

However, the nonFickian solution to the diffusion equation assumes that the wind follows a power law equation:

$$u_Z = u_1 \left(\frac{Z}{Z_1}\right)^{\alpha} = u_1 Z^{\alpha} \qquad (4)$$

for $Z_1 = 1.0$

Accordingly, an α must be estimated which gives a profile closely matching that of the power law equation. This is best done by minimizing the squared error over a representative interval. In the case of the TRAPS models, the interval of 1 to 10 meters was chosen as the best interval to fit. Since both functions are continuous in this range, the squared error can be integrated over this interval. The "α of best fit" can then be calculated iteratively. However, the original TRAPS model was modified by eliminating this iterative step through the use of a fitted polynomial equation. Examination of Equations (3) and (4) reveals that α is solely a function of z_o. The α's were then calculated for 150 different values of z_o and the results fitted to a fourth degree polynomial. This procedure reduces required computational time by approximately 50%.

Last, K_1 is estimated from an equation given by Calder (1949) to be:

$$K_1 = 0.4\ u_* \qquad (5)$$

Since the total source Q of a highway is not concentrated in a single thin line, but rather is diffused from a large area, the effect is the same as that of a line source at some distance upwind of the roadway. In order to match equation (2) to the real world, this distance must be estimated. The method used consists of independently calculating the concentration at the downwind edge of the roadway and then calculating the point in the plume that matches the concentration.

An empirical equation was used to calculate the roadedge concentration at a five foot height. This equation was obtained by dimensional analysis followed by a statistical analysis. It agrees with the form presented by Pasquill (1974). The final equation is

$$X = 3.44\ Q/(u_{10}W) \tag{6}$$

X = CO concentration at a 5 ft. height and on the downwind edge of roadway

u_{10} = 10 meter windspeed

W = width of roadway (including median)

This equation provided a better "fit" to the data from North Carolina (Noll, et al., 1975) than equations incorporating a wind direction parameter.

The result was then matched to the Gaussian plume by direct iteration. Maldonado (1976) originally used the secant method to determine the virtual origin distance. The convergence equation used is

$$X_{n+1} = \frac{Q}{rK_X} \exp\left[\frac{u_1 Z^r}{r^2 K_1 X_n}\right] \tag{7}$$

where

X_{n+1} = X of the $(n + 1)^{th}$ trial

X_n = X of the n^{th} trial

X_1 is set at three times the highway width. Convergence to plus or minus one meter usually occurs on the third or fourth trial.

Once this point is known, any downwind concentration can be calculated directly by equation (2).

Users Guide

The subroutine TRAPS II is entered from another program via a standard Fortran CALL Statement. The argument list contains 6 floating point arguments, 3 integer arguments, 2 floating point vector arguments, and a floating point matrix argument. The matrix and one integer are used as outputs by the subprogram. All other arguments are used as inputs and are returned unaltered. The seven most important intermediate variables are calculated in a labeled common to make them available to the calling program if desired.

The program was set up to take English units as its default system, with metric units as an alternate system to save the user from conversion problems. The values returned by the subprogram are either English or systemless. In order to specify a value in its primary units, the user need only input it positive. In order to input a value in metric units, the user needs to input it as a negative value. The subprogram will change its sign and convert it to the appropriate units.

The argument list is given in the subprogram source listings. It is reproduced here with additional information on each argument, its limits and its meaning.

1. XHWID - The width of the highway excluding shoulders. Center medians up to 20 ft. wide may be included. Wider medians should be treated as two independent roadways and the results summed. Inputting a value of zero for this parameter results in immediate return to the calling program with an error message. Inputting a value of less than 20 ft. (the width of a two-lane roadway) results in a warning message, although execution continues. The primary units for this variable are feet and the alternate units are meters.

2. XREFH - The height of windspeed measurements. If actual windspeed data is available, this makes it unnecessary to manually calculate the 33-foot

windspeed. The subprogram can estimate it from the given data. Its primary units are feet and alternate units are meters.

3. XRUFH - The roughness height Z_o. This determines the shape of the wind profile. It is defined as 0.15 times the height of the average obstacle on the terrain. The correlations in the program which use this parameter are valid from 4 inches to 3 ft. It must also be less than XREFH for the wind velocity profile calculations to be valid. Failure to observe these limits results in an immediate return to the calling program with an error message. The primary units are feet and alternate units are meters.

4. XUBAR - The windspeed at XREFH. This parameter must be set such that the extrapolated windspeed at 33 ft. exceeds 1.2 miles per hour. The primary units are miles per hour and the alternate units are meters per second.

5. VPH - Vehicles per hour. The number of vehicles per hour which pass the site can be extrapolated from shorter time periods or taken from loop counters. No vehicles means no pollution and negative vehicles mean negative pollution levels. No alternate units are assumed.

6. EFACT - Average vehicle emission factor. The only units for this variable are grams of CO per vehicle per mile traveled. No alternate units are available. Negative emission factors mean negative pollution levels.

7. NX - Number of downwind distances where carbon monoxide levels are desired. The number must be greater than zero and less than 11. There are no units. Specification of NX and NZ (below) will result in the calculation of a concentration matrix containing NX times NZ concentration values.

8. NZ - Number of heights where carbon monoxide levels are desired. The number must be greater than zero and less than 11. There are no units.

9. X - A real vector of length NX, containing the values of the downwind distances where the concentrations are to be calculated. Units can be mixed within the vector. Primary units are feet and alternate units are meters.

10. Z - A real vector of length NZ, containing the values of the heights where carbon monoxide concentrations are desired. A value of 0 causes an immediate return to the calling program with an error code. A value of less than 3 ft. causes a warning code to be returned, although execution continues. Units can be mixed within the vector. Primary units are feet and the alternate units are meters.

11. PPM - A real matrix of size NX by NZ containing the predicted carbon monoxide concentrations at the desired distances and heights. If a warning flag has been set in the error checking section, the sign is reversed on all values in this matrix, insuring that the user will be aware of the warning. If an error condition has been detected, the subprogram sets all values to -1000000. before returning to the caller. The first subscript gives the X coordinate, and the second gives the Z coordinate. (For example, PPM (1,2) is the concentration at X(1), Z(2).) The returned units are volume parts per million.

12. JBORT - The warning and error flag. The sign of this number tells whether the subprogram executed normally, executed with a warning, or returned on encountering an error. Its magnitude tells where the <u>last</u> warning or error was found. If a warning caused a later error, only the error code will be returned. The returned codes are:

- 0 → normal return
- -1 → a value in the Z vector is less than 3 ft. The model has not been verified here.
- -2 → XHWID is less than 29 ft. The model has not been verified here.
- 1 → A value in the Z vector is 0. This would cause an exponent underflow if execution continued. Subprogram terminates immediately.

2 → XHWID is 0. This would cause a division by 0 if execution continued. Subprogram terminates immediately.

3 → XRUFH out of range. Results would be worthless if execution continued. Subprogram terminates immediately.

4 → XREFH is less than XRUFH. The wind profile calculation cannot be carried out. Subprogram terminates immediately.

5 → Windspeed at 33 ft. is less than 1.2 mile per hour. The model is known to be wrong in this range. Subprogram terminates immediately.

6 → Convergence failure in virtual origin section. The Gaussian plume cannot be matched with the roadedge concentration. Usually this is caused by a combination of narrow roadway, low windspeed, and short roughness height.

It will be noted that all errors are positive and all warnings are negative. Thus a simple arithmetic IF in the calling program is sufficient to separate the three conditions.

For users who want or need the intermediate values generated in the subprogram seven important intermediates are calculated in a labeled common block named SCRTH. The calling program can have access to these variables simply by defining a labeled common with seven floating point values and the name SCRTH.

The variables in the common are:

1. USTAR - The roughness wind velocity in miles per hour.
2. VEL(1)- The wind velocity at 3 ft. in miles per hour.
3. VEL(2)- The wind velocity at 33 ft. in miles per hour.
4. DIFFY - Vertical eddy diffusivity in square meters per second.
5. ALPHA - Power law wind equation exponent. This is dimensionless.
6. CO - Predicted roadedge carbon monoxide concentration at the 5 foot height in volume parts per million.

7. XPRIM - Virtual origin distance of the Gaussian plume in feet.

All distances in the program are measured relative to the downwind edge of the roadway. XHWID and XPRIM are measured as positive in the upwind direction. X is measured as positive in the downwind direction. All vertical distances are measured as positive up relative to ground level. The subprogram is valid only for "at grade" roadways.

Compiler Support

The subprogram uses several features which are not supported by all Fortran compilers. Small compilers and old compilers may lack one or more of the following features. A user should carefully note them, particularly if the subprogram is to be used on a minicomputer, microcomputer, or an old large machine system. Correcting any one or two of these problems would not be difficult, but correcting them all would sacrifice too much performance and flexibility to make the program useful in any system.

The required support features are:

1. Six character subprogram names.
2. Up to 12 arguments in the subprogram list.
3. Labeled Common Blocks.
4. Execution time dimensioning of subroutine argument arrays and lists.
5. Ability to call library functions from a subprogram.
6. Library functions:

   ABS(X) floating point absolute value function.

   IABS(I) integer absolute value function.

   ALOG(X) natural logarithms function.

Most compilers support all these features. If yours does not, any one can be changed easily with the addition of a few cards and a corresponding drop in program flexibility.

Computer Listing

of

Subroutine Traps II

```
      SUBROUTINE TRAPS2 (XHWID,XREFH,XRUFH,XUBAR,VPH,EFACT,NX,NZ,X,Z,PPMTRAPS1
     >,JBORT)                                                           TRAPS2
C                                                                       TRAPS3
C                                                                       TRAPS4
C                                                                       TRAPS5
C                                                                       TRAPS6
C.......................................................................TRAPS7
C       INTRODUCTION.                                                   TRAPS8
C.......................................................................TRAPS9
C     TRAPS2 IS A SUBROUTINE VERSION OF THE TRAPS ROADWAY AIR POLLUTION  TRAPS10
C     PROGRAM DEVELOPED AT TEXAS A & M UNIVERSITY'S CHEMICAL ENGINEERING TRAPS11
C     DEPARTMENT BY CESAR MALDONADO AND DR. J. A. BULLIN IN 1975.  THE   TRAPS12
C     ORIGINAL TRAPS MODEL RELIED HEAVILY ON WORK DONE BY O. G. SUTTON,  TRAPS13
C     D. B. TURNER, AND F. PASQUILL.  SOME MODIFICATIONS TO THE MODEL    TRAPS14
C     BY JOHN POLASEK AND DR. J. A. BULLIN RESULTED IN A FASTER,         TRAPS15
C     SMALLER VERSION NAMED TRAPS II, WHICH WAS USED AS THE BASIS OF     TRAPS16
C     THIS SUBROUTINE.                                                   TRAPS17
C                                                                       TRAPS18
C                                                                       TRAPS19
C     ALL DEVELOPMENTAL WORK FOR THIS SUBROUTINE WAS CARRIED OUT         TRAPS20
C     ON AN AMDAHL 470 V/6 COMPUTER, AND CROSS CHECKED ON A META-4       TRAPS21
C     COMPUTER TO TEST MULTI MACHINE COMPATIBILITY.                      TRAPS22
C.......................................................................TRAPS23
C                                                                       TRAPS24
C                                                                       TRAPS25
C                                                                       TRAPS26
C                                                                       TRAPS27
```

```
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C      DESCRIPTION OF VARIABLES.                                             TRAPS29
C...........................................................................TRAPS30
C   VARIABLE VARIABLE  PRIMARY     SECONDARY         VARIABLE               TRAPS31
C      #       NAME     UNITS        UNITS         DESCRIPTION              TRAPS32
C===========================================================================TRAPS33
C      1      XHWID     FEET        METERS      ROADWAY WIDTH.              TRAPS34
C---------------------------------------------------------------------------TRAPS35
C      2      XREFH     FEET        METERS      HEIGHT OF WINDSPEED         TRAPS36
C                                               MEASUREMENTS.               TRAPS37
C---------------------------------------------------------------------------TRAPS38
C      3      XRUFH     FEET        METERS      ROUGHNESS HEIGHT.           TRAPS39
C---------------------------------------------------------------------------TRAPS40
C      4      XUBAR     MILE/HOUR METER/SEC     WIND SPEED AT XREFHT.       TRAPS41
C---------------------------------------------------------------------------TRAPS42
C      5      VPH       VEHICLES PER HOUR       VEHICLES PER HOUR.          TRAPS43
C---------------------------------------------------------------------------TRAPS44
C      6      EFACT     GRAM/VEHICLE-MILE       EMISSION FACTOR.            TRAPS45
C---------------------------------------------------------------------------TRAPS46
C      7      NX        *****       *****       # OF DOWNWIND RECEPTOR      TRAPS47
C                                               DISTANCES.                  TRAPS48
C---------------------------------------------------------------------------TRAPS49
C      8      NZ        *****       *****       # OF RECEPTOR HEIGHTS.      TRAPS50
C---------------------------------------------------------------------------TRAPS51
C      9      X         FEET        METERS      VECTOR OF DOWNWIND          TRAPS52
C                                               RECEPTOR DISTANCES.         TRAPS53
C---------------------------------------------------------------------------TRAPS54
C     10      Z         FEET        METERS      VECTOR OF RECEPTOR HEIGHTS.TRAPS55
C---------------------------------------------------------------------------TRAPS56
C     11      PPM       PPM         *****       MATRIX OF RETURNED CO       TRAPS57
C                                               CONCENTRATIONS AT RECEPTOR TRAPS58
C                                               LOCATIONS.                  TRAPS59
C---------------------------------------------------------------------------TRAPS60
C     12      JBORT     *****       *****       ABORT CODE (0=NORMAL,<0=    TRAPS61
C                                               NONFATAL ERROR,>0=FATAL     TRAPS62
C                                               ERROR.)                     TRAPS63
C===========================================================================TRAPS64
C...........................................................................TRAPS65
C                                                                           TRAPS66
C                                                                           TRAPS67
C                                                                           TRAPS68
C                                                                           TRAPS69
```

```
C.......................................................................TRAPS70
C       DIMENSTION VARIABLES FOR SUBROUTINE.                            TRAPS71
C.......................................................................TRAPS72
      DIMENSION X(NX),Z(NZ),PPM(NX,NZ),XDIST(10),ZDIST(10)              TRAPS73
      COMMON /SCRTH/ USTAR,VEL(2),DIFFY,ALPHA,CO,XPRIM                  TRAPS74
      HITE=1.524                                                        TRAPS75
      USTAR=0.0                                                         TRAPS76
      VEL(1)=0.0                                                        TRAPS77
      VEL(2)=0.0                                                        TRAPS78
      DIFFY=0.0                                                         TRAPS79
      ALPHA=0.0                                                         TRAPS80
      CO=0.0                                                            TRAPS81
      XPRIM=0.0                                                         TRAPS82
C.......................................................................TRAPS83
C                                                                       TRAPS84
C                                                                       TRAPS85
C                                                                       TRAPS86
C                                                                       TRAPS87
C.......................................................................TRAPS88
C       CONVERT INPUT PARAMETERS AS NECESSARY TO GET TO METRIC UNITS.   TRAPS89
C.......................................................................TRAPS90
      JBORT=2                                                           TRAPS91
      HWID=-XHWID                                                       TRAPS92
      IF (HWID) 10,240,20                                               TRAPS93
   10 HWID=XHWID*0.3048                                                 TRAPS94
   20 HWID=HWID+6.096                                                   TRAPS95
      REFHT=-XREFH                                                      TRAPS96
      IF (REFHT)30,40,40                                                TRAPS97
   30 REFHT=XREFH*0.3048                                                TRAPS98
   40 RUFHT=-XRUFH                                                      TRAPS99
      IF (RUFHT) 50,60,60                                               TRAPS100
   50 RUFHT=XRUFH*0.3048                                                TRAPS101
   60 UBAR=-XUBAR                                                       TRAPS102
      IF (UBAR) 70,80,80                                                TRAPS103
   70 UBAR=XUBAR*0.44704                                                TRAPS104
   80 CONTINUE                                                          TRAPS105
      DO 100 I=1,NX                                                     TRAPS106
      XDIST(I)=-X(I)                                                    TRAPS107
      IF (XDIST(I)) 90,100,100                                          TRAPS108
   90 XDIST(I)=X(I)*.3048                                               TRAPS109
  100 CONTINUE                                                          TRAPS110
      JBORT=1                                                           TRAPS111
       DO 140 I=1,NZ                                                    TRAPS112
      ZDIST(I)=-Z(I)                                                    TRAPS113
```

```
      IF (ZDIST(I)) 110,240,120                                         TRAPS114
  110 ZDIST(I)=Z(I)*0.3048                                              TRAPS115
  120 CONTINUE                                                          TRAPS116
      IF (ZDIST(I)-1.) 130,130,140                                      TRAPS117
  130 JBORT=-1                                                          TRAPS118
  140 CONTINUE                                                          TRAPS119
C.......................................................................TRAPS120
C                                                                       TRAPS121
C                                                                       TRAPS122
C                                                                       TRAPS123
C                                                                       TRAPS124
C.......................................................................TRAPS125
C      CHECK INPUT PARAMETERS FOR VALIDITY.                             TRAPS126
C.......................................................................TRAPS127
      IF (HWID-15.) 150,160,160                                         TRAPS128
  150 JBORT=-2                                                          TRAPS129
  160 CONTINUE                                                          TRAPS130
      IF (RUFHT-0.1) 180,170,170                                        TRAPS131
  170 CONTINUE                                                          TRAPS132
      IF (RUFHT-0.8) 190,180,180                                        TRAPS133
  180 JBORT=3                                                           TRAPS134
  190 CONTINUE                                                          TRAPS135
      IF (REFHT-RUFHT) 200,200,210                                      TRAPS136
  200 JBORT=4                                                           TRAPS137
  210 CONTINUE                                                          TRAPS138
      IF ( JBORT - 1 ) 220,220,240                                      TRAPS139
C.......................................................................TRAPS140
C                                                                       TRAPS141
C                                                                       TRAPS142
C                                                                       TRAPS143
C                                                                       TRAPS144
C.......................................................................TRAPS145
C      GENERATE METEROLOGICAL PARAMETERS.                               TRAPS146
C.......................................................................TRAPS147
  220 CONTINUE                                                          TRAPS148
      USTAR=UBAR*0.4/ALOG(REFHT/RUFHT)                                  TRAPS149
      DIFFY=0.4*USTAR                                                   TRAPS150
      VEL(1)=(USTAR/0.4)*ALOG(1.0/RUFHT)                                TRAPS151
      VEL(2)=(USTAR/0.4)*ALOG(10.0/RUFHT)                               TRAPS152
      IF (VEL(2)-0.536) 230,260,260                                     TRAPS153
C.......................................................................TRAPS154
C                                                                       TRAPS155
C                                                                       TRAPS156
C                                                                       TRAPS157
C                                                                       TRAPS158
```

```
C.......................................................................
C      FATAL ERROR HANDLER.
C.......................................................................
  230 JBORT=5
  240 CONTINUE
      JBORT=IABS(JBORT)
      DO 250 I=1,NX
      DO 250 J=1,NZ
      PPM(I,J)=-1000000.
  250 CONTINUE
      GO TO 380
C.......................................................................
C
C
C
C
C.......................................................................
C      CALCULATE THE ROADEDGE CONCENTRATION.
C.......................................................................
  260 CONTINUE
      CO=(2.3753E-06*VPH*EFACT)/(VEL(2)*HWID)
C.......................................................................
C
C
C
C
C.......................................................................
C      CALCULATE THE VIRTUAL ORIGIN DISTANCE.
C.......................................................................
      ALPHA=((3.426858*RUFHT-3.828798)*RUFHT+2.03853)*RUFHT+.11283
      R=ALPHA+1.0
      VAR1=VPH*EFACT*1.73E-07*R/VEL(1)
      VAR2=VEL(1)/(R*R*DIFFY)
      XPRIM=3.5*HWID
  270 CONTINUE
      EXPRG=HITE**R*VAR2/XPRIM
      IF ( EXPRG - 50. ) 280,280,290
  280 XPRMN=VAR1*VAR2/(CO*2.7183**EXPRG)
      XPRMD=ABS(XPRIM-XPRMN)
      XPRIM=XPRMN
      IF ( 0.5 - XPRMD ) 270,270,300
  290 JBORT=6
      GO TO 240
C.......................................................................
C
C
C
C
```

```
C...........................................................................TRAPS207
C       CALCULATE THE CONCENTRATIONS AT THE DOWNWIND RECEPTORS.             TRAPS208
C...........................................................................TRAPS209
  300 CONTINUE                                                              TRAPS210
      JBORT=JBORT-1                                                         TRAPS211
      DO 360 IZ=1,NX                                                        TRAPS212
      XDIST(IZ)=XDIST(IZ) + XPRIM  - 3.048                                  TRAPS213
      IF ( XDIST(IZ) - XPRIM ) 310,310,320                                  TRAPS214
  310 XDIST(IZ)=XPRIM                                                       TRAPS215
  320 CONTINUE                                                              TRAPS216
      DO 360 IP=1,NZ                                                        TRAPS217
       EXPRG=ZDIST(IP)**R*VAR2/XDIST(IZ)                                    TRAPS218
      IF ( EXPRG - 150.) 330,330,350                                        TRAPS219
  330 PPM(IZ,IP)=VAR1*VAR2*875./(XDIST(IZ)*2.7183**EXPRG)                   TRAPS220
      IF ( JBORT ) 340,360,240                                              TRAPS221
  340 PPM(IZ,IP)=-PPM(IZ,IP)                                                TRAPS222
      GO TO 360                                                             TRAPS223
  350 PPM(IZ,IP)=0.0                                                        TRAPS224
  360 CONTINUE                                                              TRAPS225
C...........................................................................TRAPS226
C                                                                           TRAPS227
C                                                                           TRAPS228
C                                                                           TRAPS229
C                                                                           TRAPS230
C                                                                           TRAPS231
C...........................................................................TRAPS232
C       CONVERT SCRATCH PARAMETERS TO ENGLISH UNITS.                        TRAPS233
C...........................................................................TRAPS234
      IF (JBORT) 370,380,380                                                TRAPS235
  370 JBORT=JBORT+1                                                         TRAPS236
  380 CONTINUE                                                              TRAPS237
      USTAR=USTAR/0.44704                                                   TRAPS238
      VEL(1)=VEL(1)/0.44704                                                 TRAPS239
      VEL(2)=VEL(2)/0.44704                                                 TRAPS240
      CO=CO*875.0                                                           TRAPS241
      XPRIM = XPRIM/0.3048-10.                                              TRAPS242
C...........................................................................TRAPS243
C                                                                           TRAPS244
C                                                                           TRAPS245
C                                                                           TRAPS246
C                                                                           TRAPS247
C...........................................................................TRAPS248
C       RETURN TO MAIN                                                      TRAPS249
C...........................................................................TRAPS250
      RETURN                                                                TRAPS251
      END                                                                   TRAPS252
?
```

Computer Listing of Sample Main Program

This program is a simple example using the TRAPS II subroutine in a system with a card reader and line printer. The program accepts data in the following order:

Card #	Format	Columns	Name
1.	Alphabetic	1-80	Site Identification
2.	Floating Point	1-5	Reference Height (ft. or -m)
2.	Floating Point	6-10	Obstacle Height (ft. or -m)
2.	Floating Point	11-15	Background CO (PPM)
2.	Floating Point	16-20	Highway Width (ft. or -m)
2.	Integer	21-25	Number of X's
2.	Integer	26-30	Number of Z's
3.	Floating Point	F 5.0	all X's followed by all Z's (ft. or -m)
4.	Alphabetic	1-80	Case Identifier
5.	Floating Point	1-5	Windspeed (mile/hr or -meter/sec)
5.	Floating Point	6-15	Vehicles per Hour
5.	Floating Point	16-20	Emission Factor (gm/veh-mi)
6.	Integer	1-2	Flag

If Flag is positive, the program solves the case and then expects cards 4 through 6 to be repeated with different case information. If Flag is zero, the program solves the case and expects a new set of cards 1 through 6 with different site information. If Flag is negative, the program solves the case and stops. Each successive case appears on a separate page.

```
      DIMENSION X(10),Z(10),PPM(100),  TITLE (20),CASE(20),MSG(10,6)
      DATA PPM/100*0.0/,MSG/'BAD ','HEIG','HT V','ALUE',' DET','ECTE',
     A'D   ',3*'    ','HIGH','WAY ','WIDT','H OU','T OF',' RAN','GE  '
     B,3*'    ','ROUG','HNES','S HE','IGHT',' OUT',' OF ',
     C'RANG','E   ',2*'    ','ROUG','HNES','S HE','IGHT',' GRE'
     D,'ATER',' THA','N RE','FERE','NCE ','TEN ','METE','R WI',
     E'NDSP','EED ','TOO ','LOW ',3*'    ','CONV','ERGA','NCE '
     F,'FAIL','URE ','IN V','IRTU','AL O','RGI','N   '/
      COMMON /SCRTH/ USTAR,VEL(2),DIFFY,ALPHA,COR,XPRIME
      II=5
      IO=6
    1 CONTINUE
      READ (II,100) TITLE
      READ (II,110) REFHT,OBST,BKGND,HWID,NX,NZ
      RUFHT=OBST*0.15
      READ (II,120) (X(I),I=1,NX),(Z(J),J=1,NZ)
    2 CONTINUE
      READ (II,100) CASE
      READ (II,130) UBAR,VPH,EFACT
      WRITE (IO,210) TITLE, CASE
      NT=NX*NZ
      CALL TRAPS2 (HWID,REFHT,RUFHT,UBAR,VPH,EFACT,NX,NZ,X,Z,PPM,IBORT)
      IF (IBORT) 3,5,8
    3 CONTINUE
      IBORT=-IBORT
      WRITE (IO,200) (MSG(IX,IBORT),IX=1,10)
      DO 4 IX=1,NT
      PPM(IX)=-PPM(IX)
    4 CONTINUE
    5 CONTINUE
      COR=COR+BKGND
      WRITE (IO,220)UBAR,REFHT,OBST,BKGND,HWID,VPH,EFACT,COR
      WRITE (IO,230)
      DO 6 I=1,NT
      PPM(I)=PPM(I)+BKGND
    6 CONTINUE
      DO 7 J=1,NZ
      JD=NZ+1-J
      JP=NT-NX+1
      WRITE (IO,240) Z(JD),(PPM(IX),IX=JP,NT)
      NT=NT-NX
```

```
    7 CONTINUE
      WRITE (IO,250) (X(IX),IX=1,NX)
      WRITE (IO,260)
      GO TO 9
    8 CONTINUE
      WRITE (IO,270) (MSG(IX,IBORT),IX=1,10)
    9 CONTINUE
      READ (II,140) IX
      IF (IX) 10,1,2
   10 CONTINUE
      WRITE (IO,280)
      STOP
  100 FORMAT (20 A4)
  110 FORMAT (4F5.0,2I5)
  120 FORMAT (20 F5.0)
  130 FORMAT (F5.0,F10.0,F5.0)
  140 FORMAT (I2)
  200 FORMAT (' ***WARNING*** ',10A4)
  210 FORMAT ('1 SITE:  ',20A4,/,'   CASE:  ',20A4,//,' IF THE DISPLAYE'
     A,'D VALUE IS NEGATIVE, IT IS IN MINUS THE PARENTHESISED UNITS.',/)
  220 FORMAT ('       THIS CASE ASSUMES A WIND OF ',F5.1,
     A' MILES PER HOUR(METERS PER SECOND) AT',/,' A HEIGHT OF '
     B,F5.0,' FEET(METERS) OVER TERRAIN WITH OBSTACLES AVERAGING',
     CF5.1,/,' FEET(METERS) TALL.  THE BACKGROUND IN THIS AREA IS '
     D,F4.1,' PPM.  A ROADWAY ',F5.0,/,' FEET(METERS) WIDE WILL CARR'
     E,'Y ',F6.0,' VEHICLES PER HOUR,EMITTING ',F4.1,' GRAMS CO PER',/,
     F' VEHICLE MILE TRAVELED.  THE RESULTING ROADEDGE CO CONCENTRATION'
     G,' IS ',F5.1,' PPM.')
  230 FORMAT (/,4X,'HEIGHT-FEET(METER)',8X,'DOWNWIND CONCENTRATION-PPM')
  240 FORMAT (10X,F5.0,9X,'!',10F5.1)
  250 FORMAT (/,25X,10F5.0)
  260 FORMAT (30X,'DOWNWIND DISTANCE-FEET(METER)')
  270 FORMAT (' ***ERROR*** ',10A4)
  280 FORMAT ('1')
      END
```

```
//$DATA
LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
35.  13.3 2.0  165.     5    4
15.  36.  73.  79.  165. 5.   33.  51.  99.
MID MORNING
6.15 5270.      35.
1
NOON
7.65 4886.      35.
1
MIDAFTERNOON
6.45 4770.      35.
1
LATE AFTERNOON
6.81 5584.      30.
-1
/*END
?
```

SITE: LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
CASE: MID MORNING

IF THE DISPLAYED VALUE IS NEGATIVE, IT IS IN MINUS THE PARENTHESISED UNITS.

THIS CASE ASSUMES A WIND OF 6.1 MILES PER HOUR(METERS PER SECOND) AT A HEIGHT OF 35. FEET(METERS) OVER TERRAIN WITH OBSTACLES AVERAGING 13.3 FEET(METERS) TALL. THE BACKGROUND IN THIS AREA IS 2.0 PPM. A ROADWAY 165. FEET(METERS) WIDE WILL CARRY 5270. VEHICLES PER HOUR,EMITTING 35.0 GRAMS CO PER VEHICLE MILE TRAVELED. THE RESULTING ROADEDGE CO CONCENTRATION IS 4.5 PPM.

HEIGHT-FEET(METER)	DOWNWIND CONCENTRATION-PPM				
99.	2.0	2.0	2.0	2.0	2.0
51.	2.2	2.2	2.3	2.3	2.3
33.	2.7	2.7	2.7	2.7	2.7
5.	4.4	4.1	3.7	3.7	3.2
	15.	36.	73.	79.	165.

DOWNWIND DISTANCE-FEET(METER)

SITE: LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
CASE: NOON

IF THE DISPLAYED VALUE IS NEGATIVE, IT IS IN MINUS THE PARENTHESISED UNITS.

THIS CASE ASSUMES A WIND OF 7.6 MILES PER HOUR(METERS PER SECOND) AT A HEIGHT OF 35. FEET(METERS) OVER TERRAIN WITH OBSTACLES AVERAGING 13.3 FEET(METERS) TALL. THE BACKGROUND IN THIS AREA IS 2.0 PPM. A ROADWAY 165. FEET(METERS) WIDE WILL CARRY 4886. VEHICLES PER HOUR,EMITTING 35.0 GRAMS CO PER VEHICLE MILE TRAVELED. THE RESULTING ROADEDGE CO CONCENTRATION IS 3.9 PPM.

HEIGHT-FEET(METER)	DOWNWIND CONCENTRATION-PPM				
99.	2.0	2.0	2.0	2.0	2.0
51.	2.1	2.1	2.2	2.2	2.2
33.	2.5	2.5	2.5	2.5	2.5
5.	3.8	3.6	3.3	3.3	2.9
DOWNWIND DISTANCE-FEET(METER)	15.	36.	73.	79.	165.

SITE: LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
CASE: MIDAFTERNOON

IF THE DISPLAYED VALUE IS NEGATIVE, IT IS IN MINUS THE PARENTHESISED UNITS.

THIS CASE ASSUMES A WIND OF 6.4 MILES PER HOUR(METERS PER SECOND) AT A HEIGHT OF 35. FEET(METERS) OVER TERRAIN WITH OBSTACLES AVERAGING 13.3 FEET(METERS) TALL. THE BACKGROUND IN THIS AREA IS 2.0 PPM. A ROADWAY 165. FEET(METERS) WIDE WILL CARRY 4770. VEHICLES PER HOUR,EMITTING 35.0 GRAMS CO PER VEHICLE MILE TRAVELED. THE RESULTING ROADEDGE CO CONCENTRATION IS 4.2 PPM.

HEIGHT-FEET(METER)	DOWNWIND CONCENTRATION-PPM				
99.	2.0	2.0	2.0	2.0	2.0
51.	2.1	2.2	2.2	2.2	2.3
33.	2.6	2.6	2.6	2.6	2.6
5.	4.1	3.8	3.5	3.5	3.0
DOWNWIND DISTANCE-FEET(METER)	15.	36.	73.	79.	165.

SITE: LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
CASE: LATE AFTERNOON

IF THE DISPLAYED VALUE IS NEGATIVE, IT IS IN MINUS THE PARENTHESISED UNITS.

THIS CASE ASSUMES A WIND OF 6.8 MILES PER HOUR(METERS PER SECOND) AT A HEIGHT OF 35. FEET(METERS) OVER TERRAIN WITH OBSTACLES AVERAGING 13.3 FEET(METERS) TALL. THE BACKGROUND IN THIS AREA IS 2.0 PPM. A ROADWAY 165. FEET(METERS) WIDE WILL CARRY 5584. VEHICLES PER HOUR,EMITTING 30.0 GRAMS CO PER VEHICLE MILE TRAVELED. THE RESULTING ROADEDGE CO CONCENTRATION IS 4.1 PPM.

HEIGHT-FEET(METER)	DOWNWIND CONCENTRATION-PPM				
99.	2.0	2.0	2.0	2.0	2.0
51.	2.1	2.2	2.2	2.2	2.3
33.	2.6	2.6	2.6	2.6	2.5
5.	4.0	3.7	3.4	3.4	3.0
	15.	36.	73.	79.	165.
	DOWNWIND DISTANCE-FEET(METER)				

Computer Listing of Sample Main Program for an Interactive Minicpmputer System

This program is an interactive version designed for a Nova 1200. When run, the program prompts the user on the system console (unit 10), informing the user what parameter is next expected. The values are fed directly into the subroutine and printed directly as they come from it. Thus the units are as given in the Users Guide Section.

```
;       DIMENSION X(10),Z(10),PPM(100),NAME(32)
;       COMMON /SCRTH/ USTAR,VEL(2),DIFFY,ALPHA,COR,XPRME
;       IO=10
;       WRITE (IO) ' ENTER IO DEVICES.'
;       II=11
;       READ (II) II,IO
;   1   CONTINUE
;       WRITE (IO) 'SITE IDENTIFIER:  '
;       READ(II,100) NAME(1)
;       WRITE (IO) 'NO OF XS:  '
;       READ (II) I
;       WRITE (IO) ' AND THEY ARE:  '
;       READ (II) (X(J),J=1,I)
;       WRITE (IO) 'NO OF ZS:  '
;       READ (II) J
;       WRITE (IO) 'AND THEY ARE:  '
;       READ (II) (Z(K),K=1,J)
;       WRITE (IO) 'REFERENCE HEIGHT:  '
;       READ (II) REFHT
;       WRITE (IO) 'ROUGHNESS HEIGHT:  '
;       READ (II) RUFHT
;       WRITE (IO) 'HIGHWAY WIDTH:  '
;       READ (II) HWID
;   2   CONTINUE
;       WRITE (IO) 'ENTER WINDSPEED, VEHICLES PER HOUR, AND EMISSION DATA
;       READ (II) UBAR,VPH,EFACT
;       CALL TRAPS2 (HWID,REFHT,RUFHT,UBAR,VPH,EFACT,I,J,X,Z,PPM,IBORT)
;       WRITE (IO,100) NAME(1)
;       IF (IBORT) 3,4,7
;   3   CONTINUE
;       WRITE (IO) '*********WARNING: ',IBORT,' **********'
;   4   CONTINUE
;       NT=I*J
;       IF (IO .NE. 10) WRITE (10,200) REFHT,RUFHT,HWID,UBAR,VPH,EFACT
;       WRITE (IO,210) USTAR,COR,XPRME
;       DO 5 ID=1,J
;       JD=J+1-ID
;       JP=NT-I+1
;       WRITE (IO,220) Z(JD),(PPM(IX),IX=JP,NT)
;       NT=NT-I
```

```
;  5     CONTINUE
;        WRITE (10,230) (X(IX),IX=1,I)
;        WRITE (10,240)
;        READ (II) IX
;        IF (IX) 1,2,8
;  7     CONTINUE
;        WRITE (10,250) IBORT
;        READ (II) IX
;        IF (IX) 1,2,8
;  8     CONTINUE
;        STOP
;  100   FORMAT (S64)
;  200   FORMAT (' REFERENCE HEIGHT: ', F5.1,/,' ROUGHNESS HEIGHT:   ',
;       >F5.2,/,' HIGHWAY WIDTH:    ',F6.0,/,' WINDSPEED:    ',F6.2,/,
;       >' VEHICLES PER HOUR:    ',F8.0,/,' EMISSION FACTOR:    ',F3.0)
;  210   FORMAT (' ROUGHNESS VELOCITY:    ',F7.3,/,
;       >' ROADEDGE CO CONCENTRATION:    ',F5.1,/,'  VIRTUAL ORIGIN:    ',
;       >F7.0,/,/,/,9X,'Z',10X,'CO IN PPM')
;  220   FORMAT(5X,F6.0,10F6.1)
;  230   FORMAT (5X,'XS--->',10F6.0)
;  240   FORMAT (/,/,' ENTER  -1 FOR NEW SITE, 0 FOR NEW RUN, 1 FOR END.')
;  250   FORMAT ('*********ERROR',I2,'***************',/,
;       >' ENTER -1 FOR NEW SITE, 0 FOR NEW RUN, 1 FOR END.')
;        END
```

```
 ENTER IO DEVICES.
11,10
SITE IDENTIFIER:
 LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
NO OF XS:
5
 AND THEY ARE:
15,36,73,79,165
NO OF ZS:
4
AND THEY ARE:
5,33,51,99
REFERENCE HEIGHT:
35
ROUGHNESS HEIGHT:
2
HIGHWAY WIDTH:
160
ENTER WINDSPEED, VEHICLES PER HOUR, AND EMISSION DATA
6.15,5270,35
LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
ROUGHNESS VELOCITY:      0.859
ROADEDGE CO CONCENTRATION:      2.6
 VIRTUAL ORIGIN:       117.
```

Z		CO IN PPM			
99.	0.0	0.0	0.0	0.0	0.0
51.	0.2	0.2	0.3	0.3	0.3
33.	0.7	0.7	0.7	0.7	0.7
5.	2.5	2.2	1.8	1.7	1.2
XS--->	15.	36.	73.	79.	165.

```
ENTER  -1 FOR NEW SITE, 0 FOR NEW RUN, 1 FOR END.
0
```

```
ENTER WINDSPEED, VEHICLES PER HOUR, AND EMISSION DATA
7.65,4886,35
LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
ROUGHNESS VELOCITY:      1.069
ROADEDGE CO CONCENTRATION:      1.9
 VIRTUAL ORIGIN:       117.


         Z              CO IN PPM
        99.     0.0     0.0     0.0     0.0     0.0
        51.     0.1     0.1     0.2     0.2     0.2
        33.     0.5     0.5     0.5     0.5     0.5
         5.     1.9     1.6     1.3     1.3     0.9
     XS--->     15.     36.     73.     79.    165.

ENTER  -1 FOR NEW SITE, 0 FOR NEW RUN, 1 FOR END.
0
ENTER WINDSPEED, VEHICLES PER HOUR, AND EMISSION DATA
6.54,4770,30
LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
ROUGHNESS VELOCITY:      0.914
ROADEDGE CO CONCENTRATION:      1.9
 VIRTUAL ORIGIN:       117.


         Z              CO IN PPM
        99.     0.0     0.0     0.0     0.0     0.0
        51.     0.1     0.1     0.2     0.2     0.2
        33.     0.5     0.5     0.5     0.5     0.5
         5.     1.8     1.6     1.3     1.3     0.9
     XS--->     15.     36.     73.     79.    165.

ENTER  -1 FOR NEW SITE, 0 FOR NEW RUN, 1 FOR END.
0
ENTER WINDSPEED, VEHICLES PER HOUR, AND EMISSION DATA
6.81,5584,30
LOOP 610 AT LINK ROAD, HOUSTON TEXAS; MAY 6,1976.
ROUGHNESS VELOCITY:      0.952
ROADEDGE CO CONCENTRATION:      2.1
 VIRTUAL ORIGIN:       117.


         Z              CO IN PPM
        99.     0.0     0.0     0.0     0.0     0.0
        51.     0.1     0.2     0.2     0.2     0.3
        33.     0.6     0.6     0.6     0.6     0.5
         5.     2.1     1.8     1.5     1.4     1.0
     XS--->     15.     36.     73.     79.    165.

ENTER  -1 FOR NEW SITE, 0 FOR NEW RUN, 1 FOR END.
1
STOP
```

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