TUTORIAL PACKAGE FOR THE VISCREEN MODEL

Workbook and Diskette

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PREFACE

The U. S. Environmental Protection Agency (EPA) has prepared a two-part series of related instructional materials.

Part I contains two video tapes - on the
* Guideline on Air Quality Models (Revised) and the
* Model Clearinghouse.

Part II contains tutorials on the screening models
* SCREEN,
* TSCREEN,
* VISCREEN,
* CTSCREEN, and the refined model
* ISC2, as well as the utility computer programs
* PCRAMMET and
* WRPLOT.

To use this instructional series requires a video playback unit and monitor, preferably color, and a PC with appropriate math co-processor chip installed - available memory should be at least 640 KB RAM and 10 MB hard disk storage for some tutorials. An enhanced, 101-key keyboard is also recommended. The user should have previously obtained and read the appropriate user's guide for the model. Full or abridged texts are available for downloading from the Office of Air Quality Planning and Standards (OAQPS) Technology Transfer Network (TTN) Support Center for Regulatory Air Models (SCRAM) Bulletin Board System (BBS). Other documents are recommended for reference with some model packages.

The suggested order for completing these materials is to first view the videos on the modeling guideline and the Model Clearinghouse. Then complete the tutorials, generally in the order listed above unless there is a priority to learn one model for a specific assignment. The tutorials on the utility programs are associated with the ISC2 model, except for the one on the wind rose program. Each video is about 25 minutes long and an approximate time for completing each tutorial is given in the tutorial package. Each tutorial consists of a workbook and 1-2 floppy diskettes. The workbook covers: (1) installation and set-up of the model, (2) getting hands-on experience with the model through successively complex examples, (3) advanced topics, and (4) an appendix. The floppy disk(s) contains: (1) a README file, (2) a short "demo" of the model, (3) "zip" files of the model and examples, and (4) a utility program for installing the model on the user's PC.

When the new modeler completes a given model tutorial, he/she should understand the computer operations and input requirements associated with running that air quality model and be able to apply the model to a specific air quality assessment with minimal assistance from experienced staff. Technical assistance on running a model beyond that available within the control agency's staff can be obtained through contacts in EPA's Source Receptor Analysis Branch who are assigned to monitor requests or questions through the Teleconference Section of the SCRAM BBS.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has prepared this instructional training package on the VISCREEN model to help train and increase the proficiency of modelers, especially in State and local air pollution control agencies, in applying this personal computer (PC)-based air quality model.

The intended audience for these materials on VISCREEN is those professionals who have some technical experience using a PC and whose responsibilities now include running EPA's air quality models (1) to assess the impact of emissions from new or modified sources or air toxic releases, or (2) to replicate the model results submitted in conjunction with a number of regulatory programs. The training materials are designed to be used in the self- or one-on-one instructional mode, but can be adapted to a workshop mode, given sufficient PC's, or for "train the trainer" sessions during which an experienced modeler learns to use the materials and intends to be the instructor/mentor for new modelers in his/her agency.

To use this instructional package requires a PC with appropriate math co-processor chip installed (to avoid very long model execution times) - available memory should be at least 640 KB RAM and 2.5 MB of disk storage. The user should have previously obtained and read the "Workbook for Plume Visual Impact Screening Analysis" (EPA, 1988), which includes a technical description of the VISCREEN model.

The VISCREEN tutorial package consists of this workbook and 1 double-sided, high density floppy diskette. The workbook covers: (1) installation and set-up of the model; (2) getting hands-on experience with the model through successively complex examples; (3) advanced topics; and (4) an appendix. The floppy disk contains: (1) a README file; (2) a short "demo" of the model, SCREEND; (3) "zip" files of the model and examples; and (4) a utility program for installing the model on the user's PC. The VISCREEN tutorial is based on the VISCREEN model dated 88341, including any Model Change Bulletins issued through June 1992. Most modelers who are not familiar with the VISCREEN model can complete the tutorial in about two to four hours. The time will vary depending on the extent to which the student delves into the exercises, but does not include the time to complete the section on Advanced Topics.

When the new modeler completes the VISCREEN model tutorials, he/she should understand the computer operations and input requirements associated with running VISCREEN and be able to apply the model to a specific air quality assessment with minimal assistance from experienced staff. Technical assistance on running VISCREEN beyond that available within the control agency's staff can be obtained through contacts in EPA's Source Receptor Analysis Branch who are assigned to monitor requests or questions through the Teleconference Section of the SCRAM BBS.

1.1 PURPOSE OF THE VISCREEN MODEL

In certain areas of the nation, especially in the PSD Class I areas such as national parks and wilderness areas, the natural beauty must be protected by government regulations. There are two aspects to the assessment and enforcement of visibility problems. The first one is the plume visibility.

Sources of air pollution can cause visible plumes if emissions of particulates and nitrogen oxides are sufficiently large. A plume will be visible if its constituents scatter or absorb sufficient light so that the plume is brighter or darker than its viewing background (e.g., the sky or a terrain feature such as a mountain). Therefore, The U.S. Environmental Protection Agency (EPA) affords special visibility protection designed to prevent such plume visual impacts to observers within Class I areas. The VISCREEN model is designed as a screening model to determine the visual impact parameters for plume from a single source for this application.

Another aspect of the visibility problem is the regional haze. Regional haze is the most extensive and serious form of visibility impairment throughout the United States and in Class I areas. It is caused by emissions from multiple sources located throughout a region. A single emission source may contribute to such a problem but is generally not the sole (or even major) contributor. The protection and improvement of regional visibility must be achieved through broader regulatory action than is possible with the review of a single emission source. Regional haze analysis requires a different analysis tool: regional dispersion models. VISCREEN can not deal with the regional haze problem.

1.2 OVERVIEW OF VISCREEN

VISCREEN is designed to calculate visual effects parameters for a plume as observed from a given vantage point. The model estimates the color difference parameter (Delta-E) and the plume contrast using three wavelengths of light (0.4, 0.55, 0.7 mm) for plumes against a sky background and against a terrain background. These plume visibility concepts are described in more detail in Appendix A. VISCREEN is designed to calculate these parameters for emission sources of particulate, NO, NO_2, and soot, and results are compared to screening criteria of 2.0 for Delta-E and 0.05 for green contrast. The emissions are assumed to create an infinitely long, straight plume whose position is specified by the program user. VISCREEN can be used for the first two levels of plume visual impact screening. As implied by its name, VISCREEN is designed as a conservative screening tool. Additional analysis using a more refined plume visibility model should be conducted for sources that exceed screening criteria with VISCREEN.

VISCREEN can be applied in two successive levels of screening (Levels 1 and 2) without the need for extensive input specification. Level-1 screening assumes default particle size and density, and worst-case meteorological conditions of F stability and 1.0 m/s wind speed. Level-2 screening allows user-specified particle size and density, and user-specified worst-case meteorological conditions.

If screening calculations using VISCREEN (Level-1 or Level-2) demonstrate that during worst-case meteorological conditions a plume is either imperceptible or, if perceptible, is not likely to be considered objectionable (i.e., "adverse" or "significant" in the language of the EPA PSD and visibility regulations), further analysis of plume visual impact would not be required as part of the air quality review of a source. However, if screening demonstrates that criteria are exceeded, plume visual impacts cannot be ruled out, and more detailed plume visual impact analysis to ascertain the magnitude, frequency, location, and timing of plume visual impacts would be required. Such detailed plume visual impact analysis is called Level-3 analysis and is carried out by more sophisticated plume visibility models such as PLUVUE II.

1.3 ORGANIZATION OF THE VISCREEN WORKBOOK

This tutorial document is organized as follows: Section 1 is the overview of VISCREEN. Section 2 provides step-by-step instructions for installing the VISCREEN model and related training materials. Section 3 contains hands-on guidance for running a VISCREEN test case. Section 4 provides a step-by-step procedure for implementation of the simplest, Level-1 screening analysis. Section 5 provides guidance on Level-2 screening, including the determination of worst-case meteorological conditions. Section 6 gives more practical examples. Section 7 covers the advanced topics such as complex terrain, graphical output, ..., etc. Appendix A presents a brief description of the theory and visibility concepts of VISCREEN. Appendix B introduces the concepts of Level-3 analysis of plume visual impact, which may be needed if a source fails the Level-1 and Level-2 analyses using VISCREEN. Level-3 analyses, possibly using the PLUVUE-II model, should involve discussions with the permit granting authority, and are beyond the scope of this tutorial package.

2.0 INSTALLATION AND SETUP

This section provides information on the installation and setup of the VISCREEN model and related training materials on an IBM-compatible PC.

2.1 HARDWARE REQUIREMENTS

The VISCREEN model is an IBM PC-based program. The following hardware components are required for using the VISCREEN model training package:

- IBM-PC compatible with at least 640K bytes of RAM, and a 5 1/4 inch double-sided, high-density disk drive.
- Color monitor, EGA or better.
- Diskette provided with VISCREEN model and training materials.
- Hard disk drive (minimum of 2.5 MB of memory available).
- Math coprocessor chip is highly recommended.
- Blank diskette for use in making a backup copy of software.

The minimum hardware requirements for the VISCREEN model itself are described in the visibility screening workbook (EPA, 1988).

2.2 SETUP ON THE PC

Using the DISKCOPY command of DOS (Disk Operating System) or similar routine, make a backup copy of the VISCREEN training diskette included with this training package. Store the original VISCREEN training diskette in a safe location. The DISKCOPY command will also format the blank disk if needed.

The VISCREEN model and related training materials must be installed on a hard disk drive in order to run. To install VISCREEN on a hard disk, check the available disk space by running the DOS program CHKDSK. To check to see if the DOS programs are accessible form the PATH setting, simply type:

```
PATH
```

If the DOS sub-directory or a sub-directory containing the DOS files is listed then type:

CHKDSK

at the hard disk prompt where VISCREEN is to be installed. If not, read your DOS manual to understand what you have to do to run CHKDSK. Check to make sure that there is at least 2.5 MB of available disk space. If there is enough disk space, then proceed with the installation, otherwise remove or compress some files to free up enough disk space. A batch file has been provided that will create a VISCREEN subdirectory and install the necessary files onto the hard disk. To run the VISCREEN install program, insert the VISCREEN Training Disk 1 of 1 in the appropriate high density disk drive. If the high density drive is A:, then type:

A:INSTALLA

from the C: prompt. If the high density drive is B:, then type **B:INSTALLB** from the C: prompt. If the installation process was completed successfully (note that the install program will not run if a C:\VISCREEN directory already exists), then you should be in the C:\VISCREEN directory. The install program will copy the VISCREEN model, the VISCREEN demo program, and other files necessary to complete this workbook.

2.3 RUNNING THE VISCREEN DEMO PROGRAM

VISCRND (VISCREEN Demonstration) is a brief video presentation showing the features of the SCREEN model. VISCRND provides an overview of the basic purpose and capabilities of the VISCREEN model, and presents example runs of the VISCREEN model. VISCRND also shows examples of the VISCREEN model output. For the demo to run properly it is important for the demo program and the VISCREEN model to be installed in the same directory, as described in Section 2.2. The VISCRND program requires about 530 KB of <u>available</u> RAM in order to execute properly. If a message appears indicating that there is "not enough memory to run EGA/VGA slideshow" while running the demo, then use the DOS CHKDSK command to determine how much RAM is available, and remove any unneeded device drivers or memory-resident utility programs to free up enough memory to run the demo.

To watch VISCRND, there are a few items to note:

1. To begin the demo, make sure that you are in the C:\VISCREEN directory. Then at the DOS prompt type:

   VISCRND

2. To exit the presentation at any point, press **Alt-Q.** This will take you back to the DOS prompt.

3. To return to the beginning of the demo without exiting, press **Alt-B.**

4. To speed through the presentation press the **Space Bar**.

5. To pause anytime during the presentation, press the **Pause** key on a 101-key enhanced keyboard. Press any key to resume the demo after pausing.

6. Some screens will prompt the user for a specific input. When this occurs, it is important to respond with the appropriate keystroke for the demo to continue.

3.0 GETTING HANDS-ON EXPERIENCE

Now that the VISCREEN model has been successfully installed, we are ready to run the model and then review the results. The command line to run the sample problem might look something like this on the PC:

```
C:\VISCREEN>VISCREEN
```

The "c-prompt" of DOS has been represented by the characters "C:\VISCREEN>", but may appear differently on different machines. After completing the VISCREEN demo program, you should still be in the C:\VISCREEN directory.

Type **VISCREEN** to begin the model execution. VISCREEN is an interactive model, meaning that it prompts the user for specific inputs to be entered from the keyboard. The following is a listing of the interactive session for this test case. The user responses to the model prompts are in bold face characters.

```
==============================================

    WELCOME TO PROGRAM VISCREEN! (Ver 1.01)

==============================================

Path & file name for Summary Report
(max 40 characters including file name & extension):  MY.SUM


Path & file name for Results Output
(max 40 characters including file name & extension):  MY.TST


Input the name of the emissions source:  POWER PLANT


Input the name of the receptor (Class I area):  NATIONAL PARK
Select the units of mass for emission rates--
1=gram (g); 2=kg; 3=metric tonne (mt); 4=lb; 5=ton:
Enter no. (1-5):                1


Select the units of time for emission rates--
1=sec; 2=min; 3=hr; 4=day; 5=yr:
Enter no. (1-5):                1


Input the emission rates for the following species:
Particulates (G/S   ):      10.0
NOx (as NO2) (G/S   ):       10.0


Do you want to use default (zero) emission
rates for primary NO2, soot, and sulfate (y/n)?  Y


SUMMARY: Emissions for power plant
Particulates       10.000000 G/S
NOx (as NO2)       10.000000 G/S
Primary NO2     0.000000E+00 G/S
Soot            0.000000E+00 G/S
Primary SO4     0.000000E+00 G/S

Are these the emission rates you meant to use (y/n)?  Y
```

Input the distance between the emissions source and
the observer (in kilometers): **25.**

Input the distance between the emissions source and the
closest Class I area boundary (in kilometers): **20.**

Input the distance between the emissions source and the
most distant Class I area boundary (in kilometers): **35.**

Input the background visual range for the area (km): **150.**

Do you wish to use Level-1 default parameters (y/n)? **Y**

```
SUMMARY OF ALL EMISSIONS AND METEOROLOGICAL INPUT
Emissions for power plant in G/S:
Particulate =       10.000000
NOx         =       10.000000
Primary NO2 =    0.000000E+00
Soot        =    0.000000E+00
 Primary SO4 =    0.000000E+00
Meteorological and Ambient Data for national park
Wind speed (m/s)  =         1.000000
Stability Index   =            6
Visual Range (km) =       150.000000
Ozone Conc. (ppm) =     4.000000E-02
Plume Offset Angle=        11.250000degrees
Distances Between power plant
and national park
Source-Observer      =       25.000000 km
Min. Source-Class I  =       20.000000 km
Max. Source-Class I  =       35.000000 k
```

Input values ready for execution (y/n)? **Y**
Do you want to use the default screening threshold (y/n)? **Y**

```
OVERALL RESULTS OF PLUME VISIBILITY SCREENING

SOURCE:  power plant
CLASS I AREA:  national park

  INSIDE  class I area --
 Plume delta E EXCEEDS screening criterion for SKY background
 Plume delta E EXCEEDS screening criterion for TERRAIN background
 Plume contrast EXCEEDS screening criterion for SKY background
 Plume contrast EXCEEDS screening criterion for TERRAIN background

  OUTSIDE class I area --
 Plume delta E EXCEEDS screening criterion for SKY background
 Plume delta E EXCEEDS screening criterion for TERRAIN background
```

```
Plume contrast EXCEEDS screening criterion for SKY background
Plume contrast EXCEEDS screening criterion for TERRAIN background


 SCREENING CRITERIA:        DELTA E =  2.0
                     GREEN CONTRAST =  .050

Do you want to see calculated results for lines of
sight with maximum delta E (y/n)?  N


 Do you want to see calculations for all lines of sight (y/n)?   N


Do you want to see calculated results for lines of
sight with maximum green contrast? (y/n)  N


 Do you want to see green contrast values for all lines of sight (y/n)? N


 Do you want to quit (y/n)?  Y


 *******************

 VISCREEN summary report file is: my.sum
 VISCREEN results file is: my.tst

 *******************
```

- Now **use your favored text editor to review the file "MY.SUM".**
- **Compare "MY.TST" with the output file RESULTS.TST from the SCRAM BBS that is installed in the C:\VISCREEN directory to ensure that the model is executing properly.**

EXERCISE:

1. Re-run the test case given above, except answer "**Y**" to all of the (y/n) prompts.

4.0 VISCREEN LEVEL-1 ANALYSIS

4.1 WHAT IS LEVEL-1 SCREENING?

Level-1 screening is designed to provide a conservative estimate of plume visual impacts. These impacts would be larger than those calculated with more realistic input and modeling assumptions. In selecting a Level-1 analysis, the user accepts default values for particle size and density, and a default worst-case meteorological condition of F stability and 1.0 m/s wind speed. This worst-case meteorological condition is assumed to persist for 12 hours, with a wind direction that would transport the plume directly adjacent to the observer, as shown in Figure 4-1.

4.2 INPUT FOR THE VISCREEN LEVEL-1 STUDY

Given the use of default particle size and density and the default meteorological conditions, the VISCREEN model inputs for Level-1 analyses are limited to the following:

- emission rates for particulates and nitrogen oxides;
- distances between the emission source and (1) the observer, (2) the closest Class I boundary, and (3) the most distant Class I boundary; and
- background visual range for the Class I area of interest.

Emissions:

Before using VISCREEN, the modeler should summarize the emission rates for the following species:

(1) Primary particulate matter
(2) Nitrogen oxides (NO_x)
(3) Primary nitrogen dioxide (NO_2) (if not zero)
(4) Soot (elemental carbon) (if not zero)
(5) Primary sulfate ($SO_4^=$) (if not zero)

SO_2 emissions are not required as input to VISCREEN because over the short distances (< 200 km) and stable plume transport conditions typical of plume visual impact screening, secondary sulfate is not formed to a significant degree in plumes.

For almost every emission source, the emission rates of the last three species (primary NO_2, soot, and sulfate) can be assumed to be zero. Therefore you need only input the total particulates and NO_x emission rates (the first two categories of emissions required by VISCREEN). However, if NO_2 is directly emitted from the emission source (e.g., from a chemical process such as a nitric acid plant) as opposed to being formed in the atmosphere from NO_x emissions, this primary NO_2 can be considered. Even if primary NO_2 emissions are set to zero, VISCREEN assumes that 10 percent of NO_x emissions is initially converted to NO_2 either within the stack of the source or within the first kilometer of plume transport.

If soot is known to be emitted (e.g., if diesel vehicles are a component of the emissions source), its emission rate should be provided separately from that of other particulates.

Finally, some sources (such as oil-fired power plants or smelters) may have a significant component of primary sulfate in a size range that has maximum light scattering efficiency. If so, primary sulfate emissions should be specified and input separately from either particulate or soot.

Emission rates should be the maximum short-term rates expected during the course of a year. The values used for plume visual impact screening generally would be the maximum emission rates for which the air quality permit is being applied and would correspond to those used for short-term (i.e., 1-, 3-, and 24-hour average) air quality impact analyses.

The user may specify the units to be used for inputting the emission rates. VISCREEN will prompt the user for his/her choice of units of mass (e.g., grams, kilograms, metric tonnes, pounds, or tons) and time (e.g., seconds, minutes, hours, days, or year). Thus, emissions can be specified in g/s or ton/yr or whatever combination is desired.

Distances:

In order to determine the distance variables needed for the Level-1 analysis with VISCREEN, the user should first obtain a topographic map of the area with an appropriate scale. The screening analysis assumes that the observer is located at the boundary of the Class I area that is closest to the emission

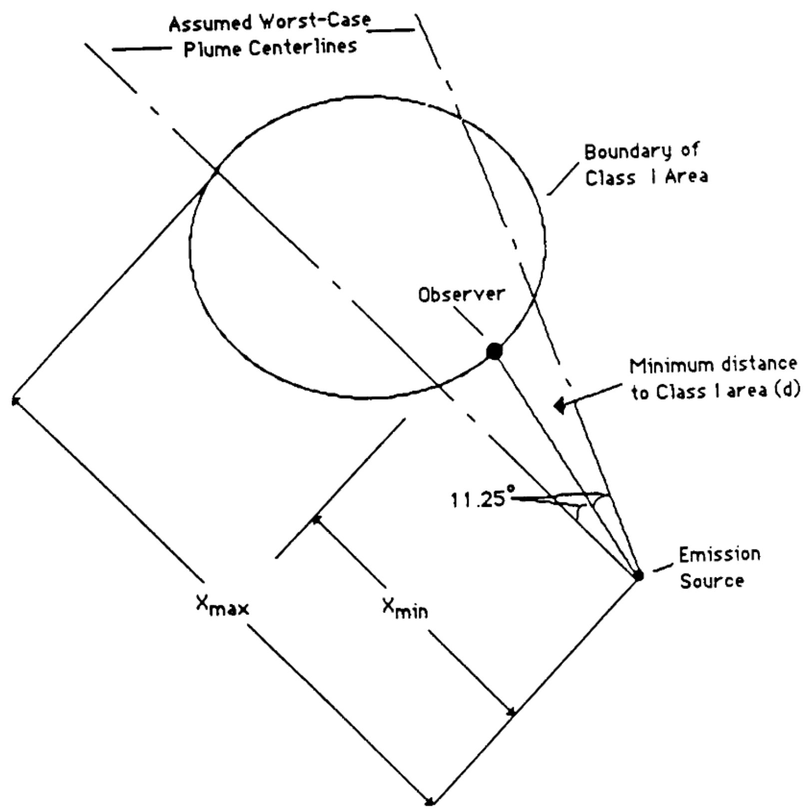

Figure 4-1. Determining Distances for Level-1 Screening

source. The user should then determine the distance between the emission source and the assumed observer location on the boundary of the Class I area (d in Figure 4-1). The modeler should then draw plume centerlines offset by half a 22.5 degree sector width (i.e., 11.25 degree) on either side of this hypothetical, worstcase observer location as shown in Figure 4-1. The modeler should determine the downwind distances (along these assumed plume centerlines) to the closest (x_{min}) and most distant (x_{max}) Class I area boundaries, respectively (even if these two distances are on opposite sides of the observer). If x_{min} is greater than d, set x_{min} equal to d for the sake of conservatism. There may be certain shapes of Class I areas where the plume centerlines drawn on opposite sides of the observer cross the Class I boundary more than once. In such cases the smallest x_{min} and the largest x_{max} should be used to be conservative (see Figure 4-2).

Background visual range:

The last input needed to perform a Level-1 screening analysis is the background visual range of the region in which the Class I area is located. Figure 4-3 provides recommended background visual ranges for the contiguous United States. The modeler may also consult with the Federal Land Manager for more representative background visual range values for the area being modeled.

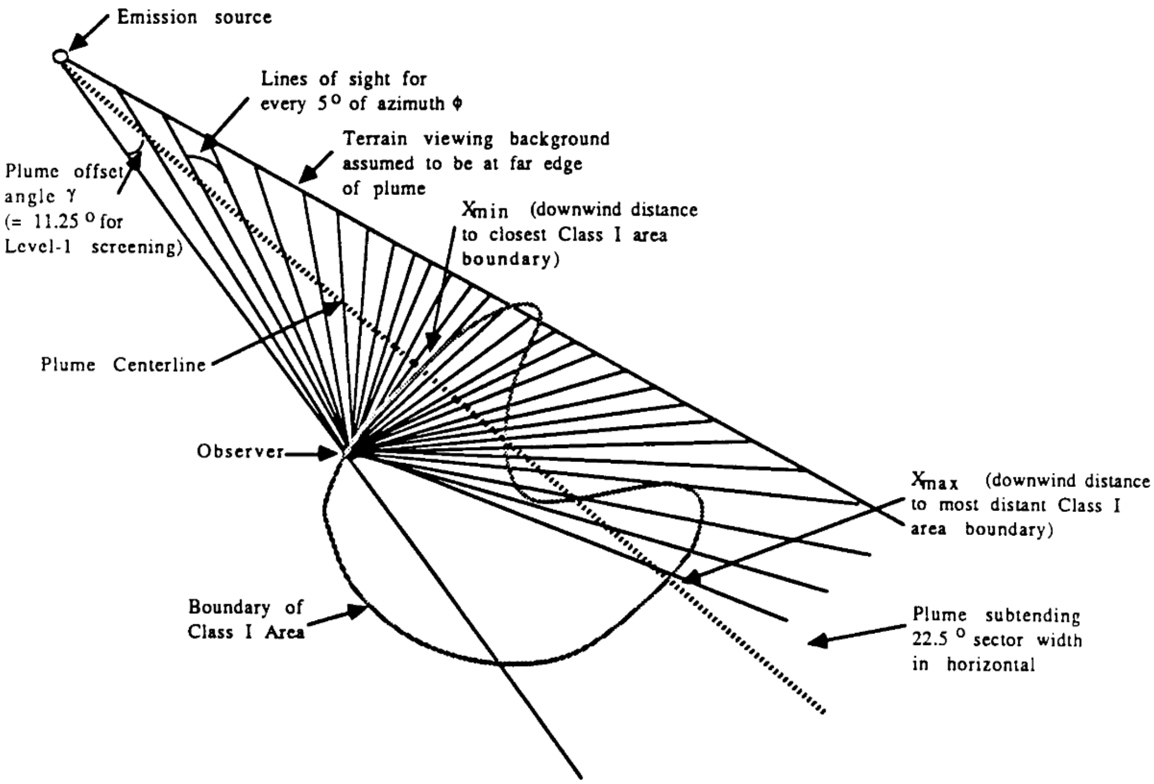

Figure 4-2. Geometry of plume and observer lines of sight used for plume visual impact screening.

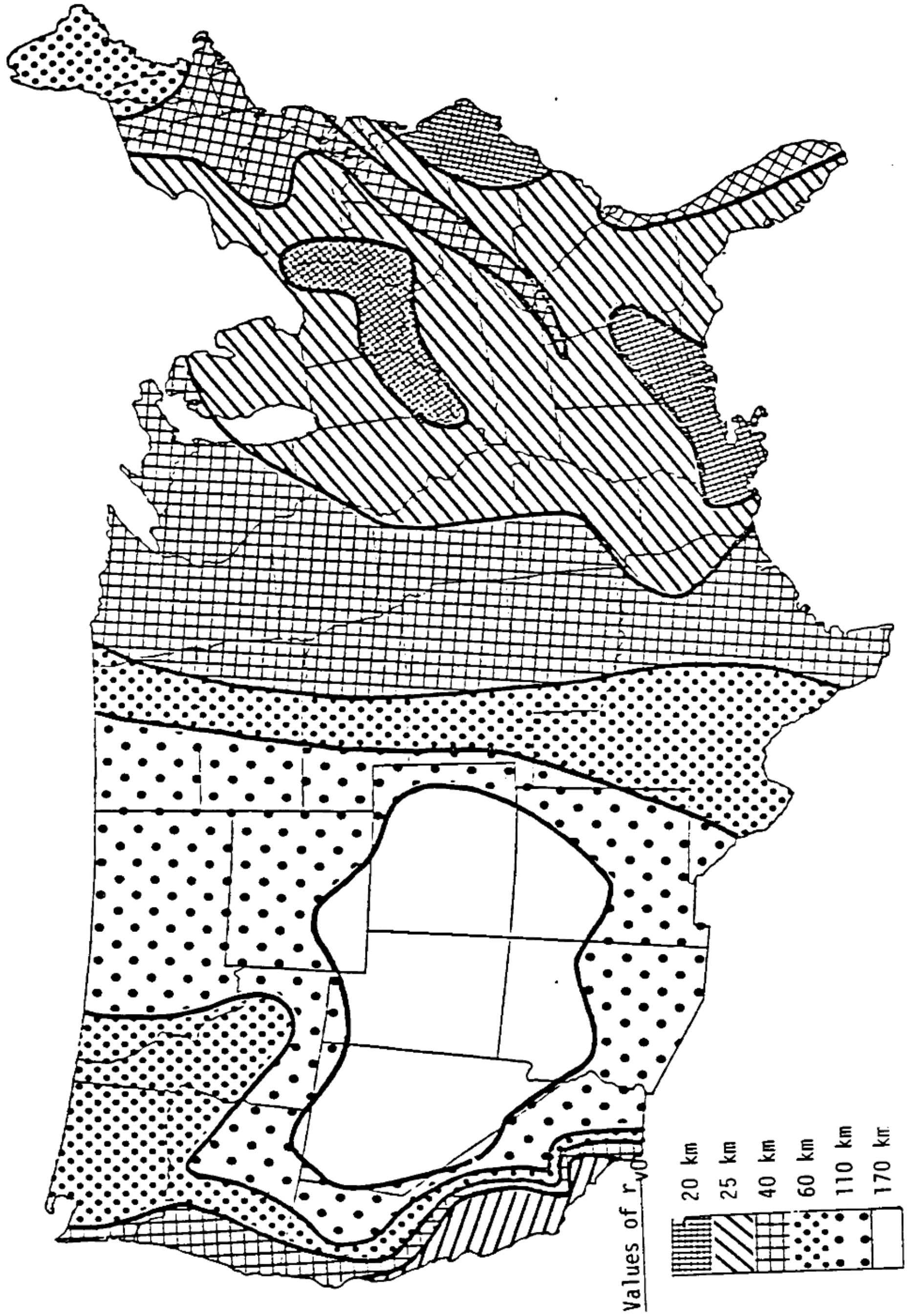

Figure 4-3. Regional background visual range values (r_{v0}) for use in level-1 visibility screening analysis procedures.

4.3 EXAMPLE #1: LEVEL-1 VISCREEN MODELING ANALYSIS

This exercise is based on a hypothetical coal-fired power plant proposed for a site approximately 70 km from a Class I PSD area in Nevada. The emissions rates for this hypothetical power plant are projected to be 25 g/s of particulates, 380 g/s of nitrogen oxides (as NO_2), and 120 g/s of sulfur dioxide. Figure 4-4 shows the relative locations of the proposed site and the Class I area. The Federal Land Manager has identified the view toward the mountains to the west as integral to the visitors' experience of the Class I area.

For conservatism, the observer is placed on the boundary of the Class I area closest to the power plant, which in this case is at the southwestern corner of the Class I area. (Although more visitors would be located at the visitors' center, the Federal Land Manager has stated that all locations in the Class I area are of interest because of widespread visitor use.) From measurements made off of a topographical map (see Figure 4-4), the distance from the proposed plant site to this closest corner is 70 km. Since the lines drawn at an 11.25 degree angle on both sides of the line between the plant site and the nearest corner of the Class I area are out-side the Class I area, the closest Class I area boundary is also selected to be 70 km, for conservatism.

4.3.1 Setting Up The Input Data

The following summarizes the basic inputs needed for this Level-1 screening analysis:

(1) Input Emissions:

Particulates	25.0 g/s
NOx	380.0 g/s

(Assume default of 0.0 for other species)

(2) Distance Parameters:

Source-Observer Distance:	70km
Min. Source-Class I Distance	70km
Max. Source-Class I Distance	90km

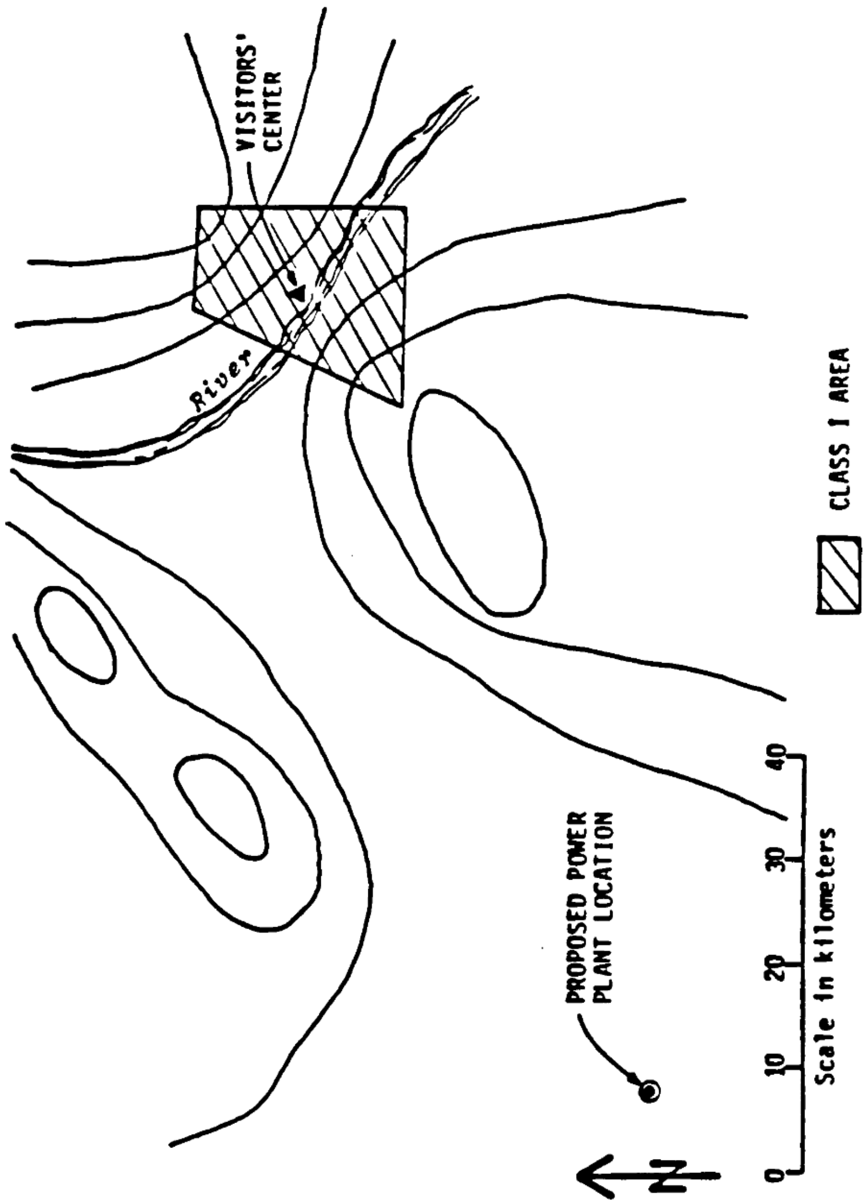

Figure 4-4. Relative locations of Example 1 proposed power plant and Class I area.

(3) In Nevada, the background visual range is 170km.

The following tables summarize the default inputs used for the Level-1 analysis:

*** Default Inputs for Level-1 Screening ***

Background Ozone:	.04 ppm
Plume-Source-Observer Angle:	11.25 degrees
Stability Category:	6 (for F)
Wind Speed:	1.00 m/s

*** Default particle size and density Specifications ***

Particle Type:	Mass Median Diameter (μm)	Density (g/cm^3)
Background fine	0.3	1.5
Background coarse	6	2.5
Plume particulate	2	2.5
Plume soot	0.1	2
Plume primary sulfate	0.5	1.5

4.3.2 Running The VISCREEN Model

Type **VISCREEN** to start the model for this Level-1 analysis. The following is a list of interactive session between the user and the model, with the user inputs given in bold face characters.

```
==============================================

   WELCOME TO PROGRAM VISCREEN! (Ver 1.01)

==============================================

Path & file name for Summary Report
(max 40 characters including file name & extension): example1.sum

Path & file name for Results Output
(max 40 characters including file name & extension): example1.tst

Input the name of the emissions source: coal-fired power plant

Input the name of the receptor (Class I area): visitor's center

Select the units of mass for emission rates--
1=gram (g); 2=kg; 3=metric tonne (mt); 4=lb; 5=ton:
Enter no. (1-5):           1

Select the units of time for emission rates--
1=sec; 2=min; 3=hr; 4=day; 5=yr:
Enter no. (1-5):           1

Input the emission rates for the following species:
Particulates (G/S   ):       25.0
 NOx (as NO2) (G/S   ):      380.0

Do you want to use default (zero) emission
rates for primary NO2, soot, and sulfate (y/n)? y


SUMMARY: Emissions for coal-fired power plant
   Particulates       25.000000 G/S
   NOx (as NO2)      380.000000 G/S
   Primary NO2     0.000000E+00 G/S
   Soot            0.000000E+00 G/S
   Primary SO4     0.000000E+00 G/S

Are these the emission rates you meant to use (y/n)? y


Input the distance between the emissions source and
the observer (in kilometers):        70.0


Input the distance between the emissions source and the
closest Class I area boundary (in kilometers):        70.0


Input the distance between the emissions source and the
most distant Class I area boundary   (in kilometers):       90.0
```

```
Input the background visual range for the area (km):       170.0


Do you wish to use Level-1 default parameters (y/n)? y



   SUMMARY OF ALL EMISSIONS AND METEOROLOGICAL INPUT
   Emissions for coal-fired power plant   in G/S:
   Particulate =       25.000000
   NOx         =      380.000000
   Primary NO2 =    0.000000E+00
   Soot        =    0.000000E+00
   Primary SO4 =    0.000000E+00

   Meteorological and Ambient Data for visitor's center
   Wind speed (m/s)  =         1.000000
   Stability Index   =            6
   Visual Range (km) =       170.000000
   Ozone Conc. (ppm) =     4.000000E-02
    Plume Offset Angle=        11.250000 degrees

   Distances Between coal-fired power plant
   and visitor's center
   Source-Observer      =       70.000000 km
   Min. Source-Class I  =       70.000000 km
   Max. Source-Class I  =       90.000000 km

Are these input values ready for execution (y/n)?  y


Do you want to use the default screening threshold (y/n)? y



OVERALL RESULTS OF PLUME VISIBILITY SCREENING

   SOURCE:  coal-fired power plant
   CLASS I AREA:  visitor's center

    INSIDE  class I area --
   Plume delta E EXCEEDS screening criterion for SKY background
   Plume delta E EXCEEDS screening criterion for TERRAIN background
   Plume contrast EXCEEDS screening criterion for SKY background
   Plume contrast EXCEEDS screening criterion for TERRAIN background

    OUTSIDE class I area --
   Plume delta E EXCEEDS screening criterion for SKY background
   Plume delta E EXCEEDS screening criterion for TERRAIN background
   Plume contrast EXCEEDS screening criterion for SKY background
   Plume contrast EXCEEDS screening criterion for TERRAIN background


    SCREENING CRITERIA:        DELTA E =  2.0
                         GREEN CONTRAST =  .050
```

```
Do you want to see calculated results for lines of
sight with maximum delta E (y/n)? y


   VIEW    ANGLES (DEGREES)       DIST (KM)  PLUME PERCEPTIBILITY  DELTA E(L*A*B*)
    no      phi  alpha   psi       x     rp         forward        backward
   ----     ---  -----   ---      ---    --         -------        --------

   Line of sight with maximum perceptibility for plume viewed
            against a SKY background INSIDE  class I area.
    33     84.4   84.4   1.54   70.0   13.7         17.8 *          10.8 *

   Line of sight with maximum perceptibility for plume viewed
            against a TERRAIN background INSIDE  class I area.
    33     84.4   84.4   1.54   70.0   13.7          8.9 *           4.0 *

   Line of sight with maximum perceptibility for plume viewed
            against a SKY background OUTSIDE class I area.
     7     35.0  133.8   1.06   55.6   18.9         20.4 *          11.1 *

   Line of sight with maximum perceptibility for plume viewed
            against a TERRAIN background OUTSIDE class I area.
     3     15.0  153.8    .60   41.0   30.9         15.8 *           4.8 *
   ------------------
    * Exceeds screening criteria

Do you want to see calculations for all lines of sight (y/n)?  n

Do you want to see calculated results for lines of
sight with maximum green contrast? (y/n) y


                                                       -GREEN PLUME CONTRAST-
   VIEW     ANGLES        DISTANCES (KM)                  forward      backward screening
    no     phi  alpha      x      rp     ro               contrast     contrast criterion
   ----    ---  -----     ---     --     --               --------     -------- ---------

   Line of sight with maximum contrast for plume viewed
            against a SKY background INSIDE  class I area.
    26    130.0   38.8   85.7   21.8   58.0         -.005        -.141 *     .05

   Line of sight with maximum contrast for plume viewed
            against a TERRAIN background INSIDE  class I area.
    33     84.4   84.4   70.0   13.7   28.0          .107 *       .041       .05

   Line of sight with maximum contrast for plume viewed
            against a SKY background OUTSIDE class I area.
     4     20.0  148.8   46.2   26.3   39.7          .019        -.246 *     .05

   Line of sight with maximum contrast for plume viewed
            against a TERRAIN background OUTSIDE class I area.
     3     15.0  153.8   41.0   30.9   44.0          .205 *       .143 *     .05
   -------------------------------
    *   Absolute value exceeds screening criteria


Do you want to see green contrast values for all lines of sight (y/n)? n

Do you want to quit (y/n)? y

*******************
```

```
VISCREEN summary report file is: example1.sum
VISCREEN results file is: example1.tst

*******************
```

4.3.3 Results And Analysis

The Following shows the results of the VISCREEN analysis for this example. The source fails the Level-1 test with a maximum delta-E of 17.8, nearly nine times the screening threshold.

R E S U L T S

Asterisks (*) indicate plume impacts that exceed screening criteria (2.0 for Delta-E and 0.05 for Contrast)

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta-E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	84	70.0	84	2.00	17.807*	.05	-.005
Sky	140	84	70.0	84	2.00	10.828*	.05	-.140*
Terrain	10	84	70.0	84	2.00	8.852*	.05	.107*
Terrain	140	84	70.0	84	2.00	4.004*	.05	.041

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta-E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	35	55.6	134	2.00	20.370*	.05	-.007
Sky	140	35	55.6	134	2.00	11.101*	.05	-.207*
Terrain	10	15	41.0	154	2.00	15.827*	.05	.205*
Terrain	140	15	41.0	154	2.00	4.791*	.05	.143*

EXERCISES:

1. Re-run the example 1 by assuming the emissions rates as follows:
   Particulates: 1 G/S
   NOx 1 G/S

2. Assume that the case in Example 1 did not happen in Nevada, but in New York (regional background visual range = 20 km) instead, re-run VISCREEN for the plume visual impact.

5.0 VISCREEN LEVEL-2 ANALYSIS

5.1 WHAT IS LEVEL-2 SCREENING?

Level-2 visual impact screening is performed if the Level-1 results exceed the screening criteria. Again, the objective of Level-2 screening is the estimation of worst-day plume visual impacts. However, in Level-2 screening more realistic (less conservative) input is provided. This situation-specific input may include particle size and density distributions for plume and background that are different from those used in the default Level-1 analysis. Median background visual range based on on-site measurements might also be used. While the Level-1 analysis assumes F stability, 1 m/s wind speed, and a wind direction that would carry plume material very close to the observer, in the Level-2 analysis, meteorological data and the topography representative of the source area and the Class I area may suggest that worst-case plume dispersion conditions are different.

5.2 SELECTING PARTICLE SIZE DISTRIBUTIONS

If the Level-1 default parameters are selected, VISCREEN assigns best estimates of particle size and density for the emitted and background atmosphere particulate (see Table 5-1).

TABLE 5-1. Default particle size and density specifications

Particle Type:	Mass Median Diameter (μm)	Density (g/cm^3)
Background fine	0.3	1.5
Background course	6	2.5
Plume particulate	2	2.5
Plume soot	0.1	2
Plume primary sulfate	0.5	1.5

However, some situations may not be adequately characterized by the default particle size and density parameters. In such cases, Level-2 screening should be carried out with different parameters. There are generally three aspects to be considered.

5.2.1 Background Particle Characteristics

The Level-1 screening default for background fine particles assumes a mass median diameter of 0.3 μm. However, in certain humid areas, the background fine particulates may be larger (0.5 μm), and in certain dry desert areas, such as the southwestern United States, they may be smaller (0.2 μm). If the analyst has measurements of background particle size distributions and densities that are different from default parameters, these site-specific values should be used and documented.

5.2.2 The Characteristics of Emitted Particulates

If information regarding the size and density distribution of emitted particulate is available, this data should be used to specify emitted particulate sizes and densities.

In many cases, particulate emission rate estimates for a source will be calculated from emission factors that do not specifically identify the expected size distribution. In such cases the default primary particle size distribution should be used. If more detailed information on actual size distributions is available, appropriate non-default values should be used in Level-2 analyses.

In general, larger particles (greater than 10 μm in diameter) have relatively small effects. Thus, if both PM-1O and TSP emission rates are available, it will usually be appropriate to use the PM-1O rate for primary particle emissions. However, if the TSP emission rate is substantially higher than that for PM-1O, the large particle effects may be appreciable. In this case the TSP rate should be used, along with appropriate size distribution parameters.

5.2.3 Modifying The Primary Particle Parameters

Another alternative exists if there are two distinct processes contributing to primary particle emissions (e.g., fuel combustion emissions from a boiler and fugitive dust from materials handling), and if there are no primary sulfate emissions from the source. In such cases the primary sulfate emission input can be used for one of the processes, with appropriate modification to particle density and size distribution inputs. If this approach is used, the data and rationale for each input to the Level-2 analysis should be thoroughly documented by the analyst, and reviewed with the permitting agency and Federal Land Manager.

5.3 DETERMINING WORST-CASE PLUME DISPERSION CONDITIONS

Probably the most important input specification for Level-2 screening analysis is for meteorological conditions: the worst-case wind direction and wind speed and atmospheric stability.

Therefore, the joint frequency distribution of these parameters as measured at or near the location of the emission source or the Class I area is an important input for Level-2 plume visual impact screening.

It is essential to consider the persistence as well as the frequency of occurrence of these conditions. For example, plume discoloration will generally be most intense during light-wind, stable conditions. However, the transport time to a Class I area increases as the wind speed decreases. As the transport time approaches 24 hours, it is increasingly probable that the plume will be broken up by convective mixing and by changes in wind direction and speed; thus it will not be visible as a plume or a discolored layer.

5.3.1 Selecting The Meteorology Data Base

Ideally, one would prefer to have a meteorological data base with detailed spatial and temporal coverage. However, this is rarely possible because of cost considerations. Several alternative approaches can be used to fill in missing data, but they all involve making assumptions. For example, if a complete meteorological data base is available only at the site of the proposed emissions source, one might assume that conditions at the site are representative of conditions at other locations in the region. However, in regions of complex terrain, this assumption may not be appropriate. Often, data collected at ground level are assumed to represent of conditions at the effective stack height, which is a poor assumption when the plume is several hundred meters above ground or the site is located in complex terrain.

Any assessment of plume visual impacts is limited by the availability, representativeness, and quality of meteorological data. The Level-1 screening analysis discussed in the previous section does not require the user to input any meteorological data; rather, conservative assumptions are made regarding worst-case stability, wind speed, and wind direction. The Level-2 screening analysis assumes that the analyst has at least one year of meteorological data from the site of the proposed emissions source, a nearby site within the region, or the Class I area(s) potentially affected by emissions. For a detailed discussion of the meteorological data input requirements, refer to the EPA Guidelines on Air Quality Models (Revised) (1986) and Supplement A (1987) [EPA 450/2-78-027R].

5.3.2 <u>Preparing The Tables of Joint Frequency of Meteorological Elements</u>

The meteorological data base discussed previously should be used to prepare tables of joint frequency of occurrence of wind speed, wind direction, and stability class. These tables should be stratified by time of day. If meteorological data are available at hourly intervals, it is suggested that these tables be stratified as follows: 0001-0600, 0601-1200, 1201-1800, and 1801-2400. If data are available twice daily, morning and afternoon data should be tabulated separately. With this stratification, diurnal variation in winds and stability is more easily discernible. If meteorological data are not available, the assumptions regarding meteorology used in the Level-1 analysis are used to assess visibility impacts.

On the basis of maps showing the source, observer location, and topography, the analyst should select the wind direction sector that would transport emissions closest to a given Class I area observer point so that the frequency of occurrence of impact can be assessed as discussed below. For example, in the schematic diagram shown in Figure 5-1, west winds would transport emissions closest to observer A, whereas either west-southwest or west winds would transport emissions closest to observer B. Observer C would be affected by emissions transported by west-northwest and northwest winds, but primarily by west-northwest winds.

For situations influenced by complex terrain, determination of this worst-case wind direction and its frequency of occurrence is much more difficult. This is addressed under Advanced Topics in Section 7.

The next step is to construct a table (see the example in Table 5-2) that shows worst-case dispersion conditions ranked In order of decreasing severity and the frequency of occurrence of these conditions associated with the wind direction that could transport emissions toward the Class I area. Dispersion conditions are ranked by evaluating the product SigmaZ*u, where SigmaZ is the Pasquill-Gifford vertical diffusion coefficient for the given stability class and downwind distance x along the stable plume trajectory identified earlier, and u is the maximum wind speed for the given wind speed category in the joint frequency table. The dispersion conditions are then ranked in ascending order of the value SigmaZ*u. This is illustrated in Table 5-2.

The downwind distance in this hypothetical case is assumed to be 100 km. Note that F,1 (stability class F associated with wind speed class 0-1 m/s) is the worst dispersion condition, since it has the smallest value of SigmaZ*u (90 m^2/s). The second worst diffusion condition in this example is E,1, followed by F,2, F,3, and so on.

The next column in Table 5-2 shows the transport time along the minimum trajectory distance from the emissions source to the Class I area, based on the midpoint value of wind speed for the given wind speed category. For example, for the wind speed category, 0-1 m/s, a wind speed of 0.5 m/s should be used to evaluate transport time; for 1-2 m/s, 1.5 m/s; and so on. The times necessary for a plume parcel to be transported 100 km are 56, 19, 11, 8, and 6 hours for wind speeds of 0.5, 1.5, 2.5, 3.5, and 4.5 m/s, respectively.

For the Level-2 screening analysis, we assume it is unlikely that steady state plume conditions will persist for more than 12 hours. Thus, if a transit time of more than 12 hours is required to transport a plume parcel from the emissions source to a Class I area for a given dispersion condition, we assume that plume material is more dispersed than a standard Gaussian plume model

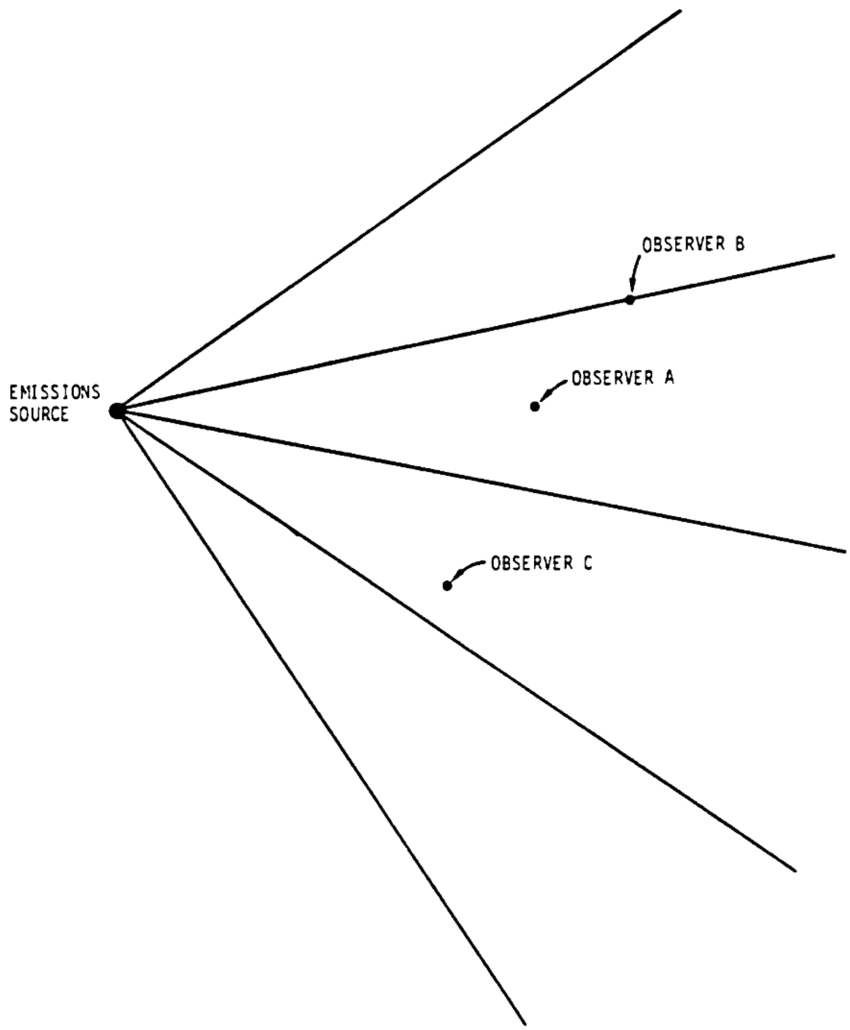

Figure 5-1. Schematic diagram showing emissions source, observer locations,and wind direction sectors.

would predict. This enhanced dilution would result from daytime convective mixing and wind direction and speed changes.

5.3.3 Finding The Worst-case Meteorological Conditions

To obtain the worst-case meteorological conditions, it is necessary to determine the dispersion condition (a given wind speed and stability class associated with the wind direction that would transport emissions toward the Class I area) that has a SigmaZ*u product with a cumulative probability of 1 percent. In other words, the dispersion condition is selected such that the sum of all frequencies of occurrence of conditions worse than this condition totals 1 percent (i.e., about four days per year). The 1-percentile meteorology is assumed to be indicative of worst-day plume visual impacts when the probability of worst-case meteorological conditions is coupled with the probability of other factors being ideal for maximizing plume visual impacts. Dispersion conditions associated with transport times of more than 12 hours are not considered in this cumulative frequency for the reasons stated above.

TABLE 5-2. Example table showing worst-case meteorological conditions for plume visual impact calculations.

			Frequency of Occurrence of Given Dispersion Condition Associated with Worst-Case Wind Direction‡ for Given Time of Day (percent)				Frequency (f) and Cumulative Frequency (cf) (percent)	
Dispersion Condition (stability, wind speed)	SigmaZ*u (m^2/s)	Transport Time (hours)	0-6	6-12	12-18	18-24	f	cf
F,1	90	56*	0.2	0.1	0.0	0.2	0.0	0.0
E,1	175	56*	0.3	0.2	0.1	0.2	0.0	0.0
F,2	180	19*	0.2	0.1	0.0	0.2	0.0	0.0
F,3	270	11	0.2	0.2	0.0	0.2	0.2	0.2
E,2	350	19*	0.4	0.3	0.0	0.2	0.0	0.2
F,4	360	8	0.3	0.2	0.0	0.2	0.3	0.5
D,1	430	56*	0.0	0.2	0.5	0.1	0.0	0.5
E,3	525	11	0.1	0.1	0.0	0.1	0.1	0.6
E,4	700	8	0.5	0.3	0.1	0.3	0.5	1.1

* Transport times to Class I areas during these conditions are longer than 12 hours, so they are not added to the cumulative frequency summation.

‡ For a given Class I area.

Note: Distance downwind, values of SigmaZ, and transport times are based on x_{min}.

This process is Illustrated by the example shown in Table 5-2, which indicates that the first three dispersion conditions would cause maximum plume visual impacts because the SigmaZ*u products are lowest for these three conditions. However, the transport time from the emissions source to the Class I area associated with each of these dispersion conditions is greater than 12 hours. With the fourth dispersion condition (F,3), emissions could be transported in less than 12 hours. The frequency of occurrence (f) of this condition is added to the cumulative frequency summation (cf). For this example, the meteorological data are stratified into four time-of-day categories. The maximum of each of the four frequencies is used to assess the cumulative frequency. This is appropriate since we are concerned with the number of days during which, at any time, dispersion conditions are worse than or equal to a given value.

Note that the worst-case, stable, light-wind dispersion conditions occur more frequently during the nighttime hours. Although plume visual impact is usually not an issue at night, nighttime dispersion conditions need to be considered because maximum plume visual impacts are often observed in the early morning after a period of nighttime transport. For these situations, the nighttime meteorological conditions are most indicative of plume dispersion when the plume is viewed at sunrise. In cooler seasons, stable stagnant conditions may also persist during daytime hours.

In our example, the following additional worst-case dispersion conditions add to the cumulative frequency: F,4; E,3; and E,4. Dispersion conditions with wind speeds less than 2 m/s (F,1; E,1; F,2; E,2; and D,1) were not considered to cause an impact because of the long transit times to the Class I area in this example. Thus, their frequencies of occurrence were not added to the cumulative frequency summation. The result of this example analysis is that the dispersion condition E,4 is associated with a cumulative frequency of 1 percent, so we would use this dispersion condition to evaluate worst-case visual impacts for the Level-2 screening analysis for this example case.

It should also be noted that if the location of the observer in the Class I area is at or near the boundary of one of the 16 cardinal wind direction sectors, it may be appropriate to interpolate the joint frequencies of wind speed, wind direction, and stability class from the two adjacent wind direction sectors, on the basis of the azimuth orientation of the observer relative to the center of the wind direction sectors.

5.4 EXAMPLE #2: LEVEL-2 VISCREEN MODELING ANALYSIS

This example is a follow-up analysis of the visibility impact problem for Example #1 in Section 4.3. The results of the VISCREEN Level-1 analysis showed that the source fails the Level-1 test with a maximum delta-E of 17.8, nearly nine times the screening threshold. In this case, a Level-2 analysis must be conducted.

5.4.1 Setting Up The Input Data

The following summarizes the basic inputs needed for this Level-2 screening analysis:

(1) Input Emissions:

Particulates 25.0 g/s
NOx 380.0 g/s
(Assume default of 0.0 for other species)

(2) Distance Parameters:

Source-Observer Distance: 70km
Min. Source-Class I Distance 70km
Max. Source-Class I Distance 90km

(3) In Nevada, the background visual range is 170km.

(4) We will assume the default particle size and density parameters, but we will input these values explicitly:

*** Default particle size and density Specifications ***

Particle Type:	Mass Median Diameter (μm)	Density (g/cm^3)
Background fine	0.3	1.5
Background coarse	6	2.5
Plume particulate	2	2.5
Plume soot	0.1	2
Plume primary sulfate	0.5	1.5

We will also input the default background ozone value of 0.04 ppm.

(5) Determining the Worst-case Meteorological Conditions.

To characterize worst-case meteorological conditions for Level-2 screening, we obtained meteorological data from an airport 100 km west of the proposed power plant. Although the intervening terrain is not flat, we judged that the 850-mb wind and stability data are the best available data source. For the trajectory passing to the northwest of the Class I area, we tabulated winds from the southwest and west-southwest for both morning and afternoon soundings. From these tabulations, a frequency of occurrence (Table 5-3) was developed. The cumulative frequency entries shows that on three to four days per year conditions with SigmaZ*u values of 212 m^2/s (E stability, 2 m/s) can be expected. Note that the bulk of the contribution to the cumulative frequency (0.9 percent out of 1.0 percent) represents the 1200 GMT E,2 dispersion conditions. This corresponds to approximately 5:00 am. LST. Note also that the afternoon sounding frequency of E,2 dispersion conditions was relatively high (0.6 percent, or about two days per year).

We will input the default plume-source-observer angle of 11.25 degrees.

TABLE 5-3. FREQUENCY OF OCCURRENCE OF SW AND WSW WINDS BY DISPERSION CONDITION AND TIME OF DAY

Dispersion Condition	SigmaZ*u (m^2/s)	Transport Time (hrs)	Time of Day*		Frequency (%)	Cumulative Frequency (%)
			00Z	12Z		
F,1	83	33	0	0	N/A	N/A**
E,1	106	33	0	0	N/A	N/A**
D,1	123	33	0	0	N/A	N/A**
F,2	166	11	0.1	0	0.1	0.1
E,2	212	11	0.6	0.9	0.9	1.0
D,2	246	11	1.6	0.8	1.6	2.6
F,3	249	7	0	0	0	2.6
E,3	318	7	0.6	1.4	1.4	4.0
F,4	332	5	0	0	0	4.0
D,3	369	7	3.4	1.2	3.4	7.4
F,5	415	4	0	0.1	0.1	7.5
E,4	424	5	0.4	1.2	1.2	8.7
D,4	492	5	2.4	1.5	2.4	11.1
F,6	498	4	0	0	0	11.1
E,5	530	4	0.2	1.8	1.8	12.9

* 00Z refers to midnight Greenwich Mean Time (GMT) and 12Z to noon GMT.

** Persistence of stable meteorological conditions for over 12 hours is not considered likely. Therefore, conditions requiring greater than 12-hour transport time are included in the cumulative frequency computation, but would not be selected as representative of the "1-percentile event."

5.4.2 Running The VISCREEN Model

Type **VISCREEN** to start the model for this Level-1 analysis. The following is a list of interactive session between the user and the model, with the user inputs given in bold face characters.

```
==============================================

   WELCOME TO PROGRAM VISCREEN! (Ver 1.01)

==============================================

Path & file name for Summary Report
(max 40 characters including file name & extension): example2.sum

Path & file name for Results Output
(max 40 characters including file name & extension): example2.tst

Input the name of the emissions source: power plant

Input the name of the receptor (Class I area): national park

Select the units of mass for emission rates--
1=gram (g); 2=kg; 3=metric tonne (mt); 4=lb; 5=ton:
Enter no. (1-5):           1

Select the units of time for emission rates--
1=sec; 2=min; 3=hr; 4=day; 5=yr:
Enter no. (1-5):           1

Input the emission rates for the following species:
Particulates (G  /S   ):        25
NOx (as NO2) (G  /S   ):       380

Do you want to use default (zero) emission
rates for primary NO2, soot, and sulfate (y/n)?  n

Primary NO2 (G  /S   ):     0

Soot        (G  /S   ):     0

Primary SO4 (G  /S   ):     0

SUMMARY: Emissions for power plant
Particulates       25.000000 G  /S
NOx (as NO2)      380.000000 G  /S
Primary NO2     0.000000E+00 G  /S
Soot            0.000000E+00 G  /S
Primary SO4     0.000000E+00 G  /S

Are these the emission rates you meant to use (y/n)? y

Input the distance between the emissions source and the
observer (in kilometers):        70

Input the distance between the emissions source and the
closest Class I area boundary (in kilometers):        70
```

```
Input the distance between the emissions source and the
most distant Class I area boundary   (in kilometers):       90

Input the background visual range for the area (km):       170

Do you wish to use Level-1 default parameters (y/n)?  n

SPECIFICATION OF PARTICLE DENSITY AND SIZE
Enter the density and the index corresponding to the
mass median diameter of the size distribution for
BACKGROUND fine and coarse particulate, and
PLUME particulate, soot, and primary sulfate).

Mass median diameter (in um): 1=0.1 um; 2=0.2 um;
3=0.3 um; 4=0.5 um; 5=1 um; 6=2 um; 7=5 um; 8=6 um;
9=10 um.
Enter density (g/cm3) and size index (default values
are shown in parentheses):
Background Fine Particulate Density (1.5): 1.5

Background Fine Particulate Size Index (3):  3

Background Coarse Particulate Density (2.5): 2.5

Background Coarse Particulate Size Index (8):  8

Plume Particulate Density (2.5):   2.5

Plume Particulate Size Index (6):    6

Plume Soot Density (2.0):          2.0

Plume Soot Size Index (1):           1

Plume Primary SO4 Density (1.5):   1.5

Plume Primary SO4 Size Index (4):    4

Are you sure these are the values you want for
particle densities and sizes (y/n)?  y

Enter Background Ozone (O3) Concentration in ppm
(default = 0.04 ppm):     0.04

Enter the wind speed (in meters/sec):    2.0

 Enter the stability index--
(1=A; 2=B; 3=C; 4=D; 5=E; 6=F):             5

Enter the plume offset angle (i.e., the angle between
the plume centerline and the line between the
```

observer and the emissions source) in degrees.
Default is 11.25 degrees (1/2 sector width): **11.25**

```
SUMMARY OF ALL EMISSIONS AND METEOROLOGICAL INPUT
Emissions for power plant
in G  /S  :
Particulate =       25.000000
NOx         =      380.000000
Primary NO2 =    0.000000E+00
Soot        =    0.000000E+00
Primary SO4 =    0.000000E+00

Meteorological and Ambient Data for national park
Wind speed (m/s)  =        2.000000
Stability Index   =           5
Visual Range (km) =      170.000000
Ozone Conc. (ppm) =     4.000000E-02
Plume Offset Angle=       11.250000 degrees

Distances Between power plant
and national park
Source-Observer      =       70.000000 km
Min. Source-Class I  =       70.000000 km
Max. Source-Class I  =       90.000000 km

Are these input values ready for execution (y/n)?  y


Do you want to use the default screening threshold (y/n)?  y



OVERALL RESULTS OF PLUME VISIBILITY SCREENING

SOURCE:  power plant
CLASS I AREA:  national park

INSIDE  class I area --
Plume delta E EXCEEDS screening criterion for SKY background
Plume delta E EXCEEDS screening criterion for TERRAIN background
Plume contrast EXCEEDS screening criterion for SKY background
Plume contrast DOES NOT EXCEED screening criterion for TERRAIN background

OUTSIDE class I area --
Plume delta E EXCEEDS screening criterion for SKY background
Plume delta E EXCEEDS screening criterion for TERRAIN background
Plume contrast EXCEEDS screening criterion for SKY background
Plume contrast EXCEEDS screening criterion for TERRAIN background

SCREENING CRITERIA:        DELTA E =  2.0
                     GREEN CONTRAST =  .050

Do you want to see calculated results for lines of
sight with maximum delta E (y/n)?  y

VIEW    ANGLES (DEGREES)       DIST (KM)  PLUME PERCEPTIBILITY   DELTA E(L*A*B*)
 no      phi  alpha   psi       x     rp         forward        backward
----     ---  -----   ---      ---    --         -------        --------

Line of sight with maximum perceptibility for plume viewed
         against a SKY background INSIDE  class I area.
 24    120.0   48.8   2.38   80.6   18.2          8.9 *           5.3 *
Line of sight with maximum perceptibility for plume viewed
         against a TERRAIN background INSIDE  class I area.
 33     84.4   84.4   3.03   70.0   13.7          4.1 *           1.8
Line of sight with maximum perceptibility for plume viewed
         against a SKY background OUTSIDE class I area.
 32       .2  168.6    .08    1.0   69.0         18.9 *           4.8 *
```

```
Line of sight with maximum perceptibility for plume viewed
         against a TERRAIN background OUTSIDE class I area.
 32       .2  168.6    .08    1.0   69.0         15.3 *           6.2 *
------------------
 * Exceeds screening criteria

Do you want to see calculations for all lines of sight (y/n)?   y

                      PLUME DELTA E AGAINST A SKY BACKGROUND
VIEW    ANGLES (DEGREES)       DIST (KM)  PLUME PERCEPTIBILITY  DELTA E(L*A*B*)
 no       phi  alpha   psi        x     rp         forward         backward
  1       5.0  163.8    .57   21.8   48.8          6.6 *           3.4 *
  2      10.0  158.8    .87   33.5   37.7          8.2 *           3.9 *
  3      15.0  153.8   1.14   41.0   30.9          9.2 *           4.7 *
  4      20.0  148.8   1.39   46.2   26.3          9.7 *           5.2 *
  5      25.0  143.8   1.62   50.0   23.1          9.9 *           5.5 *
  6      30.0  138.8   1.85   53.1   20.7          9.9 *           5.7 *
  7      35.0  133.8   2.05   55.6   18.9          9.8 *           5.8 *
  8      40.0  128.8   2.24   57.7   17.5          9.7 *           5.8 *
  9      45.0  123.8   2.41   59.5   16.4          9.5 *           5.7 *
 10      50.0  118.8   2.56   61.2   15.6          9.4 *           5.7 *
 11      55.0  113.8   2.70   62.6   14.9          9.2 *           5.6 *
 12      60.0  108.8   2.81   64.0   14.4          9.1 *           5.6 *
 13      65.0  103.8   2.90   65.3   14.1          9.0 *           5.5 *
 14      70.0   98.8   2.96   66.6   13.8          8.9 *           5.5 *
 15      75.0   93.8   3.01   67.8   13.7          8.8 *           5.5 *
 16      80.0   88.8   3.03   69.0   13.7          8.8 *           5.4 *
 17      85.0   83.8   3.03   70.2   13.7          8.8 *           5.4 *
 18      90.0   78.8   3.00   71.4   13.9          8.8 *           5.4 *
Please press [ENTER] for more, Q to quit

                      PLUME DELTA E AGAINST A SKY BACKGROUND
VIEW    ANGLES (DEGREES)       DIST (KM)  PLUME PERCEPTIBILITY  DELTA E(L*A*B*)
 no       phi  alpha   psi        x     rp         forward         backward
 19      95.0   73.8   2.95   72.6   14.2          8.8 *           5.4 *
 20     100.0   68.8   2.88   74.0   14.7          8.8 *           5.4 *
 21     105.0   63.8   2.79   75.4   15.2          8.8 *           5.4 *
 22     110.0   58.8   2.67   76.9   16.0          8.9 *           5.4 *
 23     115.0   53.8   2.54   78.7   16.9          8.9 *           5.4 *
 24     120.0   48.8   2.38   80.6   18.2          8.9 *           5.3 *
 25     125.0   43.8   2.21   82.9   19.7          8.9 *           5.2 *
 26     130.0   38.8   2.02   85.7   21.8          8.8 *           5.0 *
 27     135.0   33.8   1.81   89.1   24.6          8.3 *           4.6 *
 28     140.0   28.8   1.59   93.5   28.4          7.6 *           4.1 *
 29     145.0   23.8   1.35   99.7   33.9          6.5 *           3.3 *
 30     150.0   18.8   1.10  108.9   42.5          5.0 *           2.4 *
 31     155.0   13.8    .84  124.5   57.5          3.1 *           1.5
 32        .2  168.6    .08    1.0   69.0         18.9 *           4.8 *
 33      84.4   84.4   3.03   70.0   13.7          8.8 *           5.4 *
 34     136.1   32.6   1.76   90.0   25.3          8.2 *           4.5 *
Please press [ENTER] for more, Q to quit

                  PLUME DELTA E AGAINST A TERRAIN BACKGROUND
VIEW    ANGLES (DEGREES)       DIST (KM)  PLUME PERCEPTIBILITY  DELTA E(L*A*B*)
 no       phi  alpha   psi        x     rp         forward         backward
  1       5.0  163.8    .57   21.8   48.8          7.6 *           2.6 *
  2      10.0  158.8    .87   33.5   37.7          6.2 *           2.3 *
  3      15.0  153.8   1.14   41.0   30.9          5.7 *           2.4 *
  4      20.0  148.8   1.39   46.2   26.3          5.5 *           2.4 *
  5      25.0  143.8   1.62   50.0   23.1          5.3 *           2.5 *
  6      30.0  138.8   1.85   53.1   20.7          5.2 *           2.5 *
  7      35.0  133.8   2.05   55.6   18.9          5.0 *           2.4 *
  8      40.0  128.8   2.24   57.7   17.5          4.9 *           2.4 *
```

9	45.0	123.8	2.41	59.5	16.4	4.8 *	2.3 *
10	50.0	118.8	2.56	61.2	15.6	4.7 *	2.2 *
11	55.0	113.8	2.70	62.6	14.9	4.6 *	2.1 *
12	60.0	108.8	2.81	64.0	14.4	4.5 *	2.1 *
13	65.0	103.8	2.90	65.3	14.1	4.4 *	2.0
14	70.0	98.8	2.96	66.6	13.8	4.3 *	1.9
15	75.0	93.8	3.01	67.8	13.7	4.2 *	1.9
16	80.0	88.8	3.03	69.0	13.7	4.1 *	1.8
17	85.0	83.8	3.03	70.2	13.7	4.0 *	1.8
18	90.0	78.8	3.00	71.4	13.9	3.9 *	1.7

Please press **[ENTER]** for more, Q to quit

PLUME DELTA E AGAINST A TERRAIN BACKGROUND

VIEW	ANGLES (DEGREES)			DIST (KM)		PLUME PERCEPTIBILITY	DELTA E(L*A*B*)
no	phi	alpha	psi	x	rp	forward	backward
19	95.0	73.8	2.95	72.6	14.2	3.8 *	1.6
20	100.0	68.8	2.88	74.0	14.7	3.7 *	1.6
21	105.0	63.8	2.79	75.4	15.2	3.5 *	1.5
22	110.0	58.8	2.67	76.9	16.0	3.4 *	1.4
23	115.0	53.8	2.54	78.7	16.9	3.2 *	1.2
24	120.0	48.8	2.38	80.6	18.2	3.0 *	1.1
25	125.0	43.8	2.21	82.9	19.7	2.7 *	.9
26	130.0	38.8	2.02	85.7	21.8	2.5 *	.7
27	135.0	33.8	1.81	89.1	24.6	2.1 *	.5
28	140.0	28.8	1.59	93.5	28.4	1.5	.3
29	145.0	23.8	1.35	99.7	33.9	.9	.2
30	150.0	18.8	1.10	108.9	42.5	.2	.1
31	155.0	13.8	.84	124.5	57.5	.0	.0
32	.2	168.6	.08	1.0	69.0	15.3 *	6.2 *
33	84.4	84.4	3.03	70.0	13.7	4.1 *	1.8
34	136.1	32.6	1.76	90.0	25.3	1.9	.4

Please press **[ENTER]** for more, Q to quit

Do you want to see calculated results for lines of
sight with maximum green contrast? (y/n) **y**

						-GREEN PLUME CONTRAST-		
VIEW	ANGLES		DISTANCES (KM)			forward	backward	screening
no	phi	alpha	x	rp	ro	contrast	contrast	criterion
----	---	-----	---	--	--	--------	--------	---------
Line of sight with maximum contrast for plume viewed against a SKY background INSIDE class I area.								
27	135.0	33.8	89.1	24.6	70.0	-.003	-.076 *	.05
Line of sight with maximum contrast for plume viewed against a TERRAIN background INSIDE class I area.								
33	84.4	84.4	70.0	13.7	28.0	.047	.017	.05
Line of sight with maximum contrast for plume viewed against a SKY background OUTSIDE class I area.								
32	.2	168.6	1.0	69.0	69.5	.231 *	-.129 *	.05
Line of sight with maximum contrast for plume viewed against a TERRAIN background OUTSIDE class I area.								
32	.2	168.6	1.0	69.0	69.5	.166 *	.151 *	.05

----
* Absolute value exceeds screening criteria

Do you want to see green contrast values for all lines of sight (y/n)? **y**

PLUME CONTRAST AGAINST A SKY BACKGROUND

VIEW	ANGLES		DISTANCES (KM)			-GREEN PLUME CONTRAST-		
						forward	backward	screening
no	phi	alpha	x	rp	ro	contrast	contrast	criterion
1	5.0	163.8	21.8	48.8	58.0	-.004	-.120 *	.05
2	10.0	158.8	33.5	37.7	49.9	-.004	-.111 *	.05
3	15.0	153.8	41.0	30.9	44.0	-.003	-.103 *	.05
4	20.0	148.8	46.2	26.3	39.7	-.003	-.095 *	.05
5	25.0	143.8	50.0	23.1	36.3	-.003	-.089 *	.05
6	30.0	138.8	53.1	20.7	33.8	-.003	-.084 *	.05
7	35.0	133.8	55.6	18.9	31.8	-.003	-.079 *	.05
8	40.0	128.8	57.7	17.5	30.2	-.003	-.075 *	.05
9	45.0	123.8	59.5	16.4	29.0	-.002	-.072 *	.05
10	50.0	118.8	61.2	15.6	28.1	-.002	-.069 *	.05
11	55.0	113.8	62.6	14.9	27.4	-.002	-.067 *	.05
12	60.0	108.8	64.0	14.4	27.0	-.002	-.065 *	.05
13	65.0	103.8	65.3	14.1	26.8	-.002	-.064 *	.05
14	70.0	98.8	66.6	13.8	26.8	-.002	-.063 *	.05
15	75.0	93.8	67.8	13.7	27.0	-.002	-.062 *	.05
16	80.0	88.8	69.0	13.7	27.4	-.002	-.062 *	.05
17	85.0	83.8	70.2	13.7	28.1	-.002	-.062 *	.05
18	90.0	78.8	71.4	13.9	29.0	-.002	-.062 *	.05

When you're ready, please press **[ENTER]** for
more lines of sight (Q to quit)

PLUME CONTRAST AGAINST A SKY BACKGROUND

VIEW	ANGLES		DISTANCES (KM)			-GREEN PLUME CONTRAST-		
						forward	backward	screening
no	phi	alpha	x	rp	ro	contrast	contrast	criterion
19	95.0	73.8	72.6	14.2	30.2	-.002	-.062 *	.05
20	100.0	68.8	74.0	14.7	31.8	-.002	-.063 *	.05
21	105.0	63.8	75.4	15.2	33.8	-.002	-.064 *	.05
22	110.0	58.8	76.9	16.0	36.3	-.002	-.066 *	.05
23	115.0	53.8	78.7	16.9	39.7	-.002	-.068 *	.05
24	120.0	48.8	80.6	18.2	44.0	-.002	-.070 *	.05
25	125.0	43.8	82.9	19.7	49.9	-.002	-.072 *	.05
26	130.0	38.8	85.7	21.8	58.0	-.003	-.075 *	.05
27	135.0	33.8	89.1	24.6	70.0	-.003	-.076 *	.05
28	140.0	28.8	93.5	28.4	89.1	-.003	-.075 *	.05
29	145.0	23.8	99.7	33.9	123.8	-.002	-.072 *	.05
30	150.0	18.8	108.9	42.5	205.2	-.002	-.066 *	.05
31	155.0	13.8	124.5	57.5	614.1	-.002	-.052 *	.05
32	.2	168.6	1.0	69.0	69.5	.231 *	-.129 *	.05
33	84.4	84.4	70.0	13.7	28.0	-.002	-.062 *	.05
34	136.1	32.6	90.0	25.3	73.5	-.003	-.076 *	.05

When you're ready, please press **[ENTER]** for
more lines of sight (Q to quit)

PLUME CONTRAST AGAINST A TERRAIN BACKGROUND

VIEW	ANGLES		DISTANCES (KM)			-GREEN PLUME CONTRAST-		
						forward	backward	screening
no	phi	alpha	x	rp	ro	contrast	contrast	criterion
1	5.0	163.8	21.8	48.8	58.0	.105 *	.084 *	.05
2	10.0	158.8	33.5	37.7	49.9	.089 *	.062 *	.05
3	15.0	153.8	41.0	30.9	44.0	.081 *	.050	.05
4	20.0	148.8	46.2	26.3	39.7	.075 *	.041	.05
5	25.0	143.8	50.0	23.1	36.3	.070 *	.036	.05
6	30.0	138.8	53.1	20.7	33.8	.066 *	.031	.05
7	35.0	133.8	55.6	18.9	31.8	.062 *	.028	.05

8	40.0	128.8	57.7	17.5	30.2	.060 *	.025	.05
9	45.0	123.8	59.5	16.4	29.0	.057 *	.023	.05
10	50.0	118.8	61.2	15.6	28.1	.055 *	.021	.05
11	55.0	113.8	62.6	14.9	27.4	.053 *	.020	.05
12	60.0	108.8	64.0	14.4	27.0	.052 *	.019	.05
13	65.0	103.8	65.3	14.1	26.8	.050 *	.018	.05
14	70.0	98.8	66.6	13.8	26.8	.049	.018	.05
15	75.0	93.8	67.8	13.7	27.0	.048	.017	.05
16	80.0	88.8	69.0	13.7	27.4	.048	.017	.05
17	85.0	83.8	70.2	13.7	28.1	.047	.017	.05
18	90.0	78.8	71.4	13.9	29.0	.046	.017	.05

When you're ready, please press **[ENTER]** for
more lines of sight (Q to quit)

PLUME CONTRAST AGAINST A TERRAIN BACKGROUND

VIEW	ANGLES		DISTANCES (KM)			-GREEN PLUME CONTRAST-		
						forward	backward	screening
no	phi	alpha	x	rp	ro	contrast	contrast	criterion
19	95.0	73.8	72.6	14.2	30.2	.046	.017	.05
20	100.0	68.8	74.0	14.7	31.8	.045	.017	.05
21	105.0	63.8	75.4	15.2	33.8	.045	.017	.05
22	110.0	58.8	76.9	16.0	36.3	.044	.017	.05
23	115.0	53.8	78.7	16.9	39.7	.043	.017	.05
24	120.0	48.8	80.6	18.2	44.0	.041	.017	.05
25	125.0	43.8	82.9	19.7	49.9	.038	.017	.05
26	130.0	38.8	85.7	21.8	58.0	.035	.017	.05
27	135.0	33.8	89.1	24.6	70.0	.028	.015	.05
28	140.0	28.8	93.5	28.4	89.1	.020	.011	.05
29	145.0	23.8	99.7	33.9	123.8	.010	.006	.05
30	150.0	18.8	108.9	42.5	205.2	.002	.001	.05
31	155.0	13.8	124.5	57.5	614.1	.000	.000	.05
32	.2	168.6	1.0	69.0	69.5	.166 *	.151 *	.05
33	84.4	84.4	70.0	13.7	28.0	.047	.017	.05
34	136.1	32.6	90.0	25.3	73.5	.027	.014	.05

When you're ready, please press **[ENTER]** for
more lines of sight (Q to quit)

Do you want to quit (y/n)? **y**

****

VISCREEN summary report file is: example2.sum
VISCREEN results file is: example2.tst

****

5.4.3 Results And Analysis

The following results summarize the VISCREEN analysis using the meteorological conditions of E and 2 m/s (less extreme than the Level-1 F and 1 m/s). The maximum plume perceptibility for plume parcels located within the Class I area occurs when the sun is in front of the observer (forward-scatter conditions) and the plume is observed against the sky. For these conditions, the plume Delta-E is 8.9, still about 4.5 times larger than the screening threshold but about one half the Level-1 result of 17.8. Given the geometry shown in Figure 4-1, the possibility could not be ruled out that such a forward-scatter situation would occur. Even if such a sun angle were not possible, the second test for a backward scatter sun angle indicates that the plume would be quite visible, exceeding both the Delta-E and the green contrast screening thresholds. The even larger impacts calculated for plume parcels outside the Class I area are relevant in this example since they could occur within an identified integral vista. The maximum green contrasts for the plume parcels located outside the Class I area were 0.231 in forward scatter and -0.129 in backward scatter. These values require careful interpretation, however, as they are for the line of sight through a plume parcel only 1 km from the source.

The result of this analysis is that a Level-3 analysis would be required for this plant because of the failure of both the Level-1 and Level-2 tests for lines of sight within the Class I area.

*** User-selected Screening Scenario Results ***
Input Emissions for

Particulates	25.00	G/S
NOx (as N02)	380.00	G/S
Primary N02	.00	G/S
Soot	.00	G/S
Primary 504	.00	G/S

PARTICLE CHARACTERISTICS

	Density	Diameter
Primary Part.	2.5	6
Soot	2.0	1
Sulfate	1.5	4

Transport Scenario Specifications

Background Ozone:	.04	ppm
Background Visual Range:	170.00	km
Source-Observer Distance:	70.00	km
Min. Source-Class I Distance:	70.00	km
Max. Source-Class I Distance:	90.00	km
Plume-Source-Observer Angle:	11.25	degrees

Stability: 5
Wind Speed: 2.00 m/s

R E S U L T S

Asterisks (*) indicate plume impacts that exceed screening criteria (2.0 for Delta-E and 0.05 for Contrast)

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta-E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	120	80.6	49	2.00	8.925*	.05	-.002
Sky	140	120	80.6	49	2.00	5.312*	.05	-.070*
Terrain	10	84	70.0	84	2.00	4.050*	.05	.047
Terrain	140	84	70.0	84	2.00	1.763*	.05	.017

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta-E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	0	1.0	169	2.00	18.948*	.05	.231*
Sky	140	0	1.0	169	2.00	4.808*	.05	-.129*

Terrain	10	0	1.0	169	2.00	15.292*	.05	.166*
Terrain	140	0	1.0	169	2.00	6.160*	.05	.151*

EXERCISES:

1. Re-run the Level-2 analysis for Example #2, and assume a background fine particulate diameter of 0.5 μm.

2. Re-run the Level-2 analysis for Example #2, and assume the worst-case meteorological condition is D,2 (D stability category and 2 m/s wind speed).

6.0 MASTERING THE VISCREEN MODEL

6.1 EXAMPLE #3: CEMENT PLANT AND RELATED OPERATIONS

A cement plant has been proposed, along with related quarrying, materials handling, and transportation facilities, for a location 20 km from a Class I area. Terrain in the vicinity is relatively flat, and no external vistas from the Class I area (a national park) are considered integral to park visitor experience. However, visibility at some locations within the park boundaries is of concern.

The point in the Class I area closest to the proposed site is shown in Figure 6-1 as Point A. This point is 2O km away from the proposed plant. Lines drawn 11.25 degrees on either side of the line between the site and Point A intersect the Class I area boundary at distances (for conservatism in Level-1 screening) of 23 and 25 km, Since these distances are greater than the minimum distance, the minimum distance to the Class I area boundary (xmin) is set equal to 2O km, as suggested by the Workbook. The most distant Class I area boundary (x_{max}) for analyses on Point A is 80 km away from the cement plant site.

On the basis of discussions with the Federal Land Manager, the closest point that is likely to be visited within the Class I area is 58 km away from the site (Point B). The two dashed lines shown in Figure 6-1, which are drawn at 11.25 Degree on opposite sides of the line connecting the plant site and Point B, intersect the closest boundary at 40 and 44 km and the most distant boundary at 117 and 9O km. For conservatism, x_{min} is set at 40 km and x_{max} is set at 117 km. Also for conservatism, Level-1 analysis was performed using Point A, while Point B was used for Level-2 analysis.

The proposed project would cause elevated emissions from numerous process points and ground-level emissions of fugitive dust, (Estimated emissions rates and particle-size distributions are shown in Table 6-1.)

In the Level-1 and Level-2 screening, for conservatism, all the elevated and ground-based emissions were lumped together as if they originated from a single source. Thus, the particulate emissions were specified as the sum of the process and fugitive emissions. In the Level-1 analysis, Level-1 default particle specifications were used rather than the known particle size distributions. Exhibit 6-1 summarizes the VISCREEN analysis results. Since integral vistas are not protected at this Class I area, only the within-park impacts were relevant. Even so, every case considered-forward and backward scatter as well as sky and terrain viewing backgrounds--showed an impact exceeding the Level-1 screening criteria. Thus, further screening and analysis were warranted.

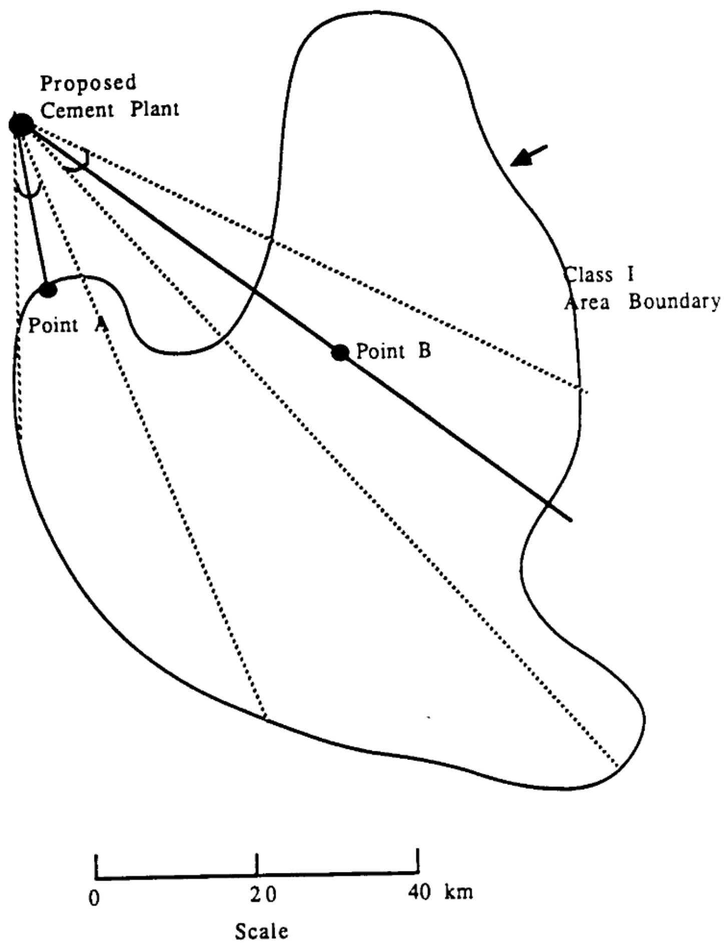

Figure 6-1. Relative locations of Example 2 proposed cement plant and Class I area.

TABLE 6-1. Estimated Project Emissions.

Emissions	Emission Rates
Particulate Matter:	
Process Sources (Effective Stack height = 50 m) DG = 1 μm SigmaG = 2 Density = 2 g cm^{-3}	0.395 MT/day
Fugitive Emissions DG = 10 μm SigmaG = 2 Density = 2 g cm^{-3}	4.54 MT/day
Sulfur Oxides (effective stack height = 50 m)	7.26 MT/day
Nitrogen Oxides (effective stack height = 50 m)	2.27 MT/day

In the Level-1 and Level-2 screening, for conservatism, all the elevated and ground-based emissions were lumped together as if they originated from a single source. Thus, the particulate emissions were specified as the sum of the process and fugitive emissions. In the Level-1 analysis, Level-1 default particle specifications were used rather than the known particle size distributions. Exhibit 6-1 summarizes the VISCREEN analysis results. Since integral vistas are not protected at this Class I area, only the within-park impacts were relevant. Even so, every case considered-forward and backward scatter as well as sky and terrain viewing backgrounds--showed an impact exceeding the Level-1 screening criteria. Thus, further screening and analysis were warranted.

The Level-2 analysis separately specified the process and fugitive emissions with their known particle-size distributions (while still assuming the two plumes overlapped). This was carried out by letting the primary particulate signify the fugitive emissions and the primary sulfate signify the process emissions. Particle sizes were specified to agree with the values in Table 6-1. The less severe worst-case meteorology was found to be D and 1 m/s.

Exhibit 6-2 shows that VISCREEN calculated impacts were not in excess of the screening criteria. The marked difference in Level-1 and Level-2 results arises in part from the less conservative meteorology and geometry of the Level-2 scenario. A major factor also, however, is the significant change in particle size characteristics used for the fugitive emissions.

***Level-1 Screening
Input Emissions for

Particulates	4.93	MT /DAY
NOx (as NO2)	2.72	MT /DAY
Primary N02	.00	MT /DAY
Soot	.00	MT /DAY
Primary S04	.00	MT /DAY

***Default Particle Characteristics Assumed

Transport Scenario Specifications:

Background Ozone:	.04	ppm
Background Visual Range:	60.00	km
Source-Observer Distance:	20.00	km
Min. Source-Class I Distance:	20.00	km
Max. Source-Class I Distance:	80.00	km
Plume-Source-Observer Angle:	11.25	degrees

Stability: 6
Wind Speed: 1.00 m/s

R E S U L T S

Asterisks (*) indicate plume impacts that exceed screening criteria

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	145	28.5	24	2.00	18.245*	.05	.287*
Sky	140	145	28.5	24	2.00	4.677*	.05	-.186*
Terrain	10	84	20.0	84	2.00	27.724*	.05	.279*
Terrain	140	84	20.0	84	2.00	4.859*	.05	.134*

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	10	9.6	159	2.00	22.273*	.05	.346*
Sky	140	10	9.6	159	2.00	5.425*	.05	-.224*
Terrain	10	35	15.9	134	2.00	30.404*	.05	.326*
Terrain	140	35	15.9	134	2.00	6.276*	.05	.190*

EXHIBIT 6-1. Level 1 screening analysis for Example #3.

***User-selected Screening Scenario Results
Input Emissions for

Particulates	4.54	MT /DAY
NOx (as N02)	2.72	MT /DAY
Primary NO2	.00	MT /DAY
Soot	.00	MT /DAY
Primary 504	.40	MT /DAY

PARTICLE CHARACTERISTICS

	Density	Diameter
Primary Part.	2.0	9
Soot	2.0	1
Sulfate	2.0	5

Transport Scenario Specifications:

Background Ozone:	.04	ppm
Background Visual Range:	60.00	km
Source-Observer Distance:	58.00	km
Min. Source-Class I Distance:	40.00	km
Max. Source-Class I Distance:	117.00	km
Plume-Source-Observer Angle:	11.25	degrees

Stability: 4
Wind Speed: 1.00 m/s

R E S U L T S

Asterisks (*) indicate plume impacts that exceed screening criteria

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE NOT Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	35	46.1	134	2.00	.657	.05	.003
Sky	140	35	46.1	134	2.00	.307	.05	-.012
Terrain	10	35	46.1	134	2.00	.724	.05	.009
Terrain	140	35	46.1	134	2.00	.155	.05	.006

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE NOT Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	0	1.0	169	2.00	.802	.05	.008
Sky	140	0	1.0	169	2.00	.421	.05	-.013
Terrain	10	0	1.0	169	2.00	1.988	.05	.018
Terrain	140	0	1.0	169	2.00	.636	.05	.018

EXHIBIT 6-2. Level 2 screening analysis for Example #3.

6.2 EXAMPLE #4: PAPER MILL NEAR CLASS I AREA

A visibility impact assessment is needed for a paper mill that is proposed near a Class I area (see Figure 6-2). Anticipated paper mill emissions are shown in Table 6-2.

TABLE 6-2. Paper mill stack emissions data.

	Stack Height (Ft)	Stack Diameter (In)	Exit Velocity (Ft/Sec)	Exit Temp (F)	Emissions (Metric Tons/Day)		
					PM	SO_2	NO_x
Power Boiler	200	144	25.36	155	1.022	1.756	2.027
Recovery Boiler	275	114	94.06	380	.491	4.069	1.560
Smelt Tank	250	72	23.00	155	.130	.064	--
Lime Kiln	260	50	26.02	160	.07	.091	.454
Total:					1.72	5.97	4.03

The closest point in the Class I area is Point A, which is 7.8 km from the mill. However, Point B is the location in the Class I area that is closest to the mill, that is relatively frequently visited, and is unobstructed by tree cover. Point A was used for Level-1 screening and Point B for Level-2 screening.

Although a plume-rise analysis shows that the plume from the largest emission source (the power boiler) would not be at the same elevation as plumes from other sources, and, thus, that plumes would not overlap, for conservatism all emissions are lumped together as a single plume. Exhibit 6-3 shows the result of Level-1 VISCREEN calculations for this plume and the closest Class I area boundary. With plume Delta-E values ranging from 10.2 to 25.7 for views against the sky (views of distant terrain were not possible at this Class I area), the screening clearly shows the significant potential for adverse plume visual impacts. The plume contrast values indicate that the plume would be bright (positive contrast) in forward scatter (sun in front of observer) and dark (negative contrast) in backward scatter (sun behind observer).

An analysis of on-site data indicated that the worst-case meteorology could be characterized by F and 3 m/s, rather than the F and 1 m/s assumed in Level-1 screening. Exhibit 6-4 summarizes VISCREEN results using this meteorology and Point B geometry (see Figure 6-2). Although impacts are substantially

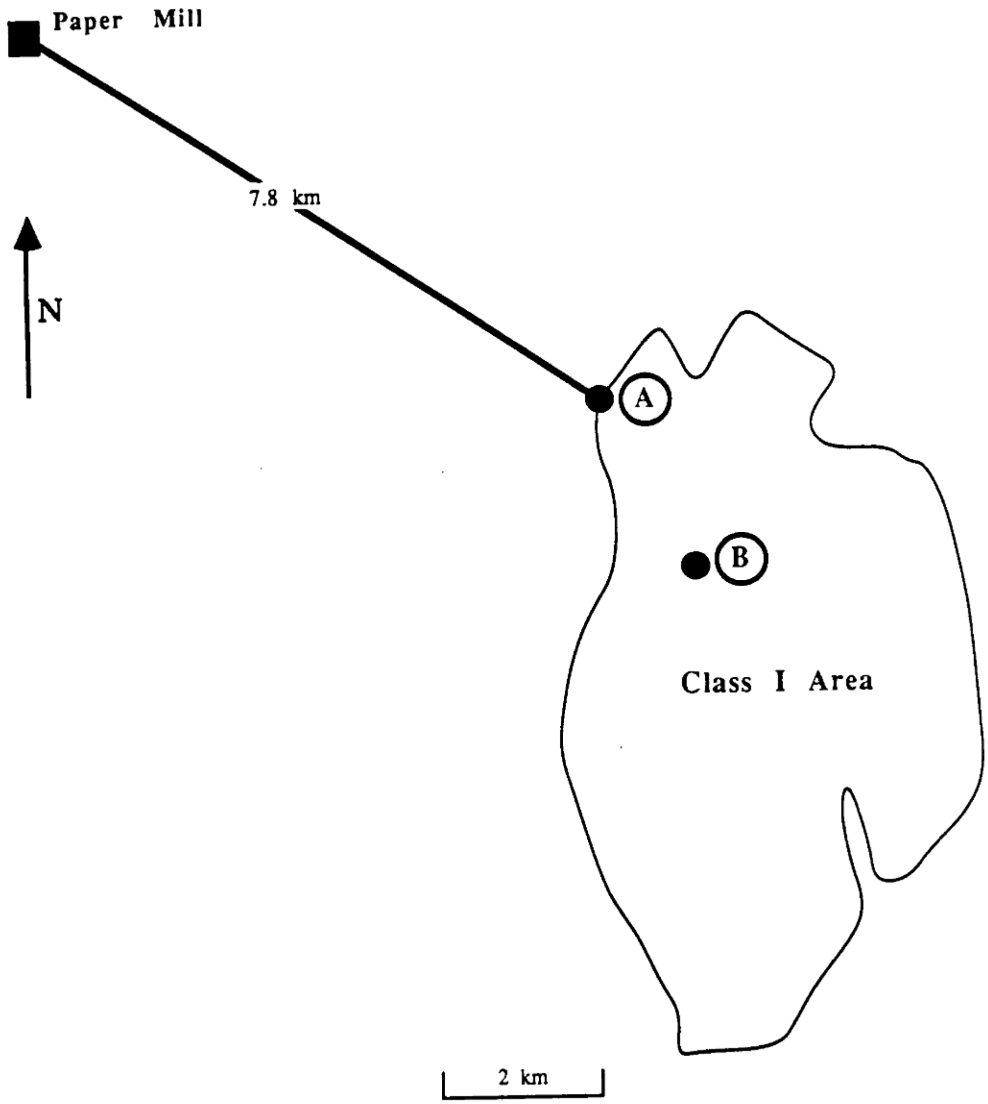

Figure 6-2. Relative locations of paper mill and Class I area used in example 3.

lower (ranging from Delta-E's of 4.0 to 8.6), they are still considerably above the Level-2 screening criteria for both scattering angles assumed. Since the plume-rise analysis indicated that the plume from the largest emitter at the mill would not overlap plumes from other sources, a final analysis was performed with emissions from this single largest emission source--the power boiler. Exhibit 6-5 summarizes the VISCREEN results. Delta-E's range from 2.2 to 4,7, down considerably from the more conservative Level-I and Level-2 analyses, but still considerably in excess of the screening threshold. Thus, a Level-3 analysis would be warranted in this case, and the possibility of adverse plume visual impact could not be ruled out without additional analysis.

***Level-1 Screening
Input Emissions for

Particulates	1.72	MT /DAY
NOx (as N02)	4.03	MT /DAY
Primary NO2	.00	MT /DAY
Soot	.00	MT /DAY
Primary S04	.00	MT /DAY

***Default Particle Characteristics Assumed

Transport Scenario Specifications:

Background Ozone:	.04	ppm
Background Visual Range:	60.00	km
Source-Observer Distance:	7.80	km
Min. Source-Class I Distance:	7.80	km
Max. Source-Class I Distance:	13.00	km
Plume-Source-Observer Angle:	11.25	degrees

Stability: 6
Wind Speed: 1.00 m/s

R E S U L T S

Asterisks (*) indicate plume impacts that exceed screening criteria

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	153	13.0	16	2.00	25.677*	.05	.201*
Sky	140	153	13.0	16	2.00	10.235*	.05	-.245*
Terrain	10	84	7.8	84	2.00	34.701*	.05	.247*
Terrain	140	84	7.8	84	2.00	5.013*	.05	.086*

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	2	1.0	167	2.00	31.191*	.05	.577*
Sky	140	2	1.0	167	2.00	8.757*	.05	-.337*
Terrain	10	2	1.0	167	2.00	52.827*	.05	.597*
Terrain	140	2	1.0	167	2.00	16.779*	.05	.564*

EXHIBIT 6-3. Level 1 screening analysis for Example #4.

***User-selected Screening Scenario Results
Input Emissions for

Particulates	1.72	MT /DAY
NOx (as N02)	4.03	MT /DAY
Primary NO2	.00	MT /DAY
Soot	.00	MT /DAY
Primary S04	.00	MT /DAY

PARTICLE CHARACTERISTICS

	Density	Diameter
Primary Part.	2.5	6
Soot	2.0	1
Sulfate	1.5	4

Transport Scenario Specifications:

Background Ozone:	.04	ppm
Background Visual Range:	60.00	km
Source-Observer Distance:	9.30	km
Min. Source-Class I Distance:	8.00	km
Max. Source-Class I Distance:	13.00	km
Plume-Source-Observer Angle:	11.25	degrees

Stability: 6
Wind Speed: 3.00 m/s

R E S U L T S
Asterisks (*) indicate plume impacts that exceed screening criteria

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	144	13.0	25	2.00	8.558*	.05	.062*
Sky	140	144	13.0	25	2.00	3.984*	.05	-.076*
Terrain	10	47	8.0	122	2.00	15.596*	.05	.105*
Terrain	140	47	8.0	122	2.00	1.948	.05	.034

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	1	1.0	167	2.00	19.745*	.05	.335*
Sky	140	1	1.0	167	2.00	5.156*	.05	-.204*
Terrain	10	1	1.0	167	2.00	36.760*	.05	.403*

Terrain	140	1	1.0	167	2.00	9.265*	.05	.294*

EXHIBIT 6-4. Level 2 Screening analysis for Example #4 (all emissions).

***User-selected Screening Scenario Results
Input Emissions for

Particulates	1.02	MT /DAY
N0x (as N02)	2.03	MT /DAY
Primary N02	.00	MT /DAY
Soot	.00	MT /DAY
Primary S04	.00	MT /DAY

PARTICLE CHARACTERISTICS

	Density	Diameter
Primary Part.	2.5	6
Soot	2.0	1
Sulfate	1.5	4

Transport Scenario Specifications:

Background Ozone:	.04	ppm
Background Visual Range:	60.00	km
Source-Observer Distance:	9.30	km
Min. Source-Class I Distance:	8.00	km
Max. Source-Class I Distance:	13.00	km
Plume-Source-Observer Angle:	11.25	degrees

Stability: 6
Wind Speed: 3.00 m/s

R E S U L T S
Asterisks (*) indicate plume impacts that exceed screening criteria

Maximum Visual Impacts INSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume
Sky	10	144	13.0	25	2.00	4.724*	.05	.041
Sky	140	144	13.0	25	2.00	2.184*	.05	-.044
Terrain	10	47	8.0	122	2.00	10.096*	.05	.064*
Terrain	140	47	8.0	122	2.00	1.150	.05	.020

Maximum Visual Impacts OUTSIDE Class I Area
Screening Criteria ARE Exceeded

					Delta E		Contrast	
Background	Theta	Azi	Distance	Alpha	Crit	Plume	Crit	Plume

Sky	10	1	1.0	167	2.00	14.179*	.05	.236*
Sky	140	1	1.0	167	2.00	3.630*	.05	-.144*
Terrain	10	1	1.0	167	2.00	29.335*	.05	.306*
Terrain	140	1	1.0	167	2.00	6.406*	.05	.192*

EXHIBIT 6-5. Level 2 screening analysis for Example #4 (power boiler emissions).

7.0 ADVANCED TOPICS

7.1 ACCOUNTING FOR COMPLEX TERRAIN

For situations influenced by complex terrain, determination of worst-case wind direction and its frequency of occurrence is much more difficult. The analyst should use professional judgment in this determination. In such situations, determination of the worst-case wind direction and its frequency of occurrence should be made on the basis of the following factors:

(1) Location(s) for which meteorological data were collected relative to terrain features, emissions source, and potentially affected class I areas.

(2) Likely plume trajectories for each wind direction (and possibly wind speed and stability) based on either data or professional judgment. For example, potential channeling, convergence, and divergence of flows should be assessed .

If the observer is located on elevated terrain or if elevated terrain is between the emissions source and the observer, dispersion patterns may be significantly different from those obtained from the procedures outlined above. For such situations, adjustments to the worst-case meteorological conditions determined by these procedures may be necessary.

For example, consider the elevated terrain feature illustrated by the shaded area in Figure 7-1. It is unlikely that a stable plume parcel would remain intact after transport to either Observer A or 8. Either the stable plume would be transported around the elevated terrain feature, resulting in a longer plume transport distance, or the plume would be broken up by turbulence encountered during the straight-line transport up and over the terrain feature. Also, stable plume transport in the direction of Observer C would be blocked by elevated terrain. On the other hand, Observer D would be in a position where straight-line stable transport is not only possible but very likely in the drainage flow off the elevated terrain feature.

Accounting for elevated terrain can be a detailed and time-consuming process, requiring complex-terrain wind field models and other sophisticated tools. Although such analytical options are encouraged, we suggest a simpler screening approach based on assumed enhancements to dispersion caused by elevated terrain.

If the observer is located on terrain at least 500 meters above the effective stack height for stable conditions (Observer C in Figure 7-1) or such elevated terrain separates the emission source and the observer (Observers A and B in Figure 7-1), the worst-case stability class should be shifted one category less stable.

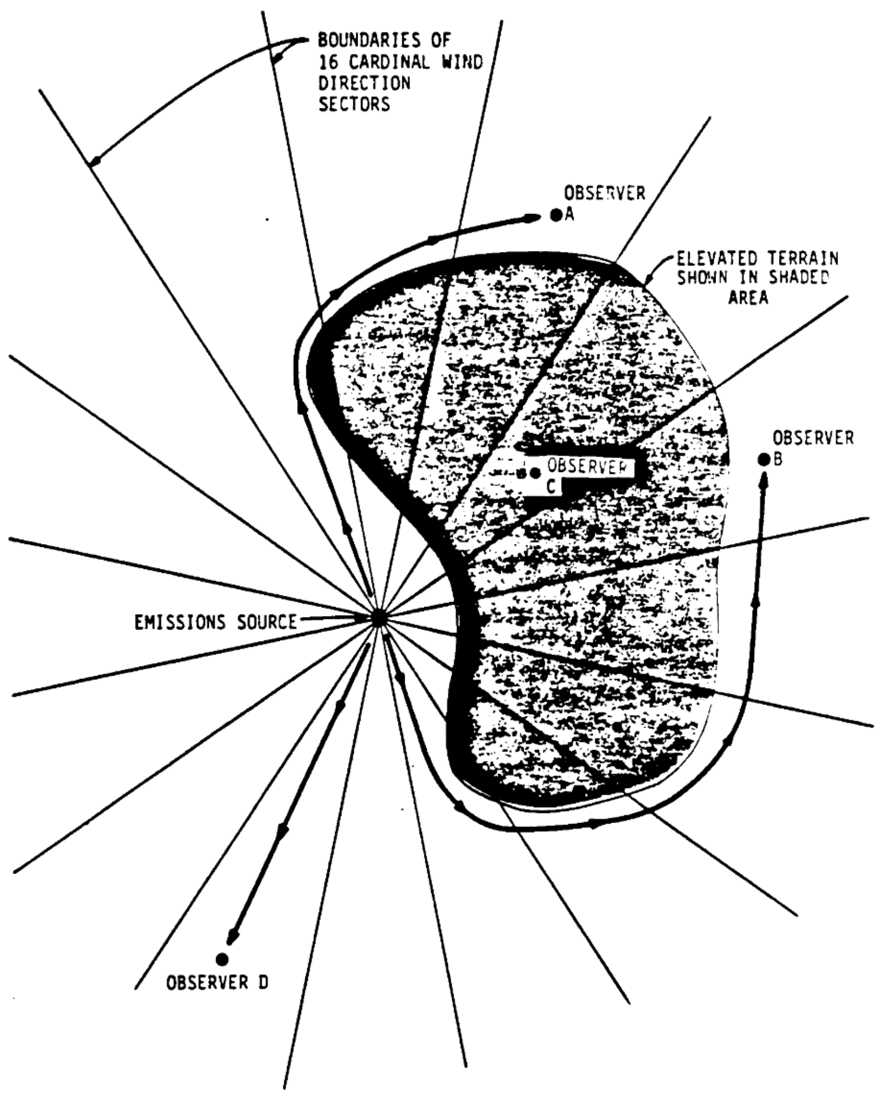

Figure 7-1. Example of map showing emissions source, elevated areas, and stable plume trajectories.

7.2 INSTRUCTIONS FOR USING THE VISCREEN LOTUS 1-2-3 SPREADSHEET

The VISCREEN.EXE model creates two disk files that contain the model outputs. One file is a summary file which contains a formatted, tabular presentation of a brief summary of the maximum predicted visual impacts. The second file, the results file, is an unformatted array of all of the predicted visual impact results. This file was created without headings to facilitate its being imported or read by other personal computer software programs that provide capability for subsequent analysis, graphing, etc., such as the spreadsheet program Lotus 1-2-3 and QUATTRO PRO.

VISCREEN.WK1 is a Lotus 1-2-3 spreadsheet that is designed to format the unformatted results file created by the VISCREEN.EXE model. VISCREEN.WK1 contains three built-in programs (or macros, as they are called) that format the results output file, create graphs of the visibility parameters delta-E, green contrast, and blue-red ratio as a function of azimuth angle, and print the input and output data. RESULTS.TST is a sample unformatted results file produced by the VISCREEN.EXE model. This file can be used as input to test the VISCREEN.WK1 spreadsheet and macros. RESULTS.WK1 is the sample Lotus spreadsheet that results from using VISCREEN.WK1 with the file RESULTS.TST.

The system requirements for using VISCREEN.WK1 are:

VISCREEN.WK1	-- Lotus 1-2-3 spreadsheet and macros
RESULTS.TST	-- sample test case input for VISCREEN.WK1
RESULTS.WK1	-- sample test case spreadsheet output

An IBM-compatible PC
Lotus 1-2-3, Release 2 or higher
Optional graphics display
Optional printer with compressed print mode

The followings are the instructions for using VISCREEN.WK1, the procedure may be altered by your own expertise:

1. Execute the model VISCREEN using the VISCREEN.EXE program. VISCREEN.EXE creates two output files: a summary file and a results file. VISCREEN.EXE prompts the user to enter the paths and names of these summary and results files the model will create. For example, if these two files were named SUMMARY.TST and RESULTS.TST and were pathed to the

\VISCREEN subdirectory of the user's hard disk drive named C, then the respective paths would be specified by C:\VISCREEN\SUMMARY.TST and C:\VISCREEN\RESULTS.TST. Consult your operating system manual for more information on paths and file names.

2. Copy the file VISCREEN.WK1 to the directory that contains the Lotus 1-2-3 software program files. Or simply put that directory into your search path in the AUTOEXEC.BAT.

3. Start the Lotus 1-2-3 program. This is generally done by changing the default directory to the one containing the 1-2-3 software program files, typing 123 and pressing the RETURN key.

4. Retrieve the VISCREEN.WK1 file:

   Press /
   Select File from the Main menu
   Select Retrieve from the submenu
   Type VISCREEN and press RETURN, or
   Move the menu pointer to the name of this file and press RETURN

   The mode indicator in the upper right corner of the screen displays WAIT. The VISCREEN.WK1 worksheet soon will appear. At this point it consists of headings and blank columns.

5. Execute macro v (for VISCREEN) by holding down the macro key and at the same time pressing the v key. On most IBM compatible PC/XT/AT keyboards the macro key is the ALT key. Thus, hold down the ALT key and press the v key at the same time. The macro v program imports a VISCREEN.EXE results file, for example the file RESULTS.TST, into Lotus 1-2-3 and adds descriptive headings for all of the input and output parameters such as emission rates, delta-E, etc..

6. A few seconds after macro v begins execution, the computer will beep and prompt the user to enter the path and name of the VISCREEN.EXE model results file:

   Type the complete path and file name of the results file and press RETURN.

For example, type C:\VISCREEN\RESULTS.TST if this file is called RESULTS.TST and is located in the \VISCREEN subdirectory in the C: drive. The supplied file RESULTS.TST may be used as a test case at this point.

7. The macro will continue executing for about one minute (on an IBM XT compatible), the mode indicator will display WAIT, and a beep will sound when the program has finished. The formatted data now appear in the spreadsheet between rows 1 and 130 and columns a and q (or, range a1..q130 in the Lotus 1-2-3 language). The VISCREEN model inputs are listed beginning at cell a3 (i.e., the intersection of column a and row 3 of the spreadsheet table). The delta E results are listed beginning at cell a37. The contrast results are listed beginning at cell a84.

8. Execute macro g (for graph) by holding down the ALT key and at the same time pressing the g key. The macro g program produces three graphs: Delta E vs. azimuth angle, green contrast vs. azimuth angle, and blue-red ratio vs. azimuth angle. The graph names are DELTA_E, GREEN, and BLUE_RED, respectively.

9. The macro will continue executing for about 1 1/4 minutes (on an IBMXT compatible), the mode indicator will display WAIT, and a beep will sound when the program has finished. To view the graphs (assuming, of course, that your computer has graphics display capability):

   Press /
   Select Graph from the Main menu
   Select View from the submenu
   Press RETURN to return to the menu and spreadsheet

   To view the other graphs:

   From the Graph submenu, Select Name
   Use the right or left arrow keys to highlight the desired graph
   Press RETURN
   Press RETURN again to return to the menu and spreadsheet
   Or from the READY mode, Press /
   Select Graph
   Select Name, then follow the above steps

To print the graphs, use Lotus PrintGraph after the graphs have been saved with the 1-2-3 command /Graph Save.

10. To print the formatted tables of data using macro p (for print):

    Turn on the printer, set condensed print mode, use wide (14 7/8") computer paper, adjust paper so the printer will begin printing at the top of the page

    From the READY mode, hold down the ALT key and at the same time press the p key.

11. To save the worksheet and graphs:

    From the READY mode, Press /
    Select File
    Select Save
    Type in a new file name (eight letters maximum) and press RETURN
    Lotus 1-2-3 automatically affixes the .WK1 file name extension.
    Select Replace

    Note: **DO NOT use the name VISCREEN.** If you do, the master spreadsheet will be overwritten with the spreadsheet created during the work session. The supplied file RESULTS.WK1 is a sample spreadsheet and set of graphs created using the RESULTS.TST file with VISCREEN.WK1.

12. For reference:

    The range containing the formatted data is a1..q130.
    The range containing the original results file is a1..aq85.
    The range containing the macro instructions is ba1..bn130.

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APPENDIX A
GENERAL CONCEPTS OF VISCREEN

In this section we present a brief overview of the concepts required to understand the technical approach used in plume visual impact screening and analysis.

A.1 WHAT MAKES A PLUME VISIBLE?

The objective of plume visual impact screening and analysis is to determine whether or not a plume is visible as an object itself. To understand what makes a plume visible, we first ask what makes any object visible.

Any viewed object is visually distinguishable to a human observer if the light emanating from the object and hitting the retina of the eye is sufficiently different from light emanating from other objects so that the difference or contrast between the given object and surrounding objects (its viewing background) produces a distinguishable signal to the optic nerve and the brain. Visual perception (recognition) requires contrast. Contrast can be large as in the case of this black type on white paper, or contrast can be small as in the case of touch-up paint that doesn't quite match.

Since the human eye responds differently to different wavelengths of light, the eye responds to color as well as brightness. The range of wavelengths to which the human eye responds is called the visible spectrum and ranges from the short-wavelength (0.4 micrometer, μm) blue to the middle-wavelength (0.55 μm) green to the long-wavelength (0.7 μm) red. Contrast can be defined at any wavelength as the relative difference in the intensity (called spectral radiance) between the viewed object and its background.

If the viewed object is brighter than its background, it will have a positive contrast. For example, a white cloud viewed against a dark blue sky will have a positive contrast. If the object is darker than the background, its contrast Is negative. For example, a distant mountain is usually visible because of a negative contrast against the horizon sky (unless the mountain is snow-covered, In which case its contrast is generally positive).

Figure A-1 illustrates the concept of contrast at different wavelengths with four hypothetical objects:

1. Object 1 has spectral radiance distribution defined by I_1 over the visible spectrum. Because Object 1's spectral radiance is uniform over all visible wavelengths, it is nominally white.

2. Object 2 is darker than Object 1 because spectral radiances at all wavelengths are lower than those for Object 1. In

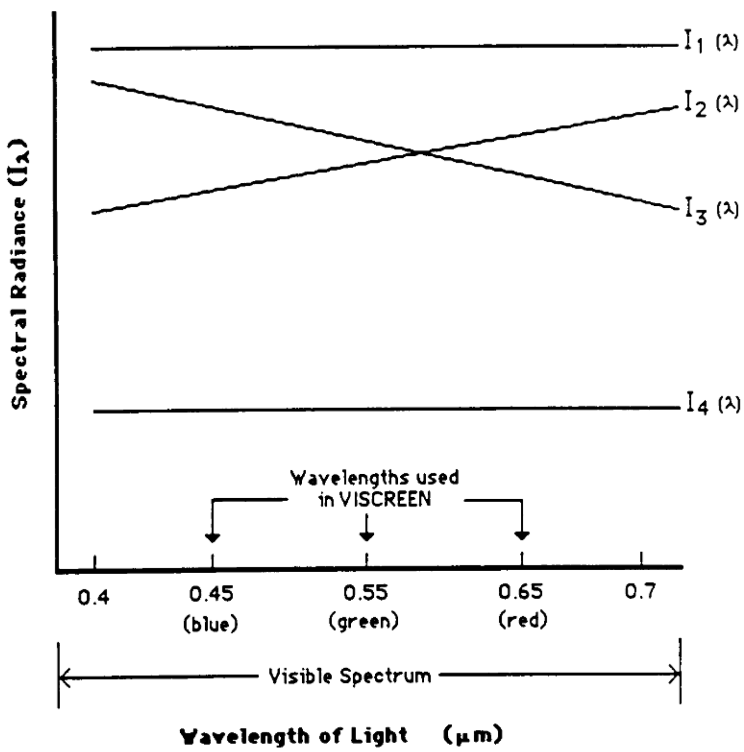


Figure A-1. Example distribution of light intensity of four objects.

addition, Object 2 is a different color because there is relatively more light at the red end of the visible spectrum than at the blue end. The contrast of Object 2 against Object 1 is negative at all wavelengths, but blue contrasts are more negative than both green and red wavelengths. As a result Object 2 would appear dark red (brown) compared to Object 1.

3. Similarly, Object 3 would appear as a dark blue.

4. And Object 4 would appear as an even darker gray (or black).

5. If Object 3 were the viewing background for Object 2, its contrast at the blue end of the visible spectrum would be negative, while its contrast at the red end would be positive. Thus, contrasts at all wavelengths in the visible spectrum characterize the brightness and color of a viewed object (such as a visible plume) relative to its viewing background.

In the plume visual impact screening model VISCREEN, contrasts at three wavelengths (0.45, 0.55, and 0.65 μm) are used to characterize blue, green, and red regions of the visible spectrum. In the plume visibility model PLUVUE, calculations are performed for 39 wavelengths. Thus, we can ascertain whether a plume will be brighter or darker or discolored compared to its viewing background by evaluating its contrasts in the blue, green, and red portions of the visible spectrum. If plume contrast is positive, the plume is brighter than its viewing background; if negative, the plume is darker. If contrasts are different at different wavelengths, the plume is discolored. If contrasts are all zero, the plume is indistinguishable from its background (i.e., imperceptible).

A.2 WHAT CAUSES PLUME CONTRAST?

The contrast of this black text against the white paper is caused by differences in the amount of light reflected from the page. Almost all of the light hitting the white paper is reflected, and almost none of the light hitting the black ink is reflected; hence, the text has a large negative contrast.

However, plume contrast is caused by a somewhat different set of physical processes: plume contrast results from an increase or decrease in light transmitted from the viewing background through the plume to the observer.

This increase or decrease in light intensity is caused by plume constituents that scatter and/or absorb light. There are only two common plume constituents that scatter or absorb light. Particulates, depending on their nature, can scatter light or both scatter and absorb light. Nitrogen dioxide (NO_2) absorbs light of all wavelengths in the visible spectrum but it is a stronger absorber at the blue end of the spectrum.

We can characterize the atmospheric optical properties of a plume in a manner equivalent to the way plume concentrations are characterized. Instead of using mass concentration ($\mu g/m^3$), which is the mass of a given species per unit volume of ambient air, we use parameters called the light scattering coefficient, the light absorption coefficient, and their sum, the light extinction coefficient. These coefficients are essentially the concentrations of the equivalent light scattering, absorption, and extinction cross-sectional area. They cross-sectional area per unit volume of air; hence, their units are m^2/m^3 or m^{-1}.

These coefficients are similar to concentration in that they are proportional to the mass concentrations of the particulates and N02 that scatter and/or absorb light; however, since different chemical species have different light extinction efficiencies, there is no simple one-to-one relationship between mass concentration and light extinction. For example, submicron particles between 0.1 and 1 µm are much more effective in scattering light per unit mass than are either smaller or larger particles. Soot is a stronger light absorber than NO_2 per unit mass. Table A-1 shows the light extinction efficiency of several common constituents of plumes and background atmospheres. Light extinction coefficient is the product of the mass concentration and the light extinction efficiency of the given species.

Plume visual impact models account for the concentrations of various species in a plume (e.g., NO_2, submicron particulate, coarse particulate, and soot) and their light scattering and absorption properties at various visible wavelengths (e.g., blue, green, red).

TABLE A-1. Typical light extinction efficiencies for constituents of plumes and background atmospheres.

CONSTITUENT	Light Extinction Efficiency at Wavelength = 0.55 μm (m^2/g)
Soot	13
Hygroscopic fine particles including (SO) and nitrates (NO)	4-8
Fine particles (0.1 < D < 1 μm)	3
Coarse particles (1 < D < 10 μm)	0.4
Nitrogen dioxide (NO_2)	0.17
Giant particles (D > 10 μm)	< 0.04

Sources: Latimer et al., 1978, 1985; Latimer and Ireson, 1980

A.3 PLUME EFFECTS ON LIGHT TRANSMISSION

Figure A-2 shows a schematic of the viewing situation that is mathematically represented in a plume visual impact model. A plume of limited dimensions is embedded in an otherwise uniform background atmosphere. The observer's line of sight intersects the center of the plume at distance r_p from the observer and it intersects a viewing background object (e.g., a mountain) at distance r_o. The direct rays from the sun are at angle q with respect to the line of sight.

The change in the spectral light intensity at any point along the line of sight (either inside or outside the plume) is a function of distance r along the line of sight and the light scattering coefficient and the light absorption coefficient. The values of these coefficients can be evaluated if the aerosol and $N0_2$ concentrations and such characteristics as the refractive index and the size distribution of the aerosol are known. Scattering and absorption are wavelength-dependent, and effects are greatest at the blue end (0.4 µm) of the visible spectrum (0.4 - 0.7 µm). $N0_2$ absorption is greatest at the blue end. This wavelength dependence causes the natural blue sky coloration as well as discoloration of the atmosphere.

The effects of light scattering and light absorption is related to the change In spectral light intensity with distance along a sight path. It is noted that NO_2 always tends to cause a decrease in light intensity . However, particles may brighten or darken a plume, depending on light scattering effects. If, at a given point along the sight path, The plume light intensity is greater than the clean horizon sky intensity, then the net effect of scattering will be to remove light from the line of sight. This effect would occur if a bright, white cloud or distant snowbank were observed through an aerosol that did not contain NO_2. If, however, The plume light intensity is less than the clean horizon sky intensity, then the net effect of scattering will be to add light to the line of sight. This effect would occur if a distant, dark mountain were observed through an aerosol that did not contain NO_2; scattering would cause the mountain to appear lighter. Only light absorption can cause The plume light intensity to be less than the clean horizon sky intensity, and whenever it happens, scattering will add light to path, thereby masking the coloration caused by NO_2 light absorption.

How a plume (either ground-based or elevated) may be visible because it contrasts with a sky viewing background as shown in Figure A-3(a) or It contrasts with a terrain feature as shown in Figure A-3(b). The plume visual impact screening model VISCREEN evaluates both of these possible viewing backgrounds.

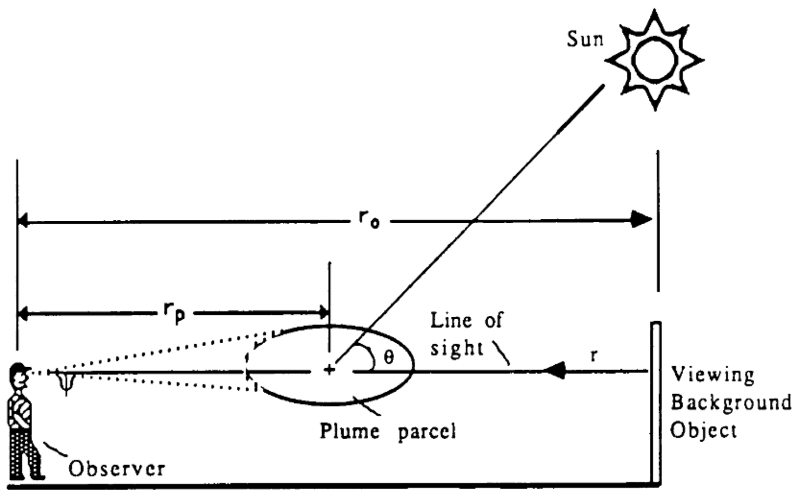
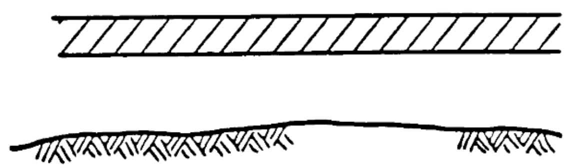
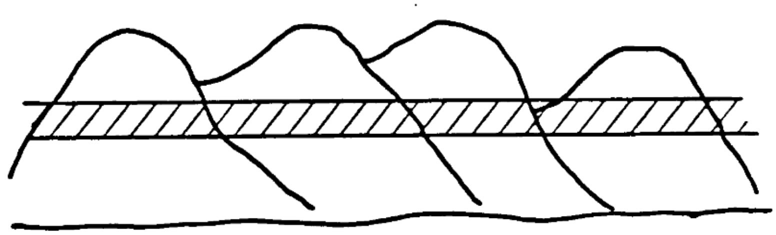


Figure A-2. Geometry of plume, observer, viewing background, and sun.



(a) Plume Visible Against the Sky



(b) Plume Visible Against Terrain

Figure A-3. Two viewing situations in which plumes may be visible.

A.3.1 Plume Contrast Against the Sky

It depends on whether the product of the phase function and the albedo for the plume Is larger or smaller than that for the background, the plume will be brighter ($C > 0$) or darker ($C < 0$) than the background horizon sky. Also note that the contrast is dependent on the plume optical thickness; as the plume optical thickness approaches zero, C approaches zero. Plume contrast also diminishes as the plume-observer distance r_p increases.

A.3.2 Plume Contrast Against Terrain

Careful examination of these two equations illustrates the following sensitivities:

1. Plume contrasts (against both the sky and terrain) increase with increasing plume light extinction (i.e., as concentrations of particulates and NO_2 in a plume increase).

2. Plume contrasts increase if the line of sight is oriented to intersect a larger amount of plume material (i.e., the line of sight is along the plume centerline).

3. Plume contrasts increase for sun angles and for particle size distributions that tend to maximize the difference (both positive and negative) between the phase functions for the background atmosphere and for the plume.

4. Plume contrasts increase if the plume is moved closer to the observer.

5. Plume contrasts increase with decreasing light extinction of the background atmosphere (i.e., with increasing background visual range).

6. Plume contrasts against terrain are maximum if the terrain object is relatively close to the observer and the terrain's intrinsic contrast is maximum (e.g., if it were black).

Since screening calculations are designed to be conservative estimates of worst-case conditions, situations are selected to (1) maximize the concentrations and light scattering efficiencies of optically active plume constituents, the intersection of the line of sight and the plume, the background visual range, the intrinsic contrast of terrain objects, and the difference between background and plume phase functions; and (2) minimize the distance between the observer and the plume. Once conservative estimates of worst-case conditions are specified, the plume visual impact screening model VISCREEN uses simplified method to calculate plume contrasts. If such contrast values are larger than screening criteria, the possibility that the plume will cause significant visual impact cannot be ruled out, and less conservative, more realistic estimates would be required.

A.4 PLUME PERCEPTIBILITY

The perceptibility of a plume is a function of the plume contrast at all visible wavelengths. Perceptibility is a function of changes in both brightness and color. The color difference parameter, Delta-E, was developed to specify the perceived magnitude of color and brightness changes and is used as the primary basis for determining the perceptibility of plume visual impacts in screening analysis.

Although a Delta-E of 1 and a contrast of 0.02 have been traditionally assumed to be the threshold of perceptibility, a survey of the literature suggests a broad range of perceptibility thresholds. The most sensitive observers are able to detect contrasts or color changes one-half this magnitude, and the casual observer may require contrast or color changes more than two times larger than these "traditional" values. In addition, the literature suggests that perceptibility thresholds increase for very wide and for very narrow plumes, with plumes less than 0.02· being essentially imperceptible. Figure A-4 summarizes the range of perceptibility thresholds supported in the literature.

The plume visual impact screening model VISCREEN is designed to ascertain whether the plume from a facility has the potential to be perceptible to untrained observers under "reasonable worst case" conditions. If either of two screening criteria is exceeded, more comprehensive (and realistic) analyses should be carried out. The first criterion is a Delta-E value of 2.0; the second is a green (0.55 µm) contrast value of 0.05. In the case of sufficiently narrow or broad plumes, the higher perception thresholds (for diffuse-edged plumes) are used instead of the above criteria.

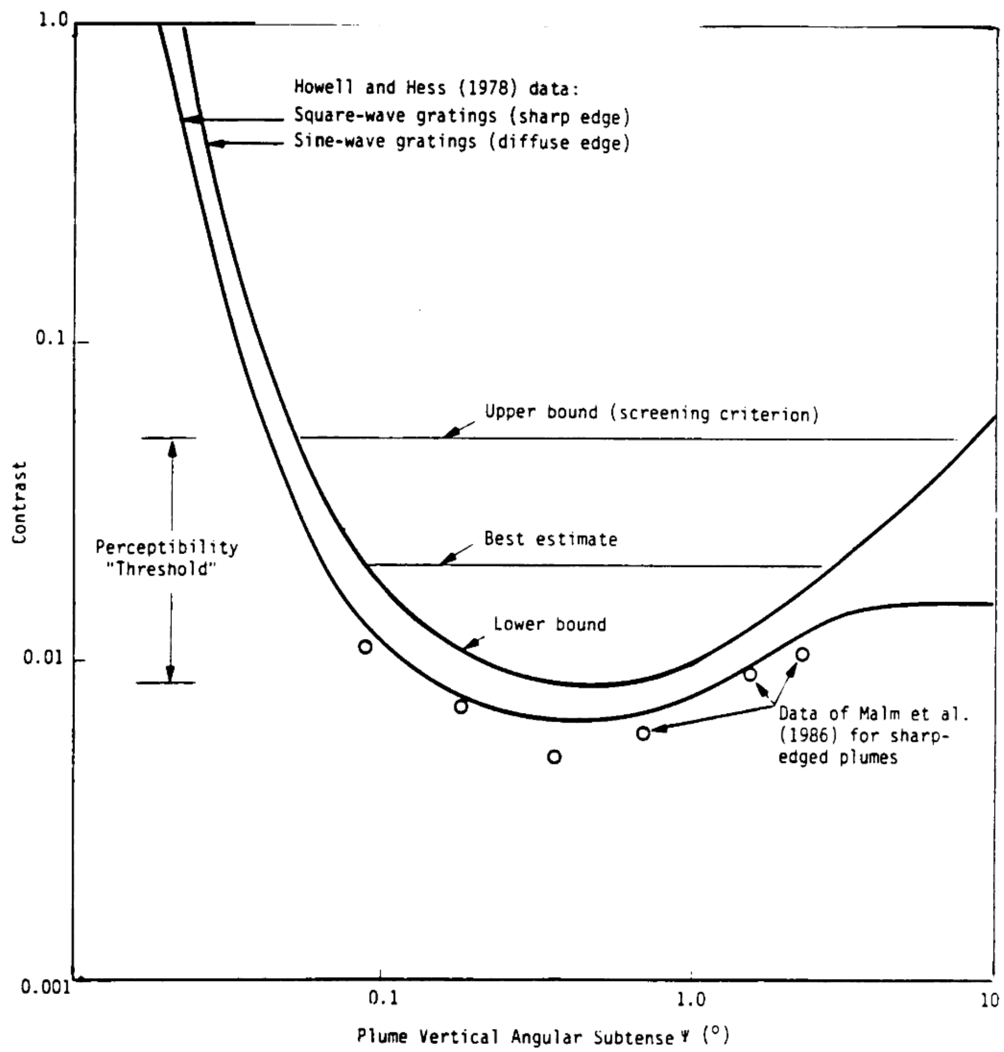


Figure A-4. Plume perceptibility threshold as a function of plume thickness (psi). See definition of psi in the Glossary in

APPENDIX B
INTRODUCING LEVEL-3 ANALYSIS

In Level-3 analysis, the objective is broadened from conservative analysis of worst-case conditions to a realistic analysis of all conditions that would be expected to occur in a typical year in the region that includes both the emission source and the observer. Level-3 analysis is no longer considered screening because it is a comprehensive analysis of the magnitude and frequency of occurrence of plume visual impacts as observed at a sensitive Class I area vista.

B.1 OBJECTIVES AND METHODS OF LEVEL-3 ANALYSIS

It is important to determine the frequency of occurrence of visual impact because the adversity or significance of impact is dependent on how frequently an impact of a given magnitude occurs. For example, if a plume is perceptible from a Class I area a third of the time, the impact would be considered much more significant than if it were perceptible only one day per year. The assessment of frequency of occurrence of impact should be an integral part of Level-3 visual impact analysis.

In this section we discuss how one can determine both the magnitude and frequency of occurrence of plume visual impact. This procedure entails making several runs with a plume visibility model for different values of the following important input parameters that are likely to vary over the course of a typical year:

Emission rates (if variable)
Wind speed
Wind direction
Atmospheric stability
Mixing depth
Background ozone concentration
Background visual range
Time of day and season
Orientation of observer, plume, and sun
Viewing background (whether it is sky, cloud, or snow-covered, sunlit, or shaded terrain).

Because of the large number of variables important to a visual impact calculation, several model calculations are needed to assess the magnitude and frequency of occurrence of visual impact. It would be ideal to calculate hourly impacts over the course of a year or more using hourly values of the above variables. However, such an extensive data base is rarely available for use. Even if it were available, the computing costs involved would be prohibitive. It is therefore preferable to select a few representative, discrete values for each of these variables to represent the range (i.e., the magnitude and frequency of occurrence) of visual impact over a given period of time, such as a season or year.

It is possible to imagine a worst-case impact condition that would never occur in the real atmosphere, this condition could be represented on a cumulative frequency plot. The impact is great, but it almost never occurs. If another worse-case situation less extreme than point A were selected, the magnitude of impact would be less, but it might occur with some nonzero frequency, about one day per year (the reasonable worst-case impacts for Level-1 and Level-2 analyses). It is possible to select various values of all the important input variables and to assess the frequency with which those conditions resulting in impacts worse than a given impact would occur. By this process, several points necessary to specify the frequency distribution could be obtained. With average (5O-percentile) conditions, a negligible impact might be found. The ordinate could be any of the parameters used to characterize visibility impairment, such as visual range reduction, plume contrast, blue-red ratio, or Delta-E, and the abscissa could represent cumulative frequency over a season or a year.

In a visual impact assessment, It is recommended that one select various combinations of upper-air wind speed, wind direction, and atmospheric stability; background ozone concentration; and background visual range to the frequency distribution of plume visual impact. If one has a large, concurrent data base of all five of these variables, it would be desirable to calculate a five-way joint-probability distribution matrix and to use these joint probabilities to calculate frequency of occurrence of impact. However, in most situations, such a data base is not available, and one must treat the various worst-case events as independent probabilities. With this assumption, the probability of worst-case impacts can be roughly estimated by multiplying the independent probabilities.

In such an application, one might obtain an estimate of cumulative frequency by using the joint frequency distribution of upper-air wind speed and wind direction and the separate frequency distributions of upper-air stability and other parameters critical to plume visual impact. If enough data are available, joint frequency distributions should be used. This is especially important if there are known conditions that contradict the assumption of independence (e.g., terrain-induced stable drainage that flows). Each of the input parameters that are important to the visibility model calculation varies significantly over the period of a year.

The most exacting way to obtain plume visual impact cumulative frequency distributions would be to apply a plume visibility model for every time period (e.g., every daylight hour or 3-hour period) with the appropriate emissions, wind speed, wind direction, stability, background ozone, background visual range, sun angle, and viewing background. Thus, one would have a calculation for every daytime period in the course of a year. If done every 3 hours, this would be approximately 1460 model applications (365 days/yr X 12 hr/day of daylight/3 hr = 1460 time periods). Such a method is not practical with current plume visual impact analysis hardware and software.

Thus, the analyst needs to estimate the plume visual impact cumulative frequency distribution using a limited set of plume visibility model runs and appropriate assumptions. There is no simple procedure that can be recommended for all Level-3 analyses. Limited comparisons of Level-3 predictions with measurements suggest that magnitudes and frequencies of plume visual impact are reasonably well estimated by the following suggested procedures. It is recommended, however, that any chosen procedures for performing a given Level-3 analysis be reviewed by the permitting authority and the Federal Land Manager of the affected Class I area before analysis commences.

B.2 FREQUENCY DISTRIBUTION OF DISPERSION CONDITIONS

A joint frequency distribution of wind speed, wind direction, and stability should be prepared separately for the following times of day: midnight to 0600, 0600 to noon, noon to 1800, and 1800 to midnight. This breakdown is necessary to identify the time of day of impacts. These distributions should be compiled for the entire year (or if possible, two or more years) and for each of the four seasons. Seasonal analysis of plume visual impact may be important for the Federal Land Manager and state to assess the number of visitors potentially impacted by a given plume. If worst-case plume visual impacts occur under stable transport conditions, they will most likely occur during the early morning hours. In such cases, it is recommended that the midnight to 0600 frequency distributions be given the primary attention in Level-3 analysis. However, for completeness, the 0600 to noon and noon to 1800 distributions should be used to characterize the frequency of midday and afternoon plume visual impacts.

B.3 CALCULATING PLUME VISUAL IMPACTS

Plume visual impacts should be calculated for a representative sample (or possibly each) of the categories of stability, wind speed, and wind direction in the joint frequency distribution. Since the objective is to estimate the cumulative frequency curve (similar to that shown in Figure 19), plume visual impact should be calculated for the most distant plume position (from the observer) within the given wind direction and the highest wind speed appropriate for a given category of the distribution. For example, for the frequency distribution cell representing F, 0-1 m/s, plume calculations should be made for 1 m/s, not a lower value, and for the most distant plume position (11.25· offset is recommended for the worst-case wind direction sector). This approach is necessary because the abscissa of the cumulative frequency plot is the frequency of conditions that produce impacts her than the ordinate value of plume visual impact magnitude (Delta-E). Plume visual impact should be calculated for a number of the cells of the frequency distribution (perhaps 20 or more). The largest impact magnitudes are likely to occur for wind directions that would carry the plume closest to the observer, light wind speeds, and stable conditions. To fill in conditions causing lower magnitudes (but higher cumulative frequencies), the analyst should identify a sample of wind directions, wind speeds, and stabilities that represent typical conditions. For example, all the 72 combinations of 8 plume positions or wind directions (e.g., worst case and three adjacent 22.5· sectors to the left and right, representing plume offset angles of 11.25, 33.75, 56.25, and 78.75·, 3 wind speeds (e.g., 0-2, 2-5, and 5-10 m/s), and 3 stabilities (e.g., F, E, and D) could be used as the input for 72 plume visibility model runs. These runs would be made using median background ozone concentration and visual range values. Sun angles would be specified by the date and time of the simulation. The worst-case sun angles should be determined by sensitivity analysis for one of the worst-case combinations of meteorological conditions before the full complement of model runs (72 in our example above) is made. Since worst-case meteorological conditions generally occur in the morning, it is suggested that simulation date/times of an hour after sunrise and an hour before sunset on 21 March, 21 June, 21 September, and 21 December be analyzed in the sensitivity test, and the worst-case date/time be used for all subsequent model runs. Model runs should be made for the appropriate viewing backgrounds for each line of sight and each plume position. If terrain is found to be the plume's viewing background, the appropriate distance between the observer and the terrain feature should be provided as part of the model input.

B.4 COUPLING MAGNITUDE AND FREQUENCY

Each of the (for example, 72) model calculations should be evaluated to select the two maximum plume Delta-E's for conditions when the plume parcel is inside and outside the Class I area's boundary, respectively. (If discussions with the Federal Land Manager of the given Class I area suggest that only within-area plume parcels are of concern, only the former Delta-E need be compiled.) The inside and outside Delta-E's separately should be put in descending order of magnitude and coupled with the corresponding frequency of dispersion conditions. Cumulative frequencies should be added by summing the individual frequencies (see Table 3). If a wind direction, stability, or wind speed class was skipped in the sampling of the cells in the frequency distribution, the frequencies for all conditions expected to cause greater plume visual impact should be added and coupled with the given plume visual impact Delta-E. Separate magnitude/frequency tables should be compiled for inside/outside views, each time of day, and each season.

B.5 INTERPRETING THE CUMULATIVE FREQUENCY CURVE

Cumulative frequency distribution curves of plume visual impacts prepared using the procedures described in the preceding paragraphs should be interpreted in light of the assumptions and simplifications underlying the various steps. Several factors that can be particularly significant include the use of median values for visual range and background ozone concentration; the persistence of stable conditions for long transport distances; and the use of Pasquill-Gifford coefficients as the sole determinant of plume dispersion. For specific cases, the combined effect of such assumptions can be that estimated frequencies of a specific level of effects (say, Delta-E greater than 5) may be higher or lower than would actually occur.

Cumulative frequency curves based solely on the joint frequency of wind speed, wind direction, and atmospheric stability ignore the probability of occurrence of other factors that affect plume visual impacts. This probability appears as "f(other factors)" in Equation 11. In our experience, wind speed, direction and stability are the principal determinants of plume visual impacts. In some cases, however, these "other factors" could be significant. Obviously, if data and resources allow, analyses can be expanded to incorporate joint frequency distributions for all key parameters. However, the number of model simulations required will increase geometrically with the addition of each new dimension. For example, treating three visual ranges (e.g., 50th, 75th, and 90th percentiles) triples the number of simulations. Further, the data required to develop such joint frequency distributions are not available for many areas.

No explicit formal guidance can be provided at this time for interpreting cumulative frequency curves. The analyst should, however, identify which transport scenarios have both high visual effects and high frequencies of occurrence. Similarly, the analyst should verify that the transport scenarios modeled include those under which visual impacts will be greatest. If it is likely that simplifying assumptions may have led to bias in the cumulative frequency curves, then the factors leading to this conclusion should be described for consideration by the permitting agency, the Federal Land Manager, and other reviewers.

B.6 SUMMARIZING RESULTS

Cumulative frequency plots similar to Figure 17 should be made for each season, time of day, and inside/outside combination. In addition, the number of mornings and afternoons in each season that Delta-E's are greater than 2 should be tabulated.

B.7 OPTIONAL USE OF VISCREEN

As a low-cost, easy-to-apply, but more conservative estimate of plume visual impact, the analyst may wish to use VISCREEN as the model for generating plume visual impact magnitudes In the Level-3 analysis. VISCREEN could be used either in place of, or in addition to, a plume visibility model. VISCREEN can also be used to choose meteorological scenarios to be further analyzed with a plume visibility model.