EPA 454/R-92-019

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

~~EPA 450/R-92-019~~
October 1992

Air

EPA

Screening Procedures for Estimating the Air Quality Impact of Stationary Sources Revised

EPA 454/R-92-019
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U.S. ENVIRONMENTAL PROTECTION AGENCY
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PREFACE

This document presents current EPA guidance on the use of screening procedures to estimate the air quality impact of stationary sources. The document is an update and revision of the original Volume 10 of the "Guidelines for Air Quality Maintenance Planning and Analysis", and the later Volume 10 (Revised), and is intended to replace Volume 10R as the standard screening procedures for regulatory modeling of stationary sources.

Many of the short-term procedures, outlined in this document, have been implemented in a computerized version in a model entitled SCREEN2. In previous editions of this document, the SCREEN user's guide was contained within an appendix to the document. As of this edition, the SCREEN2 user's guide and documentation is provided as a separate document entitled "SCREEN2 Model User's Guide," EPA-450/4-92-006. Software copies of SCREEN2 may be downloaded from the Office of Air Quality Planning and Standards (OAQPS) Technical Transfer Network (TTN) Bulletin Board System (BBS) via modem by dialing (919) 541-5742. The TTN BBS now serves as the primary source of air dispersion models, replacing the User's Network for Applied Modeling of Air Pollution (UNAMAP). Copies of SCREEN2 in diskette form may be obtained from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

ACKNOWLEDGMENTS

Special credit and thanks are due Mr. Thomas E. Pierce, EPA-AREAL, for his assistance with developing the FORTRAN code for the SCREEN model and for his technical suggestions on improving the procedures. Credit is due Mr. Russell F. Lee, who served as EPA Project Officer on the preparation of the original version of the Volume 10 procedures, and who continued to provide valuable technical assistance for this document, and Mr. Laurence J. Budney, author of the revised version of Volume 10, which served as a foundation for development of the current document. The author also acknowledges those who reviewed the document and provided many valuable comments, including the EPA Regional Modeling Contacts, several State meteorologists, and meteorologists within EPA-OAQPS. Credit and thanks are due Mr. Roger W. Brode, for developing the "Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Draft for Public Comment" documentation for SCREEN. The project officer for SCREEN2, Dennis G. Atkinson, is responsible for the first revision to this document. Mr. Atkinson is on assignment from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Final thanks are due James L. Dicke and Joseph A. Tikvart of EPA-OAQPS for their support and insight.

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LIST OF SYMBOLS

Symbol	Definition
A	Parameter used in building cavity calculations and TIBL height factor
A_p	Cross-sectional area of building normal to the wind (m^2)
B	Parameter used in building cavity calculations
C	Contribution to pollutant concentration (g/m^3)
F_b	Buoyancy flux parameter (m^4/s^3)
H	Total heat release rate from flare (cal/s)
L	Alongwind horizontal building dimension (length, m)
L_b	Lesser of building height or maximum projected width (m)
M	Merged stack parameter
Q	Pollutant emission rate (g/s)
Q_H	Sensible heat release rate from flare (cal/s)
R	Net rate of sensible heating by the sun (67 $cal/m^2/s$)
S	Length of side of square area source (m)
T_a	Ambient temperature (K)
T_s	Stack gas exit temperature (K)
V	Stack gas volume flow rate (m^3/s)
W	Crosswind horizontal building dimension (width, m)
c_p	Specific heat of air at constant pressure (0.24 cal/gK)
d_s	Stack inside diameter (m)
f	Frequency of occurrence of a wind speed and stability category combination
g	Acceleration due to gravity (9.806 m/s^2)
h	Height of release above terrain ($h = h_s - h_t$, m)

LIST OF SYMBOLS (CONT.)

Symbol	Definition
h_b	Building height (m)
h_e	Plume (or effective stack) height (m)
h_i	Height of the top of the plume ($h_e + 2\sigma_z$, m)
h_s	Physical stack height (m)
h_T	Height of the Thermal Internal Boundary Layer (TIBL) (m)
h_t	Height of terrain above stack base (m)
h_{se}	Effective stack release height for flare (m)
h_e'	Plume height modified for stack tip downwash (m)
m	Multiplicative factor to account for effects of limited mixing
p	Wind speed power law profile exponent
r	Factor to adjust 1-hour concentration to longer averaging time
t_m	Time required for inversion break-up to extend from stack top to top of plume (s)
u	Wind speed (m/s)
U_c	Critical wind speed (m/s)
u_s	Wind speed at stack height (m/s)
u_1	Wind speed at a height of Z_1 (m/s)
u_*	Friction velocity (m/s)
u_{10}	Wind speed at a height of 10m (m/s)
$u\Delta h$	Normalized plume rise (m^2/s)
v_s	Stack gas exit velocity (m/s)
x	Downwind distance (m)
x_{max}	Downwind distance to maximum ground-level concentration (m)

LIST OF SYMBOLS (CONT.)

Symbol	Definition
x_r	Length of cavity recirculation region (m)
x_s	Distance from source to shoreline (m)
x_y	Virtual point source distance (m)
z_i	Mixing height (m)
z_m	Mechanically driven mixing height (m)
Δh	Plume rise (m)
$\Delta\theta/\Delta z$	Potential temperature gradient with height (K/m)
Δx	Length of side of urban area (m)
π	pi (= 3.14159)
σ_y	Horizontal (lateral) dispersion parameter (m)
σ_{y_o}	Initial horizontal dispersion parameter for area source (m)
σ_z	Vertical dispersion parameter (m)
χ_B	Concentration contributions from other (background) sources (g/m^3)
χ_f	Maximum ground-level concentration due to fumigation (g/m^3)
χ_{max}	Maximum ground-level concentration (g/m^3)
χ_p	Maximum concentration for period greater than 1 hour (g/m^3)
χ_1	Maximum 1-hour ground-level concentration (g/m^3)
χ_{24}	Maximum 24-hour ground-level concentration (g/m^3)
χ/Q	Relative concentration (s/m^3)
$\chi u/Q$	Normalized relative concentration (m^{-2})

1. INTRODUCTION

This document is an update and revision of an earlier guideline[1,2] for applying screening techniques to estimate the air quality impact of stationary sources. The application of screening techniques is addressed in Section 4.2.1 of the Guideline on Air Quality Models (Revised).[3] The current document incorporates changes and additions to the technical approach. The techniques are applicable to chemically stable, gaseous or fine particulate pollutants. An important advantage of the current document is that the single source, short-term techniques can be easily executed on an IBM® - PC (personal computer) compatible microcomputer with at least 256K of RAM using the SCREEN2 computer code. As with the earlier versions, however, many of the techniques can be applied with a pocket or desk calculator.

The techniques described in this document can be used to evaluate the air quality impact of sources pursuant to the requirements of the Clean Air Act,[4] such as those sources subject to the prevention of significant deterioration (PSD) regulation, addressed in 40 CFR 52.21. The techniques can also be used, where appropriate, for new major or minor sources or modifications subject to new source review regulations, and existing sources of air pollutants, including toxic air pollutants. This document presents a three-phase approach that is applicable to the air quality analysis:

Phase 1. Apply a simple screening procedure (Section 4.1) to determine if either (1) the source clearly poses no air quality problem or (2) the potential for an air quality problem exists.

Phase 2. If the simplified screening results indicate a potential threat to air quality, further analysis is warranted, and the detailed screening (basic modeling) procedures described in Sections 4.2 through 4.5 should be applied.

Phase 3. If the detailed screening results or other factors indicate that a more refined analysis is necessary, refer to the Guideline on Air Quality Models (Revised).[3]

The simple screening procedure (Phase 1) is applied to determine if the source poses a potential threat to air quality. The purpose of first applying a simple screening procedure is to conserve resources by eliminating from further analysis those sources that clearly will not cause or contribute to ambient concentrations in excess of short-term air quality standards or allowable concentration increments. A relatively large degree of "conservatism" is incorporated in that screening procedure to provide reasonable assurance that maximum concentrations will not be underestimated.

If the results of the simple screening procedure indicate a potential to exceed allowable concentrations, then a detailed screening analysis is conducted (Phase 2). The Phase 2 analysis will yield a somewhat conservative first approximation (albeit less conservative than the simple screening estimate) of the source's maximum impact on air quality. If the Phase 2 analysis indicates that the new source does not pose an air quality problem, further modeling may not be necessary. However, there are situations in which analysis beyond the scope of this document (Phase 3) may be required; for example when:

1. A more accurate estimate of the concentrations is needed (e.g., if the results of the Phase 2 analysis indicate a potential air quality problem).
2. The source configuration is complex.
3. Emission rates are highly variable.
4. Pollutant dispersion is significantly affected by nearby terrain features or large bodies of water.

In most of those situations, more refined analytical techniques, such as computer-based dispersion models,[3] can be of considerable help in estimating air quality impact.

In all cases, particularly for applications beyond the scope of this guideline, the services of knowledgeable, well-trained air pollution meteorologists, engineers and air quality analysts should be engaged. An air quality simulation model applied improperly can lead to serious misjudgments regarding the source impact.

2. SOURCE DATA

In order to estimate the impact of a stationary point or area source on air quality, certain characteristics of the source must be known. The following minimum information should generally be available:

- Pollutant emission rate;
- Stack height for a point source and release height for an area source;
- Stack gas temperature, stack inside diameter, and stack gas exit velocity (for plume rise calculations);
- Location of the point of emission with respect to surrounding topography, and the character of that topography;
- A detailed description of all structures in the vicinity of (or attached to) the stack in question. (See the discussion of aerodynamic downwash in Section 4.5.1); and
- Similar information from other significant sources in the vicinity of the subject source (or air quality data or dispersion modeling results that demonstrate the air quality impact of those sources).

At a minimum, impact estimates should be made with source characteristics representative of the design capacity (100 percent load). In addition, the impacts should be estimated based on source characteristics at loads of 50 percent and 75 percent of design capacity, and the maximum impacts selected for comparison to the applicable air quality standard. Refer to Section 9.1.2 in the Guideline on Air Quality Models (Revised)[3] for a further discussion of source data.

2.1 Emissions

The analysis of air quality impact requires that the emissions from each source be fully and accurately characterized. If the pollutants are not emitted at a constant rate (most are not), information should be obtained on how emissions vary with season, day of the week, and hour of the day. In most cases, emission rates vary with the source production rate or rate of fuel consumption. For example, for a coal-fired power plant, emissions are related to the kilowatt-hours of electricity produced, which is proportional to the tonnage of coal used to produce the electricity. Fugitive emissions from an area source are likely to vary with wind speed and both atmospheric and ground moisture content. If pollutant emission data are not directly available, emissions can be estimated from fuel consumption or production rates by multiplying the rates by appropriate emission factors. Emission factors can be determined using three different methods. They are listed below in decreasing order of confidence:

1. Stack-test results or other emission measurements from an identical or similar source.
2. Material balance calculations based on engineering knowledge of the process.
3. Emission factors derived for similar sources or obtained from a compilation by the U.S. Environmental Protection Agency.[5]

In cases where emissions are reduced by control equipment, the effectiveness of the controls must be accounted for in the emissions analysis. The source operator should be able to estimate control effectiveness in reducing emissions and how this effectiveness varies with changes in plant operating conditions.

2.2 Merged Parameters for Multiple Stacks

Sources that emit the same pollutant from several stacks with similar parameters that are within about 100m of each other may be analyzed by treating all of the emissions as coming from a single representative stack. For each stack compute the parameter M:

$$M = \frac{h_s \, V \, T_s}{Q} , \tag{2.1}$$

where:

M = merged stack parameter which accounts for the relative influence of stack height, plume rise, and emission rate on concentrations

h_s = stack height (m)

V = $(\pi/4)\ d_s^2\ v_s$ = stack gas volumetric flow rate (m^3/s)

d_s = inside stack diameter (m)

v_s = stack gas exit velocity (m/s)

T_s = stack gas exit temperature (K)

Q = pollutant emission rate (g/s)

The stack that has the lowest value of M is used as a "representative" stack. Then the sum of the emissions from all stacks is assumed to be emitted from the representative stack; i.e., the equivalent source is characterized by h_{s_1}, V_1, T_{s_1} and Q, where subscript 1 indicates the representative stack and $Q = Q_1 + Q_2 + \ldots + Q_n$.

The parameters from dissimilar stacks should be merged with caution. For example, if the stacks are located more than about 100m apart, or if stack heights, volumetric flow rates, or stack gas exit temperatures differ by more than about 20 percent, the resulting estimates of concentrations due to the merged stack procedure may be unacceptably high.

2.3 Topographic Considerations

It is important to study the topography in the vicinity of the source being analyzed. Topographic features, through their effects on plume behavior, will sometimes be a significant factor in determining ambient ground-level pollutant concentrations. Important features to note are the locations of large bodies of water, elevated terrain, valley configurations, and general terrain roughness in the vicinity of the source.

Section 4.5.2 provides a screening technique for estimating ambient concentrations due to plume impaction at receptors located on elevated terrain features above stack height. The effects of elevated terrain below stack height can be accounted for in Sections 4.2 and 4.3. A screening technique for estimating concentrations under shoreline fumigation conditions is presented in Section 4.5.3. Any other topographic considerations, such as terrain-induced plume downwash and valley stagnation, are beyond the scope of this guideline.

2.4 Source Building Complex

The downwash phenomenon caused by the aerodynamic turbulence induced by a building may result in high ground-level concentrations in the vicinity of an emission source. It is therefore important to characterize the height and width of structures nearby the source. For purposes of these analyses, "nearby" includes structures within a distance of five times the lesser of the height or width of the structure, but not greater than 0.8km (0.5 mile).[6] The screening procedure for building downwash is described in Section 4.5.1.

3. METEOROLOGICAL DATA

The computational procedures given in Section 4 for estimating the impact of a stationary source on air quality utilize information on the following meteorological parameters:

- Wind speed and direction
- Stability class
- Mixing height
- Temperature

A discussion of each of these parameters follows.

3.1 Wind Speed and Direction

Wind speed and direction data are required to estimate short-term peak and long-term average concentrations. The wind speed is used to determine (1) plume dilution, and (2) the plume rise downwind of the stack. These factors, in turn, affect the magnitude of and distance to the maximum ground-level concentration.

Most wind data are collected near ground level. The wind speed at stack height, u_s, can be estimated from the following power law equation:

$$u_s = u_1 \left[\frac{h_s}{z_1}\right]^p , \qquad (3.1)$$

where:

u_s = the wind speed (m/s) at stack height, h_s,

u_1 = the wind speed at a reference height, z_1 (such as the anemometer height), and

p = the stability-related power law exponent from Table 3-1.

Table 3-1. Wind Profile Exponent as a Function of Atmospheric Stability for Rural and Urban Sites*

Stability Class	Rural Exponent	Urban Exponent
A	0.07	0.15
B	0.07	0.15
C	0.10	0.20
D	0.15	0.25
E	0.35	0.30
F	0.55	0.30

The power law equation may be used to adjust wind speeds over a height range from about 10 to 300m. Adjustments to heights above 300m should be used with caution. For release heights below 10m the reference wind speed should be used without adjustment. For the procedures in Section 4 the reference height is assumed to be at 10m.

The wind direction is an approximation to the direction of transport of the plume. The variability of the direction of transport over a period of time is a major factor in estimating ground-level concentrations averaged over that time period.

Wind speed and direction data from National Weather Service (NWS), Air Weather Service, and Naval Weather Service stations are available from the National Climatic Data Center (NCDC), Federal Building, Asheville, NC [(704) 259-0682]. Wind data are often also recorded at existing plant sites and at air quality monitoring sites. It is important that the equipment used to record such data be properly designed, sited, and maintained to record data that are reasonably representative of the direction and speed of the plume.

*The classification of a site as rural or urban should be based on one of the procedures described in Section 8.2.8 of the Guideline on Air Quality Models (Revised).[3]

Guidance on collection of on-site meteorological data is contained primarily in Reference 7, but also in References 3 and 8.

3.2 Stability

Stability categories, as depicted in Tables 3-1 and 3-2, are indicators of atmospheric turbulence. The stability category at any given time will depend upon static stability (related to the change in temperature with height), thermal turbulence (caused by heating of the air at ground level), and mechanical turbulence (a function of wind speed and surface roughness). It is generally estimated by a method given by Turner,[9] which requires information on solar elevation angle, cloud cover, cloud ceiling height, and wind speed (see Table 3-2). Opaque cloud cover should be used if available, otherwise total cloud cover may be used. The solar elevation angle is a function of the time of year and the time of day, and is presented in charts in the Smithsonian Meteorological Tables.[10] The hourly NWS observations include cloud cover, ceiling height, and wind speed. These data are available from NCDC or the SCRAM BBS.* Methods for estimating atmospheric stability categories from on-site data are presented in Reference 7. For computation of seasonal and annual concentrations, a joint frequency distribution of stability class, wind direction, and wind speed (stability wind rose) is needed. Such distributions, called STAR summaries, can be obtained from NCDC for NWS stations.

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*Support Center for Regulatory Air Models Bulletin Board System is a component of the TTN (Technology Transfer Network) BBS maintained by OAQPS, accessible via modem by dialing (919) 541-5742.

Table 3-2. Key to Stability Categories*

Surface Wind Speed at a Height of 10m (m/s)	Day Incoming Solar Radiation (Insolation)***			Night**	
	Strong	Moderate	Slight	Thinly Overcast or ≥ 4/8 Low Cloud Cover	≤ 3/8 Cloud Cover
< 2	A	A - B	B	F	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

* The neutral class (D) should be assumed for all overcast conditions during day or night.

** Night is defined as the period from 1 hour before sunset to 1 hour after sunrise.

*** Appropriate insolation categories may be determined through the use of sky cover and solar elevation information as follows:

Sky Cover (Opaque or Total)	Solar Elevation Angle > 60°	Solar Elevation Angle ≤ 60° but > 35°	Solar Elevation Angle ≤ 35° but > 15°
4/8 or Less or Any Amount of High Thin Clouds	Strong	Moderate	Slight
5/8 to 7/8 Middle Clouds (7000 to 16,000ft base)	Moderate	Slight	Slight
5/8 to 7/8 Low Clouds (less than 7000ft base)	Slight	Slight	Slight

3.3 Mixing Height

The mixing height is the distance above the ground to which relatively unrestricted vertical mixing occurs in the atmosphere. When the mixing height is low (but still above plume height) ambient ground-level concentrations will be relatively high because the pollutants are prevented from dispersing upward. For estimating long-term average concentrations, it is generally adequate to use an annual-average mixing height rather than daily values.

Mixing height data are generally derived from surface temperatures and from upper air soundings which are made at selected NWS stations. The procedure used to determine mixing heights is one developed by Holzworth.[11] Tabulations and summaries of mixing height data can be obtained from NCDC.

For the purposes of calculations made in Section 4.2 and for use in the SCREEN2 model, a mechanically driven mixing height is estimated to provide a lower limit to the mixing height used during neutral and unstable conditions. The mechanical mixing height is calculated from:[12]

$$Z_m = \frac{0.3\ u_*}{f}, \qquad (3.2)$$

where:

u_* = friction velocity (m/s)

f = Coriolis parameter ($9.374 \times 10^{-5} s^{-1}$ at 40° latitude)

Using a log-linear vertical profile for the wind speed, and assuming a surface roughness length of about 0.3m, u_* may be estimated from the 10m wind speed, u_{10}, as

$u_* = 0.1\ u_{10}$

Substituting for u_* in (3.2) yields

$$z_m = 320\ u_{10} \qquad (3.3)$$

If the plume height is calculated to be above the mixing height determined from Equation 3.3, then the mixing height is set at 1m above the plume height for conservatism in SCREEN2.

3.4 Temperature

Ambient air temperature must be known in order to calculate the amount of rise of a buoyant plume. Plume rise is proportional to a fractional power of the temperature difference between the stack gases and the ambient air (see Section 4.2). Ambient temperature data are collected hourly at NWS stations, and are available from NCDC or from the SCRAM BBS. For the procedures in Section 4, a default value of 293K is used for ambient temperature if no data are available.

4. ESTIMATING SOURCE IMPACT ON AIR QUALITY

A three-phase approach, as discussed in the introduction, is recommended for estimating the air quality impact of a stationary source:*

Phase 1. Simple screening analysis

Phase 2. Detailed screening (basic modeling) analysis

Phase 3. Refined modeling analysis

The Phase 3 analysis is beyond the scope of this guideline, and the user is referred to the Guideline on Air Quality Models (Revised).[3] This section presents the simple screening procedure (Section 4.1) and the detailed screening procedures (Sections 4.2 through 4.5). All of the procedures, with the partial exception of the procedures in Sections 4.5.2 and 4.5.3, are based upon the bi-variate Gaussian dispersion model assumptions described in the Workbook of Atmospheric Dispersion Estimates.[9] A consistent set of units (meters, grams, seconds) is used throughout:

Distance (m)

Pollutant Emission Rate (g/s)

Pollutant Concentration (g/m^3)

Wind Speed (m/s)

To convert pollutant concentration to micrograms per cubic meter ($\mu g/m^3$) for comparison with air quality standards, multiply the value in g/m^3 by 1×10^6.

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*The techniques described in this section can be used, where appropriate, to evaluate sources subject to the prevention of significant deterioration regulations (PSD - addressed in 40 CFR 52.21), new major or minor sources subject to new source review regulations, and existing sources of air pollutants, including toxic air pollutants.

4.1 Simple Screening Procedure

The simple screening procedure is the "first phase" that is recommended when assessing the air quality impact of a new point source. The purpose of this screening procedure is to eliminate from further analysis those sources that clearly will not cause or contribute to ambient concentrations in excess of short-term air quality standards.

The scope of the procedure is confined to elevated point sources with plume heights of 10 to 300m, and concentration averaging times of 1-hour to annual. The procedure is particularly useful for sources where the short-term air quality standards are "controlling"; i.e., in cases where meeting the short-term standards provides good assurance of meeting the annual standard for that pollutant. Elevated point sources (i.e., sources for which the emission points are well above ground level) are often in that category, particularly when they are isolated from other sources.

When applying the screening procedure to elevated point sources, the following assumptions must apply:

1. No aerodynamic downwash of the effluent plume by nearby buildings occurs. (Refer to Section 4.5.1 to determine if building downwash is a potential problem.)
2. The plume does not impact on elevated terrain. (Refer to Section 4.5.2 to determine if elevated terrain above stack height may be impacted.)

If the potential for building downwash exists, then SCREEN2 should be used to estimate air quality impact and the simple screening procedure is not applicable.

If the potential for plume impaction on elevated terrain exists, then the calculation procedure described in the indicated section should also be applied, and the higher concentration from the terrain impaction procedure and the simple screening procedure should be selected to estimate the maximum ground-level concentration. The effects of elevated terrain below stack height should also be accounted for by reducing the computed plume heights by the maximum terrain height above stack base.

The screening procedure utilizes the Gaussian dispersion equation to estimate the maximum 1-hour ground-level concentration for the source in question (Computations 1-6 below). To obtain concentrations for other averaging times up to annual, multiply the 1-hour value by an appropriate factor (Computation 7). Then account for background concentrations (Computation 8) to obtain a total concentration estimate. That estimate is then used, in conjunction with any elevated terrain estimates, to determine if further analysis of the source impact is warranted (Computation 9):

Step 1. Estimate the **normalized plume rise** ($u\Delta h$) that is applicable to the source during neutral and unstable atmospheric conditions. (Stable atmospheric conditions are not treated explicitly since this simple screening procedure does not apply to stack heights less than 10m or cases with terrain intercepts.) First, compute the buoyancy flux parameter, F_b:

$$F_b = \frac{g}{4} v_s d_s^2 \left[\frac{T_s - T_a}{T_s}\right] \qquad (4.1)$$

$$= 3.12V \left[\frac{T_s - T_a}{T_s}\right] ,$$

where:

g = acceleration due to gravity (9.806 m/s^2)

v_s = stack gas exit velocity (m/s)*

d_s = stack inside diameter (m)

T_s = stack gas exit temperature (K)*

T_a = ambient air temperature (K) (If no ambient temperature data are available, assume that T_a = 293K.)

$V = (\pi/4)d_s^2v_s$ = actual stack gas volume flow rate (m^3/s)

Normalized plume rise ($u\Delta h$) is then given by:

$$u\Delta h = 21.4F_b^{3/4} \text{ when } F_b < 55 \text{ m}^4/\text{s}^3 \quad (4.2)$$

$$u\Delta h = 38.7F_b^{3/5} \text{ when } F_b \geq 55 \text{ m}^4/\text{s}^3$$

Step 2. Divide the $u\Delta h$ value obtained from Equation 4.2 by each of five wind speeds (u = 1.0, 2.0, 3.0, 5.0 and 10 m/s) to estimate the actual plume rise (Δh) for each wind speed:

$$u\Delta h = (u\Delta h)/u$$

Step 3. Compute the plume height (h_e) that will occur during each wind speed by adding the respective plume rises to the stack height (h_s):

$$h_e = h_s + \Delta h$$

If the effects of elevated terrain below stack height are to be accounted for, then reduce each plume height by the maximum terrain height above stack base.

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*If stack gas temperature or exit velocity data are unavailable, they may be approximated from guidelines that yield typical values for those parameters for existing sources.[13]

Step 4. For each plume height computed in (3), estimate a $\chi u/Q$ value from Figure 4-1.[14]

Step 5. Divide each $\chi u/Q$ value by the respective wind speed to determine the corresponding χ/Q values:

$$\frac{\chi}{Q} = \frac{\chi u/Q}{u}$$

Step 6. Multiply the maximum $\chi u/Q$ value obtained in (5) by the emission rate Q (g/s), and incorporate a factor of 2 margin of safety, to obtain the maximum 1-hour ground-level concentration χ_1 (g/m^3) due to emissions from the stack in question:

$$\chi_1 = 2Q \left[\frac{\chi}{Q}\right]$$

The margin of safety is incorporated in the screening procedure to account for the potential inaccuracy of concentration estimates obtained through calculations of this type.

If more than one stack is being considered, and the procedure for merging parameters for multiple stacks is not applicable (Section 2.2), (1) through (6) must be applied for each stack separately. The maximum values (χ_1) found for each stack are then added together to estimate the **total** maximum 1-hour concentration.

Step 7. To obtain a concentration estimate (χ_p) for an averaging time greater than one hour, multiply the 1-hour value by an appropriate factor, r:*

$$\chi_p = r\,\chi_1$$

---

*See the discussion in Step 5 of Section 4.2 which addresses multiplication factors for averaging times longer than 1-hour.

Step 8. Next, contributions from other sources (χ_B) should be taken into account, yielding the final screening procedure concentration estimate χ_{max} (g/m^3):

$$\chi_{max} = \chi_p + \chi_B.$$

Procedures on estimating concentrations due to other sources are provided in Section 4.5.5.

Step 9. Based on the estimate of χ_{max} and (if applicable) estimate of concentrations due to terrain impaction problems, determine if further analysis of the source is warranted. If any of the estimated concentrations exceeds the air quality level of concern (e.g., an air quality standard), proceed to Section 4.2 for further analysis. If the concentrations are below the level of concern, the source can be safely assumed to pose no threat to that air quality level, and no further analysis is necessary.

4.2 Estimating Maximum Short-Term Concentrations

The basic modeling procedures described in the remainder of this document comprise the recommended "second phase" (or detailed screening) that may be used in assessing air quality impacts. The procedures are intended for application in those cases where the simple screening procedure (first phase) indicates a potential air quality problem. As with the first phase (simple screening) analysis in Section 4.1, if elevated terrain above stack height occurs within 50km of the source, then the procedure in Section 4.5.2 should be applied in addition to the procedures in this section. The highest concentration from all applicable procedures should then be selected to estimate the maximum ground-level concentration. Even if the plume is not likely to impact on elevated terrain, the user should account for the effects of elevated terrain below stack height. If the terrain is relatively uniform around the source, then a procedure to account for terrain effects is to reduce the computed plume height, h_e (for all stabilities), by the maximum terrain elevation above stack base within a 50km radius from the source. The adjusted plume height can then be used in conjunction with the "flat terrain" procedures described in this section.

If there are only a few isolated terrain features in otherwise flat terrain, then the flat terrain estimates from this section should be expanded to include the procedures of Section 4.3 applied to the locations with elevated terrain. For the additional calculations the computed plume height, h_e should be reduced by the terrain height above stack base corresponding to the specific terrain features. The procedures in this section can be applied without the aid of a computer (a pocket or desk calculator will suffice). However, they are subject to the same limitations as the simple screening procedure, i.e., no building downwash occurs (see Section 4.5.1), no terrain impaction occurs (Section 4.5.2), and plume heights do not exceed 300m. An alternative approach is to use the SCREEN2 computer code that has been made available by EPA for use on an IBM® - PC compatible microcomputer with at least 256K of RAM. The SCREEN2 code replaces the PTPLU, PTMAX, and PTDIS codes previously used in conjunction with Volume 10R[2] and the original SCREEN model. It is applicable to all of the procedures contained in this section and Section 4.3, but also includes calculations for the special cases of building downwash, fumigation, elevated terrain, area sources and long range transport described in Section 4.5. Complete documentation on the use of these procedures is provided in the SCREEN2 Model User's Guide.

This section (4.2) presents the basic procedures for estimating maximum short-term concentrations for specific meteorological situations. If building downwash occurs (see Section 4.5.1), then SCREEN2 must be used in lieu of these procedures. In Steps 1-3, plume rise[15,16,17] and a critical wind speed are computed. In Step 4, maximum 1-hour concentrations are estimated. In Step 5, the 1-hour concentrations are used to estimate concentrations for averaging times up to 1 year. Contributions from other sources are accounted for in Step 6.

Step 1. Estimate the normalized plume rise ($u\Delta h$) that is applicable to the source during neutral and unstable atmospheric conditions. First, compute the buoyancy flux term, F_b, using Equation 4.1 (repeated here for convenience):

$$F_b = \frac{g}{4} v_s d_s^2 \left[\frac{T_s - T_a}{T_s}\right] = 3.12V \left[\frac{T_s - T_a}{T_s}\right]$$

(4.1),
where:

g = acceleration due to gravity (9.806 m/s^2)

v_s = stack gas exit velocity (m/s)*

d_s = stack inside diameter (m)

T_s = stack gas exit temperature (K)*

T_a = ambient air temperature (K) (If no ambient temperature data are available, assume that T_a = 293K.)

V = $(\pi/4)d_s^2 v_s$ = actual stack gas volume flow rate (m^3/s)

Normalized plume rise ($u\Delta h$) is then given by:

$$u\Delta h = 21.4F_b^{3/4} \text{ when } F_b < 55\ m^4/s^3$$
$$u\Delta h = 38.7F_b^{3/5} \text{ when } F_b \geq 55\ m^4/s^3 \quad (4.2)$$

If the emissions are from a flare, then the normalized plume rise and an effective release height may be determined with the following procedure:

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*If stack gas temperature or exit velocity data are unavailable, they may be approximated from guidelines that yield typical values for those parameters for existing sources.[13]

(a) Calculate the total heat release rate, H (cal/s), of the flared gas based on the heat content and the gas consumption rate.

(b) Calculate the buoyancy flux term, F_b, for the flare:*

$$F_b = 1.66 \times 10^{-5} \times H \qquad (4.3)$$

(c) Calculate the normalized plume rise ($u\Delta h$) from Equation 4.2.

(d) Calculate the vertical height of the flame, h_f (m), assuming the flame is tilted 45° from the vertical:[19]

$$h_f = 4.56 \times 10^{-3} \times H^{0.478} \qquad (4.4)$$

(e) Calculate an effective release height for the tip of the flame:

$$h_{se} = h_s + h_f.$$

Use h_{se} in place of h_s along with the value of $u\Delta h$ calculated from (c) in determining plume heights in the following procedures.

Step 2. Estimate the critical wind speed (u_c) applicable to the source during neutral and near-neutral atmospheric conditions. The critical wind speed is a function of two opposing effects that occur with increasing wind speed; namely, increased dilution of the effluent as it leaves the stack (which tends to **decrease** the maximum impact on ground-level concentration) and suppression of plume rise (tending to **increase** the impact). The wind speed at which the interaction of those opposing effects results in the highest ground-level concentration is the critical wind speed.

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*This formula was derived from: $F_b = \frac{gQ_H}{\pi \rho c_p T_a}$ (Eqn. 4.20, Briggs[15]), assuming T_a = 293K, ρ = 1205 g/m^3, and c_p = 0.24 cal/gK, and that the sensible heat release rate, Q_H = (0.45)H.[18]

The critical wind speed can be estimated through the following approximation:

$$u_c = \frac{u\Delta h}{h_s} \qquad (4.5)$$

Assume that the value of u_c from Equation 4.5 corresponds to the stack height wind speed. If the value of u_c calculated from Equation 4.5 is less than 1.0 m/s, then use u_c = 1.0 m/s. If the value of u_c calculated from Equation 4.5 is greater than 15.0 m/s, then use u_c = 15.0 m/s.

Step 3. Stable atmospheric conditions may be critical if the emission height is less than 50m. The stable case plume rise (Δh) should be estimated as follows:

$$\Delta h = 2.6 \left[\frac{F_b T_a}{ug\Delta\theta/\Delta z}\right]^{1/3} \qquad (4.6)$$

The value $\Delta\theta/\Delta z$ is the change in potential temperature with height. A value of 0.035 K/m for F stability should be used for both urban and rural sites. The classification criteria of a site as rural or urban should be based on one of the procedures described in Section 8.2.8 of the Guideline on Air Quality Models (Revised).[3]

Step 4. Estimate maximum 1-hour concentrations that will occur during various dispersion situations. First, using Table 4-1 as a guide, determine the dispersion situations and corresponding calculation procedures applicable to the source being considered. Then apply the applicable calculation procedures, which are described on the following pages, in order to estimate maximum 1-hour concentrations. Then proceed to Step 5.

As discussed earlier and as noted in Table 4-1, the hand calculation procedures presented in this step are limited by certain assumptions, namely that no building downwash occurs (Section 4.5.1), no terrain impaction occurs (Section 4.5.2), and that

Table 4-1. Calculation Procedures to Use with Various Release Heights

Height of Release Above Terrain, h	Applicable Calculation Procedures
$h \geq 50m$	(a) Unstable / Limited Mixing (b) Near-neutral / High Wind
$10 \leq h < 50m$	(a) Unstable / Limited Mixing (b) Near-neutral / High Wind (c) Stable
$h < 10m$ and Ground Level Sources	(b) Near-neutral / High Wind (c) Stable

NOTE:*

If $h_s < h_b + 1.5L_b$, refer to Section 4.5.1 on building downwash and use SCREEN2.

If elevated terrain above stack height occurs within 50km, refer to Section 4.5.2.

If fumigation is potentially a problem (e.g., for rural sources with $h_s \geq 10m$), refer to Section 4.5.3.

If the plume height, $h_e = h_s + (u\Delta h/u_s)$ is greater than 300m, then the procedures in this section are not applicable (i.e., SCREEN2 may be used without this restriction).

*$h = h_s - h_t$
h_s = physical stack height
h_t = terrain height above stack base
h_b = height of nearby structure
L_b = lesser of height or maximum projected width of nearby structure

plume heights are below 300m. For cases involving building downwash or plume heights above 300m, SCREEN2 should be used. Documentation for these procedures is provided in SCREEN2 Model User's Guide.

Procedure (a): Unstable/Limited Mixing

During very unstable conditions, the plume from a stack will be mixed to ground level relatively close to the source, resulting in high short-term concentrations. These concentrations can be significantly increased when the unstable conditions occur in conjunction with a limited mixing condition. Limited mixing (also called plume trapping) occurs when a stable layer aloft limits the vertical mixing of the plume. The highest concentrations occur when the mixing height is at or slightly above the plume height.

Calculation Procedure:

1. Compute the plume height, h_e, that will occur during A stability and 10m wind speeds of 1 and 3 m/s. Adjust the wind speeds from 10m to stack height using Equation 3.1 and the exponent for stability class A. Use the $u\Delta h$ value computed in Step 1.

$$h_e = h_s + \frac{u\Delta h}{u_s}$$

$$= h_s + \Delta h$$

If $v_s < 1.5u_s$, account for stack tip downwash as follows:

$$h_e = h_s + \Delta h + 2[\frac{v_s}{u_s} - 1.5]d_s \qquad (4.7)$$

If elevated terrain is to be accounted for, then reduce the computed plume height for each wind speed by the maximum terrain elevation above stack base.

2. For both wind speeds considered in (1), determine the maximum 1-hour $\chi u/Q$ using the curve for stability A on Figure 4-2 (rural)[9] or A-B on Figure 4-3 (urban).[20]

3. Compute the maximum 1-hour concentration, χ_1, for both cases using:

$$\chi_1 = mQ \frac{\chi u/Q}{u_s} , \tag{4.8}$$

where **m** is a conservative factor to account for the increase in concentration expected due to reflections of the plume off the top of the mixed layer. The value of **m** depends on the plume height as follows:*

$m = 2.0$ for $290m \le h_e$
$m = 1.8$ for $270m \le h_e < 290m$
$m = 1.5$ for $210m \le h_e < 270m$
$m = 1.2$ for $180m \le h_e < 210m$
$m = 1.1$ for $160m \le h_e < 180m$
$m = 1.0$ for $h_e < 160m$

Select the highest concentration computed.

<u>Procedure (b)</u>: Near-neutral/High Wind

Some buoyant plumes will have their greatest impact on ground-level concentrations during neutral or near-neutral conditions, often in conjunction with high wind speeds.

Calculation procedure:

1. Compute the plume height, h_e, that will occur during C stability with a stack height wind speed of $u_s = u_c$, the value of the critical wind speed computed in Step 2. If $u_c < 10$ m/s, then also compute the plume height that will occur during C stability with

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*The values of m are based on an assumed minimum daytime mixing height of about 320m (see Section 3.3).

a 10m wind speed of 10 m/s. Adjust the 10 m/s wind speed from 10m to stack height using Equation 3.1 and the exponent for stability class C. Use the uΔh value computed in Step 1:

$$h_e = h_s + \frac{u\Delta h}{u_s}$$

If $v_s < 1.5u_s$, account for stack tip downwash using Equation 4.7. If elevated terrain is to be accounted for, then reduce the computed plume height for each wind speed by the maximum terrain elevation above stack base.

2. For the wind speed(s) considered in (1), determine the maximum 1-hour $\chi u/Q$ using the curve for stability C on Figure 4-2 (rural)[9] or Figure 4.3 (urban).[20]

3. Compute the maximum 1-hour concentration χ_1 for each case using:

$$\chi_1 = Q \frac{\chi u/Q}{u_s}$$

and select the highest concentration computed.

<u>Procedure (c)</u>: **Stable**

Low-level sources (i.e., sources with stack heights less than about 50m) sometimes produce the highest concentrations during stable atmospheric conditions. Under such conditions, the plume's vertical spread is severely restricted and horizontal spreading is also reduced. This results in what is called a fanning plume.

Calculation procedures:

A. For low-level sources with some plume rise, calculate the concentration as follows:

1. Compute the plume height (h_e) that will occur during F stability (for rural cases) and 10m wind speeds of 1, 3, and 4 m/s,* or E stability (for urban cases) and 10m wind speeds of 1, 3, and 5 m/s. Adjust the wind speeds from 10m to stack height, using Equation 3.1 and the appropriate exponent. Use the stable plume rise (Δh) computed from Equation 4.6 in Step 3:

$$h_e = h_s + \Delta h$$

If $v_s < 1.5u_s$, account for stack tip downwash using Equation 4.7. If elevated terrain is to be accounted for, then reduce the computed plume height for each wind speed by the maximum terrain elevation above stack base.

2. For each wind speed and stability considered in (1), find the maximum 1-hour $\chi u/Q$ from Figure 4-2 (rural)[9] or 4-3 (urban).[20] Compute the maximum 1-hour concentration for each case, using

$$\chi_1 = Q \frac{\chi u/Q}{u_s}$$

and select the highest concentration computed.

B. For low-level sources with no plume rise ($h_e = h_s$), find the maximum 1-hour $\chi u/Q$ from Figure 4-2 (rural case - assume F stability) or 4-3 (urban case - assume E stability). Compute the maximum 1-hour concentration, assuming a 10m wind speed of 1 m/s. Adjust the wind speed from 10m to stack height using Equation 3.1 and the appropriate exponent.

$$\chi_1 = Q \frac{\chi u/Q}{u_s}$$

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*Refer to the discussion on worst case meteorological conditions in the SCREEN2 User's Guide for an explanation of the use of F stability with a 4 m/s wind speed.

<u>Step 5</u>. Obtain concentration estimates for the averaging times of concern. The maximum 1-hour concentration (χ_1) is the highest of the concentrations estimated in Step 4, Procedures (a) - (c). For averaging times greater than 1-hour, the maximum concentration will generally be less than the 1-hour value. The following discussion describes how the maximum 1-hour value may be used to make an estimate of maximum concentrations for longer averaging times.

The ratio between a longer-term maximum concentration and a 1-hour maximum will depend upon the duration of the longer averaging time, source characteristics, local climatology and topography, and the meteorological conditions associated with the 1-hour maximum. Because of the many ways in which such factors interact, it is not practical to categorize all situations that will typically result in any specified ratio between the longer-term and 1-hour maxima. Therefore, ratios are presented here for a "general case" and the user is given some flexibility to adjust those ratios to represent more closely any particular point source application where actual meteorological data are used. To obtain the estimated maximum concentration for a 3-, 8-, 24-hour or annual averaging time, multiply the 1-hour maximum (χ_1) by the indicated factor:

Averaging Time	Multiplying Factor	
3 hours	0.9	(±0.1)
8 hours	0.7	(±0.2)
24 hours	0.4	(±0.2)
Annual	0.08	(±0.02)

The numbers in parentheses are recommended limits to which one may diverge from the multiplying factors representing the general case. For example, if aerodynamic downwash or terrain is a problem at the facility, or if the emission height is very low, it may be necessary to **increase** the factors (within the limits specified in parentheses). On the other hand, if the stack is relatively tall and there are no terrain or downwash problems, it may be appropriate to **decrease** the factors. Agreement should be reached with the Regional Office prior to modifying the factors.

The multiplying factors listed above are based upon general experience with elevated point sources. The factors are only intended as a rough guide for estimating maximum concentrations for averaging times greater than one hour. A degree of conservatism is incorporated in the factors to provide reasonable assurance that maximum concentrations for 3-, 8-, 24-hour and annual values will not be underestimated.

Step 6. Add the expected contribution from other sources to the concentration estimated in Step 5. Concentrations due to other sources can be estimated from measured data, or by computing the effect of existing sources on air quality in the area being studied. Procedures for estimating such concentrations are given in Section 4.5.5. At this point in the analysis, a first approximation of maximum short-term ambient concentrations (source impact plus contributions from other sources) has been obtained. If concentrations at specified locations, long-term concentrations, or other special topics must be addressed, refer to applicable portions of Sections 4.3 to 4.5.

4.3 Short-Term Concentrations at Specified Locations

In Section 4.2, maximum concentrations are generally estimated without specific attention to the location(s) of the receptor(s). In some cases, however, it is particularly important to estimate the impact of a source on air quality in **specified** (e.g., critical) areas. For example, there may be nearby locations at which high pollutant concentrations already occur due to other sources, and where a relatively small addition to ambient concentrations might cause ambient standards to be exceeded. Another example would be where an isolated terrain feature occurs in otherwise flat terrain, and concentrations at the elevated terrain location may exceed those estimated for flat terrain. These procedures assume that no building downwash occurs (Section 4.5.1), no terrain impaction occurs (Section 4.5.2), and that plume heights do not exceed 300m.

Each of the sources affecting a given location can be expected to produce its greatest impact during certain meteorological conditions. The composite maximum concentration at that location due to the interaction of all the sources may occur under different meteorological conditions than those which produce the highest impact from any one source. Thus, the analysis of this problem can be difficult, and may require substantial use of high-speed computers. Despite the potential complexity of the problem, some preliminary calculations can be made that will at least indicate whether or not a more detailed study is needed. For example, if the preliminary analysis indicates that the estimated concentrations are near or above the air quality standards of concern, a more detailed analysis will probably be required.

Calculation procedure:*

Step 1. Compute the normalized plume rise ($u\Delta h$) for neutral and unstable conditions, utilizing the procedure described in Step 1 of Section 4.2.

Step 2. Compute the plume rise, Δh, that will occur during C stability (to represent neutral and unstable conditions) with 10m wind speeds of 1, 3, 5, 10, and 20 m/s. Adjust

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*If SCREEN2 is used, refer to the discrete distance option described in the SCREEN2 Model User's Guide.

the wind speeds from 10m to stack height using Equation 3.1 and the exponent for stability class C.

$$\Delta h = \frac{u\Delta h}{u_s}$$

<u>Step 3</u>. Compute the **plume height (h_e)** that will occur during each wind speed by adding the respective plume rises to the stack height (h_s):

$$h_e = h_s + \Delta h$$

If $v_s < 1.5\ u_s$, account for stack tip downwash using Equation 4.7. If elevated terrain is to be accounted for, then reduce the computed plume height for each wind speed by the terrain elevation above stack base for the specified location.

<u>Step 4</u>. For each stability class-wind speed combination listed below, **at the downwind distance of the "specified location,"** determine the $\chi u/Q$ value from Figures 4-4 through 4-7 (rural) or Figures 4-10 through 4-12 (urban) for non-stable conditions. Note that in those figures (see the captions) very restrictive mixing heights are assumed, resulting in trapping of the entire plume within a shallow layer.

Stability Class	10m Wind Speed (m/s)
A	1, 3
B	1, 3, 5
C	1, 3, 5, 10
D	1, 3, 5, 10, 20

<u>Step 5</u>. (If the physical stack height is greater than 50m and flat terrain is being assumed, Steps 5 and 6 may be skipped.) Compute plume heights (h_e) that will occur for stability class E and 10m wind speeds of 1, 3, and 5 m/s, and for stability class F (rural

sources only) and 10m wind speeds of 1 and 3 and 4 m/s.* Adjust the wind speeds from 10m to stack height using Equation 3.1 and the appropriate exponent. Use the stable plume rise (Δh) computed from Equation 4.6 in Step 3 of Section 4.2:

$$h_e = h_s + \Delta h.$$

If $v_s < 1.5u_s$, account for stack tip downwash using Equation 4.7. If elevated terrain is to be accounted for, then reduce the computed plume height for each case by the terrain elevation above stack base for the specified location.

<u>Step 6</u>. For each stability class-wind speed combination considered in Step 5, at the downwind distance of the specified location, determine a $\chi u/Q$ value from Figures 4-8 and 4-9 (or Figure 4-13 for the urban case).

<u>Step 7</u>. For each $\chi u/Q$ value obtained in Step 4 (and Step 6 if applicable), compute χ/Q:

$$\frac{\chi}{Q} = \frac{\chi u/Q}{u_s}$$

<u>Step 8</u>. Select the largest χ/Q and multiply by the source emission rate (g/s) to obtain a 1-hour concentration value (g/m^3):

$$\chi_1 = Q\left(\frac{\chi}{Q}\right)_{max}$$

<u>Step 9</u>. To estimate concentrations for averaging time greater than 1-hour, refer to the averaging time procedure described earlier (Step 5 of Section 4.2). To account for contributions from other sources, see Section 4.5.5.

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*Refer to the discussion on worst case meteorological conditions in the SCREEN2 Model User's Guide for an explanation of the use of F stability with a 4m/s wind speed.

4.4 Annual Average Concentrations

This section presents procedures for estimating annual average ambient concentrations caused by a single point source. The procedure for estimating the annual concentration at a specified location is presented first, followed by a suggestion of how that procedure can be expanded to estimate the overall maximum annual concentration (regardless of location). The procedures assume that the emissions are continuous and at a constant rate. The data required are emission rate, stack height, stack gas volume flow rate (or diameter and exit velocity), stack gas temperature, average afternoon mixing height, and a representative stability wind rose.* Refer to Sections 2 and 3 for a discussion of such data.

4.4.1 Annual Average Concentration at a Specified Location

Calculation procedure:

Step 1. (Applicable to stability categories A through D). Using the procedure described in Step 1 of Section 4.2 (Equations 4.1 and 4.2) obtain a normalized plume rise value, $u\Delta h$.

Step 2. (Applicable to stability categories E and F). Use Equation 4.6 from Step 3 of Section 4.2 to estimate the plume rise (Δh) as a function of wind speed for both stable categories (E and F) using values of $\Delta\theta/\Delta z$ = 0.02 K/m for category E and $\Delta\theta/\Delta z$ = 0.035 K/m for category F.

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*The stability wind rose is a joint frequency distribution of wind speed, wind direction and atmospheric stability for a given locality. Stability wind roses for many locations are available from the National Climatic Data Center, Asheville, North Carolina.

Step 3. Compute plume rise (Δh) for each stability-wind speed category in Table 4-2 by (1) substituting the corresponding wind speed for u in the appropriate equations referenced in Step 1 or 2 above and (2) solving the equation for Δh. The wind speeds listed in Table 4-2 are derived from the wind speed intervals used by NCDC (Table 4-3) in specifying stability-wind roses. The wind speeds may be adjusted from 10m to stack height using Equation 3.1.

Step 4. Compute plume height (h_e) for each stability-wind speed category in Table 4-2 by adding the physical stack height (h_s) to each of the plume rise values computed in Step 3:

$$h_e = h_s + \Delta h$$

Step 5. Estimate the contribution to the annual average concentration at the specified location for each of the stability-wind speed categories in Table 4-2. First, determine the vertical dispersion coefficient (σ_z) for each stability class for the downwind distance (x) between the source and the specified location, using Figure 4-14. (Note: For **urban** F stability cases, use the σ_z for stability E.) Next, determine the mixing height (z_i) applicable to each stability class. For stabilities A to D, use the average afternoon mixing height for the area (Figure 4-15). For **urban** stability E use the average morning mixing height (Figure 4-16). For **rural** stabilities E and F, mixing height is not applicable. Then, use that information as follows: for all stability-wind conditions when the plume height (h_e) is greater than the mixing height (z_i), assume a zero contribution to the annual concentration at the specified location. For each condition when $\sigma_z \leq 0.8 z_i$ and for all **rural** stability E and F cases, apply the following equation[9] to estimate the contribution C (g/m^3):

Table 4-2. Stability-Wind Speed Combinations That Are Considered in Estimating Annual Average Concentrations

Atmospheric Stability Categories	Wind Speed (m/s)					
	1.5	2.5	4.5	7	9.5	12.5
A	*	*				
B	*	*	*			
C	*	*	*	*	*	
D	*	*	*	*	*	*
E	*	*	*			
F	*	*				

* It is only necessary to consider the stability-wind speed conditions marked with an asterisk.

Table 4-3. Wind Speed Intervals Used by the National Climatic Data Center (NCDC) for Joint Frequency Distributions of Wind Speed, Wind Direction and Stability

Class	Speed Interval		Representative Wind Speed (m/s)
	m/s	knots	
1	0 to 1.8	0 to 3	1.5
2	1.8 to 3.3	4 to 6	2.5
3	3.3 to 5.4	7 to 10	4.5
4	5.4 to 8.5	11 to 16	7.0
5	8.5 to 11.0	17 to 21	9.5
6	> 11.0	> 21	12.5

$$C = [\frac{2.032\ Q\ f}{\sigma_z\ u\ x}]\ \exp\ [-\frac{1}{2}\ (\frac{h_e}{\sigma_z})^2] \qquad (4.9)$$

For each condition during which $\sigma_z > 0.8z_i$, the following equation[9] is applied:

$$C = \frac{2.55\ Q\ f}{z_i\ u\ x} \qquad (4.10)$$

In equations 4.9 and 4.10:

Q = pollutant emission rate (g/s)

u = wind speed (m/s)

f = frequency of occurrence of the particular wind speed-stability combination (obtained from the stability-wind rose (STAR) summary available from NCDC) for the wind direction of concern. Only consider the wind speed-stability combinations for the wind direction that will bring the plume closest to the specified location.

Step 6. Sum the contributions (C) computed in Step 5 to estimate the annual average concentration at the specified location.

4.4.2 Maximum Annual Average Concentration

To estimate the overall maximum annual average concentration (the maximum concentration regardless of location) follow the procedure for the annual average concentration at a specified location, repeating the procedure for each of several receptor distances, and for all directions. Because of the large number of calculations required, it is recommended that a computer model such as ISCLT2 be used.[21]

4.5 Special Topics

4.5.1 Building Downwash

In some cases, the aerodynamic turbulence induced by a nearby building will cause a pollutant emitted from an elevated source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentration immediately to the lee of the building than would otherwise occur. Thus, when assessing the impact of a source on air quality, the possibility of downwash problems should be investigated. For purposes of these analyses, "nearby" includes structures within a distance of five times the lesser of the height or width of the structure, but not greater than 0.8km (0.5 mile).[6] If downwash is found to be a potential problem, its effect on air quality should be estimated. Also when Good Engineering Practice (GEP) analysis indicates that a stack is less than the GEP height, the following screening procedures should be applied to assess the potential air quality impact. The best approach to determine if downwash will be a problem at a proposed facility is to conduct observations of effluent behavior at a similar facility. If this is not feasible, and if the facility has a simple configuration (e.g., a stack adjacent or attached to a single rectangular building), a simple rule-of-thumb[22] may be applied to determine the stack height (h_s) necessary to avoid downwash problems:

$$h_s \geq h_b + 1.5\ L_b\ , \qquad (4.11)$$

where h_b is building height and L_b is the lesser of **either** building height or maximum projected building width. In other words, if the stack height is equal to or greater than $h_b + 1.5\ L_b$, downwash is unlikely to be a problem.

If there is more than one stack at a given facility, the above rule must be successively applied to each stack. If more than one building is involved the rule must be successively applied to each building. Tiered structures and groups of structures should be treated according to Reference 6. For relatively complex source configurations the rule may not be applicable, particularly when the building shapes are much different from the simple rectangular building for which the above equation was derived. For these cases, refined modeling techniques[3] or a wind tunnel study is recommended.

If it is determined that the potential for downwash exists, then SCREEN2 should be used to estimate the maximum ground-level pollutant concentrations that occur as a result of the downwash. The building downwash screening procedure is divided into the following two major areas of concern:

A. Cavity Region, and
B. Wake Region

Generally, downwash has its greatest impact when the effluent is caught in the cavity region. However, the cavity may not extend beyond the plant boundary and, in some instances, impacts in the wake region may exceed impacts in the cavity region. Therefore, impacts in both regions must be considered if downwash is potentially a problem.

When SCREEN2 is run for building downwash calculations, the program prompts the user for the building height, the minimum horizontal building dimension, and the maximum horizontal building dimension.

A. Cavity Region

The cavity calculations are made using methods described by Hosker.[23] Cavity calculations are based on the determination of a critical (i.e., minimum) wind speed required to cause entrainment of the plume in the cavity (defined as being when the plume centerline height equals the cavity height). Two cavity calculations are made, the first using the minimum horizontal dimension alongwind, and the second using the maximum horizontal dimension alongwind. The SCREEN2 output provides the cavity concentration, cavity length (measured from the lee side of the building), cavity height and critical wind speed for each orientation. The highest concentration value that potentially affects ambient air should be used as the maximum 1-hour cavity concentration for the source. A more detailed description of the cavity effects screening procedure is contained in the SCREEN2 Model User's Guide. For situations significantly different from the worst case, and for complex source configurations, a more detailed analysis is required.[24,25] If this estimate proves unacceptable, one may also wish to consider a field study or fluid modeling demonstration to show maintenance of the NAAQS (National Ambient Air Quality Standard) or PSD increments within the cavity. If such options are pursued, prior agreement on the study plan and methodology should be reached with the Regional Office.

B. Wake Region

Wake effects screening can also be performed with SCREEN2. SCREEN2 uses the downwash procedures contained in the User's Guide for the Industrial Source Complex (ISC2) Dispersion Models[21] and applies them to the full range of meteorological conditions described in the SCREEN2 Model User's Guide. SCREEN2 accounts for downwash effects within the "near" wake region (out to ten times the lesser of the building height or projected building width, $10L_b$), and also accounts for the effects of enhanced dispersion of the plume within the "far" wake region (beyond $10L_b$). The same building dimensions as described above for the cavity calculations are used, and SCREEN2 calculates the maximum projected width from the values input for the minimum and maximum horizontal dimensions. The wake effects procedures are described in more detail in the ISC2 manual.

4.5.2 Plume Impaction on Elevated Terrain

There is growing acceptance of the hypothesis that greater concentrations can occur on elevated than on flat terrain in the vicinity of an elevated source.* That is particularly true when the terrain extends well above the effective plume height. A procedure is presented here to (1) determine whether or not an elevated plume may impact on elevated terrain and, (2) estimate the maximum 24-hour concentration if terrain impaction is likely. The procedure is based largely upon the 24-hour mode of the EPA Valley Model.[26] A similar procedure that accounts for terrain heights above plume height using the Valley Model, and compares results from the Valley Model to simple terrain calculations for terrain between stack height and plume height, is included in the SCREEN2 program. A concentration estimate obtained through the procedure in this section will likely be somewhat greater than provided by the Valley Model or by the SCREEN2 program, primarily due to the relatively conservative plume height that is used in Step 1:

Step 1. Determine if the plume is likely to impact on elevated terrain in the vicinity of the source:

(1) Compute one-half the plume rise that can be expected during F stability and a stack height wind speed (u_s) of 2.5 m/s. (The reason for using only one-half the normally computed plume rise is to provide a margin of safety in determining both if the plume may intercept terrain and the resulting ground-level concentration. This assumption is necessary because actual plume heights will be lower with higher stack height wind speeds, and because impacts on intervening terrain above stack height but below the full plume height might otherwise be missed.)

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*An exception may be certain flat terrain situations where building downwash is a problem (See Section 4.5.1).

$$\Delta h = \frac{2.6 \left[\frac{F_b T_a}{u_s g \Delta\theta / \Delta z}\right]^{1/3}}{2} \qquad (4.12)$$

Refer to Steps 1 and 3 of Section 4.2 for a definition of terms.

(2) Compute a conservative plume height (h_e) by adding the physical stack height (h_s) to Δh:

$$h_e = h_s + \Delta h$$

(3) Determine if any terrain features in the vicinity of the source are as high as h_e. If so, proceed with Step 2. If that is **not** the case, the plume is not likely to intercept terrain, and Step 2 is not applicable.*

<u>Step 2</u>. Estimate the maximum 24-hour ground-level concentration on elevated terrain in the vicinity of the source:

(1) Using a topographic map, determine the distance from the source to the nearest ground-level location at the height h_e.

(2) Using Figure 4-17 and the distance determined in (1), estimate a 24-hour χ/Q value.

(3) Multiply the $(\chi/Q)_{24}$ value by the emission rate Q (g/s) to estimate the maximum 24-hour concentration, χ_{24}, due to plume impaction on elevated terrain:

$$\chi_{24} = Q \left[\frac{\chi}{Q}\right]_{24}$$

*Even if the plume is not likely to impact on elevated terrain (and for all concentration averaging times of concern) the user should account for the effects of elevated terrain on maximum concentrations. A procedure to account for elevated terrain below stack height is described in Section 4.2 and consists of reducing the computed plume height, h_e (for all stabilities), by the elevation difference between stack base and location of the receptor(s) in question. The adjusted plume heights can then be used in conjunction with the "flat-terrain" modeling procedures described earlier.

4.5.3 Fumigation

Fumigation occurs when a plume that was originally emitted into a stable layer is mixed rapidly to ground-level when unstable air below the plume reaches plume level. Fumigation can cause very high ground-level concentrations.[27] Typical situations in which fumigation occurs are:

1. Breaking up of the nocturnal radiation inversion by solar warming of the ground surface;
2. Shoreline fumigation caused by advection of pollutants from a stable marine environment to an unstable inland environment; and
3. Advection of pollutants from a stable rural environment to a turbulent urban environment.

The following procedure can be used for estimating concentrations due to inversion break-up and shoreline fumigation in rural areas. Sources located within 3km of a large body of water should be evaluated for shoreline fumigation. Procedures for estimating concentrations during the third type, rural/urban, are beyond the scope of this document.

Calculation procedures:

Step 1. Compute the plume height (h_e) that will occur during F stability and a stack height wind speed of 2.5 m/s:

$$h_e = h_s + \Delta h$$

To obtain a value for Δh, use the procedure described in Step 3 of Section 4.2 with u = 2.5 m/s. If $v_s < 1.5u_s$, account for stack tip downwash using Equation 4.7.

Step 2. Estimate the downwind distance to maximum ground-level concentration using (a) for inversion break-up and (b) for shoreline fumigation.

(a) For inversion break-up fumigation, use Table 4-4 (derived from Equation (5.5) of Turner's Workbook)[9] to estimate the downwind distance at which the maximum fumigation concentration is expected to occur, which is based on the time required for the mixed layer to develop from the top of the stack to the top of the plume. If this distance is less than about 2km, then fumigation concentrations are not likely to exceed the limited mixing concentrations estimated in Step 4, Procedure (a), of Section 4.2, and may be ignored.

(b) For shoreline fumigation, the maximum fumigation concentration is expected to occur where the top of the stable plume intercepts the top of the thermal internal boundary layer (TIBL). The distance to this location, measured from the shoreline, may be estimated from Table 4-5. The distances in Table 4-5 are based on the assumption of a parabolic TIBL shape.[28] Subtract the distance from the source to the shoreline from the value in Table 4-5 in order to obtain the downwind distance to the maximum from the source. If the distance obtained is less than 0.2km, then the shoreline fumigation screening procedure should not be applied since the plume/TIBL interaction may be influenced by transitional plume rise effects.

Step 3. At the distance estimated in (2), determine the value of σ_y from Figure 4-18 and of σ_z from Figure 4-14 for F stability. Since the effects of buoyancy-induced dispersion (BID) have been incorporated in the distances determined in (2) above, it is recommended that the values for σ_y and σ_z be adjusted for BID effects as follows:

$$\sigma_y' = \sqrt{\sigma_y^2 + [\frac{\Delta h}{3.5}]^2} \,, \qquad \sigma_z' = \sqrt{\sigma_z^2 + [\frac{\Delta h}{3.5}]^2} \,, \tag{4.13}$$

where Δh is the plume rise determined in (1) above. The maximum fumigation estimate, particularly for shoreline fumigation, is sensitive to the inclusion of BID since it effects the distance to the maximum as well as the actual concentration calculation.

Table 4-4. Downwind Distance (km) to the Maximum Ground Level Concentration for Inversion Break-up Fumigation as a Function of Stack Height (h_s) and Plume Height (h_e)*

h_s	Plume Height, h_e													
	< 60	60	70	80	90	100	125	150	175	200	225	250	275	300
10	(< 2)	2.6	3.6	4.7	5.9	7.2	11	16	20	26	32	38	46	53
20	(< 2)	2.3	3.3	4.3	5.5	6.8	11	15	20	25	31	38	45	52
30	(< 2)	(< 2)	2.9	3.9	5.1	6.4	10	14	19	24	30	37	44	51
40	(< 2)	(< 2)	2.5	3.5	4.7	5.9	9.5	14	19	24	30	36	43	50
50	(< 2)	(< 2)	2.0	3.1	4.2	5.4	9.0	13	18	23	29	35	42	49
60	-	(< 2)	(< 2)	2.5	3.7	4.9	8.4	12	17	22	28	34	41	48
70	-	-	(< 2)	(< 2)	3.1	4.3	7.7	12	16	21	27	33	40	47
80	-	-	-	(< 2)	2.4	3.6	7.1	11	16	21	26	32	39	46
90	-	-	-	-	(< 2).	2.9	6.3	10	15	20	25	31	38	45
100	-	-	-	-	-	(< 2)	5.5	9.4	14	19	24	30	37	44
125	-	-	-	-	-	-	3.2	7.2	12	17	22	28	34	41
150	-	-	-	-	-	-	-	4.5	9.0	14	19	25	31	37
175	-	-	-	-	-	-	-	-	5.9	11	16	22	28	34
200	-	-	-	-	-	-	-	-	-	7.5	13	18	24	31
225	-	-	-	-	-	-	-	-	-	-	9.1	15	21	27
250	-	-	-	-	-	-	-	-	-	-	-	11	17	23
275	-	-	-	-	-	-	-	-	-	-	-	-	13	19
300	-	-	-	-	-	-	-	-	-	-	-	-	-	14

*Assume Stability Class F and Wind Speed = 2.5 m/s.

Step 4. Compute the maximum fumigation concentration (χ_f), using the following equation:[9]

$$\chi_f = \frac{Q}{\sqrt{2\pi}u\,[\sigma_y' + (\frac{h_e}{8})]\,[h_e + 2\sigma_z']} \tag{4.14}$$

For the inversion break-up case, the concentration χ_f can be expected to persist for about 30 to 90 minutes. For shoreline fumigation, the high ground-level concentrations can persist as long as the stable onshore flow persists, up to several hours, although the location may shift as the direction of the onshore flow shifts.

Step 5. If the estimated fumigation concentration, χ_f, is less than the maximum 1-hour concentration, χ_1, estimated from Step 4 of Section 4.2, then the effects of fumigation may be ignored. If the estimated fumigation concentration exceeds the maximum 1-hour concentration estimated from Step 4 of Section 4.2, then the effect of fumigation on longer averaging periods may be accounted for as follows. The value of χ used with the multiplying factors in Step 5 (Section 4.2) should be adjusted using a weighted average of χ_1 and χ_f, assuming that χ_f persists for 90 minutes. The weighted average should be calculated as follows:

Averaging Time	Adjustment of χ_1 for Fumigation
3 hours	$\chi_1' = \frac{\chi_1 + \chi_f}{2}$
8 hours	$\chi_1' = \frac{13\chi_1 + 3\chi_f}{16}$
24 hours	$\chi_1' = \frac{15\chi_1 + \chi_f}{16}$

Table 4-5. Downwind Distance (km) to the Maximum Ground Level Concentration for Shoreline Fumigation as a Function of Stack Height (h_s) and Plume Height (h_e)*

h_s	Plume Height, h_e													
	< 60	60	70	80	90	100	125	150	175	200	225	250	275	300
10	(<0.2)	0.22	0.31	0.42	0.54	0.67	1.1	1.6	2.2	2.9	3.6	4.5	5.4	6.5
20	(<0.2)	(<0.2)	0.28	0.38	0.49	0.62	1.0	1.5	2.1	2.8	3.5	4.4	5.3	6.3
30	(<0.2)	(<0.2)	0.25	0.34	0.45	0.58	0.96	1.4	2.0	2.7	3.4	4.2	5.2	6.2
40	(<0.2)	(<0.2)	0.22	0.31	0.41	0.53	0.90	1.4	1.9	2.6	3.3	4.1	5.0	6.0
50	(<0.2)	(<0.2)	(<0.2)	0.28	0.38	0.49	0.85	1.3	1.8	2.5	3.2	4.0	4.9	5.9
60	-	(<0.2)	(<0.2)	0.25	0.34	0.45	0.79	1.2	1.8	2.4	3.1	3.9	4.8	5.8
70	-	-	(<0.2)	0.23	0.31	0.42	0.75	1.2	1.7	2.3	3.0	3.8	4.7	5.6
80	-	-	-	0.22	0.29	0.39	0.70	1.1	1.6	2.2	2.9	3.7	4.5	5.5
90	-	-	-	-	0.28	0.36	0.66	1.1	1.5	2.1	2.8	3.6	4.4	5.4
100	-	-	-	-	-	0.35	0.62	1.0	1.5	2.1	2.7	3.5	4.3	5.2
125	-	-	-	-	-	-	0.57	0.89	1.3	1.9	2.5	3.2	4.0	4.9
150	-	-	-	-	-	-	-	0.85	1.2	1.7	2.3	3.0	3.8	4.6
175	-	-	-	-	-	-	-	-	1.2	1.6	2.2	2.8	3.5	4.4
200	-	-	-	-	-	-	-	-	-	1.6	2.0	2.6	3.3	4.1
225	-	-	-	-	-	-	-	-	-	-	2.0	2.5	3.2	3.9
250	-	-	-	-	-	-	-	-	-	-	-	2.5	3.0	3.7
275	-	-	-	-	-	-	-	-	-	-	-	-	3.0	3.6
300	-	-	-	-	-	-	-	-	-	-	-	-	-	3.6

*Assume Stability Class F and Wind Speed = 2.5 m/s.

The adjusted value, χ_1', should then be used with the multiplying factors in Step 5 of Section 4.2.

4.5.4 Estimated Concentrations from Area Sources

The SCREEN2 area source algorithm is based on the equation for a finite line segment source. The current version of the Industrial Source Complex (ISC2)[21] model also incorporates this method of calculating downwind concentrations from area sources. This algorithm requires that the area source be square in shape. That is, the length of one side of the square is input to the program. Areas which have irregular shapes can be simulated by dividing the area source into multiple squares that approximate the geometry of the area source. The centerline ground-level concentration at a downwind distance x (measured from the downwind edge of the area source) is given by:

$$\chi_o = \frac{Q_A K x_o}{\sqrt{2}\, u_s \sigma_z}\, erf\left(\frac{x_o}{\sqrt{2\pi}\,\sigma_y}\right), \qquad (4.15)$$

where:

Q_A = area source emission rate (mass per unit area per unit time)

K = a scaling coefficient to convert calculated concentrations to desired units (default value of 1×10^6 for Q in g/m^2s and concentration in $\mu g/m^3$)

x_o = length of the side of the area source (m)

It is recommended that, if the separation between an area source and a receptor is less than one length of the side of the area source x_o, then the area source should be subdivided into smaller area sources.

Estimate maximum short-term (1-hour) concentrations by following the procedure for point sources outlined in Step 4 of Section 4.2, assuming no plume rise, $\Delta h = 0$. Do not use the multiplying factors in Step 5 of Section 4.2 to correct for averaging times greater than 1 hour. Concentrations close to an area source will not vary as much as those for point sources in response to varying wind directions, and the meteorological conditions which are likely to give maximum 1-hour concentrations (Procedures (b) and (c) of Section 4.2) can persist for several hours. Therefore it is recommended that the maximum 1-hour concentration be conservatively assumed to apply for averaging periods out to 24 hours.

4.5.5 Volume Sources

SCREEN2 uses a virtual point source algorithm to model the effects of volume sources. Therefore, the Gaussian equation is used to calculate concentrations produced by volume source emissions. This method for calculating volume sources is also used by the Industrial Source Complex (ISC2)[21] model. If the volume source is elevated, the user assigns the effective emissions height h_e. The user also assigns initial lateral (σ_{yo}) and vertical (σ_{zo}) dimensions for the volume source. Lateral (x_y) and vertical (x_z) virtual distances are added to the actual downwind distance x for the σ_y and σ_z calculations. The virtual distances are calculated from solutions to the sigma equations as is done for point sources with building downwash.

The volume source option is used primarily to simulate the effects of non-buoyant emissions from sources such as building roof vents. Table 4-6 below summarizes the general procedures suggested for estimating initial lateral (σ_{yo}) and vertical (σ_{zo}) dimensions for a single volume source. There are two types of volume sources: (1) surface-based sources, which may also be modeled as area sources, and (2) elevated sources.

Table 4-6. Summary of Suggested Procedures for Estimating Initial Lateral (σ_{yo}) and Vertical Dimensions (σ_{zo}) for Single Volume Sources

Description of Source	Initial Dimension: Lateral (σ_{yo})	Initial Dimension: Vertical (σ_{zo})
Surface-based source ($h_e \sim 0$)	side length divided by 4.3	vertical dimension divided by 2.15
Elevated source ($h_e > 0$) on or adjacent to a building	"	building height divided by 2.15
Elevated source ($h_e > 0$) **not** on or adjacent to a building	"	vertical dimension divided by 4.3

4.5.6 Contributions from Other Sources

To assess the significance of the air quality impact of a proposed source, the impact of nearby sources and "background" must be specifically determined. (Background includes those concentrations due to natural sources, and distant or unspecified man-made sources.) The impact of the proposed source can be separately estimated, applying the techniques presented elsewhere in Section 4, and then superimposed upon the impact of the nearby sources and background to determine total concentrations in the vicinity of the proposed source. This section addresses the estimation of concentrations due to nearby sources and background. Three situations are considered:

A. A proposed source relatively isolated from other sources.

B. A proposed source in the vicinity of a few other sources.

C. A proposed source in the vicinity of an urban area or other large number of sources.

It must be noted that in all references to air quality monitoring in the following discussion, it is assumed that the source in question is not yet operating. If the source is emitting pollutants during the period of air quality data collection, care must be taken not to use monitoring data influenced by the impact of the source. Additional guidance on determining background concentrations is provided in Section 9.2 of the Guideline on Air Quality Models (Revised).[3]

A. <u>Relatively Isolated Proposed Source</u>

A proposed source may be considered to be isolated if it is expected that background will be the only other significant contributor to ambient pollutant concentrations in its vicinity. In that case, it is recommended that air quality data from monitors in the vicinity of the proposed source be used to estimate the background concentrations. If monitoring data are not available from the vicinity of the source, use data from a "regional" site; i.e., a site that characterizes air quality across a broad area, including that in which the source is located. Annual average concentrations should be relatively easy to determine from available air quality data. For averaging times of about 24 hours or less, meteorology should be accounted for; i.e., the combined source / background concentration must be calculated for several meteorological conditions to ensure that the maximum total concentration is determined.

B. Proposed Source in the Vicinity of a Few Other Sources

If there already are a few sources in the vicinity of the proposed facility, the air quality impact of these sources should be accounted for. As long as the number of nearby sources is relatively small, the recommended procedure is to use (1) air quality monitoring data to estimate background concentrations and (2) dispersion modeling to estimate concentrations due to the nearby source(s). Then superimpose those estimates to determine total concentrations in the vicinity of the proposed source.

To estimate background concentrations, follow the same basic procedure as in the case of an isolated source. In this case, however, there is one added complication. Wind direction must be accounted for in order to single out the air quality data that represent background only (i.e., data that are not affected by contributions from nearby sources). Concentrations due to the nearby sources will normally be best determined through dispersion modeling. The modeling techniques presented in this guideline may be used. The user should model each source separately to estimate concentrations due to each source during various meteorological conditions and at an array of receptor locations (e.g., see Sections 4.3 and 4.4.1) where interactions between the effluents of the proposed source and the nearby sources can occur. Significant locations include (1) the area of expected maximum impact of the proposed source, (2) the area of maximum impact of the nearby sources, and (3) the area where all sources will combine to cause maximum impact. It may be necessary to identify those locations through a trial and error analysis.

C. Proposed Source Within an Urban Area or in the Vicinity of a Large Number of Sources

For more than a very small number of nearby sources, it may be impractical to model each source separately. Two possible alternatives for estimating ambient concentrations due to the other sources are to use air quality monitoring data or a multisource dispersion model. If data from a comprehensive air monitoring network are available, it may be possible to rely entirely on the measured data. The data should be adequate to permit a reliable assessment of maximum concentrations, particularly in (1) the area of expected maximum impact of the proposed source, (2) the area of maximum impact of the existing sources and (3) the area where all sources will combine to cause maximum impact. In some cases, the available air quality monitor data will only be adequate to estimate general area-wide background concentrations. In such cases, there is no choice but to use dispersion modeling to estimate concentrations due to the nearby sources. If possible, a multisource dispersion model should be used. The ISCLT model can be applied for long-term concentration estimates, and the MPTER or ISCST model for short-term estimates (MPTER can handle up to 250 point sources but cannot handle building downwash effects). If it is not feasible to apply a multisource model, and there is a considerable number of nearby sources, a rough estimate of maximum concentrations due to those sources can be made by arbitrarily grouping the sources into an area source through the following equation.[29] (The estimate is primarily applicable to receptor locations near the center of the area source, defined below, although it may be considered a reasonable first-approximation for any location within the area):

$$C = 18Q \frac{[\Delta x]^{1/4}}{u} , \tag{4.17}$$

where:

C = maximum short term (1 - 24 hours) contribution to ground-level concentrations from the area source (g/m^3)

Q = average emission rate ($g/m^2/s$) within the area defined by Δx

u = assumed average wind speed (m/s) for the averaging time of concern (use 2 m/s if no data are available)

Δx = length (m) of one side of the smallest square area that will contain the nearby sources, ignoring relatively small outlying sources or any source that is considerably removed from the other sources.

The best results will be obtained with the above equation when emissions are uniformly distributed over the defined area. Any large point sources in the vicinity should be modeled separately, and the estimated concentrations manually superimposed upon that computed for the area source. Because this is an area source approximation, the adjustment factors for averaging times greater than one hour should not be used.

4.5.7 Long Range Transport

In certain instances it will be necessary to estimate the air quality impact of a proposed source at locations beyond its vicinity (beyond roughly 30 - 50km). To estimate seasonal or annual average concentrations (out to about 100km) the procedures of Section 4.4 provide a rough estimate. The procedures are limited to plume heights greater than 50m, and should **not** be applied beyond 100km. For short-term estimates (concentration averaging times up to about 24 hours) beyond the vicinity of the source and out to 100km downwind, the following procedure is recommended. The procedure accounts for the meteorological situations with the greatest persistence that are likely to result in the highest concentrations at large distances, i.e., neutral/high wind conditions (Steps 1-4) and stable conditions (Steps 5-7):

Step 1. Estimate the normalized plume rise ($u\Delta h$) applicable to **neutral and unstable** atmospheric conditions. Use the procedure described in Step 1 of Section 4.2.

Step 2. Compute plume height, h_e, that will occur during D stability with a 10m wind speed of 5 m/s. Adjust the wind speed from 10m to stack height, using Equation 3.1 and the exponent for stability class D:

$$h_e = h_s + \frac{u\Delta h}{u_s}$$

Step 3. Using Figure 4-19, obtain a $\chi u/Q$ value for the desired downwind distance (D stability case). (If the plume height is greater than 300m, then the value corresponding to h_e = 300m may be used for conservatism.)

Step 4. Compute the maximum 1-hour D stability concentration, x_{max}, using the $\chi u/Q$ value obtained in Step 3:

$$x_{max} = Q\,\frac{\chi u/Q}{u_s}$$

For Q, substitute the source emission rate (g/s), and use the value of u_s determined in Step 2.

Step 5. Compute the plume height $h_e = h_s + \Delta h$ that will occur during E stability with a 10m wind speed of 2 m/s. Adjust the wind speed from 10m to stack height using Equation 3.1 and the exponent for stability class E. Use the stable plume rise (Δh) computed from Equation 4.6 in Step 3 of Section 4.2:

$$h_e = h_s + \Delta h$$

Step 6. From Figure 4-20, obtain a $\chi u/Q$ value for the same distance considered in Step 3 above. (If the plume height is greater than 300m, then the value corresponding to h_e = 300m may be used for conservatism).

Step 7. Compute the maximum 1-hour E stability concentration, x_{max}, using the $\chi u/Q$ value obtained in Step 6:

$$x_{max} = Q \frac{\chi u/Q}{u_s} ,$$

where u_s was determined in Step 5.

Step 8. Select the higher of the χ_{max} values computed in Steps 4 and 7. The selected value represents the highest 1-hour concentration likely to occur at the specified distance.

Step 9. To estimate concentrations for averaging times up to annual, multiply the 1-hour value by the factors presented in Step 5 of Section 4.2.

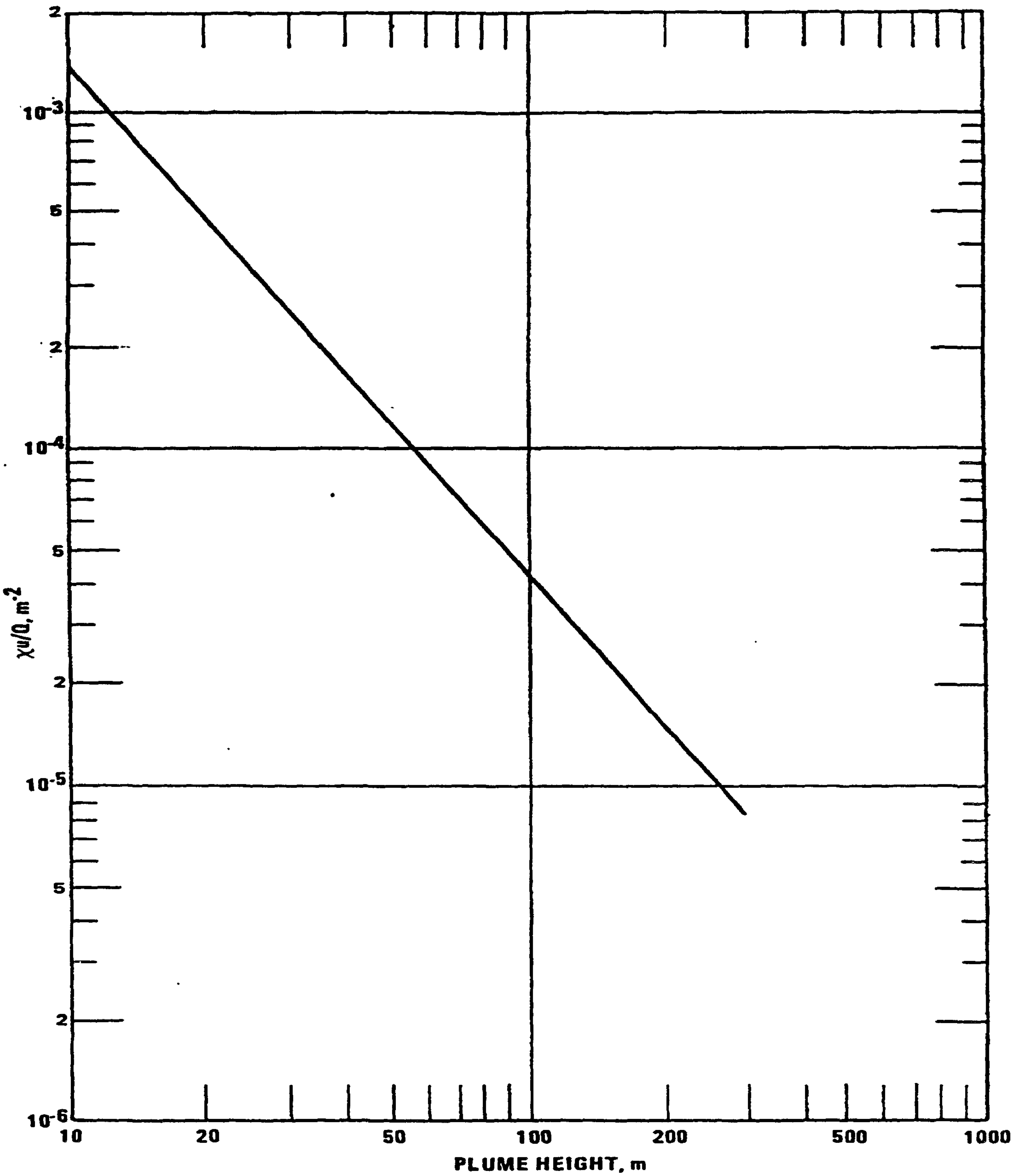

Figure 4-1. Maximum $\chi u/Q$ as a function of plume height, H (for use only with the simple screening procedure).

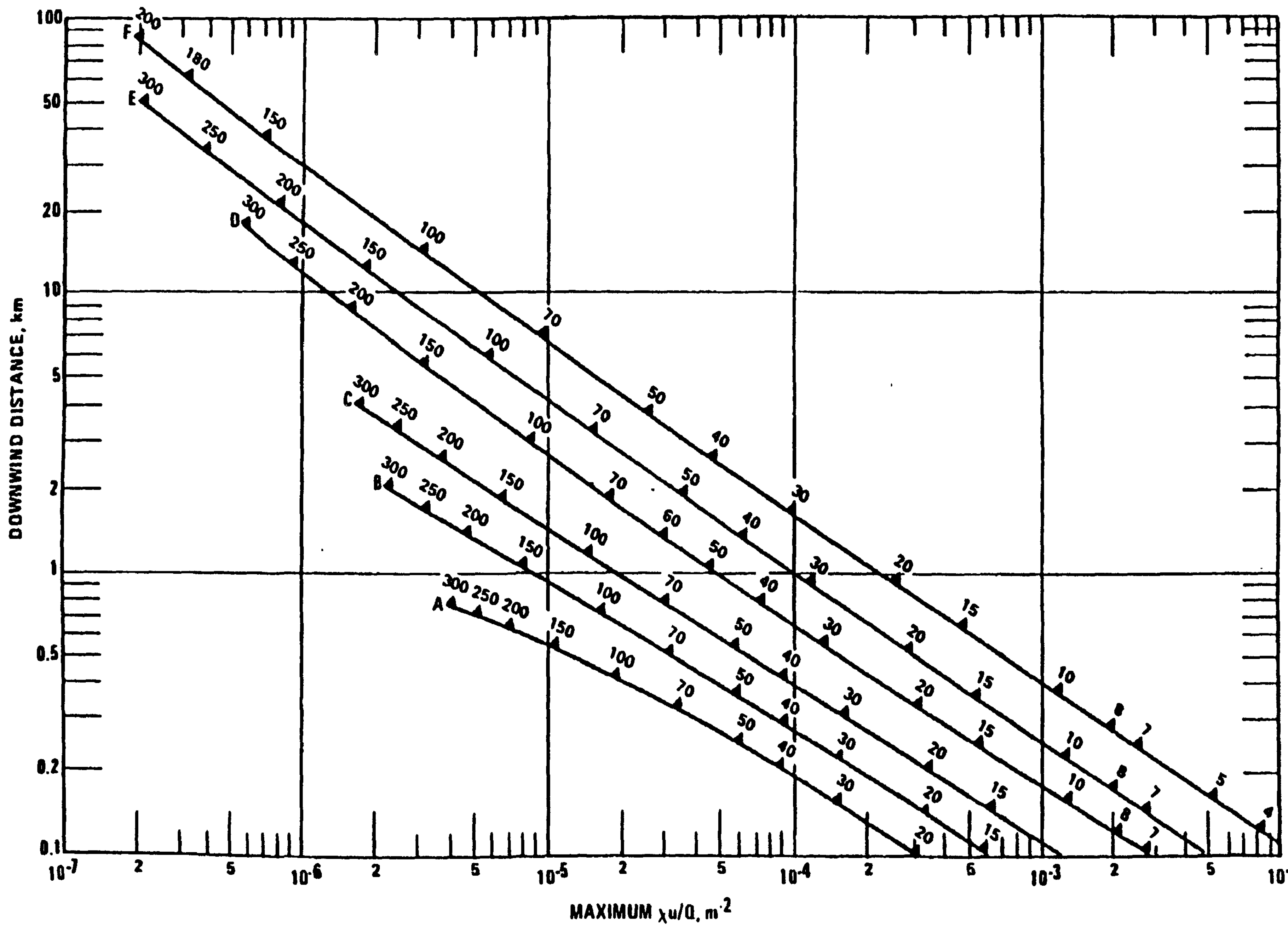

Figure 4-2. Downwind distance to maximum concentration and maximum $\chi u/Q$ as a function of stability class for rural terrain.[17] Plume heights (m) are indicated on the curves.

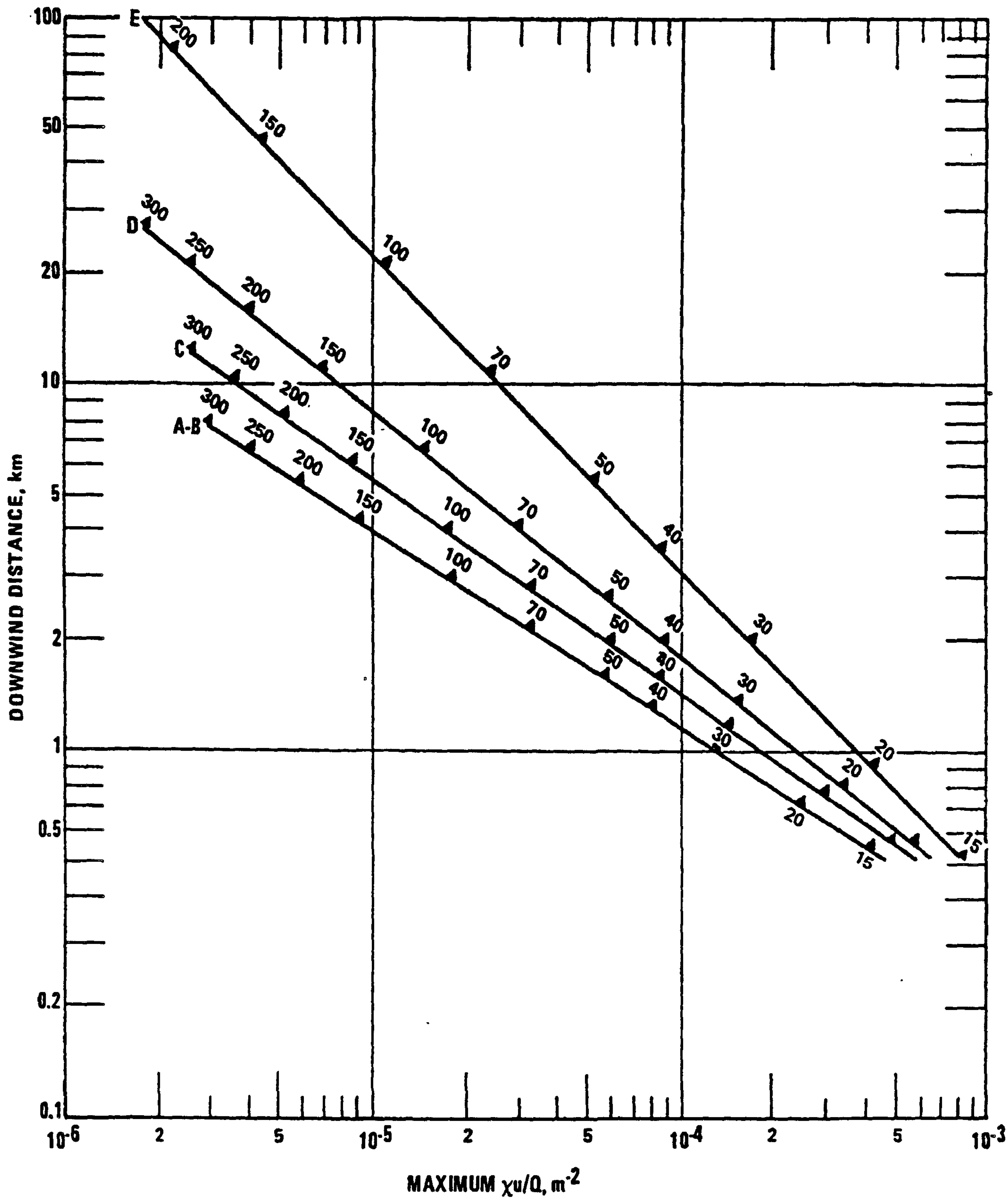

Figure 4-3. Downwind distance to maximum concentration and maximum $\chi u/Q$ as a function of stability class for urban terrain. Plume heights (m) are indicated on the curves.

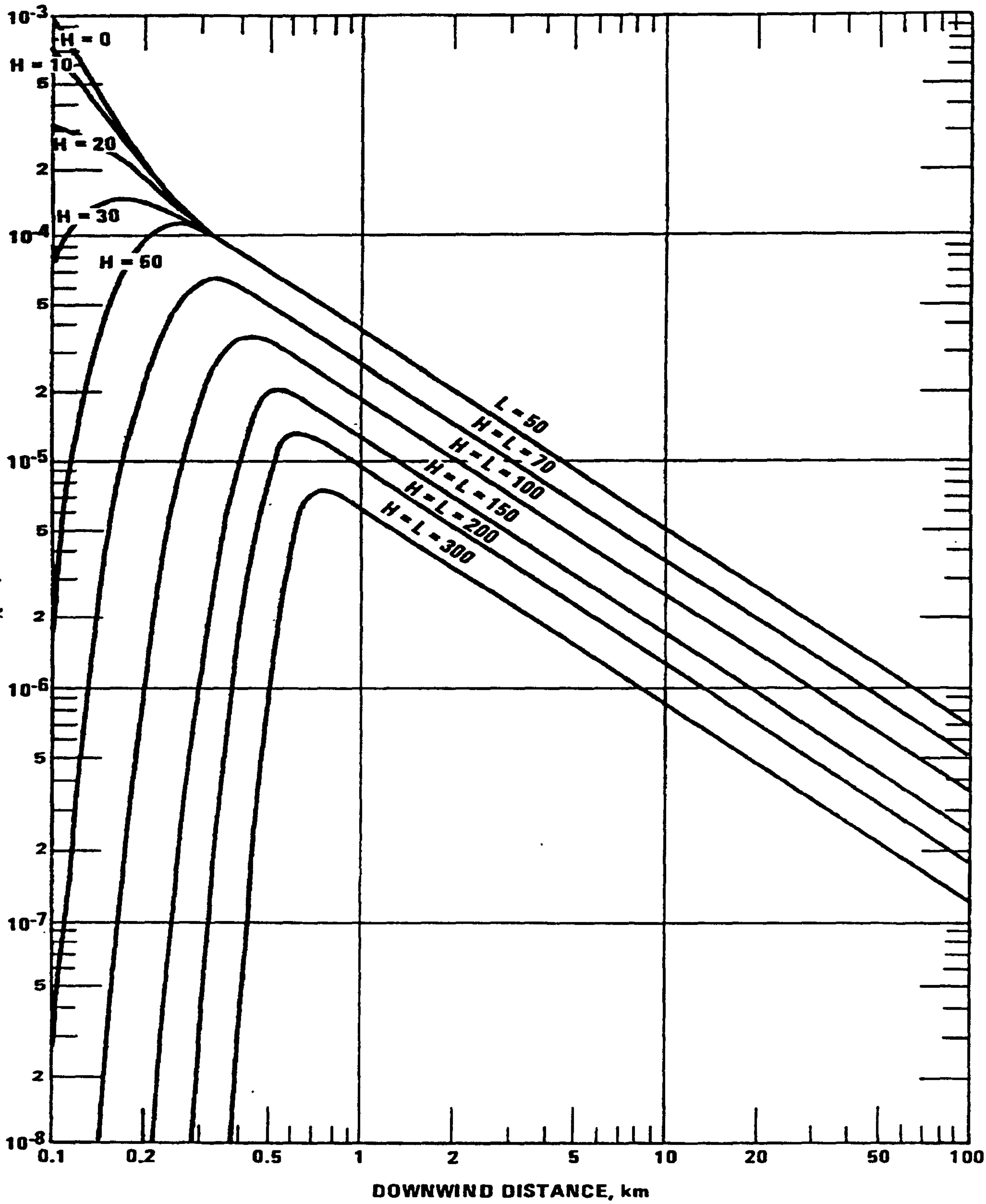

Figure 4-4. Stability class A, rural terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

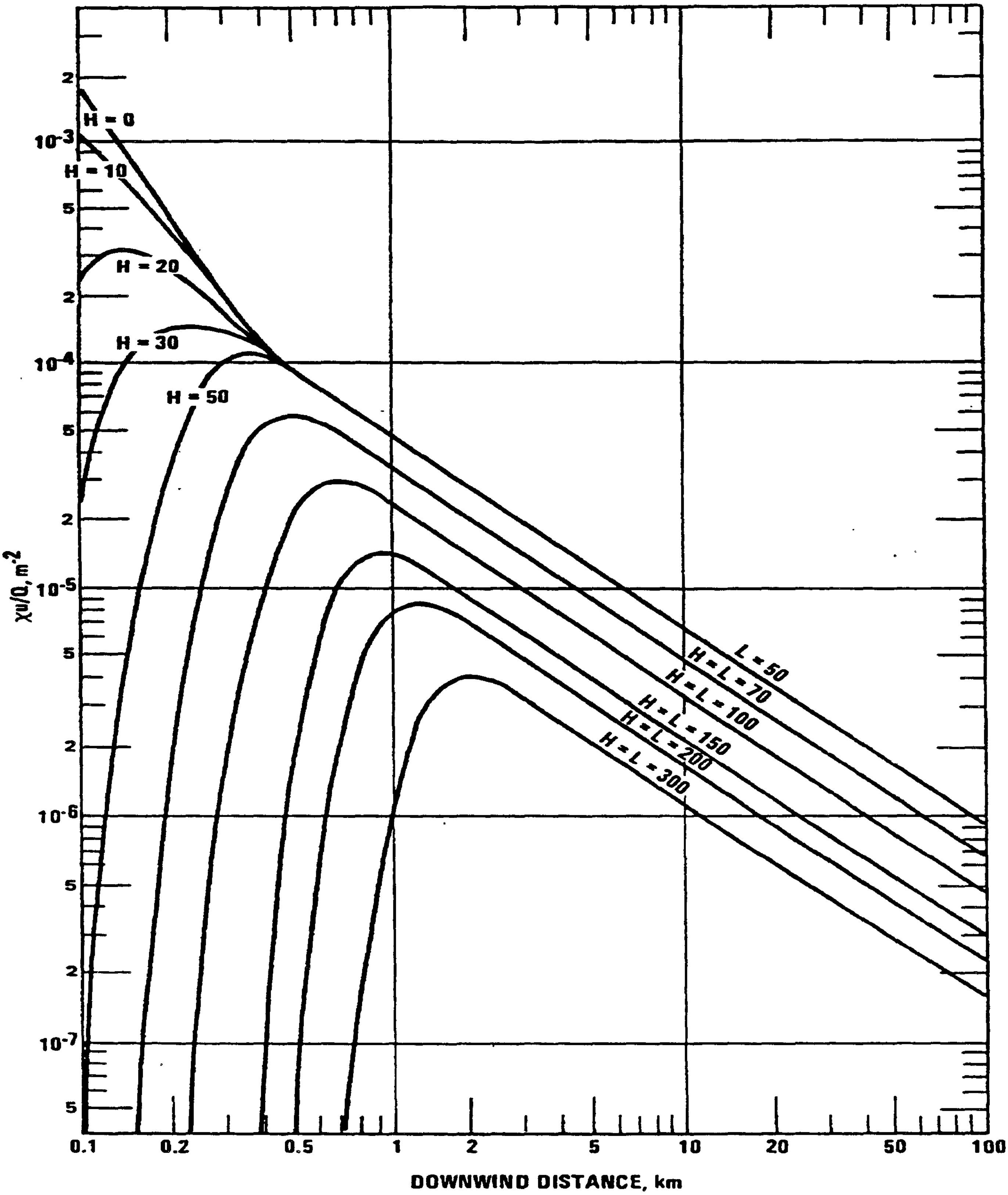

Figure 4-5. Stability class B, rural terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

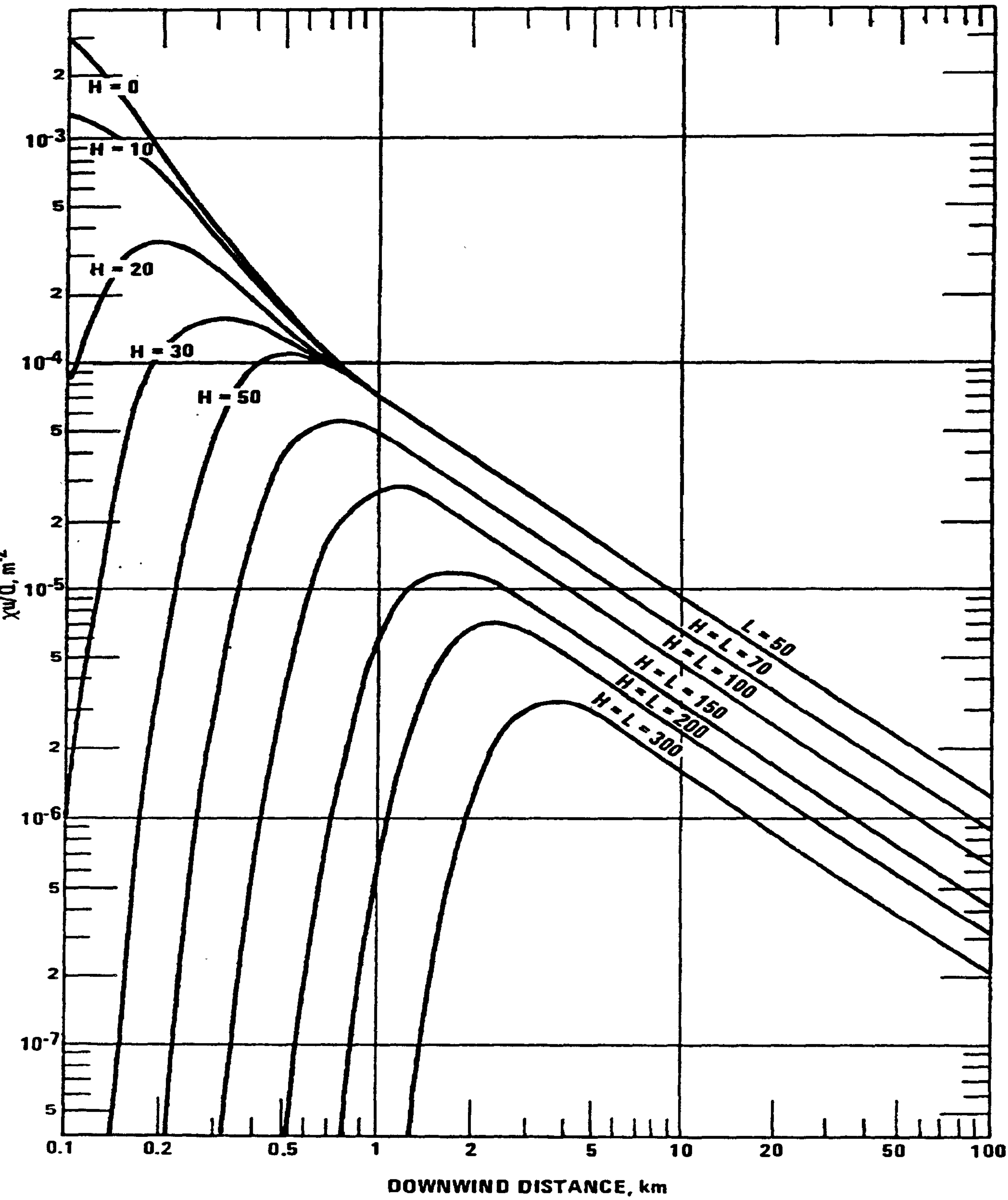

Figure 4-6. Stability class C, rural terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

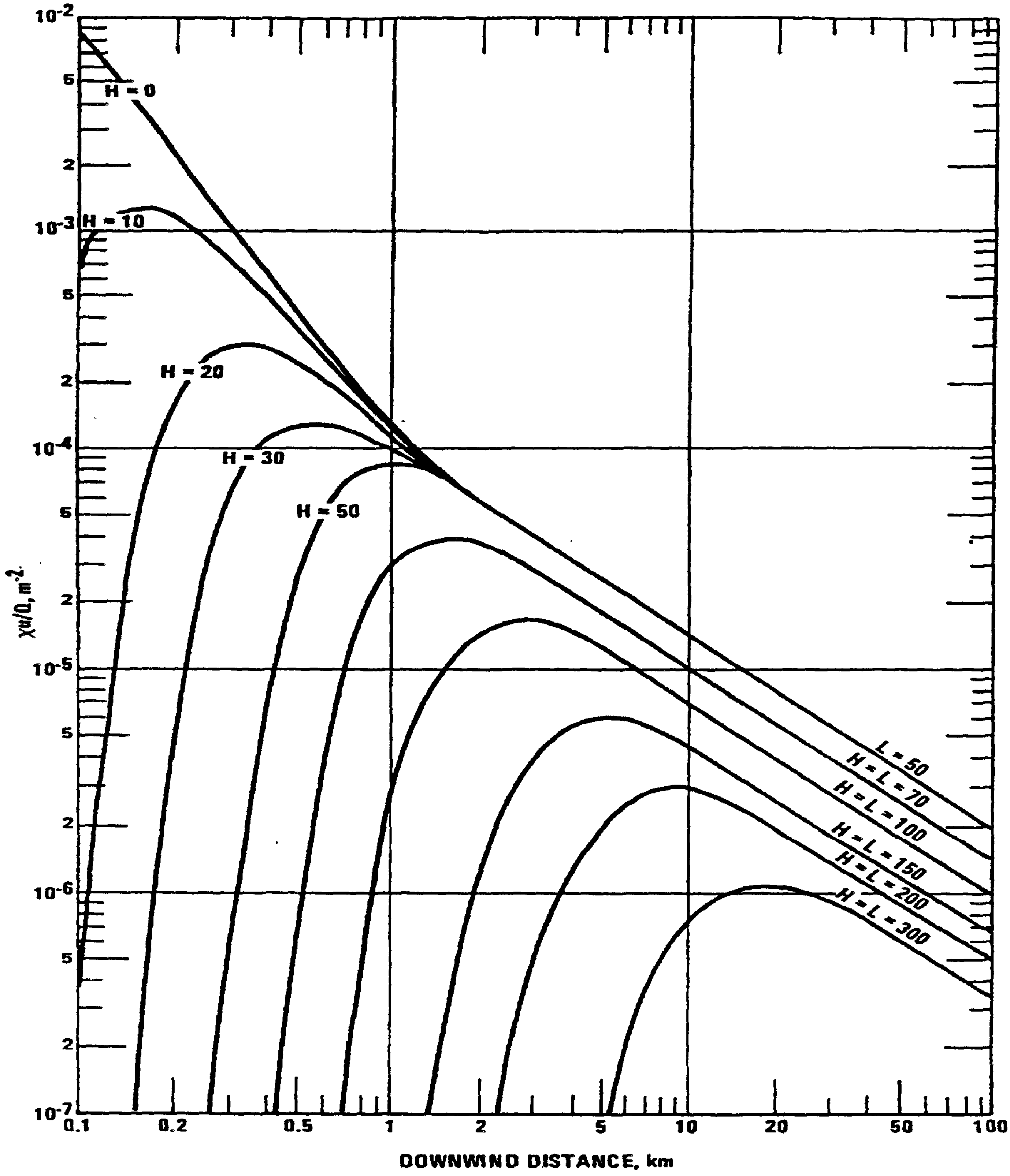

Figure 4-7. Stability class D, rural terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

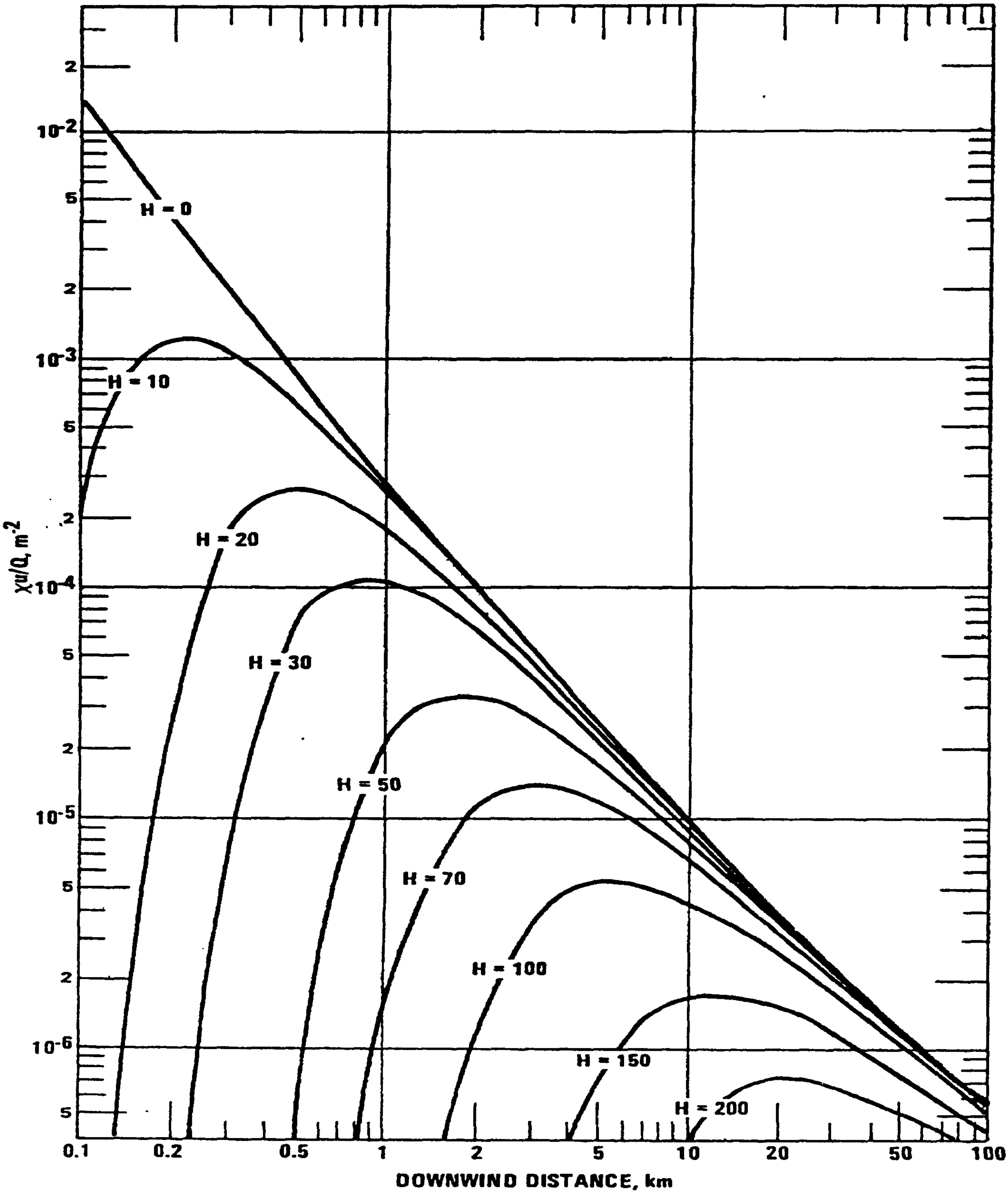

Figure 4-8. Stability class E, rural terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

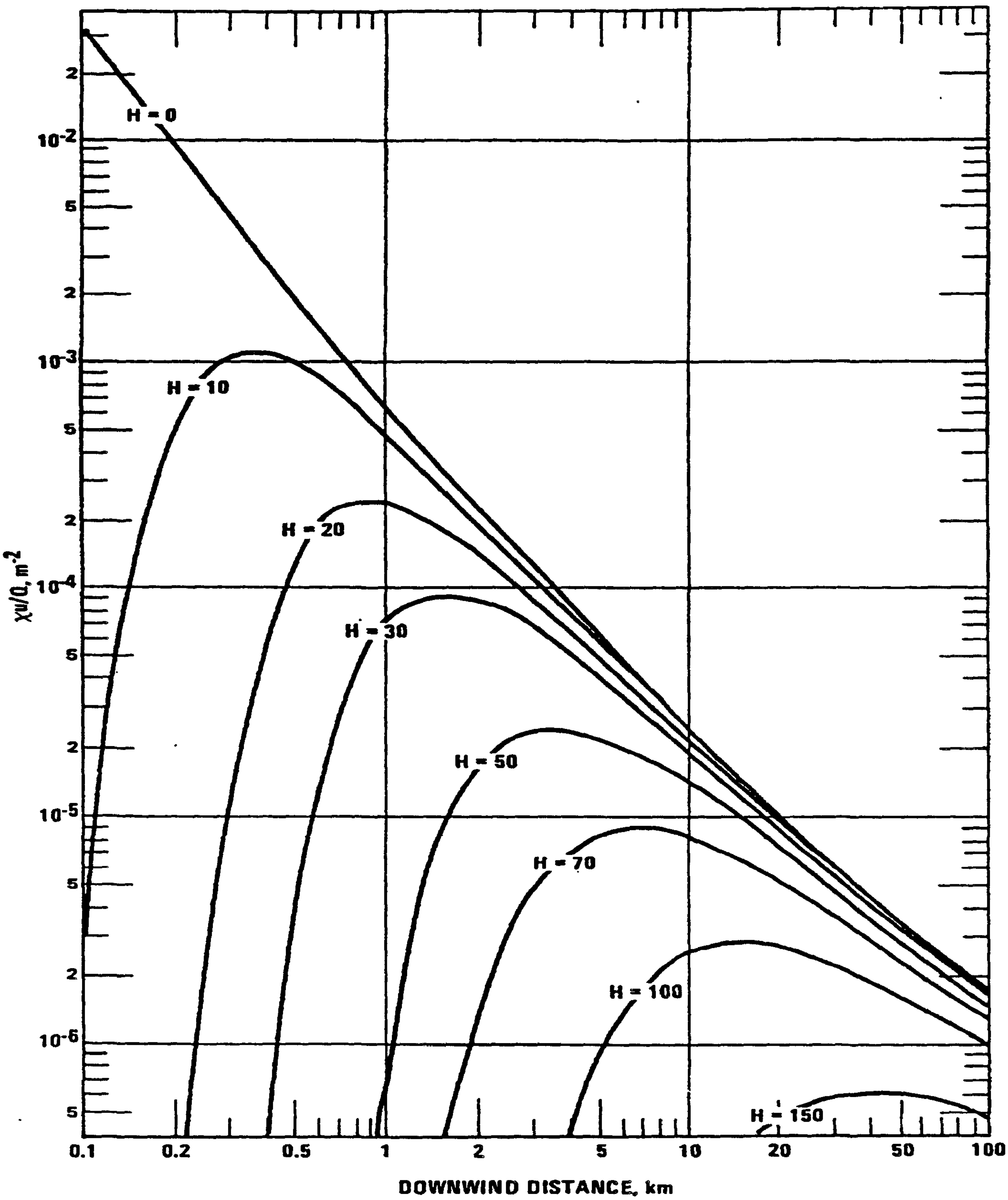

Figure 4-9. Stability class F, rural terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

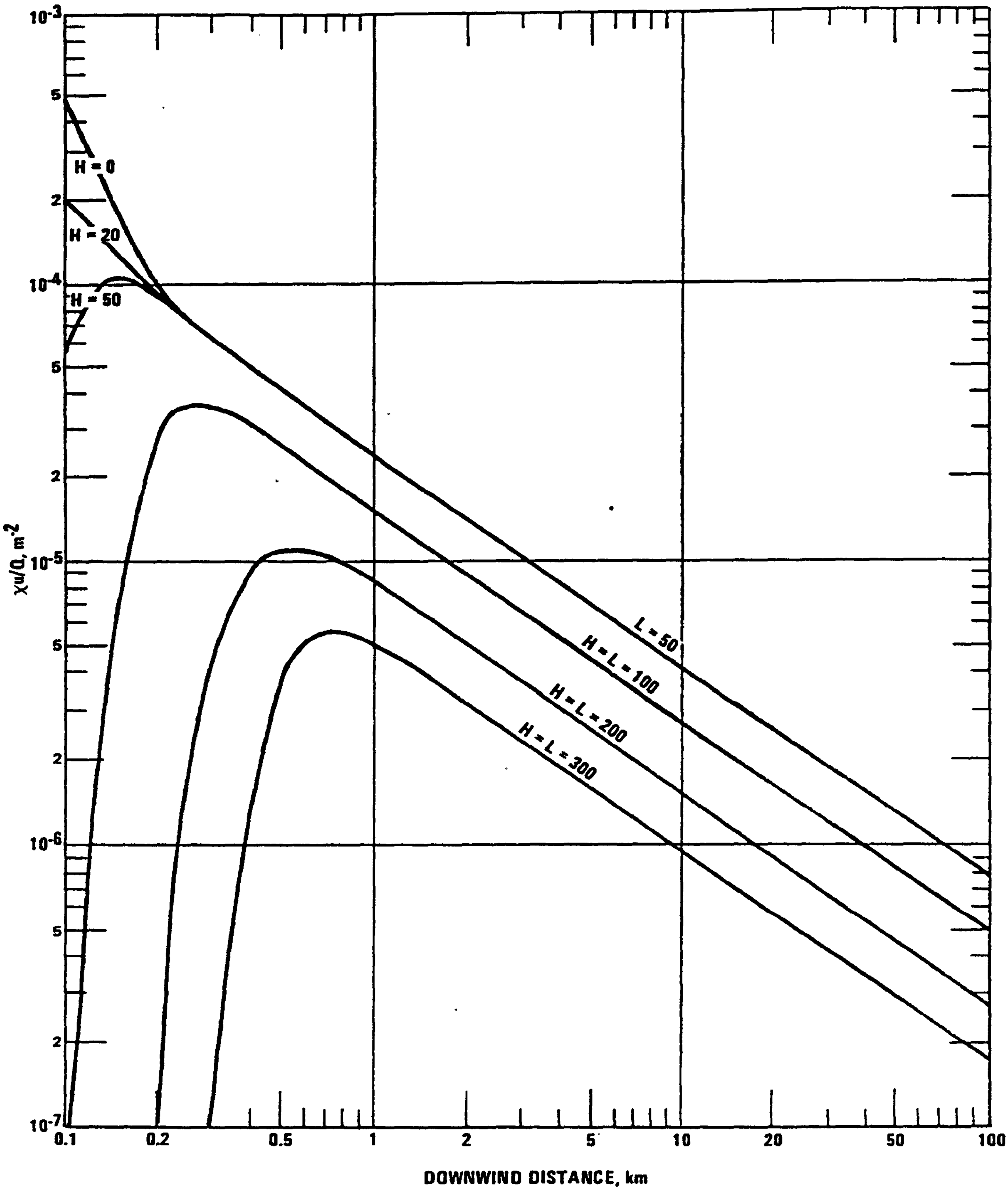

Figure 4-10. Stability classes A and B, urban terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

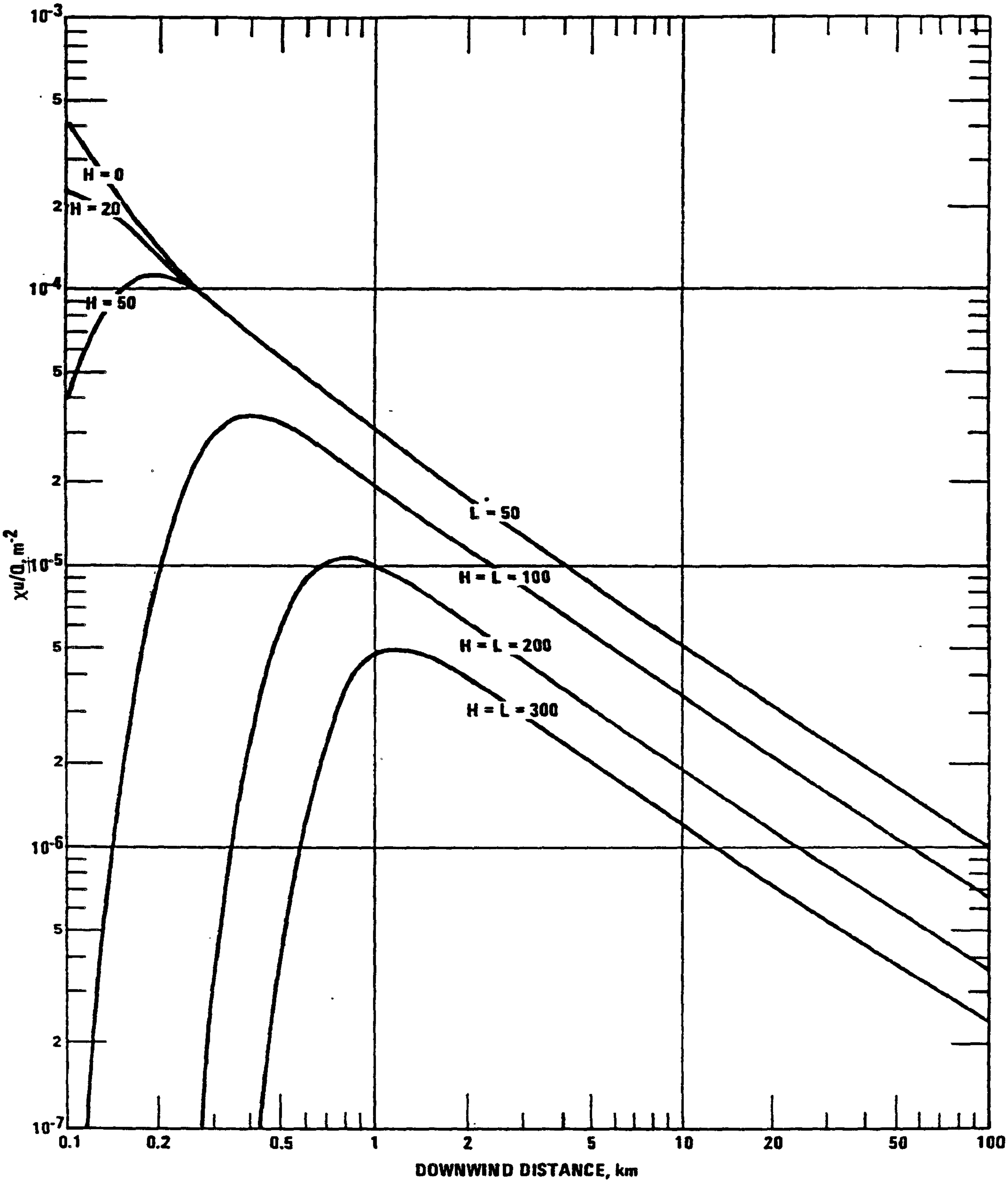

Figure 4-11. Stability class C, urban terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

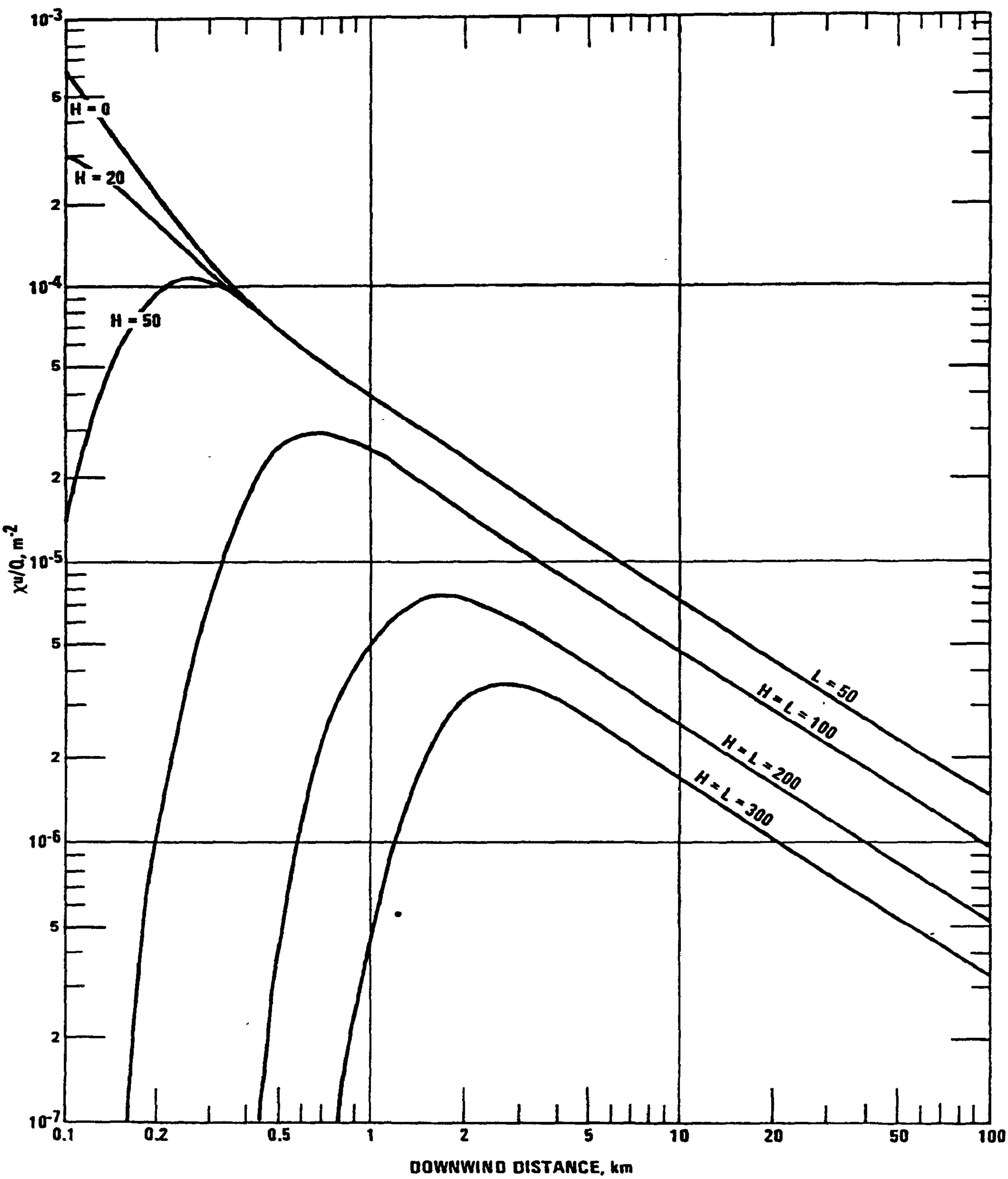

Figure 4-12. Stability class D, urban terrain; $\chi u/Q$ vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H $\leq$ 50m; L = H for H > 50m.

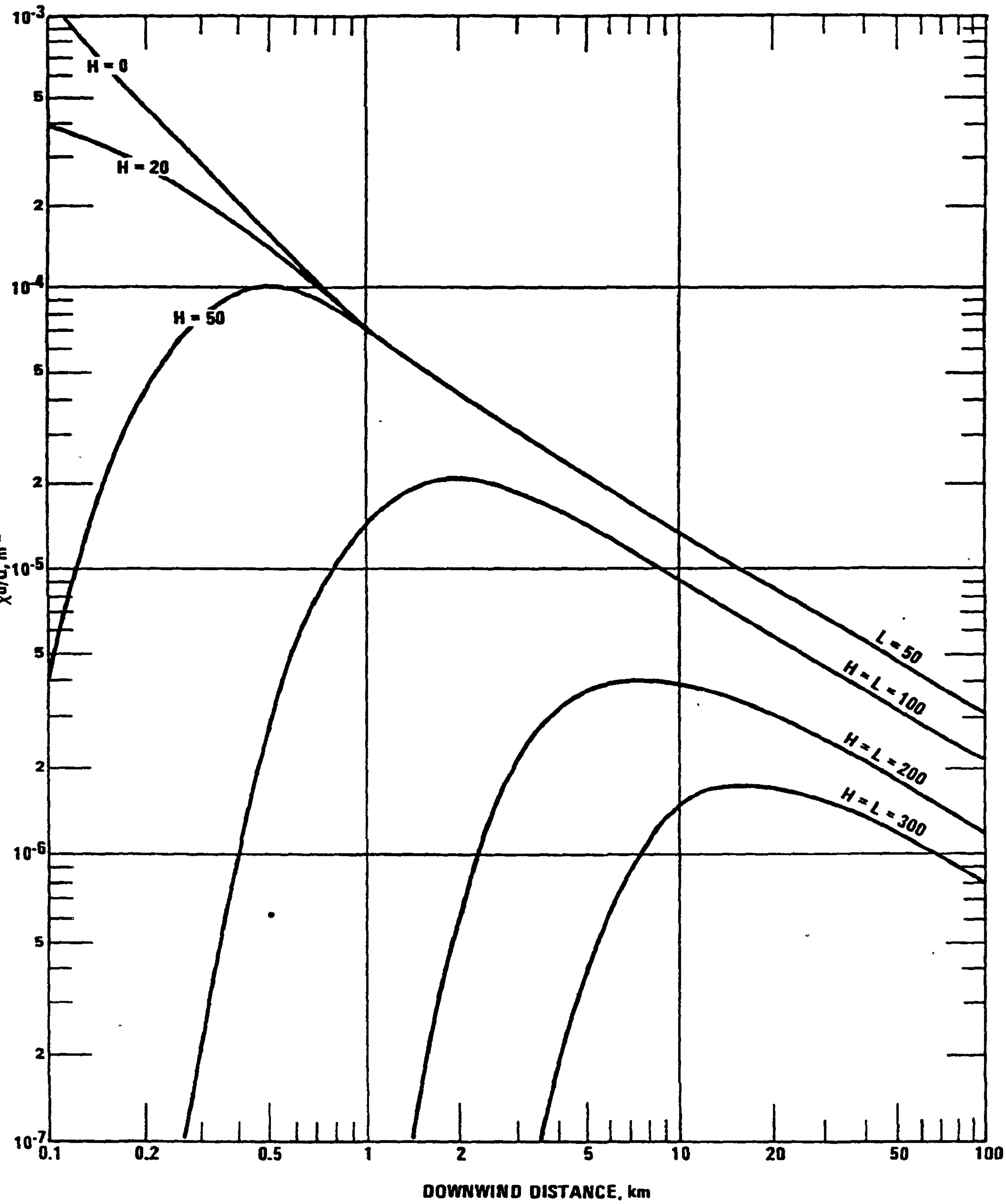

Figure 4-13. Stability class E, urban terrain; χu/Q vs. distance for various plume heights (H), assuming very restrictive mixing heights (L); L = 50m for H ≤ 50m; L = H for H > 50m.

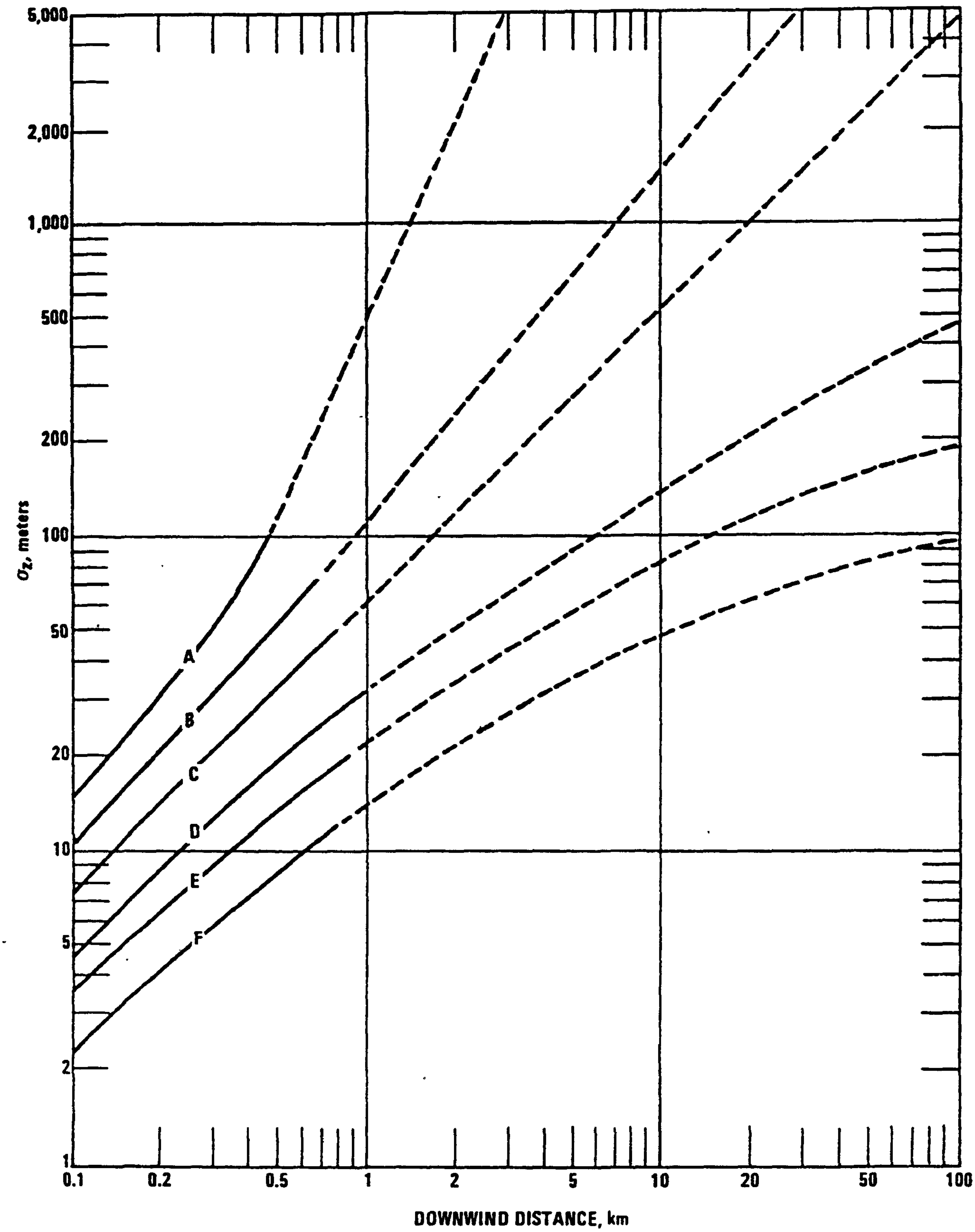

Figure 4-14. Vertical dispersion parameter (σ_z) as a function of downwind distance and stability class; rural terrain.

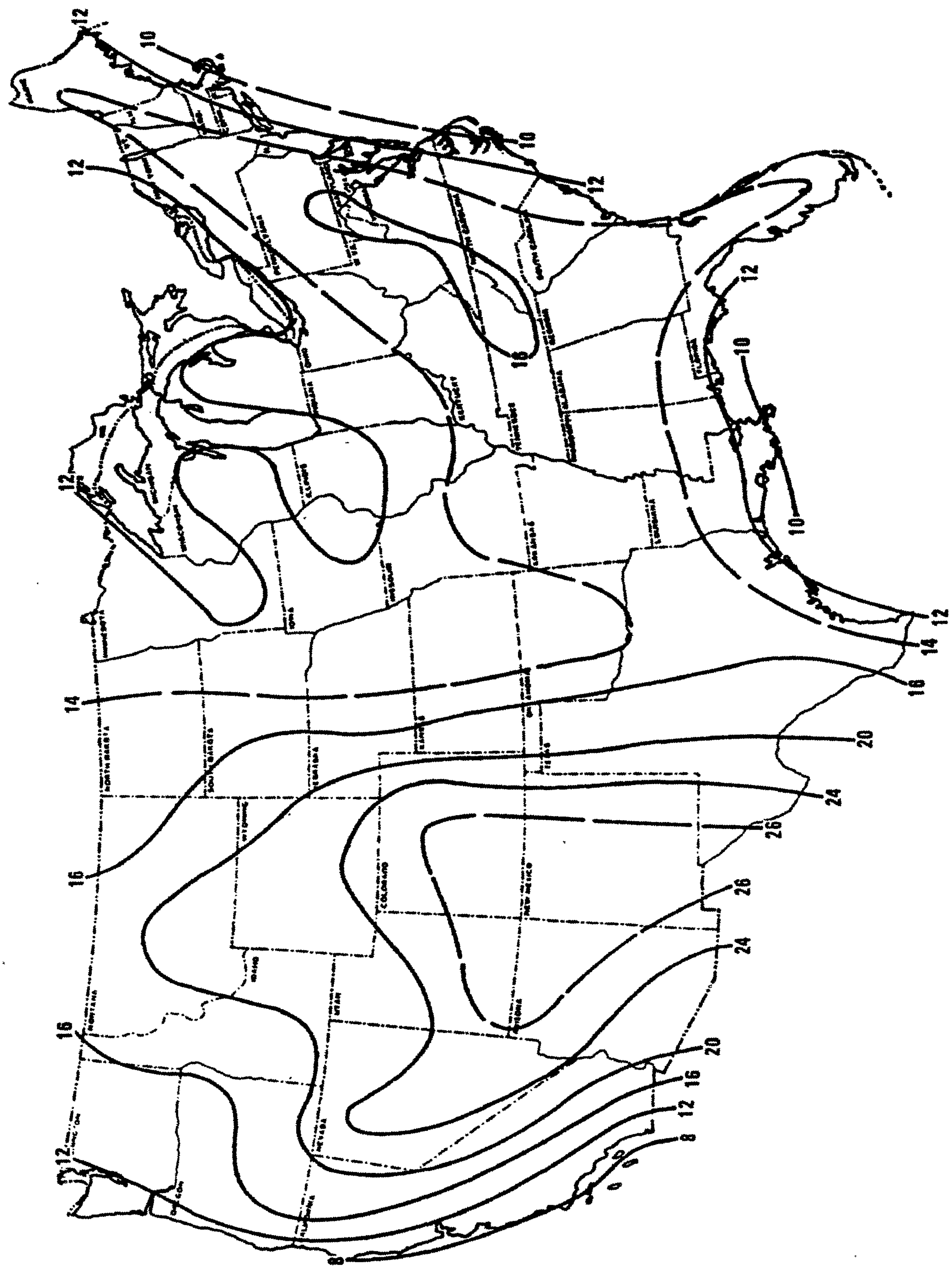

Figure 4-15. Isopleths (hundredths of meters) of mean annual afternoon mixing heights.

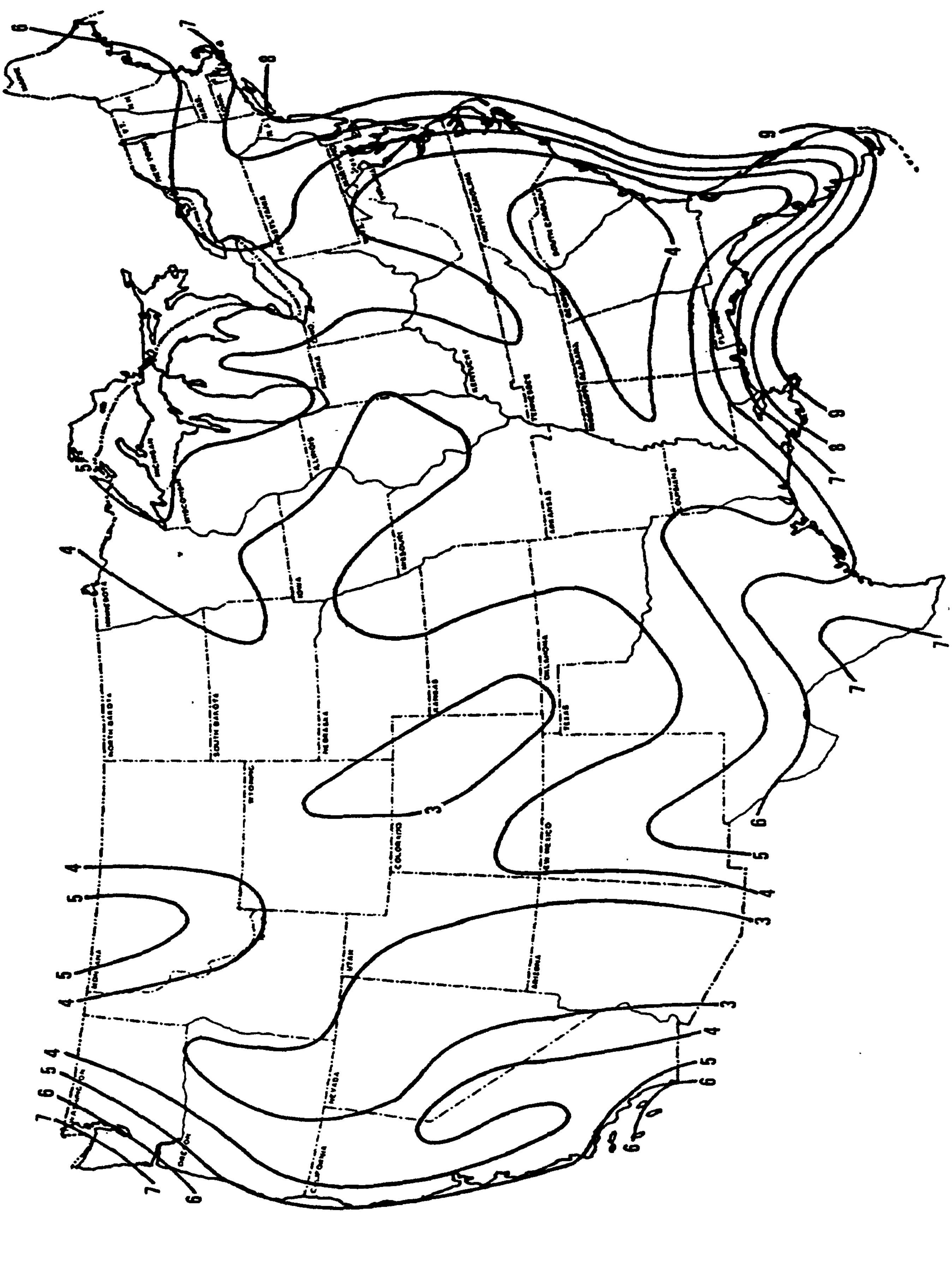

Figure 4-16. Isopleths (hundredths of meters) of mean annual morning mixing heights.

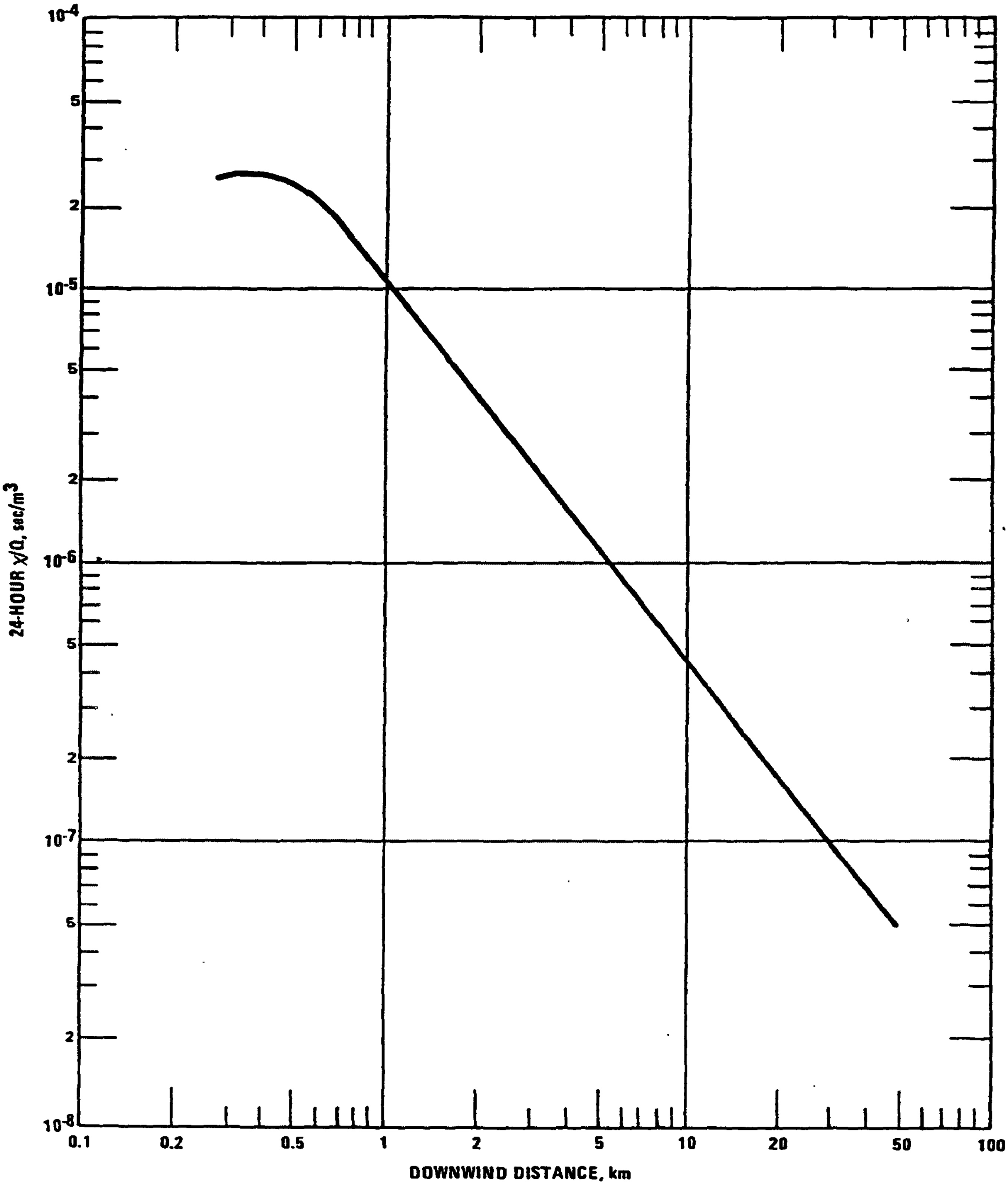

Figure 4-17. 24-hour χ/Q vs. downwind distance, obtained from the Valley model. Assumptions include: stability class F, wind speed = 2.5 m/s, and plume height 10m above terrain.

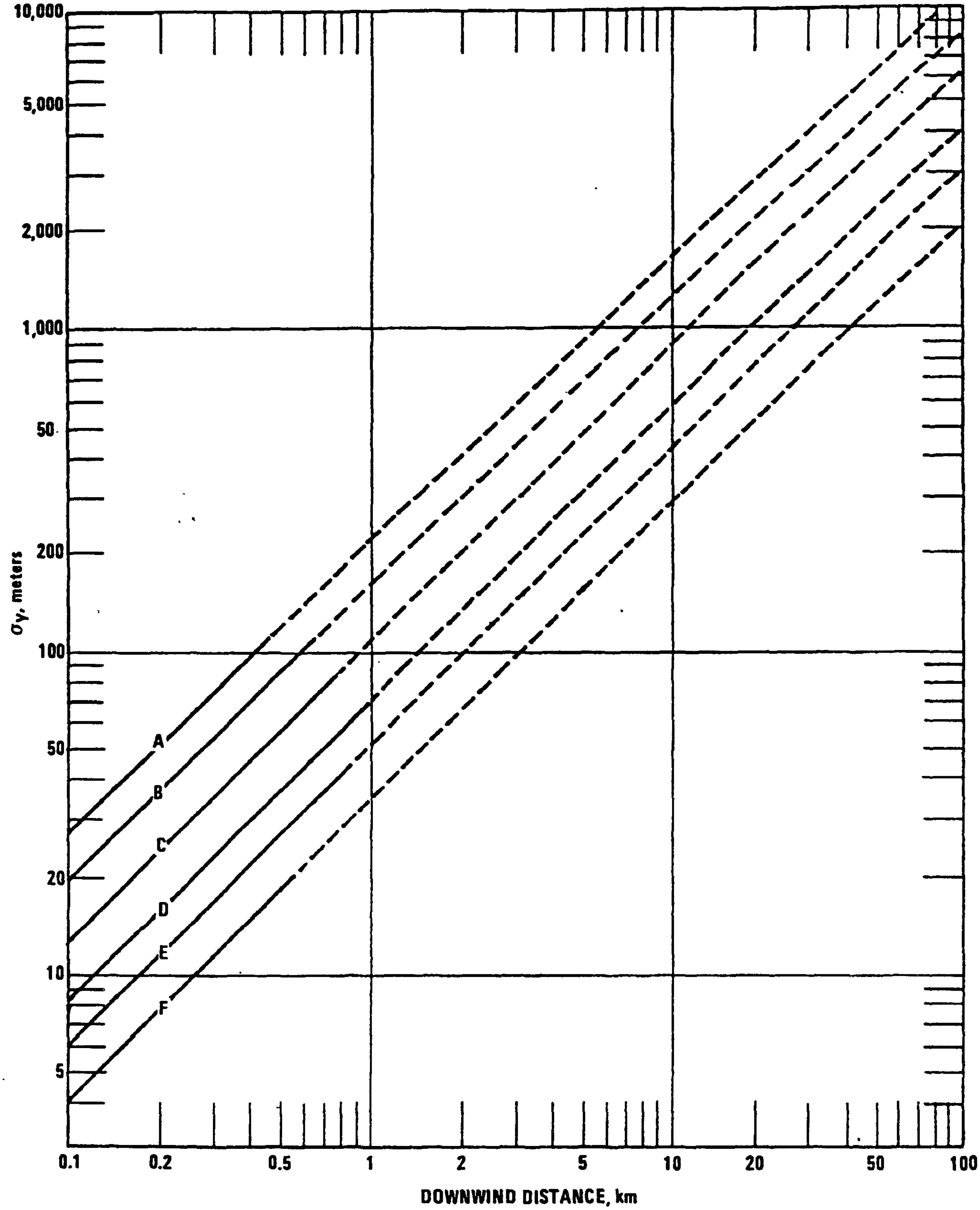

Figure 4-18. Horizontal dispersion parameter (σ_y) as a function of downwind distance and stability class; rural terrain.

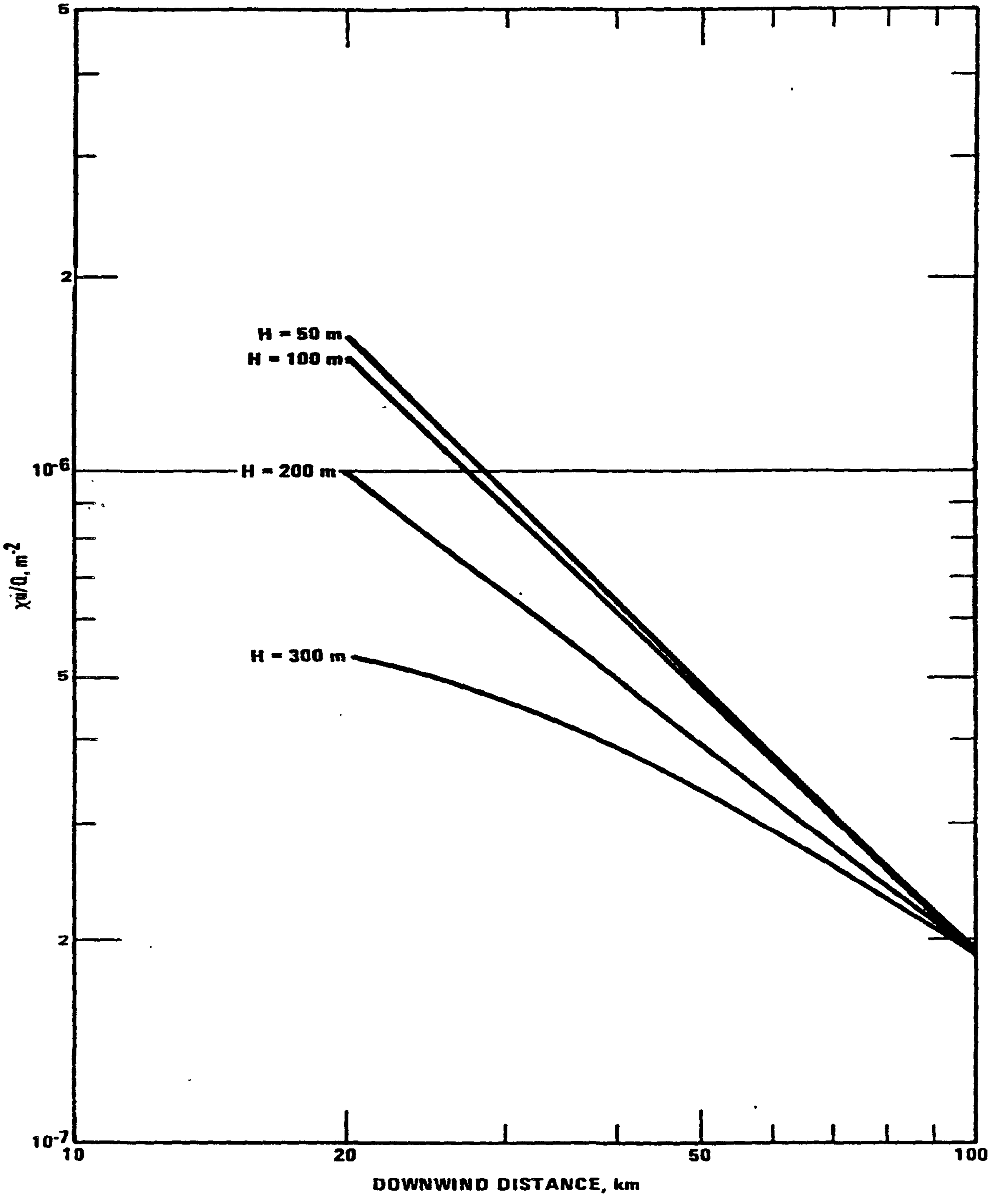

Figure 4-19. Maximum $\chi u/Q$ as a function of downwind distance and plume height (H), assuming a mixing height of 500m; D stability.

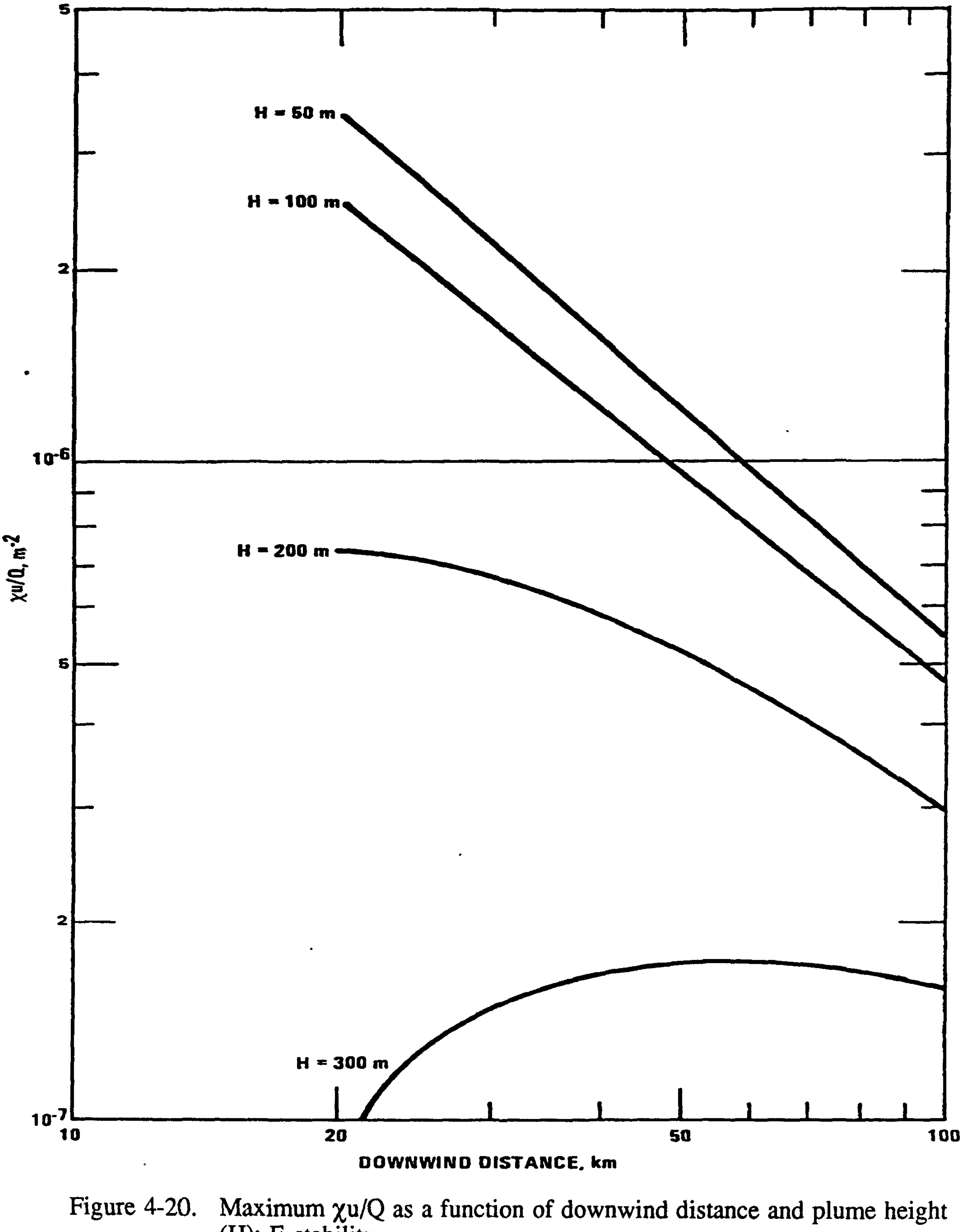

Figure 4-20. Maximum $\chi u/Q$ as a function of downwind distance and plume height (H); E stability.

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9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Air Quality Planning and Standards U. S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This document presents current EPA guidance on the use of the revised screening procedures for estimating the air quality impact of stationary sources. The original version of this document (EPA-450/4-88-010) was a draft for public comment which has subsequently been included as part of the Guideline on Air Quality Models. SCREEN2 technical support is provided herein. Major changes in this version of SCREEN2 are the finite line segment method for area sources, addition of wind speeds in the wind speed-stability matrix for calculating concentrations, and the inclusion a single volume source option.

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