Department of the
Environment, Transport
and the Regions

Partners in Technology

Passive Venting of Soil Gases Beneath Buildings

Research Report

Guide for Design

Volume 2 Computational Fluid Dynamics Modelling: Example Output

COOPER CLARKE GROUP PLC

cordek

BRE

ARUP
Ove Arup & Partners
Arup Environmental

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Foreword

Volume 2 of this Guide for Design presents, in graphical form, example output results of computational fluid dynamics (CFD) modelling carried out as a core part of this Partners in Technology research project into passive venting of soil gases beneath buildings. A summary description of the principles of CFD modelling for this application and the input assumptions used are also presented herein.

CONTENTS

Volume 2

FIGURES

A.1 Application of Fluids Dynamics Modelling

CFD modelling is based on solving conservation statements for momentum, mass and energy. The approach is one of representing the flow domain by a grid (mesh), defining control-volumes over which the governing equations are numerically integrated and solved. An iterative solution approach is demanded by strong non-linearities in the convection components of the equation set.

CFD modelling has been used in this research project to compare the relative performance of different media and arrangements used in sub-floor passive ventilation systems. The solution variables were the three components of the velocity vector (in 3D flows), pressure, and concentration of species (representing the as-released gas from the ground). Values of the solution variables were obtained at each of the hundreds or thousands of control-volumes defining the grid.

In modelling flows through porous media of the type considered in this project, the Darcy-Forsheimer equation is used. This represents the relationship between velocity and pressure loss. The exact form of the relationship is defined by prescribing two coefficients. The first is a permeability coefficient which is associated with laminar (linear) flow and the second is the Forcheimer term which defines the extent to which the relationship possesses a turbulent (non-linear) characteristic. The porous media relationship is applied in the CFD code through a 'sink' term in the momentum conservation equation. A flow porosity is also prescribed. This defines the free area available for flow relative to the total area.

The majority of the CFD modelling carried out for this research project utilised an Arup in-house developed CFD code 'AIRFLO'. This code is used extensively for ventilation studies in buildings. A second code, 'Star-CD', which is a commercially-available general purpose code, was used for predicting the laminar flow pressure loss characteristic of Ventform 150 and 200 (circular leg).

A.2 Modelling Assumptions Used

The CFD modelling assumed idealised conditions as follows:

(i) the ventilation layer is continuous, i.e. no obstructions;
(ii) the slab above the ventilation layer provides a perfect seal;
(iii) installation of the ventilation layer is unaffected by workmanship;
(iv) where pipes or geocomposite strips are used their boundaries have a similar (or higher) porosity to the surrounding gravels, i.e. the "drain" offers no resistance to flow of gas such that any gas that encounters the pipe or geocomposite strip can immediately enter;
(v) the side vents are not obstructed by the components of the ventilation layer;
(vi) wind conditions are continuous;
(vii) soil gas emissions are uniform over the complete area of the foundation/ventilation layer;
(viii) no temperature differential between external air and soil gas emissions;
(ix) buoyancy of gas(es) are ignored.

A.3 Input Parameters

The models considered in the CFD calculations are shown as Figures 1 and 2 in Volume 1. The input parameters are given below.

(i) Foundation sizes: (a) 5m x 5m, and
(b) 30 m wide strip.

(ii) Wind pressures, equivalent to wind speeds of between 0.3m/s and 3.0m/s, were applied as +$^1/_2$ a dynamic head to the side vents on the windward face with -$^1/_2$ a dynamic head on the leeward face(A1), and are shown below.

Wind Speed (m/s)	Equivalent Wind Pressure (Pa)
3	5.4
1	0.6
0.3	0.054

(iii) Gas emission rate of 1.96x10-6 $m^3/m^2/s$ (equivalent to a gas velocity of 0.01m/s from a 50mm ID standpipe, and an area of borehole influence of 10m^2 [as proposed by Peckson(A2)]).

(iv) Side ventilation alternatives are as described on Figures 1 and 2 in Volume 1.

(v) Intrinsic permeability, Forcheimer term and porosity for gravel aggregates, VENTFORM products and GEOFIN 40 were as shown below.

Ventilation Media	Intrinsic Permeability k (m^2)	Forcheimer Term, C (s/m)	Porosity	Source
Ventform 80	7.5×10^{-5}	-	0.33	1
Ventform 100	1.1×10^{-4}	-	0.33	1
Ventform 150	3.7×10^{-4}	-	0.50	1
Ventform 200	5.0×10^{-4}	-	0.50	1
Geofin 40	2.0×10^{-6}	1.6	0.90	2
20mm single sized	9.9×10^{-8}	6.7	0.43	3
MOT Type 1 sub-base	2.7×10^{-8}	13.4	0.32	3

Source 1 From 3D CFD calculations (by Arup) and CORDEK product data sheets.
Source 2 Calculated from physical testing results supplied by Cooper Clark Group plc.
Source 3 Unpublished BRE test results on uncompacted gravels.

A.4 Results of CFD Simulations

The results of the CFD simulations are presented numerically and graphically in Volume 1 of this Guide to Design as follows:

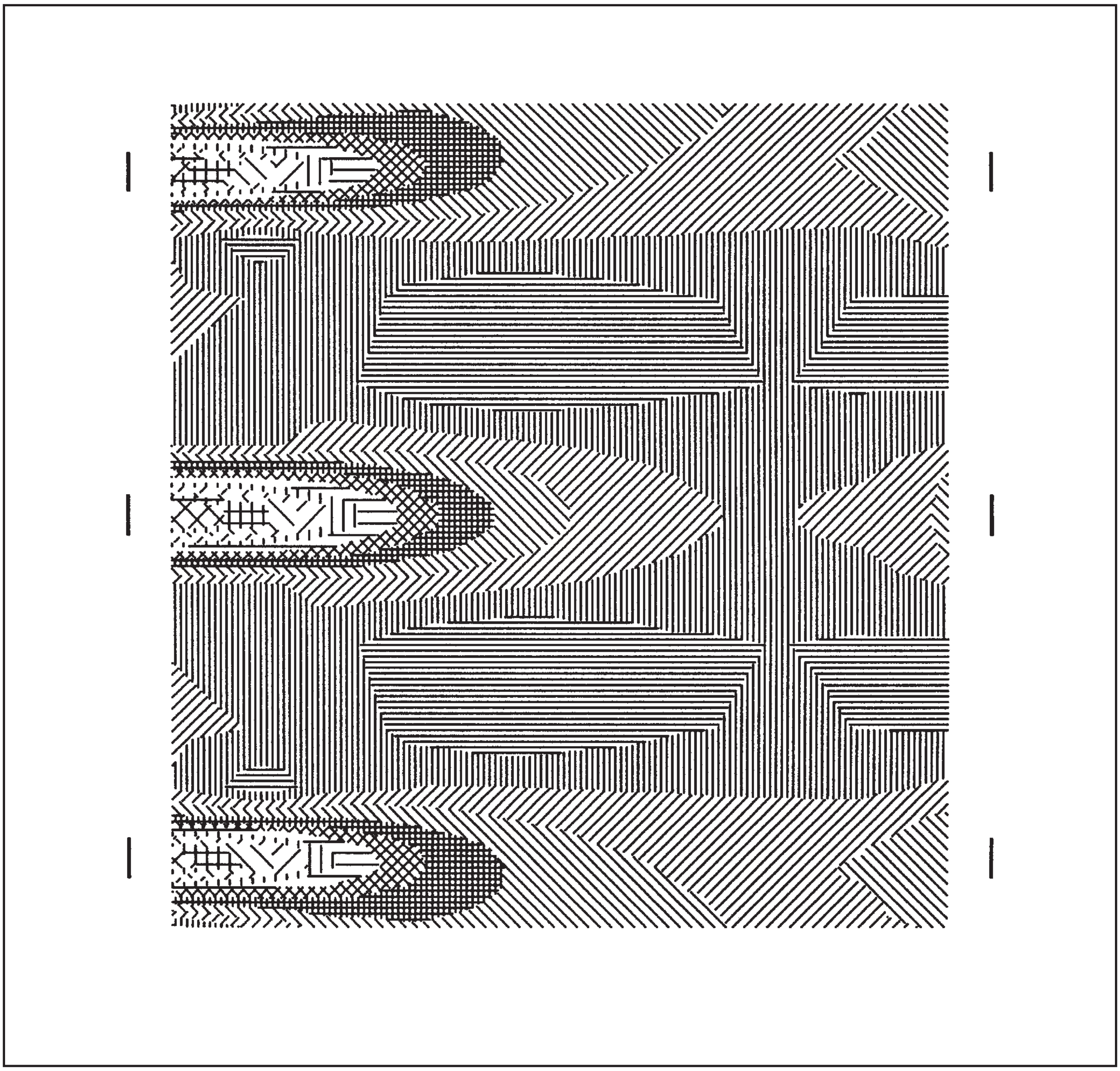
Open Void Ventilation Layer:	Tables 8, 9 and 10 Figures 6 and 7
Expanded Polystyrene Layer:	Tables 12, 13 and 14 Figures 8 and 9
Geocomposite Blanket:	Tables 16, 17 and 18 Figures 10 and 11
Gravel Blanket:	Tables 20, 21 and 22 Figures 12 and 13
Gravel Blanket with Pipes:	Tables 24, 25 and 26 Figure 14

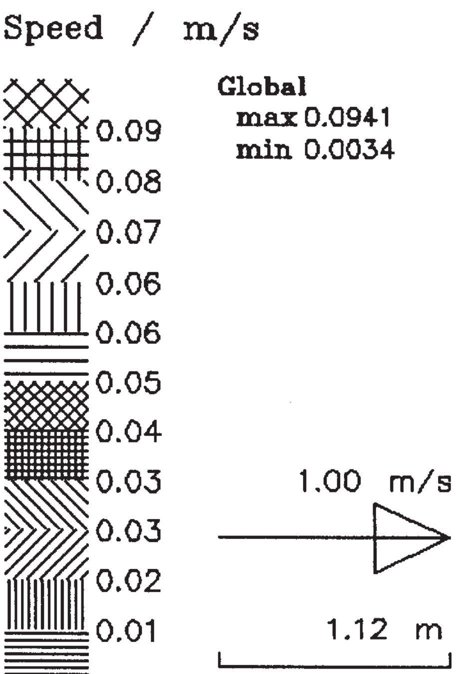
Example plots for a wind speed of 3m/s are reproduced as Figures A1.1 to A12.3 in this Volume. The key to the concentration plots refers to the proportion of soil gas to external air (expressed as a percentage) within the ventilation layer.

A.5 References

(A1) BRITISH STANDARDS INSTITUTION. BS 6339: Part 2 : 1995. Loading for Buildings. Part 2. Code of Practice for Wind Loads. BSI, 1995.

(A2) PECKSEN, G.N. London Environmental Supplement No. 13. Methane and the development of derelict land. GLC, 1985.





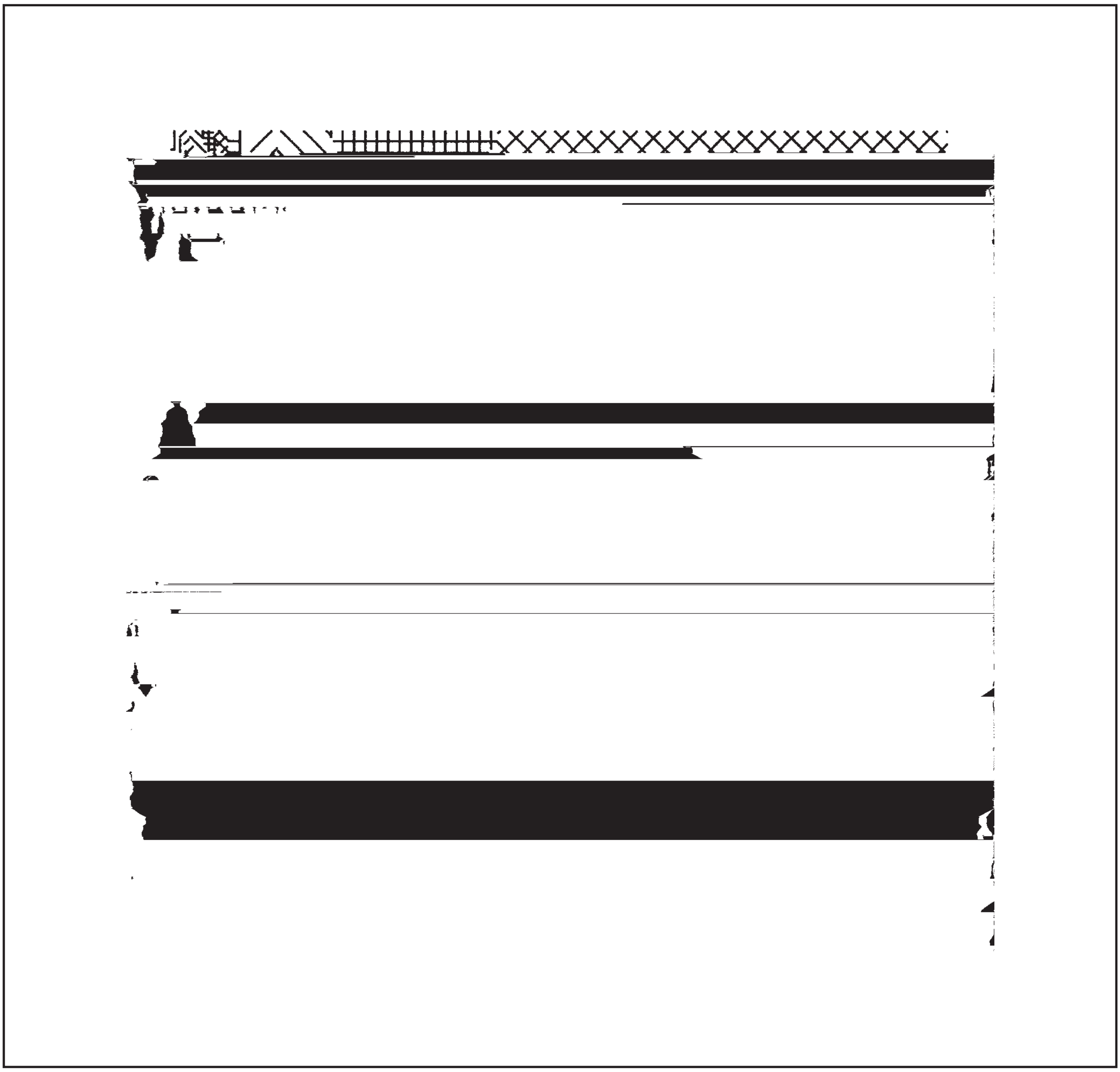
MODEL 1: 5m x 5m Foundation

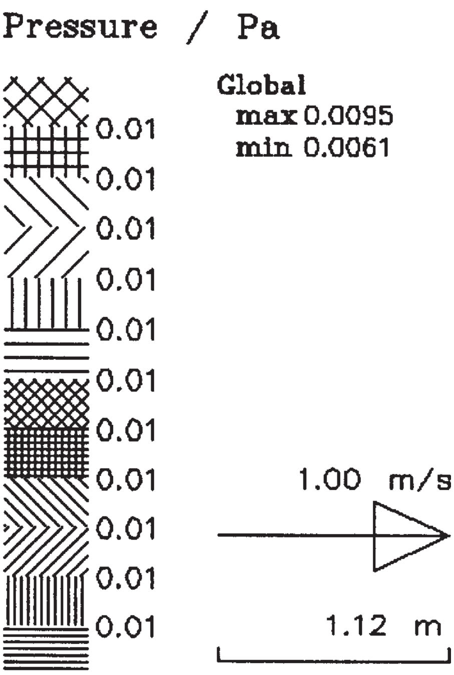
200mm deep VOID

Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A1.1

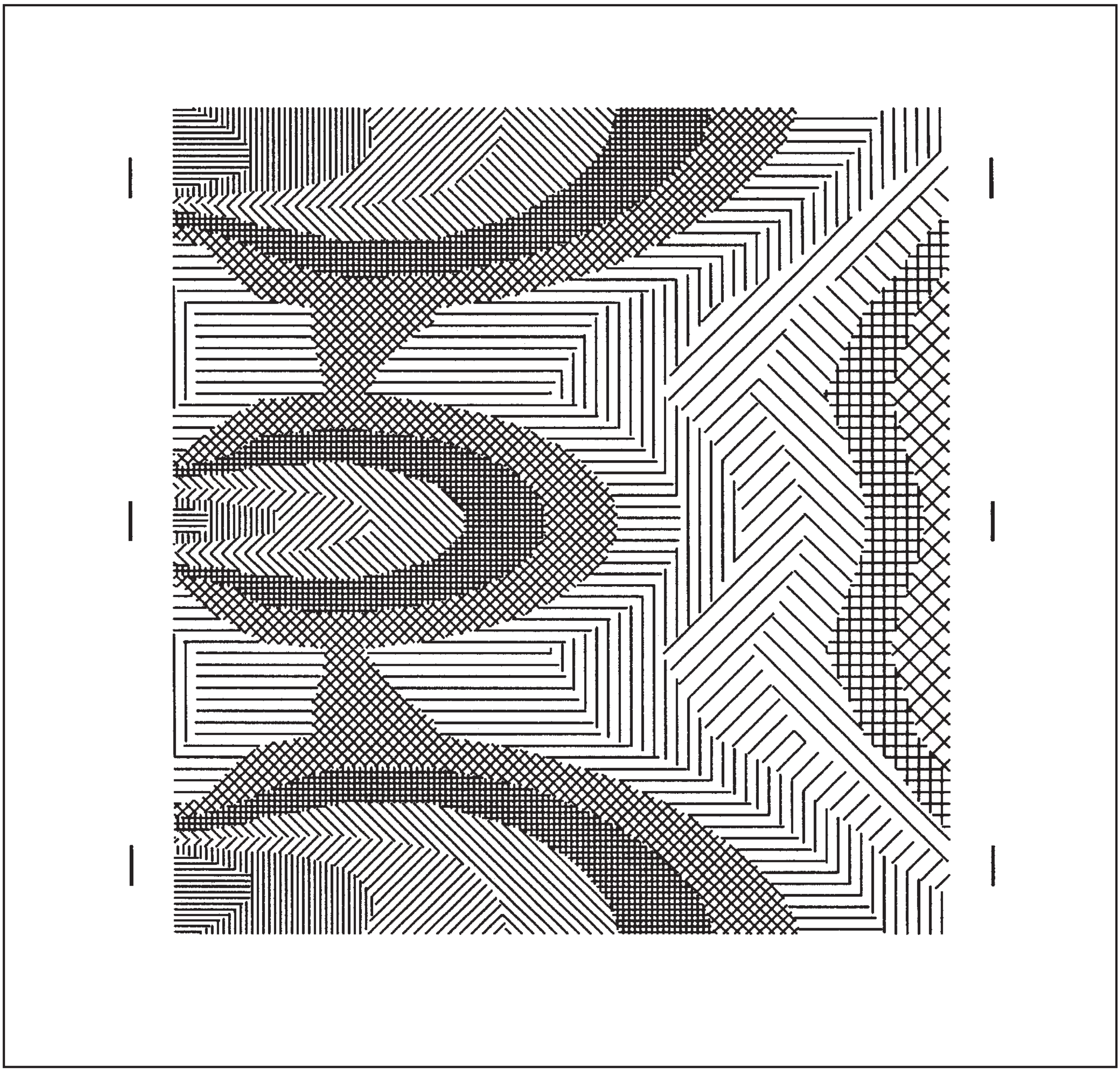


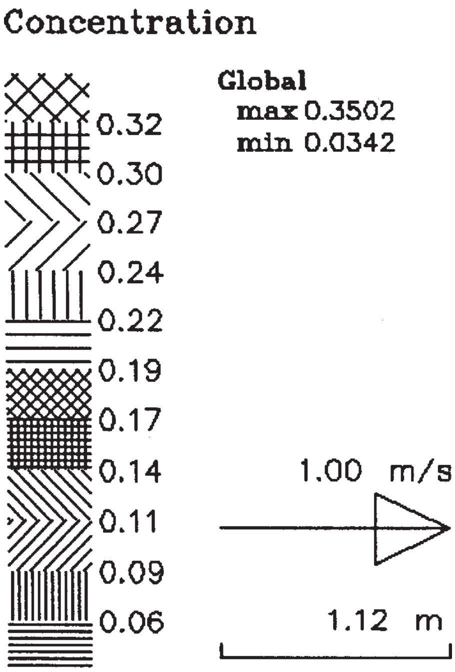


MODEL 1: 5m x 5m Foundation
200mm deep VOID
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A1.2

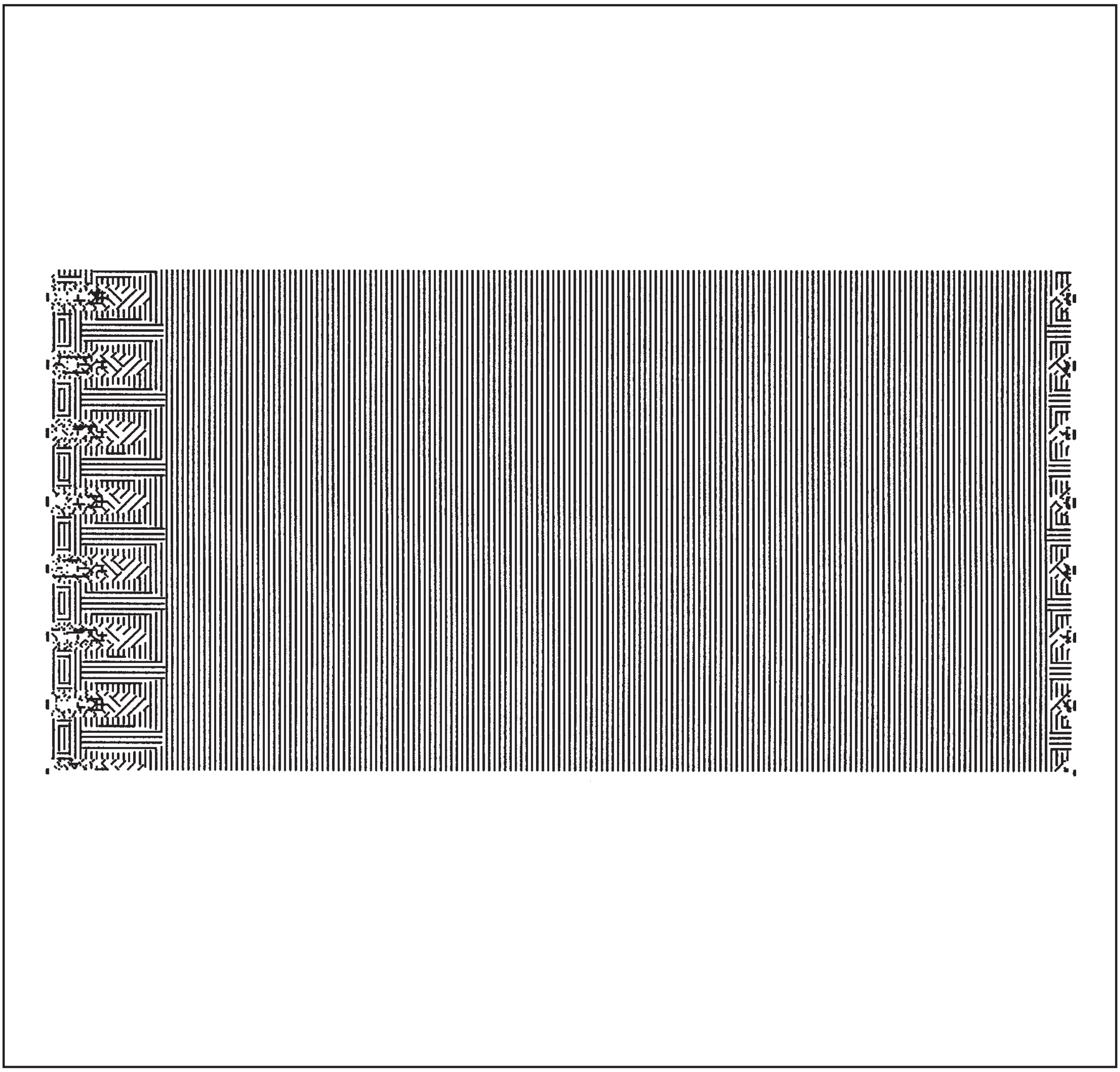


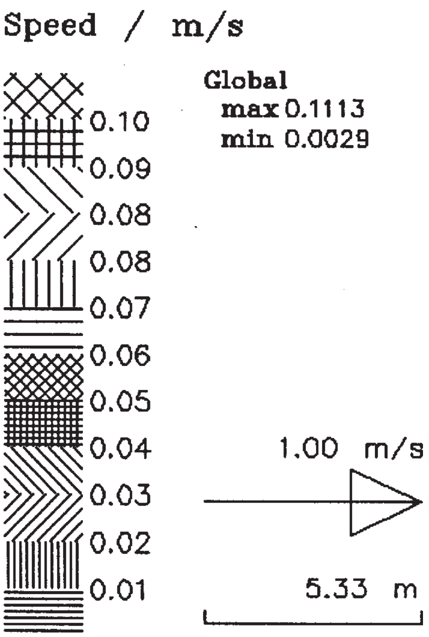


MODEL 1: 5m x 5m Foundation
200mm deep VOID
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A1.3



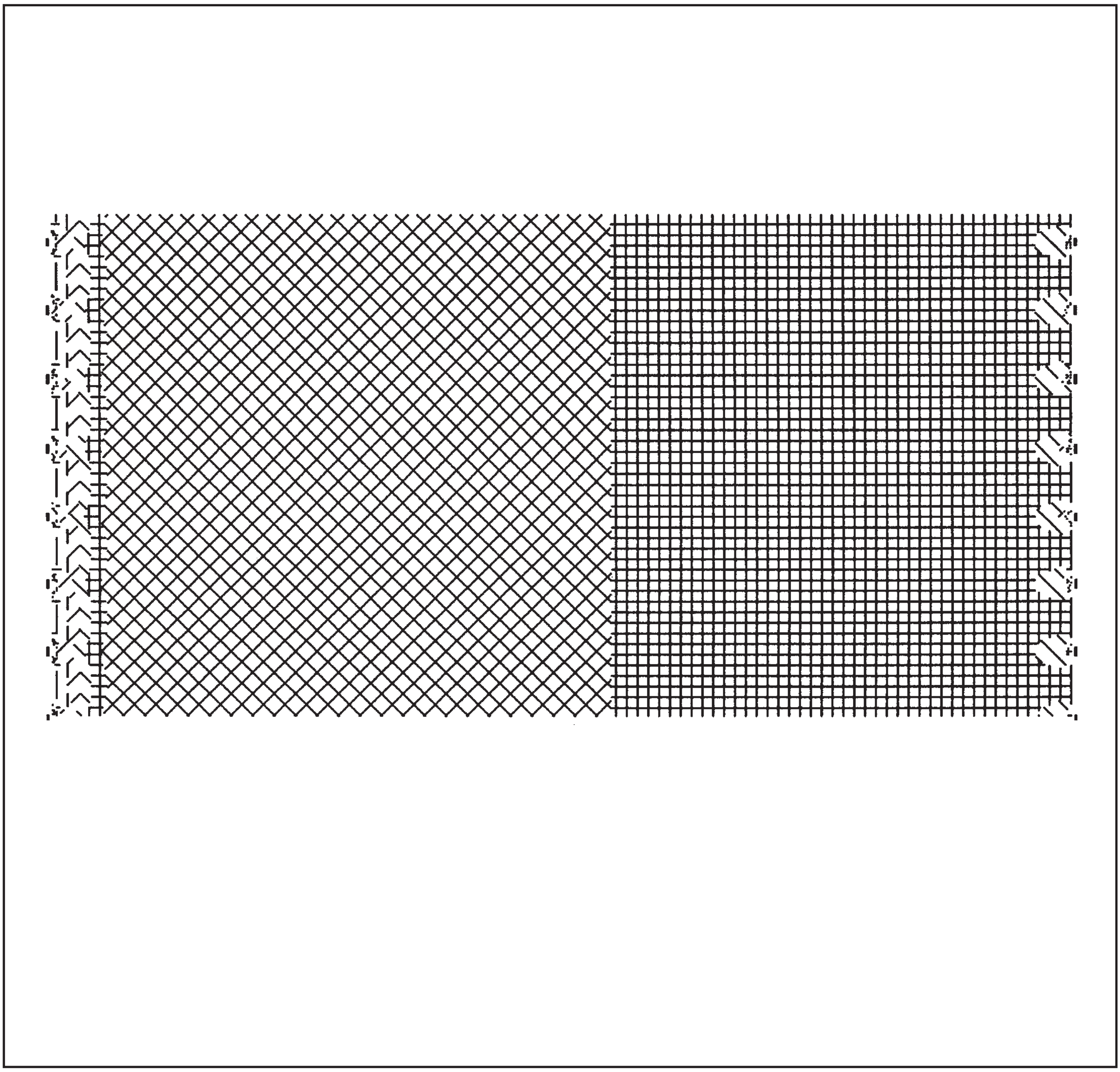


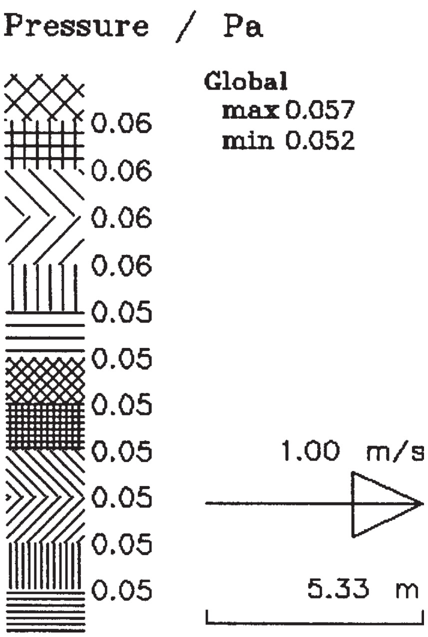
MODEL 2: 30m wide Foundation

200mm deep VOID
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A2.1

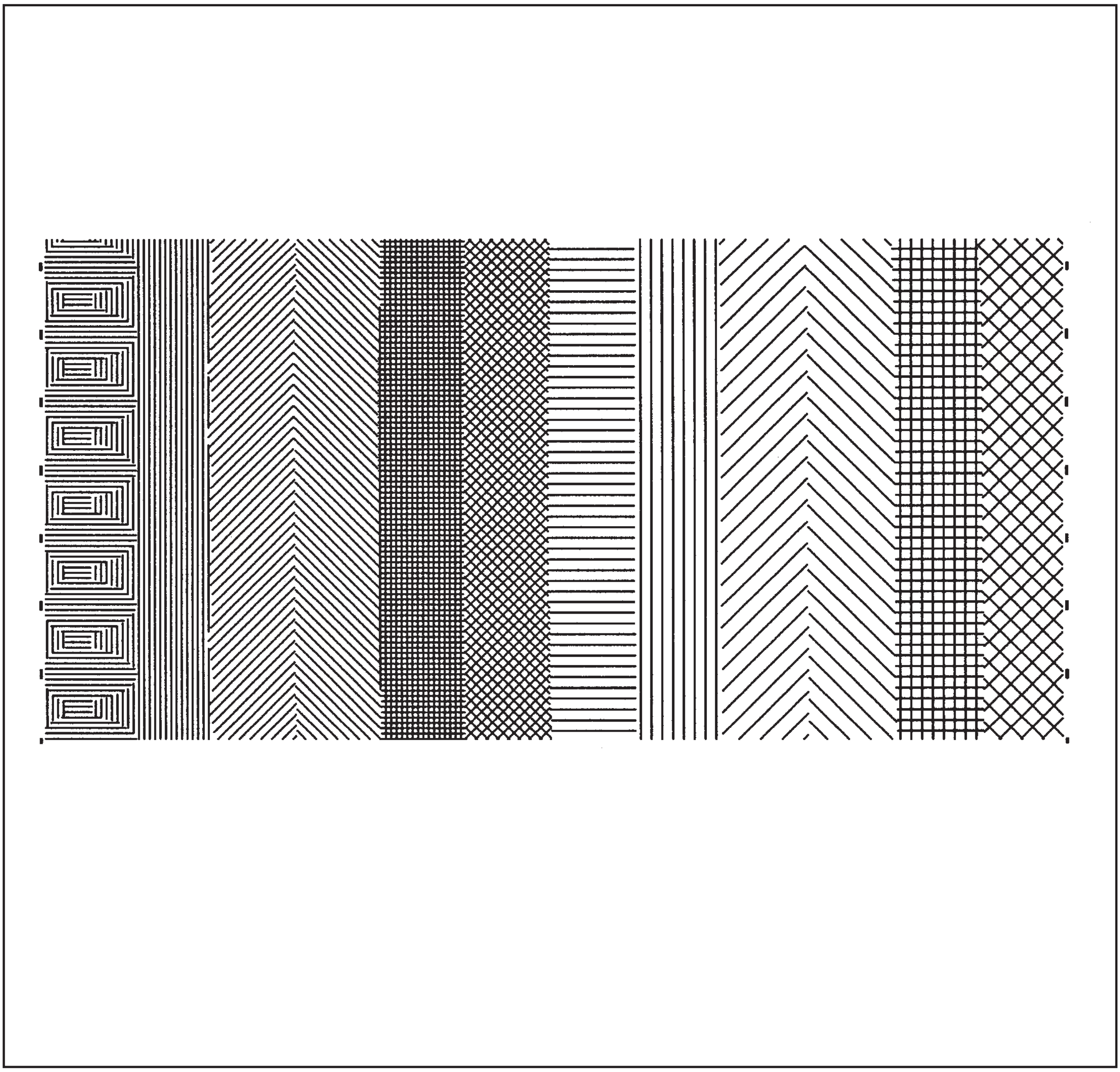


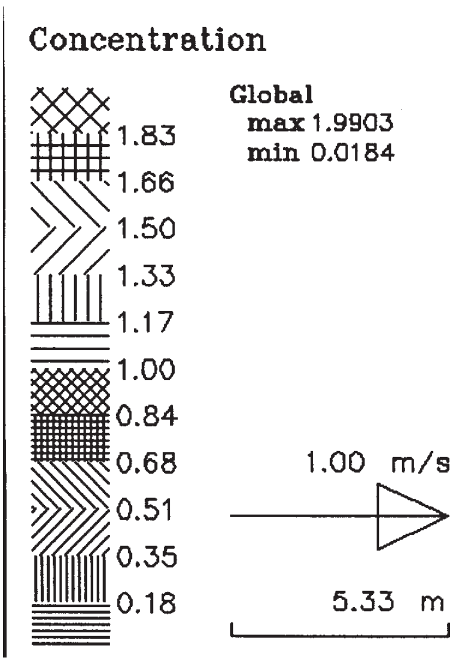


MODEL 2: 30m wide Foundation
200mm deep VOID
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A2.2

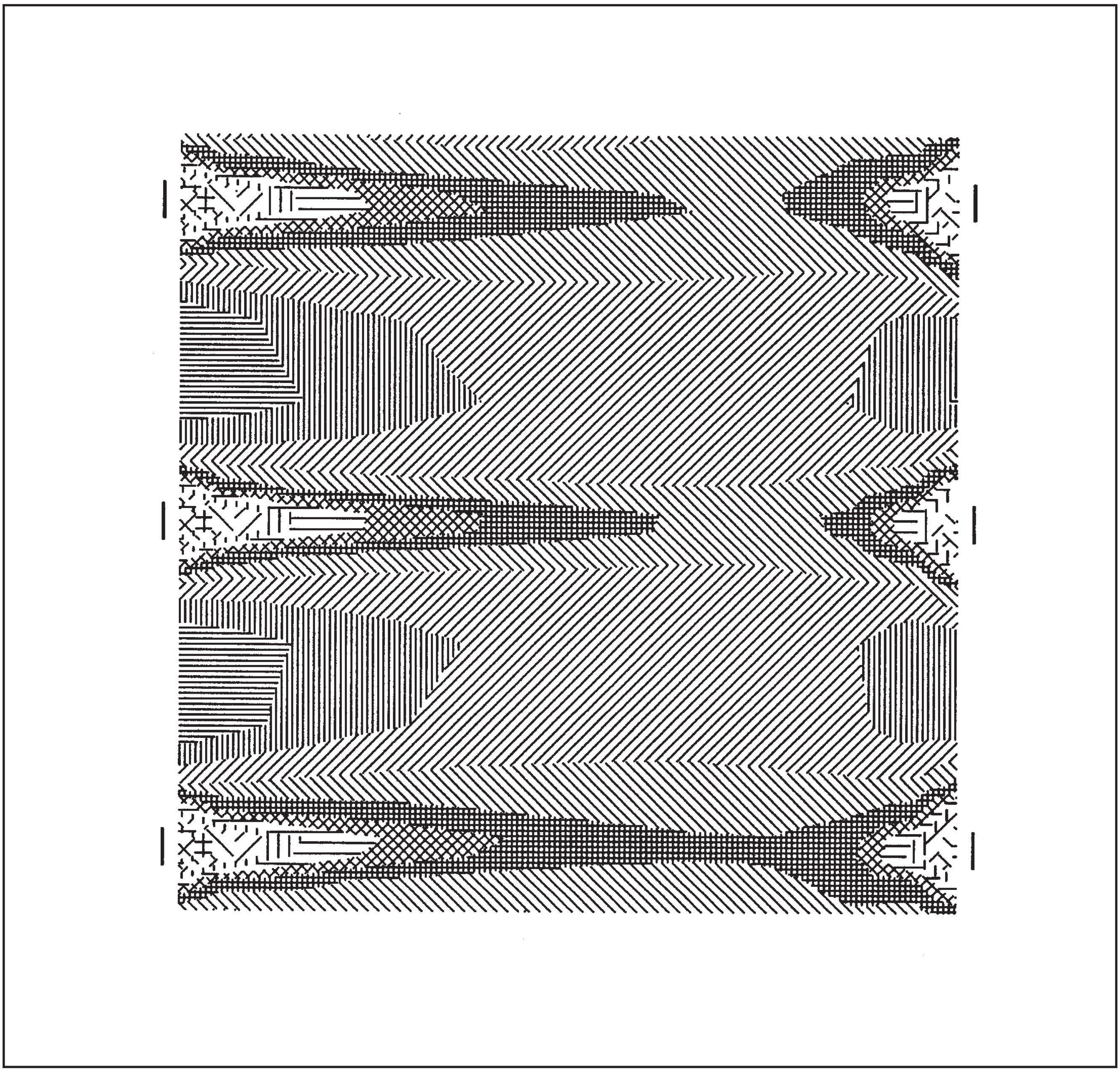


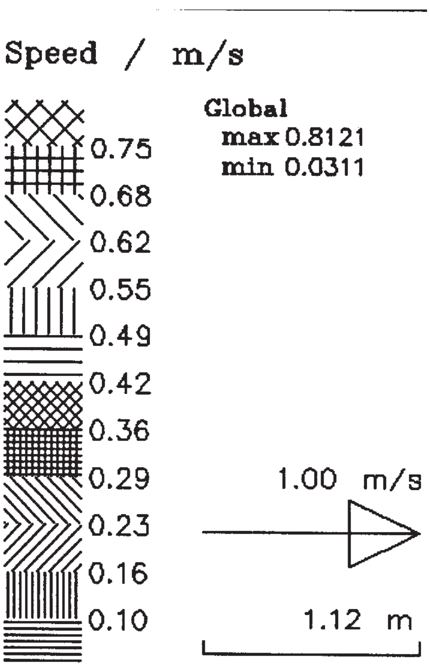


MODEL 1: 30m wide Foundation
200mm deep VOID
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A2.3

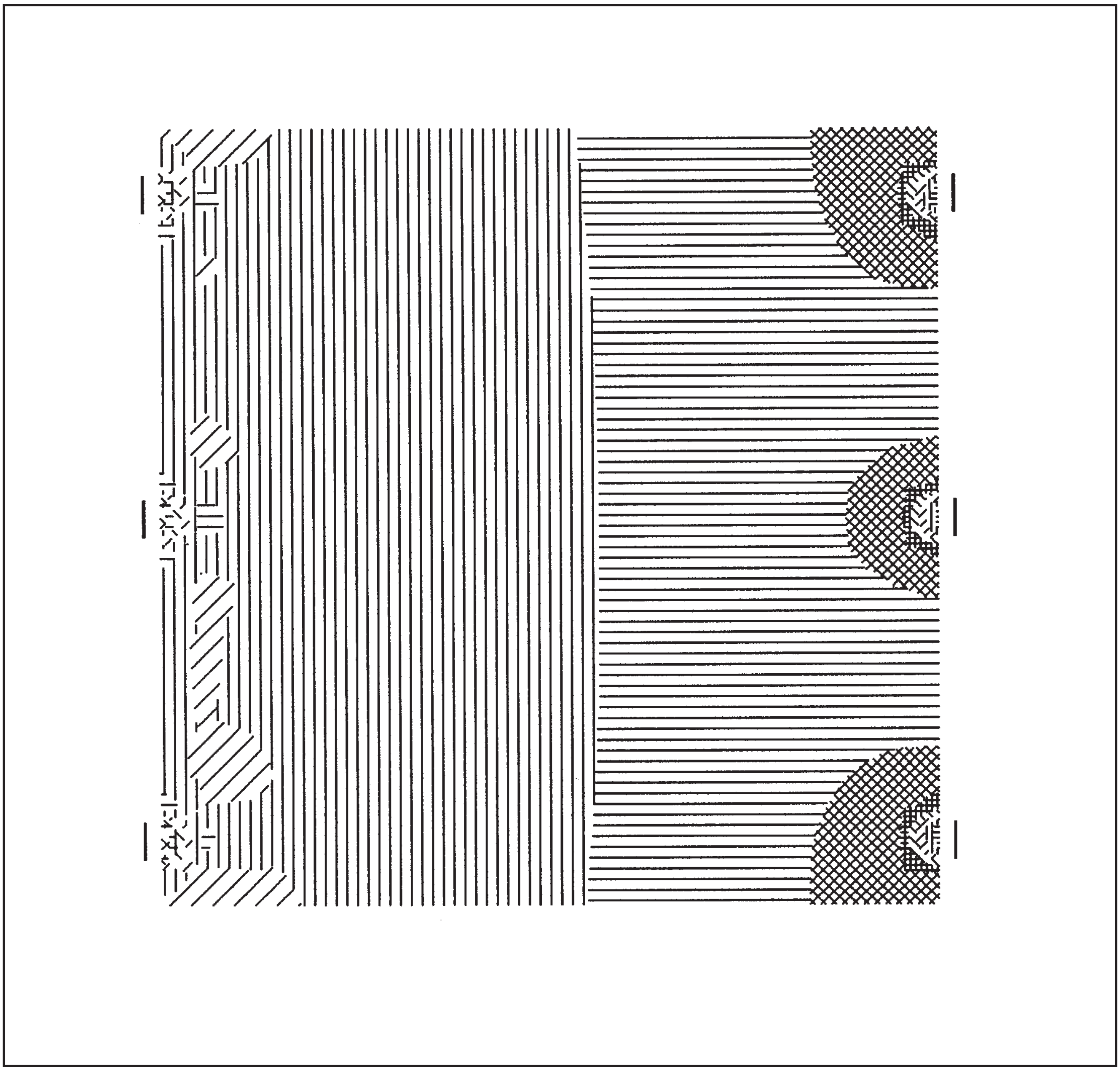


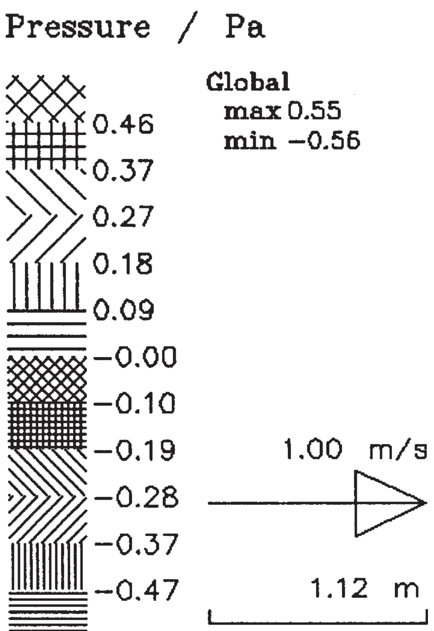


MODEL 1 : 5m x 5m Foundation
VENTFORM 80
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A3.1

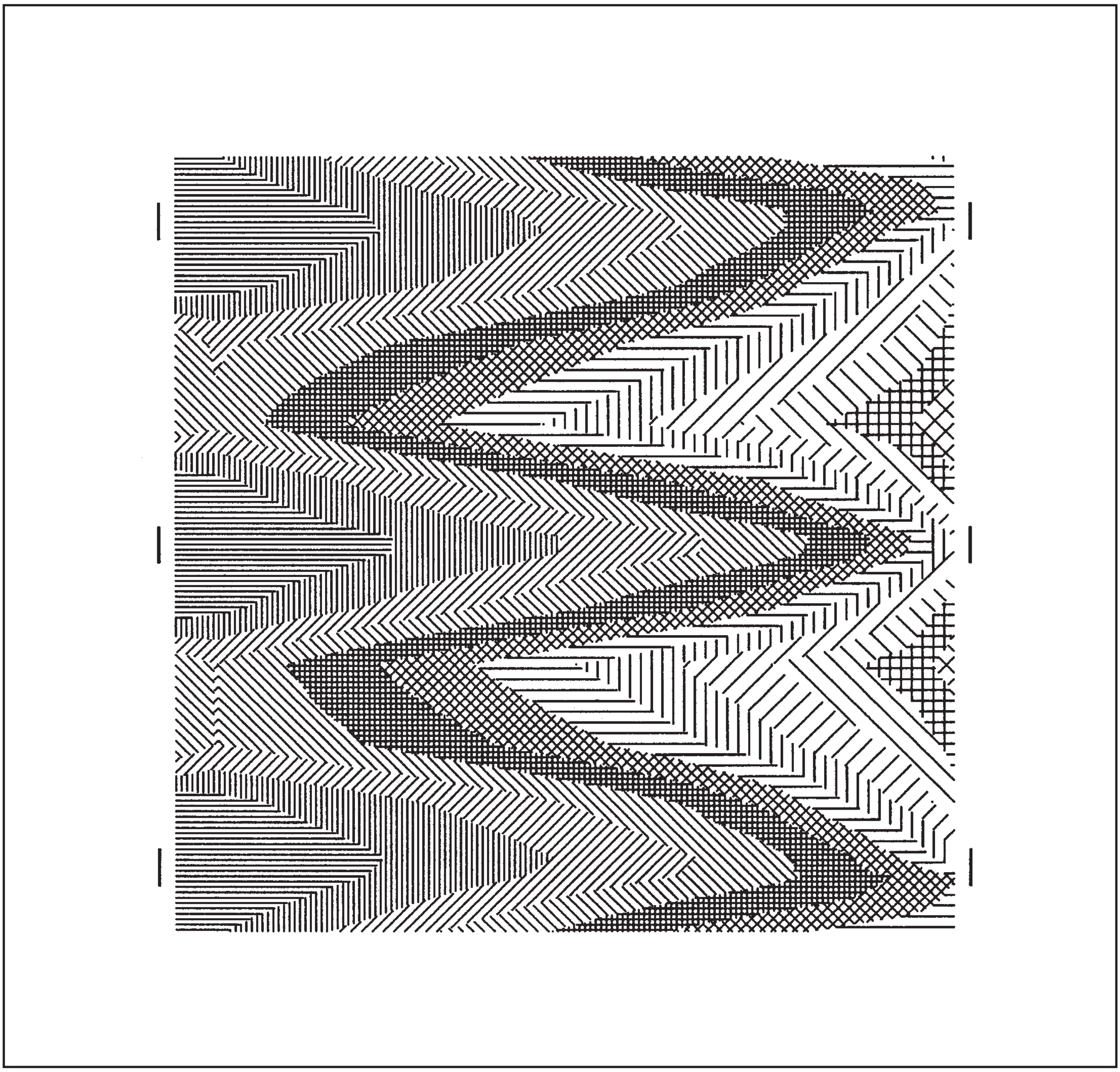


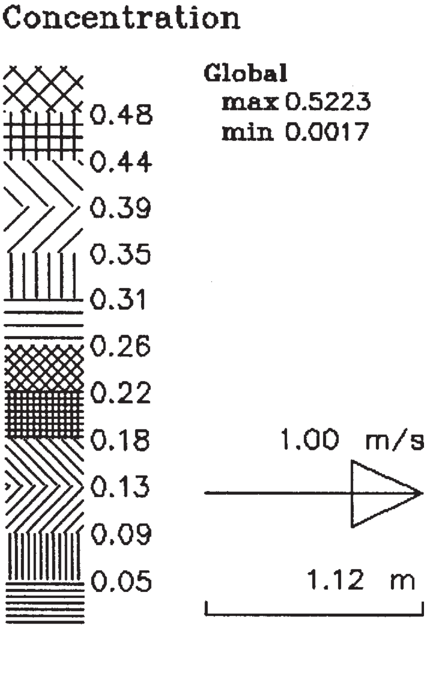


MODEL 1 : 5m x 5m Foundation
VENTFORM 80
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A3.2

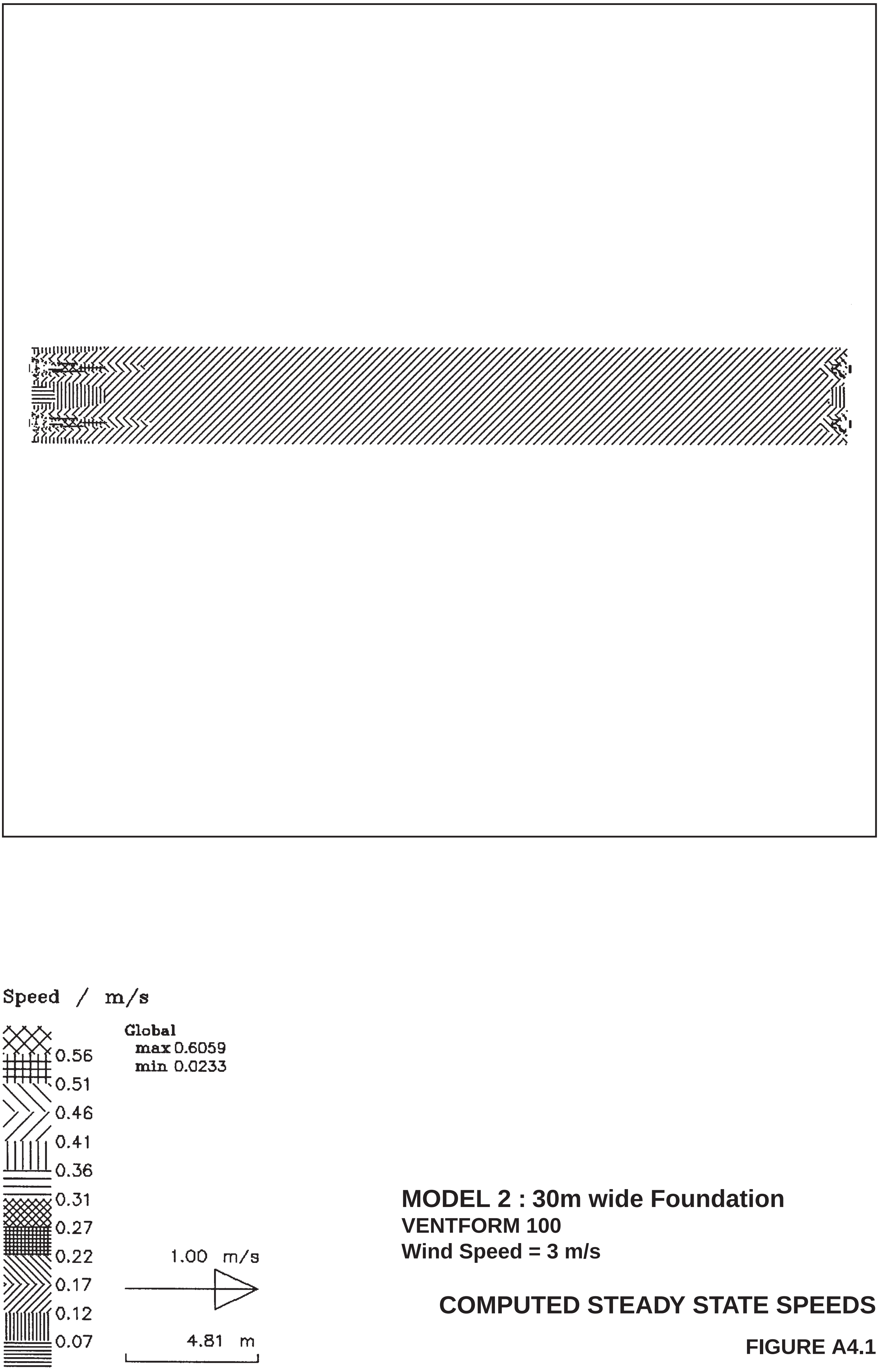




MODEL 1 : 5m x 5m Foundation
VENTFORM 80
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

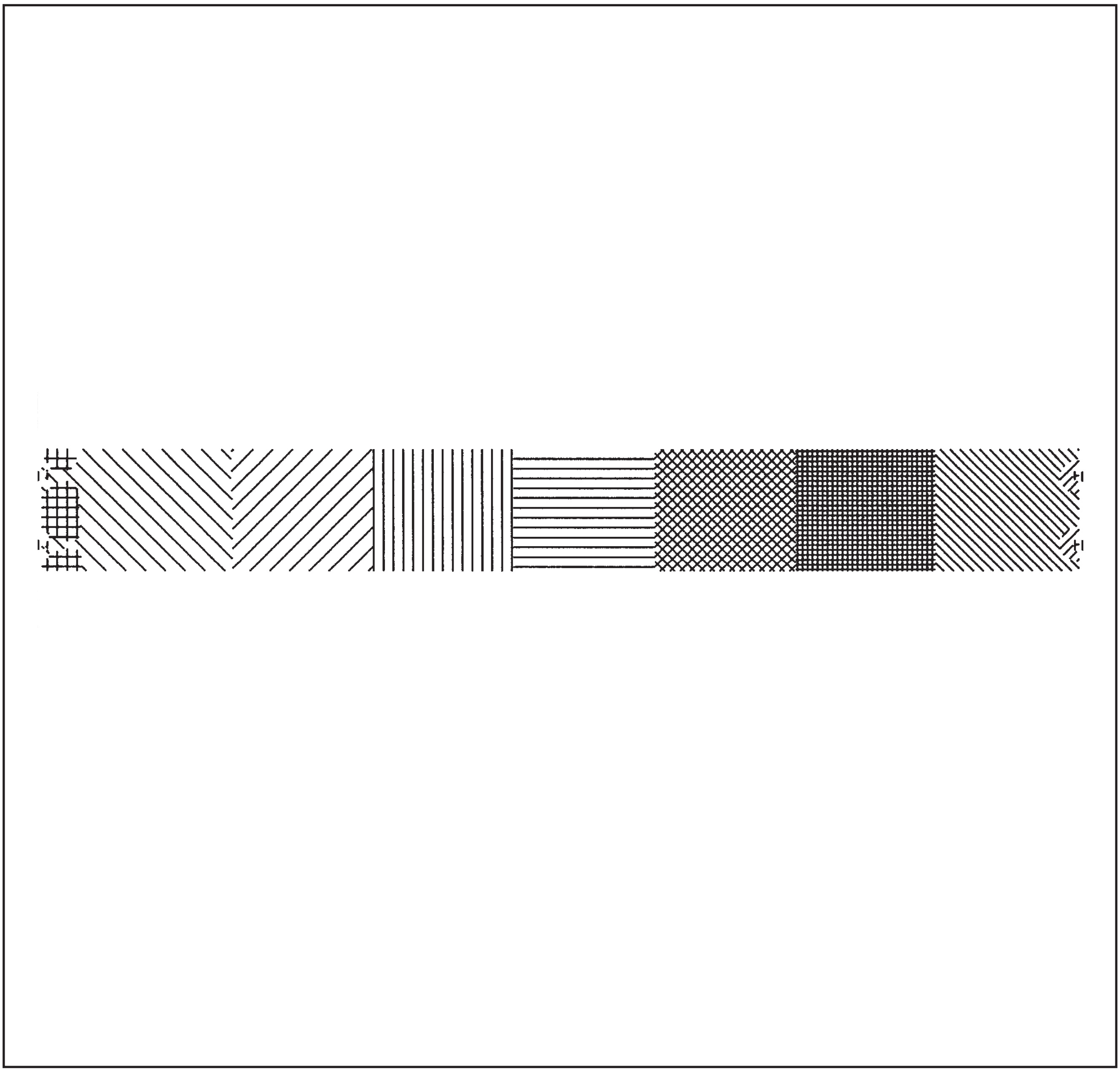
FIGURE A3.3

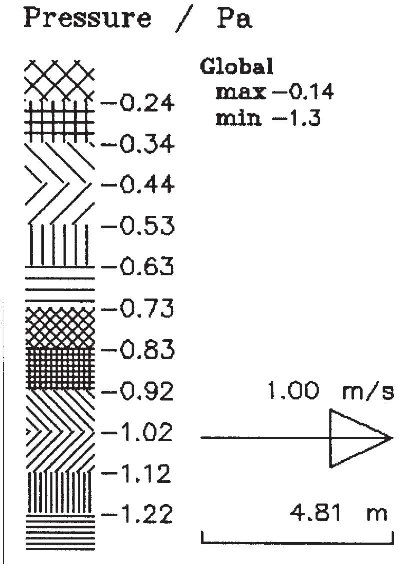


MODEL 2 : 30m wide Foundation
VENTFORM 100
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A4.1

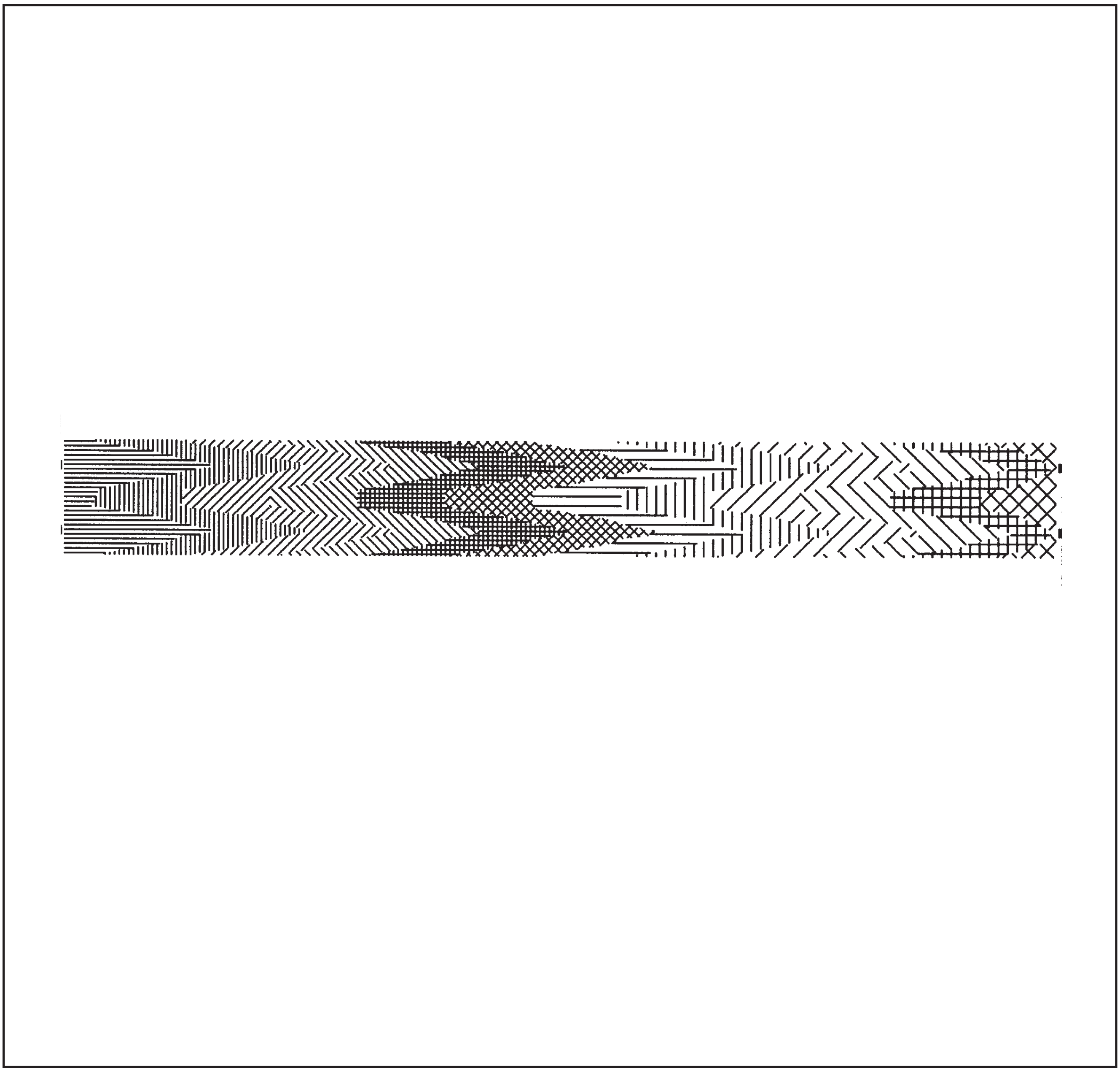


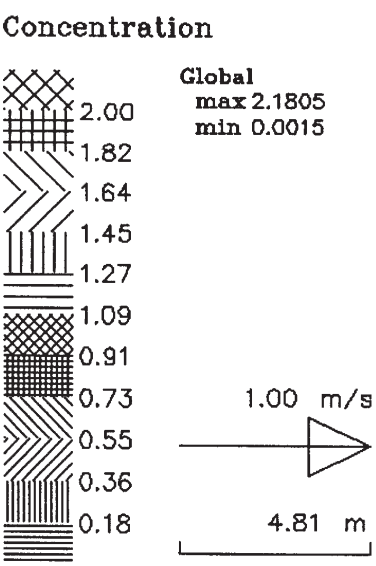


MODEL 2 : 30m wide Foundation
VENTFORM 100
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A4.2

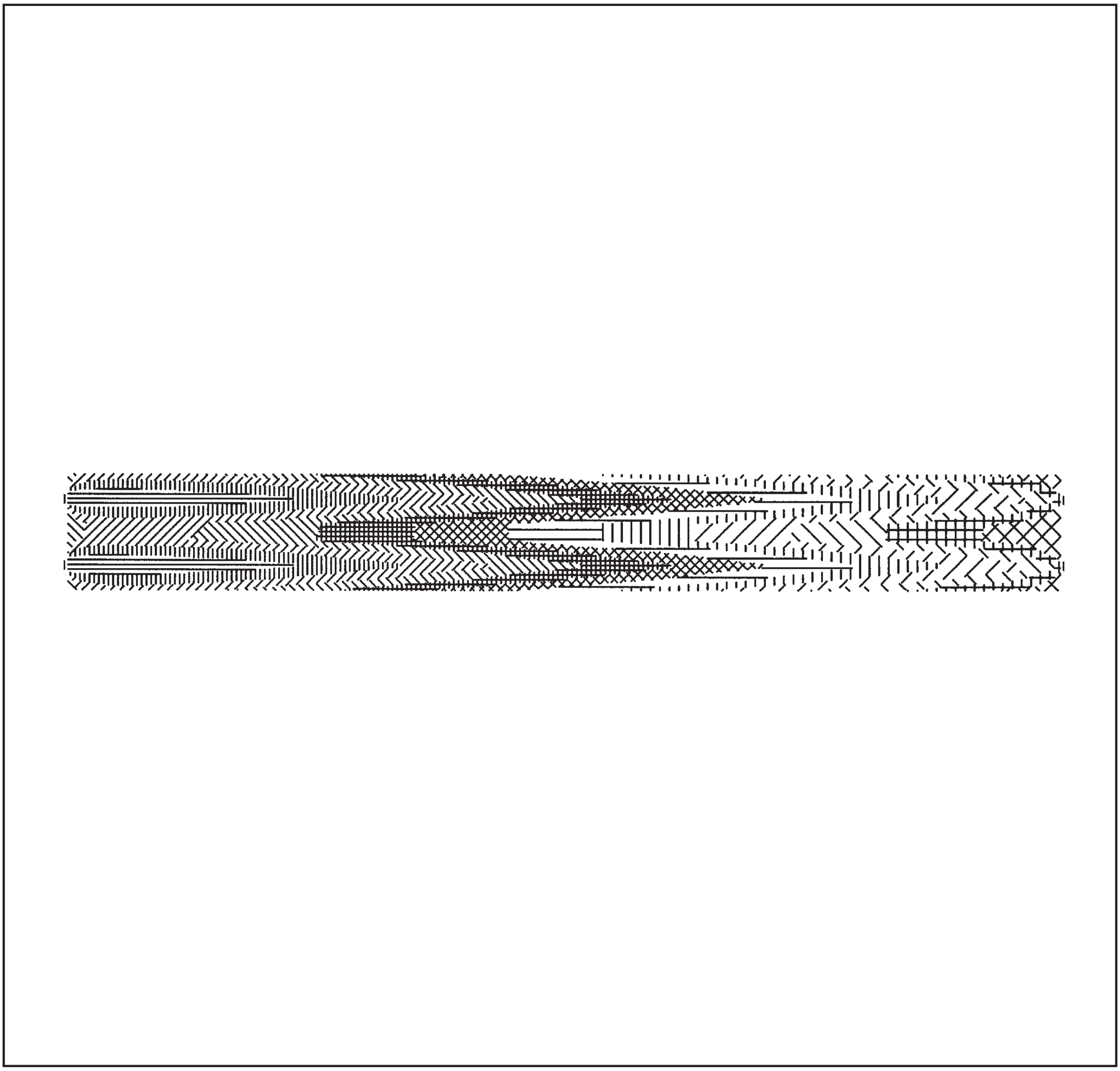


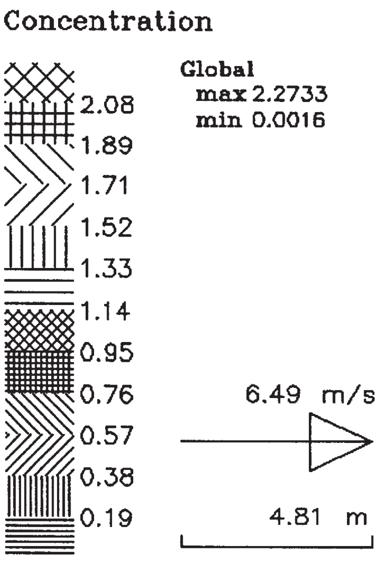


MODEL 2 : 30m wide Foundation
VENTFORM 100
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A4.3

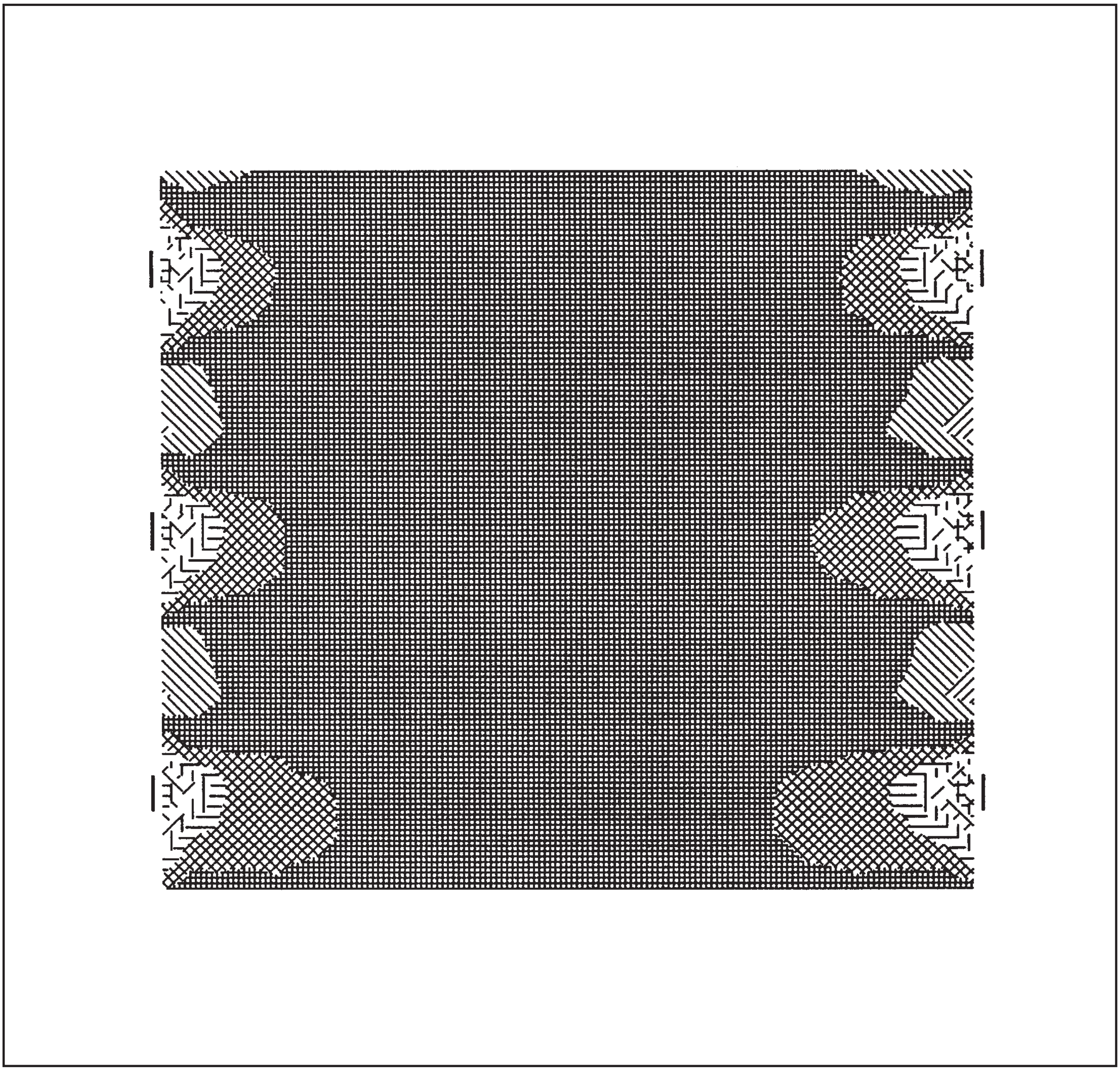


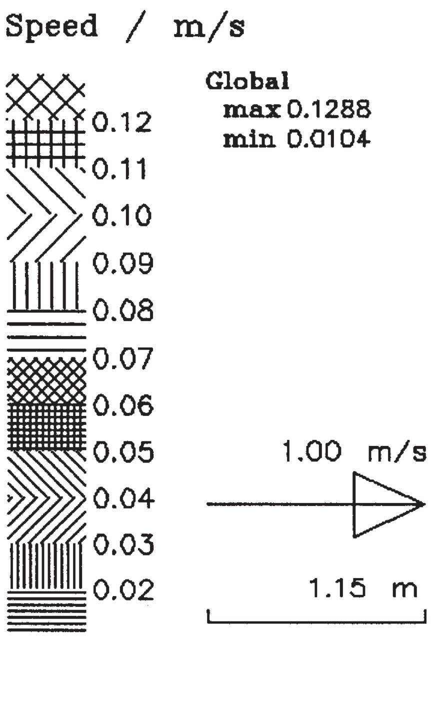


MODEL 2 : 30m wide Foundation
VENTFORM 200
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A4.4

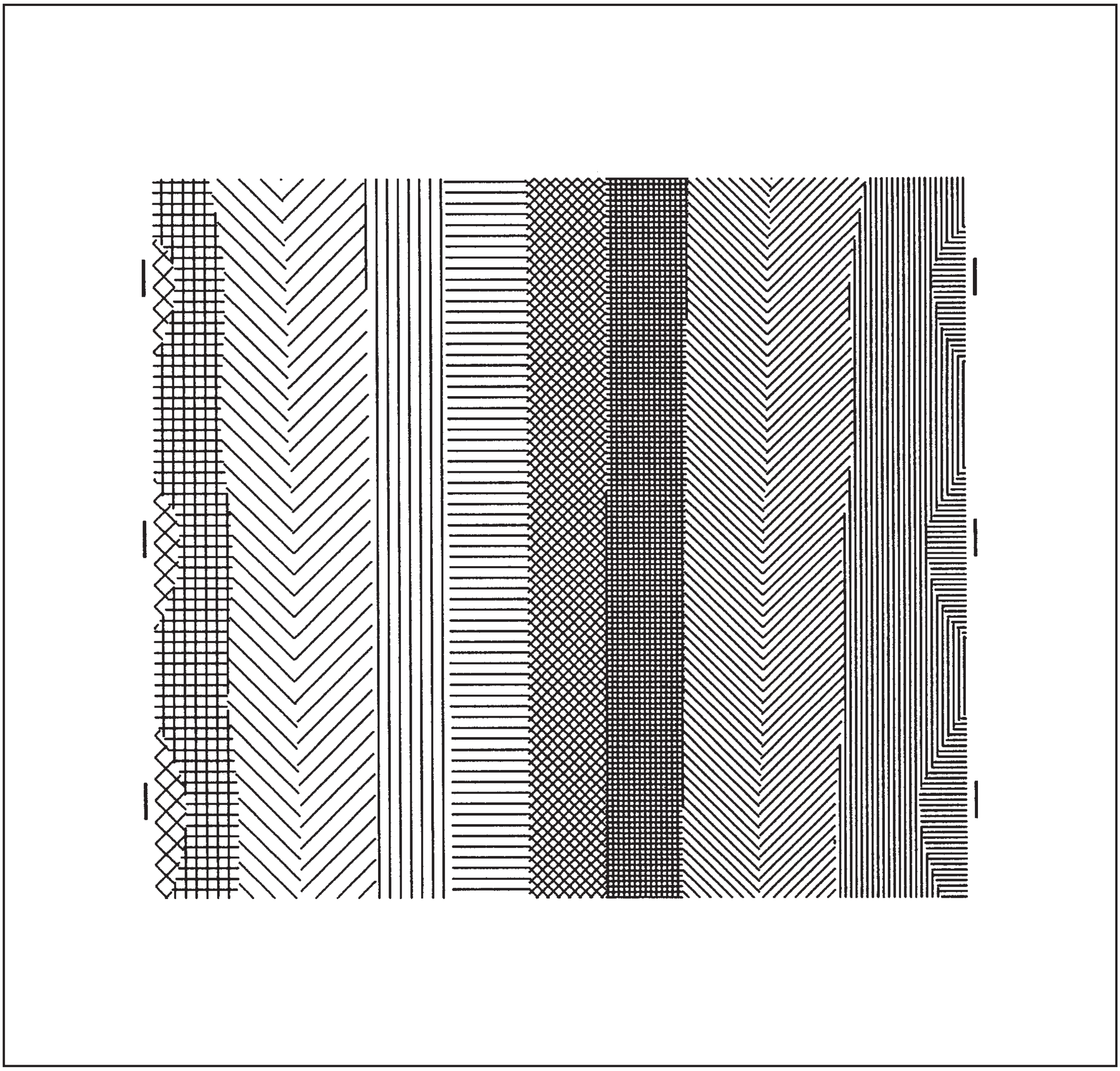


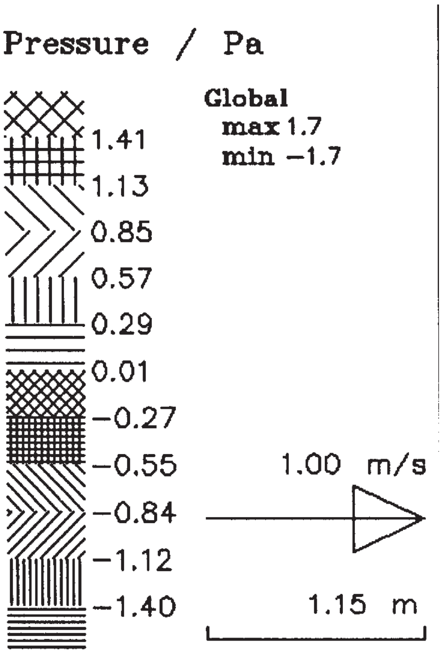


MODEL 1: 5m x 5m Foundation
GEOFIN 40mm - top
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A5.1

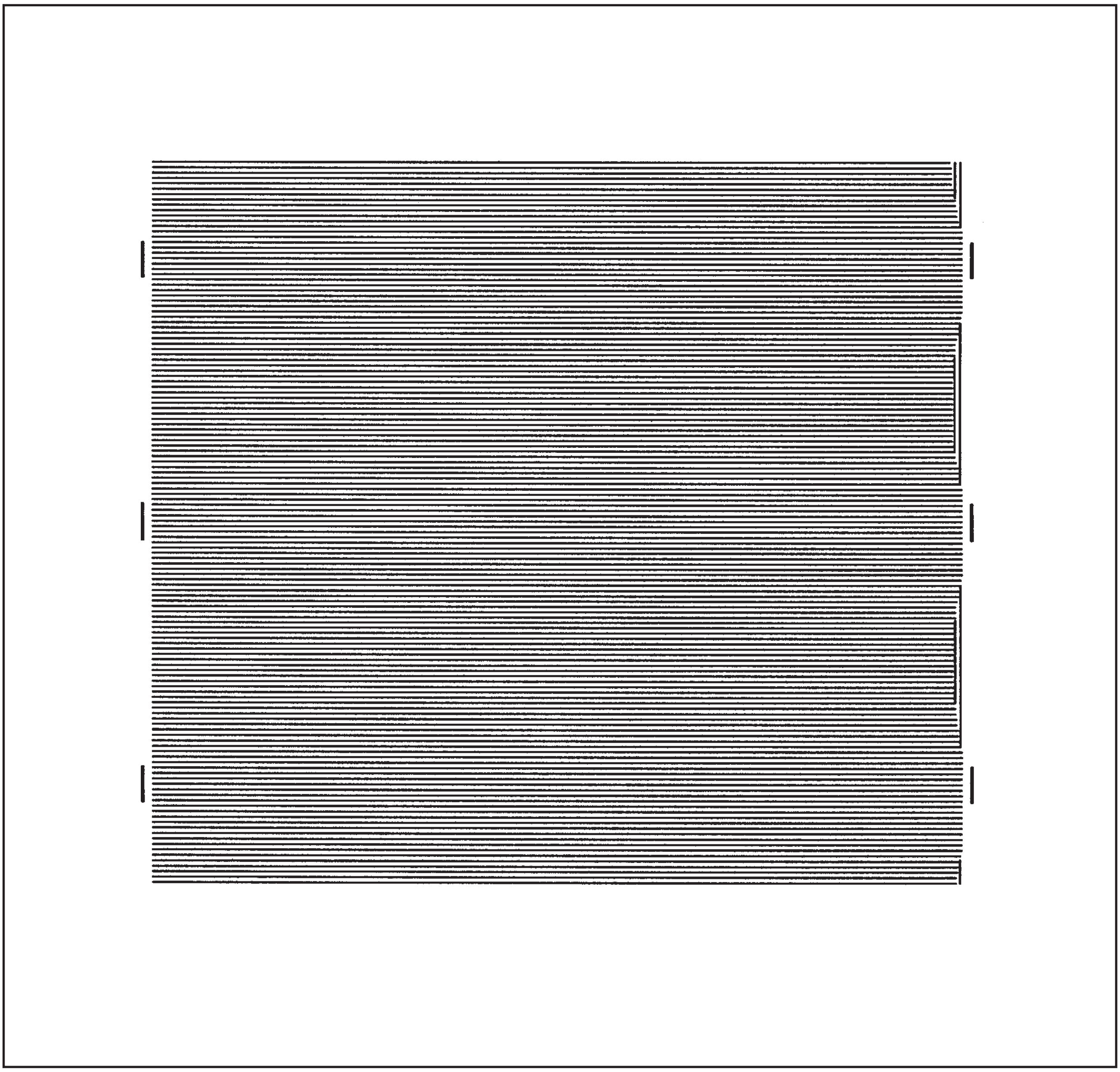


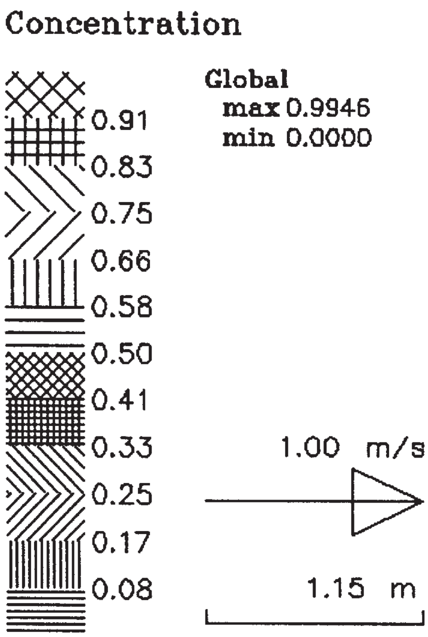


MODEL 1: 5m x 5m Foundation
GEOFIN 40mm - top
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A5.2

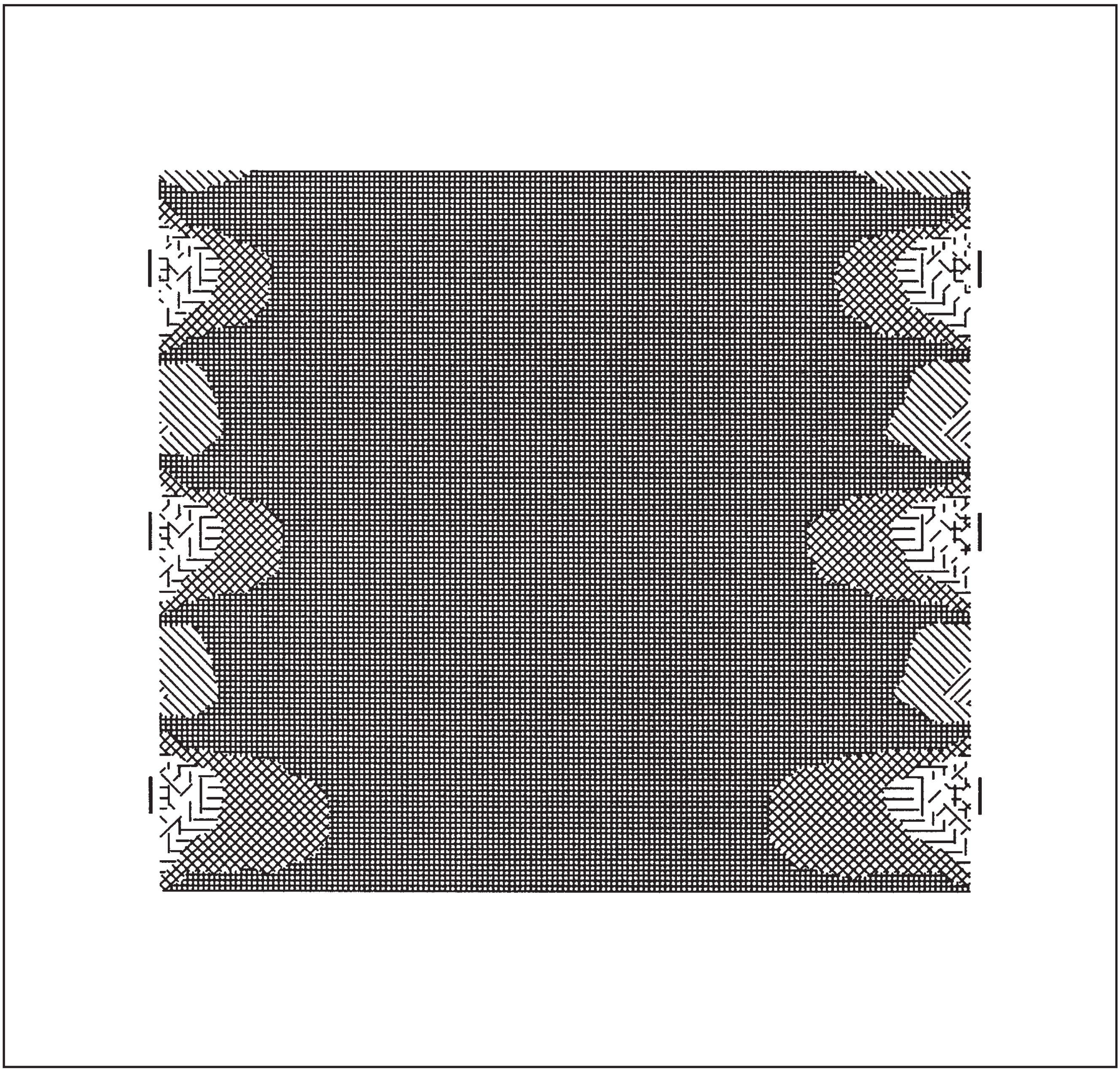


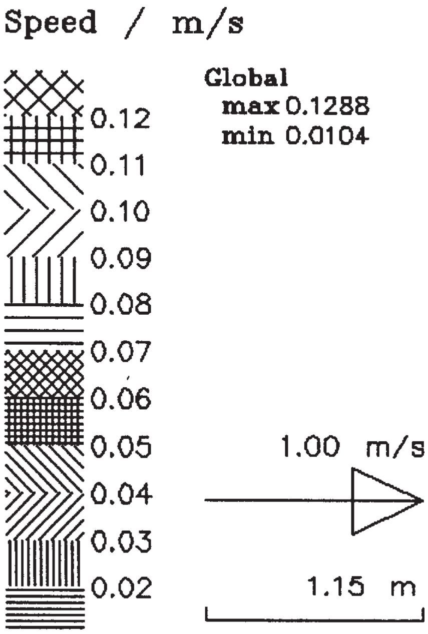


MODEL 1: 5m x 5m Foundation
GEOFIN 40mm - top
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A5.3

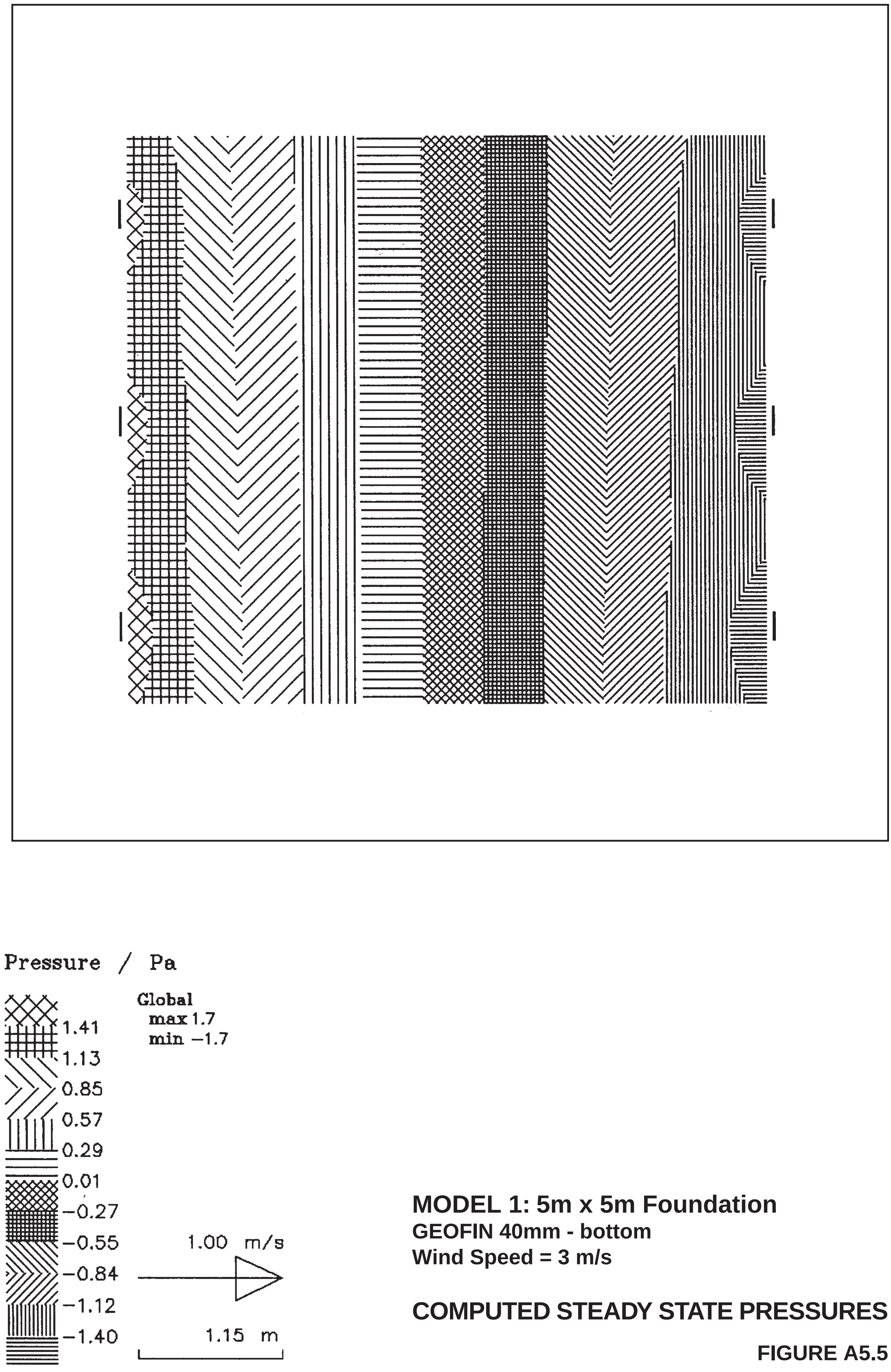




MODEL 1: 5m x 5m Foundation
GEOFIN 40mm - bottom
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

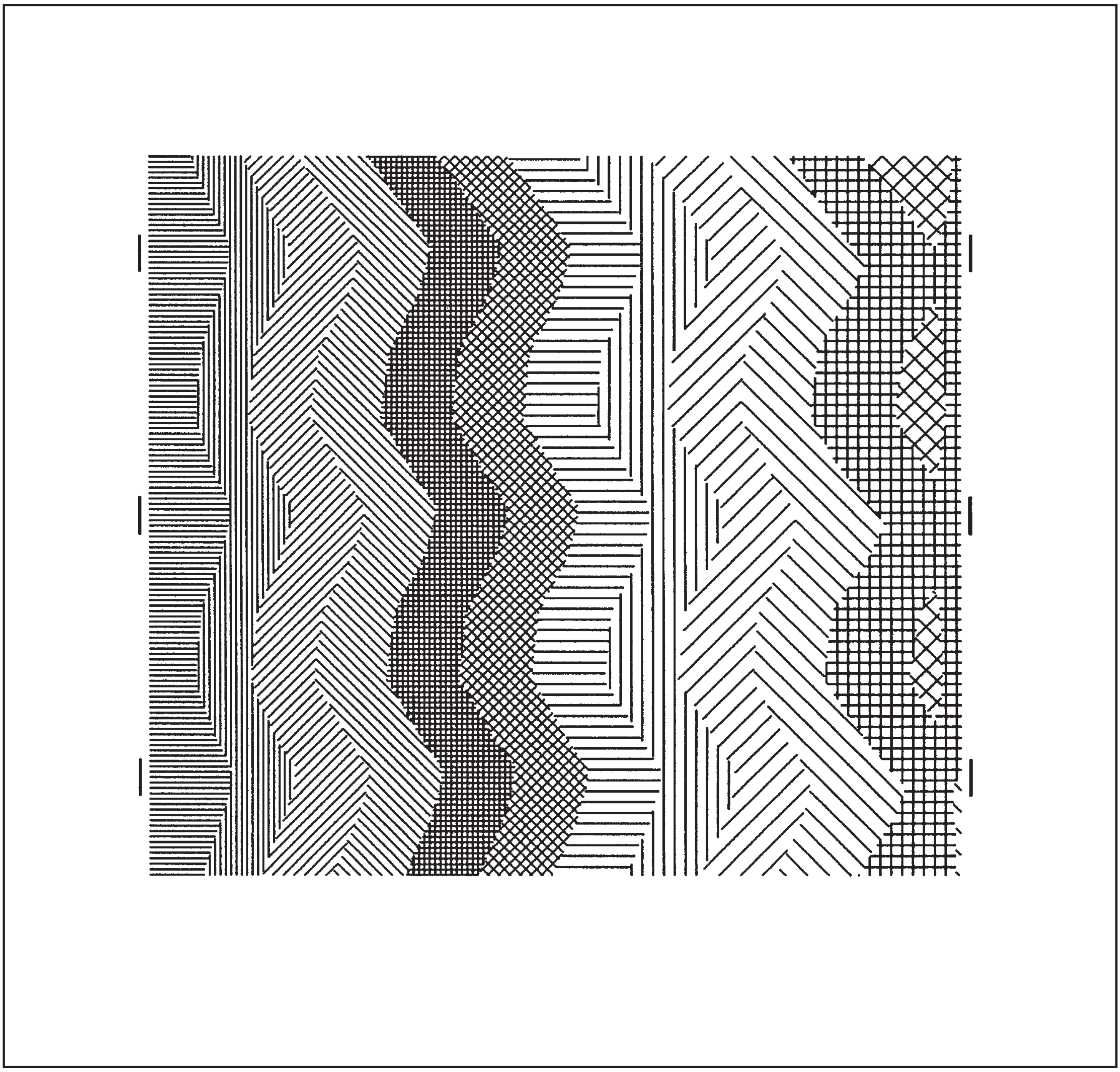
FIGURE A5.4

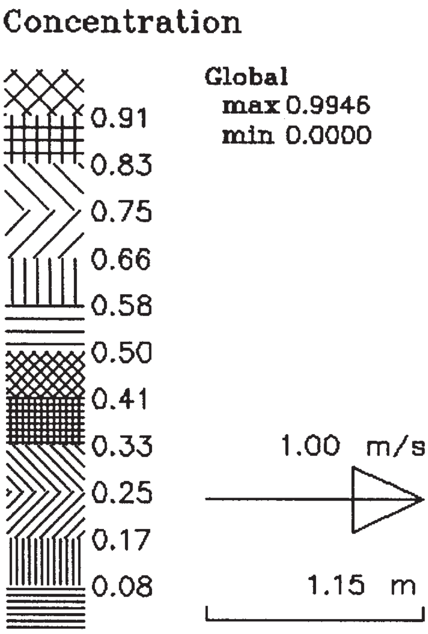


MODEL 1: 5m x 5m Foundation
GEOFIN 40mm - bottom
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A5.5

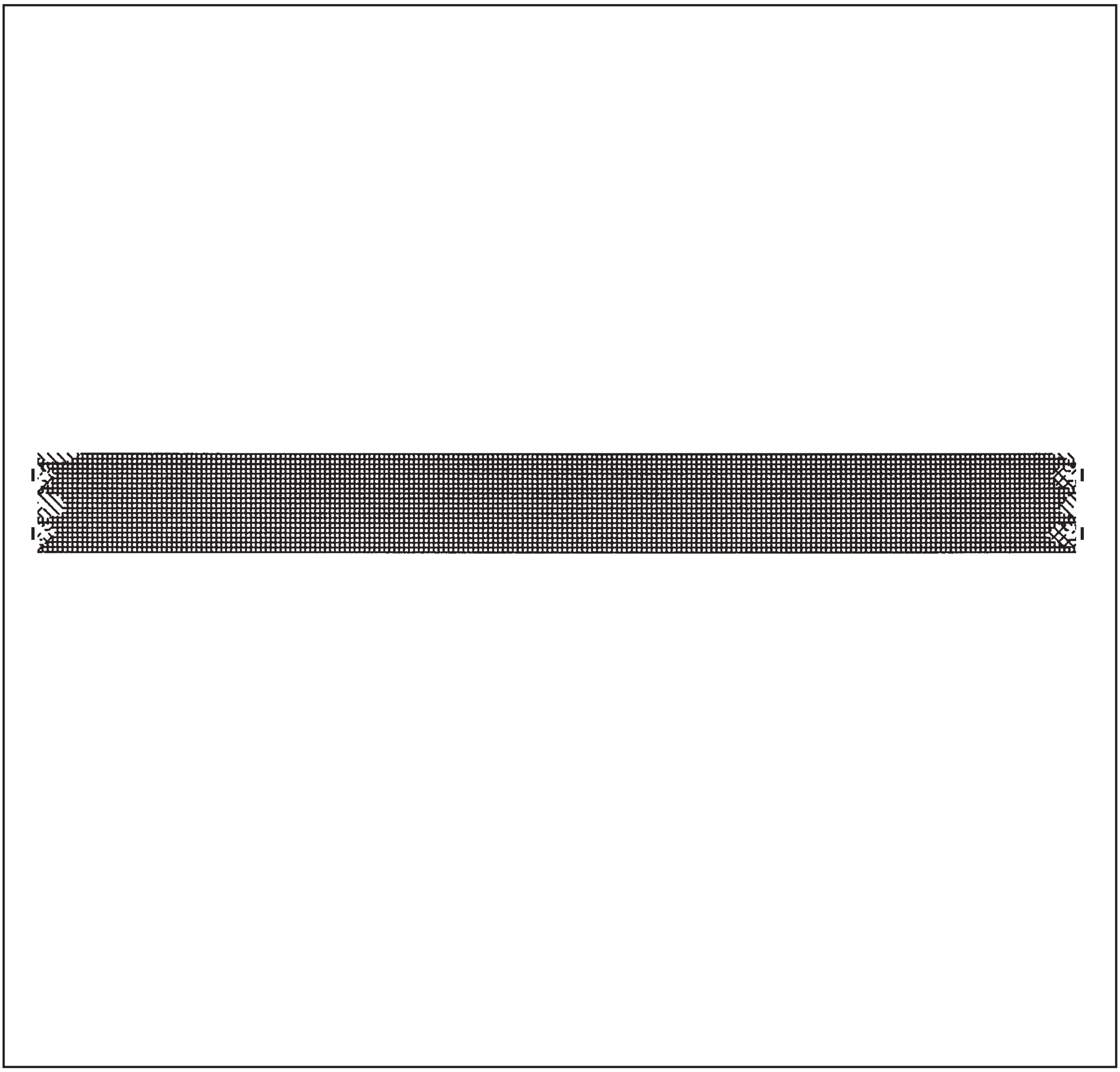


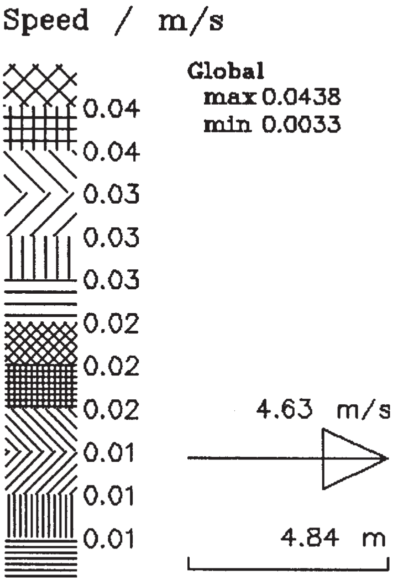


MODEL 1: 5m x 5m Foundation
GEOFIN 40mm - bottom
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A5.6

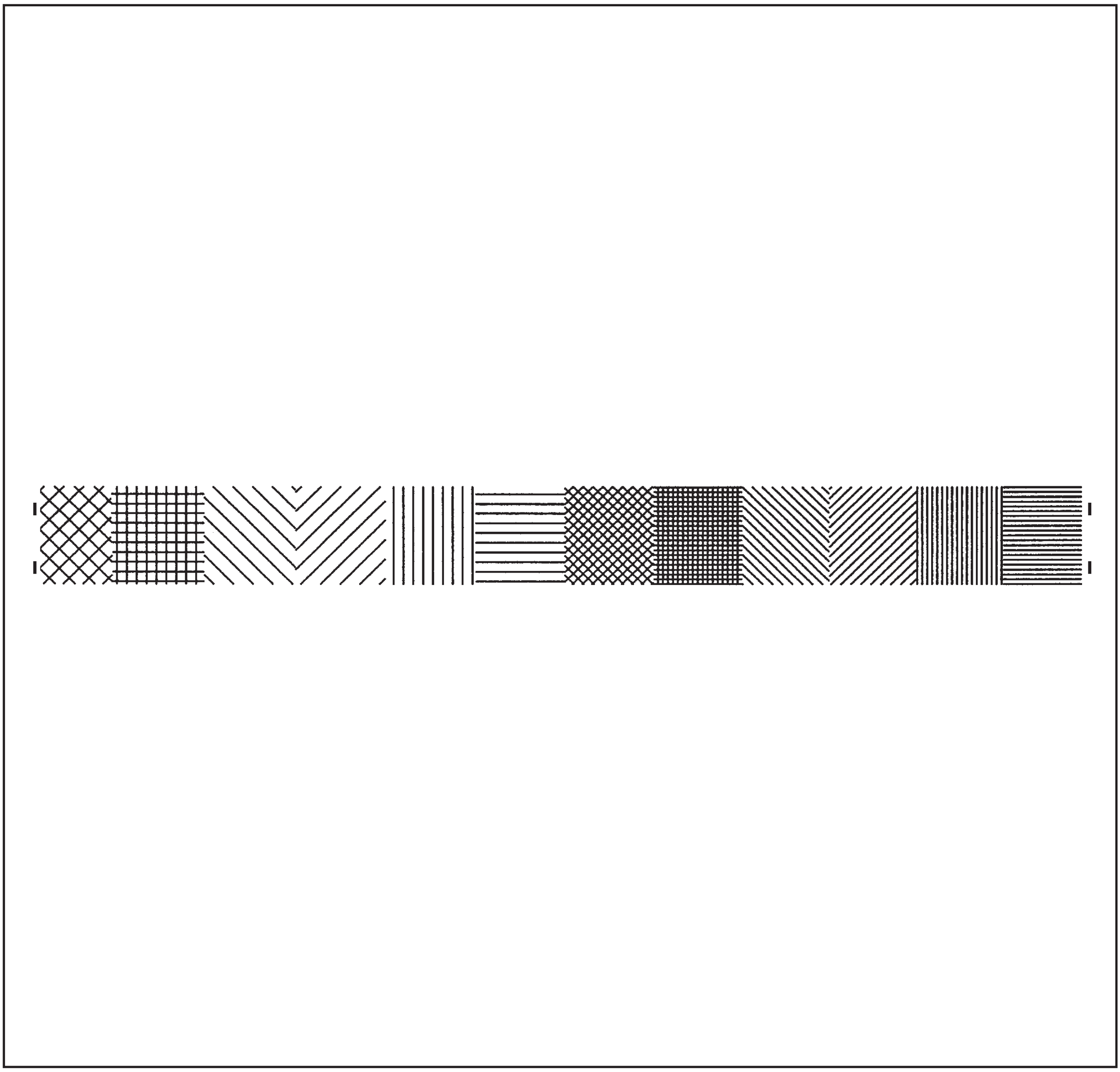


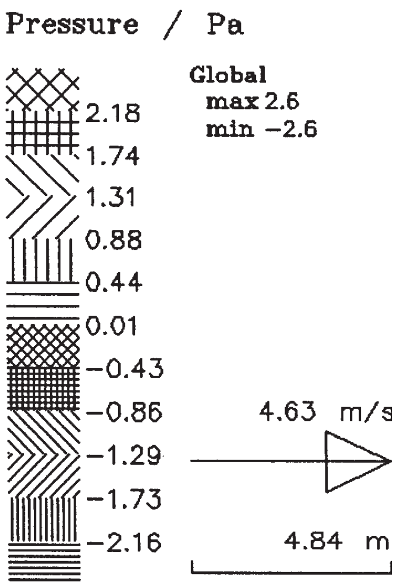


MODEL 2 : 30m wide Foundation
GEOFIN 40mm - top
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A6.1





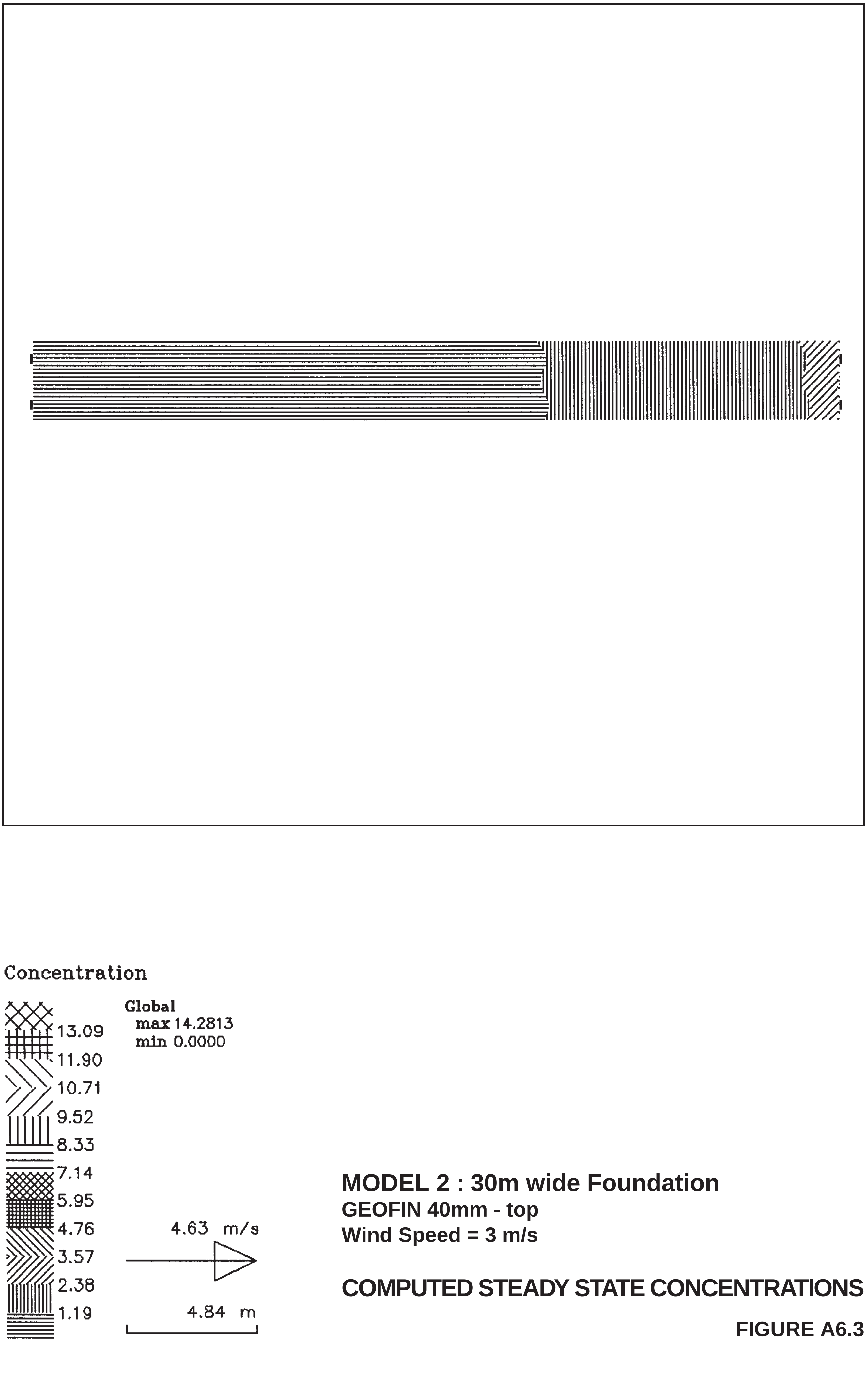
MODEL 2 : 30m wide Foundation

GEOFIN 40mm - top

Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

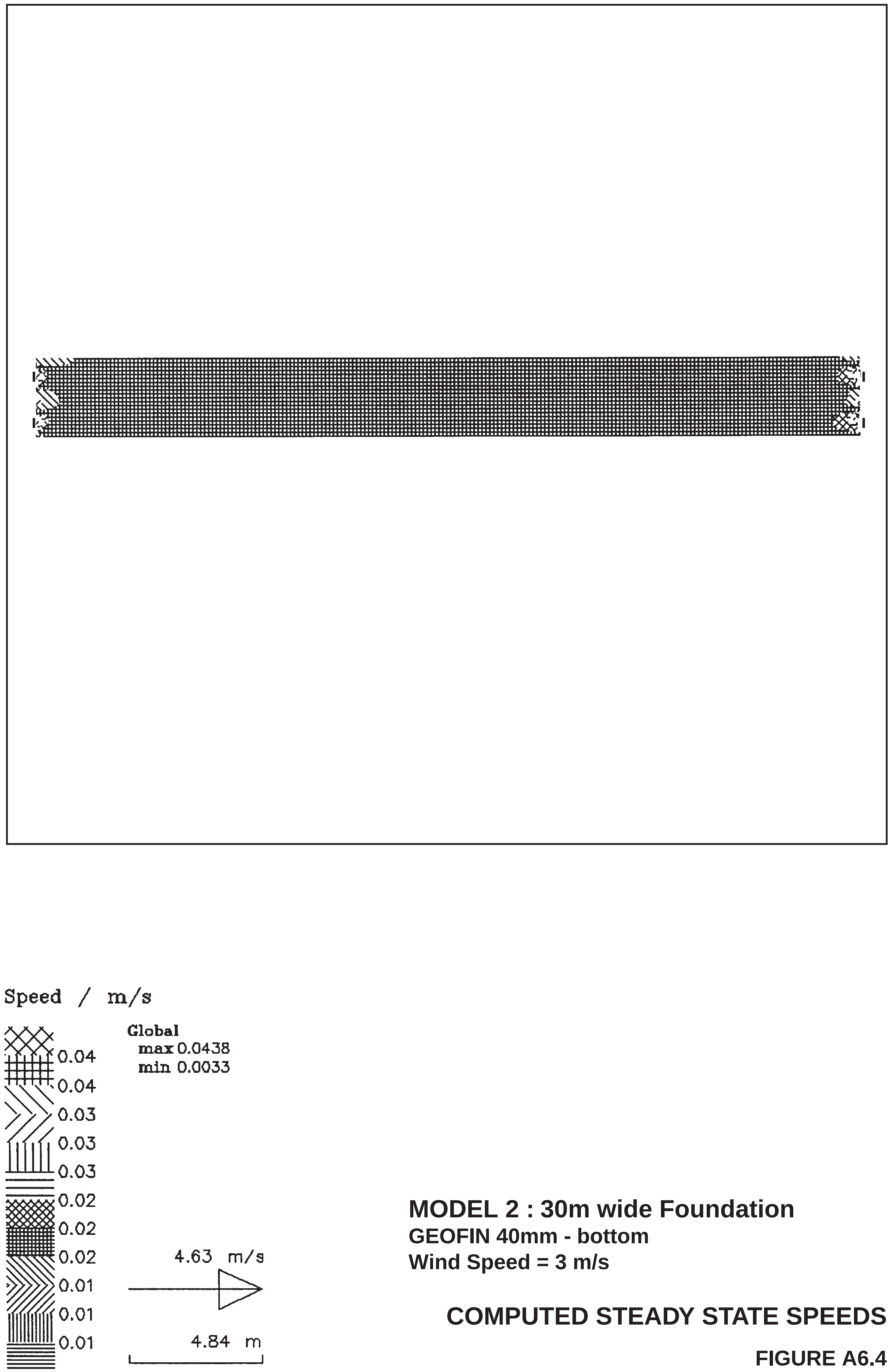
FIGURE A6.2



MODEL 2 : 30m wide Foundation
GEOFIN 40mm - top
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

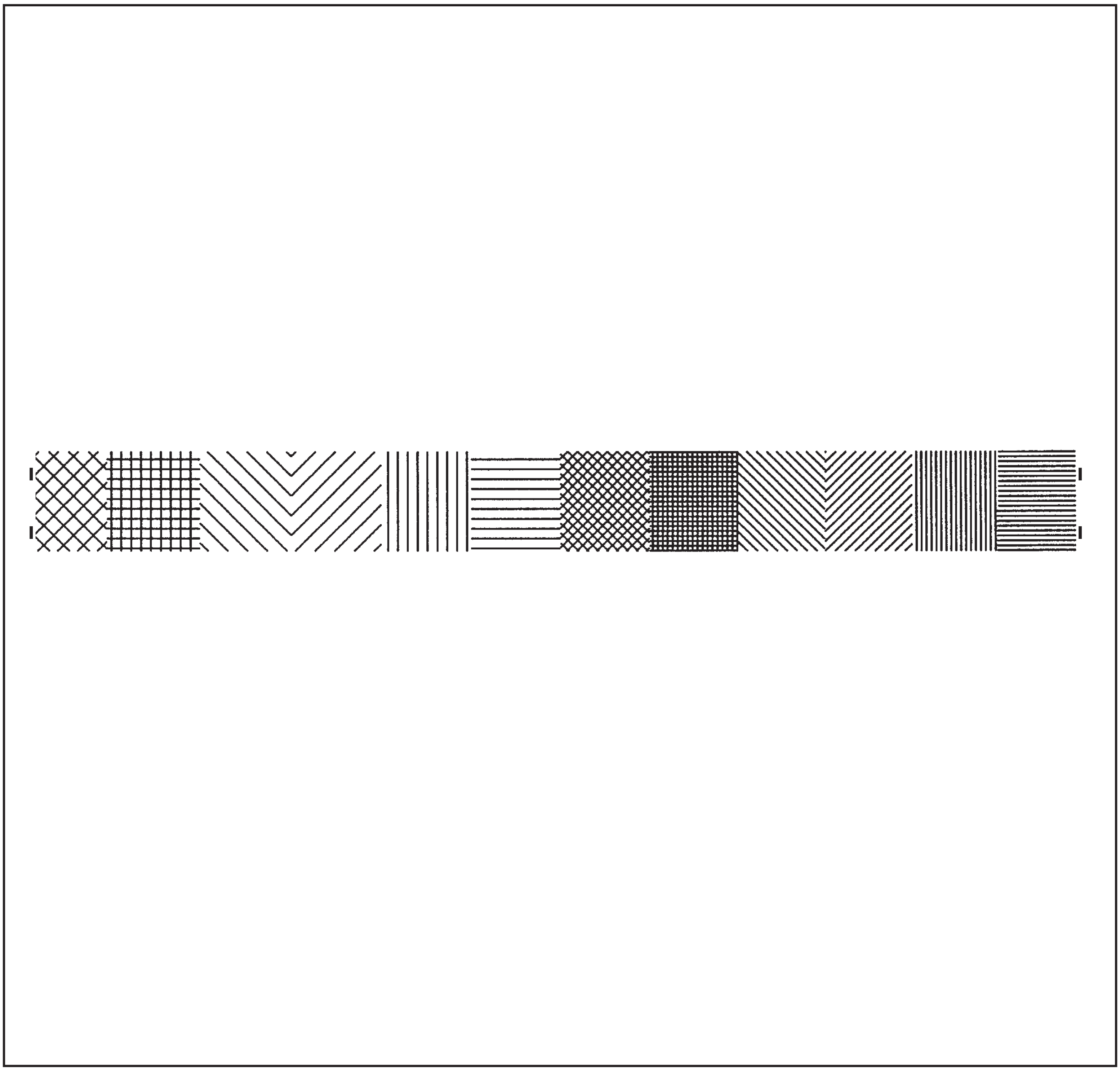
FIGURE A6.3

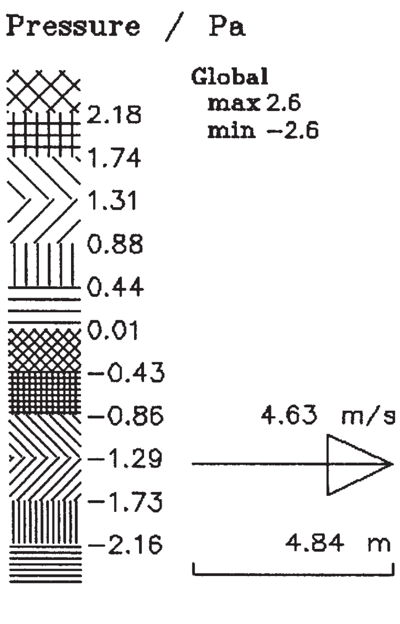


MODEL 2 : 30m wide Foundation
GEOFIN 40mm - bottom
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A6.4

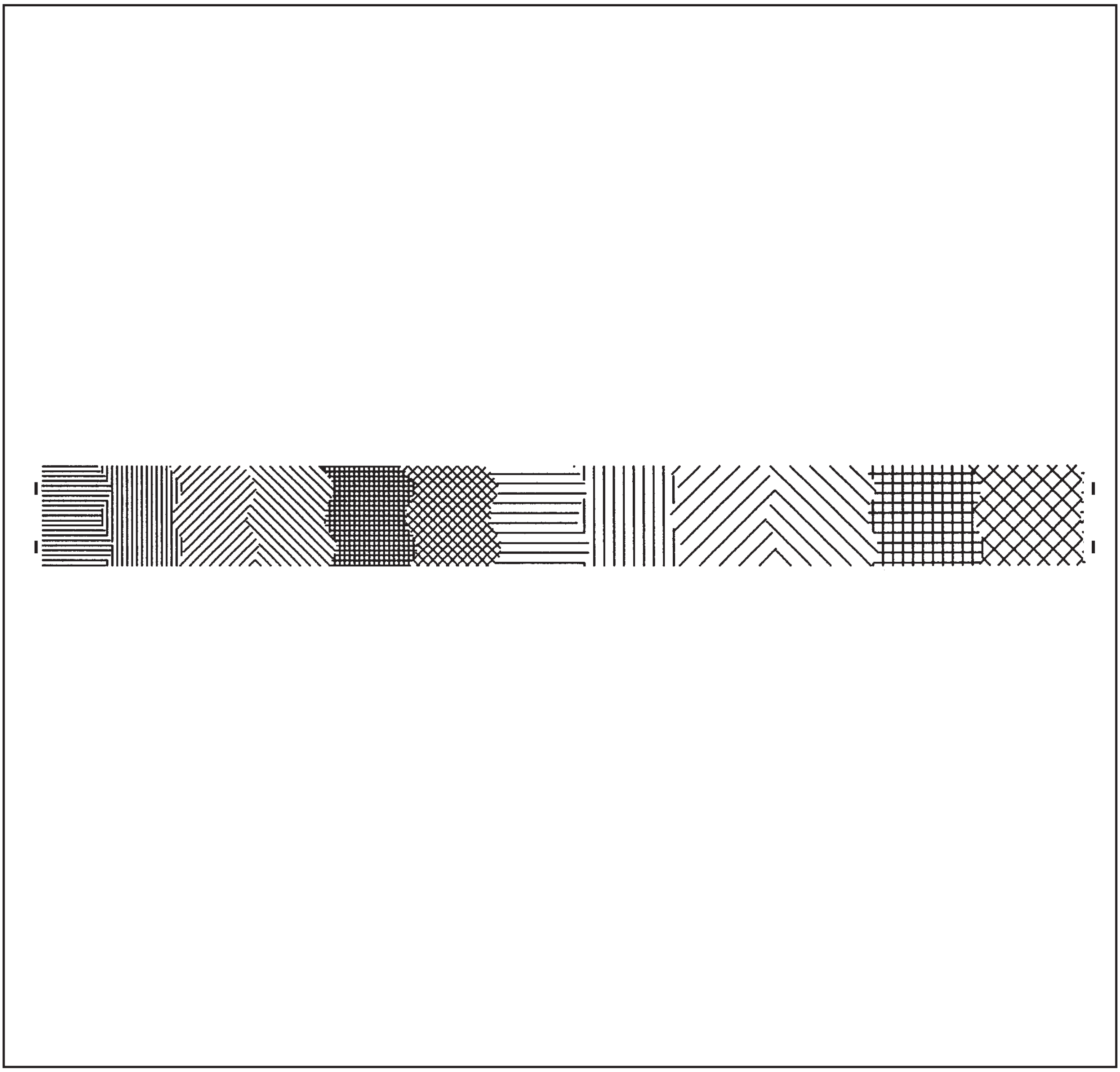


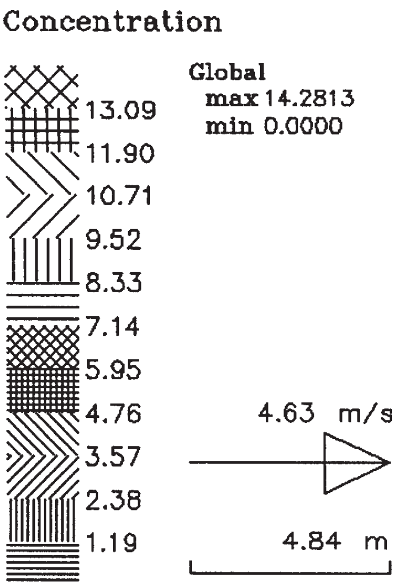


MODEL 2 : 30m wide Foundation
GEOFIN 40mm - bottom
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A6.5

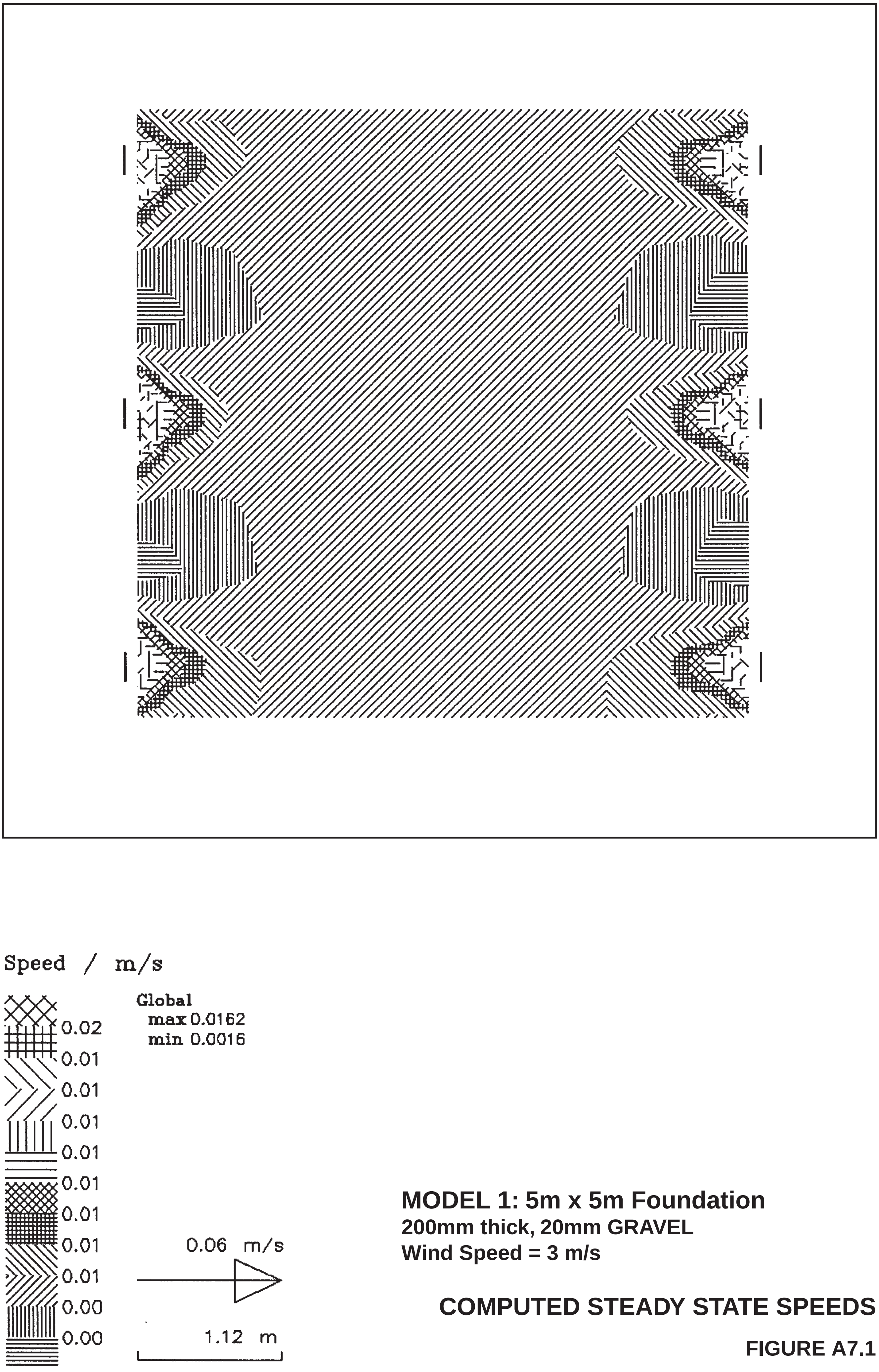




MODEL 2 : 30m wide Foundation
GEOFIN 40mm - bottom
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

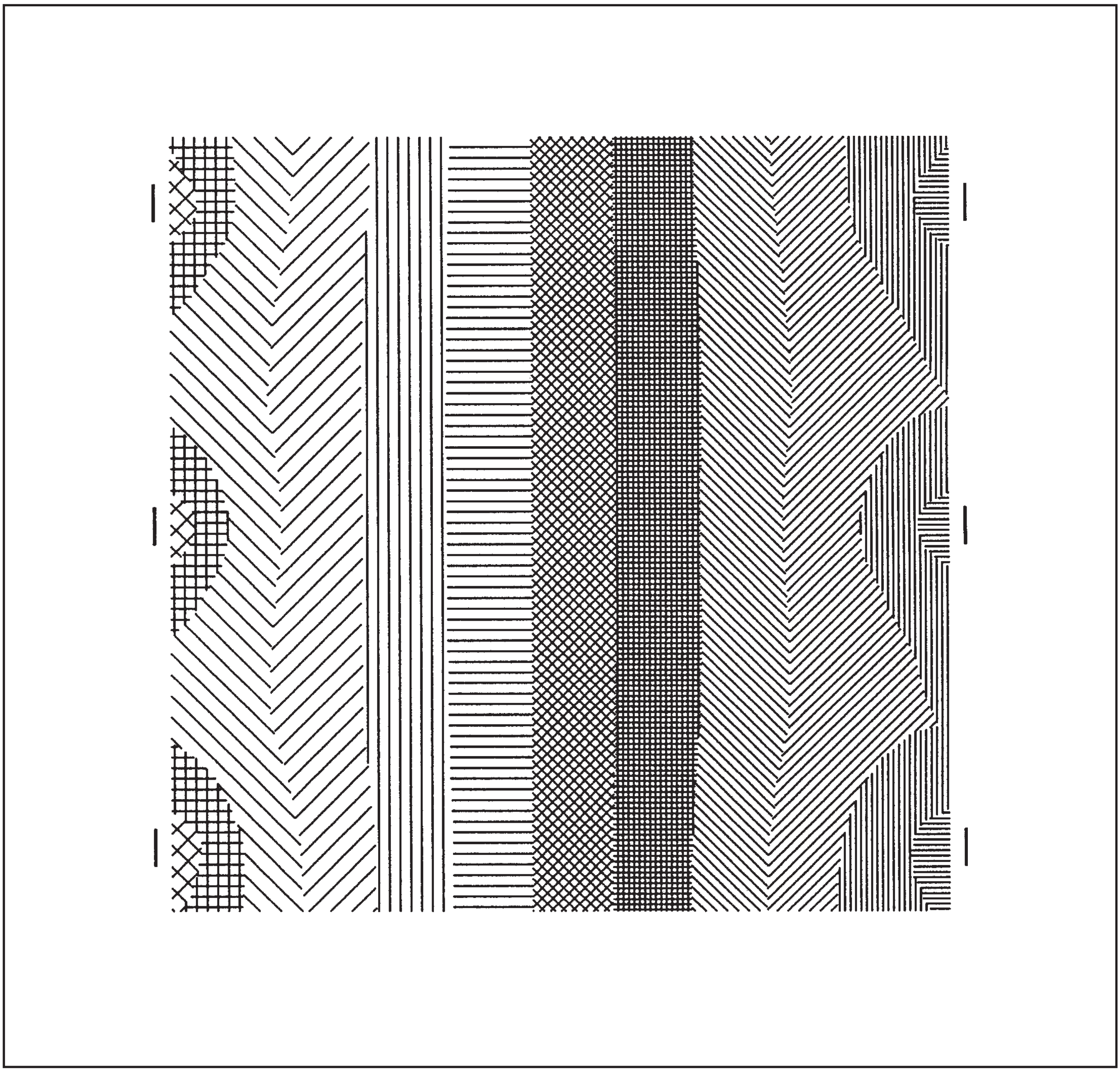
FIGURE A6.6

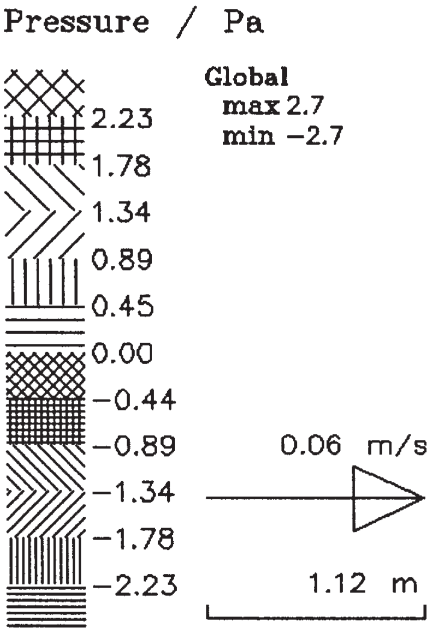


MODEL 1: 5m x 5m Foundation
200mm thick, 20mm GRAVEL
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A7.1

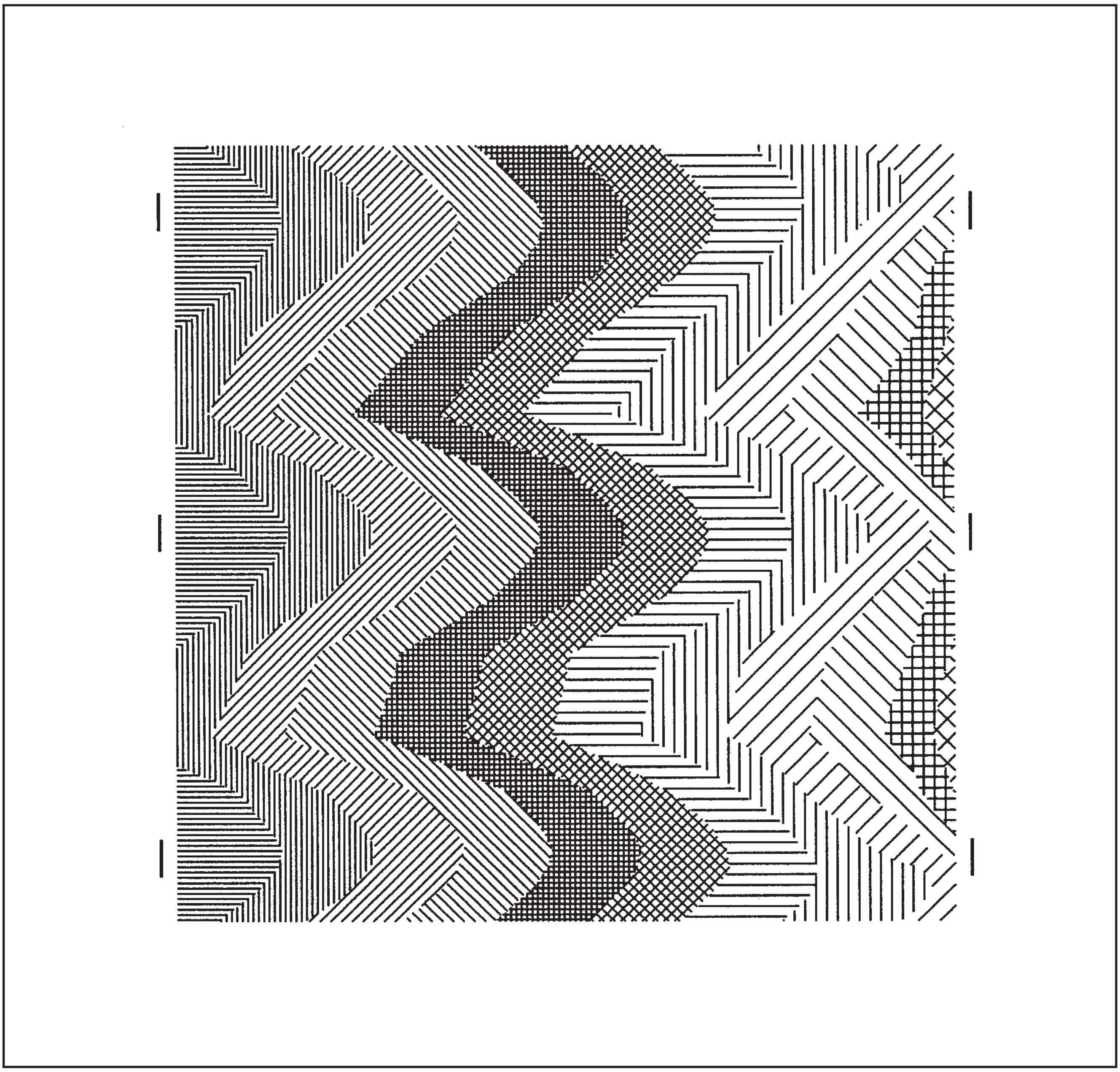


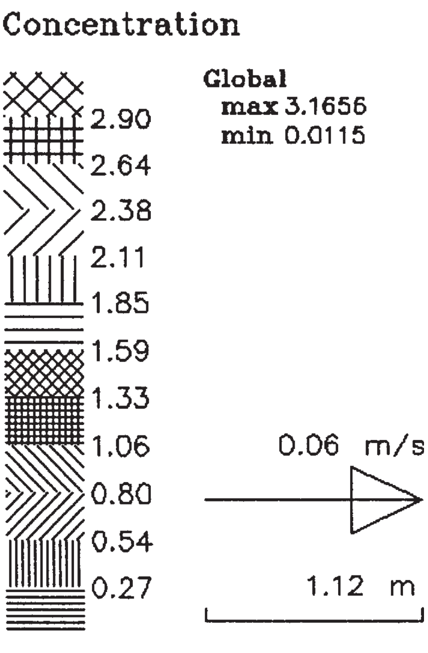


MODEL 1: 5m x 5m Foundation
200mm thick, 20mm GRAVEL
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A7.2





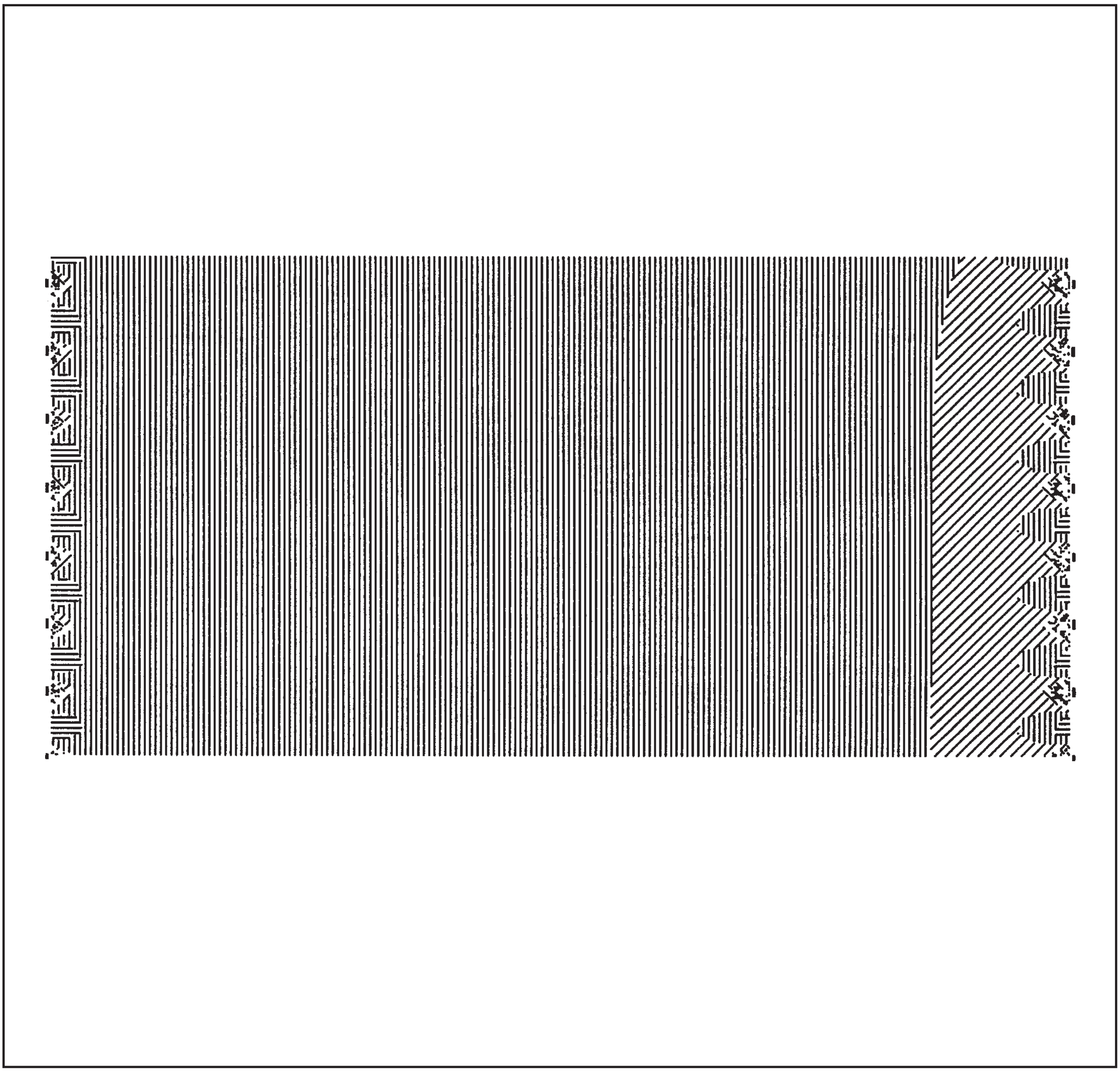
MODEL 1: 5m x 5m Foundation

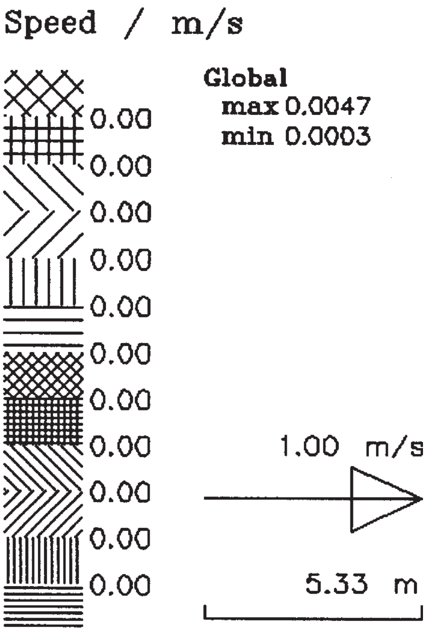
200mm thick, 20mm GRAVEL

Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A7.3

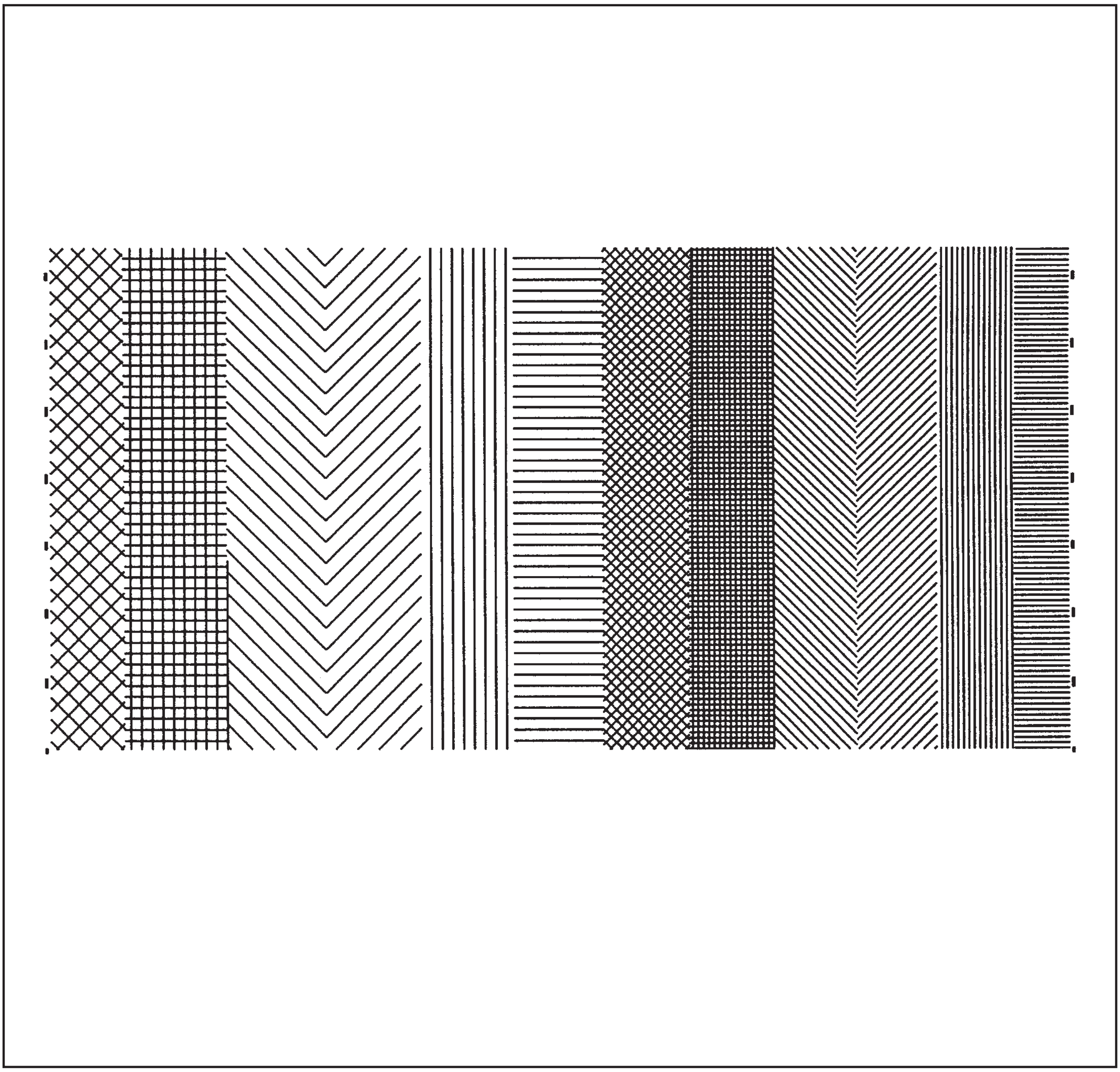


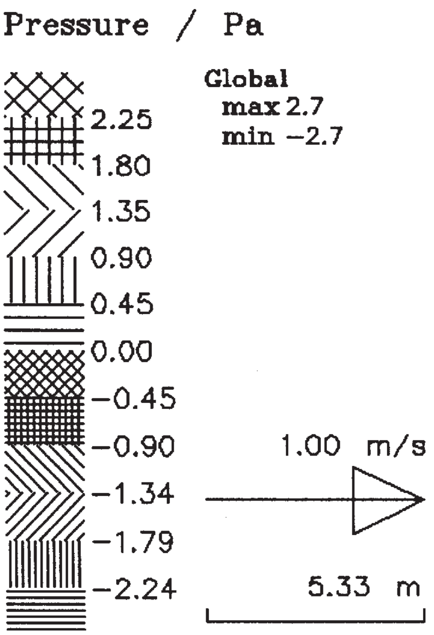


MODEL 2: 30m wide Foundation
400mm deep, 20mm GRAVEL
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A8.1

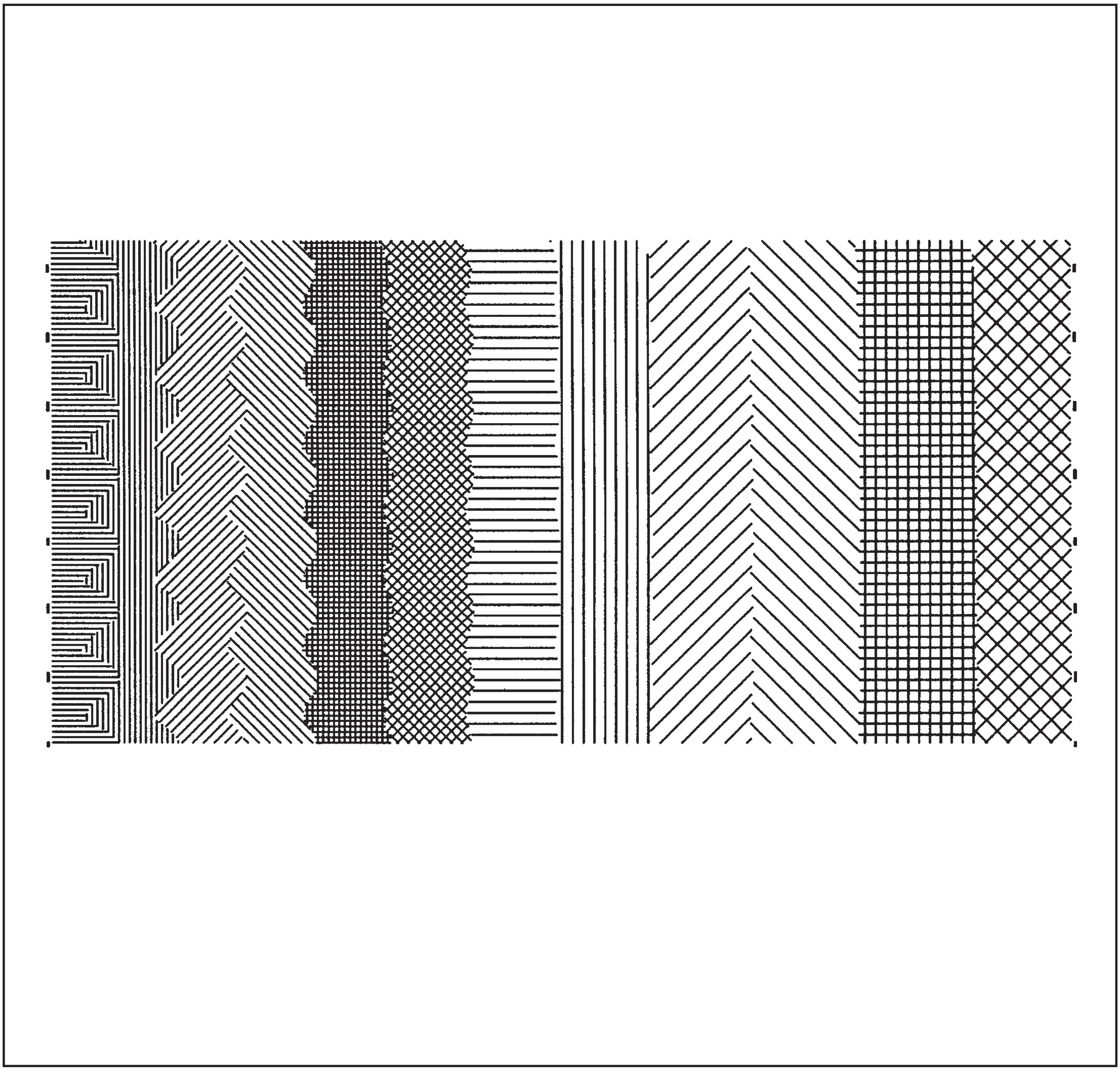


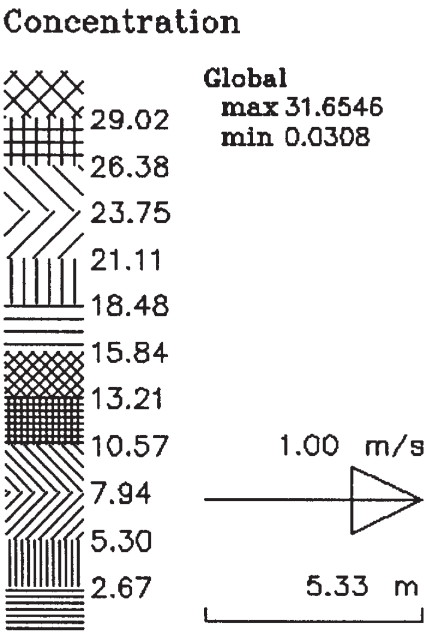


MODEL 2: 30m wide Foundation
400mm deep, 20mm GRAVEL
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A8.2

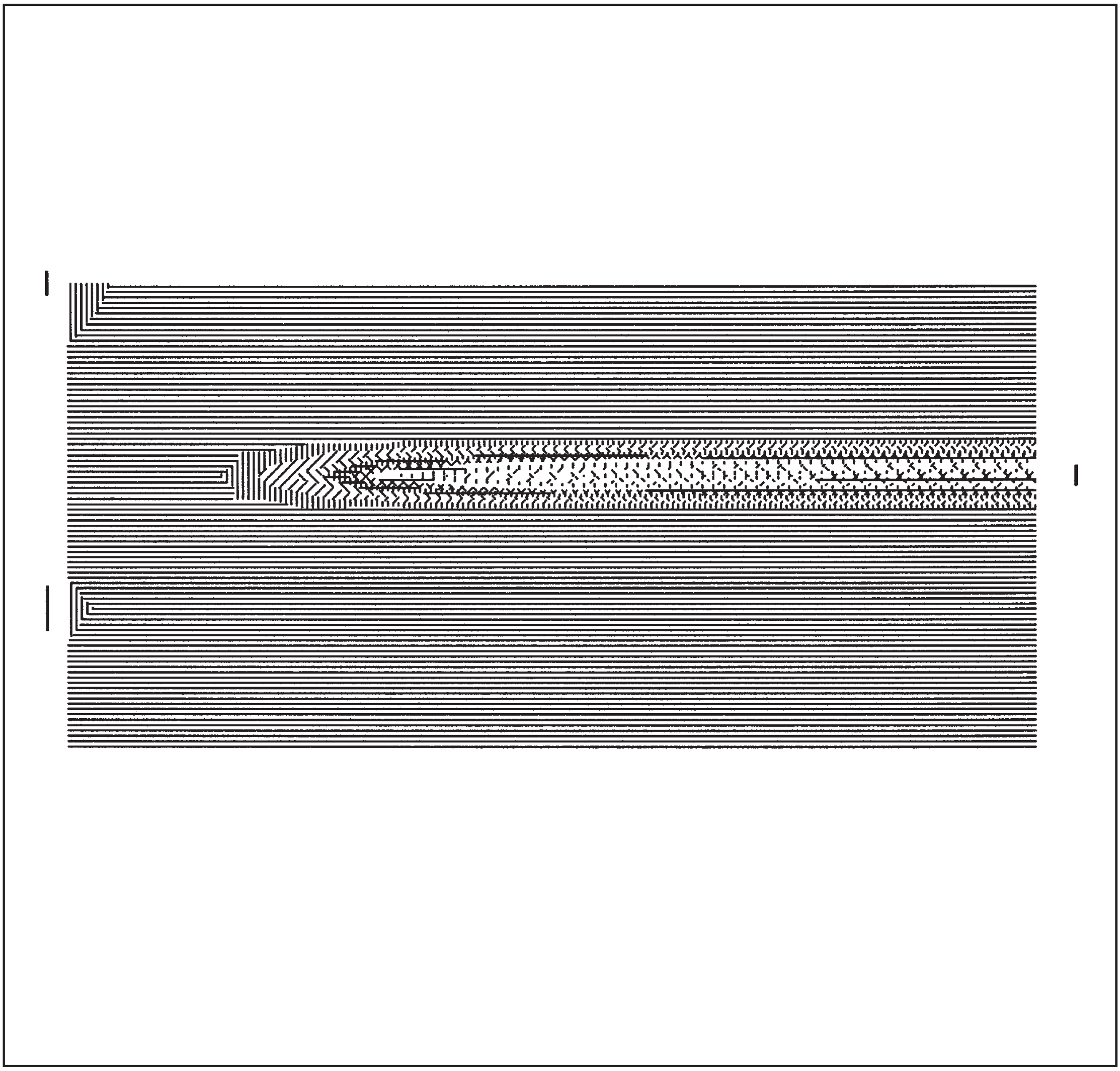


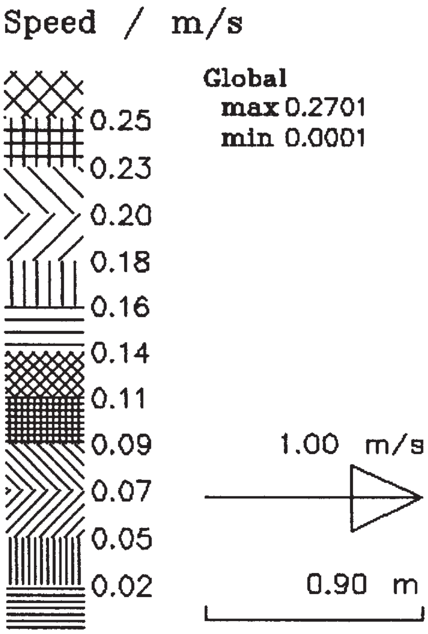


MODEL 2: 30m wide Foundation
400mm deep, 20mm GRAVEL
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A8.3





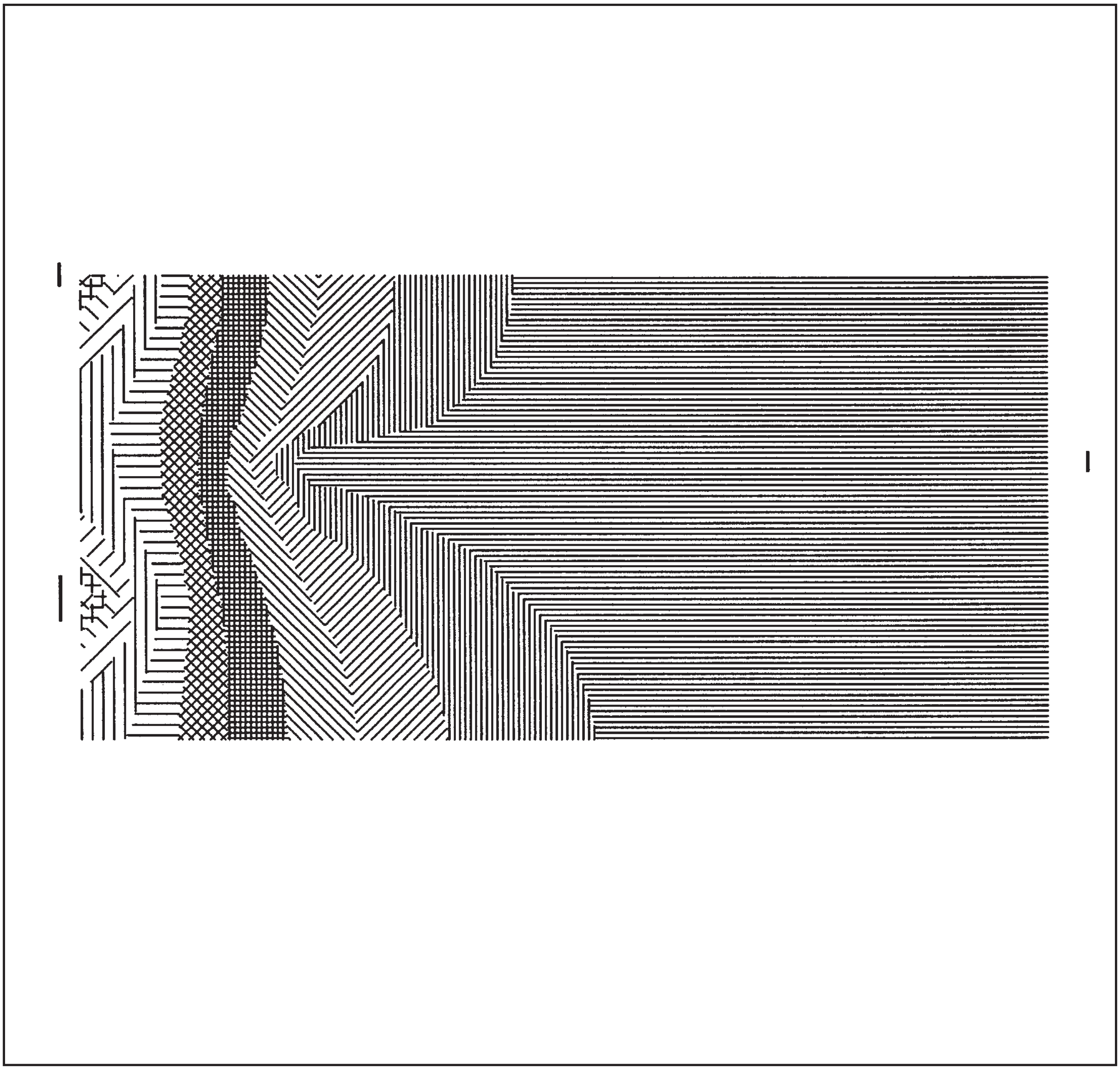
MODEL 3: 5m x 5m Foundation

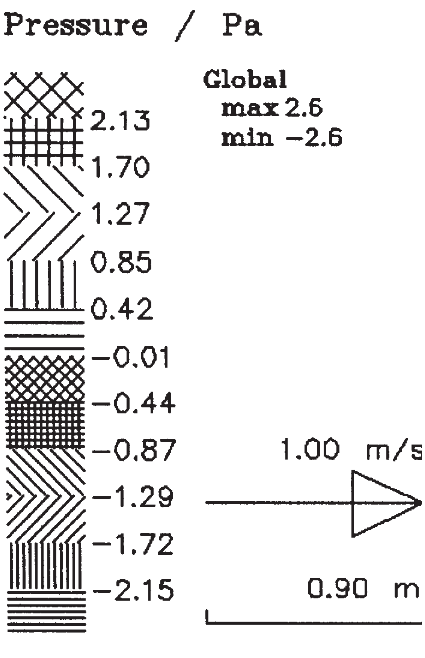
200mm thick, 20mm GRAVEL with pipes at 2m c/c

Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A9.1.1

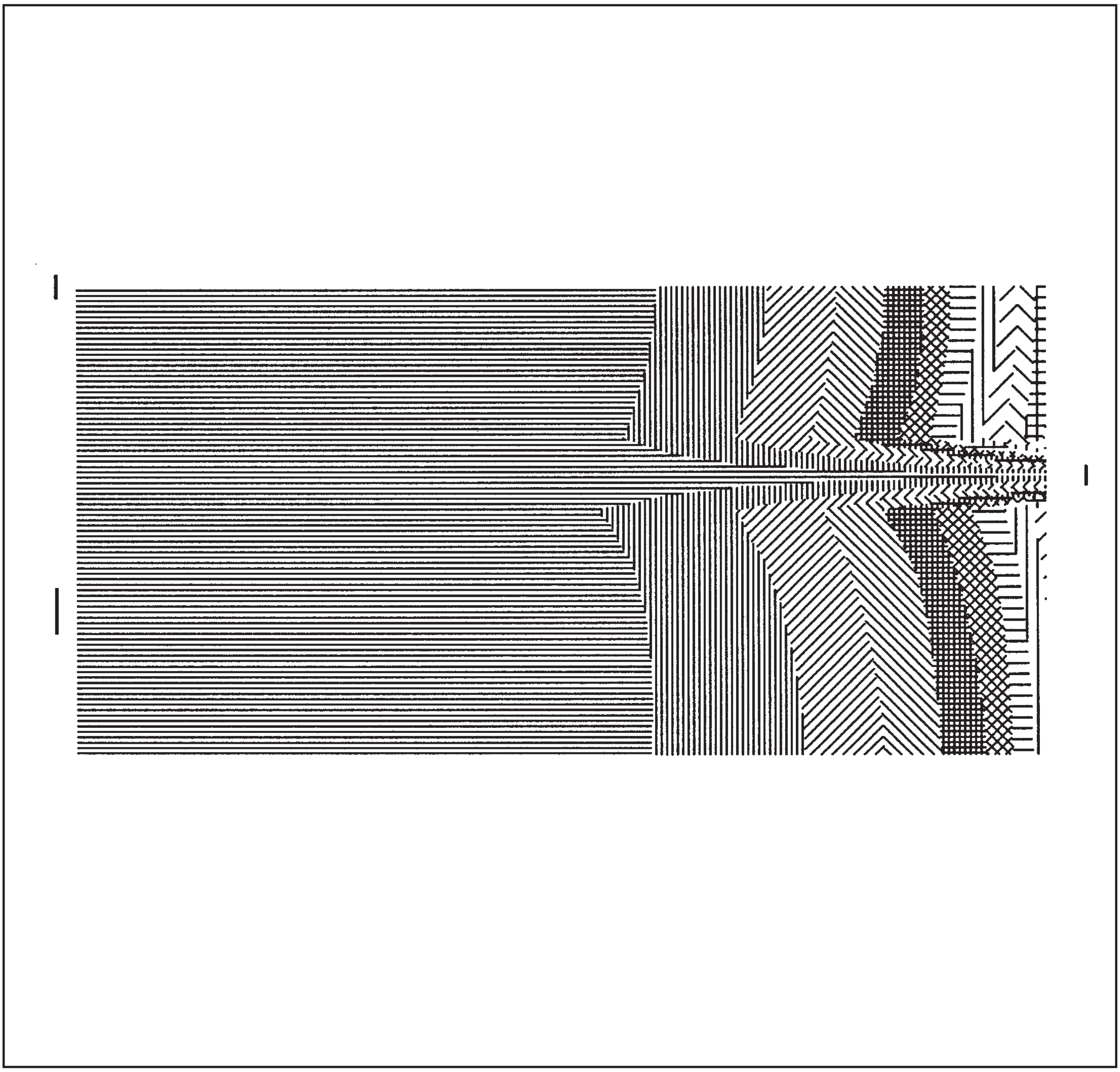


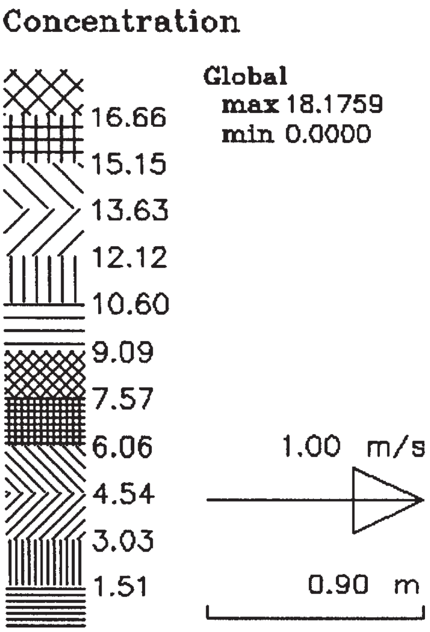


MODEL 3: 5m x 5m Foundation
200mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A9.1.2

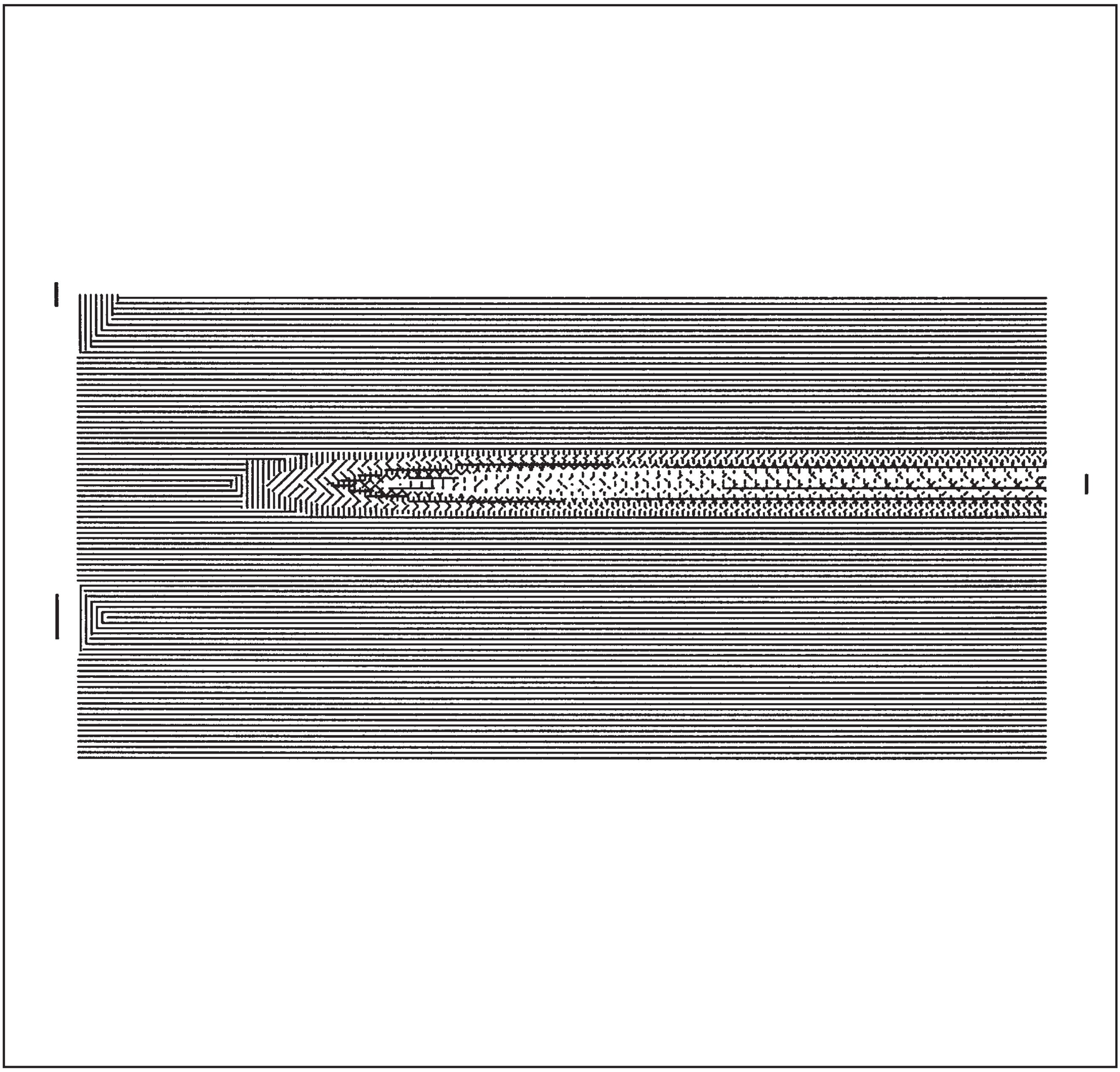


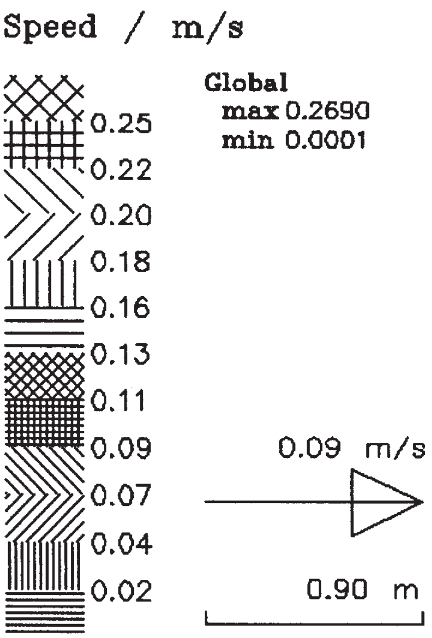


MODEL 3: 5m x 5m Foundation
200mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A9.1.3





MODEL 3: 5m x 5m Foundation

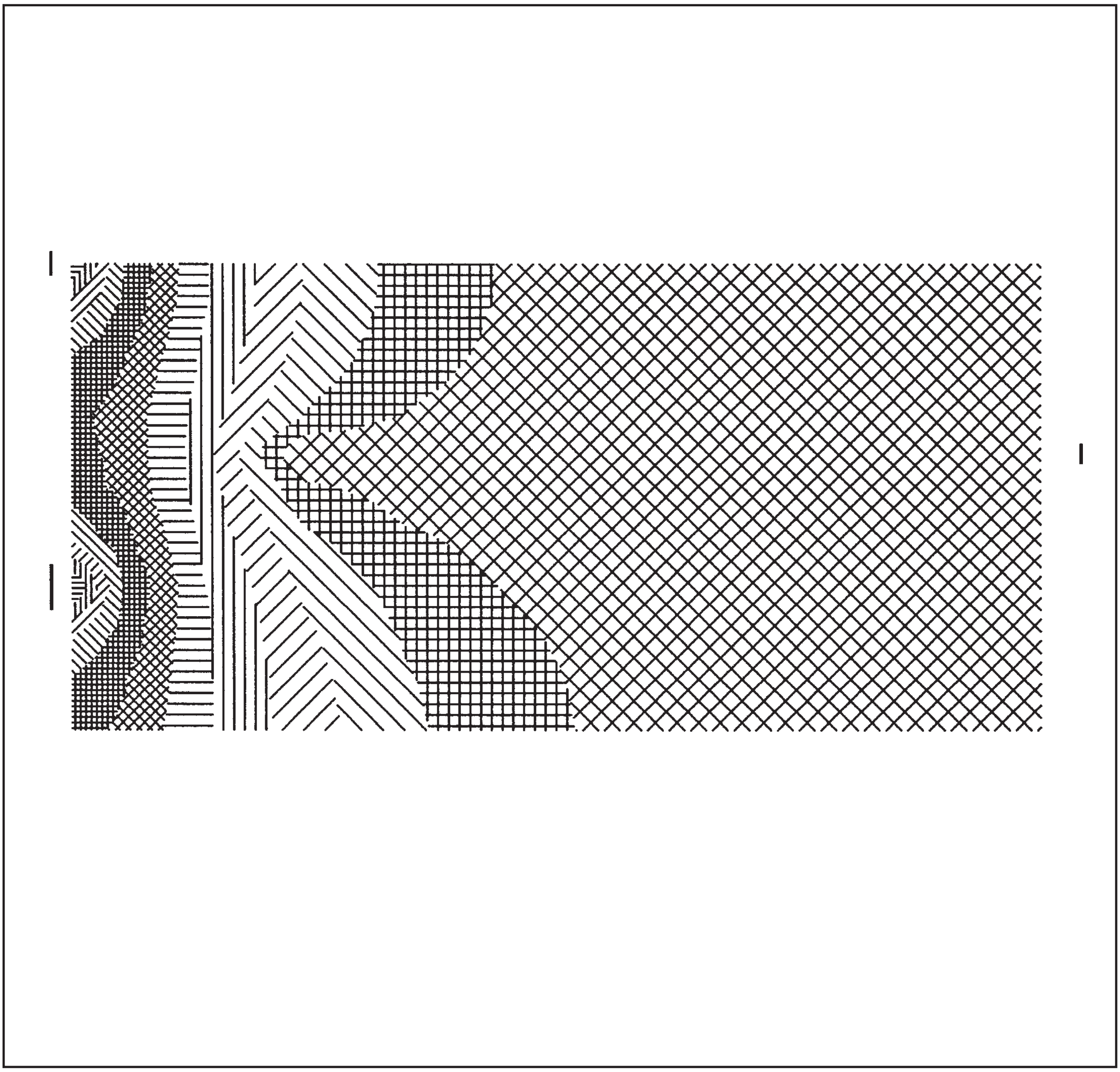
200mm thick, 20mm GRAVEL with pipes at 2m c/c

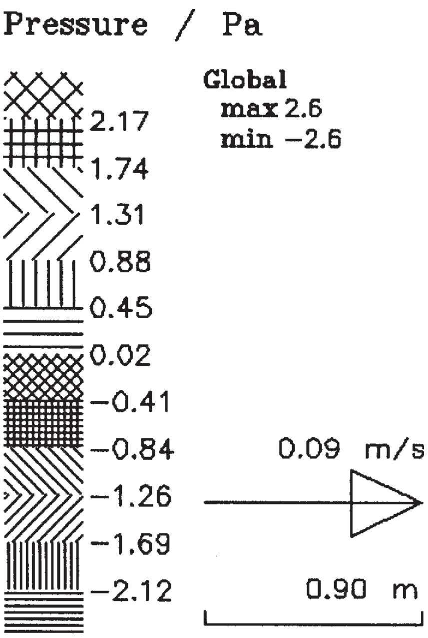
Wind Speed = 3 m/s

Reverse Flow

COMPUTED STEADY STATE SPEEDS

FIGURE A9.2.1

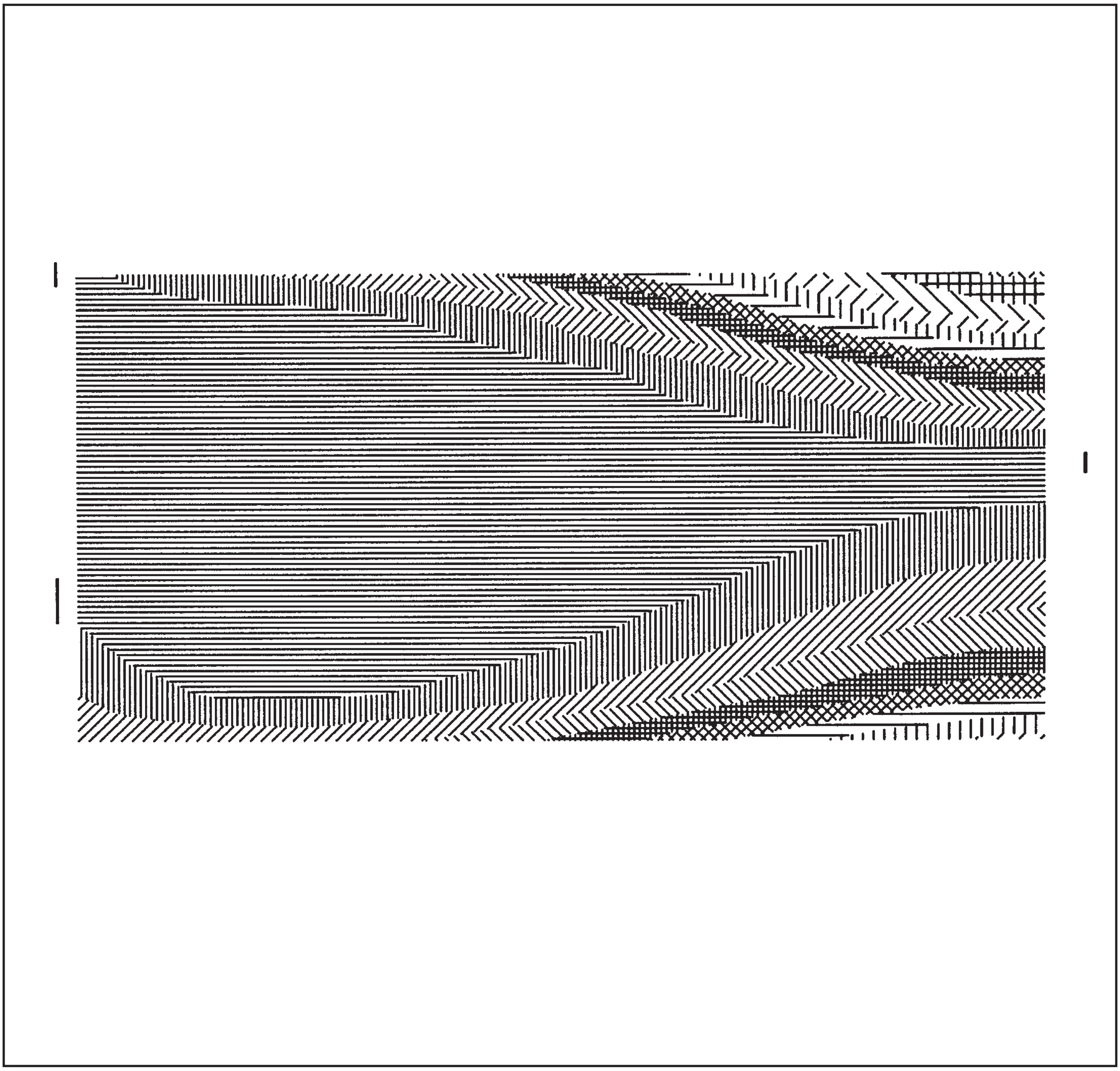


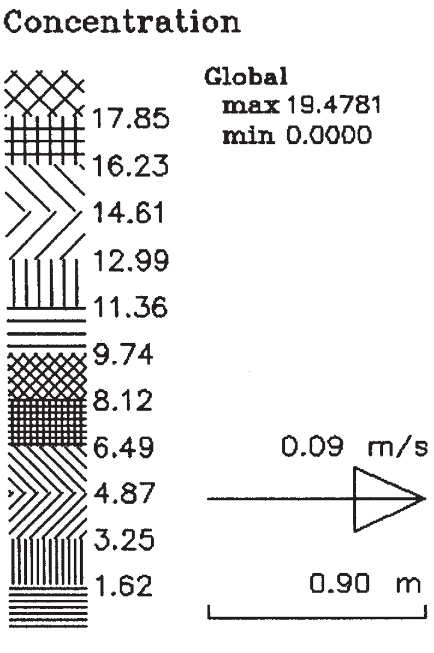


MODEL 3: 5m x 5m Foundation
200mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s
Reverse Flow

COMPUTED STEADY STATE PRESSURES

FIGURE A9.2.2





MODEL 3: 5m x 5m Foundation

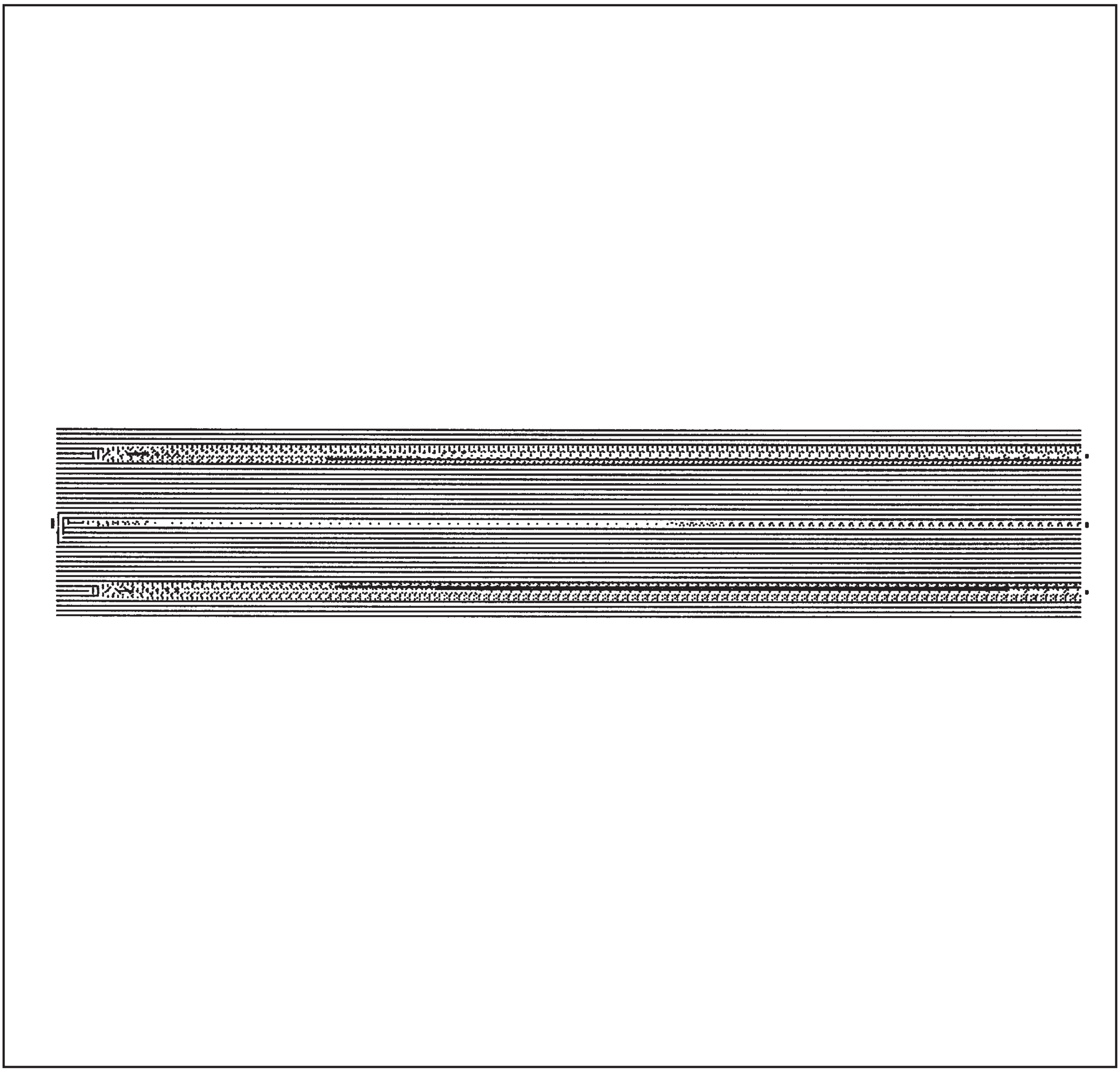
200mm thick, 20mm GRAVEL with pipes at 2m c/c

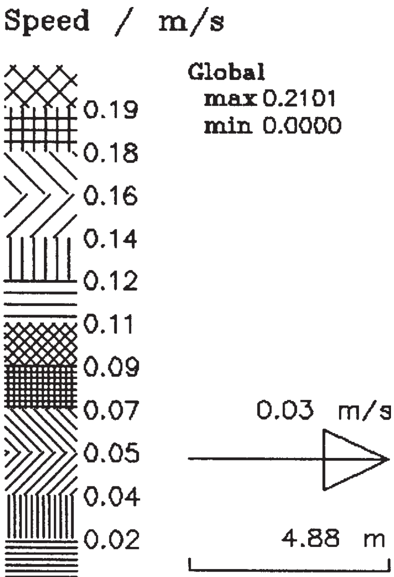
Wind Speed = 3 m/s

Reverse Flow

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A9.2.3



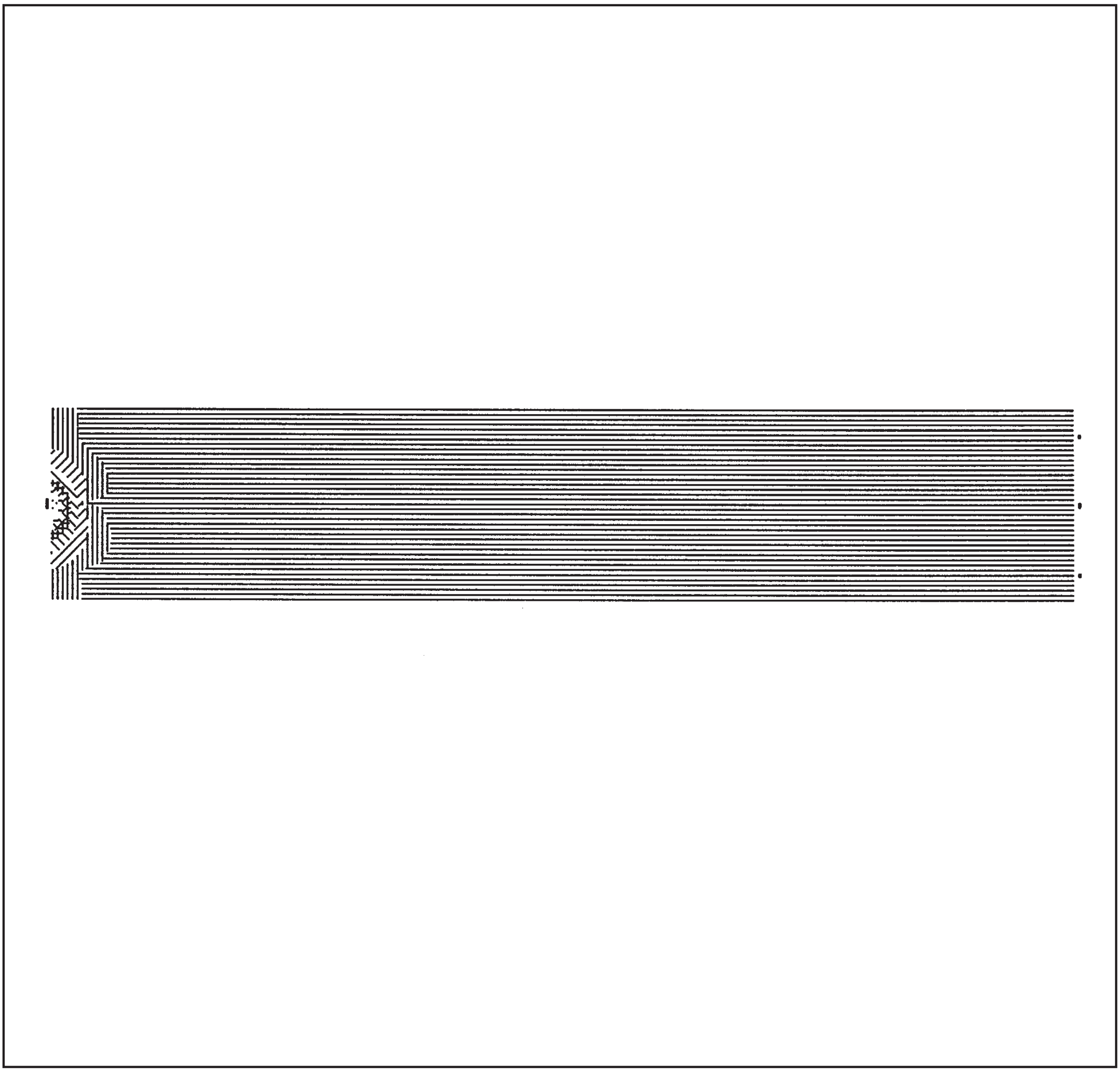


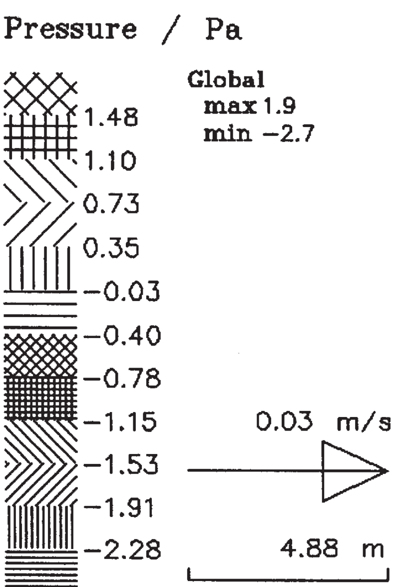
MODEL 4: 30m wide Foundation

400mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A10.1.1

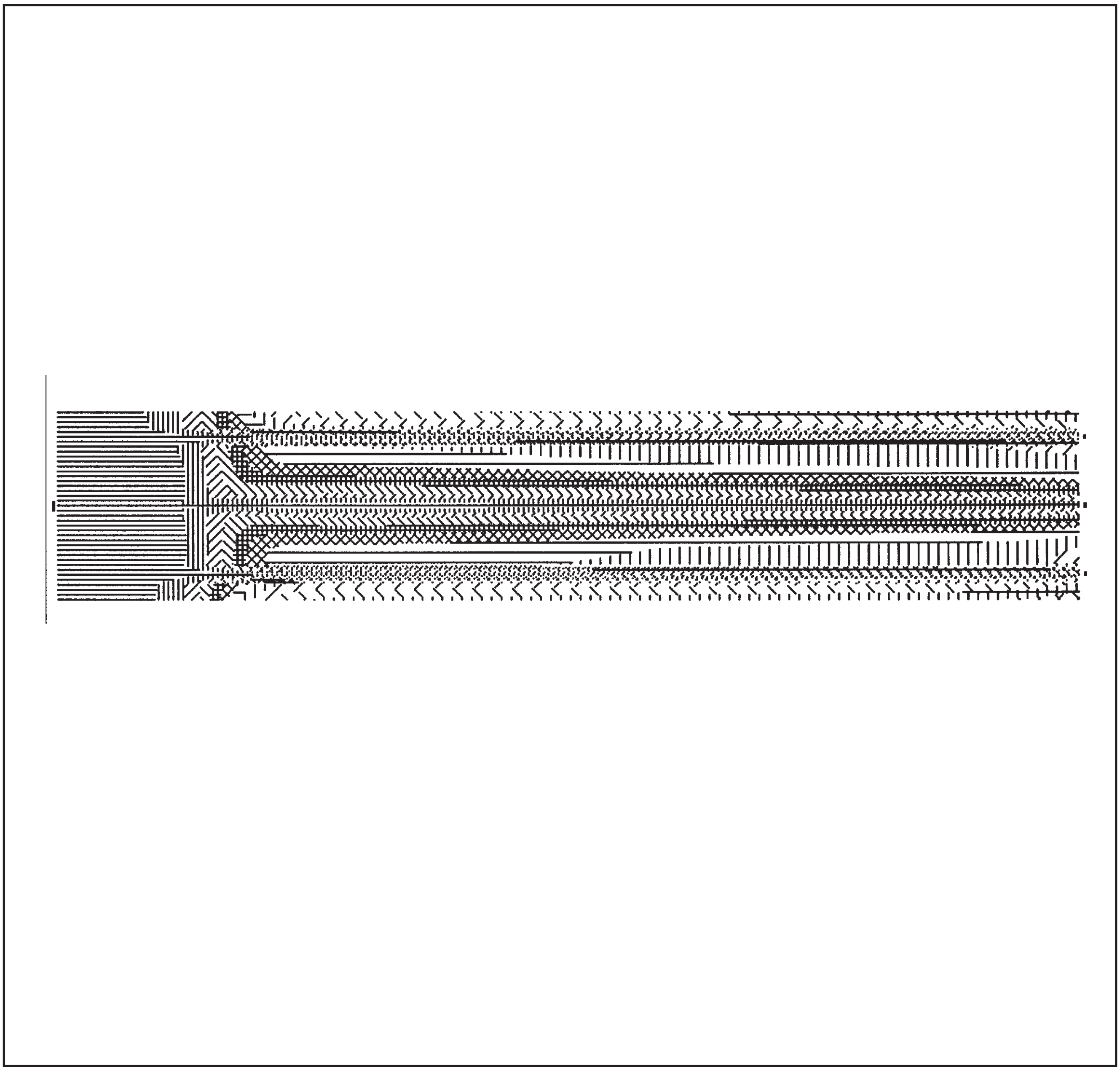


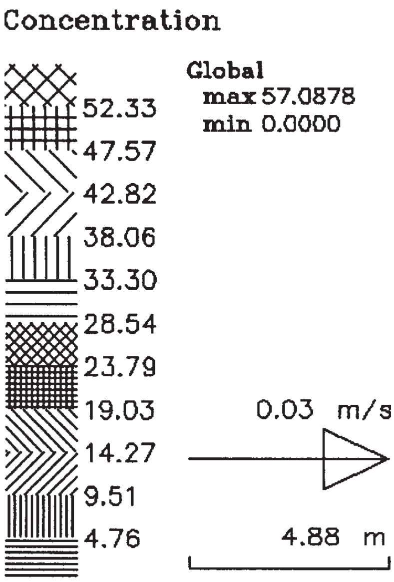


MODEL 4: 30m wide Foundation
400mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A10.1.2

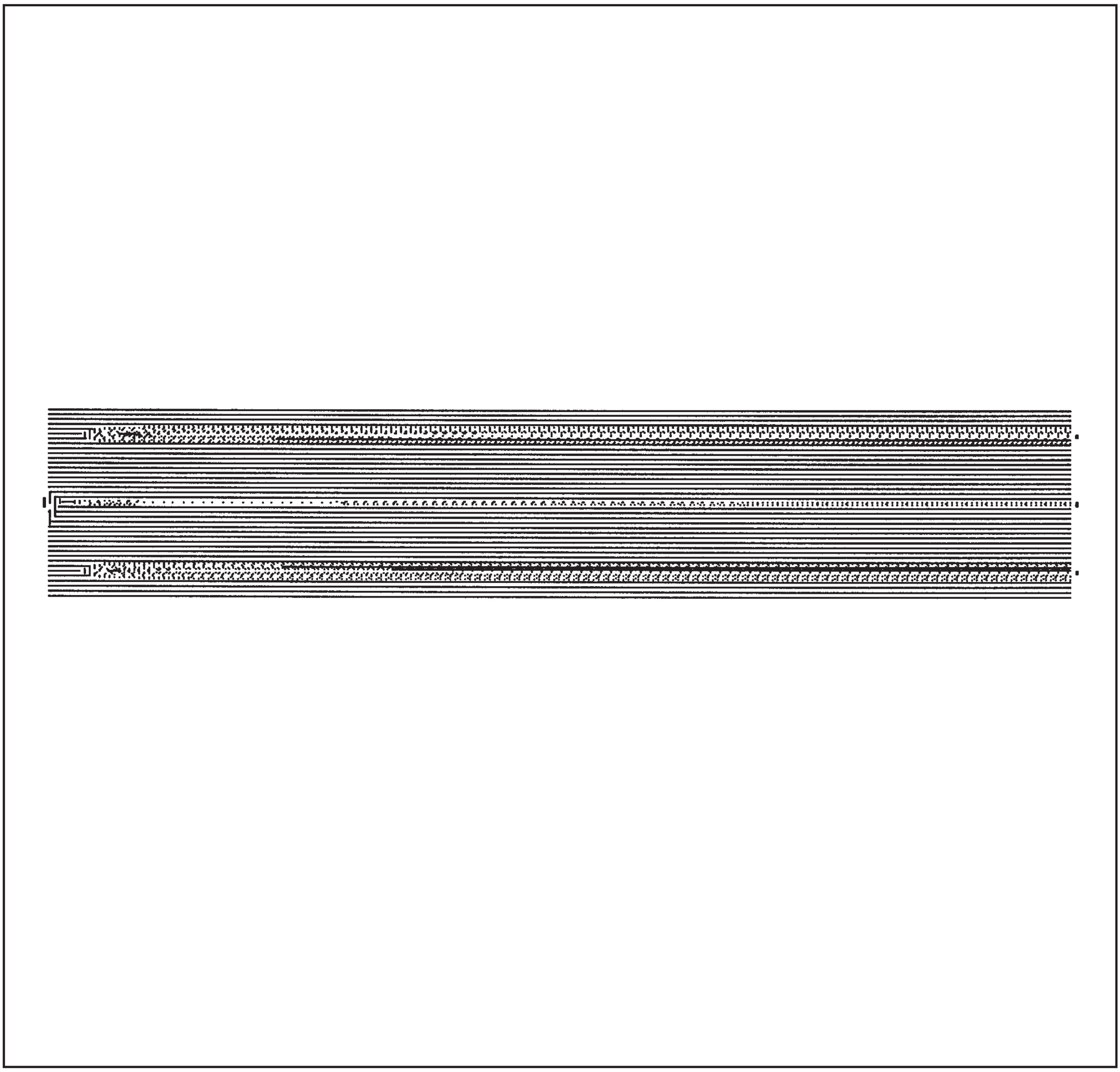


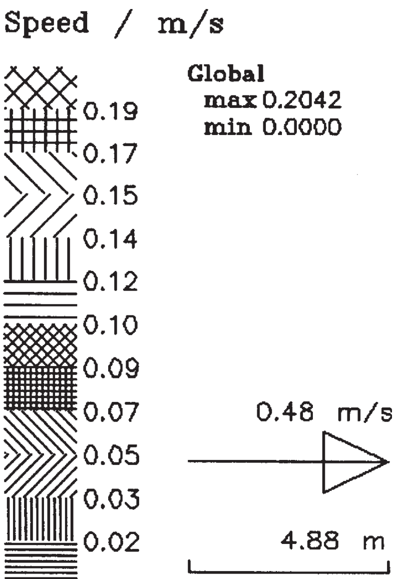


MODEL 4: 30m wide Foundation
400mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A10.1.3

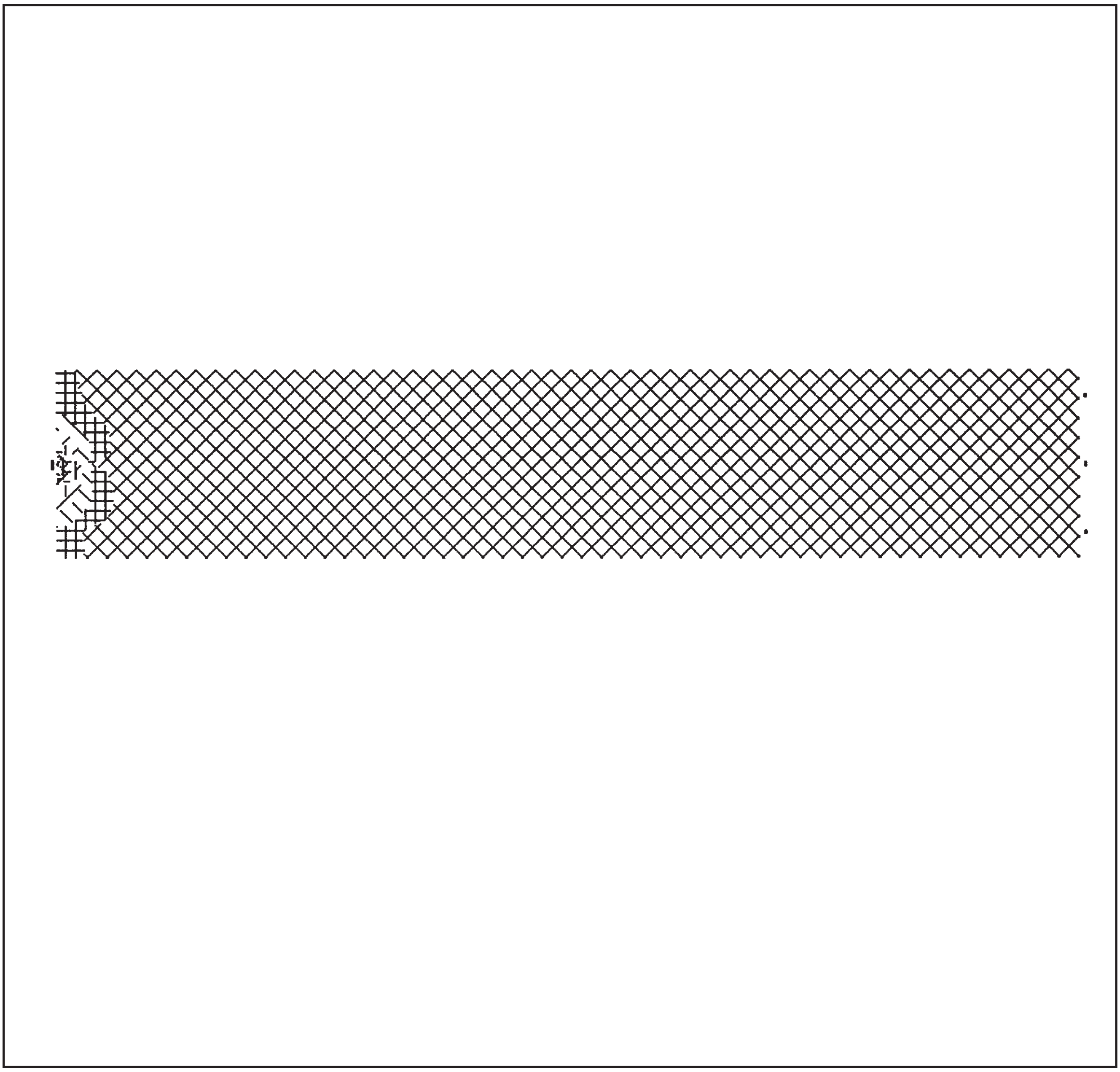


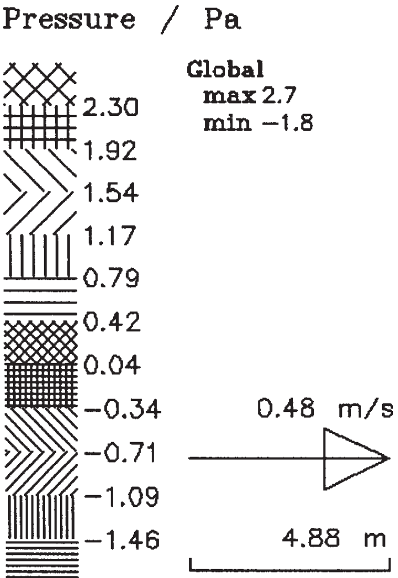


MODEL 4: 30m wide Foundation
400mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s
Reverse Flow

COMPUTED STEADY STATE SPEEDS

FIGURE A10.2.1



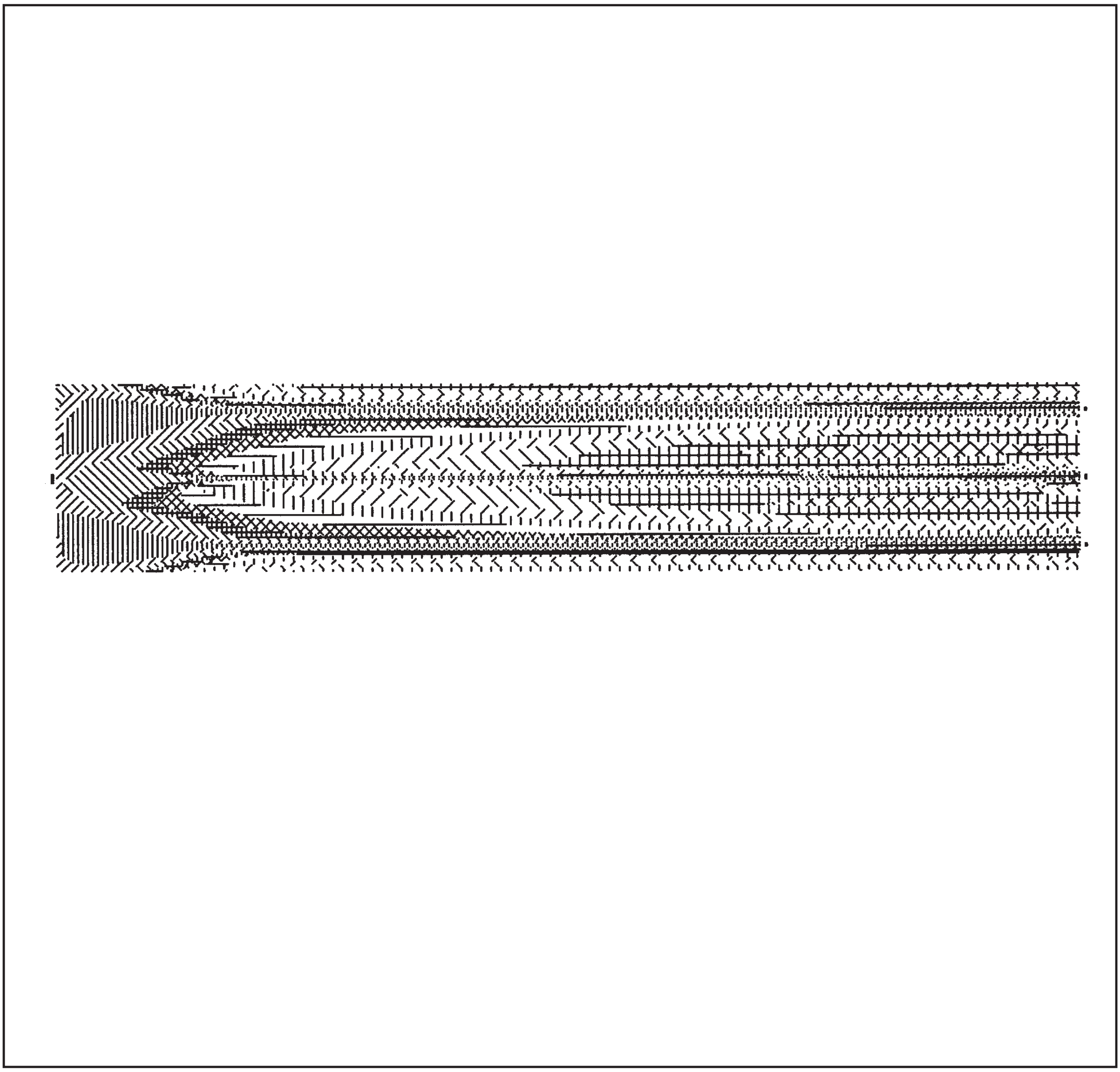


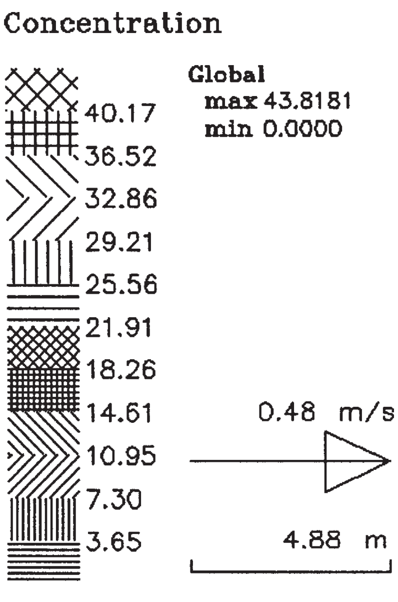
MODEL 4: 30m wide Foundation

400mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s
Reverse Flow

COMPUTED STEADY STATE PRESSURES

FIGURE A10.2.2

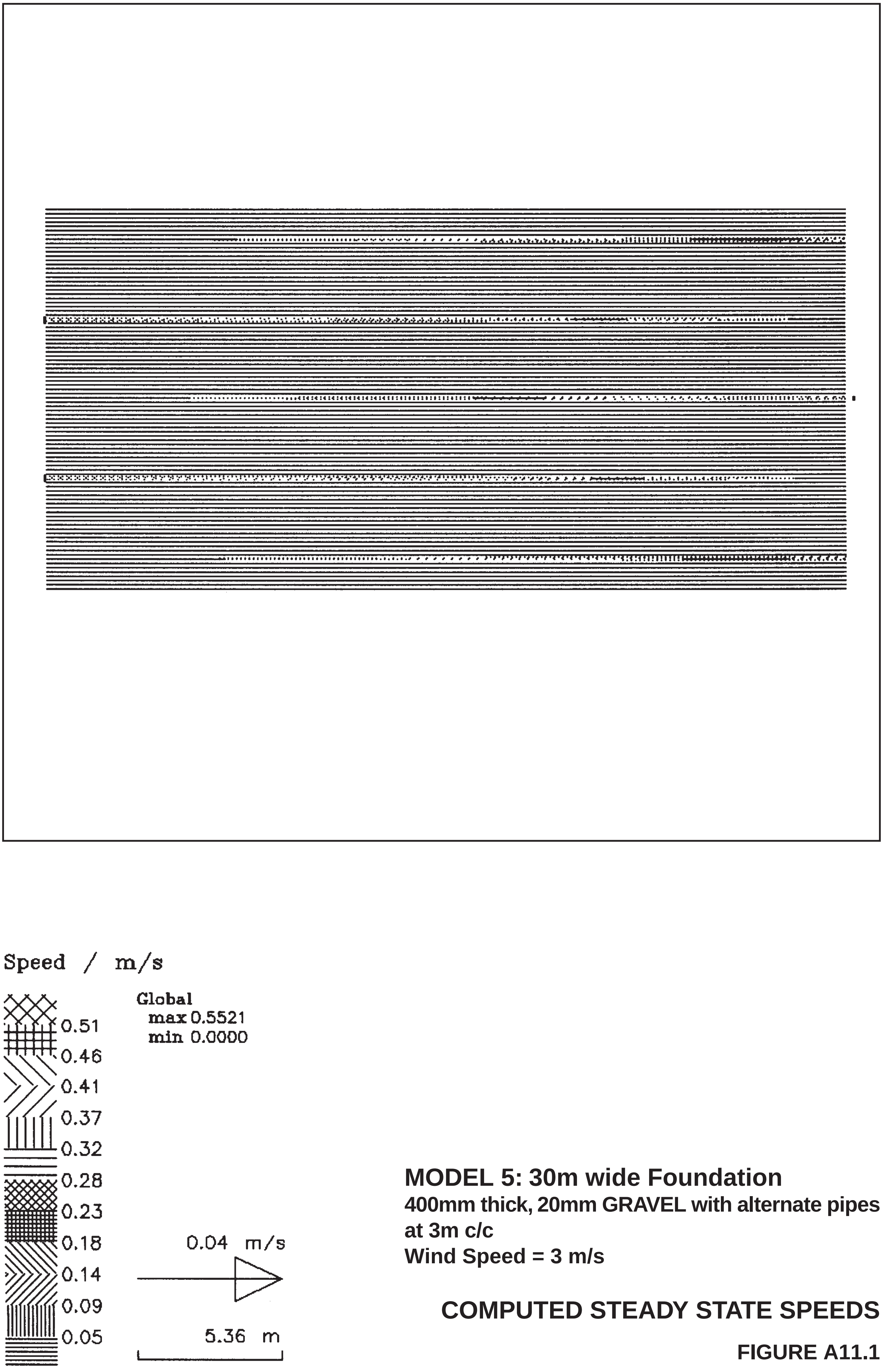




MODEL 4: 30m wide Foundation
400mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s
Reverse Flow

COMPUTED STEADY STATE CONCENTRATIONS

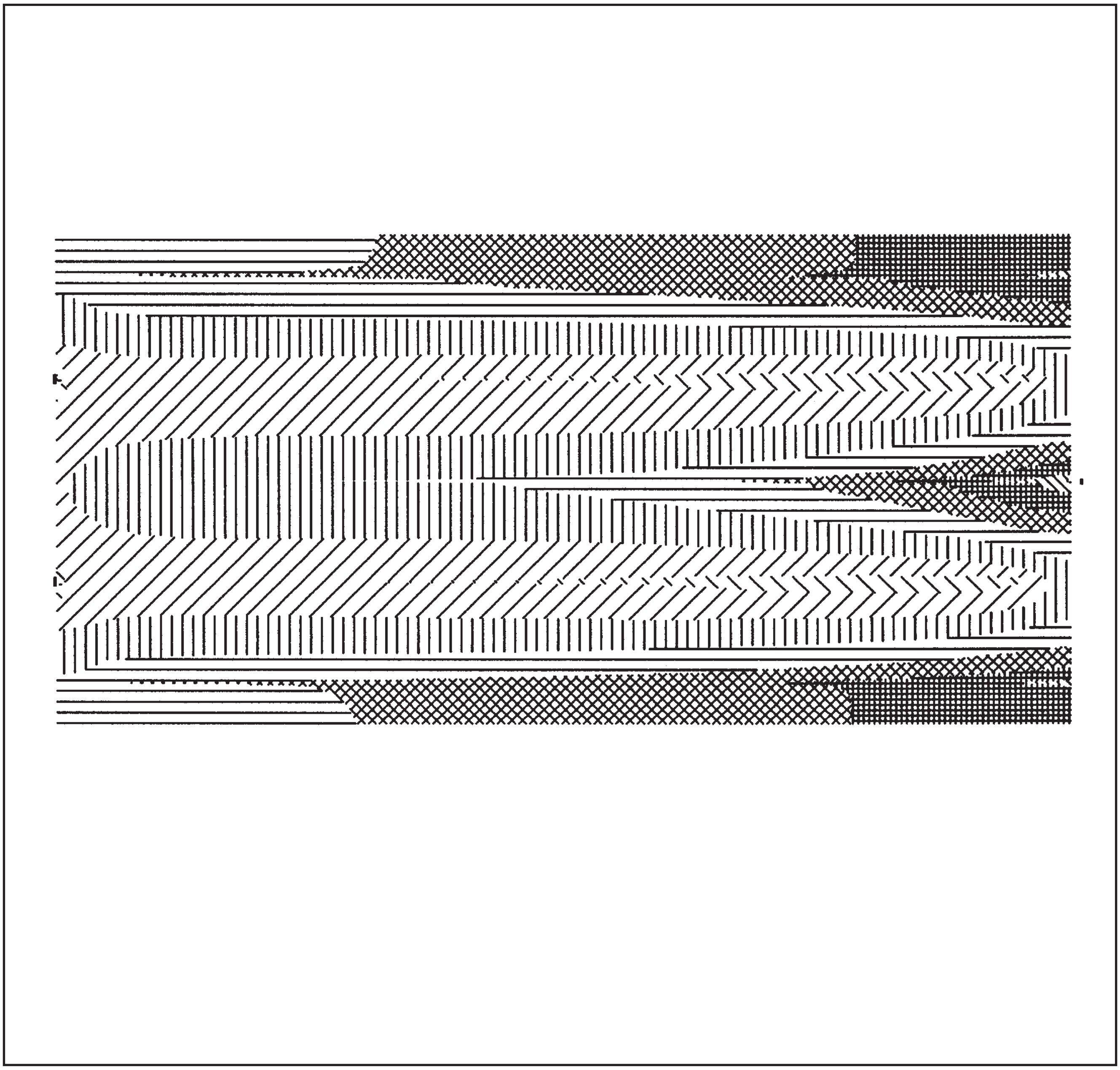
FIGURE A10.2.3

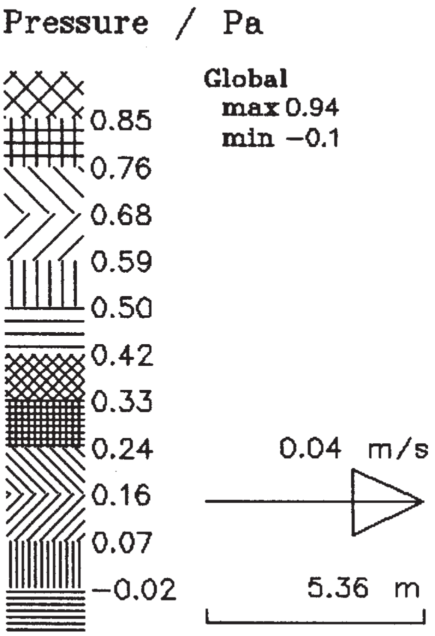


MODEL 5: 30m wide Foundation
400mm thick, 20mm GRAVEL with alternate pipes at 3m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A11.1





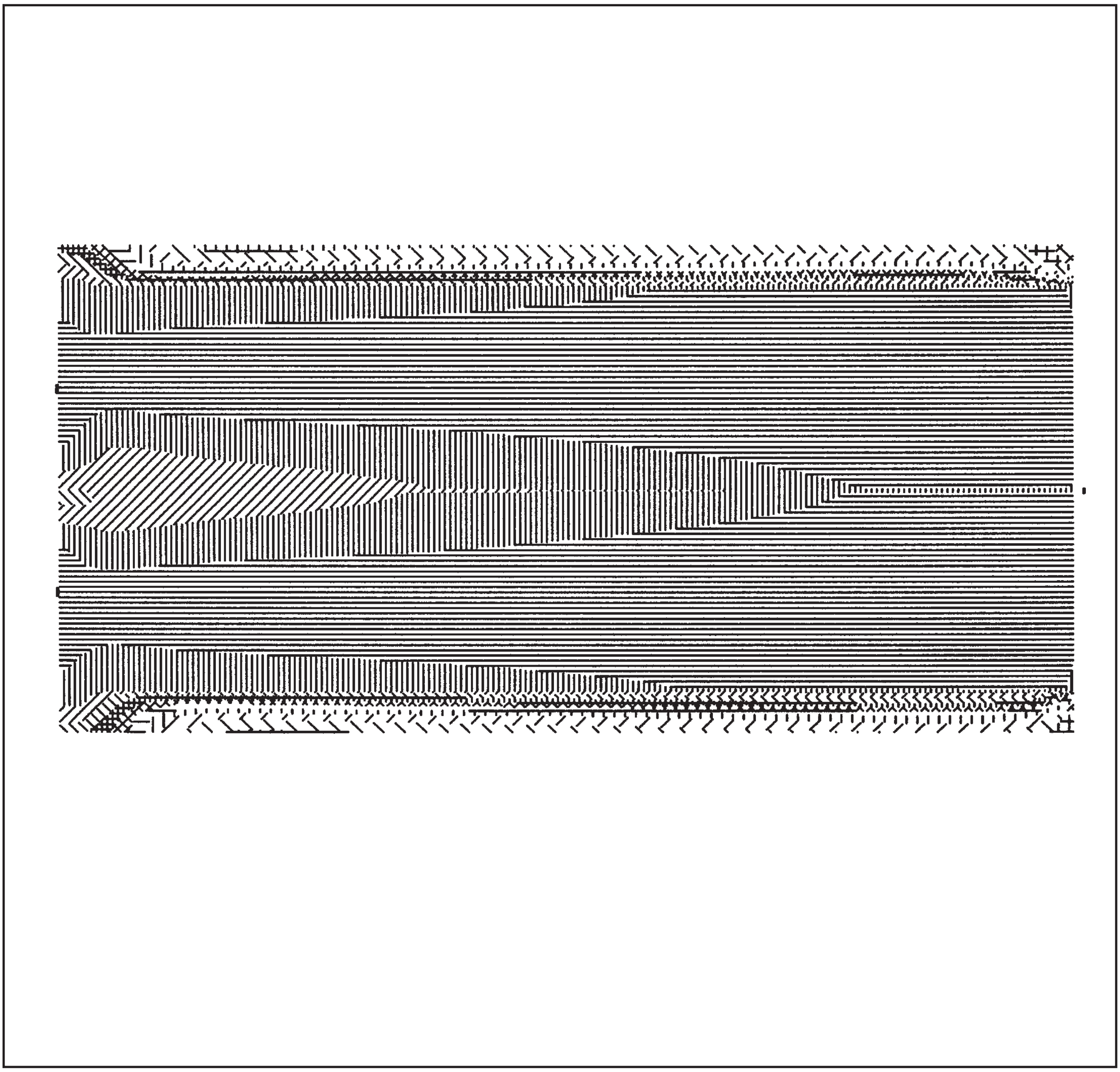
MODEL 5: 30m wide Foundation

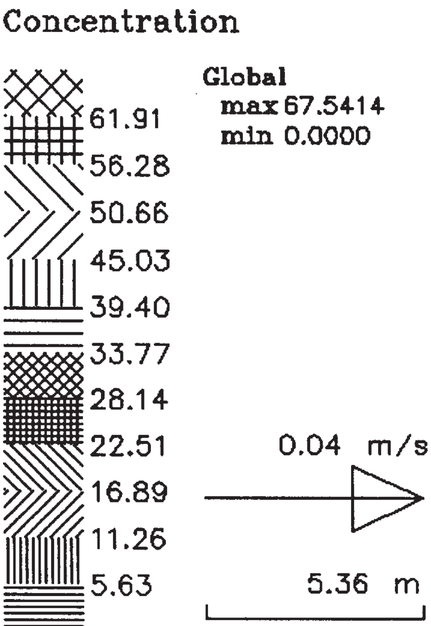
400mm thick, 20mm GRAVEL with alternate pipes at 3m c/c

Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A11.2

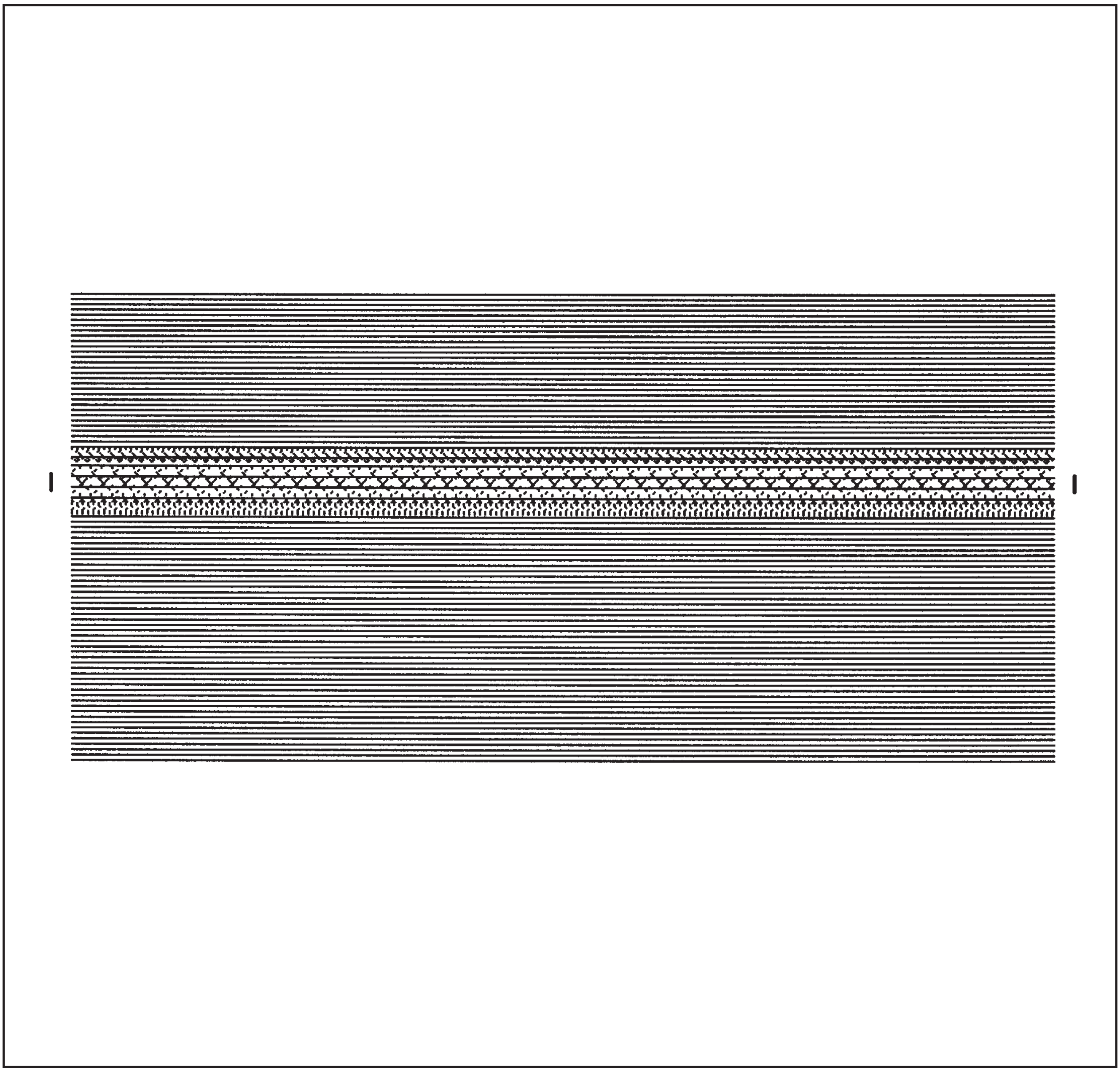


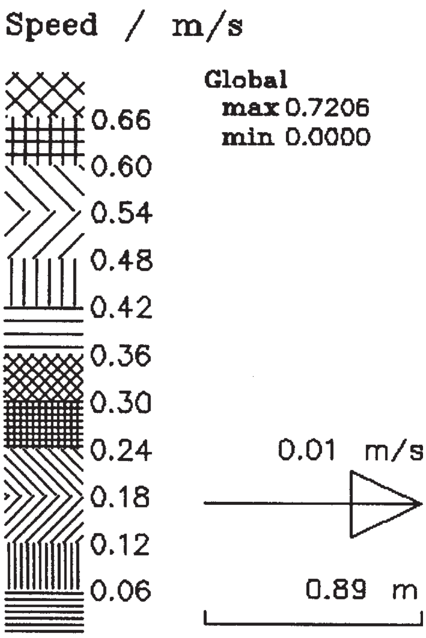


MODEL 5: 30m wide Foundation
400mm thick, 20mm GRAVEL with alternate pipes at 3m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A11.3





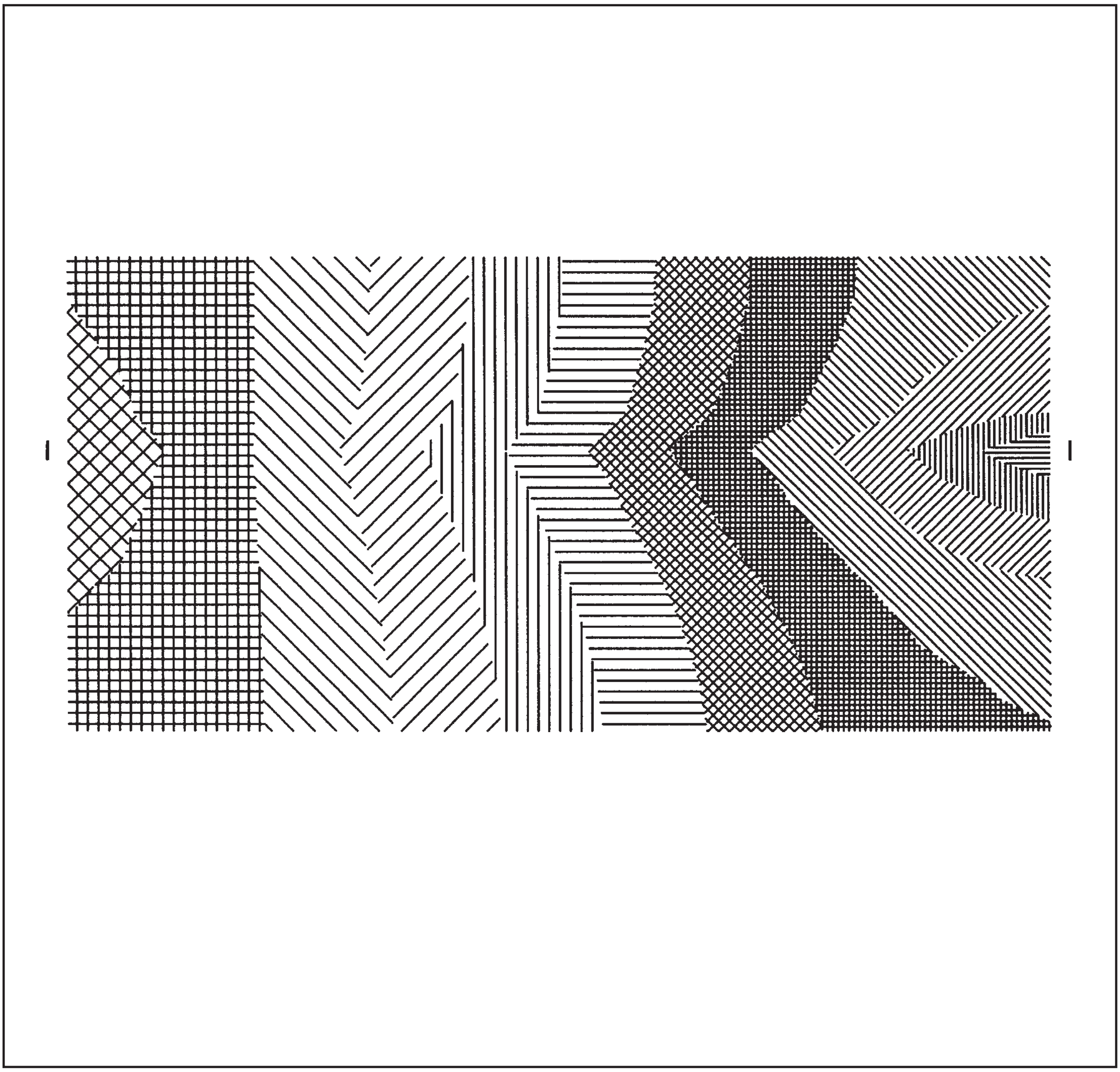
MODEL 6: 5m x 5m Foundation

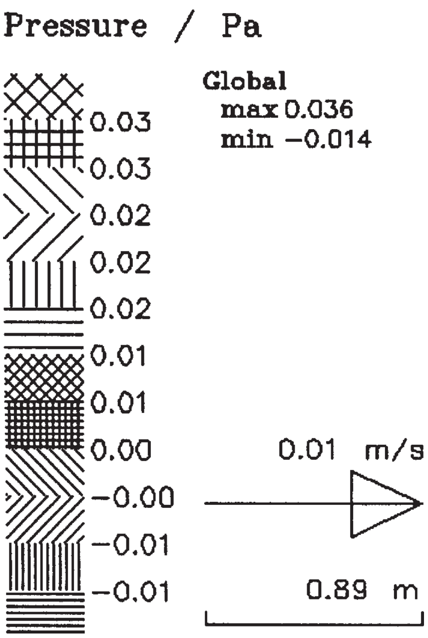
200mm thick, 20mm GRAVEL with pipes at 2m c/c

Wind Speed = 3 m/s

COMPUTED STEADY STATE SPEEDS

FIGURE A12.1

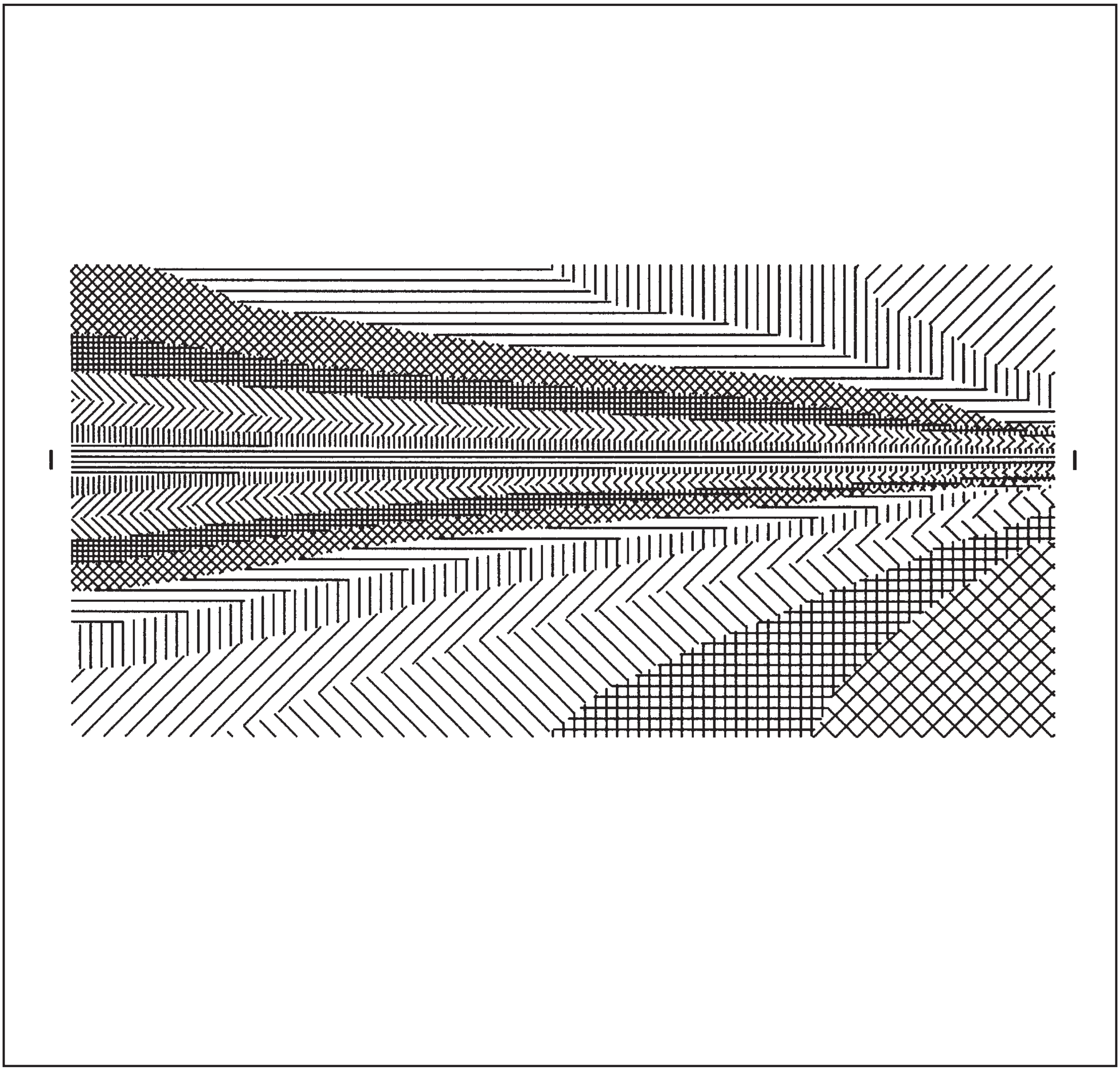


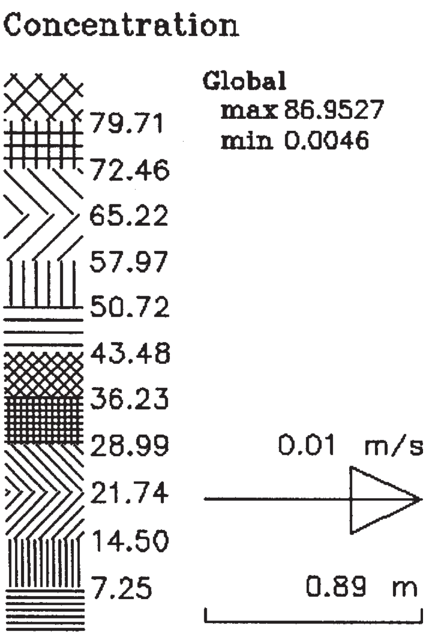


MODEL 6: 5m x 5m Foundation
200mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE PRESSURES

FIGURE A12.2





MODEL 6: 5m x 5m Foundation
200mm thick, 20mm GRAVEL with pipes at 2m c/c
Wind Speed = 3 m/s

COMPUTED STEADY STATE CONCENTRATIONS

FIGURE A12.3

Copies of this report may be obtained from

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Fax. 0171 465 3510