WIND-TUNNEL STUDY OF ALLEGHENY INTERNATIONAL BUILDING, PITTSBURGH

by

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LIST OF SYMBOLS

Symbol	Definition
U	Local mean velocity
D	Characteristic dimension (building height, width, etc.)
ν, ρ	Kinematic viscosity and density of approach flow
$\frac{UD}{\nu}$	Reynolds number
E	Mean voltage
A, B, n	Constants
U_{rms}	Root-mean-square of fluctuating velocity
E_{rms}	Root-mean-square of fluctuating voltage
U_{∞}	Reference mean velocity outside the boundary layer
Z	Height above surface
δ	Height of boundary layer
T_u	Turbulence intensity $\frac{U_{rms}}{U_{\infty}}$ or $\frac{U_{rms}}{U}$
$(\ )_{min}$	Minimum value during data record
$(\ )_{max}$	Maximum value during data record

1. INTRODUCTION

Increased use of pedestrian plazas adjacent to buildings has led to increased awareness of user comfort. Failure to consider the possibility of wind-related problems has caused many pedestrian-use areas to be used much less frequently than anticipated by the designer. Tall buildings near the plaza area can deflect high winds from upper elevations of the building down to plaza level causing unexpectedly windy environments near the base of the buildings. Wind-tunnel experiments can identify potential pedestrian comfort problems during design stages of a project so that remedial action can be considered during the design stage.

The investigation reported herein examines the influence of the proposed Allegheny International building in Pittsburgh on the pedestrian wind environment about the base of the building.

2. WIND-TUNNEL MODEL

2.1 Modeling

Techniques have been developed in the past two decades for wind-tunnel modeling of proposed structures which allow the prediction of wind velocities and gusts in pedestrian areas adjacent to a building, wind pressures on cladding and windows, and overall structural loading. Information on sidewalk-level gustiness allows plaza areas to be protected by design changes before the structure is constructed. Alternatively, structures with existing design problems can be tested for proposed solutions to optimize the benefit to cost ratio.

Modeling of the wind flow about a structure requires special consideration of flow conditions in order to obtain similitude between model and prototype. A detailed discussion of the similarity requirements and their wind-tunnel implementation can be found in references (1), (2) and (3). In general, the requirements are that the model and prototype be geometrically similar, that the approach mean velocity at the building site have a vertical profile shape similar to the full-scale flow, that the turbulence characteristics of the flows be similar, and that the Reynolds number for the model and prototype be equal.

These criteria are satisfied by constructing a scale model of the structure and its surroundings and performing the wind tests in a wind tunnel specifically designed to model atmospheric boundary-layer flows. Reynolds number similarity requires that the quantity UD/ν be similar for model and prototype. Since ν, the kinematic viscosity of air, is identical for both, Reynolds numbers cannot be made precisely equal with reasonable wind velocities. To accomplish this the air velocity in the wind tunnel would have to be as large as the model scale factor times the prototype wind velocity, a velocity which would introduce unacceptable compressibility effects. However, for sufficiently high Reynolds numbers ($>2\times10^4$) the flow pattern will remain fixed so that wind velocity at any location on the model will be a constant factor of a reference velocity in the approaching wind for a large range of Reynolds numbers. Typical values encountered are 10^7-10^8 for the full-scale and 10^5-10^6 for the wind-tunnel model. In this range acceptable flow similarity is achieved without precise Reynolds number equality.

2.2 Experimental Configuration

The wind-tunnel study was performed in the Fluid Dynamics and Diffusion Laboratory at Colorado State University (Figure 1). Three large wind tunnels are available for wind loading studies depending on the detailed requirements of the study. The Industrial Aerodynamics wind tunnel used for this investigation is shown in Figure 2. All tunnels have a flexible roof adjustable in height to maintain a zero pressure gradient along the test section. The mean velocity can be adjusted continuously in each tunnel to the maximum velocity available.

In order to obtain an accurate assessment of local wind velocities, the model was constructed to the largest scale that did not produce significant blockage in the wind-tunnel test section and which provided necessary adjacent buildings on the turntable. The 1:400 scale model was constructed of Lucite plastic. Significant variations in the building surface were modeled.

A circular area 1650 ft in radius was modeled in detail. Structures within the modeled region were made from styrofoam and cut to the individual building geometries. They were mounted on the turntable in their proper locations. Significant terrain features were included as needed. The model was mounted on a turntable (Figure 2) near the downwind end of the test section. Any buildings or terrain features which did not fit on the turntable were placed on removable pieces which were placed upwind of the turntable for appropriate wind directions. A plan view of the building and its surroundings is shown in Figure 3. The turntable was calibrated to indicate azimuthal orientation to 0.1 degree.

The region upstream from the modeled area was covered with a randomized roughness constructed using 2 in. cubes placed on the floor of the wind tunnel. Spires were installed at the test-section entrance to provide a thicker boundary layer than would otherwise be available. The thicker boundary layer permitted a somewhat larger scale model than would otherwise be possible. The spires were approximately triangularly shaped pieces of 1/2 in. thick plywood 6 in. wide at the base and 1 in. wide at the top, extending from the floor to the top of the test section. They were placed so that the broad side intercepted the flow. A barrier approximately 8 in. high was placed on the test-section floor downstream of the spires to aid in development of the boundary-layer flow.

The distribution of the roughness cubes and the spires was designed to provide a boundary-layer thickness of approximately 3.5 ft, a velocity profile power-law exponent similar to that expected to occur in the region approaching the modeled area for each wind direction (a number of wind directions may have the same approach roughness). Mean velocity and turbulence intensity profiles approaching the model site are shown in Figure 4. Because pedestrian wind speeds are relatively insensitive to changes in approach wind profiles, a single approach profile was used for measurement of pedestrian winds. Three approach profiles will be used for wind load measurements on the tower. Photographs of the model in the wind-tunnel are shown in Figure 5. The wind-tunnel ceiling was adjusted after placement of the model to obtain a zero pressure gradient along the test section.

3. DATA ACQUISITION AND RESULTS

3.1 Flow Visualization

Making the air flow visible in the vicinity of the model is helpful in indicating areas where pedestrian discomfort may be a problem. Titanium dioxide smoke was released from sources on and near the model to make the flow lines visible and to make it possible to obtain videotape records of the tests. Flow visualization of the site will be included in the final project report.

3.2 Velocity Measurements

Mean velocity and turbulence intensity profiles were measured upstream of the model to determine that an approach boundary-layer flow appropriate to the site had been established. Tests were made at one wind velocity in the tunnel. This velocity was well above that required to produce Reynolds number similarity between the model and the prototype as discussed in Section 2.1.

In addition, mean velocity and turbulence intensity measurements were made 5 to 7 ft (prototype) above the surface at 33 locations near the building for 16 wind directions. Of these, 16 were measured without the new building in place and 17 were measured with the Allegheny International building in place. The measurement locations are shown on Figure 3. The surface measurements are indicative of the wind environment to which a pedestrian at the measurement location would be subjected. The locations were chosen to determine the degree of pedestrian comfort or discomfort at the building corners where relatively severe conditions frequently are found, near building entrances and on adjacent sidewalks where pedestrian traffic might be heavy.

Measurements were made with a single hot-film anemometer mounted with its axis vertical. The instrumentation used was a Thermo Systems constant temperature anemometer (Model 1050) with a 0.001 in. diameter platinum film sensing element 0.020 in. long. Output was directed to the on-line data acquisition system for analysis.

Calibration of the hot-wire anemometer was performed by comparing output with a pitot-static tube in the wind tunnel. The calibration data were fit to a variable exponent King's Law relationship of the form

$$E^2 = A + BU^n$$

where E is the hot-wire output voltage, U the velocity and A, B, and n are coefficients selected to fit the data. The above relationship was used to determine the mean velocity at measurement points using the measured mean voltage. The fluctuating velocity in the form U_{rms} (root-mean-square velocity) was obtained from

$$U_{rms} = \frac{2\ E\ E_{rms}}{B\ n\ U^{n-1}}$$

where E_{rms} is the root-mean-square voltage output from the anemometer. For interpretation all turbulence measurements for pedestrian winds were divided by the mean velocity outside the boundary-layer U_∞. Turbulence intensity in velocity profile measurements used the local mean velocity.

3.3 Results and Discussion

Velocity and turbulence profiles approaching the model are shown in Figure 4. Profiles were taken upstream from the model which are characteristic of the boundary layer approaching the model. The boundary-layer thickness, δ, is shown in Figure 4. The corresponding prototype value of δ for this study is also shown in the figure. This value was established as a reasonable height for this study. The mean velocity profile approaching the modeled area has the form

$$\frac{U}{U_\infty} = \left(\frac{z}{\delta}\right)^n .$$

The exponent n for the approach flow established for this study is shown in Figure 4. The value n = 0.36 is characteristic of the area about the Allegheny International building site.

Profiles of longitudinal turbulence intensity in the flow approaching the modeled area are shown in Figure 4. The turbulence intensities are appropriate for the approach mean velocity profile selected. For the velocity profiles, turbulence intensity is defined as the root-mean-square about the mean of the longitudinal velocity fluctuations divided by the local mean velocity U,

$$Tu = \frac{U_{rms}}{U} \quad .$$

Velocity data obtained at each of the pedestrian measurement locations shown in Figure 3 are listed in Table 1 as mean velocity U/U_∞, turbulence intensity U_{rms}/U_∞, and largest effective gust

$$U_{pk} = \frac{U + 3U_{rms}}{U_\infty} \quad .$$

These data are plotted in polar form in Figure 6. These data show the approach wind directions giving the highest wind speeds at each site.

To enable a quantitative assessment of the wind environment, the wind-tunnel data were combined with wind frequency and direction information obtained at the local airport. Table 2 shows wind frequency by direction and magnitude obtained from summaries published by the National Weather Service. These data, obtained at an elevation of 984 ft, were converted to velocities at the reference velocity height for the wind-tunnel measurements and combined with the wind-tunnel data to obtain cumulative probability distributions (percent time a given velocity is exceeded) for wind velocity at each measuring location. The percentage times were summed by wind direction to obtain a percent time exceeded at each measuring position independent of wind direction (but accounting for the fact that the wind blows from different directions with varying frequency). These results are plotted in Figure 7.

Interpretation of Figure 7 is aided by a description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806 for use at sea and is still in use today. Several recent investigators have added to the knowledge of wind effects on pedestrians. These investigations along with suggested criteria for acceptance have been summarized by Penwarden and Wise (4) and Melbourne (5). The Beaufort scale (from ref. 4), based on mean velocity, is reproduced as Table 3 including qualitative descriptions of wind effects. Table 3 suggests that mean wind speeds below 12 mph are of minor concern and that mean speeds above 24 mph are definitely inconvenient. Quantitative criteria for acceptance from reference 5 are superimposed as dashed lines on Figure 7. The peak gust curves shown in Figure 7 are the percent of time during which a short gust of the stated magnitude could occur (say about one of these gusts per hour).

The overall indications of pedestrian wind comfort are best described by Figure 7, in particular the percent time exceeded plots which show the effective gust (mean plus 3*rms). The mean velocity percent time exceeded plots are useful, but may present too severe a comparison to acceptance criteria because of conservative assumptions about anticipated urban turbulence intensities which were incorporated into the acceptance criteria.

The results of Figure 7 show that, for effective gusts, no measured velocity location either with or without the Allegheny International building exceeded the unacceptable level and no measured location exceeded the walking discomfort level more than 3 percent of the time. Only a few locations exceeded the walking comfort level at any percentage level.

Locations 1-16 were measured in both the existing pre-construction configuration and in the built configuration including the Allegheny International building. It is useful to compare the data from the two configurations for gust winds in Figure 7. Locations which experienced a decrease in wind speeds in the built configuration were 10, 12 and 16. Remaining about the same in wind speeds were 1, 2, 3, 13 and 15. Locations increasing in wind speeds were locations 4, 5, 6, 7, 8, 9, 11 and 14. The locations which increased in wind speed were all on streets immediately adjacent to the project site. Tall buildings are known to bring higher wind speeds from elevations above the surface down to ground level. The increases in wind speed observed about the base of the building are typical for a building of this height. The increases observed at some locations, for example 14 and possibly 9 and 6, might be expected to be reduced if a building were constructed on the open lot on the southwest corner of Penn Ave. and 7th Street.

It is anticipated that pedestrian wind speeds measured on streets about the base of the Allegheny International building will be higher in a few local areas than those existing prior to the building construction, but will be considered as normal and acceptable winds by pedestrians. It is not likely that amelioration will be necessary. If desired, a small reduction in wind speeds on sidewalk areas could be achieved by including trees, planters and shrubs where space permitted.

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3. Cermak, J. E., "Aerodynamics of Buildings," Annual Review of Fluid Mechanics, Vol. 8, 1976, pp. 75-106.

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FIGURES

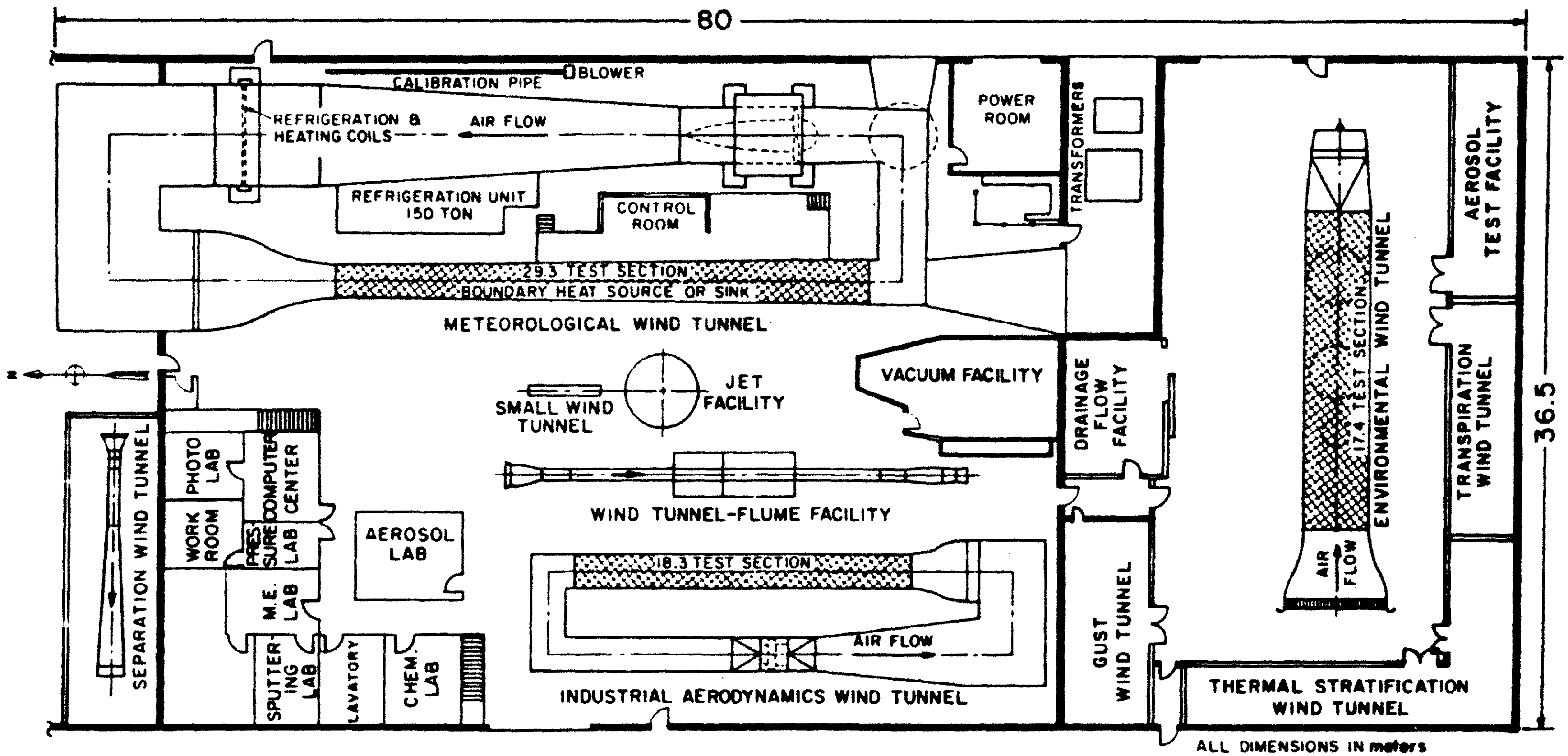
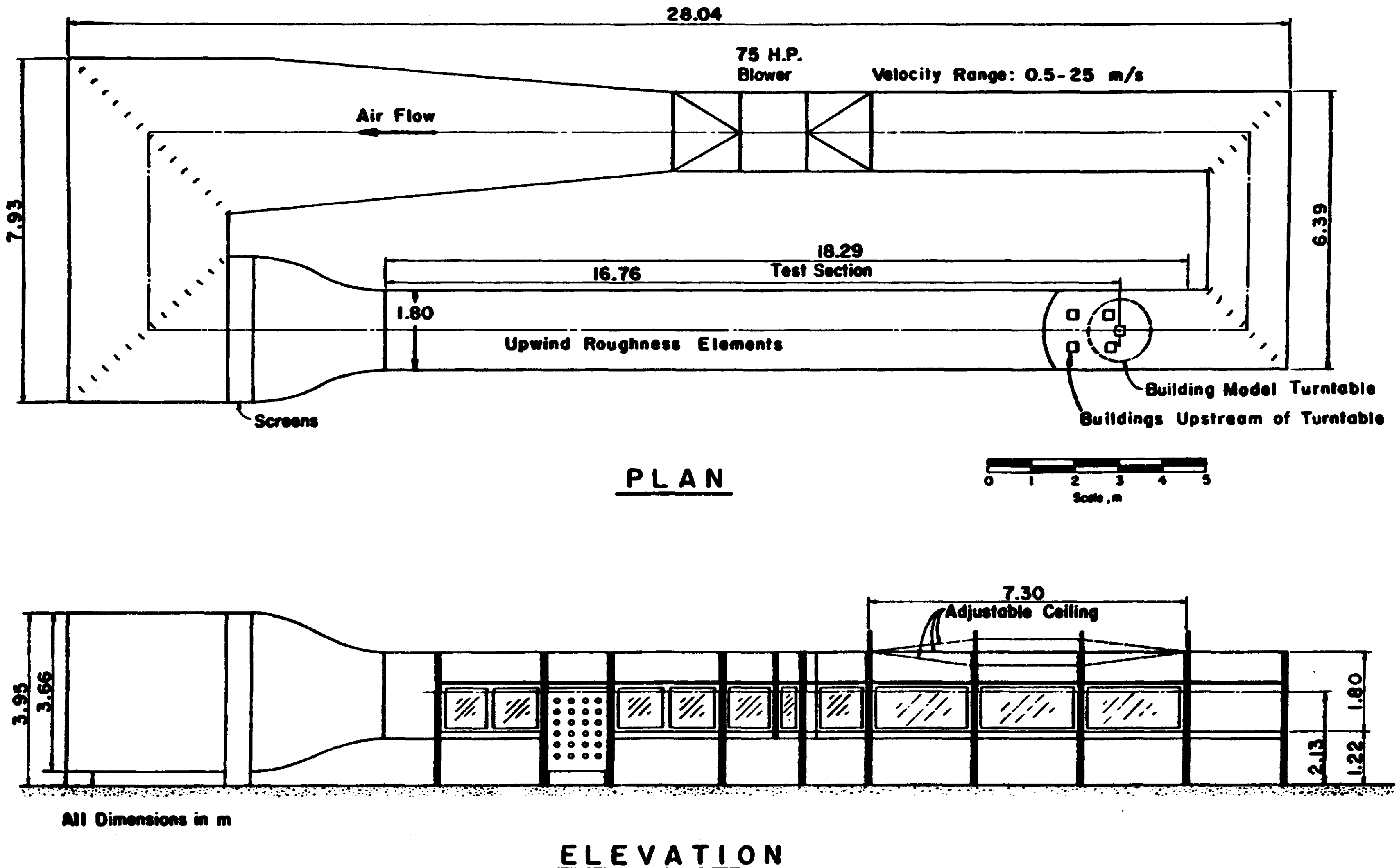


Figure 1. **FLUID DYNAMICS AND DIFFUSION LABORATORY COLORADO STATE UNIVERSITY**



INDUSTRIAL AERODYNAMICS WIND TUNNEL

Figure 2 - Wind Tunnel Configuration

Figure 3. Pedestrian Wind Velocity Measuring Positions

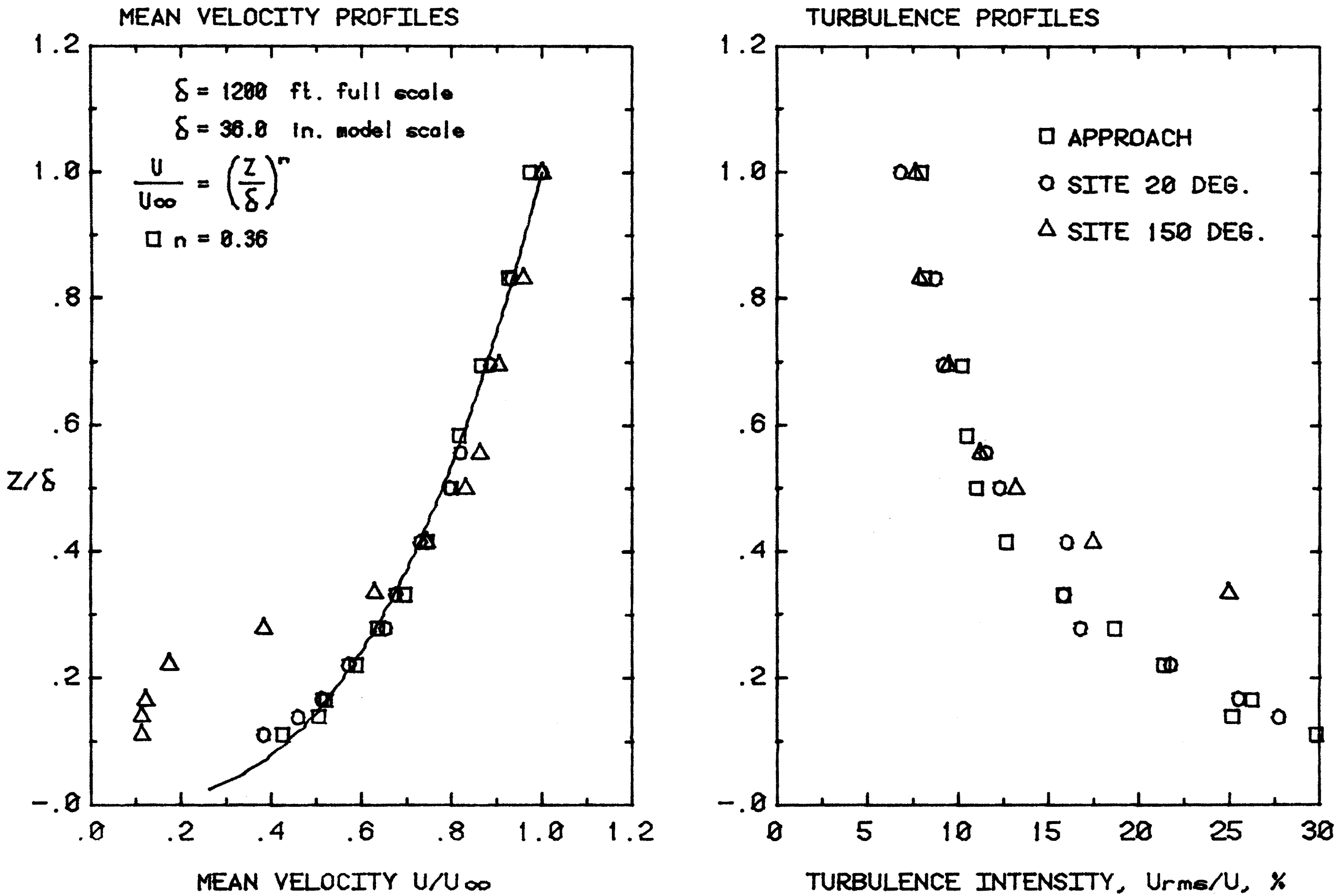


Figure 4. Mean Velocity and Turbulence Profiles Approaching the Model

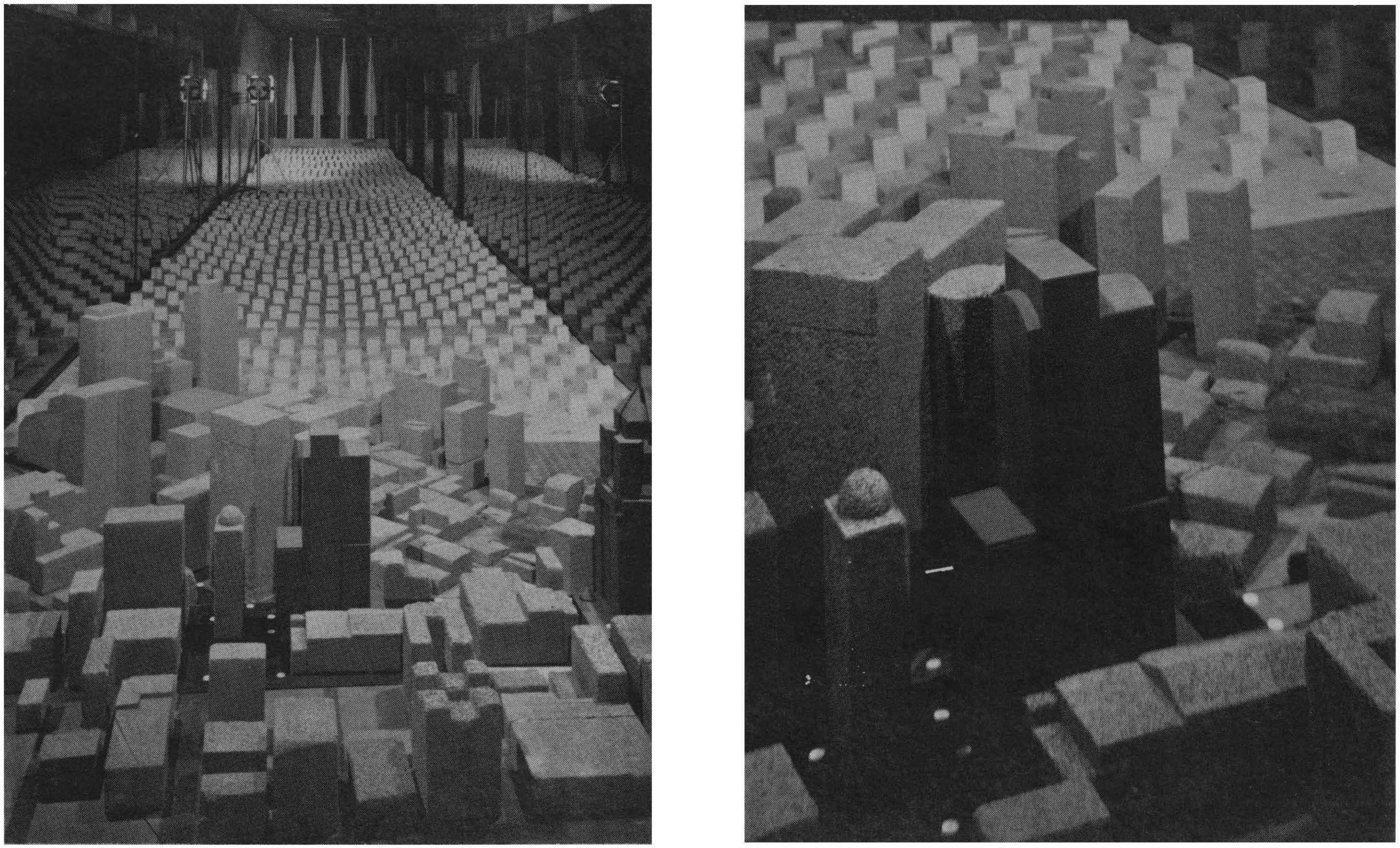
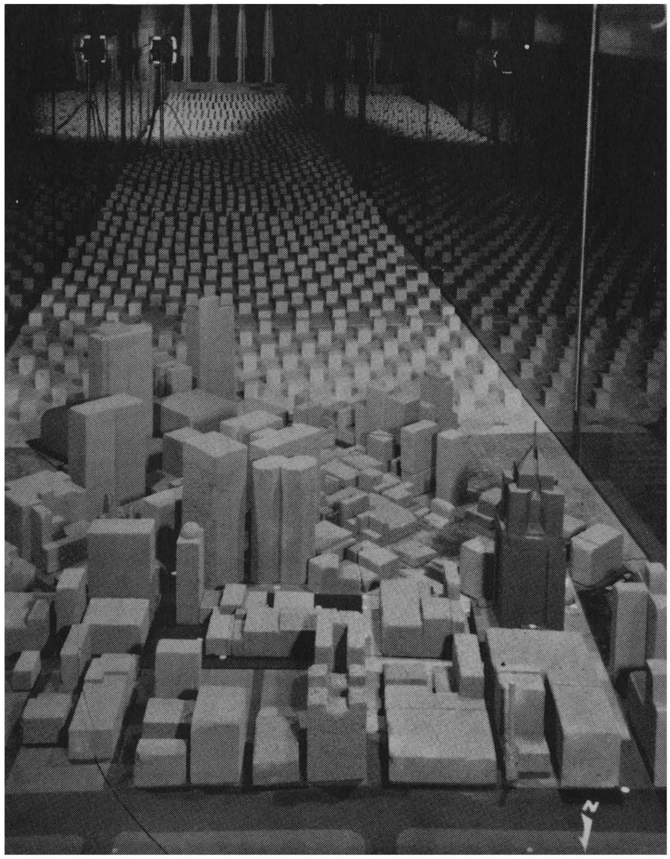


Figure 5a. Completed Model in the Wind Tunnel

Existing Configuration



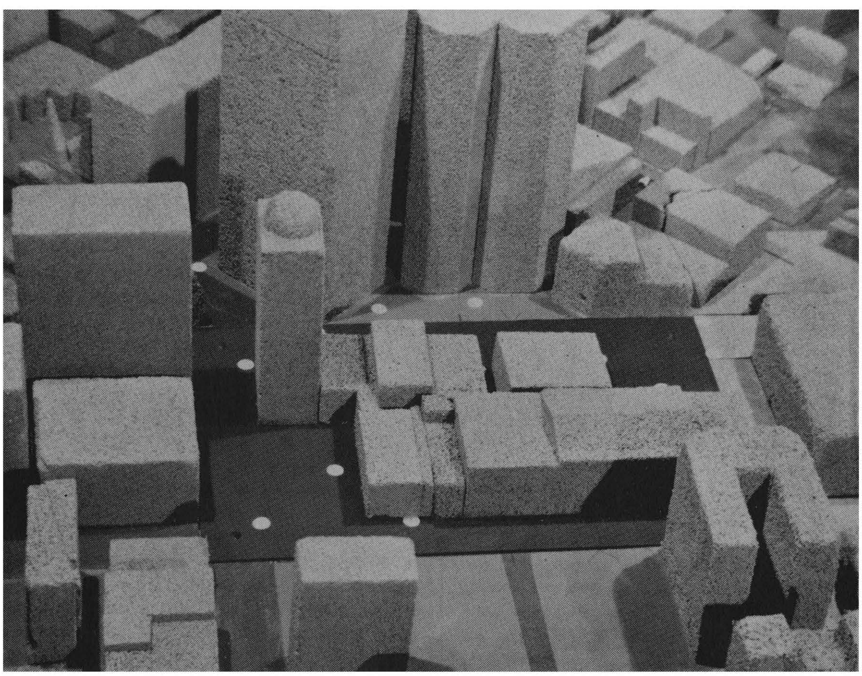


Figure 5b. Completed Model in the Wind Tunnel

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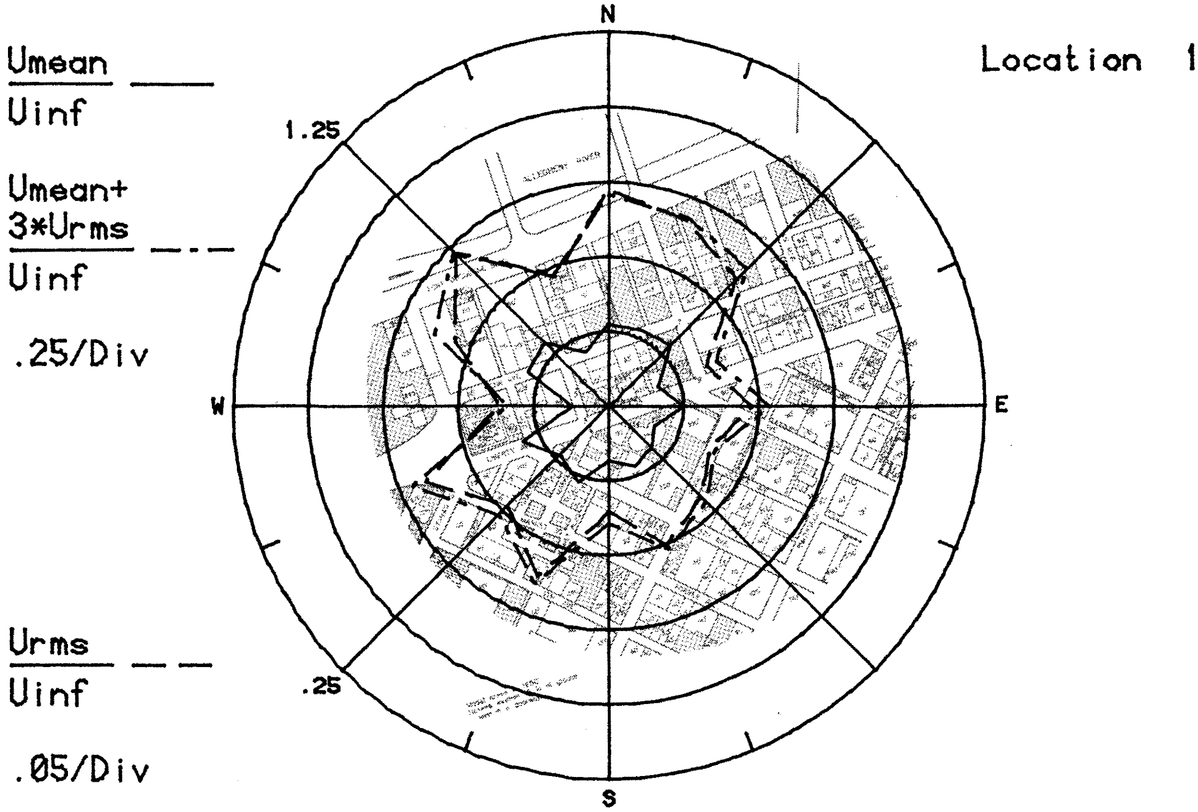


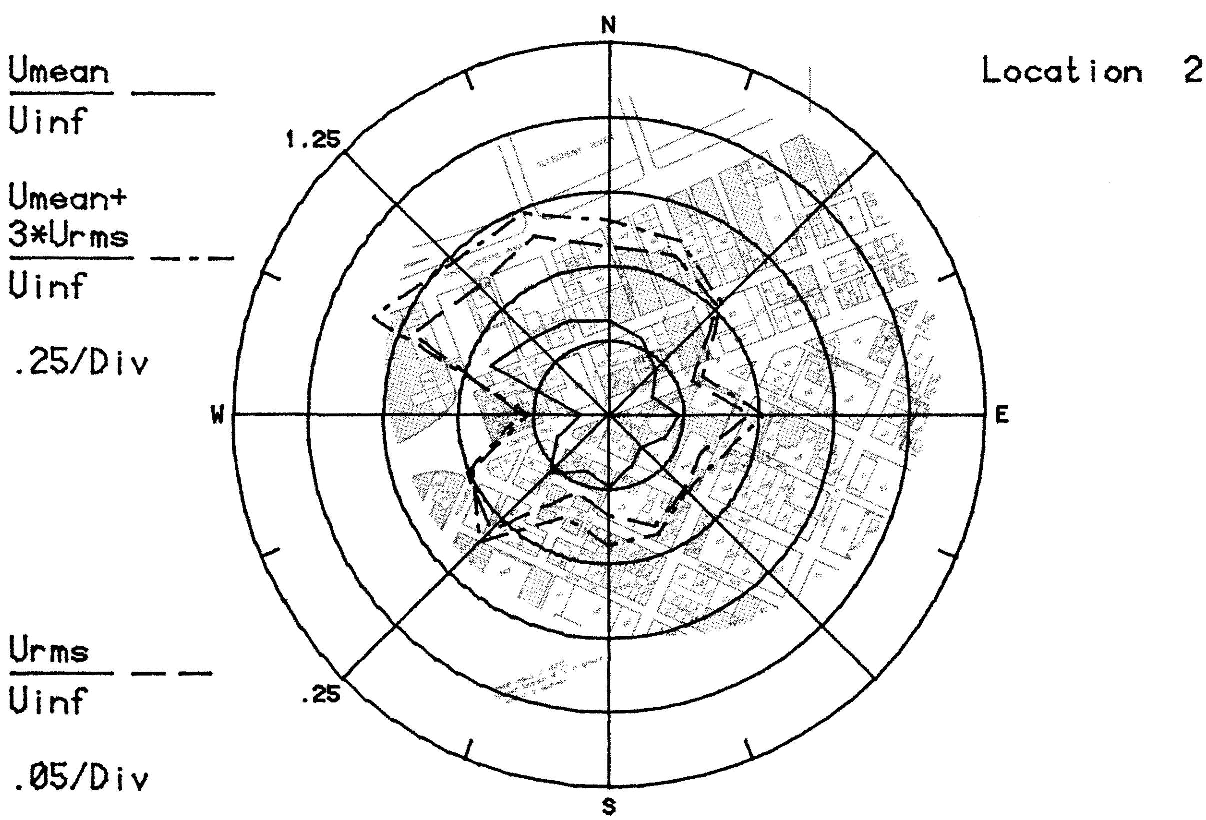
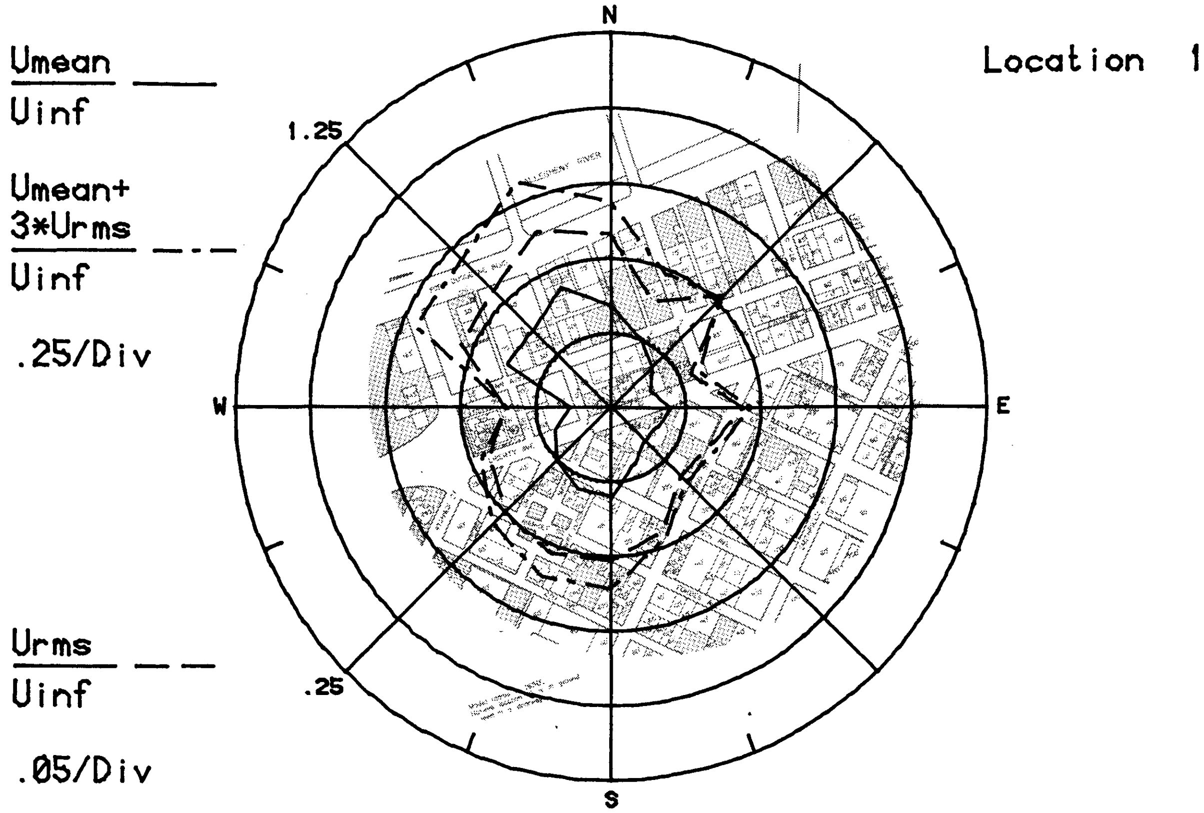


Figure 6a. Mean Velocities and Turbulence Intensities at Pedestrian Locations 1 and 2

Existing Configuration



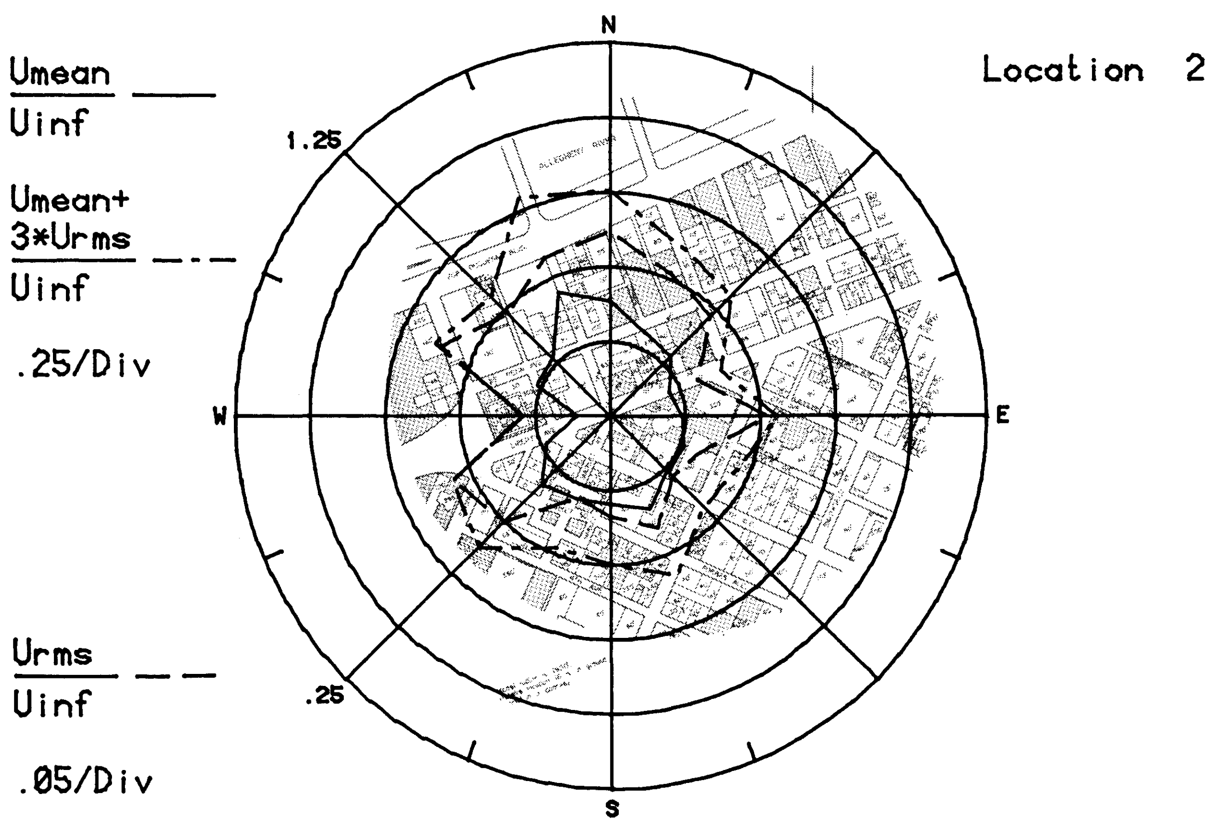
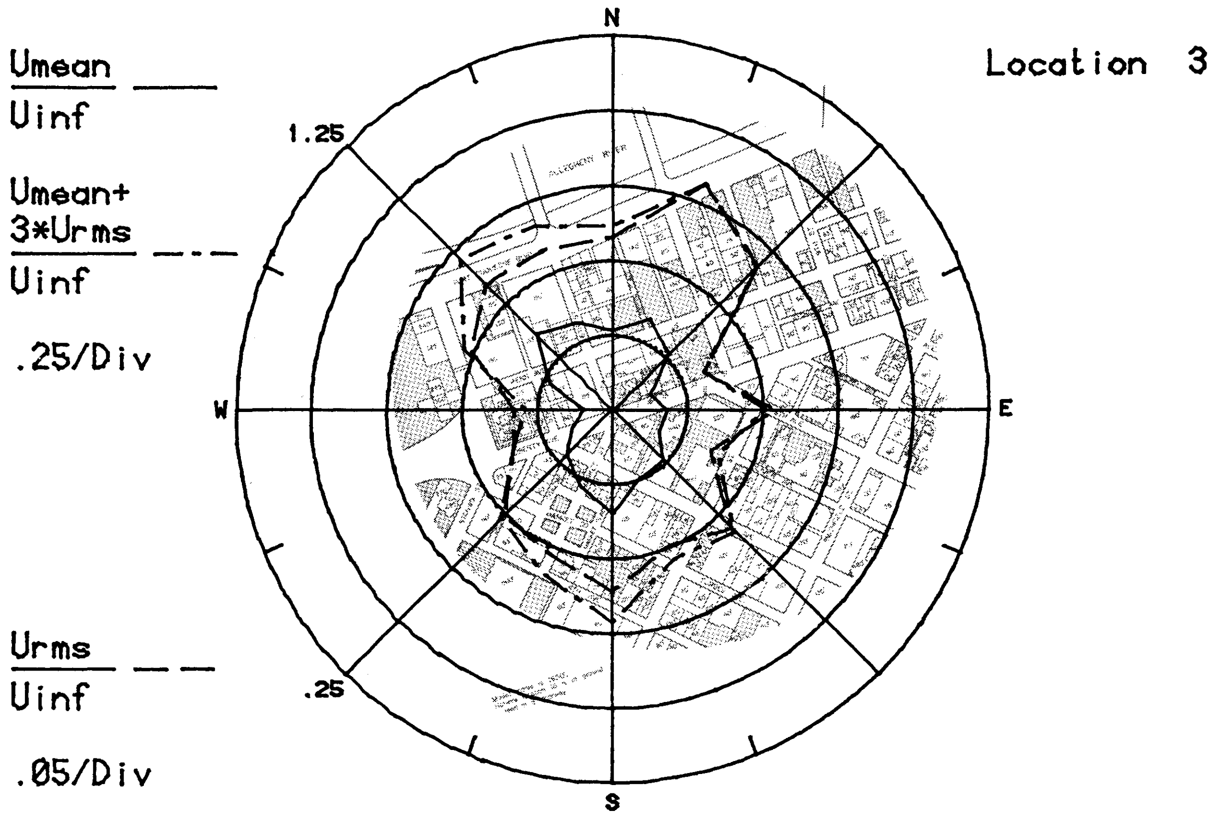


Figure 6b. Mean Velocities and Turbulence Intensities at Pedestrian Locations 1 and 2

Allegheny International



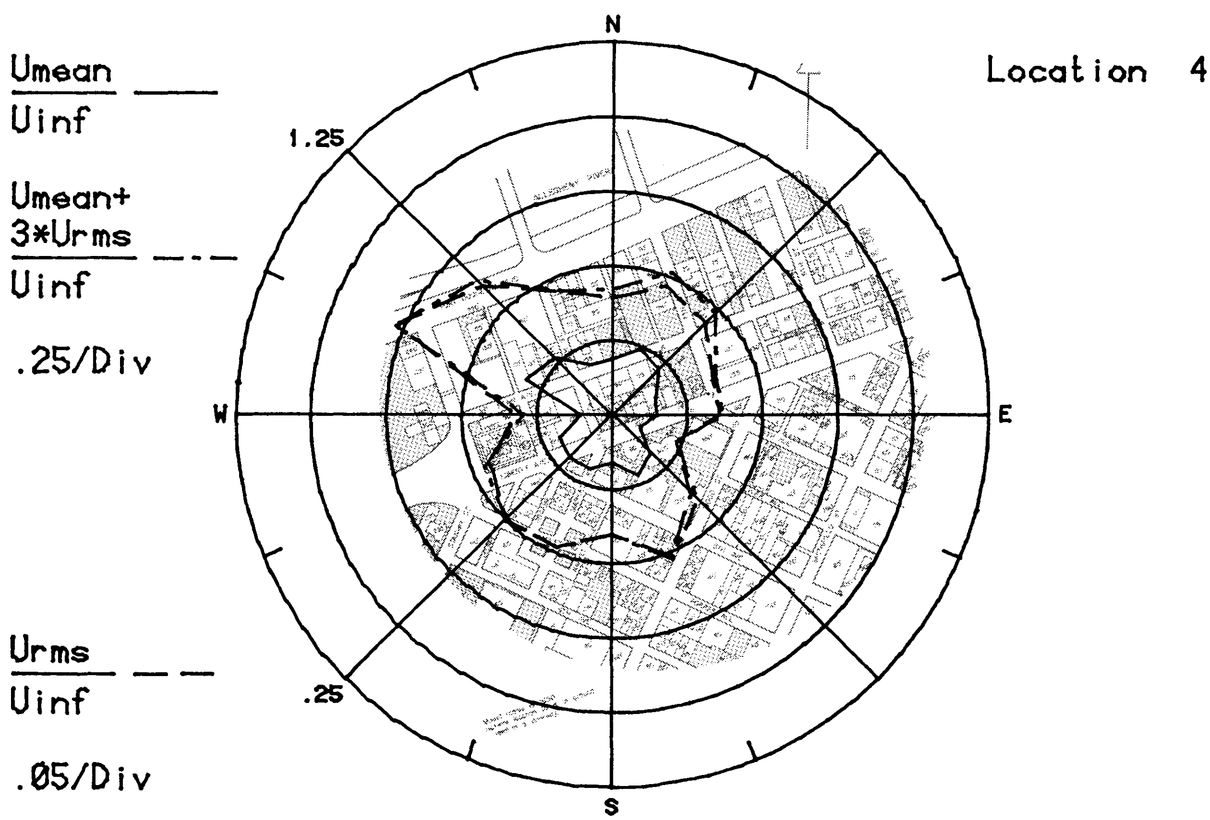
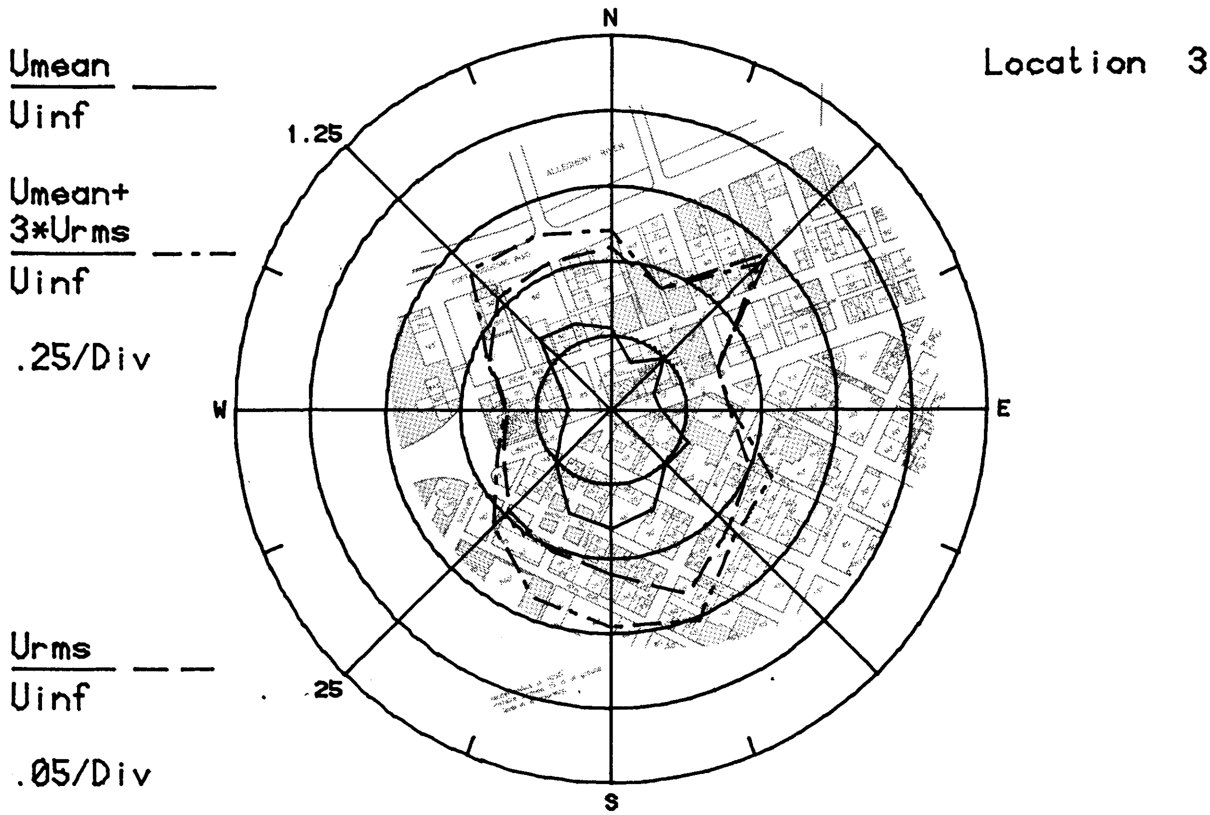


Figure 6c. Mean Velocities and Turbulence Intensities at Pedestrian Locations 3 and 4

Existing Configuration



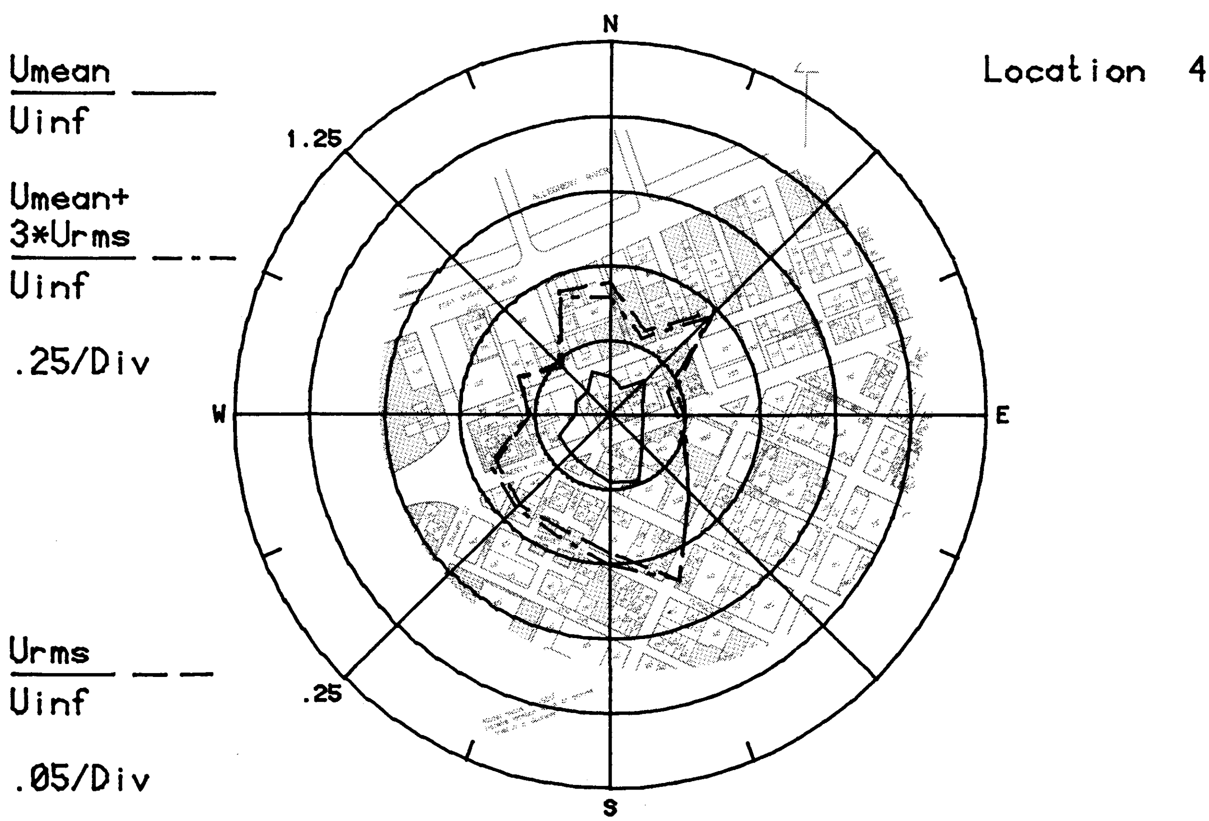
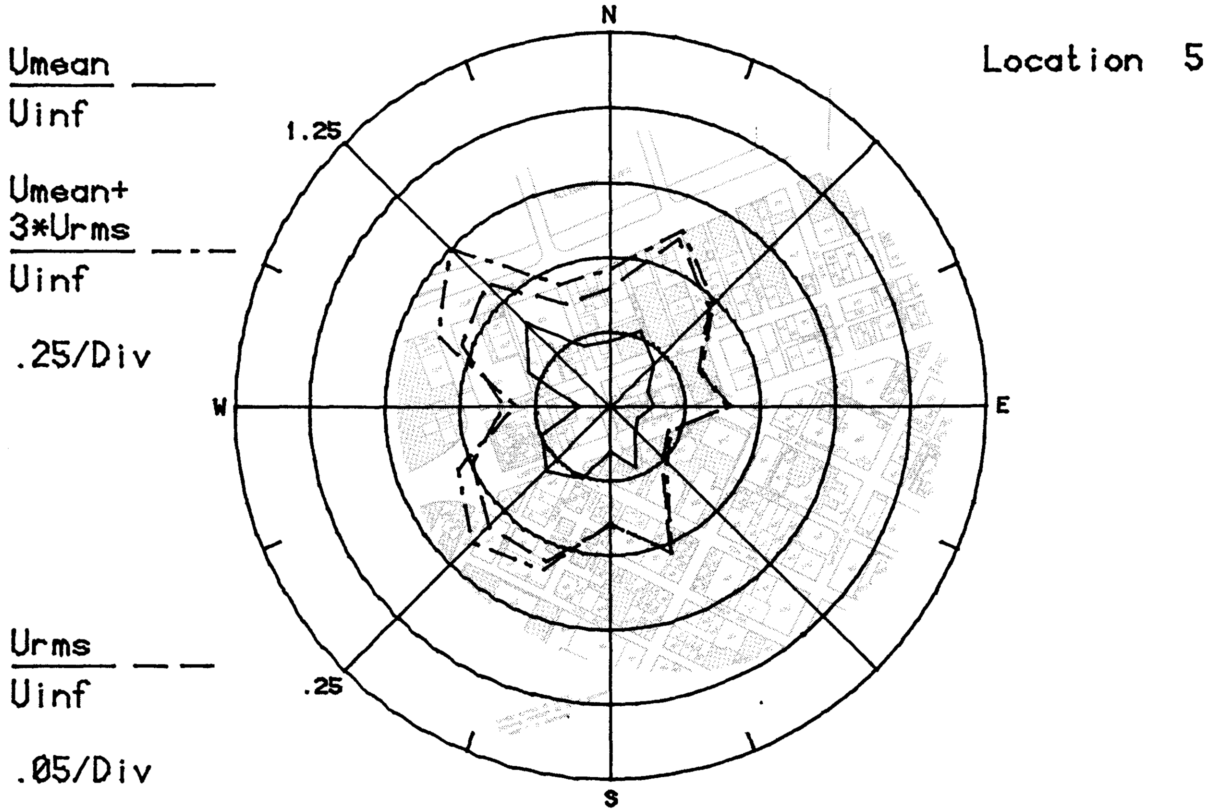


Figure 6d. Mean Velocities and Turbulence Intensities at Pedestrian Locations 3 and 4



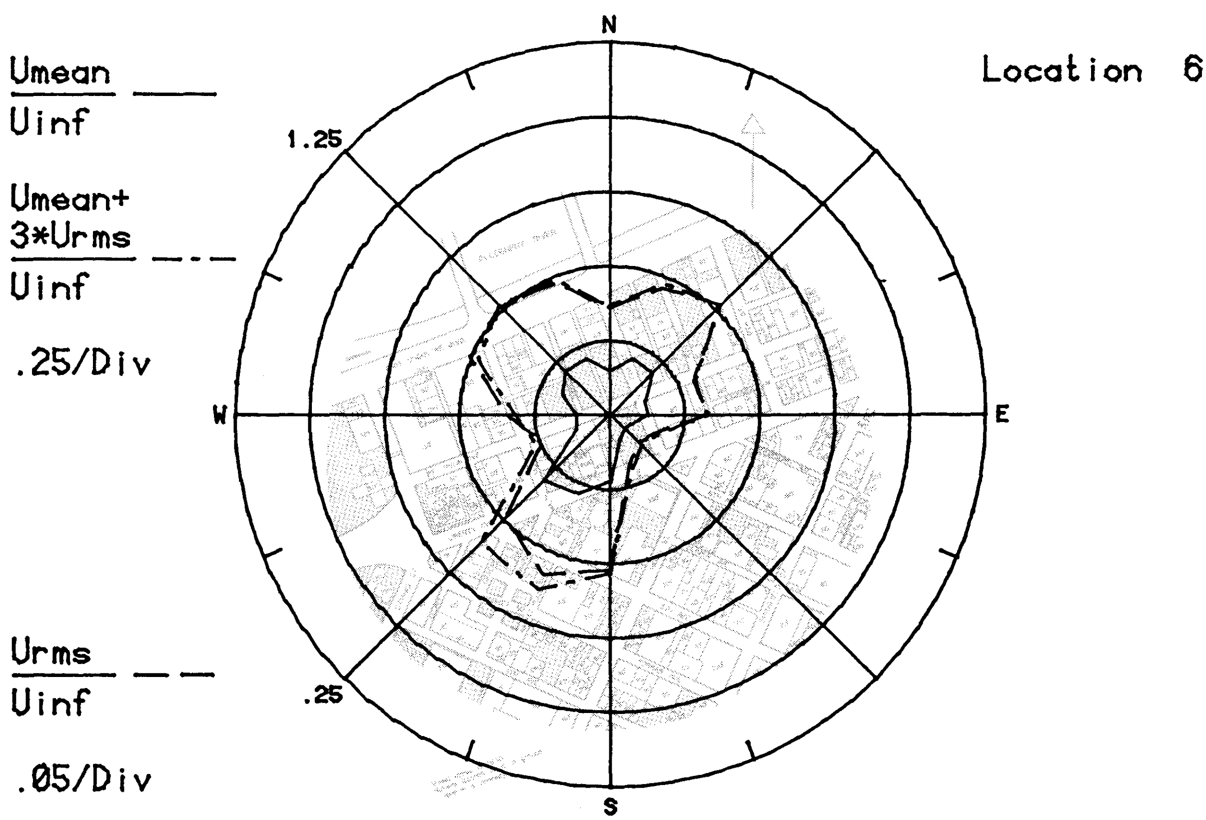


Figure 6e. Mean Velocities and Turbulence Intensities at Pedestrian Locations 5 and 6

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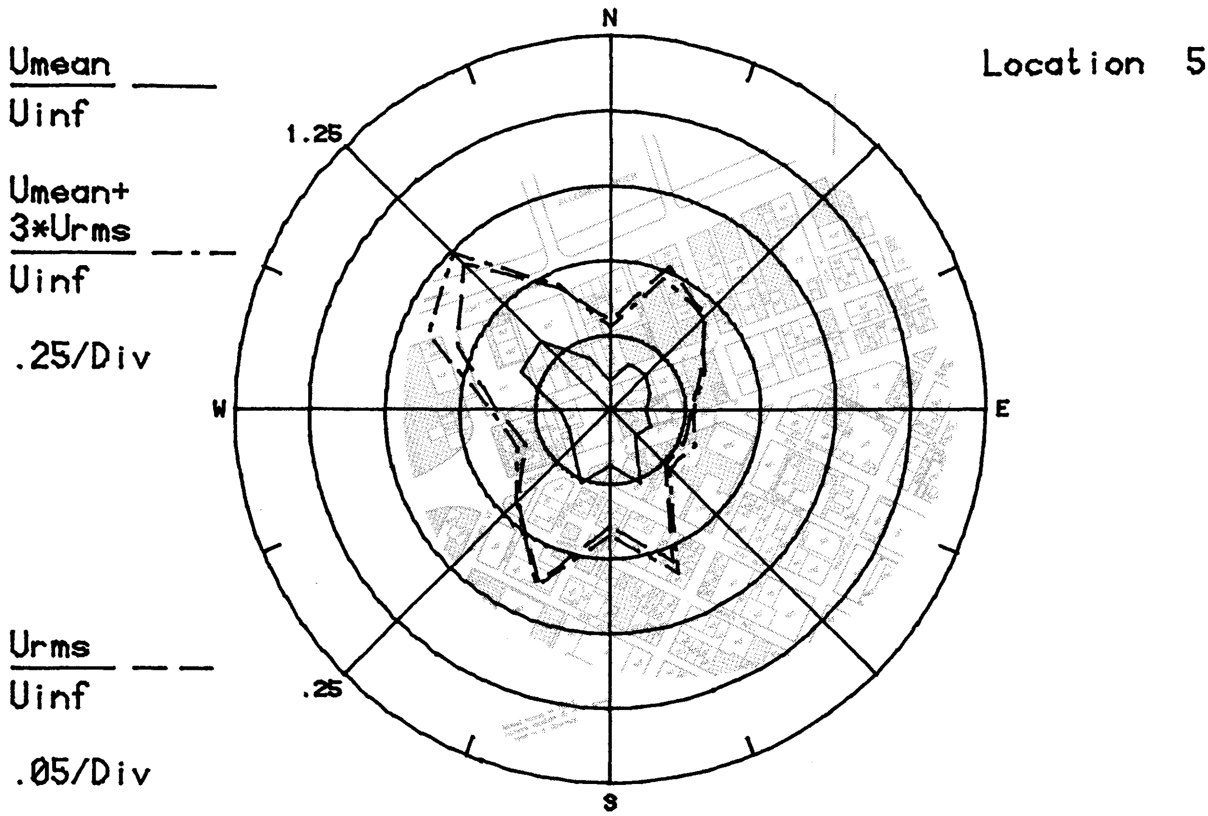

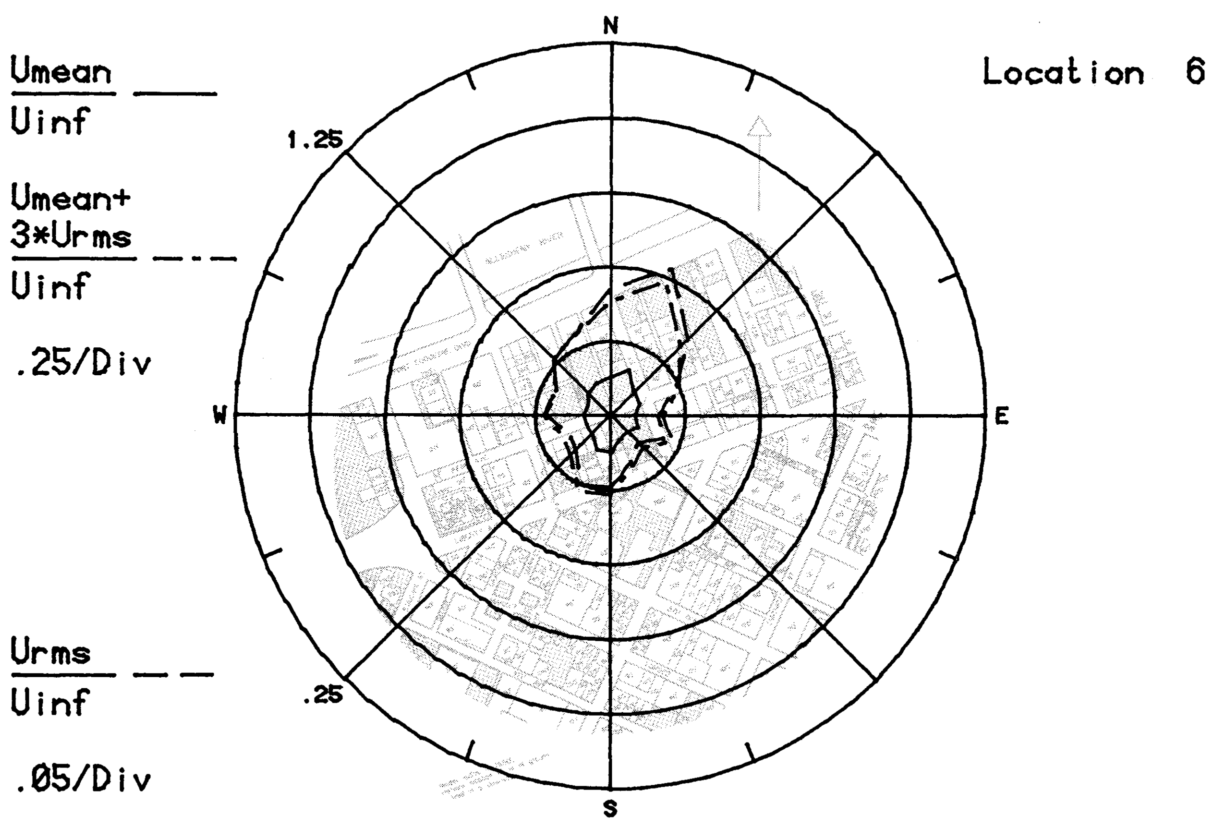

Figure 6f. Mean Velocities and Turbulence Intensities at Pedestrian Locations 5 and 6

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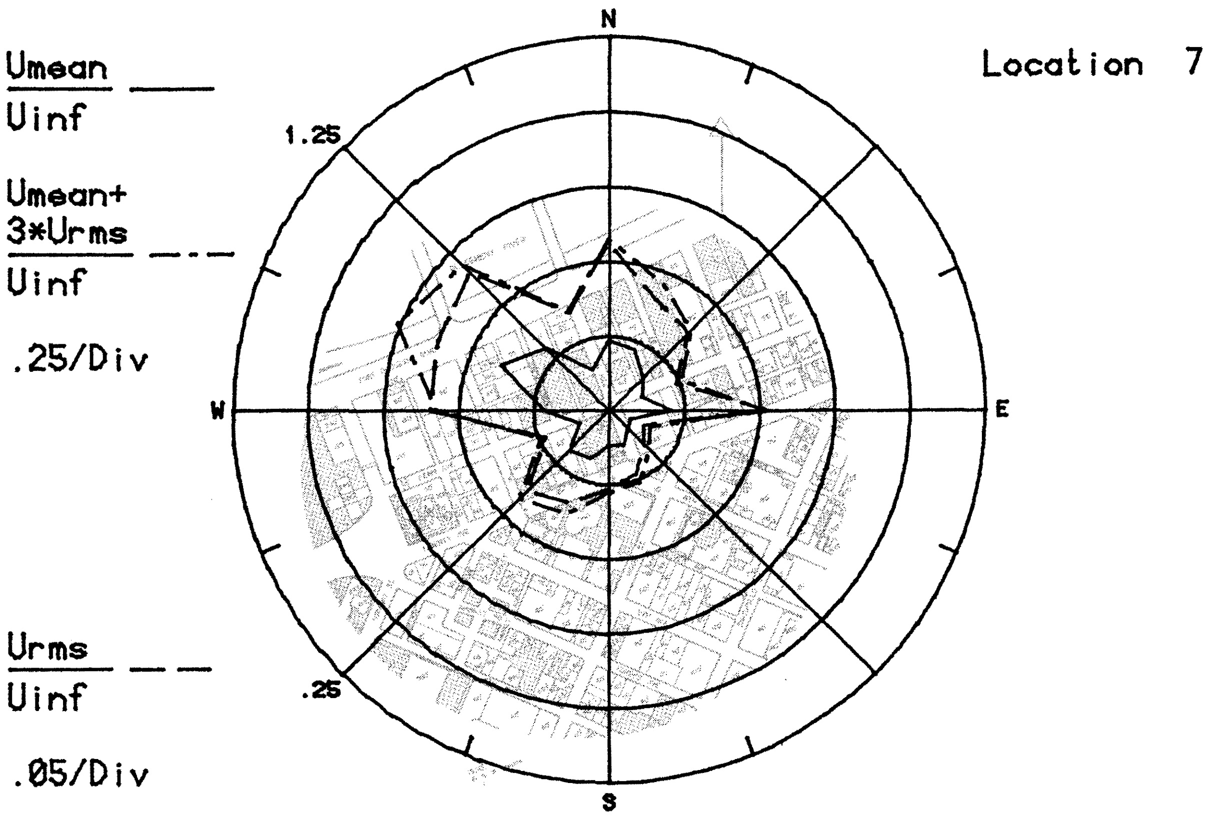

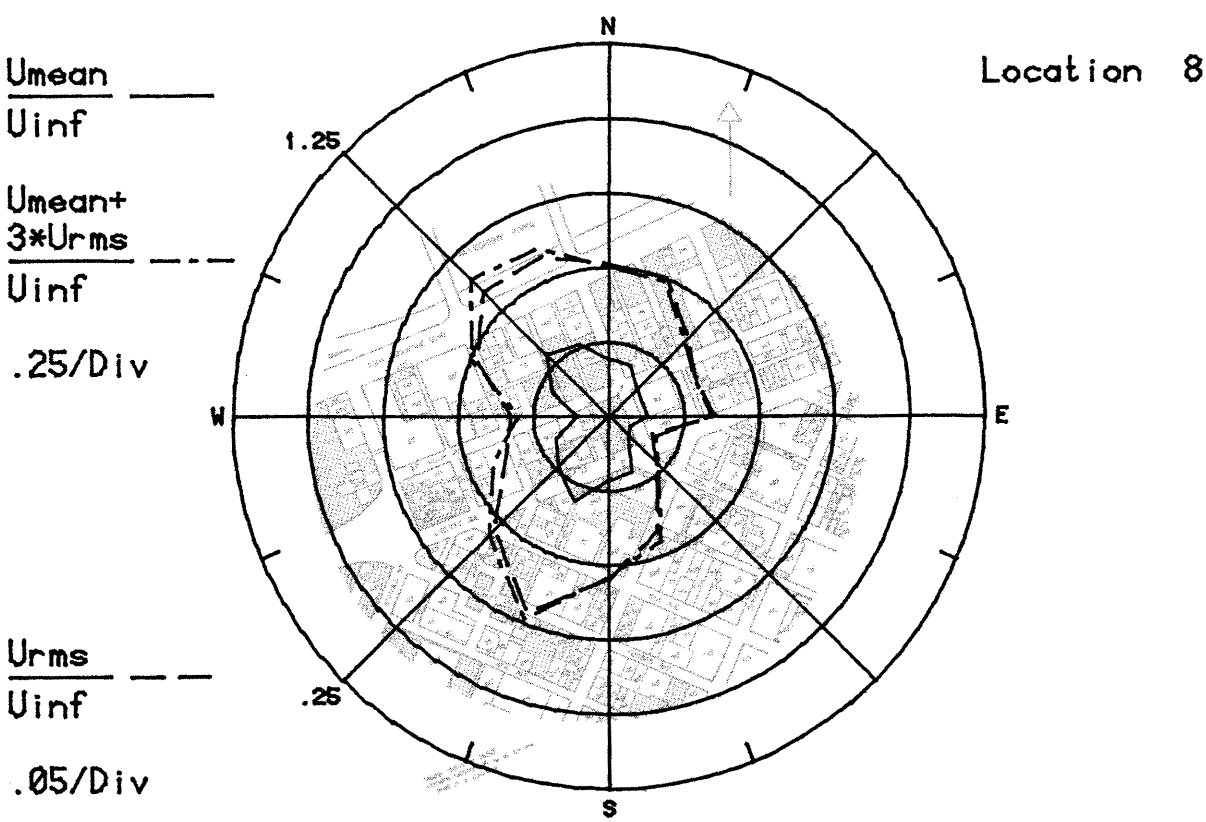

Figure 6g. Mean Velocities and Turbulence Intensities at Pedestrian Locations 7 and 8

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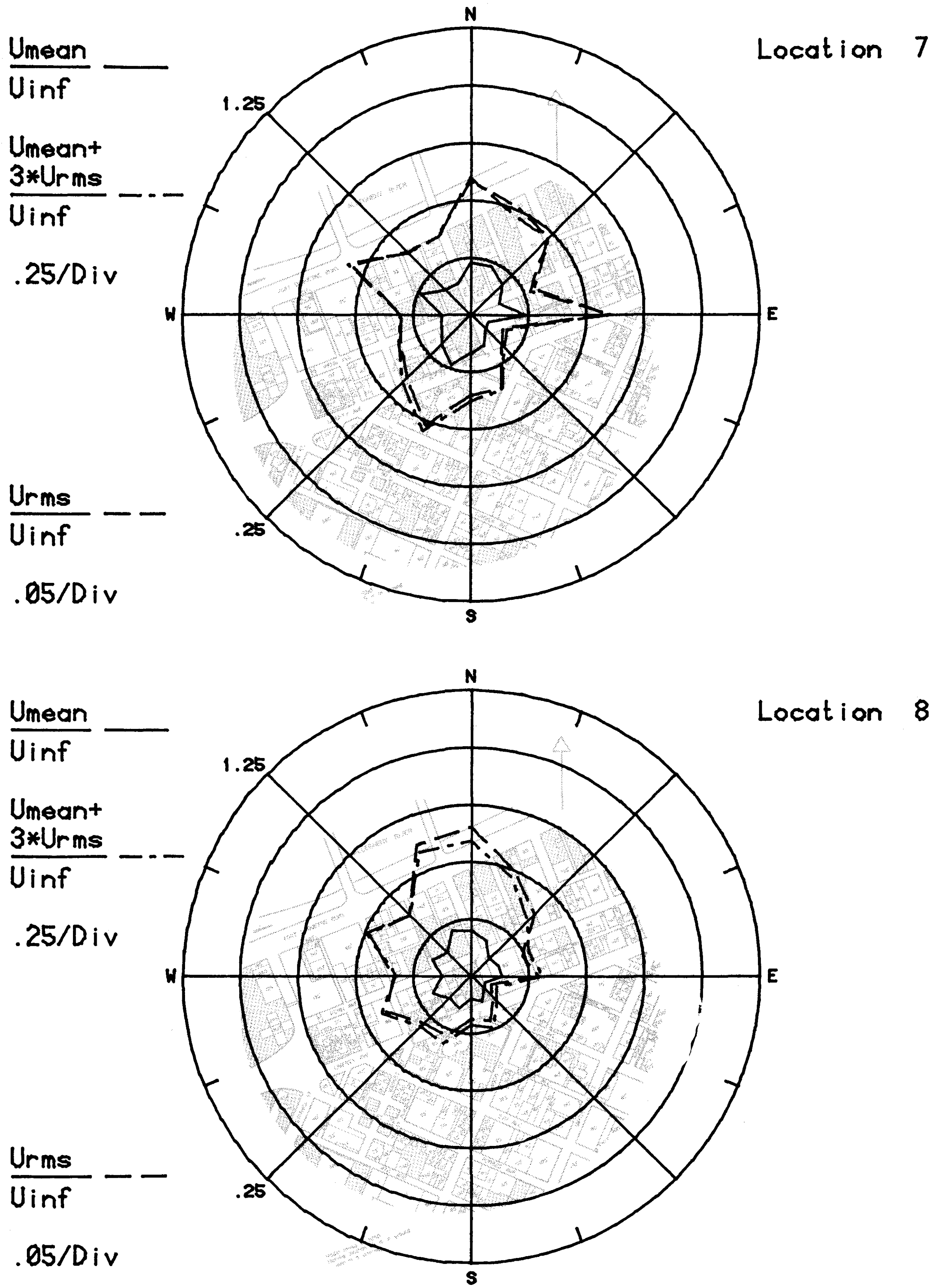
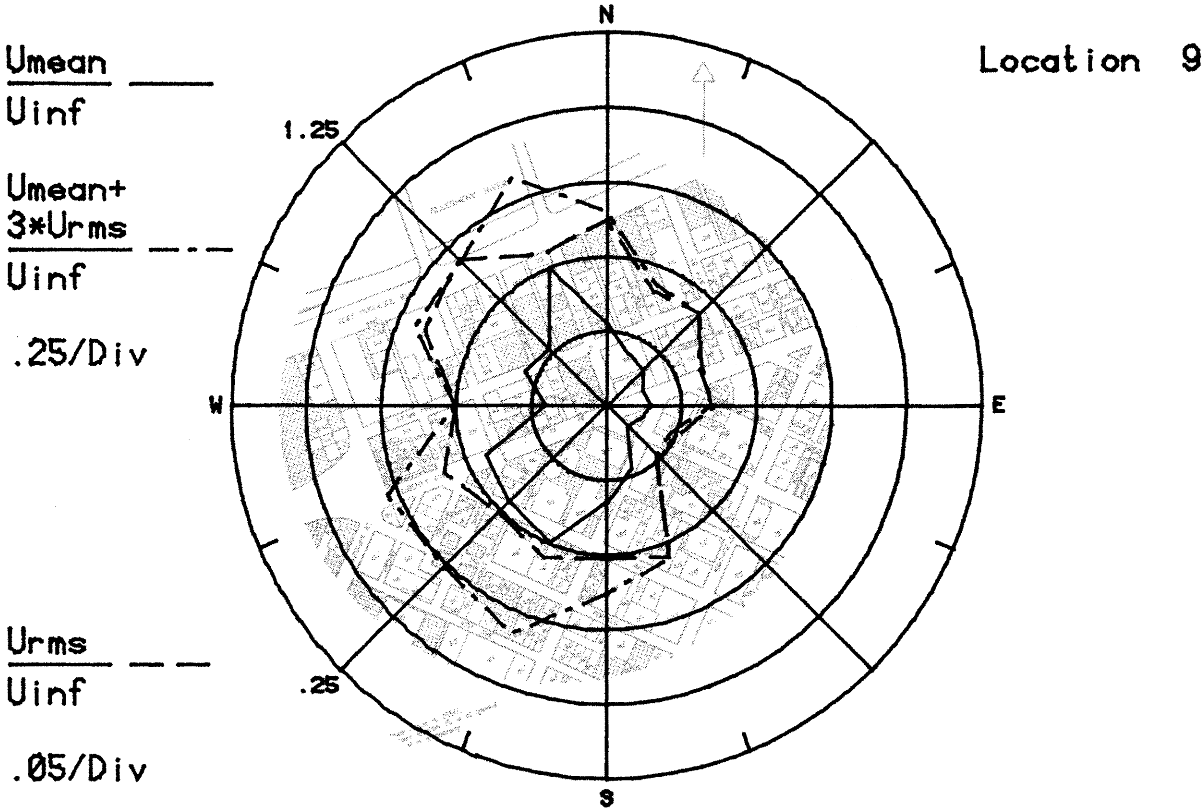


Figure 6h. Mean Velocities and Turbulence Intensities at Pedestrian Locations 7 and 8

Allegheny International



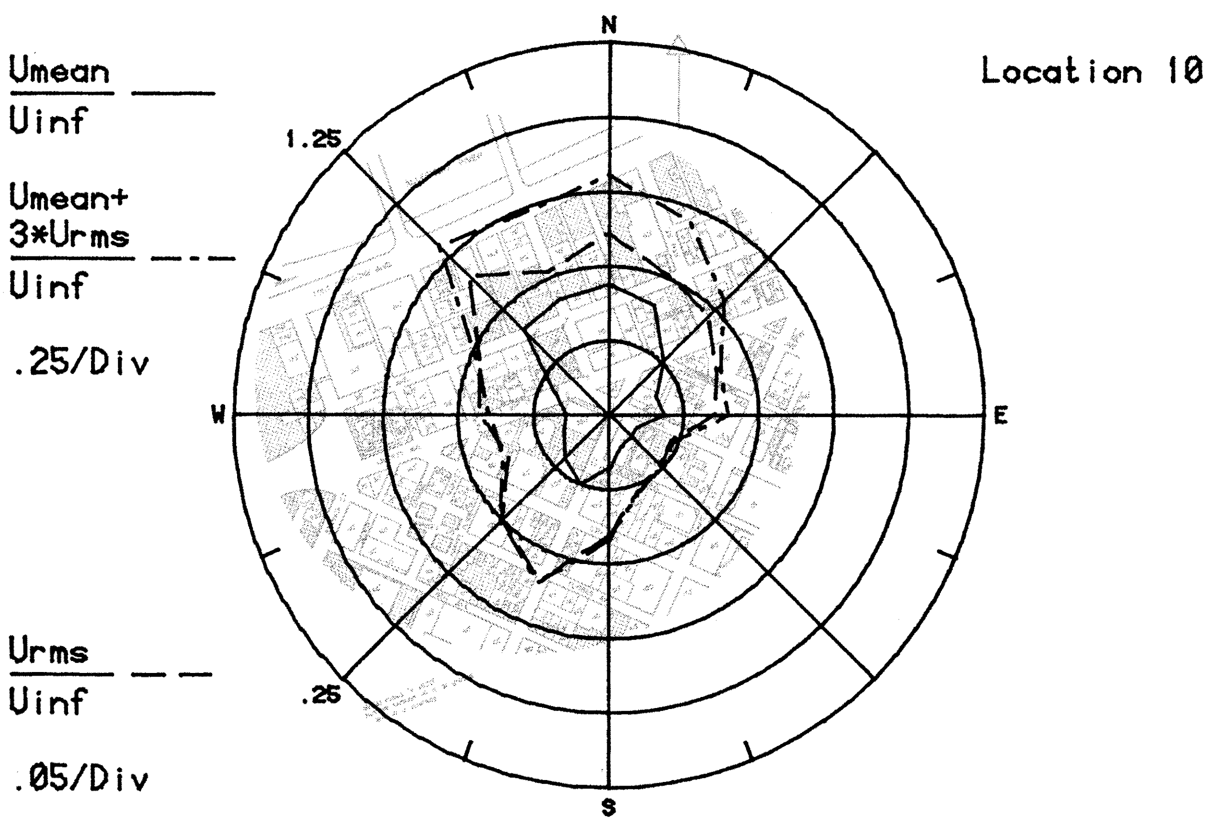
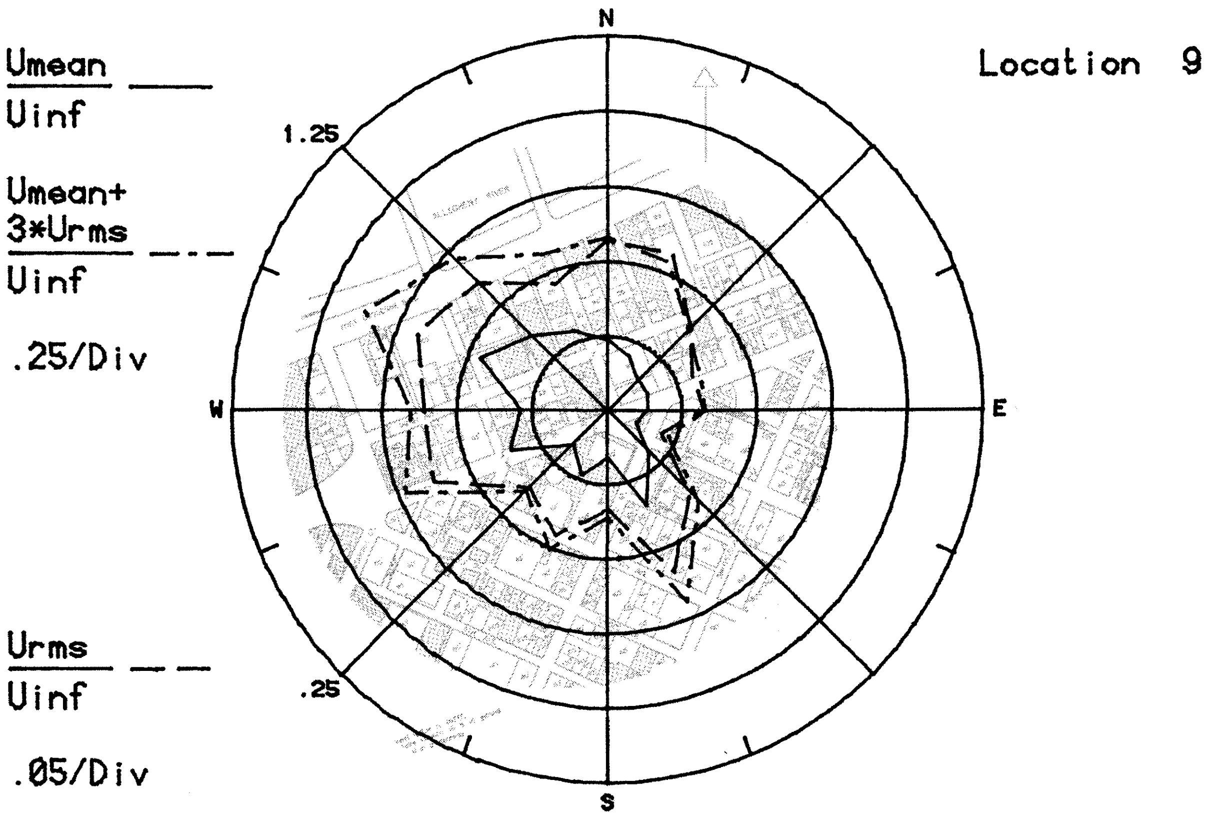


Figure 6i. Mean Velocities and Turbulence Intensities at Pedestrian Locations 9 and 10

Existing Configuration



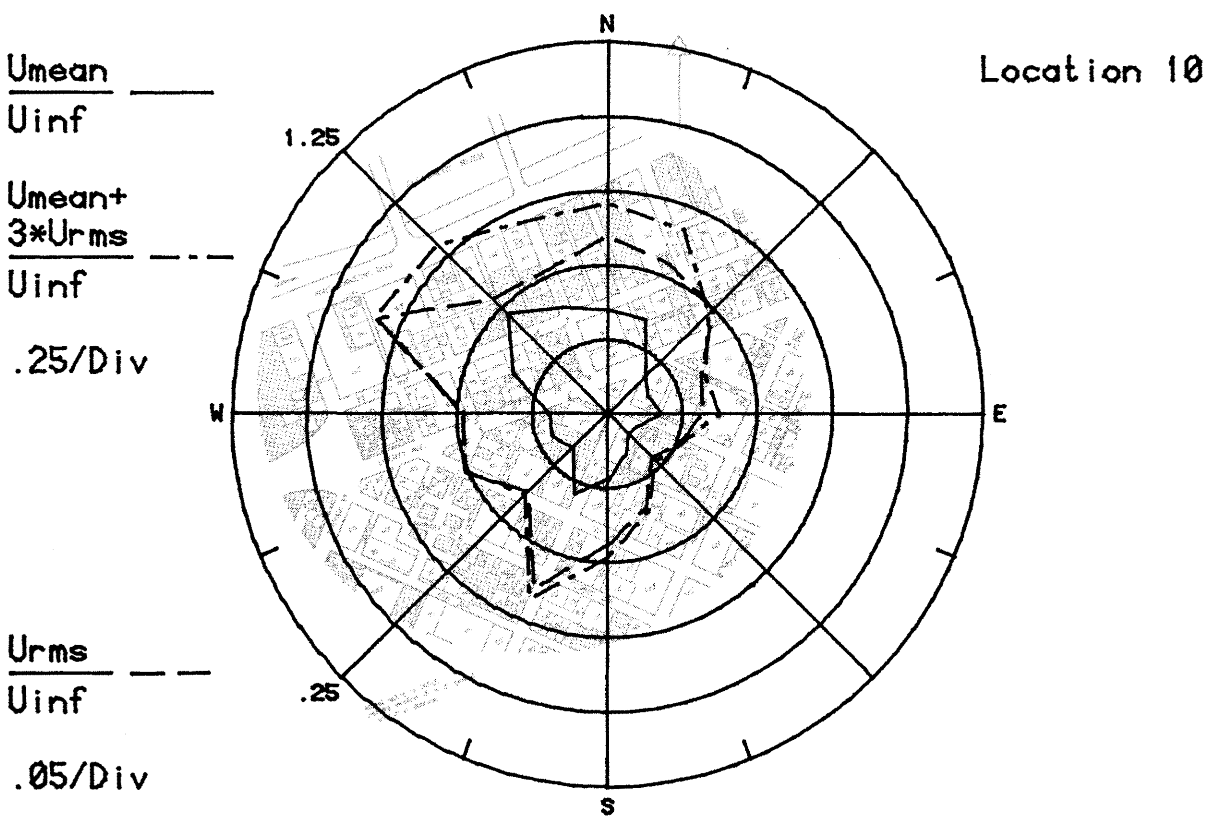


Figure 6j. Mean Velocities and Turbulence Intensities at Pedestrian Locations 9 and 10

Allegheny International

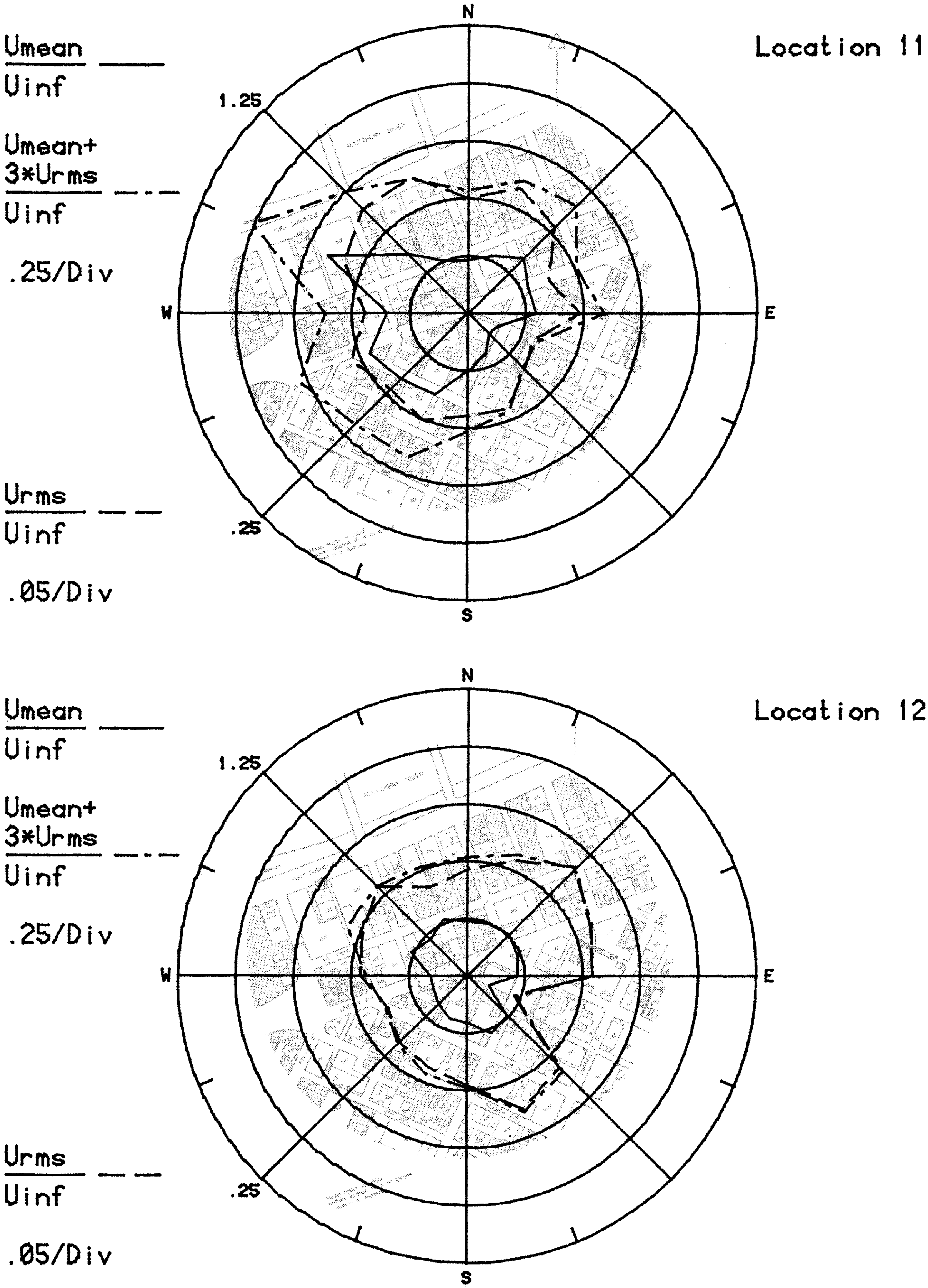


Figure 6k. Mean Velocities and Turbulence Intensities at Pedestrian Locations 11 and 12

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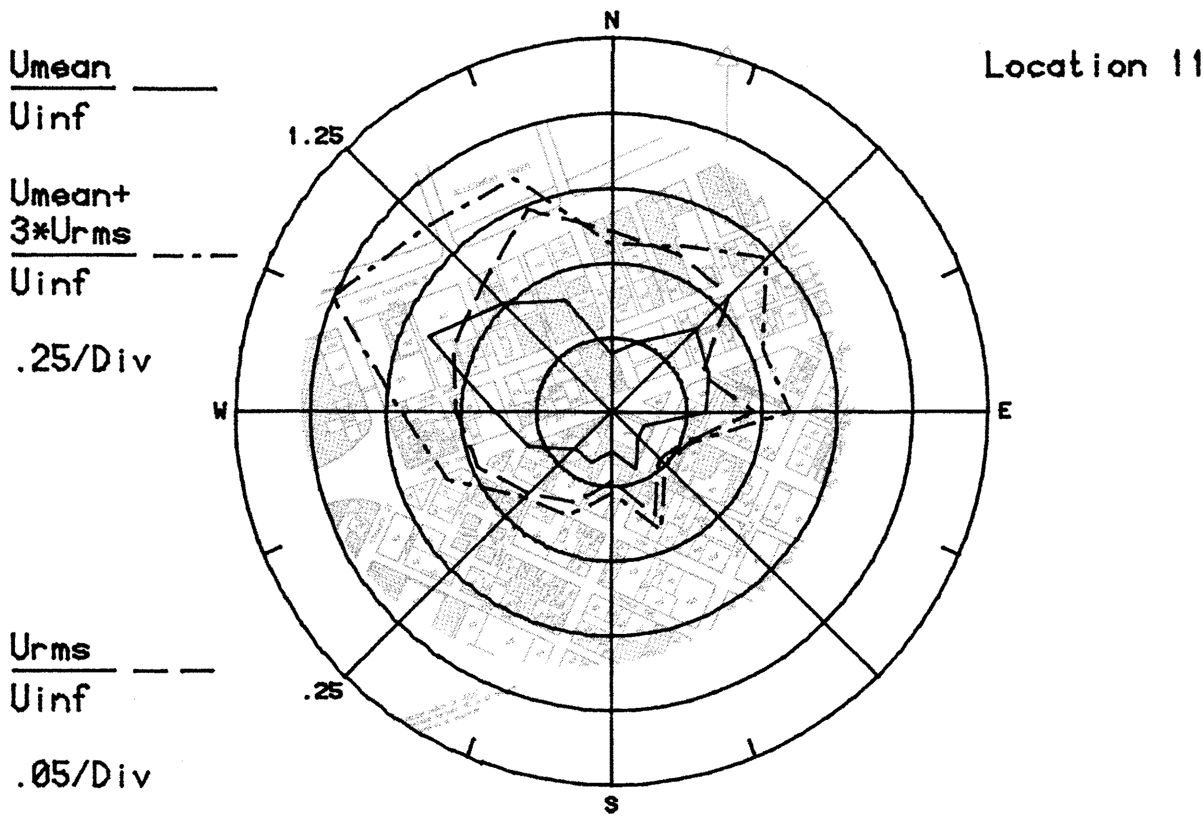

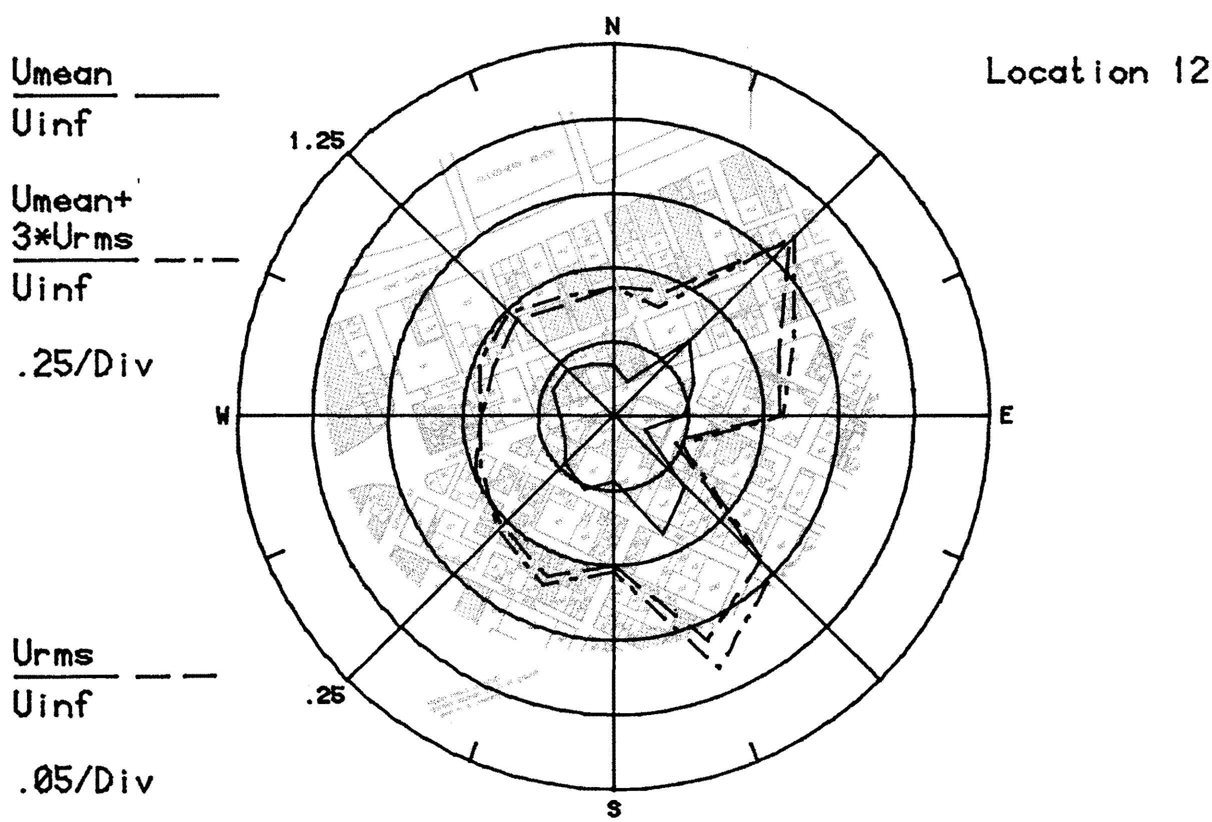

Figure 61. Mean Velocities and Turbulence Intensities at Pedestrian Locations 11 and 12

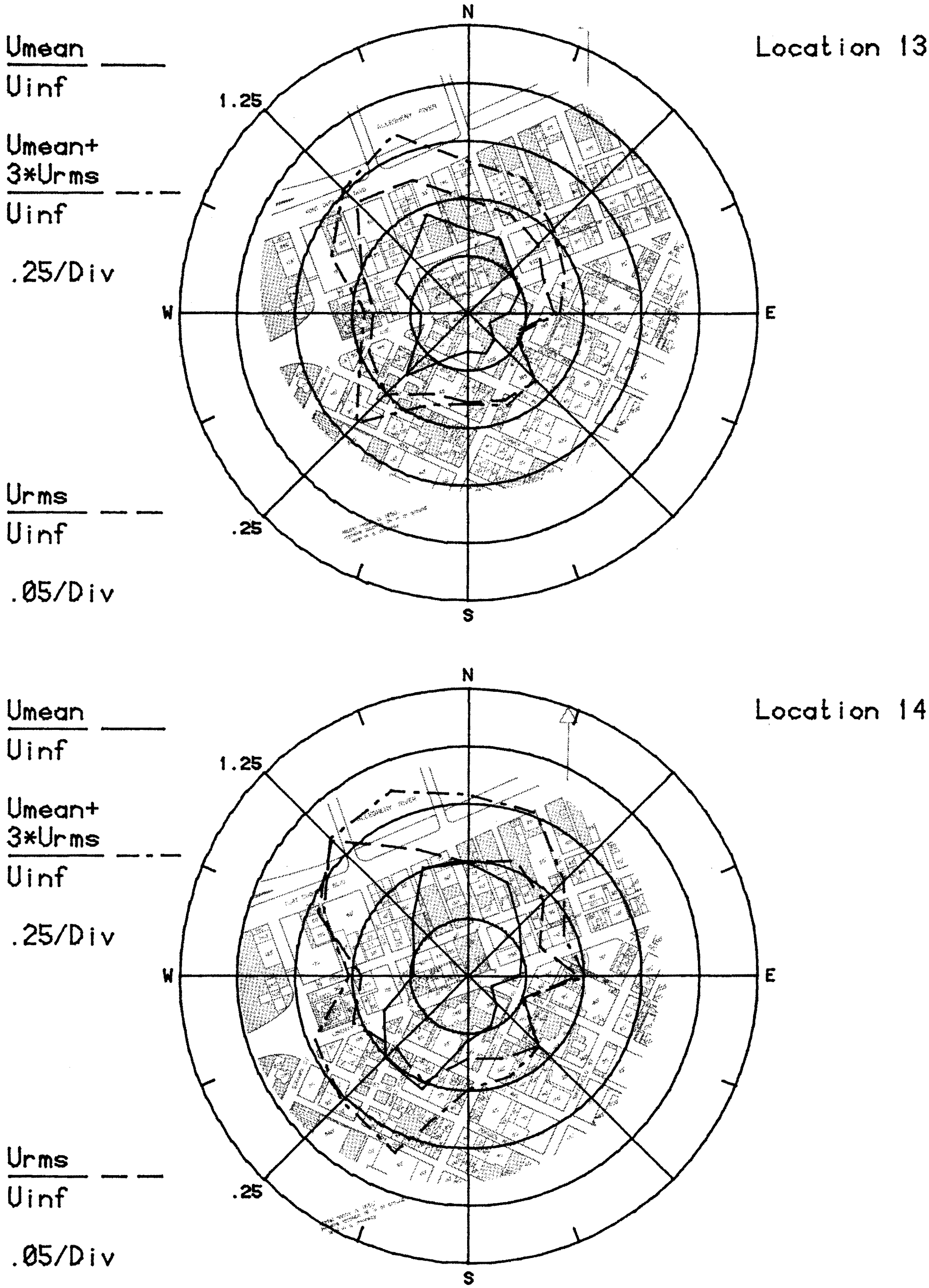

Figure 6m. Mean Velocities and Turbulence Intensities at Pedestrian Locations 13 and 14

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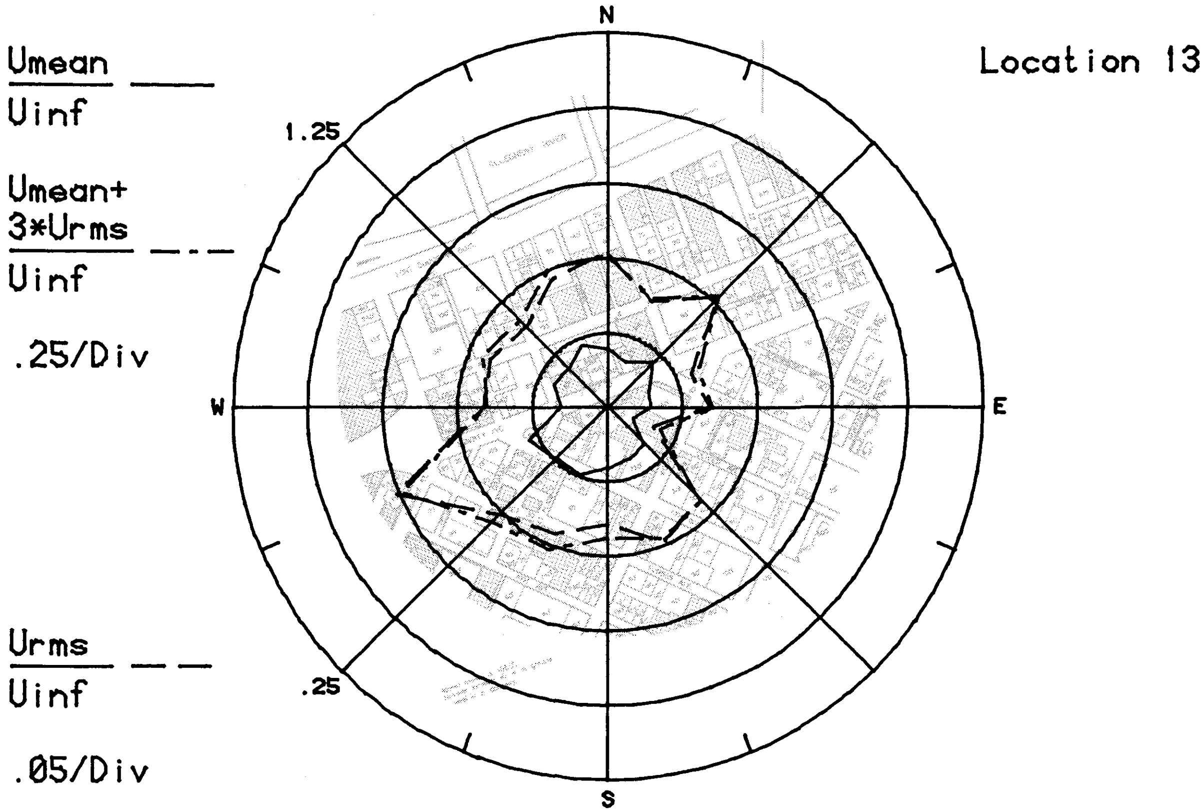

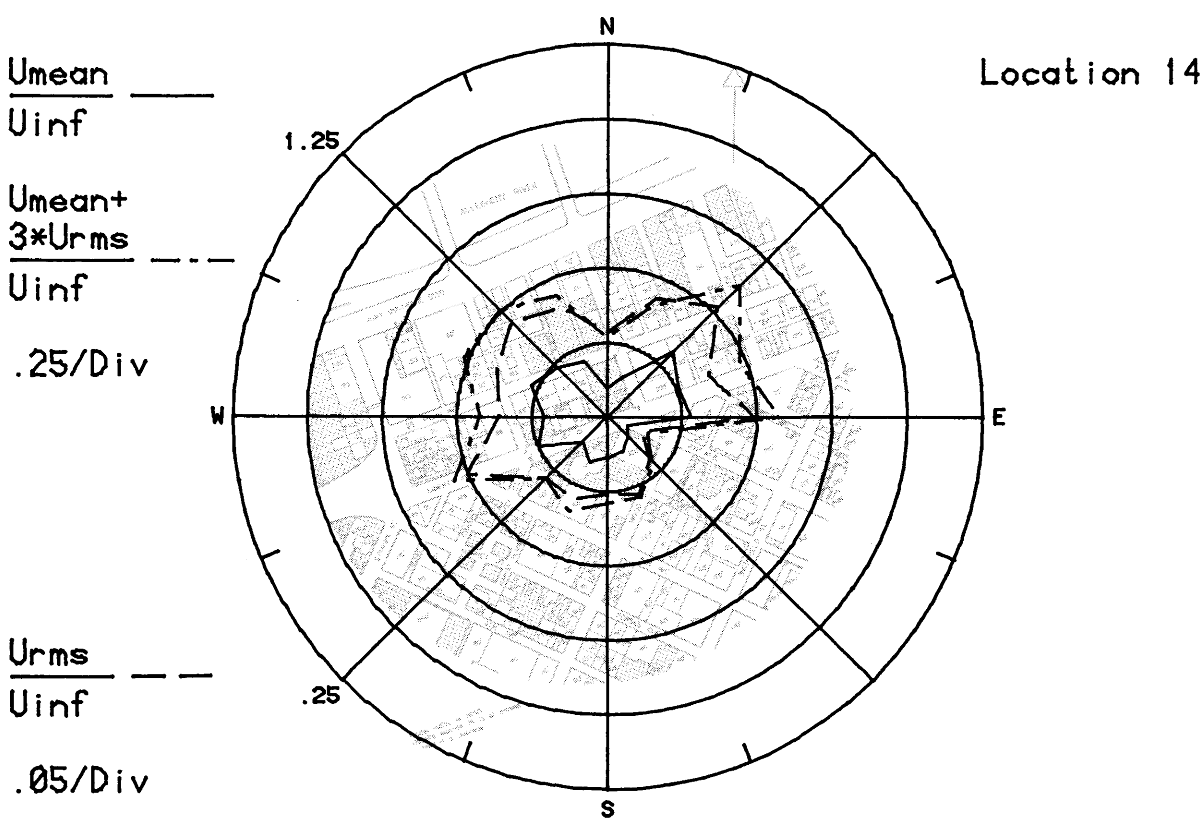

Figure 6n. Mean Velocities and Turbulence Intensities at Pedestrian Locations 13 and 14

Allegheny International

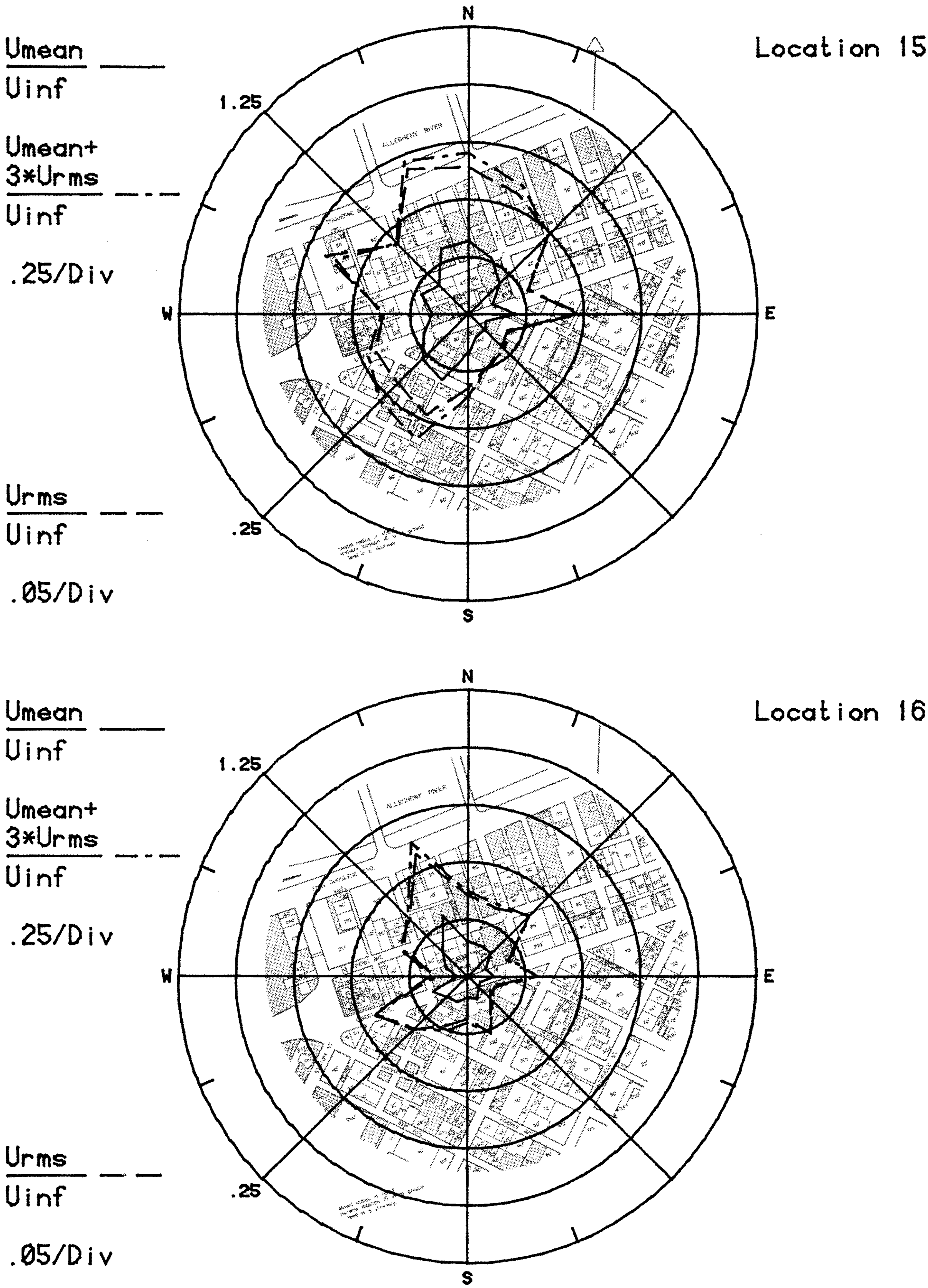

Figure 6o. Mean Velocities and Turbulence Intensities at Pedestrian Locations 15 and 16

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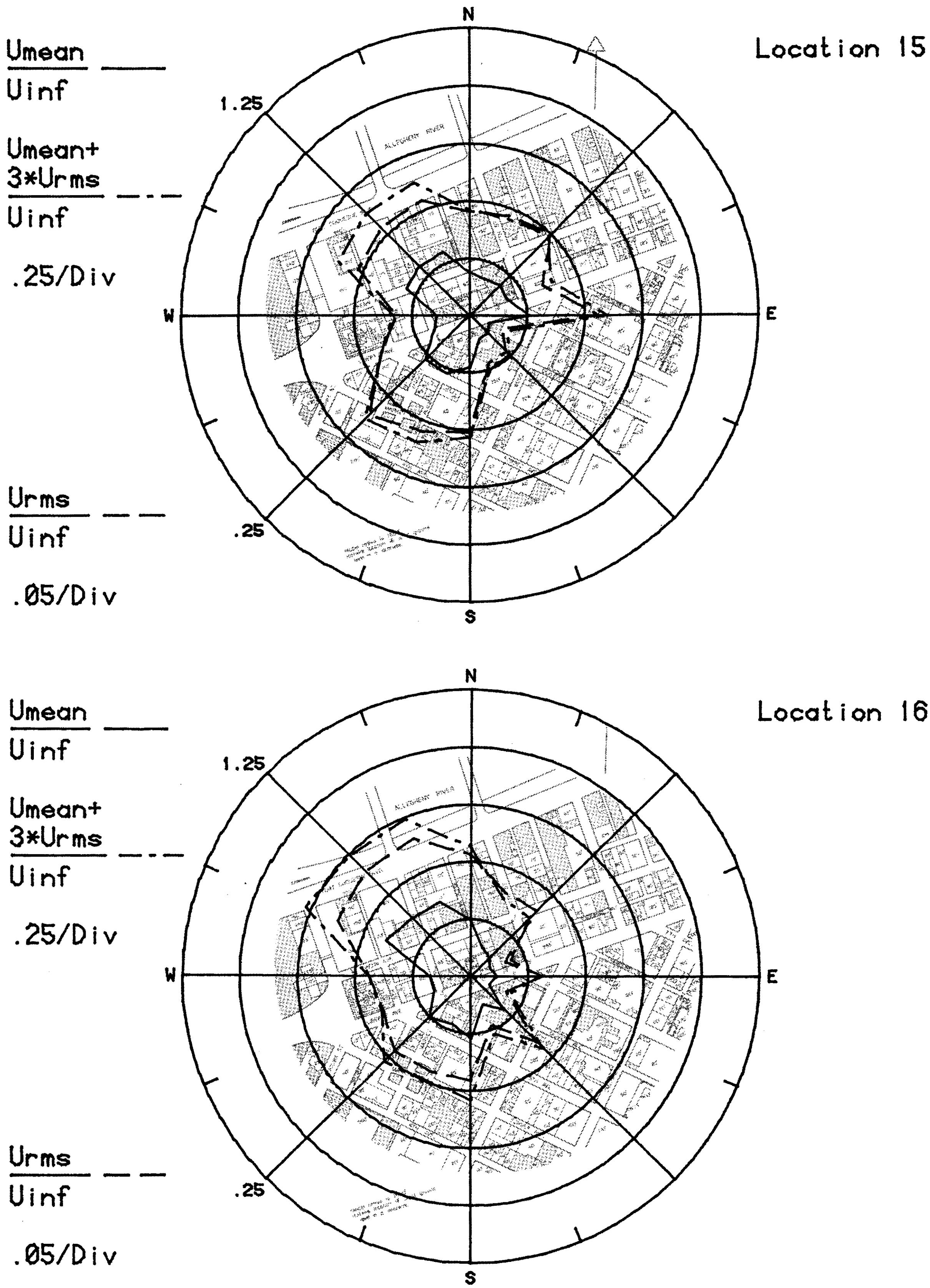

Figure 6p. Mean Velocities and Turbulence Intensities at Pedestrian Locations 15 and 16

Allegheny International

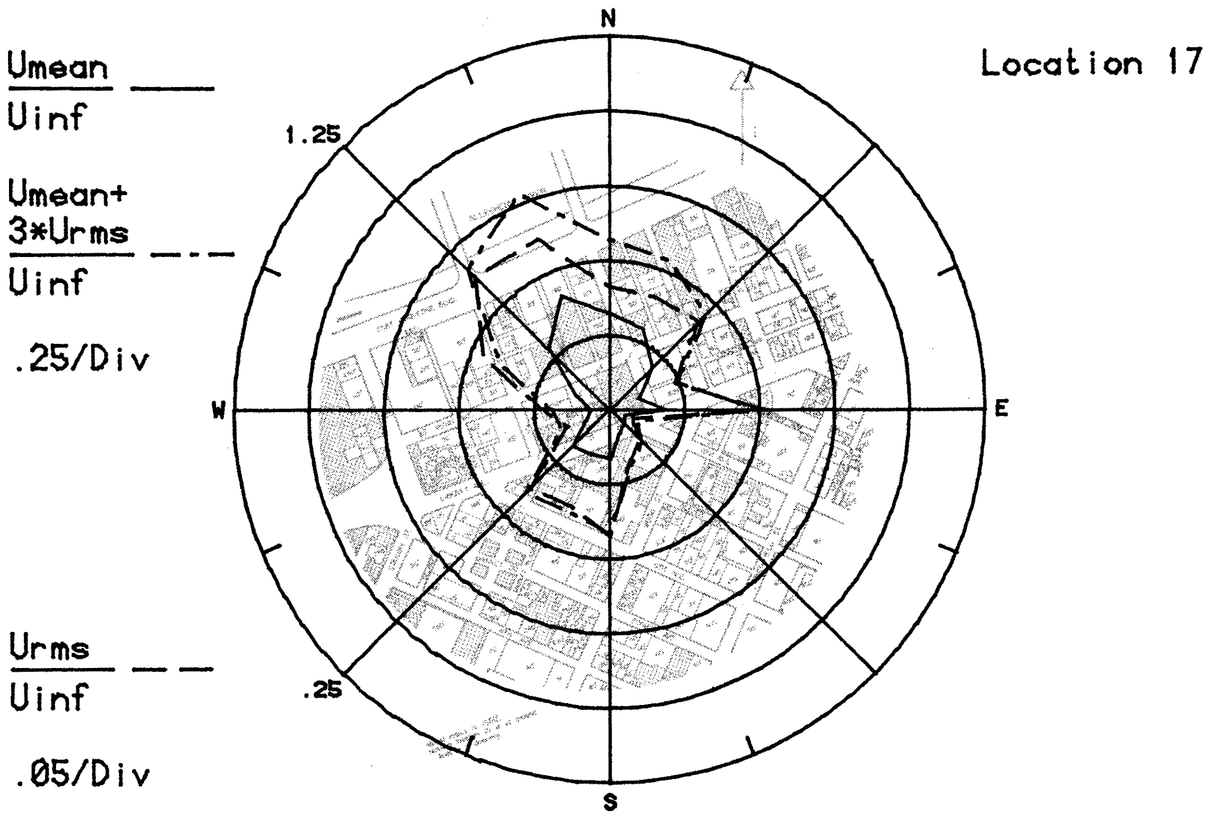

Figure 6q. Mean Velocities and Turbulence Intensities at Pedestrian Location 17

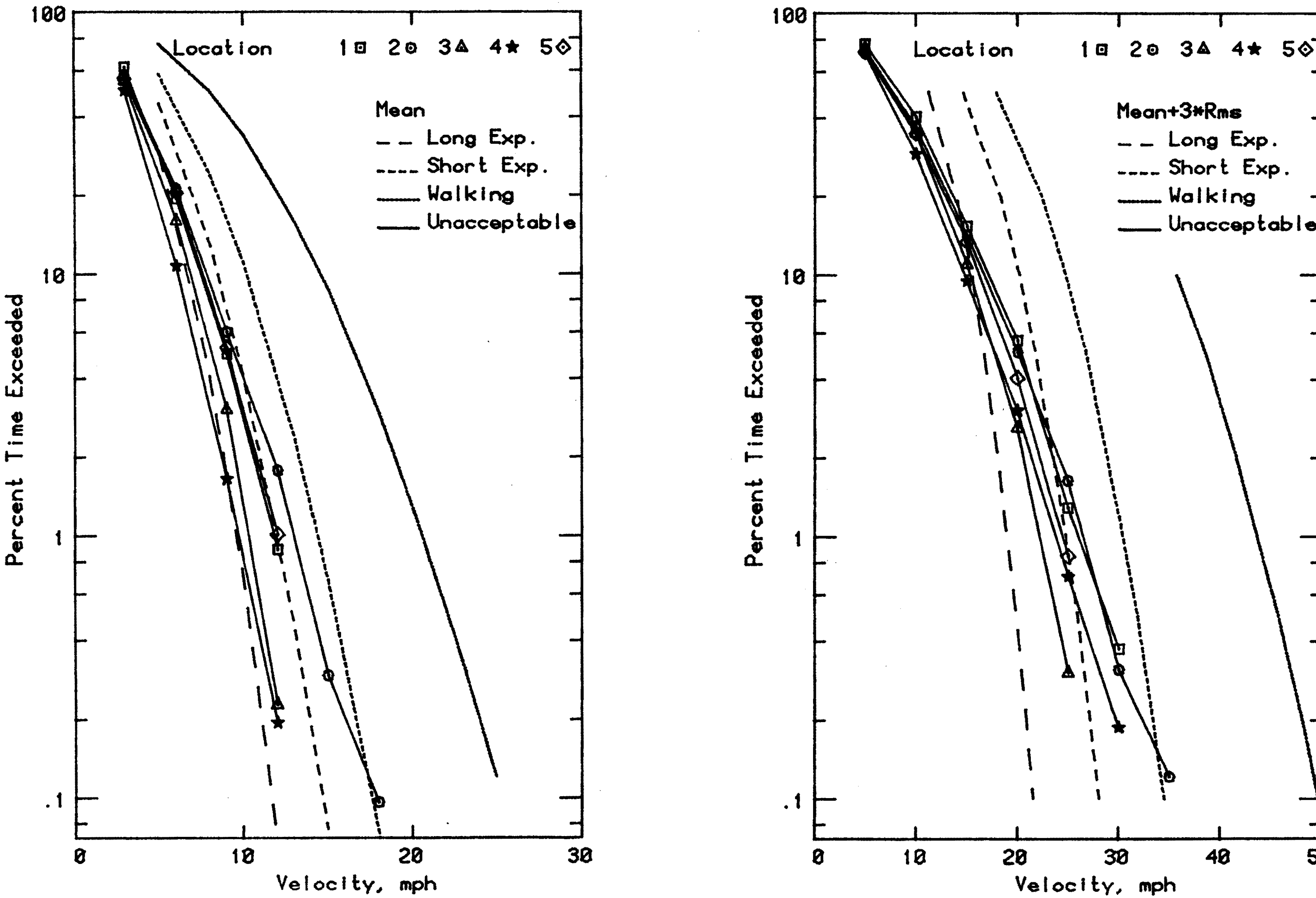

Figure 7a. Wind Velocity Probabilities for Pedestrian Locations

Existing Configuration

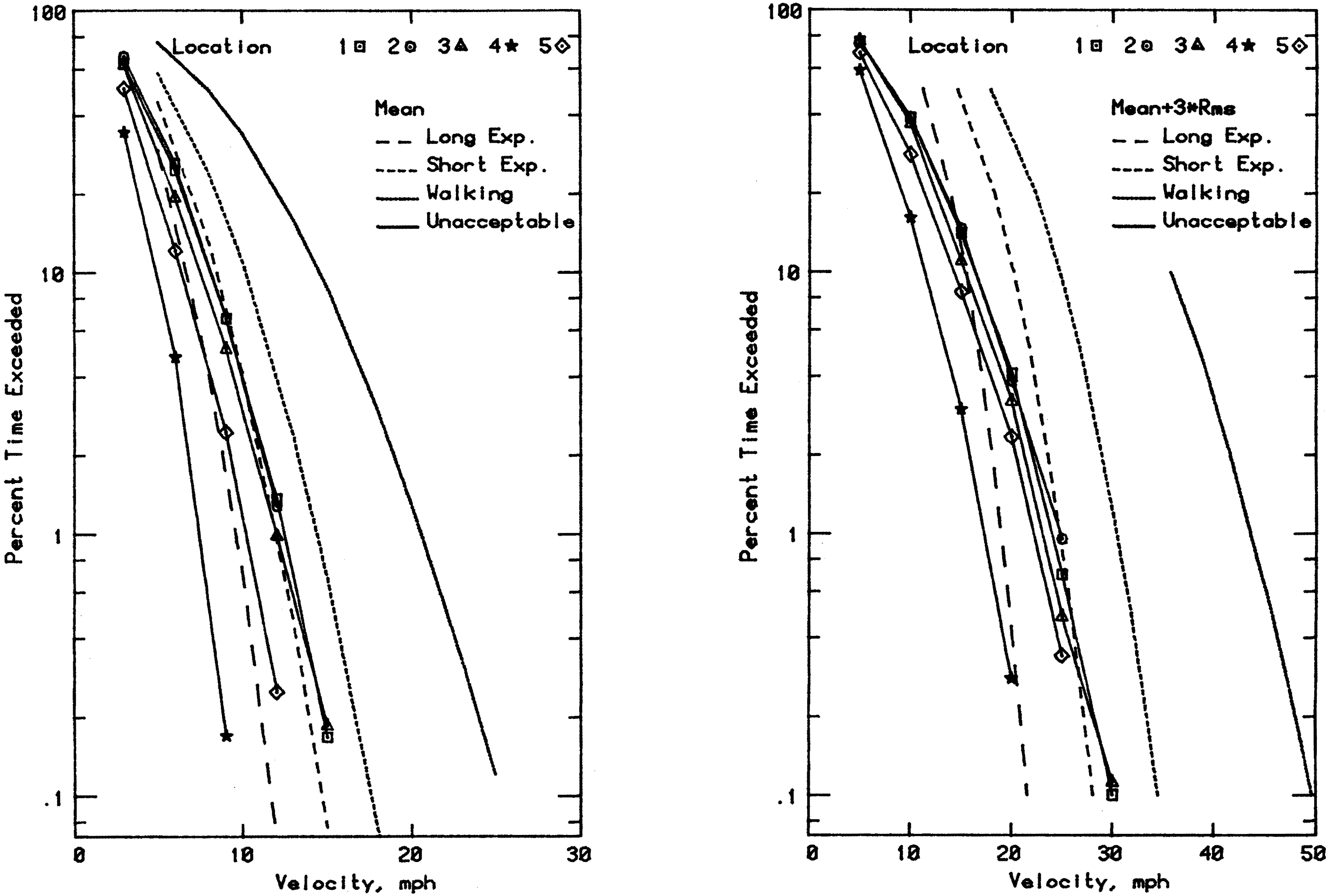

Figure 7b. Wind Velocity Probabilities for Pedestrian Locations

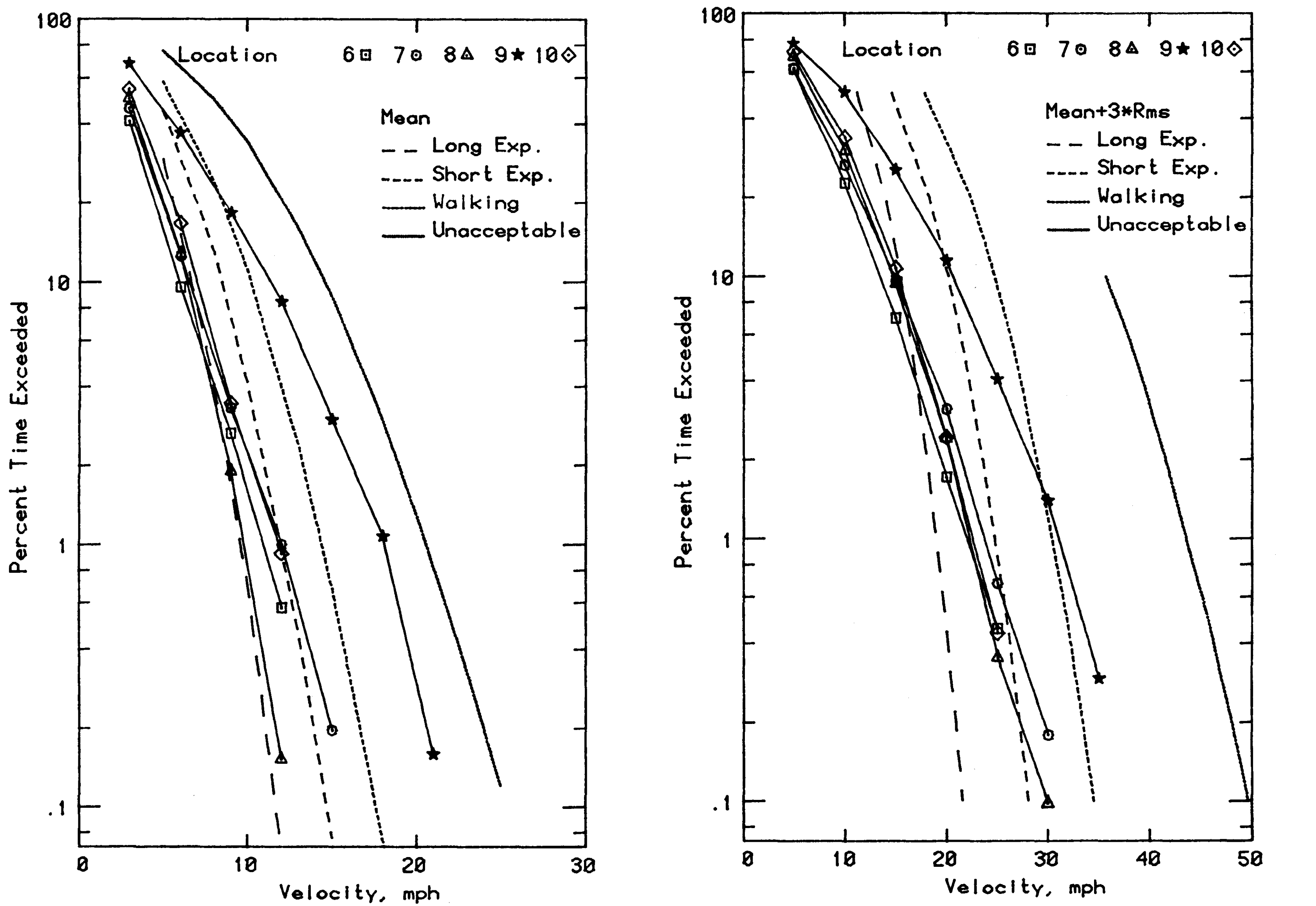

Figure 7c. Wind Velocity Probabilities for Pedestrian Locations

Existing Configuration

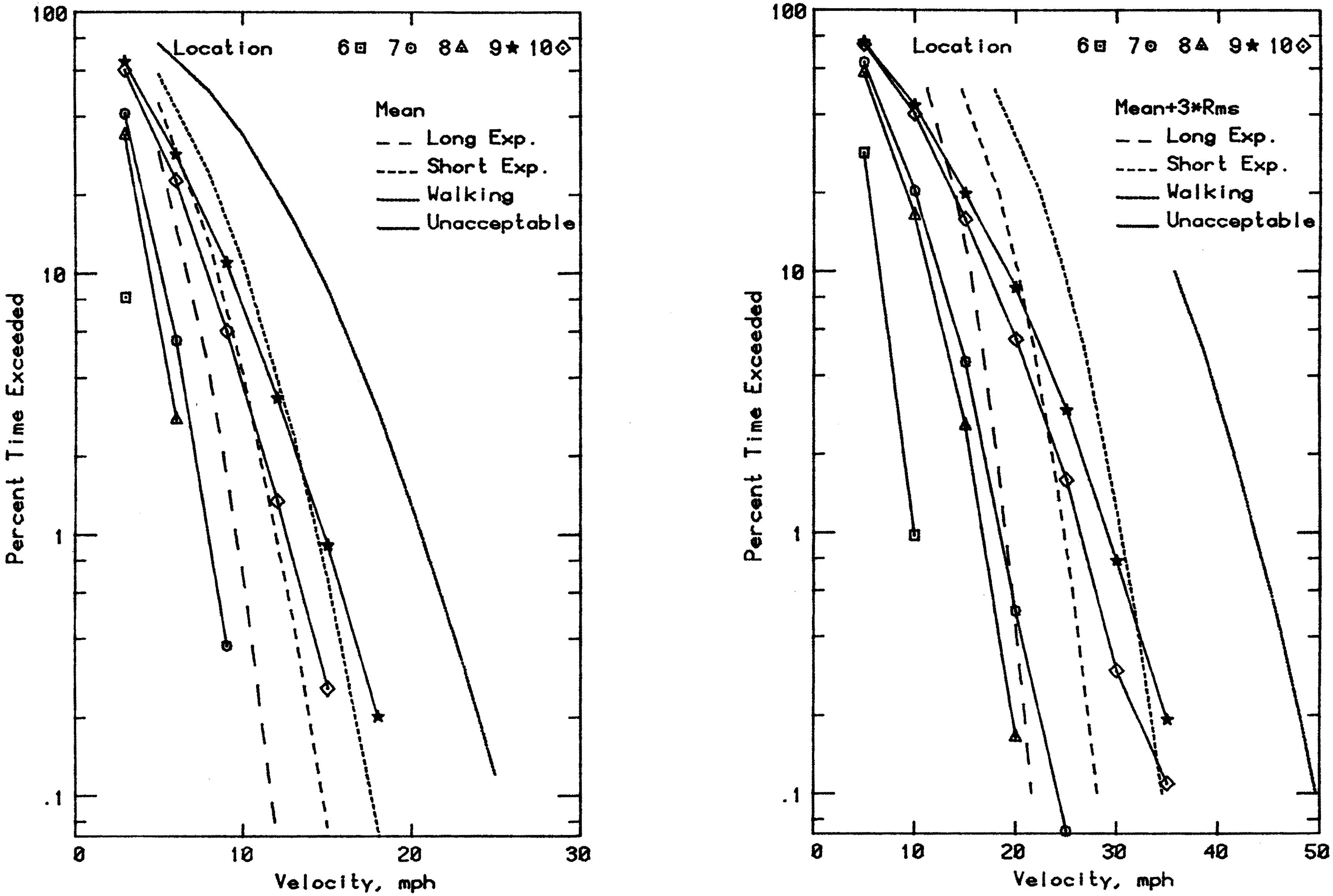

Figure 7d. Wind Velocity Probabilities for Pedestrian Locations

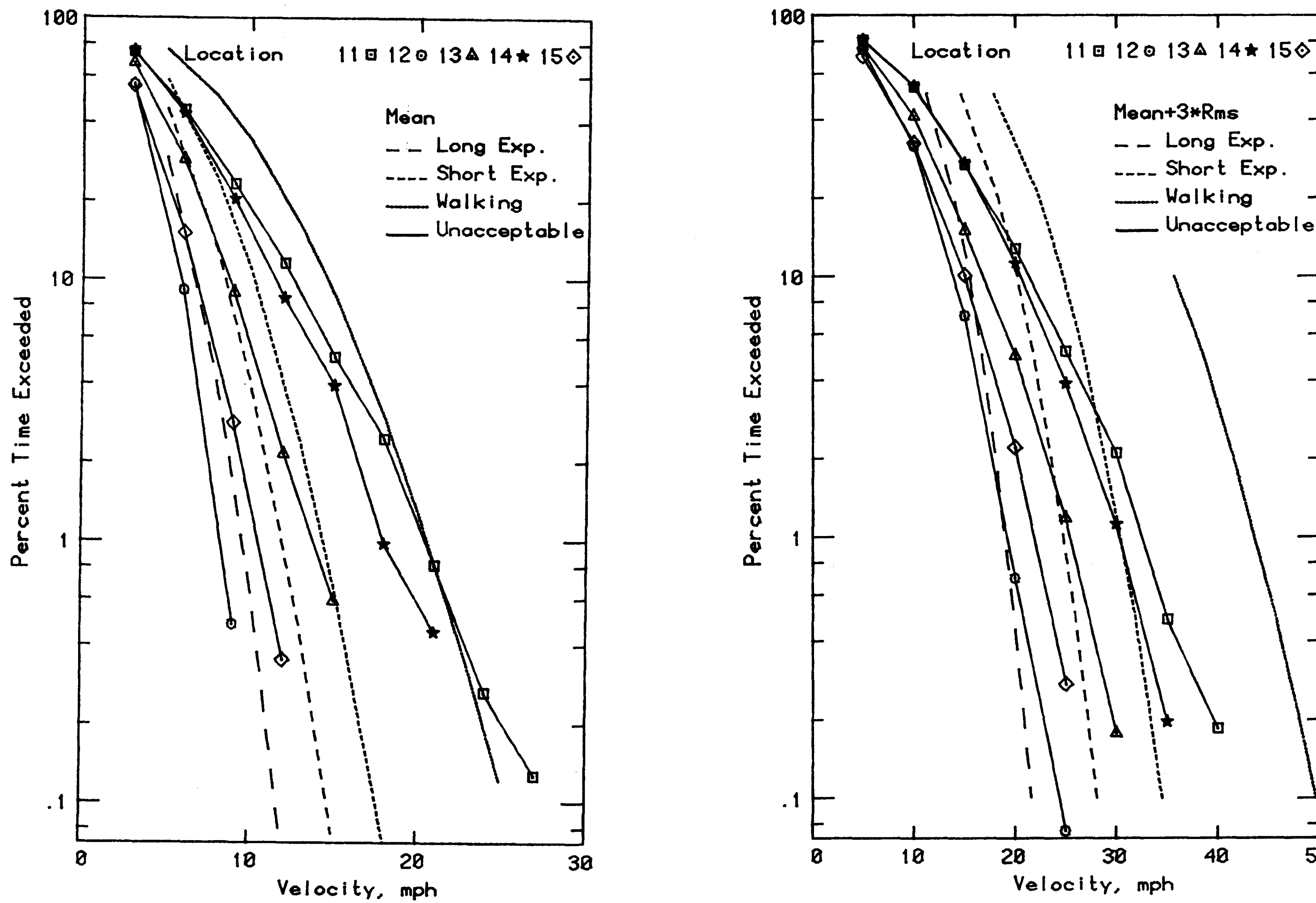

Figure 7e. Wind Velocity Probabilities for Pedestrian Locations

Existing Configuration

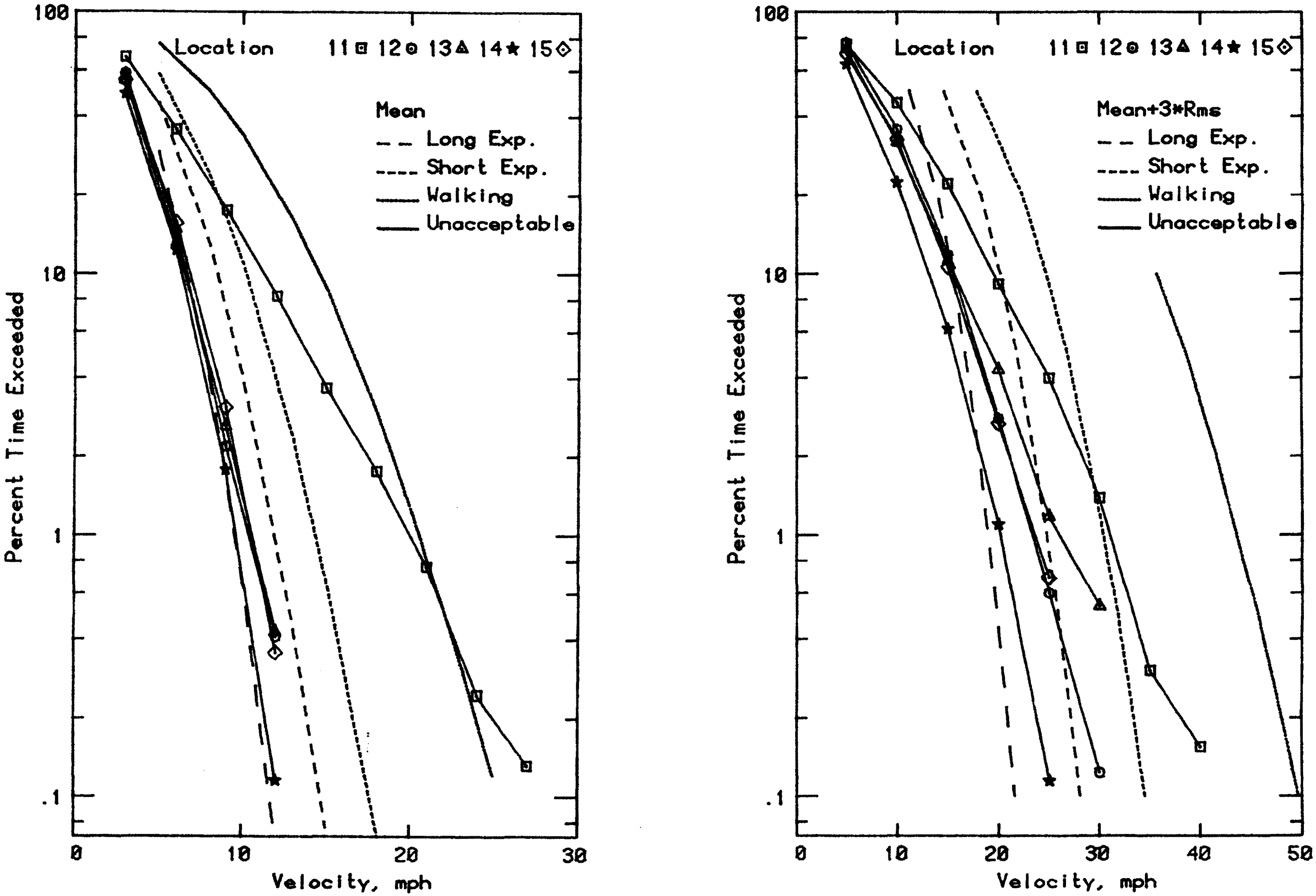

Figure 7f. Wind Velocity Probabilities for Pedestrian Locations

Allegheny International

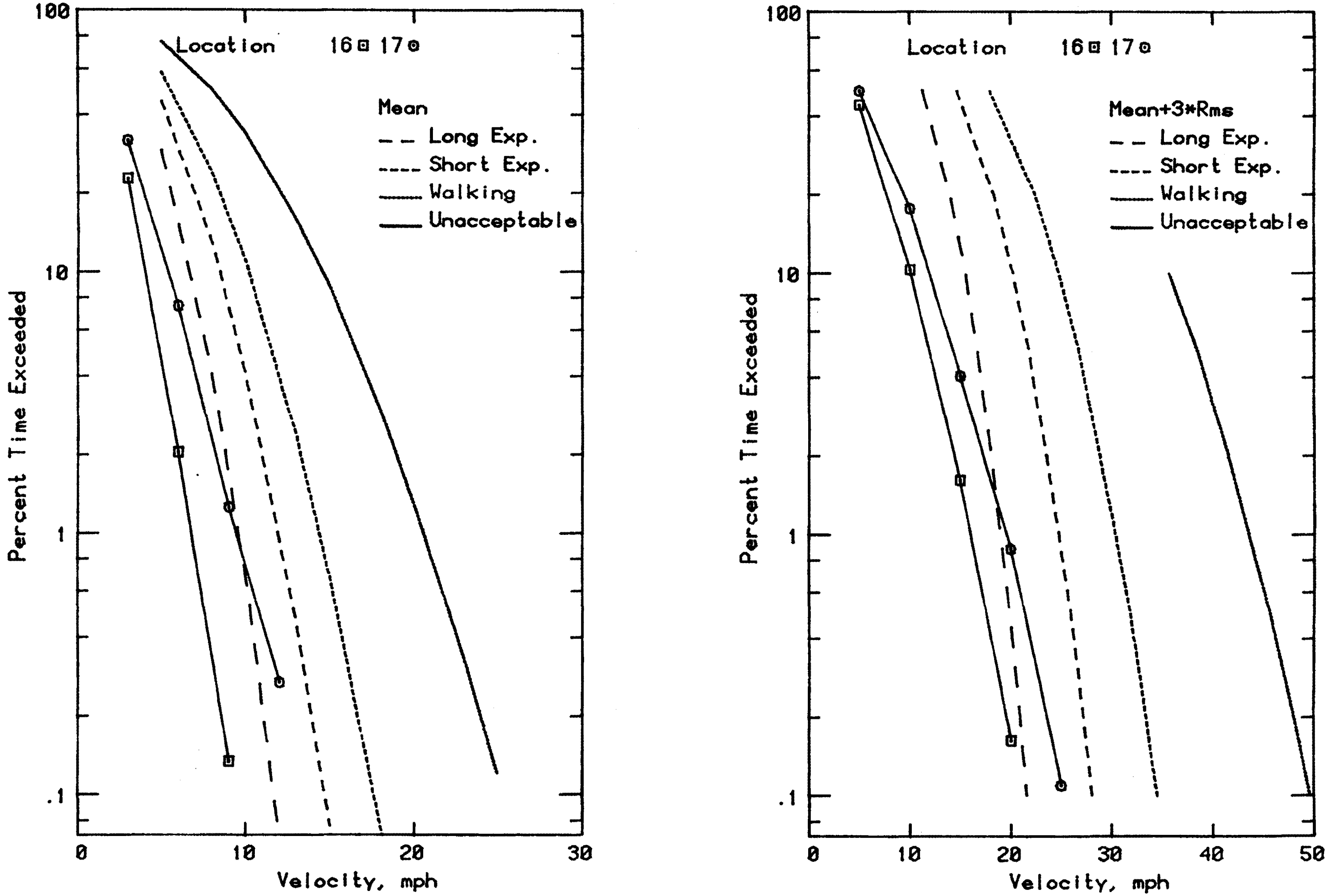

Figure 7g. Wind Velocity Probabilities for Pedestrian Locations

Existing Configuration

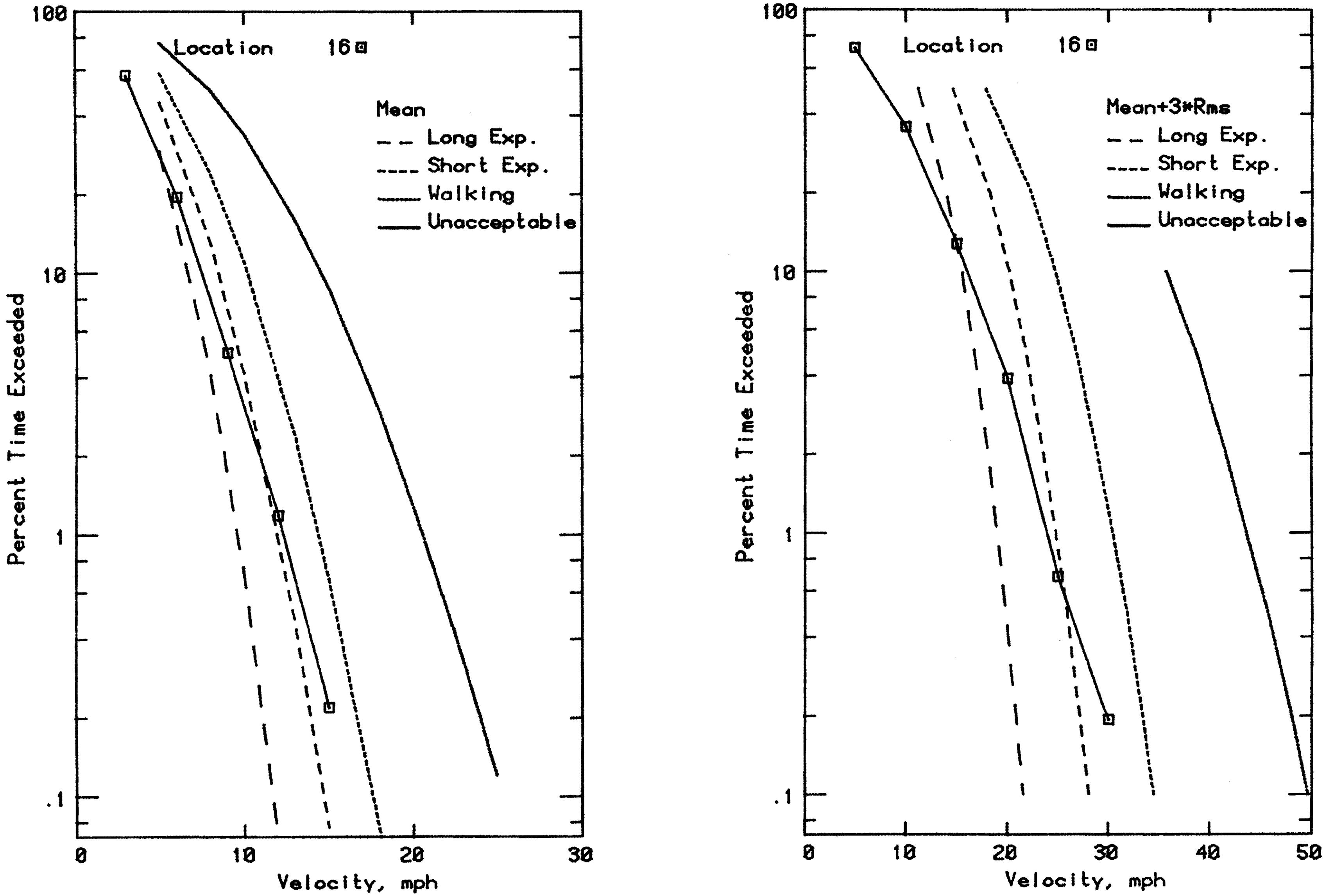

Figure 7h. Wind Velocity Probabilities for Pedestrian Locations

TABLES

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ALLEGHENY INTERNATIONAL

LOCATION 1

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	27.2	14.5	70.6
22.50	27.7	13.5	68.1
45.00	29.1	12.0	65.1
67.50	17.7	7.1	38.8
90.00	25.2	9.6	53.9
112.50	16.3	7.3	38.3
135.00	19.9	8.6	45.8
157.50	21.6	10.1	51.9
180.00	18.2	7.1	39.5
202.50	27.3	12.4	64.4
225.00	23.1	9.5	51.6
247.50	31.2	13.2	71.0
270.00	11.9	7.2	33.5
292.50	29.3	11.1	62.5
315.00	29.7	14.3	72.7
337.50	19.5	9.3	47.5

LOCATION 2

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	31.5	11.3	65.4
22.50	28.2	11.6	63.1
45.00	22.3	10.3	53.2
67.50	15.7	6.0	33.6
90.00	23.7	9.4	51.8
112.50	19.7	6.7	39.6
135.00	15.2	7.1	36.6
157.50	18.9	8.0	43.0
180.00	23.7	6.8	44.0
202.50	20.2	5.6	37.1
225.00	27.5	11.0	60.7
247.50	18.3	10.2	48.8
270.00	9.1	5.8	26.5
292.50	42.7	14.1	85.1
315.00	36.0	12.2	72.6
337.50	34.4	12.9	73.2

LOCATION 3

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	26.7	11.5	61.3
22.50	32.9	16.3	81.7
45.00	26.8	13.6	67.6
67.50	13.4	6.5	33.0
90.00	18.4	10.8	50.9
112.50	16.9	7.1	38.1
135.00	23.9	11.2	57.7
157.50	24.5	9.9	54.1
180.00	34.7	12.2	71.2
202.50	28.0	10.6	59.8
225.00	21.7	10.1	51.9
247.50	14.2	7.1	35.5
270.00	9.3	6.5	28.9
292.50	22.8	10.2	53.3
315.00	36.0	11.8	71.5
337.50	31.8	11.6	66.6

LOCATION

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	18.8	7.8	42.2
22.50	23.6	9.4	51.7
45.00	22.2	8.7	48.4
67.50	15.6	7.2	37.2
90.00	15.2	7.2	36.8
112.50	9.6	4.6	23.3
135.00	17.9	7.5	40.3
157.50	21.6	10.2	52.2
180.00	16.3	8.0	40.4
202.50	19.4	9.6	48.1
225.00	20.2	9.9	50.0
247.50	19.4	8.7	45.7
270.00	10.2	6.4	29.4
292.50	31.2	15.5	77.8
315.00	27.1	12.2	63.7
337.50	18.1	8.9	44.9

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ALLEGHENY INTERNATIONAL

LOCATION 5

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	22.1	7.9	45.7
22.50	27.2	12.1	63.6
45.00	20.8	9.4	48.9
67.50	13.6	6.4	32.7
90.00	14.7	8.1	39.0
112.50	9.6	4.2	22.1
135.00	11.6	4.9	26.4
157.50	22.0	10.5	53.6
180.00	15.3	8.0	39.2
202.50	25.8	11.3	59.6
225.00	30.5	11.5	64.9
247.50	25.0	9.9	54.8
270.00	9.9	7.1	31.2
292.50	29.8	10.7	61.8
315.00	39.7	11.6	74.6
337.50	22.0	7.4	44.1

LOCATION 6

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	14.8	7.2	36.3
22.50	20.2	9.2	47.7
45.00	20.3	10.4	51.7
67.50	12.6	6.1	30.7
90.00	13.1	6.6	32.9
112.50	7.5	3.1	16.8
135.00	6.8	2.7	14.9
157.50	8.6	3.5	19.1
180.00	22.2	10.4	53.5
202.50	28.4	11.6	63.3
225.00	31.2	9.9	60.9
247.50	11.9	4.9	26.6
270.00	11.0	6.8	31.5
292.50	17.2	10.1	47.5
315.00	20.9	10.3	51.7
337.50	20.2	9.6	48.9

LOCATION 7

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	23.5	11.2	57.2
22.50	22.1	8.0	46.3
45.00	16.1	7.4	38.4
67.50	11.7	4.7	25.8
90.00	20.7	10.5	52.2
112.50	7.1	2.5	14.5
135.00	8.7	3.3	18.6
157.50	12.4	4.6	26.3
180.00	11.8	5.3	27.5
202.50	17.3	6.7	37.5
225.00	18.8	7.7	41.8
247.50	10.6	4.6	24.3
270.00	21.7	11.9	57.4
292.50	39.3	12.3	76.1
315.00	29.6	13.1	68.9
337.50	14.9	7.1	36.2

LOCATION 8

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	19.3	10.2	49.9
22.50	18.7	10.0	48.8
45.00	13.4	7.5	35.8
67.50	12.3	6.3	31.2
90.00	12.9	7.1	34.1
112.50	7.5	3.1	16.7
135.00	9.6	4.6	23.3
157.50	20.0	8.3	45.0
180.00	21.3	10.9	54.0
202.50	30.8	14.2	73.5
225.00	24.2	10.8	56.5
247.50	19.3	7.3	41.4
270.00	10.5	6.5	29.9
292.50	20.8	9.5	49.2
315.00	29.6	11.8	65.0
337.50	26.1	11.6	60.8

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ALLEGHENY INTERNATIONAL

LOCATION 9

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	27.7	12.5	65.1
22.50	18.8	8.3	43.7
45.00	17.3	8.8	43.6
67.50	13.0	6.9	33.6
90.00	15.2	7.0	36.2
112.50	11.7	4.6	25.6
135.00	9.8	4.7	23.7
157.50	22.6	11.0	55.5
180.00	32.2	10.2	62.9
202.50	49.5	11.0	82.6
225.00	45.9	10.2	76.4
247.50	43.7	11.7	78.7
270.00	20.2	10.0	50.3
292.50	29.7	13.1	69.1
315.00	26.9	13.8	68.4
337.50	49.7	11.0	82.7

LOCATION 10

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	44.0	12.2	80.4
22.50	39.9	10.2	70.5
45.00	26.1	9.4	54.3
67.50	16.9	7.8	40.2
90.00	18.8	7.1	40.0
112.50	9.9	4.5	23.3
135.00	10.5	4.8	24.8
157.50	11.2	5.4	27.3
180.00	17.7	8.1	42.1
202.50	24.7	12.1	61.0
225.00	20.9	10.0	51.0
247.50	16.3	7.2	37.9
270.00	14.1	8.6	39.8
292.50	19.5	9.3	47.5
315.00	40.5	13.1	79.9
337.50	42.2	10.4	73.5

LOCATION 11

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	23.1	10.0	53.3
22.50	27.1	11.7	62.3
45.00	34.2	10.6	66.0
67.50	28.3	7.5	50.9
90.00	29.8	9.7	58.8
112.50	13.9	6.1	32.2
135.00	12.6	6.9	33.3
157.50	19.2	9.0	46.2
180.00	24.8	8.9	51.6
202.50	37.8	10.1	68.0
225.00	40.3	9.4	68.6
247.50	46.0	10.9	78.6
270.00	34.9	8.9	61.5
292.50	65.9	11.6	100.6
315.00	36.3	12.8	74.8
337.50	24.9	12.7	63.0

LOCATION 12

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	24.0	9.2	51.6
22.50	24.6	10.9	57.2
45.00	25.7	13.3	65.7
67.50	23.7	11.5	58.2
90.00	21.7	10.9	54.5
112.50	9.8	4.4	23.0
135.00	24.7	11.3	58.7
157.50	26.6	12.5	64.2
180.00	20.3	9.5	48.9
202.50	20.2	8.7	46.2
225.00	17.6	8.2	42.2
247.50	15.7	7.4	37.8
270.00	16.0	9.2	43.5
292.50	26.5	9.7	55.7
315.00	22.4	10.9	55.1
337.50	26.5	8.4	51.6

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ALLEGHENY INTERNATIONAL

LOCATION 13

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	36.2	9.9	65.9
22.50	35.3	9.3	63.3
45.00	26.8	8.5	52.3
67.50	23.9	7.1	45.3
90.00	17.2	7.5	39.6
112.50	10.1	4.3	23.0
135.00	16.1	8.3	40.9
157.50	18.8	8.2	43.4
180.00	16.6	7.8	39.8
202.50	20.4	7.6	43.1
225.00	37.9	10.1	68.0
247.50	22.6	9.2	50.4
270.00	20.2	8.2	44.7
292.50	34.2	10.0	64.1
315.00	35.4	13.6	76.2
337.50	46.4	12.5	84.1

LOCATION 14

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	49.3	9.8	78.8
22.50	44.2	10.8	76.7
45.00	31.1	9.2	58.7
67.50	24.9	6.7	45.0
90.00	22.2	9.6	50.8
112.50	10.9	5.1	26.0
135.00	17.6	8.6	43.5
157.50	23.7	7.8	47.1
180.00	27.9	7.2	49.5
202.50	53.1	10.0	83.2
225.00	50.7	8.9	77.2
247.50	39.5	10.8	71.8
270.00	23.8	9.2	51.3
292.50	25.4	14.1	67.6
315.00	34.4	16.6	84.3
337.50	51.2	11.9	86.9

LOCATION 15

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	31.8	12.8	70.2
22.50	26.7	11.3	60.5
45.00	19.5	9.8	48.9
67.50	11.2	5.5	27.8
90.00	20.9	9.5	49.3
112.50	8.1	3.6	19.0
135.00	9.9	4.0	21.9
157.50	10.1	4.8	24.5
180.00	16.5	6.5	35.9
202.50	30.7	9.5	59.1
225.00	28.0	8.6	53.8
247.50	20.8	8.7	46.8
270.00	15.5	7.3	37.4
292.50	22.0	13.3	62.0
315.00	17.9	8.6	43.7
337.50	31.0	13.7	71.9

LOCATION 16

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	15.5	7.1	36.9
22.50	14.8	6.5	34.2
45.00	14.6	7.5	37.2
67.50	8.6	3.8	19.9
90.00	12.1	6.1	30.4
112.50	5.9	2.1	12.3
135.00	7.0	2.9	15.7
157.50	10.4	5.3	26.3
180.00	9.2	3.7	20.2
202.50	11.9	4.5	25.5
225.00	12.4	6.6	32.1
247.50	16.7	8.8	43.0
270.00	4.2	3.2	13.7
292.50	10.6	6.3	29.4
315.00	15.3	7.0	36.3
337.50	28.5	11.5	63.1

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ALLEGHENY INTERNATIONAL

LOCATION 17

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	32.3	8.2	56.9
22.50	29.5	8.1	53.8
45.00	20.4	8.4	45.5
67.50	10.1	4.7	24.2
90.00	18.9	10.3	49.8
112.50	5.1	1.6	10.0
135.00	6.6	2.9	15.4
157.50	8.4	3.6	19.3
180.00	16.1	8.4	41.4
202.50	15.8	6.9	36.5
225.00	17.2	7.5	39.6
247.50	8.3	3.0	17.3
270.00	6.1	4.4	19.3
292.50	12.0	9.1	39.2
315.00	28.6	12.6	66.5
337.50	41.0	12.3	78.1

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ALLEGHENY INTERNATIONAL

** GREATEST VALUES **

UMEAN/UINF (PERCENT)

LOC	AZ	MEAN	RMS	M+3RMS
11	292.5	65.9	11.6	100.6
14	202.5	53.1	10.0	83.2
14	337.5	51.2	11.9	86.9
14	225.0	50.7	8.9	77.2
9	337.5	49.7	11.0	82.7
9	202.5	49.5	11.0	82.6
14	0.0	49.3	9.8	78.8
13	337.5	46.4	12.5	84.1
11	247.5	46.0	10.9	78.6
9	225.0	45.9	10.2	76.4

URMS/UINF (PERCENT)

LOC	AZ	MEAN	RMS	M+3RMS
14	315.0	34.4	16.6	84.3
3	22.5	32.9	16.3	81.7
4	292.5	31.2	15.5	77.8
1	0.0	27.2	14.5	70.6
1	315.0	29.7	14.3	72.7
8	202.5	30.8	14.2	73.5
2	292.5	42.7	14.1	85.1
14	292.5	25.4	14.1	67.6
9	315.0	26.9	13.8	68.4
15	337.5	31.0	13.7	71.9

UMEAN+3*RMS/UINF (PERCENT)

LOC	AZ	MEAN	RMS	M + 3RMS
11	292.5	65.9	11.6	100.6
14	337.5	51.2	11.9	86.9
2	292.5	42.7	14.1	85.1
14	315.0	34.4	16.6	84.3
13	337.5	46.4	12.5	84.1
14	202.5	53.1	10.0	83.2
9	337.5	49.7	11.0	82.7
9	202.5	49.5	11.0	82.6
3	22.5	32.9	16.3	81.7
10	0.0	44.0	12.2	80.4

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

EXISTING CONFIGURATION

LOCATION 1

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	34.1	11.6	68.8
22.50	25.4	7.7	48.4
45.00	19.7	10.6	51.6
67.50	14.4	5.8	31.6
90.00	20.2	8.8	46.7
112.50	16.7	7.0	37.7
135.00	15.6	6.5	35.2
157.50	20.3	9.0	47.3
180.00	29.8	10.3	60.7
202.50	29.5	10.6	61.3
225.00	25.6	9.9	55.4
247.50	20.4	8.8	46.7
270.00	13.5	7.0	34.5
292.50	37.8	10.8	70.2
315.00	36.7	11.1	69.9
337.50	43.4	12.7	81.6

LOCATION 2

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	38.5	12.3	75.5
22.50	30.3	10.4	61.5
45.00	28.6	9.5	57.0
67.50	21.1	6.3	39.9
90.00	24.0	10.5	55.4
112.50	26.4	6.5	45.8
135.00	26.2	5.8	43.5
157.50	33.5	8.1	57.8
180.00	29.6	6.7	49.8
202.50	29.9	6.0	47.8
225.00	32.4	10.0	62.4
247.50	22.9	11.4	57.0
270.00	11.1	5.9	28.7
292.50	26.7	12.2	63.2
315.00	27.0	9.7	56.0
337.50	44.8	11.4	79.1

LOCATION 3

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	27.6	10.9	60.2
22.50	17.4	8.8	43.9
45.00	24.9	14.9	69.5
67.50	15.1	7.6	38.0
90.00	16.6	7.9	40.3
112.50	27.9	10.0	57.8
135.00	25.2	11.1	58.5
157.50	36.2	13.3	76.2
180.00	39.7	11.0	72.8
202.50	37.2	10.3	68.0
225.00	26.4	9.6	55.2
247.50	17.8	7.8	41.1
270.00	14.3	6.9	35.0
292.50	18.4	8.8	44.7
315.00	34.2	10.7	66.2
337.50	31.6	10.7	63.7

LOCATION

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	12.7	8.9	39.3
22.50	9.7	6.1	27.9
45.00	16.4	9.9	46.0
67.50	11.5	4.2	23.9
90.00	11.2	4.5	24.7
112.50	11.4	5.3	27.5
135.00	14.8	7.4	37.0
157.50	23.7	12.0	59.7
180.00	22.6	9.3	50.5
202.50	19.4	8.3	44.4
225.00	18.7	8.5	44.2
247.50	18.8	8.2	43.5
270.00	11.5	5.2	27.2
292.50	12.1	6.7	32.1
315.00	10.8	4.5	24.4
337.50	15.5	9.0	42.4

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

EXISTING CONFIGURATION

LOCATION 5

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	9.8	6.0	27.7
22.50	16.4	10.4	47.5
45.00	16.9	9.0	43.8
67.50	14.4	6.6	34.1
90.00	11.6	5.4	27.8
112.50	14.6	5.4	30.8
135.00	11.9	5.3	27.7
157.50	26.5	10.9	59.3
180.00	18.7	7.8	42.2
202.50	26.4	12.5	64.1
225.00	18.0	8.7	44.1
247.50	15.2	6.1	33.4
270.00	17.2	7.6	40.1
292.50	32.3	11.0	65.4
315.00	32.4	13.8	73.8
337.50	18.7	8.8	45.2

LOCATION 6

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	12.7	8.5	38.1
22.50	16.6	10.7	48.6
45.00	11.2	7.3	33.2
67.50	10.8	4.7	24.9
90.00	8.2	3.2	17.6
112.50	10.3	4.0	22.4
135.00	7.4	2.6	15.2
157.50	8.4	3.4	18.7
180.00	12.1	4.8	26.3
202.50	12.5	5.0	27.6
225.00	9.1	3.3	19.0
247.50	8.6	3.0	17.6
270.00	9.2	4.4	22.2
292.50	8.0	3.9	19.7
315.00	10.5	5.4	26.7
337.50	11.7	5.9	29.5

LOCATION 7

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	22.6	11.9	58.4
22.50	23.0	9.5	51.5
45.00	19.3	9.4	47.7
67.50	13.1	5.5	29.5
90.00	24.0	12.1	60.4
112.50	7.9	3.0	16.8
135.00	8.8	3.8	20.1
157.50	14.5	7.0	35.4
180.00	16.7	7.1	37.8
202.50	23.4	10.4	54.6
225.00	18.3	7.8	41.7
247.50	14.0	6.6	33.8
270.00	12.5	6.0	30.4
292.50	24.0	11.3	57.8
315.00	15.6	7.7	38.8
337.50	14.9	7.5	37.3

LOCATION 8

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	19.9	13.0	59.0
22.50	17.0	10.0	46.9
45.00	11.2	7.7	34.4
67.50	12.9	4.8	27.2
90.00	13.6	5.9	31.3
112.50	6.3	1.8	11.8
135.00	7.6	2.7	15.8
157.50	11.5	4.2	24.2
180.00	9.8	3.8	21.1
202.50	14.8	5.6	31.6
225.00	13.6	5.8	31.1
247.50	18.2	8.0	42.2
270.00	12.5	6.6	32.3
292.50	18.7	9.8	48.3
315.00	14.8	7.5	37.3
337.50	21.7	12.4	58.8

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

EXISTING CONFIGURATION

LOCATION 9

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	23.8	11.3	57.8
22.50	19.6	11.4	53.8
45.00	14.7	8.0	38.6
67.50	14.9	6.2	33.5
90.00	13.7	6.5	33.1
112.50	10.4	3.9	22.2
135.00	19.7	7.8	43.1
157.50	34.3	11.7	69.5
180.00	16.2	6.7	36.2
202.50	23.3	9.1	50.6
225.00	16.4	7.4	38.4
247.50	35.1	12.5	72.7
270.00	28.6	12.2	65.1
292.50	46.1	13.6	87.0
315.00	35.5	12.1	71.8
337.50	29.0	9.2	56.5

LOCATION 10

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	34.9	11.9	70.7
22.50	34.3	10.9	66.9
45.00	18.1	10.0	48.0
67.50	14.9	6.8	35.2
90.00	18.4	6.4	37.5
112.50	10.8	5.2	26.4
135.00	10.0	4.2	22.5
157.50	15.2	6.9	35.9
180.00	21.9	8.8	48.4
202.50	29.1	12.8	67.5
225.00	16.3	7.5	38.8
247.50	19.9	10.3	50.8
270.00	19.6	9.6	48.4
292.50	34.0	16.6	83.8
315.00	47.2	10.8	79.7
337.50	38.7	10.4	69.9

LOCATION 11

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	19.8	12.1	56.2
22.50	25.8	11.5	60.2
45.00	39.7	11.0	72.7
67.50	34.9	6.5	54.4
90.00	31.1	9.5	59.5
112.50	11.5	5.3	27.3
135.00	12.0	4.4	25.3
157.50	20.3	7.5	42.7
180.00	13.3	4.7	27.3
202.50	17.9	6.6	37.7
225.00	17.4	7.8	40.7
247.50	30.2	9.7	59.2
270.00	39.1	10.4	70.2
292.50	66.3	11.3	100.3
315.00	51.1	12.1	87.4
337.50	40.7	14.7	84.6

LOCATION 12

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	17.1	8.7	43.1
22.50	12.5	9.0	39.6
45.00	35.7	16.6	85.5
67.50	29.1	11.9	64.9
90.00	23.1	11.1	56.4
112.50	11.4	4.4	24.6
135.00	33.5	13.8	74.9
157.50	42.5	16.2	91.1
180.00	22.1	10.0	52.2
202.50	26.5	11.6	61.4
225.00	22.8	10.5	54.2
247.50	17.8	9.9	47.5
270.00	18.1	8.8	44.4
292.50	22.3	8.6	48.1
315.00	21.6	9.1	48.8
337.50	19.0	8.1	43.2

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

EXISTING CONFIGURATION

LOCATION 13

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	19.7	10.4	50.9
22.50	16.4	7.7	39.5
45.00	21.4	10.4	52.6
67.50	14.7	6.0	32.8
90.00	14.6	6.9	35.3
112.50	8.9	3.3	18.9
135.00	17.6	8.9	44.2
157.50	18.5	9.7	47.8
180.00	20.2	7.9	43.9
202.50	24.3	9.1	51.7
225.00	24.1	10.2	54.7
247.50	28.6	15.2	74.3
270.00	15.6	8.3	40.4
292.50	19.7	8.4	44.9
315.00	18.3	7.6	41.2
337.50	22.3	9.4	50.4

LOCATION 14

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	9.6	5.6	26.5
22.50	14.6	8.6	40.4
45.00	31.2	10.4	62.5
67.50	25.9	7.3	47.9
90.00	28.2	9.8	57.7
112.50	6.9	2.5	14.5
135.00	9.7	4.0	21.7
157.50	12.2	5.6	28.9
180.00	13.4	5.2	29.0
202.50	16.3	6.0	34.2
225.00	12.0	5.7	29.2
247.50	25.0	10.1	55.3
270.00	20.9	7.2	42.4
292.50	27.9	7.9	51.7
315.00	23.5	9.0	50.4
337.50	20.3	8.0	44.2

LOCATION 15

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	18.9	9.1	46.0
22.50	17.2	9.3	45.1
45.00	18.7	10.0	48.7
67.50	18.0	6.8	38.4
90.00	26.2	11.1	59.6
112.50	8.7	3.1	18.0
135.00	11.1	4.5	24.6
157.50	11.0	4.4	24.3
180.00	22.8	10.2	53.5
202.50	27.1	10.9	59.9
225.00	27.2	12.3	64.1
247.50	16.4	8.2	41.0
270.00	14.0	6.3	33.0
292.50	30.0	10.4	61.2
315.00	30.6	10.8	62.8
337.50	30.1	10.9	62.8

LOCATION 16

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3*URMS/UR (PERCENT)
0.00	24.7	10.6	56.5
22.50	13.2	7.9	36.9
45.00	11.6	8.1	35.9
67.50	9.1	3.2	18.8
90.00	11.5	6.3	30.4
112.50	8.8	3.3	18.8
135.00	20.2	8.1	44.4
157.50	13.1	4.6	26.9
180.00	26.9	9.1	54.2
202.50	22.2	9.0	49.2
225.00	25.1	9.3	52.9
247.50	17.0	8.1	41.3
270.00	17.8	8.8	44.1
292.50	40.0	12.5	77.4
315.00	35.7	12.8	74.2
337.50	35.1	12.9	73.9

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

EXISTING CONFIGURATION

** GREATEST VALUES **

UMEAN/UINF (PERCENT)

LOC	AZ	MEAN	RMS	M+3RMS
11	292.5	66.3	11.3	100.3
11	315.0	51.1	12.1	87.4
10	315.0	47.2	10.8	79.7
9	292.5	46.1	13.6	87.0
2	337.5	44.8	11.4	79.1
1	337.5	43.4	12.7	81.6
12	157.5	42.5	16.2	91.1
11	337.5	40.7	14.7	84.6
16	292.5	40.0	12.5	77.4
3	180.0	39.7	11.0	72.8

URMS/UINF (PERCENT)

LOC	AZ	MEAN	RMS	M+3RMS
12	45.0	35.7	16.6	85.5
10	292.5	34.0	16.6	83.8
12	157.5	42.5	16.2	91.1
13	247.5	28.6	15.2	74.3
3	45.0	24.9	14.9	69.5
11	337.5	40.7	14.7	84.6
12	135.0	33.5	13.8	74.9
5	315.0	32.4	13.8	73.8
9	292.5	46.1	13.6	87.0
3	157.5	36.2	13.3	76.2

UMEAN+3*RMS/UINF (PERCENT)

LOC	AZ	MEAN	RMS	M + 3RMS
11	292.5	66.3	11.3	100.3
12	157.5	42.5	16.2	91.1
11	315.0	51.1	12.1	87.4
9	292.5	46.1	13.6	87.0
12	45.0	35.7	16.6	85.5
11	337.5	40.7	14.7	84.6
10	292.5	34.0	16.6	83.8
1	337.5	43.4	12.7	81.6
10	315.0	47.2	10.8	79.7
2	337.5	44.8	11.4	79.1

TABLE 2

PERCENTAGE FREQUENCY OF WIND DIRECTION AND SPEED

PITTSBURGH, PA PITTSBURGH GREATER INTNL. AIRPORT (60-64)

SEASON: ANNUAL NO. OF OBS. = 3542 HT. OF MEAS. = 984 ft.

DIRECTION	0-10	11-22	23-33	34-45	46-56	57 +	TOTAL
N	1.63	2.59	.22	0.00	0.00	0.00	4.46
NNE	1.35	1.75	.19	.02	0.00	0.00	3.33
NE	1.15	1.29	0.00	0.00	0.00	0.00	2.46
ENE	1.35	1.38	.22	0.00	0.00	0.00	2.97
E	1.10	1.43	.33	0.00	0.00	0.00	2.88
ESE	.95	1.83	.33	.08	0.00	0.00	3.21
SE	1.10	2.28	.59	.05	0.00	0.00	4.03
SSE	1.18	1.94	.59	.05	0.00	0.00	3.78
S	1.35	1.75	.93	.11	0.00	0.00	4.15
SSW	1.43	3.58	1.55	.19	0.00	0.00	6.75
SW	1.27	6.60	3.04	.76	.05	0.00	11.74
WSW	1.66	6.80	3.92	1.04	.05	0.00	13.49
W	1.80	6.80	3.67	.73	.02	0.00	13.04
WNW	1.86	5.39	2.42	.31	0.00	0.00	9.99
NW	1.80	4.96	1.10	.02	0.00	0.00	7.90
NNW	1.55	3.86	.64	0.00	0.00	0.00	6.07
CALM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOT	22.47	54.32	19.73	3.41	.14	0.00	100.00

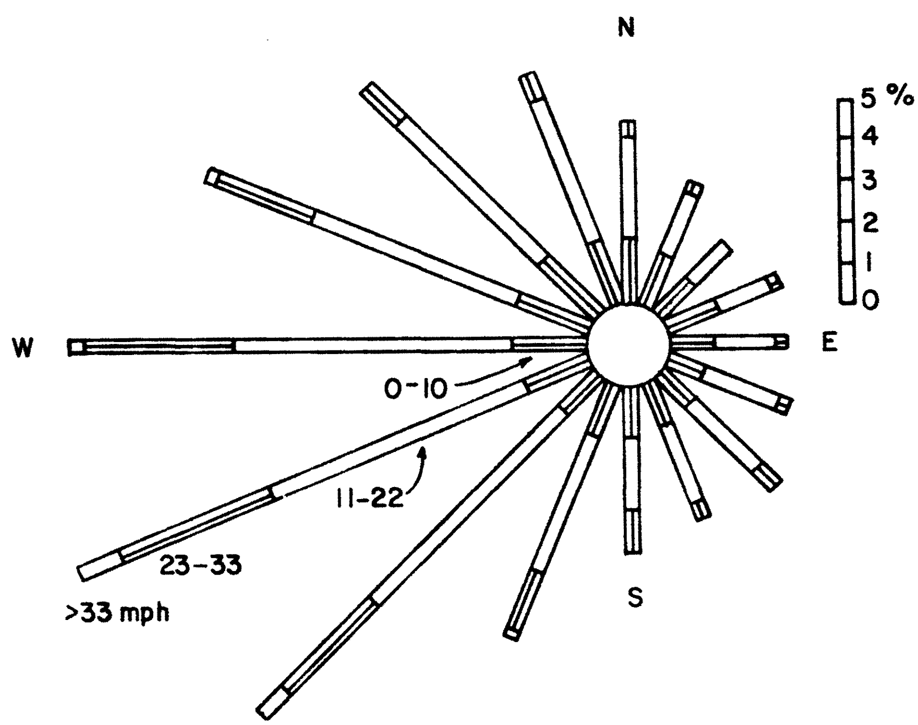

TABLE 3

SUMMARY OF WIND EFFECTS ON PEOPLE

	Beaufort number	Speed (mph)	Effects
Calm, light air	0, 1	0- 3	Calm, no noticeable wind
Light breeze	2	4- 7	Wind felt on face
Gentle breeze	3	8-12	Wind extends light flag Hair is disturbed Clothing flaps
Moderate breeze	4	13-18	Raises dust, dry soil and loose paper Hair disarranged
Fresh breeze	5	19-24	Force of wind felt on body Drifting snow becomes airborne Limit of agreeable wind on land
Strong breeze	6	25-31	Umbrellas used with difficulty Hair blown straight Difficult to walk steadily Wind noise on ears unpleasant Windborne snow above head height (blizzard)
Near gale	7	32-38	Inconvenience felt when walking
Gale	8	39-46	Generally impedes progress Great difficulty with balance in gusts
Strong gale	9	47-54	People blown over by gusts

Note: Table from Reference 4, p. 40.