WIND-TUNNEL STUDY OF
MARRIOTT BEACH HOTEL--MAUI, HAWAII

by

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LIST OF SYMBOLS

U	Mean velocity at height z
U_∞	Mean velocity at 50 in. height in wind tunnel
Z	Height above wind-tunnel floor
Z_∞	Height of 50 in. above wind-tunnel floor
E	Mean voltage output of hot-film anemometer
A,B,n	Constants
E_{rms}	Root-mean-square voltage output from anemometer
U_{rms}	Root-mean-square velocity
U-30	Mean velocity at 30 scale ft above model ground level
UMEAN	Mean velocity at 5 scale ft above model ground level
URMS	Root-mean-square velocity at 5 scale ft above model ground level

1. INTRODUCTION

High winds in pedestrian areas such as lounging, walking and eating areas can lead to personal discomfort and a tendency not to use those areas during periods when winds are of significant magnitude. References 1-7 discuss various aspects of the problem and suggest acceptability criteria for pedestrian comfort. These references indicate that for winds of sufficiently low velocity--below approximately 12 mph--little effect of winds on human activity can be detected. As velocity increases, adverse effects of wind increase until winds of 35-40 mph and above can be considered hazardous to at least a portion of the population.

It is desirable to determine locations of possible pedestrian problems during the design phase of a building in order to permit modifications to be incorporated at minimum cost which could improve wind conditions in those areas. Wind-tunnel modeling provides quantitative data on winds in possible problem areas. Wind-tunnel modeling of atmospheric winds and wind effects has been discussed in the literature [8-10] and is now a well-established technique.

The proposed Marriott Beach Hotel is to be located on the coast near Lahaina on the island of Maui, Hawaii. Because the hotel plan includes passageways that connect high-pressure regions on the windward side with low pressure regions on the leeward side, concern over possible uncomfortable conditions indicated a need for a wind-tunnel study to identify and quantify winds at locations with strong winds. This study reports the results of a wind-tunnel investigation of wind flows through the proposed Marriott Beach Hotel and the results of several corrective measures.

2. PHYSICAL MODEL AND MEASUREMENTS

The study was performed in the Industrial Aerodynamics and Wind Tunnel located in the Fluid Dynamics and Diffusion Laboratory at Colorado State University (Figure 1). The tunnel is a closed-circuit facility driven by a 75 hp variable-pitch propeller. The test section is nominally 6 ft square and 60 ft long and is fed through a 4-to-1 contraction section about 10 ft long. The roof is adjustable in height to maintain a zero pressure gradient along the test section. The mean velocity can be adjusted continuously from 1 to 65 fps.

A 1:192 scale model of the hotel, supplied by the architect, was installed on the turntable at the downstream end of the test section. The floor upstream from the model was smooth to simulate approach wind over water or relatively open terrain. Spires were introduced at the test section entrance to provide a thicker boundary layer than would otherwise be available. A photograph of the model installed in the tunnel is shown in Figure 2. The approach flow characteristics measured with a hot-wire anemometer to be described later are shown in Figure 3. The mean velocity followed a 0.13 power-law profile which is characteristic of open country terrain. The turbulence intensity distribution was also characteristic of open country. Modeling criteria for this project followed generally accepted modeling procedures [8-10].

Flow around and through the hotel was studied qualitatively with titanium-oxide smoke to determine areas where strong winds could create uncomfortable conditions. A motion picture was made to document the wind flow patterns primarily for prevailing wind directions and locations which showed high wind magnitudes.

Twenty-three locations on the model were selected for detailed quantitative measurement of mean and fluctuating velocity at a height of about 5 ft. Measurements were made with a single hot-wire anemometer mounted with its axis vertical in order to measure the horizontal velocity component. A Thermo Systems constant-temperature anemometer (Model 1050) was used with a 0.001 in. diameter platinum-film sensing element 0.020 in. long. Output was directed to an analog-to-digital converter and then to an on-line minicomputer which performed the data analysis.

Calibration of the hot-wire anemometer was performed using a Thermo Systems calibrator (Model 1125). 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 mean and rms velocities were divided by the mean velocity at 30 ft elevation in the approach boundary layer U-30.

The site of the Marriott Beach Hotel experiences winds which come predominantly from two basic wind directions. A wind rose for the site, supplied by the sponsor, obtained at a nearby airport is shown in Figure 4. Almost all winds of significance come from the northeast or the southwest. If any unpleasant winds occur within the hotel for northwest or southeast winds, their low frequency of occurrence should not require design modification. Conversely, unpleasant winds in the hotel with northeast or southwest winds will be aggravated because of their percentage of occurrence. For this reason, the investigation was limited to a range of wind directions from north through east and south through west.

In cooperation with the sponsor, a series of modifications were made to the model to improve flow characteristics in those areas which appeared to have the worst wind environment. Wind flow magnitudes were measured with the hot wire at those locations to determine whether an improvement occurred and to quantify the improvement.

3. RESULTS

3.1 Flow Visualization

The flow visualization study showed several areas within and adjacent to the hotel where strong winds were evident. A scene guide to the motion picture is shown in Table 1. Wind flow patterns that were of most concern are shown in Figure 5. Each part of Figure 5 shows strong air currents at ground level for a different approach wind direction imposed on a plan view of the building drawn to show ground-level details as well as building outlines and overhangs. For generally northerly to northeasterly winds, areas of strong winds in the hotel appeared to be in the entrance region, lobby and bar. The north end of both wings caused flow down the face of the wall and strong flows at ground level into the wing underneath the wall. For southwesterly approach winds, high velocities were observed in the passages at the south end of both wings and in passages leading into the northwesterly side of the southern wing (B) near the open-walled restaurant. Some flow entered the restaurant as well. Rapidly recirculating winds were observed in some of the balconies on the south side of the north wing (A).

3.2 Wind Velocities--Configuration A

The 23 measurement points selected for quantitative evaluation are shown in Figure 6. Most of these points were selected to determine velocities in high wind areas. A few, however, were selected to provide an open-area reference point which was undisturbed by the building to provide a reference against which the windier locations could be compared (locations 20 and 22 for example).

Table 2 shows the mean velocity, rms velocity, and an effective peak velocity (defined by UMEAN + 3URMS) at each of the 23 locations for configuration A, the original configuration, for a selection of approach wind directions. Each velocity is expressed as a percentage of the mean velocity at 30 ft elevation in the approach flow. Wind directions were selected to cover the wind directions where high velocities were observed during flow visualization and, in some cases, to show the velocity at a wind direction where wind velocity was not high.

In the approach flow, the ratio of mean velocity at 5 ft to that at 30 ft expressed as a percentage was 74 percent. Thus we would expect a site such as 20 and 22 to have velocity ratios of about the magnitude for wind directions where the building was not a significant influence on the flow at those points. Table 2 shows that mean velocity ratios up to 79 and 77 percent were recorded at locations 20 and 22 indicating that the only influence of the building was to decrease the velocity at those locations for some wind directions. Turbulence intensity in the approach flow at 5 ft referenced to the mean velocity at 30 ft was about 13-14 percent. Since the turbulence intensities at locations 20 and 22 were about 10-13 percent, the fluctuating velocity was characteristic of an open environment. Based on this analysis, we can use a mean velocity ratio of about 80 percent and a turbulence ratio of 15 percent in Table 2 to determine whether other measurement locations on the model were experiencing higher mean velocity or higher turbulence intensity than would be experienced in an open area away from significant building influence. Locations 5, 7, 10, 12, 13, 15, 17, 19 and 21 experienced mean or rms velocities above a U_m of 80 percent or U_{rms} above 20 percent of U-30 from wind directions with significant percentages of winds in the range of 13 to 24 mph. The largest mean winds were measured at locations 19, 17 and 10 with 107, 105 and 104 percent of the mean velocity at 30 ft, U-30.

A third indication of excess wind magnitude is an effective peak velocity of $U_{mean} + 3\ (U_{rms})$ (Ref. 3). For an open area near the hotel site, an effective peak velocity of 80 + 3(15) = 125 percent of the mean velocity at 30 ft, U-30, might be expected. Using this measure as a criteria for selection of locations which would experience winds higher than in a nearby open area, the same locations as cited above (except location 15) are seen from Table 2 to have effective peak velocities for some wind directions in excess of 125 percent of U-30. Some of these peak velocities are rather large: 170 and 174 at location 7, 149 and 158 at location 10 and 156 at location 5.

Areas of concern are the ground level entrances to both wings (locations 7, 10, 12, 13, 15, 17), the bar off the main lobby (location 5) and the area outside the end of the south wing (location 19). In addition, for northerly winds, wind flow through the doorways between locations 2 and 3 and the doorway near location 4 appeared to be stronger than those measured at locations 2, 3 and 4, but sensors could not be successfully maneuvered into those doorways. The bar near location 5 appeared to have relatively strong winds for several of the more common approach wind directions--both north-northeast and south-southwest winds.

This location would probably be too windy for sitting patrons except on days with low winds. The restaurant, represented by measurement location 23 (the probe was inserted underneath the overhang) did not show high winds, but the winds measured could prove disturbing in a dining environment on days when south to west winds are moderate or strong.

3.3 Configuration B Velocities

In order to provide an improved wind environment, a series of modifications were made to the model. Table 3, with Figures 7 and 8, includes a description of the various modifications listed as configurations B-E. Configuration A was the original model without modification. Data was obtained for configuration B at locations where configuration A showed large velocities and where modifications were made to reduce those velocities. These data are presented in Table 2. Because flow visualization with smoke indicated that the region of maximum velocity near location 7 might have moved somewhat with the addition of the roof section at the north end of the north tower, a measurement location 24 was added (see Figure 6) to determine velocity magnitude at that point.

Comparison of velocity data for configuration B with that of configuration A in Table 2 shows that velocity magnitudes were significantly decreased at many locations. For example, the effective peak velocity at location 17 dropped from 145 percent of U-30 to 30 percent with the closure of the passageway near that point (a door which can be closed during high winds from the critical directions would be adequate to create this improvement). Locations 12 and 13 showed moderate decreases from maximum peak velocities of 137 and 141 percent to 117 and 134 percent, bringing them close to the open area environment for limited wind directions. The peak velocities at location 23 changed from 89, 74 and 52 percent for three south-southwest wind directions in configuration A to 87, 56 and 35 percent for the same wind directions in configuration B. The additional foliage near the restaurant improved wind conditions for two of three wind directions. It might be advisable to provide roll-down screens to protect the restaurant area during the high wind conditions--particularly when precipitation accompanies the winds.

Improvement in wind velocities was not equally successful at all locations. At location 5, peak wind velocities were decreased for some wind directions, but increased at other wind directions due to the modifications of configuration B. Thus, the fairly windy environment in the lobby bar was not significantly improved by configuration B changes. At location 7, peak winds were decreased from 170-174 percent of U-30 to 147-155 percent, but the direction of the approach winds where worst conditions occur was shifted toward the direction of highest frequency of strong winds.

3.4 Configuration C Velocities

In order to lower wind velocities in the lobby bar and underneath the north walls of both towers, additional modifications were added to configuration B to create configuration C. A glass wall was installed on the south side of the lobby bar, a more extensive roof was added to the north end of the south wing, and the north wall of the north wing was replaced with a 50 percent porous screen (Figure 8). A more extensive roof at the north end of the north tower was rejected by the sponsor because of cost. Data from configuration C are presented in Table 2.

Peak velocities at location 5 were reduced from 151 percent of U-30 for configuration B to 100 percent for configuration C. Since location 5 was located on the lobby side of the bar, velocities under the overhang covering the bar area for configuration C should be even less. Peak velocities at location 7 decreased from 174 percent for configuration A and 155 percent for configuration B to 128 percent for configuration C. The peak velocity wind direction also shifted to 67 degrees toward a lower frequency of occurrence of high wind speeds. Locations 6 and 24 showed peak velocities of 103 and 109 percent. The extended roof at the north end of the south wing brought peak velocities at locations 11 and 12 down to 115 and 68 percent respectively.

Configuration C appears to represent a reasonable improvement in all high-velocity areas. One disadvantage is that pedestrians on the walkways inside the north wall of the north wing would be exposed to increased wind and possibly precipitation when rain and northeast winds occur simultaneously.

3.5 Configuration D Velocities

Tests were run on configuration D to determine whether increased foliage height in front of the hotel would, by itself, improve conditions under the north wall of the north tower. The foliage was the only modification to configuration A. Data are presented in Table 2. Peak velocity at location 7 was decreased from 174 percent of U-30 to 172 percent of U-30--an insignificant improvement.

3.6 Configuration E Velocities

Tests were run on configuration E to determine whether increased foliage height in front of the hotel combined with a porous north wall of the north wing would, by themselves, improve wind conditions at locations 6 and 7. Peak velocities at location 7 decreased to 149 percent of U-30. This reduction was not as large as the reduction to 100 percent provided by configuration C.

4. CONCLUSIONS

Based on wind-tunnel tests of a 1:192 scale model of the Marriott Beach Hotel, the following conclusions can be drawn:

(1) Wind magnitudes at several pedestrian locations within the hotel could reach objectionable levels for significant percentages of time.

(2) Modifications to the hotel listed under configuration B and C in Table 3 of the report would result in significant reductions in wind velocities in wind sensitive areas of the building. Modifications include 15-25 ft high foliage along the drive in front of the hotel, roof addition below the north wall of the north wing (as designed by the architect), roof addition below the north wall of the south wing (roof tested in configuration C was an improvement over the roof design supplied by the architect and tested in configuration B), porous north wall on the north wing, glass wall added on the south side of the lobby bar, doors added to the passages at the south end of both wings, foliage added near restaurant (movable screens may also be needed for the restaurant).

(3) Flow visualization studies indicated that the flow environment under the north wall of the north tower could probably be further improved with a larger roof below the north wall.

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FIGURES

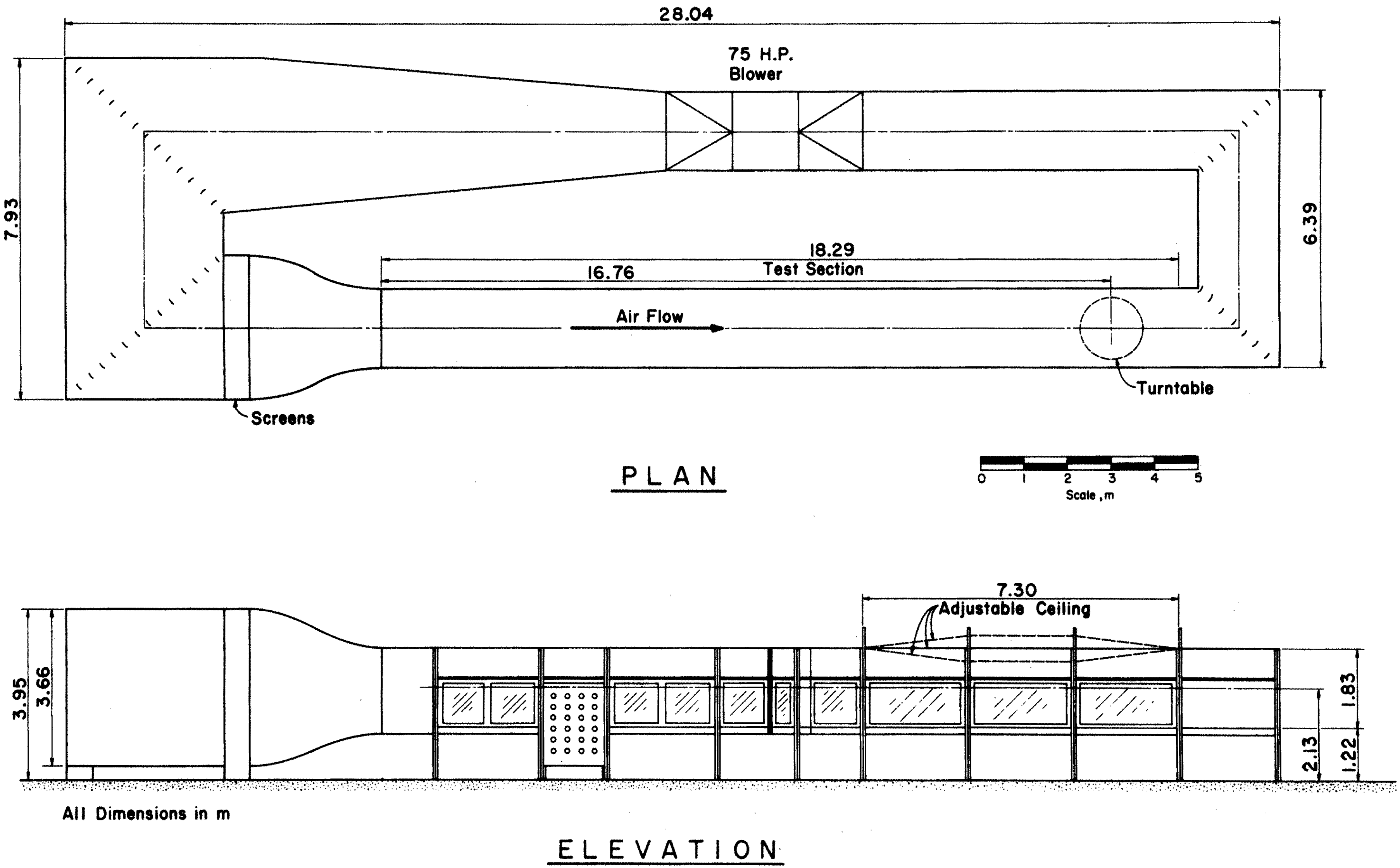


Figure 1. Industrial Aerodynamics Wind Tunnel

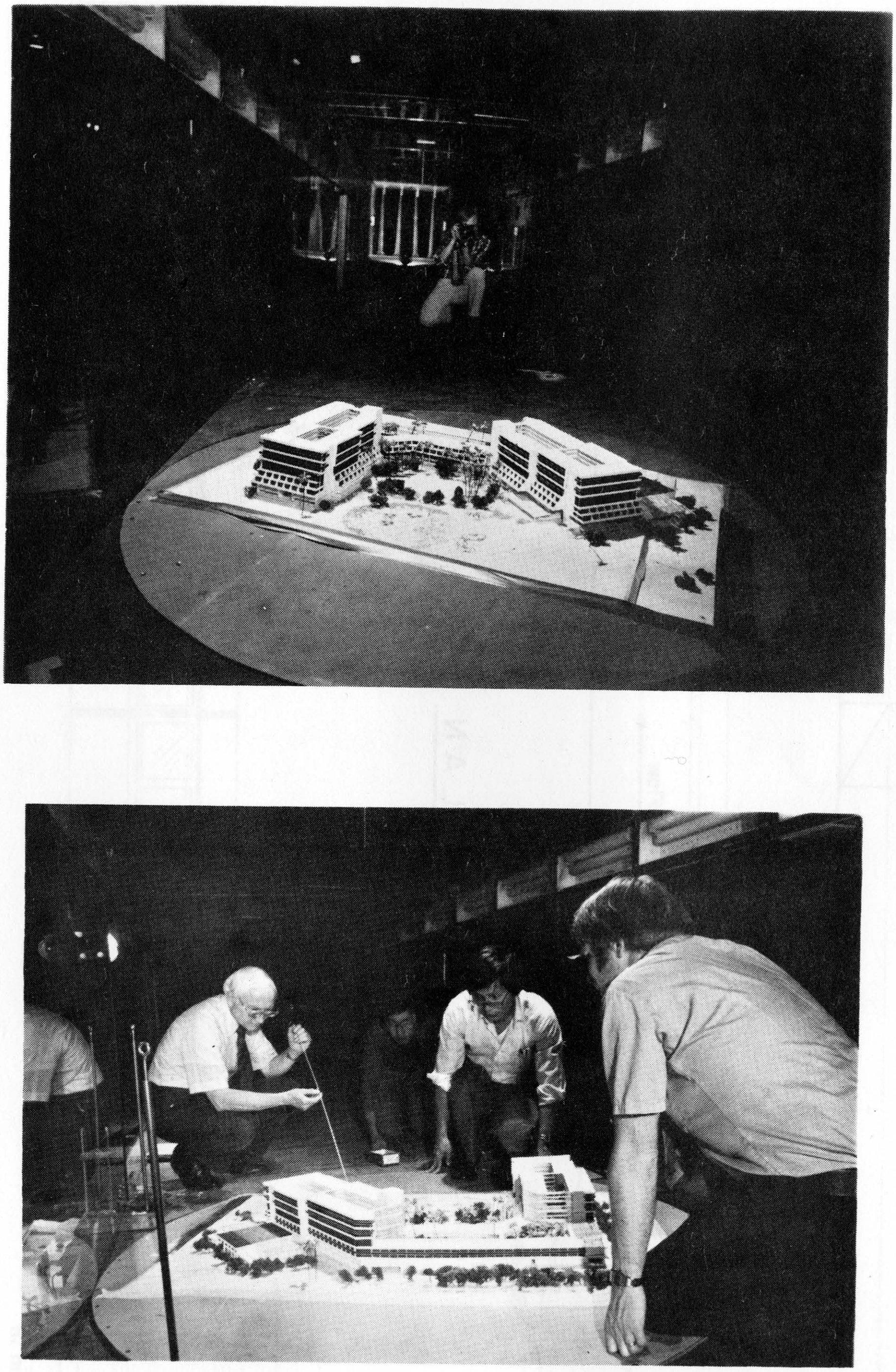


Figure 2. Model Installed in the Wind Tunnel

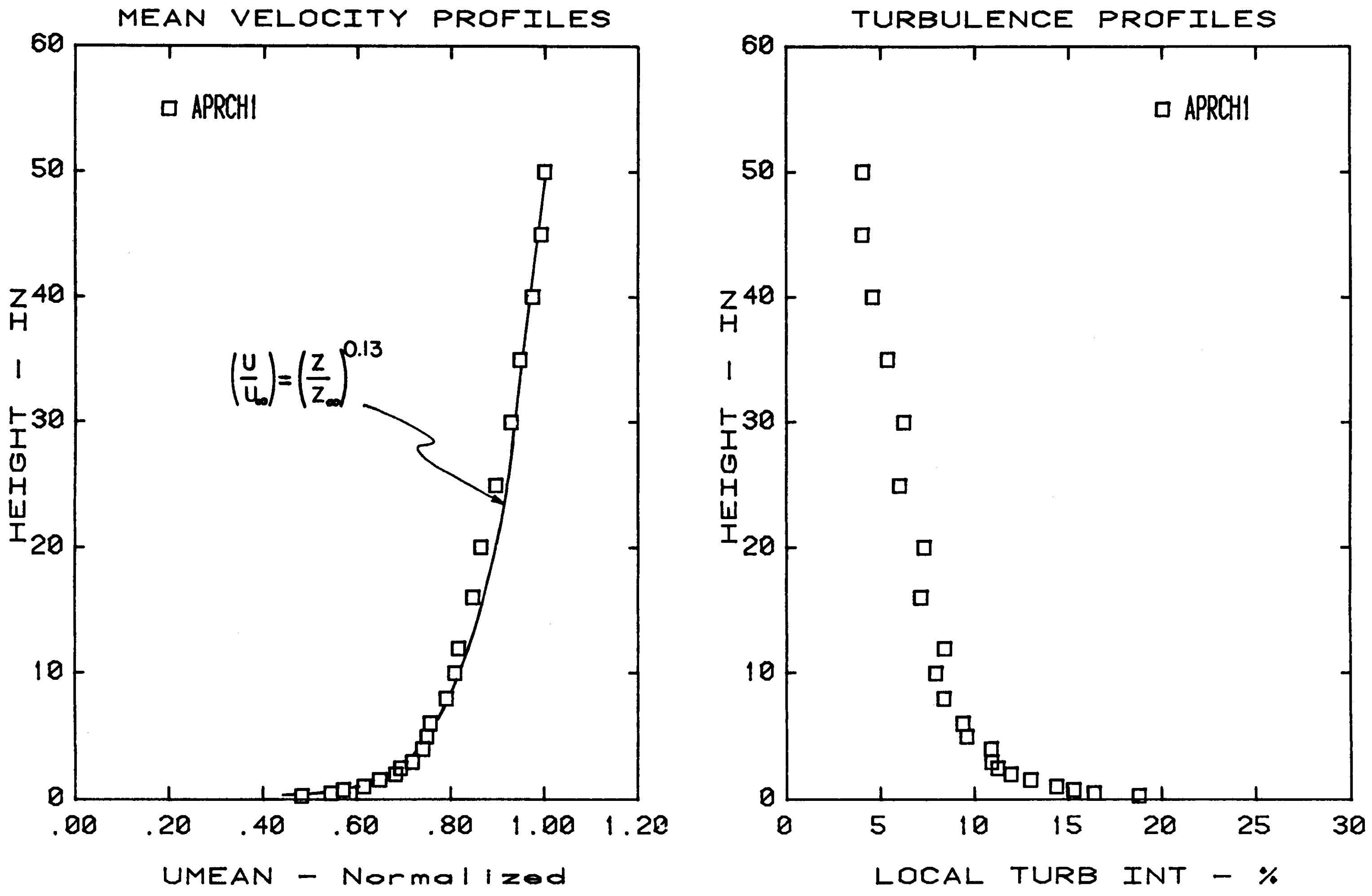


Figure 3. Approach Flow Characteristics

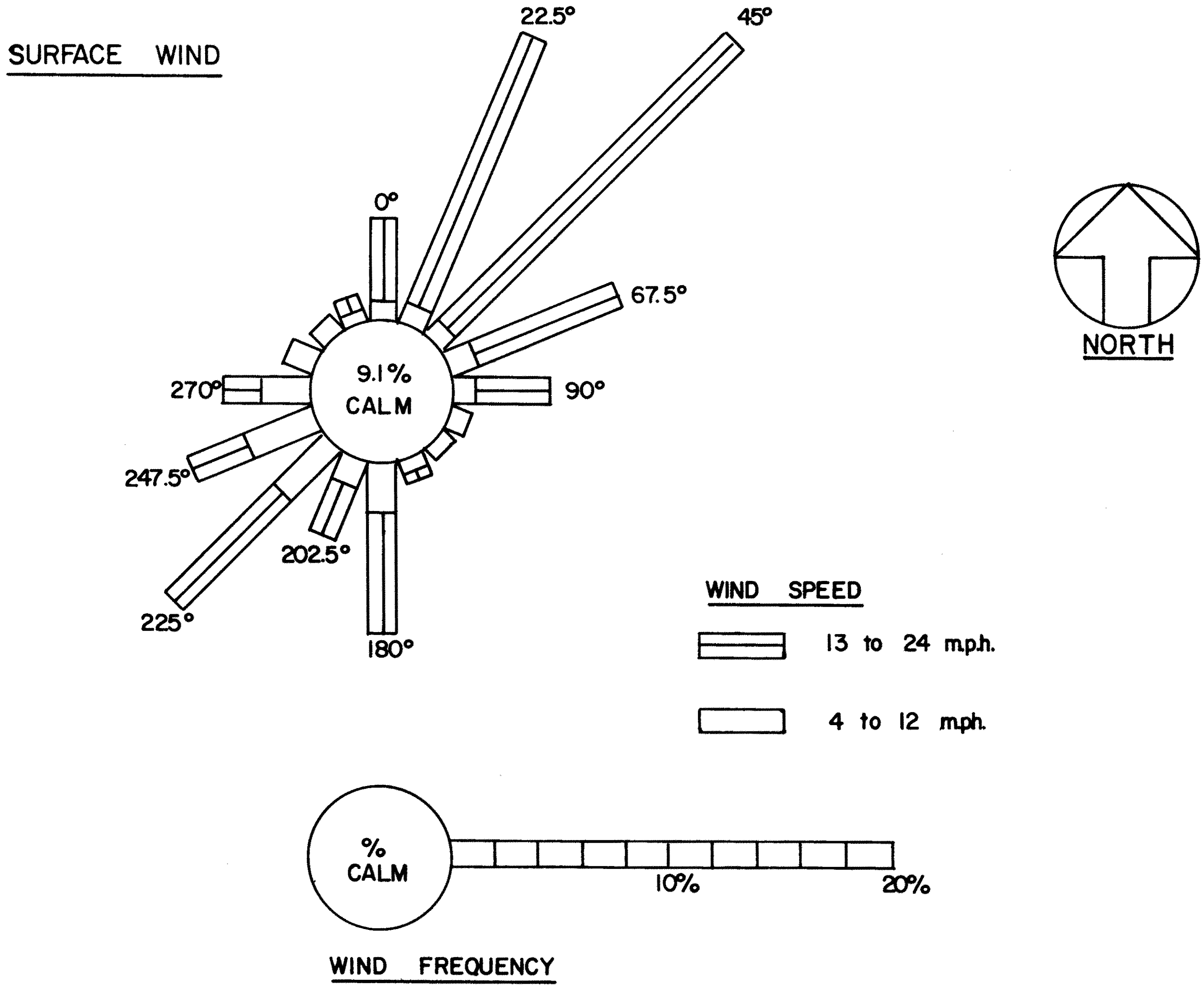
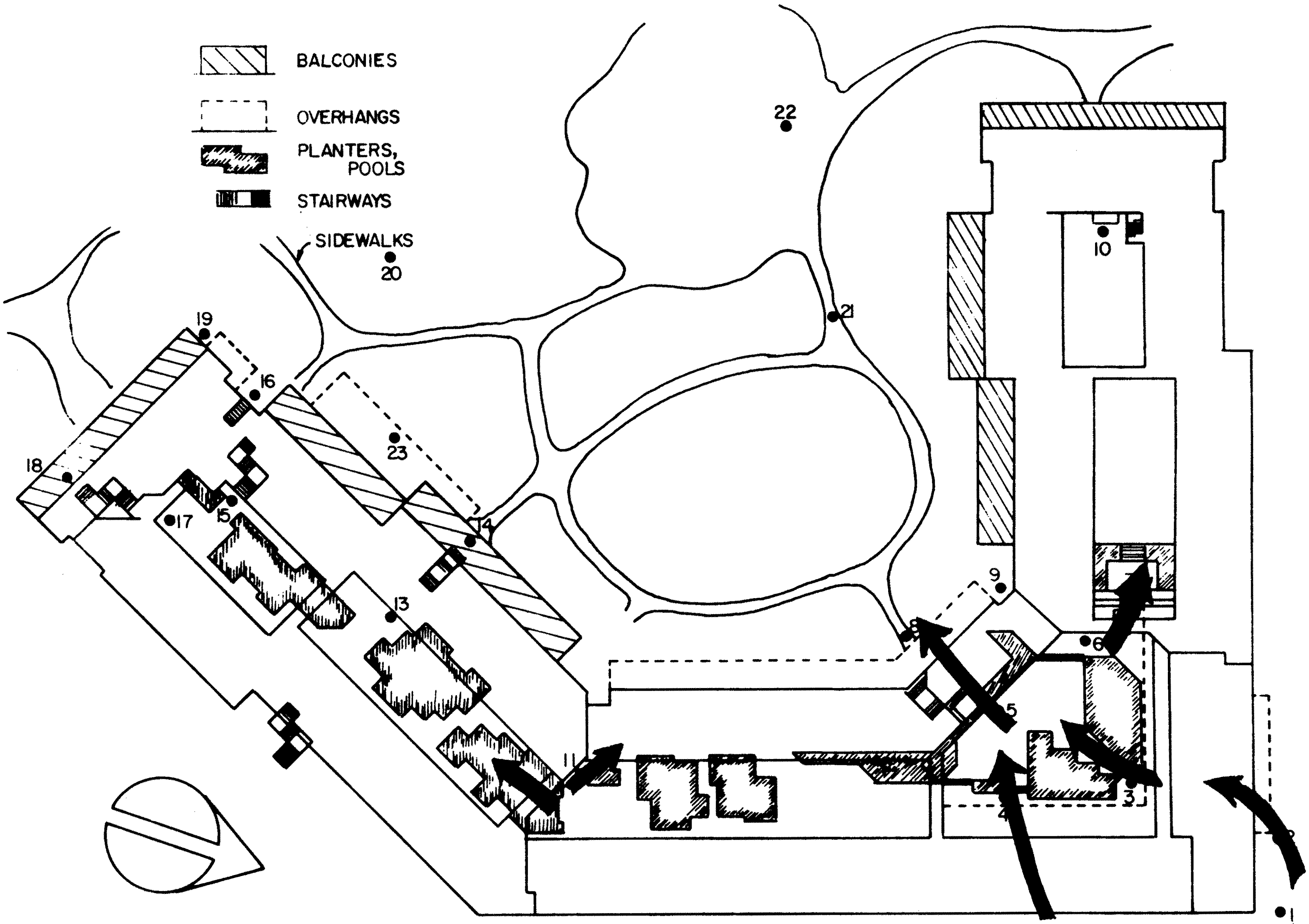
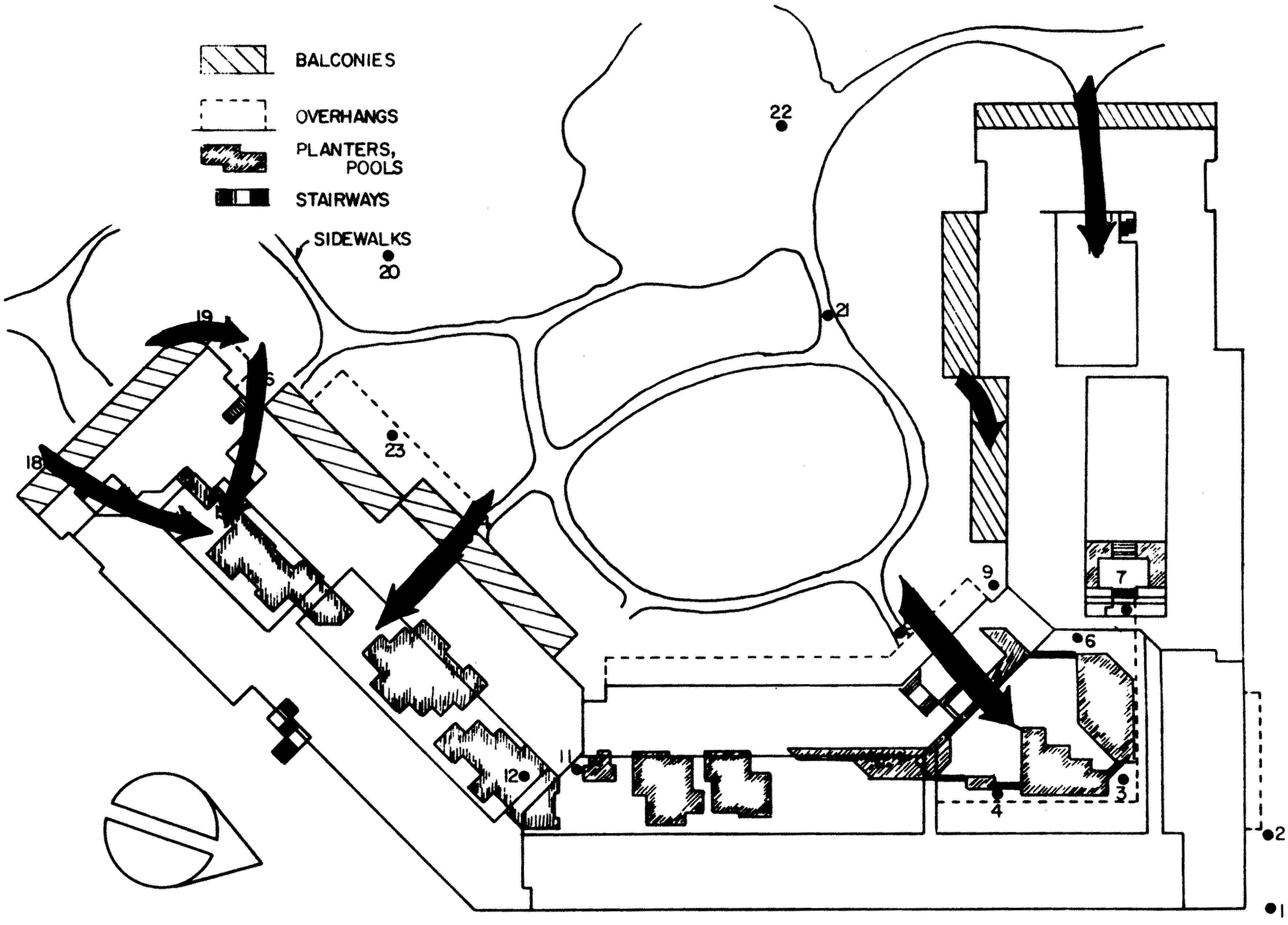


Figure 4. Wind Rose for the Hotel Site



NORTHEAST WINDS

Figure 5a. High Velocity Areas Determined by Flow Visualization



SOUTHWEST WINDS

Figure 5b. High Velocity Areas Determined by Flow Visualization

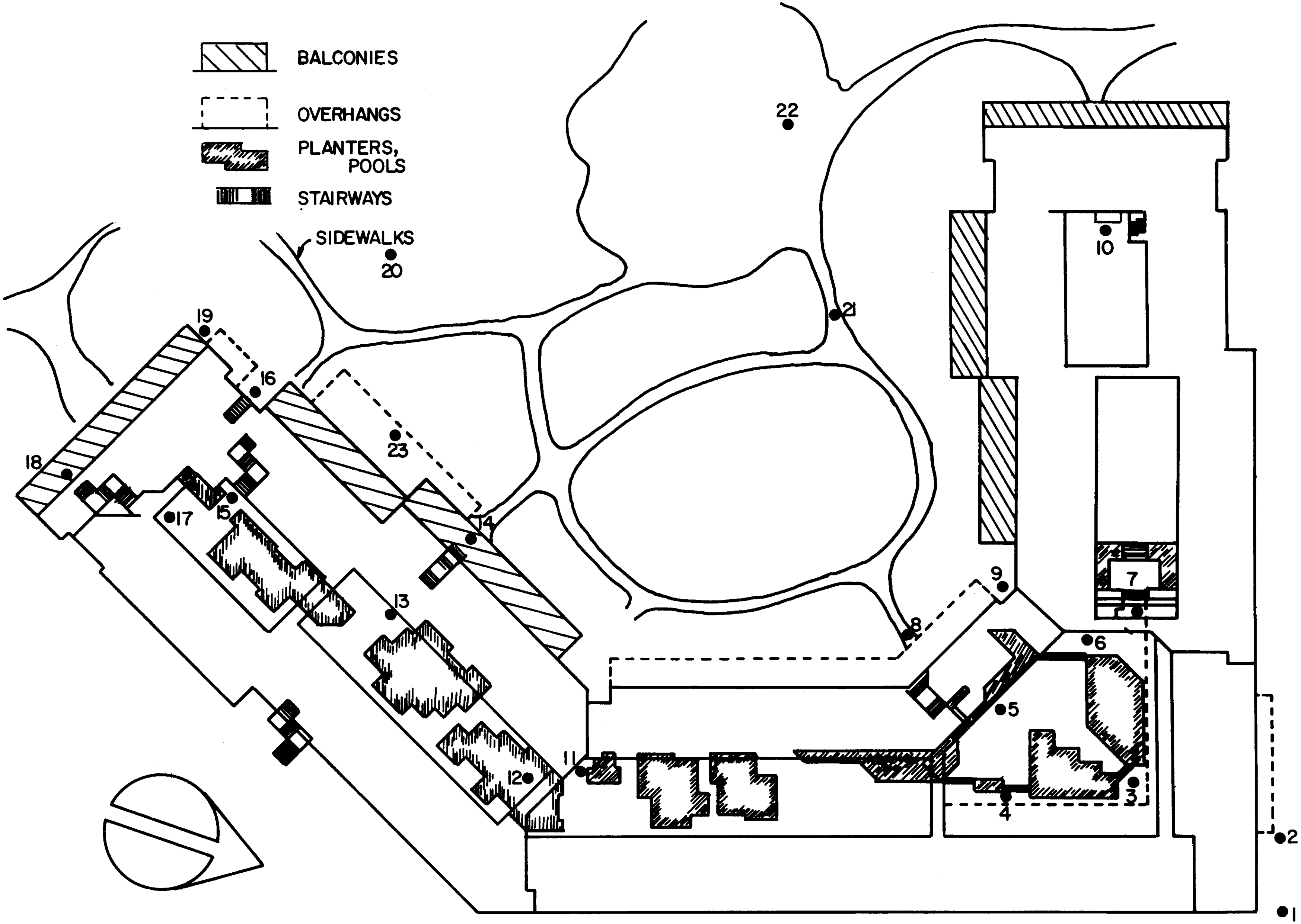


Figure 6. Locations Selected for Velocity Measurements

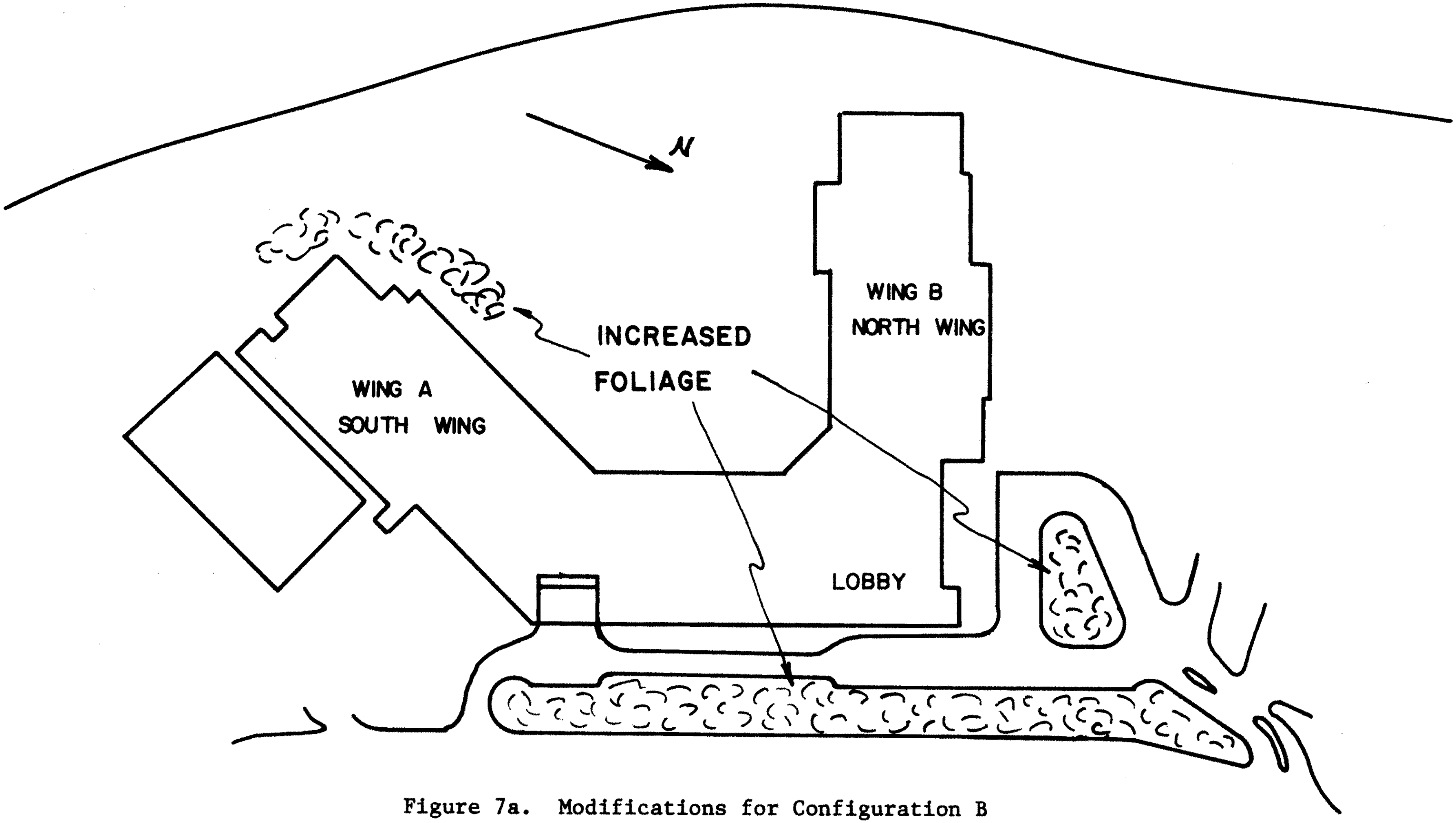


Figure 7a. Modifications for Configuration B

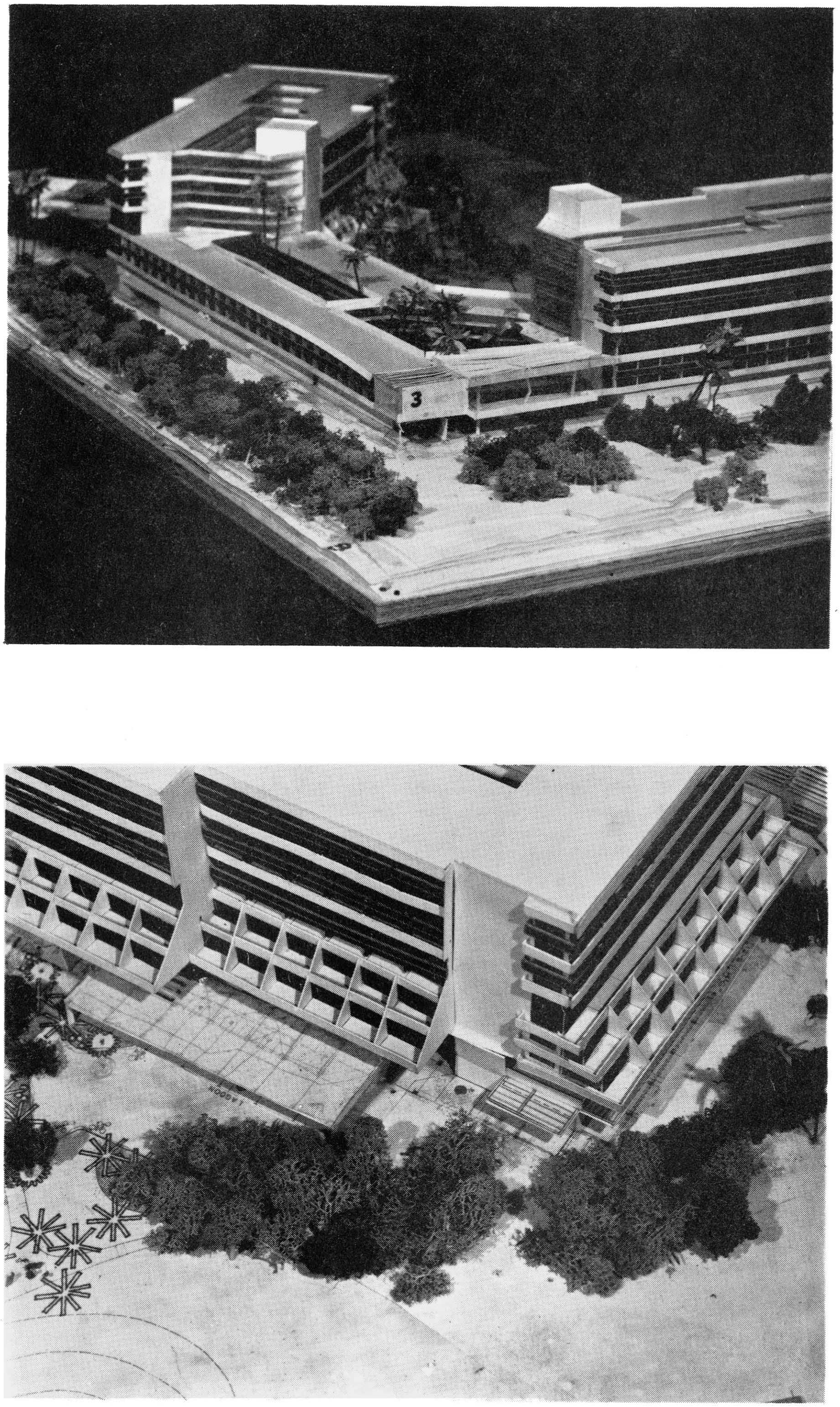


Figure 7b. Modifications for Configuration B

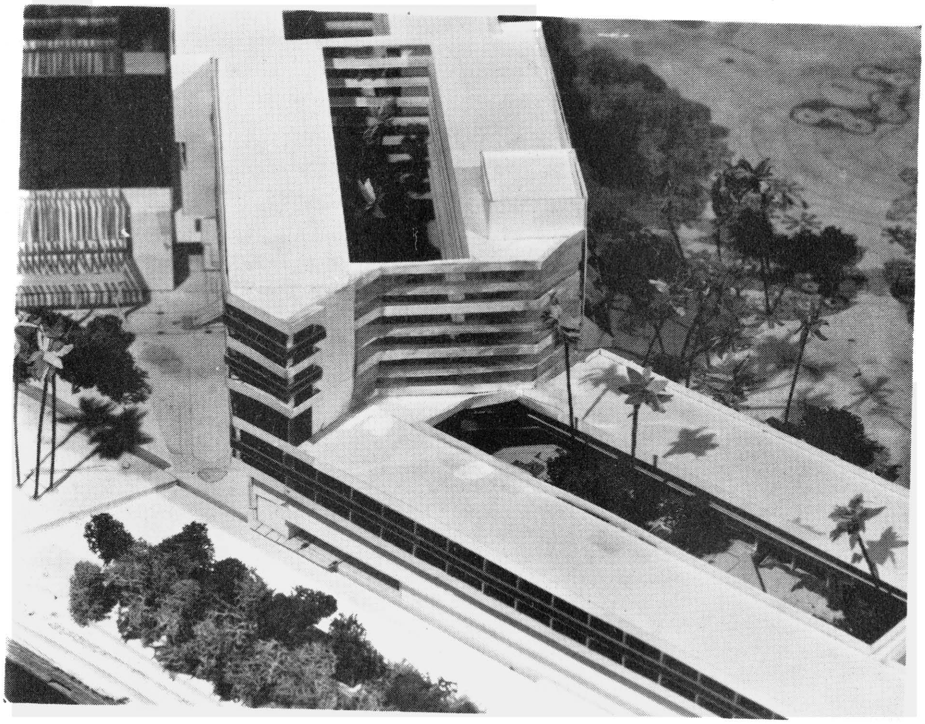


Figure 7c. Modifications for Configuration B

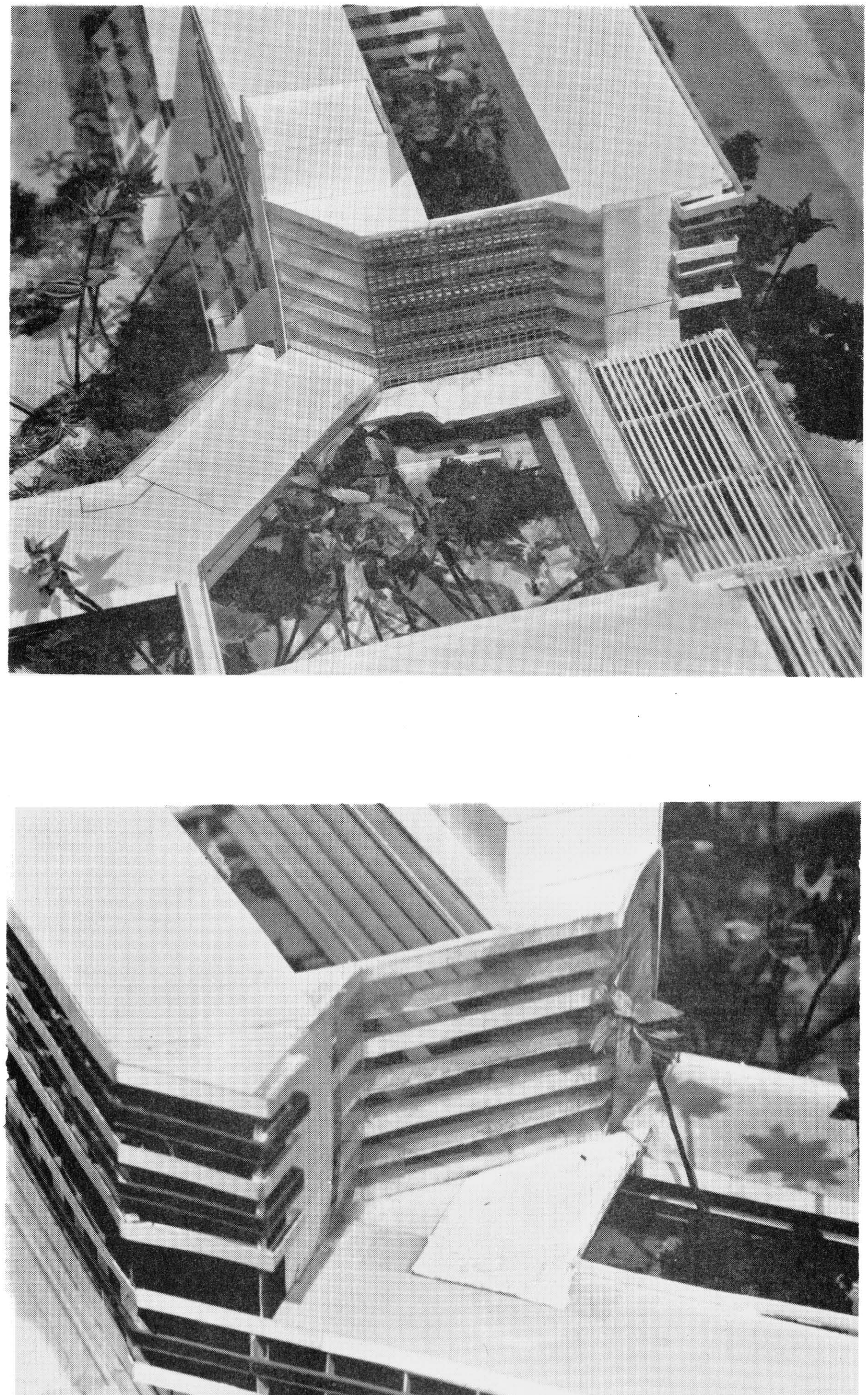


Figure 8. Modifications for Configuration C

TABLES

TABLE 1

MOTION PICTURE SCENE GUIDE

Run No.	Wind Direction	Camera Angle	Smoke Release
1	NE	Top	NE interior corner
2	NE	Side	NE corner outside north wall
3	NE	Side	NE corner outside east wall
4	SW	Side	Cocktail bar off entrance lobby
5	NNE	Side and Top	South tower north wall downdraft
6	SW	Side	South tower under the south side balcony
7	SW	Top	Inside south tower
8	SW	Side	South tower west wall
9	WSW	45 degree angle	North tower balconies

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ORIGINAL CONFIGURATION A

LOCATION 1

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	61.0	12.8	99.5
22.5	18.1	8.0	42.0
45.0	66.0	14.4	109.2
67.5	79.3	12.0	115.4
90.0	70.5	15.9	118.2
180.0	24.5	8.9	51.2
225.0	19.8	8.6	45.6

LOCATION 2

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	23.1	9.9	52.8
22.5	47.1	10.2	77.7
45.0	72.2	12.8	110.7
67.5	63.8	15.2	109.4
90.0	24.7	10.2	55.2
180.0	14.3	6.3	33.3
225.0	16.9	7.4	39.0

LOCATION 3

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	37.9	11.2	71.5
45.0	29.3	11.2	62.9
90.0	20.5	7.5	42.9
202.5	32.4	10.9	65.0
225.0	24.6	8.4	49.7

LOCATION 4

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	26.6	5.8	44.1
45.0	49.4	14.9	94.2
90.0	44.8	11.1	78.0
202.5	27.8	10.1	58.0
225.0	37.2	12.7	75.3

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ORIGINAL CONFIGURATION A

LOCATION 5

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	28.9	9.5	57.4
22.5	34.7	8.1	59.1
45.0	69.4	12.1	105.7
67.5	36.8	15.4	83.1
90.0	29.7	11.1	63.1
180.0	82.4	24.6	156.1
202.5	77.4	17.3	129.3
225.0	58.2	16.3	107.0
247.5	58.3	12.8	96.8
270.0	39.7	12.0	75.6

LOCATION 6

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	42.8	12.9	81.5
67.5	60.6	17.7	113.7
90.0	46.6	17.5	99.2
202.5	13.1	4.8	27.4
225.0	25.6	6.2	44.0

LOCATION 7

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	34.1	13.5	74.5
67.5	67.5	35.5	173.9
90.0	89.3	27.0	170.3
202.5	24.8	8.1	49.0
225.0	19.3	8.5	44.9

LOCATION 8

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	22.0	5.7	39.1
22.5	41.4	8.6	67.3
45.0	13.2	7.1	34.6
67.5	9.5	2.5	17.0
90.0	26.3	9.0	53.4
180.0	43.7	13.0	82.7
202.5	58.8	10.2	89.4
225.0	23.0	8.7	49.2
247.5	29.2	9.5	57.9
270.0	40.8	14.1	83.0

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ORIGINAL CONFIGURATION A

LOCATION 9

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	9.5	2.7	17.5
180.0	47.6	14.9	92.3
225.0	32.1	9.3	60.0
270.0	19.5	8.3	44.3

LOCATION 10

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	18.3	6.8	38.7
90.0	19.8	6.0	37.6
180.0	30.4	13.0	69.3
225.0	94.2	21.2	157.8
270.0	104.1	14.9	148.6

LOCATION 11

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	18.6	11.1	51.9
22.5	30.6	10.8	63.0
45.0	26.2	9.6	54.9
270.0	13.2	4.7	27.2

LOCATION 12

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	59.1	22.3	125.9
22.5	69.6	17.9	123.2
45.0	70.5	22.0	136.6
270.0	15.4	7.4	37.7

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ORIGINAL CONFIGURATION A

LOCATION 13

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	48.4	14.1	90.8
180.0	13.6	4.7	27.8
225.0	92.1	16.1	140.5
270.0	64.6	21.6	129.4

LOCATION 14

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
180.0	11.1	4.7	25.1
225.0	61.4	12.5	98.9
270.0	58.0	11.5	92.5

LOCATION 15

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	11.8	5.0	26.7
180.0	8.1	2.0	14.2
225.0	16.9	6.3	35.6
270.0	49.9	23.9	121.6

LOCATION 16

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	12.0	5.3	27.8
180.0	16.3	5.5	32.7
202.5	41.7	17.7	94.8
225.0	64.6	10.5	96.0
247.5	57.2	12.6	94.9
270.0	44.1	11.8	79.4

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ORIGINAL CONFIGURATION A

LOCATION 17

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
180.0	104.5	13.6	145.4
225.0	81.0	16.7	131.0
270.0	17.9	7.5	40.4

LOCATION 18

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
180.0	37.2	13.8	78.5
225.0	74.3	11.9	110.1
270.0	50.6	16.4	99.8

LOCATION 19

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	20.5	6.9	41.1
180.0	107.1	13.8	148.6
225.0	40.3	14.8	84.8
270.0	83.3	16.7	133.3

LOCATION 20

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	29.1	15.7	76.1
22.5	31.7	14.9	76.4
45.0	24.9	9.4	53.0
67.5	23.4	11.5	58.0
90.0	26.6	11.6	61.4
180.0	78.8	11.8	114.1
202.5	64.4	12.8	102.9
225.0	51.0	11.8	86.5
247.5	42.8	12.5	80.2
270.0	40.4	12.9	79.0

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

ORIGINAL CONFIGURATION A

LOCATION 21

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	12.4	5.3	28.2
202.5	22.3	10.1	52.6
225.0	26.0	14.0	68.0
270.0	60.1	25.3	136.0

LOCATION 22

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	22.0	10.0	51.9
202.5	30.2	11.9	66.0
225.0	44.5	11.6	79.3
270.0	76.9	13.6	117.6

LOCATION 23

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	17.4	7.0	38.6
180.0	20.9	10.5	52.4
225.0	43.3	10.3	74.4
270.0	47.5	14.0	89.4

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION B

LOCATION 1

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	33.5	11.3	67.2
22.5	20.9	9.9	50.5
45.0	34.3	6.7	54.2
67.5	47.8	11.0	80.8
90.0	64.4	15.0	109.4

LOCATION 2

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	16.9	8.0	40.8
22.5	33.8	11.8	69.0
45.0	37.6	6.6	57.2
67.5	20.8	11.0	53.7
90.0	21.4	10.2	52.1

LOCATION 5

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	26.5	8.2	51.1
45.0	59.1	10.3	89.9
90.0	50.2	18.8	106.5
180.0	78.6	24.0	150.6
225.0	60.7	13.2	100.3
270.0	56.4	14.8	100.8

LOCATION 6

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	28.6	14.3	71.5
67.5	52.0	21.9	117.6
90.0	46.4	14.5	89.8

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION B

LOCATION 7

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	93.6	20.5	155.1
67.5	73.1	24.7	147.2
90.0	33.0	17.5	85.5

LOCATION 8

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	23.9	4.3	36.8
45.0	22.3	12.2	58.8
90.0	22.9	9.7	52.0
180.0	48.0	20.3	108.9
225.0	50.6	8.4	75.9
270.0	57.1	14.4	100.3

LOCATION 11

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	32.7	14.3	75.7
22.5	69.2	21.1	132.5
45.0	70.9	20.2	131.4

LOCATION 12

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	64.9	17.0	115.9
22.5	58.1	19.7	117.3
45.0	40.4	14.1	82.6

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION B

LOCATION 13

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
225.0	39.5	15.4	85.8
270.0	71.6	20.9	134.4

LOCATION 14

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
225.0	35.1	7.7	58.3
270.0	55.1	11.0	88.0

LOCATION 15

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
225.0	33.7	12.6	71.5
270.0	32.9	14.4	76.0

LOCATION 16

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
202.5	46.7	12.1	82.9
225.0	33.5	8.3	58.4
247.5	39.5	7.9	63.2
270.0	30.1	10.7	62.4

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION B

LOCATION 17

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
180.0	12.0	6.0	30.0
225.0	11.8	5.0	26.7

LOCATION 23

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
180.0	14.0	7.0	35.0
225.0	30.9	8.3	55.8
270.0	39.2	15.9	86.8

LOCATION 24

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	59.4	14.5	103.0
67.5	51.7	18.5	107.1
90.0	11.2	5.7	28.2

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION C

LOCATION 5

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	17.6	6.7	37.8
45.0	59.4	13.4	99.7
90.0	50.5	14.9	95.3
180.0	24.1	12.0	60.2
225.0	39.3	12.0	75.3
270.0	46.0	13.4	86.2

LOCATION 6

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	56.2	15.5	102.6
67.5	47.8	15.1	93.1
90.0	31.9	11.9	67.5

LOCATION 7

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	68.4	17.6	121.1
67.5	61.5	22.0	127.6
90.0	15.8	6.9	36.5

LOCATION 8

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
0.0	26.0	6.3	44.9
45.0	28.0	4.3	41.0
90.0	20.4	7.9	44.0
180.0	90.8	10.8	123.0
225.0	42.7	7.8	66.1
270.0	42.3	13.8	83.7

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION C

LOCATION 11

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
22.5	48.7	22.2	115.4
45.0	38.2	9.4	66.3

LOCATION 12

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
22.5	39.9	9.2	67.6
45.0	42.5	4.9	57.2

LOCATION 24

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	59.9	16.5	109.4
67.5	21.9	11.1	55.3
90.0	16.6	6.0	34.4

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION D

LOCATION 6

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	40.3	9.1	67.7
67.5	35.9	9.5	64.4
90.0	45.6	15.4	91.8

LOCATION 7

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	79.2	25.4	155.4
67.5	101.5	23.5	171.9
90.0	22.9	9.9	52.5

LOCATION 24

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	69.5	20.4	130.8
67.5	92.4	24.5	165.9
90.0	16.2	10.3	47.2

TABLE 2--PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES

MODIFIED CONFIGURATION E

LOCATION 6

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	29.2	10.1	59.5
67.5	38.4	10.9	71.1

LOCATION 7

WIND AZIMUTH	UMEAN/U-30 (PERCENT)	URMS/U-30 (PERCENT)	UMEAN+3*URMS/U-30 (PERCENT)
45.0	80.4	22.8	148.9
67.5	34.2	16.0	82.1

TABLE 3

HOTEL MODIFICATION CONFIGURATIONS

Configuration	Description
A	Original configuration
B	Modifications to Configuration A (see Figure 7): 1) Passage closed between locations 17 and 18 2) Foliage 15-25 ft high along drive in front of hotel 3) Foliage 15 ft high near restaurant 4) Added roof below vertical walls at north ends of both towers as specified by architects drawings
C	Changes to Configuration B (see Figure 8): 1) Extended roof at north end of south wing 2) Glass wall on south side of lobby bar 3) Vertical wall at north end of north wing replaced with 50 percent porous screen
D	Modifications to Configuration A 1) Foliage along drive in front of hotel as in configuration B
E	Changes to Configuration D 1) Vertical wall at north end of north wing replaced with 50 percent porous screen