

**APPENDIX E**  
**AIR QUALITY**

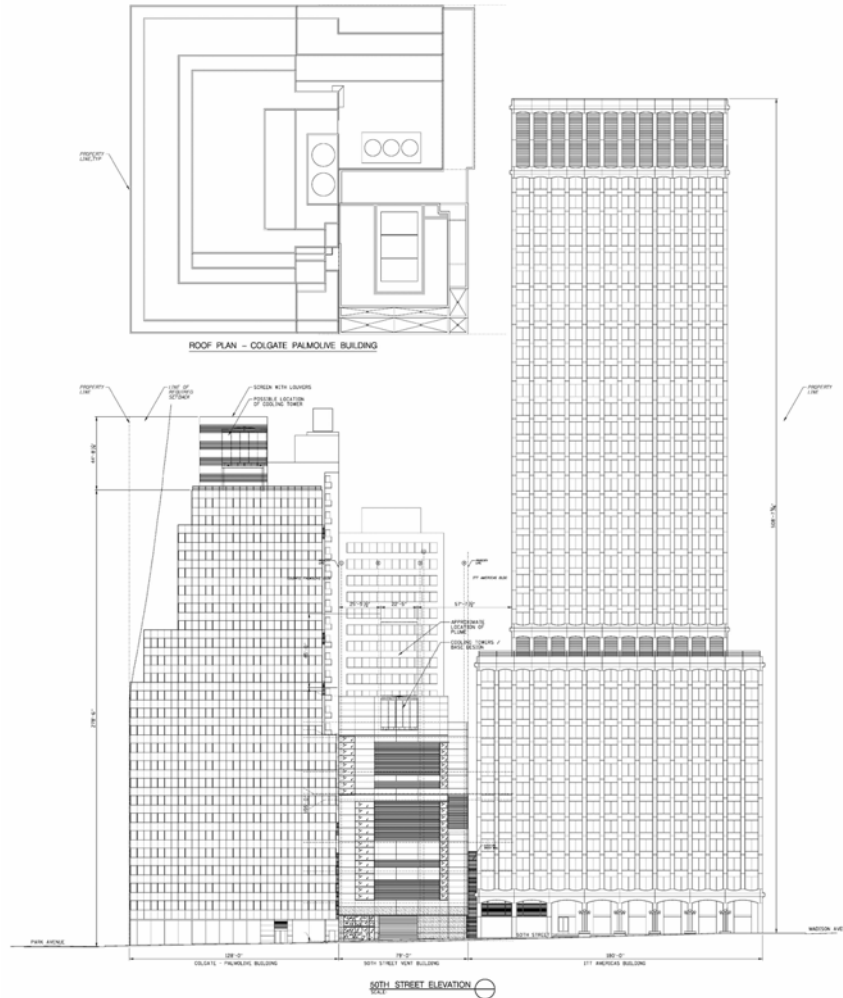
**APPENDIX E-1**

**MTA/LIRR East Side Access Project 50th Street Vent  
Building Cooling Tower Impacts Analysis,  
TRC Environmental Corporation, July 2004**

### **Notice of Clarification**

All references to the “ITT Americas” building should be read as “437 Madison Avenue.”

**MTA/LIRR East Side Access Project  
50<sup>th</sup> Street Vent Building  
Cooling Tower Impacts Analysis**



*Prepared for*

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**July 2004**

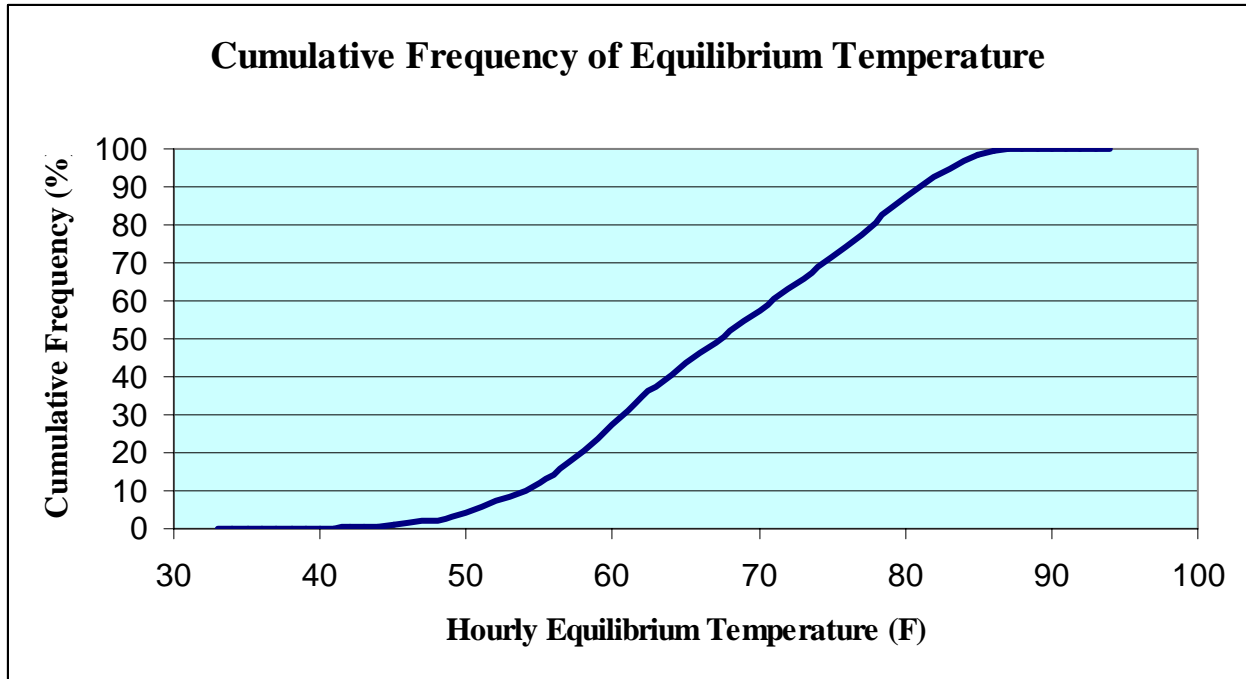
## ***INTRODUCTION***

The East Side Access (ESA) project will connect the Long Island Rail Road's (LIRR) Main and Port Washington lines in Queens to a new LIRR terminal beneath Grand Central Terminal in Manhattan. As part of the design, a ventilation building is proposed for 50<sup>th</sup> Street that will include a wet evaporative cooling tower to support the air conditioning load of the concourse of this new terminal. The possibility of condensed water vapor plumes from this cooling tower impinging on the windows of adjacent buildings and/or obscuring the view from these windows has been raised as a potential operational impact of the new system. TRC was retained by the ESA Project Management team to conduct an analysis of the vapor plume and evaluate the potential for these effects to occur. This report provides a discussion of the condensed plume modeling methodology and the results of the evaluation of the potential impacts associated with the operation of a proposed three-cell mechanical-draft Heating, Ventilation and Air Conditioning (HVAC) cooling tower. The purpose of this analysis is to evaluate frequency of occurrence of the condensed vapor (also called a steam) plume from the cooling tower, and the frequency any condensed vapor plumes impinging upon the adjoining buildings. The tower is proposed to be located on the 50<sup>th</sup> Street vent building between Park Avenue and Madison Avenue at a height of about 135 feet above street level, between the ITT-Americas Building (437 Madison Avenue) and the Colgate Palmolive Building (300 Park Avenue). The height places the outlet of the tower level with the 13<sup>th</sup> floors of the adjacent buildings. The Colgate Palmolive building has 25 floors above ground while the ITT Americas building has 40 floors above ground. One concern is the aesthetic impact associated with viewing of the plume by tenants on and above the 13<sup>th</sup> floors of the adjacent buildings. Since aesthetics is the primary concern, the modeling analysis was limited to determine the frequency of *visible* plumes which include only those condensed plumes that occur during the daylight hours. A second concern is the potential for the warm and moist cooling tower plume to impact upon the ventilation air intakes on the adjoining buildings. The cooling tower plume may impact upon the air intakes even if no visible plume is present. As such, the study also tabulates the average rise in temperature and relative increase moisture of the cooling tower plume in the directions of the air intakes on the adjacent buildings.

## ***MODELING METHODOLOGY***

The cooling tower visible plume analysis was performed using TRC's proprietary cooling tower model. TRC's model is a post processor used with dispersion modeling output results from the widely recognized USEPA ISCST3 atmospheric dispersion model. Water vapor is a non-reactive gas and assumed to be emitted at the equilibrium temperature of the cooling tower. The downwind dispersion characteristics of the cooling tower plume are considered to be accurately simulated using ISCST3. The model was run using five years of hourly meteorological data that includes: wind speed and direction; ambient temperature and moisture (relative humidity or dew point); and atmospheric stability (an indicator of the turbulence in the atmosphere). The cooling tower equilibrium temperature is calculated based on the maximum design heat duty requirement of the cooling tower (i.e. the amount of heat required to be rejected to the atmosphere) and the ambient air temperature and dew point temperature. The heat rejected by the tower is primarily through evaporation, which may range from about 50% during the wintertime, to as much as

90% during the summertime. The tower outlet air temperature is then assumed to be equal to the return circulating water temperature. Generally, the outlet temperature is higher than the ambient temperature; however, under conditions with low relative humidity and high air flow, the outlet temperature may be cooler than the ambient air. Under such conditions the plume would not have any associated vertical plume rise and the plume would remain level with the tower. The following figure is a summary of the cumulative distribution of circulating water return temperatures over an entire year based on five years of hourly observations. The return water temperature for each hour assessed is assumed equal to the equilibrium temperature of the tower.



As shown in the above figure, the range of the basin or return circulating water temperature is typically between 50F and 85F. The circulating water temperature can be kept at a higher level by turning off the fans from one or more cells, and indeed the cooling tower is operated at various loads throughout the year by cycling the fans.

The cooling tower is rated with a heat duty of 45 MMBtu/hour. During the summer the expected operation would be with three-cells operating with a heat duty of 80% rated capacity. During the winter, the tower is expected to operate with one cell with a heat duty on the tower of only 25% rated capacity. In order to conservatively simulate the full range of temperature and humidity conditions throughout the year, the tower was considered to operate during the following operating ranges.

- 1 cell with 33% rated heat duty when ambient temperature are less than 50F
- 2 cells with 67% rated heat duty when ambient temperatures are between 50F and 80F
- 3 cells with 100% rated heat duty when ambient temperature is greater than 80F

The equilibrium temperature for each hour was calculated based upon the enthalpy of the inlet air and the enthalpy added by the hot water from the cooling tower in order to dissipate the required heat duty for each of the above temperature regimes. The water emission rates were calculated on an hour by hour basis using the various expected heat duty of the tower expected during the year. The water evaporated is calculated from the difference in the absolute humidity of the outlet air of the tower (which is generally saturated, i.e. at 100% relative humidity) minus the absolute humidity of the inlet air. The tower outlet temperature is assumed to be the equilibrium temperature of the return circulating water. The dispersion of the water vapor emitted by the tower is then simulated using the ISCST3 air quality dispersion model. The plume temperature at specific receptors downwind is calculated by using the dilution of the plume exhaust temperature with the ambient air. The dilution factor is also determined by the dispersion model.

One goal of the cooling tower plume study is to determine the potential total number of hours of visible plumes expected to occur during an average year. To calculate the total average number of visible plumes, the analysis is simplified by using the same wind direction for each hour. The atmospheric mixing heights (a measure of the vertical limit for the dispersion of the plume) are set to 10km (to avoid plume reflection conditions) and thus are essentially ignored by the ISC model. The transitional plume rise option (i.e. the plume is bent over by the wind as it rises) is used to simulate the transitional vertical rise of the plume, rather than using the final plume rise which is the ISC model default option. Additionally, all calms are set to 0.5 m/s second and evaluated by the model. Calms are considered very important since the vertically rising plume which occurs under light winds during high humidity conditions presents a high likelihood for a visible plume formation.

The modeling analysis also considers wake effects (which include suppressed plume rise and vigorous mixing) behind the cooling tower due to strong winds. Plume downwash will occur in the lee of the tower under strong winds and is simulated by the stack-tip downwash function in the ISC model<sup>1</sup>. The effect caused by strong winds is that the plume is simulated to be emitted at a height lower than the physical height of the tower. This effect is called “flagging” where the plume appears to not rise, but is blown over the side of the tower and appears to look like a flag on the side of the tower. This effect appears in the accompanying figures where the plumes originate below the outlet of the tower.

Visible cooling tower plume formation is determined by comparing the hourly water vapor concentrations calculated at all receptors<sup>2</sup> to actual meteorological observations and the calculated saturation deficit. The saturation deficit is a measure of the amount of additional water vapor that must be added to a volume of air to bring it to saturation (i.e. 100% humidity.) The associated weather conditions (rain, snow, and fog) were identified along with time of day (day or night) for each calculated condensed vapor plume. A visible plume was assumed to occur if the water vapor concentration exceeded the saturation deficit (plus a threshold quantity) for each specific location and hour modeled. Under these conditions, TRC's model assumes the vapor plume will condense to form a visible cloud. The model calculates the total number of

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<sup>1</sup> User's Guide for the Industrial Source Complex (ISC) Dispersion Models – Volume II Description of Model Algorithms. U.S.E.P.A. Research Triangle Park, NC. June 1999

<sup>2</sup> A “receptor” is a location above and downwind of the cooling tower where plume calculations are performed.

hours of plume formation for all of the hours within the meteorological data set. These hours are divided into various categories (time of day, and meteorological conditions), which may preclude observation of the condensed vapor plume by the casual observer.

These periods include:

- Total number of hours when condensed water vapor plumes formed
- Plumes during the night only
- Plumes during the day only
- Plumes during obscuring weather
- Plumes during clear weather
- Plumes during the day with clear weather

Note that the 1996-2000 LaGuardia meteorological data had only limited weather condition data that were able to be used to exclude plumes formed during inclement weather. Since the “current weather” observations in the hourly data were missing for the years 1996-1998 the visible plumes were primarily segregated by only daytime and nighttime for three of the five years. The lack of “current weather” observations caused the number of visible plumes to be overstated by approximately 10 percent since plumes during inclement weather would not have been discounted during the 1996 - 1998. Inclement weather events were considered during 1999 and 2000.

Sunrise and sunset for each day of the year were calculated based on the actual geographic location of the proposed source to be examined. Daylight periods included one hour before sunrise until one hour after sunset (dawn and twilight). Obscuring weather included rain, snow, and natural fog (but not blowing snow or ground fog). TRC considers that only plumes that occur during the day with clear weather are visible condensed vapor plumes from the cooling tower.

#### ***Cooling Tower Visible Plume Density***

The cooling tower model assumes that a visible plume will occur when the dispersed water vapor concentration of the cooling tower plume exceeds the saturation deficit. Since the additional water vapor (over the vapor necessary to saturate the air) cannot remain as a vapor, the excess is assumed to immediately condense to form fog droplets. The visual density of the plume therefore is dependent upon the liquid water content (LWC) which is excess moisture over saturation, and size of the water droplets. Initially, the fog droplets will be very small and numerous and the apparent density of the plume will be proportional to the liquid water content. The liquid water content associated with atmospheric clouds is provided for reference in the following table:

### Liquid water content of typical atmospheric clouds

Cloud type	LWC (g/m <sup>3</sup> )
Small cumulus	0.2 - 0.5
Larger cumulus	0.5 – 1.0
Cumulonimbus (thunderstorm)	1.0 – 5.0+
Alto cumulus/altostratus	0.2 – 0.5
Stratus	0.1 – 0.5
Nimbostratus (rainstorm)	0.2 - 5

Source: Weatherwise, American Meteorological Society, May/June 2000

The visual density of the condensed cooling tower plume is also dependent on the thickness of the plume. In general, the width of the plume will not be any greater than the projected width of the cooling tower in the direction the wind is blowing. The plume therefore is rarely thicker across its width than the length of the tower. However, the plume can appear optically denser when the plumes from the separate cells align, such that the individual plumes overlap. This provides a narrower but denser plume. The cooling tower model considers that clouds with a LWC of less than 0.2 g/m<sup>3</sup> are sufficiently nebulous as to not be considered a distinct cloud or plume. As such, the threshold for plume formation is assumed to be the saturation deficit plus 0.2 g/m<sup>3</sup>.

However, the threshold of 0.2 g/m<sup>3</sup> only provides the outer envelop of the visible plume. The optical density of the plume is also characterized by the LWC as presented by in a paper by Eldridge.<sup>3</sup> The optical visibility of a stable fog is shown by Eldridge to be related logarithmically to the LWC. A plume water content greater than 4 g/m<sup>3</sup> would have an optical visibility of less than 10 meters (or 30 feet). This would mean that a plume greater than 30 feet in width or length would appear optically opaque (i.e. the observer would not be able to see through the plume). As the LWC decreases, the optical visibility of the plume increases indicating that the plume transitions from optically opaque, to translucent, to nebulous and finally evaporates altogether. The optical visibility transition points are identified in the following table.

### Plume Optical Visibility

Transition schema	LWC (g/m <sup>3</sup> )
Plume is not visible	<0.2
Plume is dissipating and broken	0.2 – 0.5
Plume appears somewhat opaque	0.5 – 1.5
Plume appears opaque	> 1.5

Source: Eldridge, interpreted by TRC

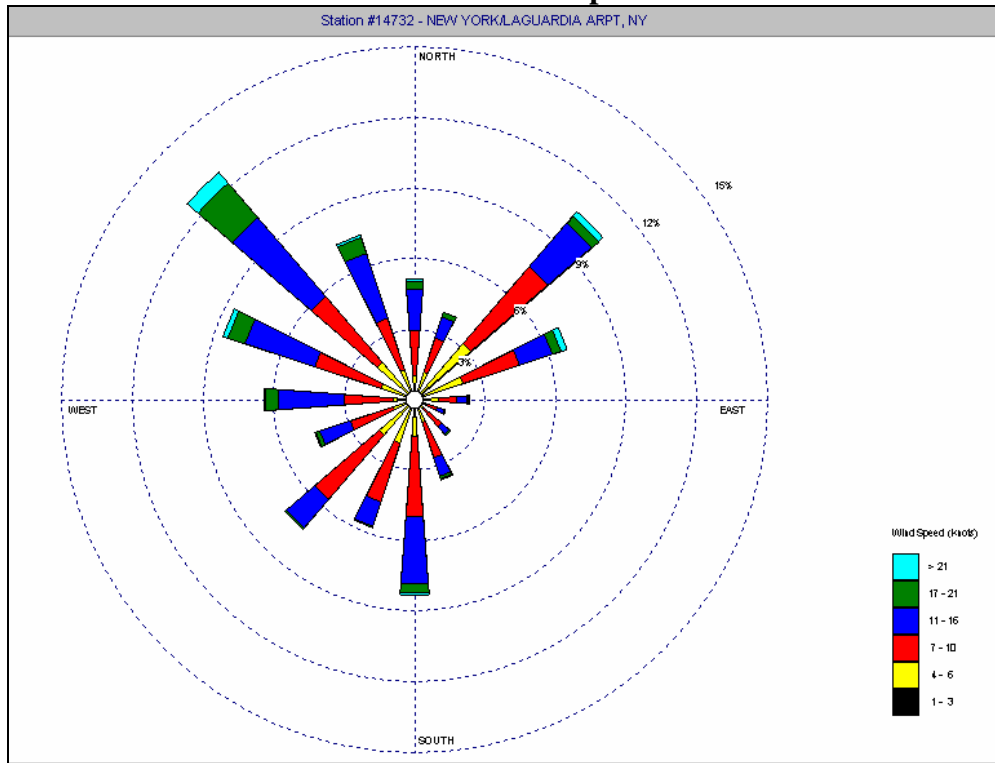
<sup>3</sup> Eldridge, Ralph G., The Relationship Between Visibility and Liquid Water Content in Fog. Journal of the Atmospheric Sciences, October 1971.

Note that the plume transition schema indicated are subjective and apply primarily to relatively small cooling tower plumes that are viewed along the length of the plume, rather than head-on with the plume.

**Model Input Parameters**

The cooling tower model used the design parameters for the proposed cooling tower with five years of hourly meteorological data (1996-2000) recorded at the LaGuardia Airport. Figure 1 shows a composite frequency distribution of the five-year database of wind speed and direction data. This figure is also called a wind rose and graphically presents the distribution of the average wind speeds and direction. The “petals” of the figure represent directions from which the wind is blowing.

**Figure 1 – Wind Rose for New York LaGuardia Airport – 1996-2000**



The wind rose illustrates that winds occur predominantly from the northwest, northeast and south through southwest. The wind speeds are measured at 20 feet, while the cooling tower will be at a height of 150 feet. Winds are normally stronger above the surface because of reduced friction effects, and the wind speeds were adjusted to account for the height difference.

The wind power law is used to adjust the observed wind speed,  $u_{ref}$ , from a reference measurement height,  $z_{ref}$ , to the tower release height,  $h_s$ . The tower height wind speed,  $u_s$ , is used in the dispersion model equation for calculating the dilution of the plume in the atmosphere based on the adjusted wind speed. The wind power law equation is of the form:

$$u_s = u_{ref} \times (h_s/z_{ref})^p$$

Where:  $h_s = 150$   
 $z_{ref} = 20$

The exponent (p) is a value dependent upon whether the area is urban or rural and the atmospheric stability index. For this study, the urban wind profile exponents were used. The values for (p) for an urban environment are:

**Power Law Exponents**

Stability class	A	B	C	D	E	F
Urban Exponent	0.15	0.15	0.2	0.25	0.3	0.3

The stability class is a measure of the turbulence of the atmosphere where class A is very turbulent while classes E and F are stable.

Additionally, due to the high buildings located along 50<sup>th</sup> Street in the vicinity of the proposed 50<sup>th</sup> Street Vent Building, the winds from the eastern to southeastern quarter will be channeled along 50<sup>th</sup> Street towards the northwest and likewise, winds from the northwest through west will be channeled towards the southeast. This will cause an increased number of cooling tower plumes to potentially impact upon the ITT-Americas building to the northwest and the Colgate-Palmolive building to the southeast. Therefore, the cooling tower model assessed two different wind direction scenarios. The plume study determined the number of visible plumes that may form based on ambient temperature and humidity; wind speed and atmospheric stability and segregated by the hours when the wind would be channeled towards the northwest (ITT Americas) and towards the southeast (Colgate Palmolive). The analysis further examined the three operating loads for each of these cases. This resulted in six plume scenarios being assessed.

***SUMMARY OF COOLING TOWER MODELING RESULTS***

The proposed 50<sup>th</sup> Street Vent Building cooling tower was conservatively assessed using the TRC’s cooling tower assessment model. Table 1 presents the cooling tower design parameters input to the model. Note that as previously discussed the equilibrium temperature (outlet air temperature from the tower) and the added water content due to evaporation were calculated and assessed on an hour-by-hour basis. This section presents and discusses the formation of the condensed visible plumes and provides a graphical illustration of the extent and frequency of the visible plumes. Figure 2 graphically illustrates the location of the receptors used in the modeling analysis. The ITT-Americas and Colgate-Palmolive buildings are included as a visual reference for the height of the receptors relative to the cooling tower and these adjacent buildings.

***Frequency of Visible Plumes***

The following table presents a summary of the six visible plume scenarios as average hours per year a visible plume may be expected to occur during the specific temperature regimes. The values represent average hours per year for each of the assessed conditions and temperature ranges. The total average hours per year would be the sum of the hours across the ranges.

## Visible Plume Analysis Summary

	Colgate Palmolive			ITT Americas		
	< 50F	50F - 80F	> 80F	< 50F	50F - 80F	> 80F
Total Plumes Formed	194	746	82	666	1199	72
Plumes during night only	101	250	3	285	346	3
Plumes during day only	93	496	79	381	854	69
Plumes during obscuring conditions	12	28	0	68	72	0
Plumes during clear conditions	182	718	82	598	1128	72
Plumes during day and clear conditions (visible plumes)	86	477	79	341	803	69

As shown in the above table, an average of only 86 hours per year will result in a visible plume when the wind is blowing towards the Colgate Palmolive building and the temperature is less than 50F. This relatively low value can be attributed to the low operating load requirement on the cooling tower during the cooler temperature conditions. An average of 477 hours of visible plumes was calculated during the generally temperate range between 50F and 80F. This increased value is due to the greater number of hours when the temperatures are within this range and the increased load on the tower. Finally, only 79 hours of visible plumes were calculated to occur when the temperature exceeds 80F. A total of 642 hours of visible plumes was calculated, which is approximately 12% of the total daylight hours during the year when visible plumes may occur towards the Colgate Palmolive building. The results for the ITT Americas building can be identified from the table with somewhat higher number of plumes during the cooler and moderate temperatures. A total of 1,212 hours of visible plume or 22% of the daylight hours had visible plumes directed towards ITT Americas. Tables 2 and 3 provide the distribution of visible plume hours by month and hour of day. As shown on these tables, the distributions tend to peak during the warmer months and during the warmer hours of the day. This is likely due to the higher heat duty assumed for the tower during the warmer temperatures.

Figures 3 through 5 illustrates the frequency (average hours per year) that the visible plumes may extend towards the Colgate Palmolive Building for the three temperature ranges. Similarly, Figures 6 through 8 illustrate the frequency (average hours per year) that the visible plumes may extend towards the ITT Americas Building. As shown on these figures, the majority of the total visible plumes are confined to the region immediately above or beside the cooling tower. The plumes would extend beyond the 50<sup>th</sup> Street Vent Building in the direction of the Colgate Palmolive Building less than 100 hours during the year would, and for less 10 hours a year the plumes may extend about 200 feet downwind. Similarly, the plumes would extend beyond the 50<sup>th</sup> Street Vent Building in the direction of the ITT Americas Building less than 200 hours during the year would, and for less 20 hours a year the plumes may extend beyond the ITT Americas Building downwind. The weather conditions associated with such extended plumes are light to moderate winds with high humidity.

### *Visualization of Individual Plumes*

The previous figures illustrated the average counts of plumes that may occur when the winds direct the plumes towards either of the adjacent buildings. However, it should be emphasized that the contours are not illustrations of the actual visual plumes that will form. The contours in

Figures 3 through 8 indicate the expected number of hours a visible plume envelope will be observed at the specific receptor. In order to provide a visualization of typical plumes for each of the temperature regions, the following Figures 9 and 10 illustrate the typical single plumes that may be observed towards the Colgate Palmolive and ITT Americas buildings, respectively. These plumes represent the plumes that will most likely occur and be visible to the general public. The plumes are segmented based on the liquid water content of various portions of the plume in order to illustrate the optical density of the plumes. Note that each figure represents a “snapshot” of a plume based on an hourly averaged wind speed and temperature and that the actual plumes constantly change from moment to moment. These figures also illustrate that one third to one half of the calculated visible plume length is expected to be opaque or nearly opaque.

### ***Plume Temperature and Humidity***

An additional concern associated with the cooling tower plumes being directed towards the adjacent buildings is the potential increase in temperature and humidity over ambient that may be experienced at the HVAC air intake vents. As shown in the preceding illustrations the plume from the cooling tower can be warmer than the ambient temperature and not saturated. However, the plume would have an increased humidity and temperature over ambient and if directed towards the HVAC vents on the adjacent buildings may pose an additional cooling/dehumidifying load for the HVAC units. Figures 11 through 14 illustrate the maximum average temperature and percent humidity increase over the ambient conditions when the plumes are directed towards the Colgate Palmolive and ITT Americas buildings. These figures represent the maximum averages across the three operating load ranges.

As shown by these figures, the average maximum temperature increase is less than 4 degrees F at the edge of the 50<sup>th</sup> Street Vent Building in either direction, with an average of less than a 75% increase in absolute humidity over ambient, also at the edge of the vent building. Such relatively slight increases in both temperature and humidity and only within a short distance from the cooling tower suggest that the proposed cooling tower would have a trivial if any adverse impact on the cooling load of the adjacent building HVAC units. The greatest temperature and humidity differences will occur during the colder months when an increase in temperature and humidity should have little to no effect on the cooling/dehumidifying load of the adjacent buildings.

### ***Window Fogging and Icing***

Fogging on a window due to a plume can occur if the plume impinges directly on the window and if the plume is sufficiently dense to allow the liquid water cloud droplets to impact and adhere. Fogging can also occur if the window is well below ambient temperature and the moist plume condenses on the window. Window fogging can occur when the air conditioning causes the windows to be much cooler than the outside temperature. Should the ambient humidity be nearly 100 percent, condensation may occur. However, such condensation would occur regardless of the cooling tower plume impacting the building, and if it occurs should not be attributed to the cooling tower.

Similarly, icing, in the form of rime ice can occur when the dense plume impacts a surface (i.e. window) that is well below freezing. Rime ice formation on wing surfaces is a concern for pilots flying through super-cooled clouds, but rarely an issue from an HVAC cooling tower. The super-cooled cooling tower plume droplets can freeze on contact with a cold surface. The actual

mechanism for rime ice formation is complicated and is predicated on the liquid water content of super-cooled cloud droplets, wind speed, and angle of the freezing surface, to name a few factors. However, both fogging and rime ice formation on windows is mainly dependent on the dense portion of the plume impacting the windows. As shown in the previous figures, the densest portion of the cooling tower plume is directly adjacent to the cooling tower and essentially never impacts the windows on adjacent buildings. Furthermore, in very cold weather a substantial amount of heat is lost through the windows, causing the outside surface to be warmer than ambient. Even if the ambient air were saturated, the warmer film of air immediately next to the window would preclude condensation and/or rime ice formation. Therefore, fogging and/or icing on the adjacent building windows would be very unlikely to occur.

## **SUMMARY AND CONCLUSION**

The proposed ESA project 50<sup>th</sup> Street Vent Building cooling tower was rigorously assessed using actual historical meteorological data representative of the area and a cooling tower model developed by TRC. The model incorporated the operational design data of the cooling tower to accurately calculate the hourly exhaust temperature and water evaporation rate. These parameters were then used with a state-of-the-art air dispersion simulation model – ISCST3. In this manner, both the thermodynamics of the tower operation and the dispersion of the tower plume were considered to be accurately simulated. The analysis examined nearly 44,000 combinations of historical temperature and humidity, wind speed and atmospheric stability. The analysis specifically examined the wind directions when the cooling tower plumes would blow towards the Colgate Palmolive and ITT Americas Buildings. The analysis determined that a small vapor plume will be present immediately above the cooling tower while it is operating. Only rarely would the visible plume extend any substantial distance downwind from the cooling tower. Plumes that extend beyond the 50<sup>th</sup> Street Vent Building towards the Colgate Palmolive building occur less than 100 hours out of a possible 4,000 hours per year. This represents only 2.5% of the possible hours during which a plume could be visible. Similarly, the visible plumes that extend beyond the 50<sup>th</sup> Street Vent Building towards the ITT Americas building occur less than 200 hours out of a possible 4,000 visible hours, or 5% of the time. This low amount of visible plumes extending beyond the vent building is considered a trivial and insignificant quantity.

Similarly, the average plume temperature and moisture increase was examined. On average, the temperature would not increase by more than 4 degrees F beyond the edge of the vent building, and generally less than 1 degree within 150 feet. The additional moisture is also confined to immediately above the tower and at the edge of the vent building is expected to average less than a 75% increase over the ambient absolute humidity. Finally, based on the relatively low liquid water content of the condensed vapor plumes, it is anticipated that fogging and icing of windows would be rare or non-existent.

In conclusion, the proposed cooling tower for the 50<sup>th</sup> Street Vent Building will result in some visible plumes and increased temperature and humidity in the immediate vicinity of the tower. However, the plumes will be relatively small and generally confined to an area immediately at the tower. Under high humidity conditions a condensed visible plume may extend a few hundred

feet east or west, but such plumes would dissipate quickly such that the plume would not extend beyond the adjacent buildings. As such, it is anticipated that the proposed cooling tower will have minimal to no adverse effects due to visible plumes or associated increase in ambient temperature or moisture.

**Table 1**  
**50<sup>th</sup> Street Vent Building Cooling Tower Operating Parameters**

<b>Parameter</b>	<b>Value</b>
Tower design operating condition:	Full load (3 Cells)
Tower Orientation and configuration	NE/SW 3x1
Number of Cells:	3
Tower Height (top of fan above street level) (feet):	150
Tower Length (feet):	42.3
Tower Width (feet):	22.4
Individual Fan Diameter (feet):	12
Tower Effective Diameter <sup>(1)</sup> (feet):	20.9
Tower Air Flow (CFM):	813,300
Tower Air Flow (lbs/min) <sup>(2)</sup> :	60,244
Circulating Water (gpm)	9,000
Circulating Water (lbs/min)	75,060
Liquid to Gas (L/G) ratio:	1.246
Design Hot Water Temperature: (F)	95
Design Cold Water Temperature: (F)	85
Total Tower Rated Heat Duty (MMBtu/hr):	45.04
Operating Loads: Ambient Temperature < 50F Ambient Temperature 50F – 80F Ambient Temperature > 80F	1 cell 33% Rated Capacity 2 cell 67% Rated Capacity 3 cell 100% Rated Capacity <sup>(3)</sup>
Site Latitude (degrees):	40.7567 N
Site Longitude (degrees):	73.9727 W

1. Equivalent diameter of 3 cells  $12 * 3^{0.5}$

2. 13.5 CF/lb dry air at 65F

3. Tower heat duty expected to be 80% rated capacity during typical summer conditions.

**Table 2**  
**Summary of Annual Hours of Visible Plume Formation by Month**

<b>Month</b>	<b>Directions<sup>2</sup> towards Colgate Palmolive</b>	<b>Directions<sup>1</sup> towards ITT-Americas</b>
Jan	20	66
Feb	23	76
Mar	41	89
Apr	62	104
May	82	160
Jun	100	151
Jul	88	128
Aug	69	143
Sep	68	106
Oct	51	80
Nov	23	53
Dec	15	56
<b>Total</b>	<b>642</b>	<b>1,212</b>

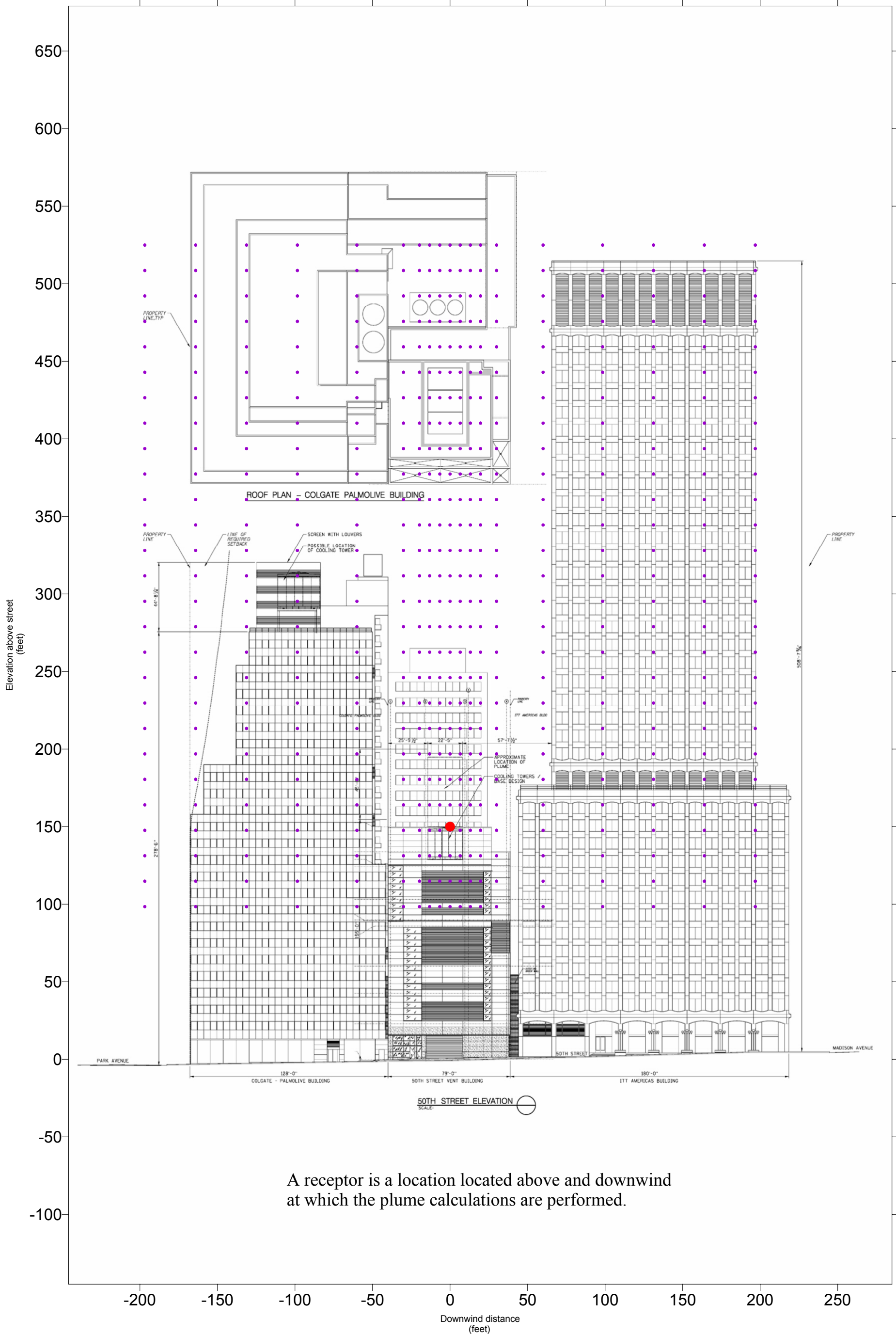
1. Winds channeled northwest along 50<sup>th</sup> Street.
2. Winds channeled southeast along 50<sup>th</sup> Street.
3. Obscuring conditions (i.e. inclement weather) were only recorded for the last two years of the LaGuardia weather data (1999-2000).

**Table 3**  
**Summary of Annual Hours of Visible Plume Formation by Hour of Day**

<b>Hour</b>	<b>Directions<sup>2</sup> towards Colgate Palmolive</b>	<b>Directions<sup>1</sup> towards ITT-Americas</b>
1	0	0
2	0	0
3	13	24
4	20	44
5	28	66
6	26	74
7	24	81
8	22	84
9	23	88
10	23	87
11	28	88
12	35	81
13	41	77
14	45	78
15	52	75
16	65	76
17	73	70
18	55	56
19	45	42
20	24	20
21	0	0
22	0	0
23	0	0
24	0	0
<b>Total</b>	<b>642</b>	<b>1,212</b>

1. Winds channeled northwest along 50<sup>th</sup> Street.
2. Winds channeled southeast along 50<sup>th</sup> Street.
3. Obscuring conditions (i.e. inclement weather) were only recorded for the last two years of the LaGuardia weather data (1999-2000).

FIGURE 2 - RECEPTOR LOCATIONS



A receptor is a location located above and downwind at which the plume calculations are performed.

FIGURE 3 : < 50F TOWARDS COLGATE PALMOLIVE

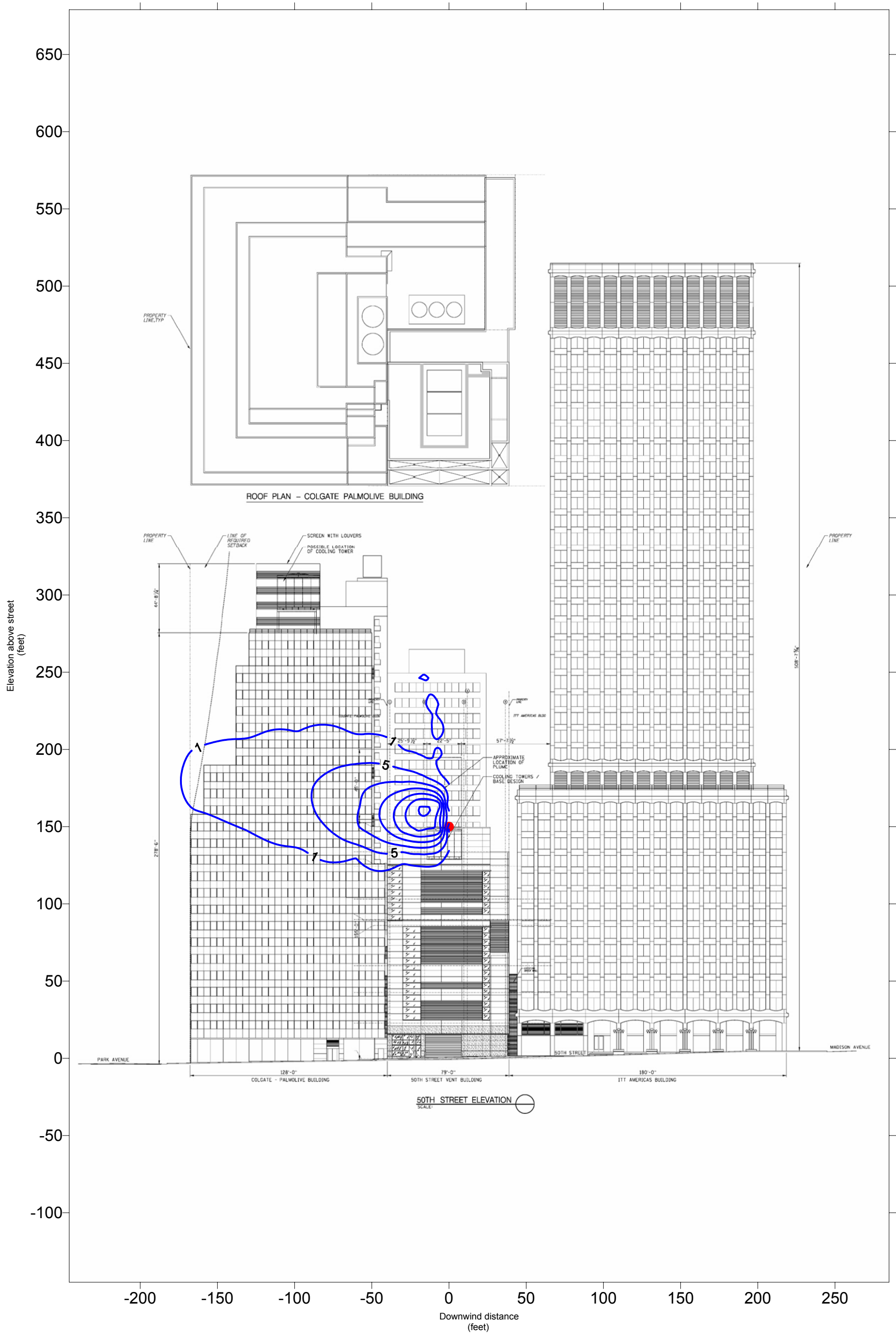


FIGURE 4 : 50F - 80F TOWARDS COLGATE PALMOLIVE

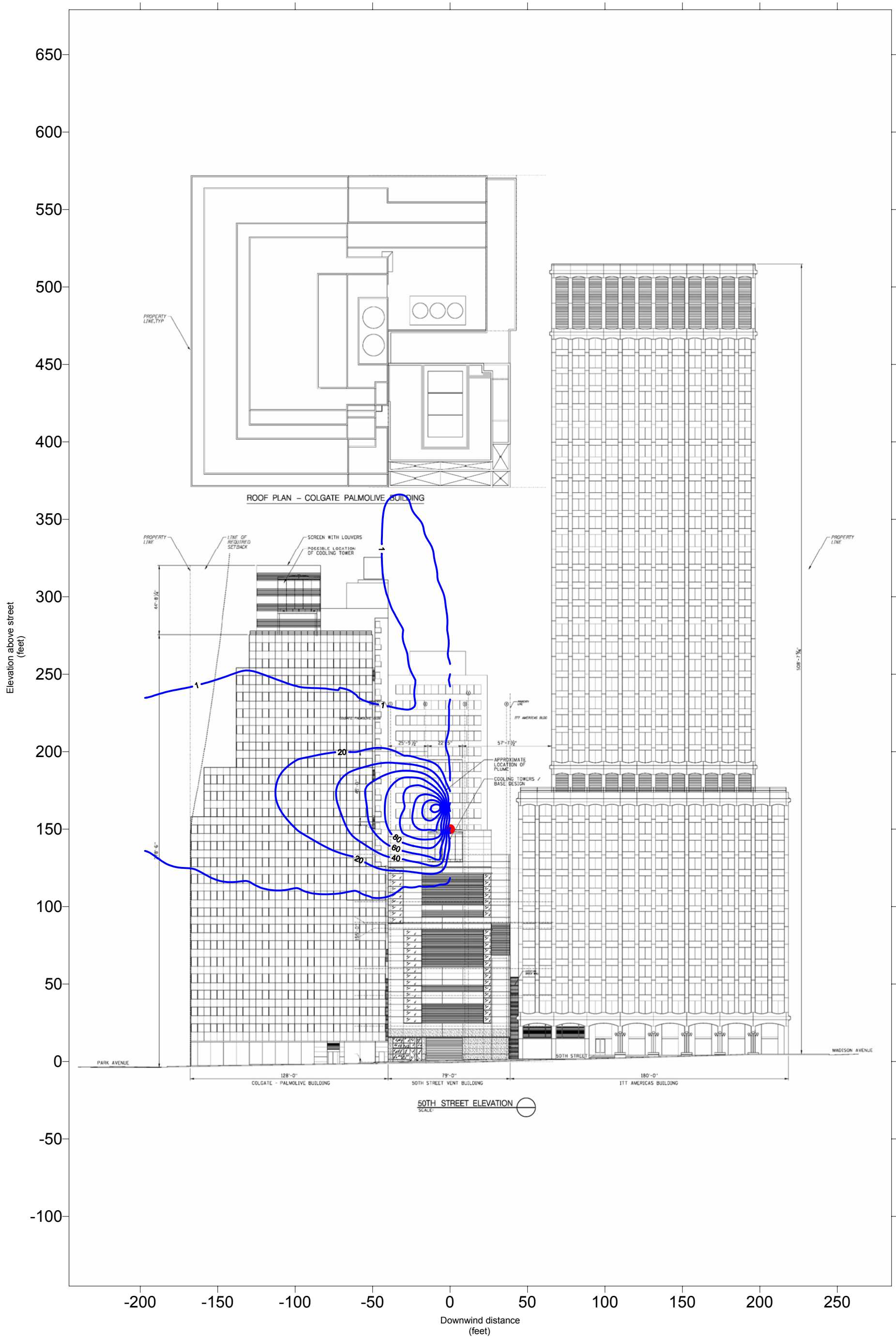


FIGURE 5 : > 80F TOWARDS COLGATE PALMOLIVE

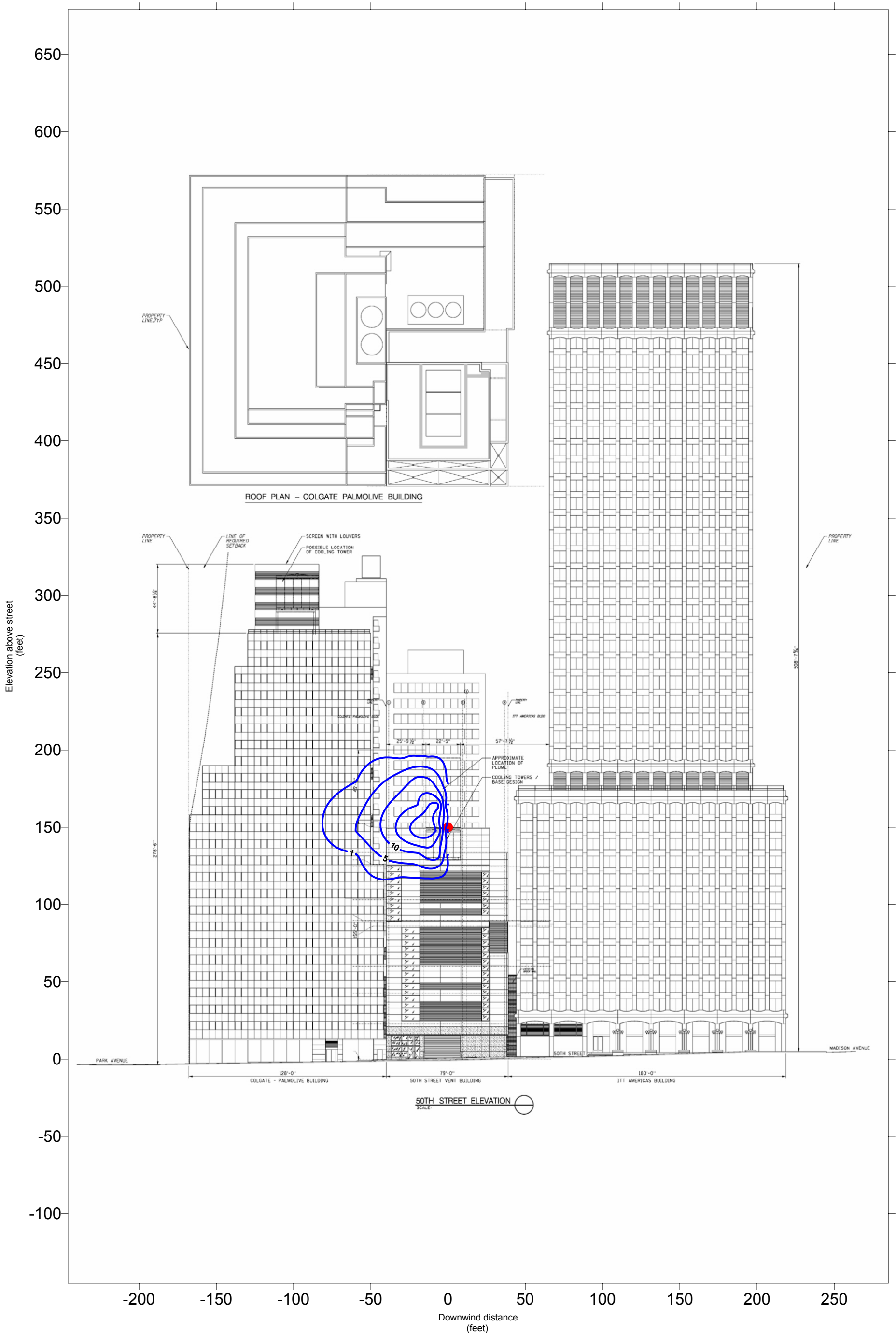


FIGURE 6: < 50F TOWARDS ITT AMERICAS

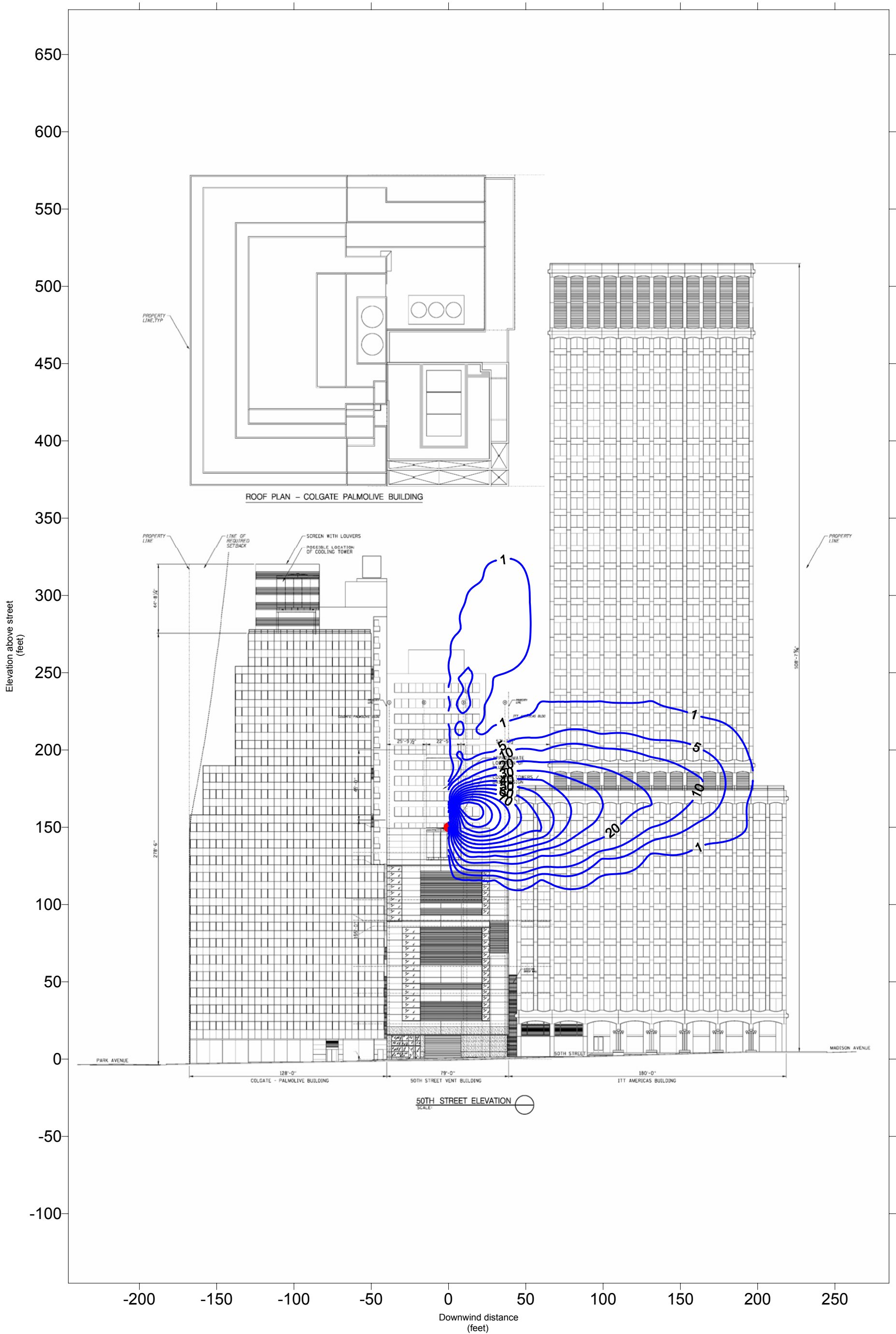


FIGURE 7 : 50F - 80F TOWARDS ITT AMERICAS

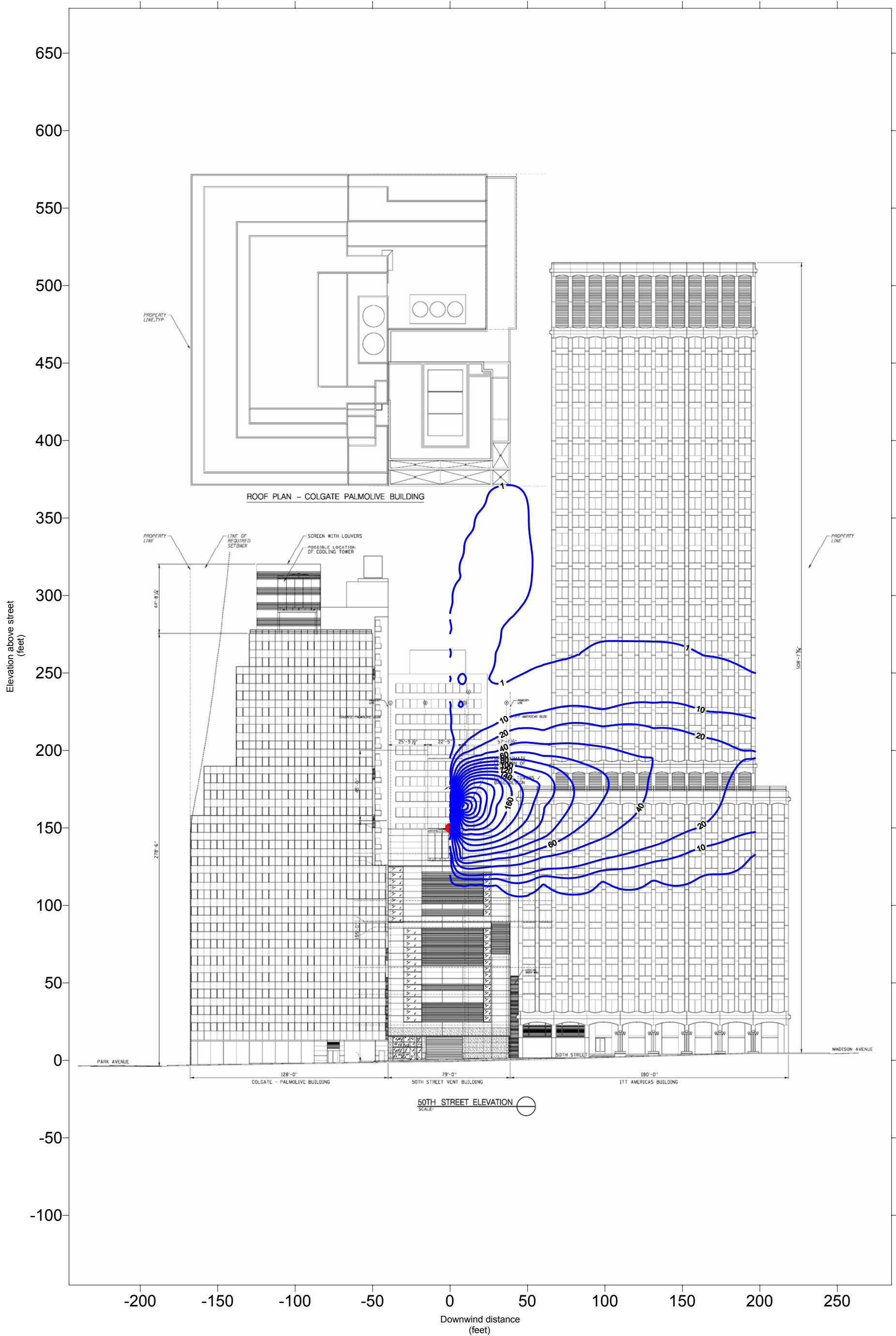


FIGURE 8 : > 80F TOWARDS ITT AMERICAS

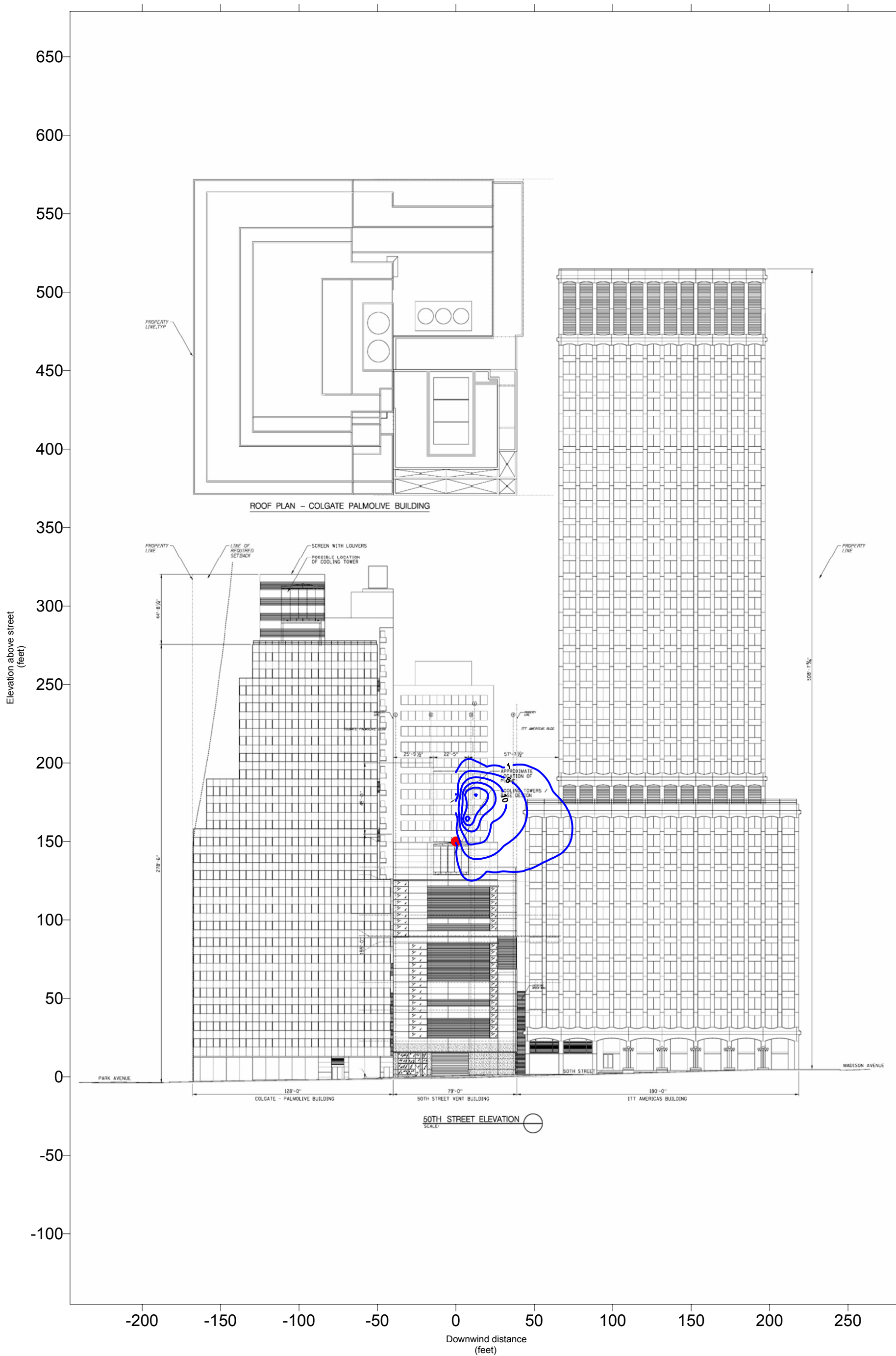


FIGURE 9 : TYPICAL VISIBLE PLUME TOWARDS COLGATE PALMOLIVE

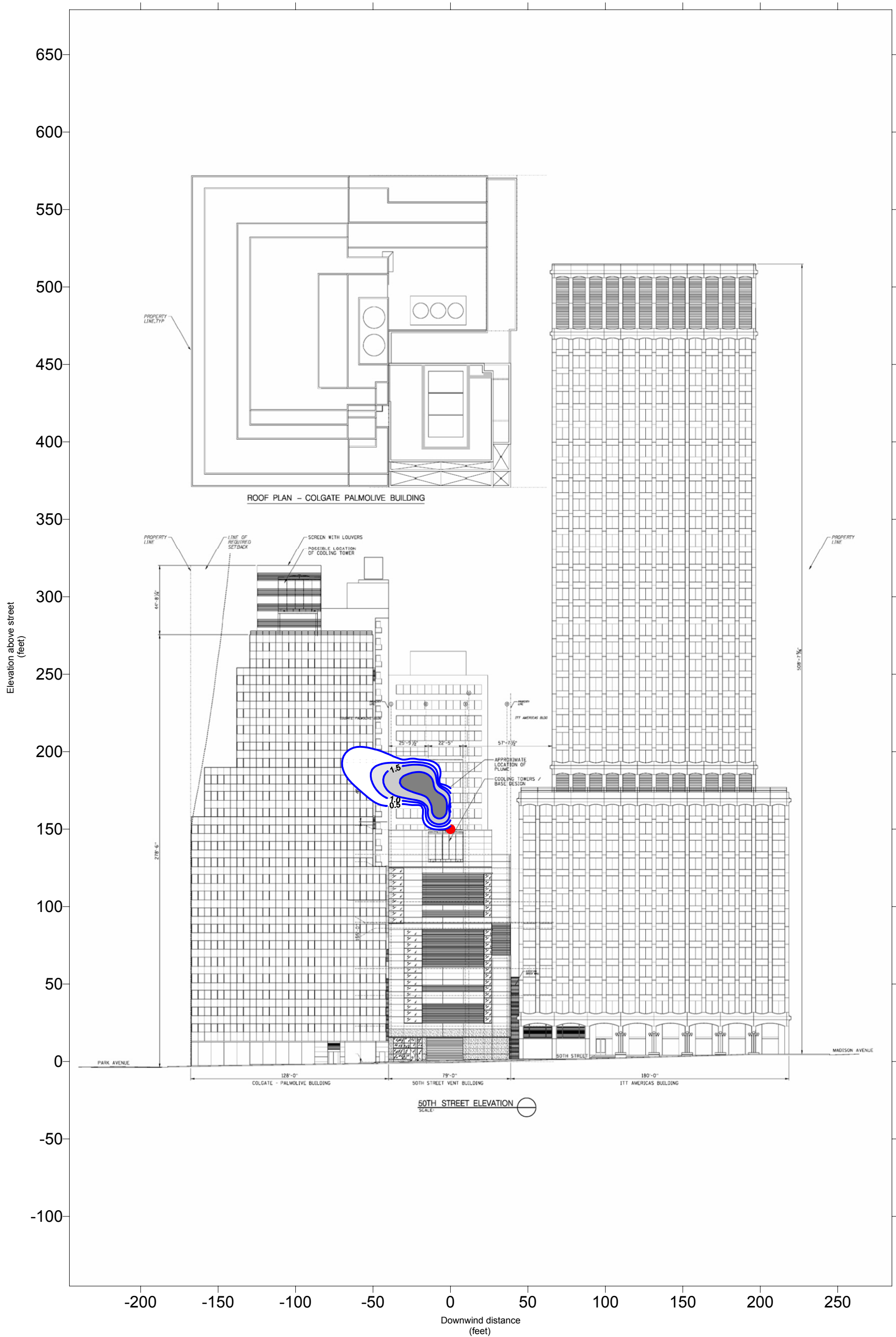


FIGURE 10 : TYPICAL VISIBLE PLUME TOWARDS  
ITT AMERICAS

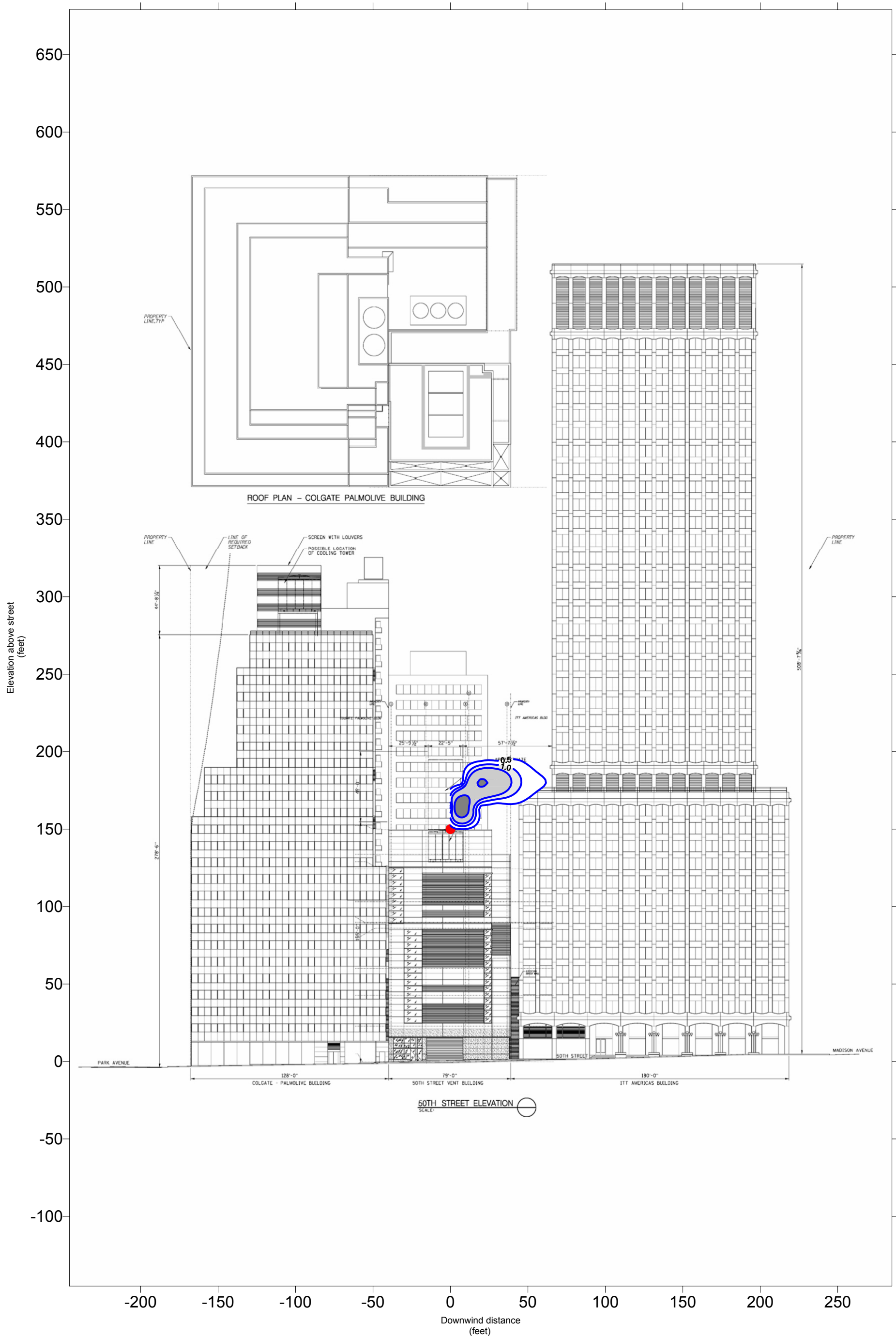


FIGURE 11 : MAXIMUM AVERAGE TEMPERATURE INCREASE TOWARDS COLGATE PALMOLIVE

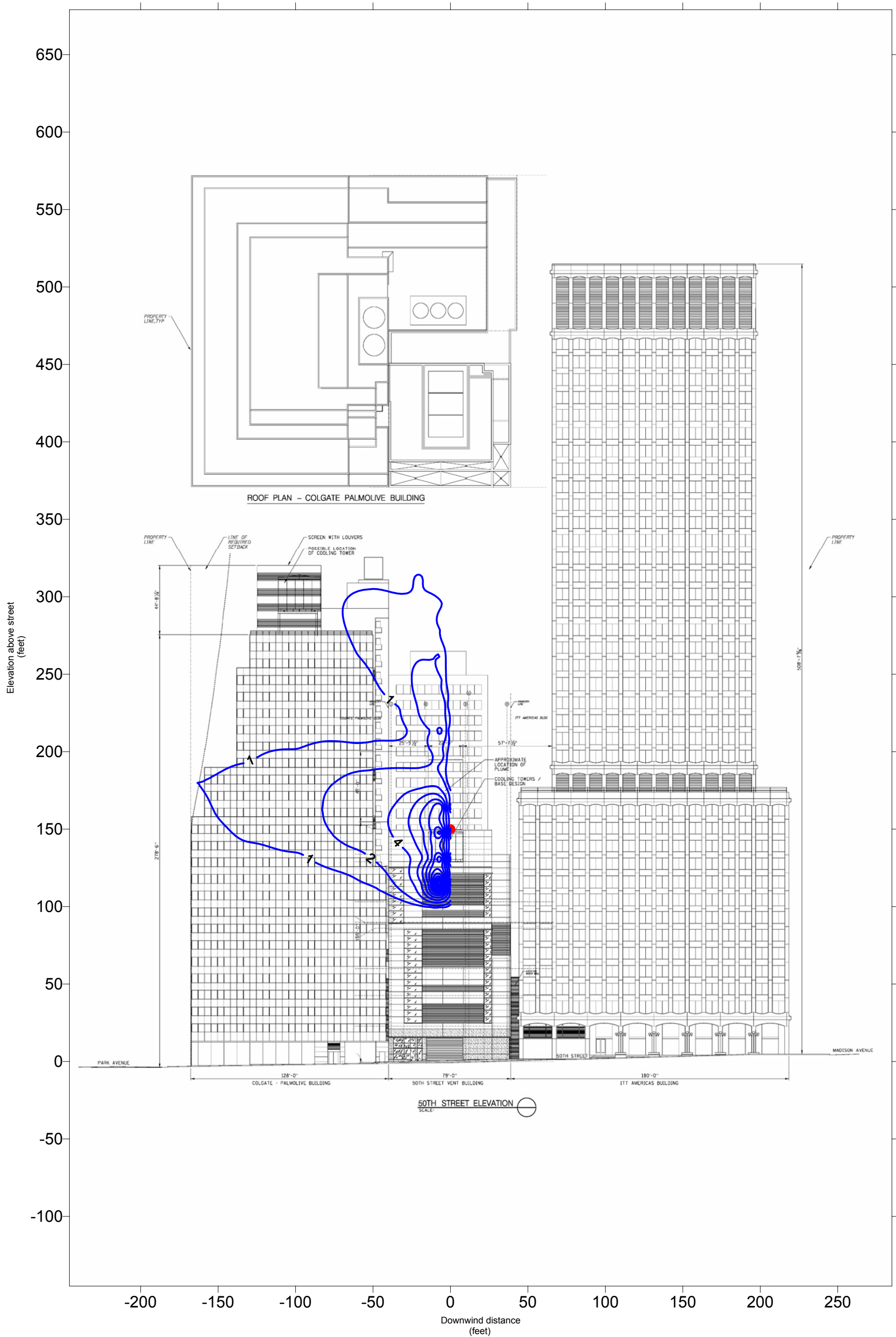


FIGURE 12 : MAXIMUM AVERAGE PERCENT MOISTURE INCREASE TOWARDS COLGATE PALMOLIVE

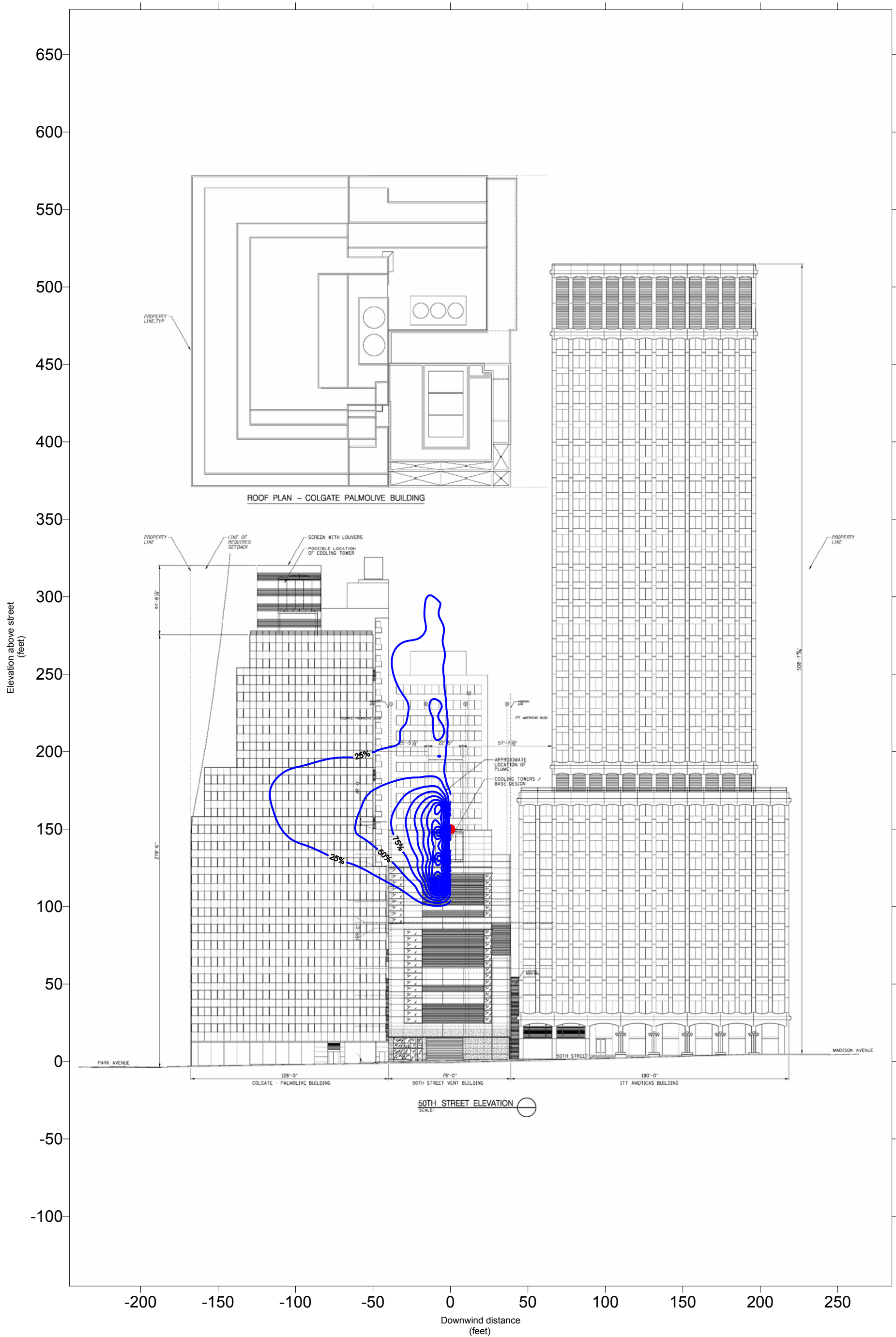




FIGURE 14 : MAXIMUM AVERAGE PERCENT MOISTURE INCREASE TOWARDS ITT AMERICAS

