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Document Title:	Digital Realty's Revised Airspace Technical Memo - LBGF
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Kimley»Horn

MEMORANDUM

To:	Scott Galati DayZen LLC
From:	Andrew Scanlon Kimley-Horn and Associates, Inc.
Date:	October 20, 2022 Updated December 8, 2022
Subject:	Lafayette Data Center Plume Airspace Analysis

On behalf of DayZen LLC (Client) Kimley-Horn conducted an airspace study to analyze potential aeronautical impacts of the thermal plume for a proposed 576,120 square foot datacenter with an associate backup generator facility and chiller system located near Norman Y. Mineta San Jose International Airport (SJC). As discussed in this document, an overall approximated building/generator/chiller footprint was analyzed. The building has previously been analyzed by the FAA and a Determination of No Hazard was issued. These determinations are attached to this study. Height of the thermal plumes to be analyzed were provided by the Client and adjusted by the Client to represent the maximum height from the ground. Therefore, Kimley-Horn did not adjust the thermal plume heights to account for any stacks or exhaust cowls.

Proposed Site

The site is located at 2825 Lafayette Street, shown in Figure 1. The site is within 0.19 nautical miles (nm) of the physical end of Runway 12R. Table 1 provides points analyzed which approximates the overall potential footprint of the plume location. The client provided Electrical Site Plan has been annotated with point numbers which correlates to the tabular data represented in Table 1 and is included as an attachment.

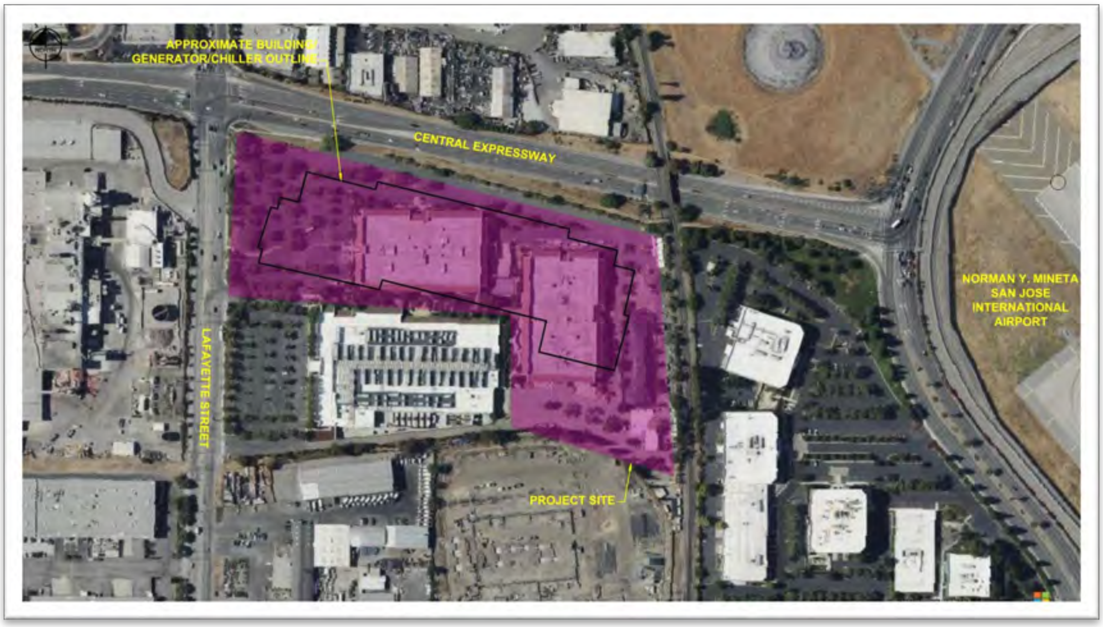

Figure 1 – Project Site

Table 1 – Points Analyzed

Point	Latitude	Longitude
Point 1	37° 22' 25.15" N	121° 56' 55.02" W
Point 2	37° 22' 23.91" N	121° 56' 48.27" W
Point 3	37° 22' 23.66" N	121° 56' 48.32" W
Point 4	37° 22' 23.34" N	121° 56' 46.57" W
Point 5	37° 22' 22.90" N	121° 56' 46.69" W
Point 6	37° 22' 22.78" N	121° 56' 45.96" W
Point 7	37° 22' 21.50" N	121° 56' 46.13" W
Point 8	37° 22' 19.98" N	121° 56' 46.62" W
Point 9	37° 22' 20.46" N	121° 56' 49.27" W
Point 10	37° 22' 21.33" N	121° 56' 49.03" W
Point 11	37° 22' 22.41" N	121° 56' 54.80" W
Point 12	37° 22' 22.14" N	121° 56' 54.91" W
Point 13	37° 22' 22.83" N	121° 56' 59.15" W
Point 14	37° 22' 23.27" N	121° 56' 59.18" W
Point 15	37° 22' 24.39" N	121° 56' 58.75" W
Point 16	37° 22' 25.40" N	121° 56' 57.51" W

For the site, two plume heights were evaluated: the diesel generator plume which was calculated to be 112.9 feet Above Ground Level (AGL, rounded to 113 feet for this analysis) and the chiller plume which was calculated to be 132.4 feet AGL (rounded to 133 feet for this analysis). For the purposes of this evaluation, a site elevation of 40 feet was assumed and added to the plume heights to get a top Mean Sea Level (MSL) elevation of 153 and 173 feet for the diesel and chiller plumes, respectively.

The plume heights were provided by others and were calculated assuming a max height associated with a velocity of 5.3 m/s which represents the minimum velocity to cause light turbulence. The Vertical Plume Velocity Assessment Report is attached to this analysis for reference.

Methodology

Kimley-Horn modeled the airport imaginary surfaces at SJC, as defined in 14 Code of Federal Regulations (CFR) Part 77 (Part 77) and evaluated applicable airport design standards set forth in Federal Aviation Administration (FAA) Advisory Circular (AC) 150/300-13B, Airport Design.

Kimley-Horn also modeled the obstacle clearance surfaces as defined in FAA Order 8260-3E, United States Standard for Terminal Instrument Procedures (TERPS), including Change 1. Specifically, Kimley-Horn modeled:

- TERPS 40:1 Departure Surface for Runways 30L and 30R
- ILS[1] or LOC[2] Runway (RWY) 12R
- RNAV[3] RNP[4] Approach to RWY 12R
- RNAV GPS[5] Approach to RWY 12R
- RNAV RNP Approach to RWY 12L
- RNAV GPS Approach to RWY 12L

Assumptions and Limitations

Ultimately, the FAA is responsible for making the final determination regarding the cumulative impacts resulting from this development. The results of Kimley-Horn's modeling should be used for informational purposes only.

This analysis is limited to an airspace study and does not include the investigation of potential impacts of the proposed development to navigational facilities (i.e., interference).

It is also important to note that the FAA evaluates the elevations of proposed construction with respect to MSL. Often, civil engineers and surveyors report elevation values using other vertical datums, which, when compared with MSL, can cause discrepancies between the proposed and evaluated elevations. It is recommended that the Client consult with their surveyor prior to setting final building elevations, as to ensure consistency with the elevation values. The FAA requires the

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[1] ILS – Instrument Landing System
[2] LOC – Localizer
[3] RNAV – Area Navigation
[4] RNP – Required Navigation Approach
[5] GPS – Global Positioning System

coordinates in North American Datum of 1983 (NAD83) and elevations in North American Vertical Datum of 1988 (NAVD88).

Findings

The following includes findings for the project site.

PART 77

The site is very near the Runway 12R end and falls mostly within the Transitional Surface and partially within the Horizontal Surface for SJC. The Transitional Surface is a sloping surface, that gains one foot vertically for every seven feet horizontally, as it extends perpendicular to the runway centerline. The Horizontal Surface is a flat plane, 150 feet above the airport elevation. At SJC, the Horizontal Surface is 212.16 feet MSL. A graphical depiction of the site and overlying Part 77 surfaces is found in Figure 2. The Transitional Surface is represented in green, and the Horizontal Surface is represented in blue. Table 2 presents the results at each of the 16 points evaluated. Negative numbers represent penetrations to the Part 77 Surfaces.

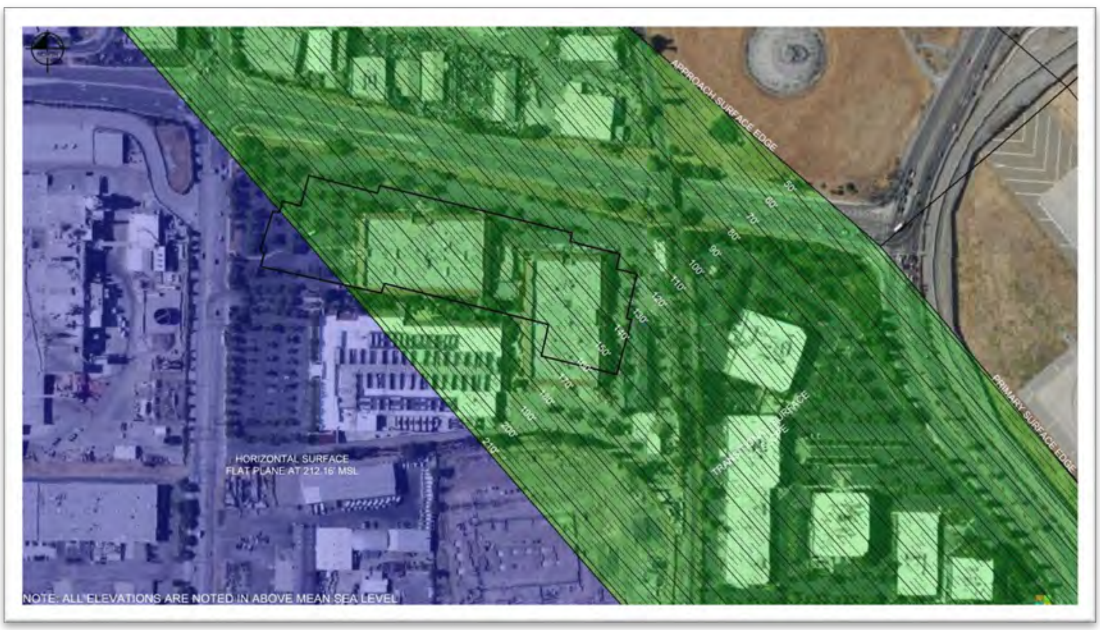


Figure 2 – Part 77 Transitional Surface

Table 2 – Part 77 Allowable MSL

Point	Latitude	Longitude	Surface Elevation (in MSL)	Diesel Plume Results	Chiller Plume Results
Point 1	37° 22' 25.15" N	121° 56' 55.02" W	174	21	1
Point 2	37° 22' 23.91" N	121° 56' 48.27" W	128	-25	-45
Point 3	37° 22' 23.66" N	121° 56' 48.32" W	131	-22	-42
Point 4	37° 22' 23.34" N	121° 56' 46.57" W	119	-34	-54
Point 5	37° 22' 22.90" N	121° 56' 46.69" W	124	-29	-49
Point 6	37° 22' 22.78" N	121° 56' 45.96" W	119	-34	-54
Point 7	37° 22' 21.50" N	121° 56' 46.13" W	133	-20	-40
Point 8	37° 22' 19.98" N	121° 56' 46.62" W	152	-1	-21
Point 9	37° 22' 20.46" N	121° 56' 49.27" W	170	17	-3
Point 10	37° 22' 21.33" N	121° 56' 49.03" W	160	7	-13
Point 11	37° 22' 22.41" N	121° 56' 54.80" W	199	46	26
Point 12	37° 22' 22.14" N	121° 56' 54.91" W	202	49	29
Point 13	37° 22' 22.83" N	121° 56' 59.15" W	212	59	39
Point 14	37° 22' 23.27" N	121° 56' 59.18" W	212	59	39
Point 15	37° 22' 24.39" N	121° 56' 58.75" W	212	59	39
Point 16	37° 22' 25.40" N	121° 56' 57.51" W	194	41	21
Negative numbers represent penetrations to the Part 77 Surfaces.					

Penetrations to the Part 77 Transitional Surface are common occurrences at airports. Based upon the currently FAA approved Airport Layout Plan (ALP), SJC features over 100 obstacles which currently penetrate the Part 77 Transitional Surfaces. Aircraft will not be regularly flying over this area at these low elevations. It is assumed that the plumes will not represent a hazard to air navigation because it does not impact any of the published approach, missed approach, or departure procedures for SJC (see subsequent sections in this report).

AIRPORT DESIGN SURFACES

The project site is outside of Airport Design Surfaces and therefore does not adversely impact the airport design surfaces at SJC. However, the San Jose VOR/DME[6] is near the project site and is within the 1,000-foot VOR critical area (see Figure 3). Solid or fixed structures will represent a more critical concern for the VOR critical area than the plumes associated with the chillers or backup diesel generators. As previously noted, a 7460 for the proposed building was submitted to the FAA for review. The FAA analyzed potential impacts to air navigation, inclusive of this navigational aid, and made a “Determination of No Hazard” for the building. The determinations are attached to this report.

[6] VOR/DME – Very High Frequency Omni-Directional Range/Distance Measuring Equipment

The FAA Technical Operations Line of Business is provided an opportunity to comment during the 7460 review process. No comments were received, and a Determination of No Hazard was issued.

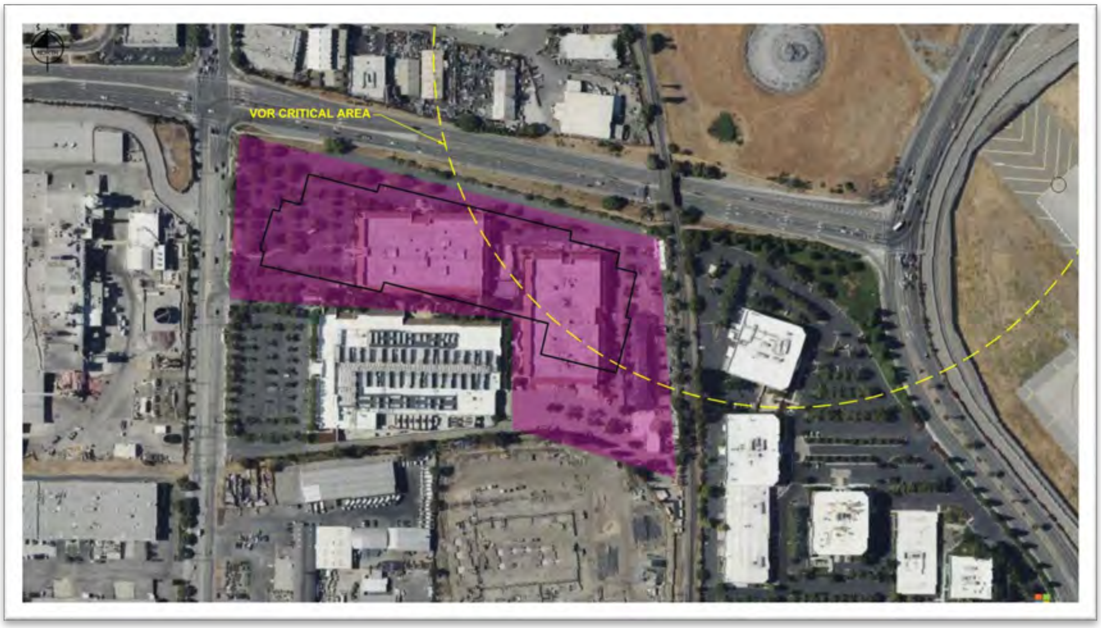


Figure 3 – VOR Critical Area Over Project Site

DEPARTURE SURFACE FOR RUNWAYS 30L AND 30R (TERPS)

The northeastern portion of the project site lies within the TERPS 40:1 Departure Surfaces for Runways 30L and 30R. Specifically, Points 2 through 6 are within the lateral limits of the TERPS 40:1 Departure Surfaces. Neither the diesel plume, nor the chiller plume, impacts the TERPS 40:1 Departure Surfaces. The lowest elevation of the Runway 30L TERPS 40:1 Departure Surface is at Point 4, where it is about 351 feet MSL and 368 feet MSL for the Runway 30R TERPS 40:1 Departure Surface.

ILS OR LOC RWY 12R

The ILS or LOC RWY 12 instrument approach procedure consists of Vertically Guided (ILS) and Non-Vertically Guided (Localizer) components. The northeastern portion of the site, specifically Points 2 through 7, is within the obstacle identification surface for both the ILS and Localizer components. At the studied MSLs, the diesel and chiller plumes do not impact the ILS or Localizer components. The maximum top elevation before adversely impacting the Localizer approach to Runway 12R is 196 feet MSL.

RNAV (GPS) RWY 12R

The RNAV (GPS) RWY 12R instrument approach procedure consists of Precision Vertically Guided (LPV), Non-Precision Vertically Guided (LNAV/VNAV) and Non-Precision (LNAV) lines of minima. Each are discussed below.

LPV: The LPV uses the same obstacle identification surfaces as the above-mentioned ILS procedure. Thus, Points 2 through 7 are within the obstacle identification surface and do not penetrate the LPV procedure.

LNAV/VNAV: Points 2 through 7 are within the obstacle identification surface of the LNAV/VNAV procedure. The plumes – diesel and chiller – do not adversely impact the existing LNAV/VNAV procedure. The required Decision Altitude (DA) to clear the plumes is 371 feet MSL, which matches the currently published DA. Any increase in site elevation will impact this procedure.

LNAV: The Points 2 through 7 are also within the LNAV obstacle identification surface. The existing LNAV procedure is not adversely impacted by the diesel and chiller plumes.

Missed Approach: For the RNAV (GPS) RWY 12R approach procedure, there is a missed approach segment. This protects for aircraft executing an aborted landing maneuver when the runway is not in sight at the specified DA or Minimum Descent Altitude (MDA). The entire site is within Missed Approach surface and the chiller plume is clear by at least 37 feet.

RNAV (RNP) RWY 12R

The RNAV (RNP) RWY 12R instrument approach procedure consists of Vertically Guided (RNP) segments that have different obstacle evaluation areas to accommodate aircraft with advanced avionics. The project site is partially within the obstacle evaluation areas and does not represent an obstacle at the evaluated heights.

RNAV (GPS) RWY 12L

The RNAV (GPS) RWY 12L instrument approach procedure also consists of LPV, LNAV/VNAV, and LNAV lines of minima.

LPV: There are no penetrations to the LPV procedure.

LNAV/VNAV: The plumes – diesel and chiller – do not adversely impact the existing LNAV/VNAV procedure.

LNAV: The LNAV procedure is also not adversely impacted by the diesel and chiller plumes.

Missed Approach: The site is also within the Missed Approach surfaces associated with this instrument approach procedure and does not cause an adverse impact at either plume height. The chiller plume height is clear of the Missed Approach surface by 7 feet.

RNAV (RNP) RWY 12L

The project site is partially within the RNAV (RNP) RWY 12L obstacle evaluation areas and does not represent an obstacle at the evaluated points and heights. None of the points analyzed are within the missed approach surface.

Analysis of Overflights

At the request of SJC staff, additional analysis was performed to determine the frequency at which overflights occurred over the project site, and at what altitudes those overflights occurred. Kimley-Horn obtained Automatic Dependent Surveillance – Broadcast (ADS-B) data for the area identified in Figure 4. Powered aircraft are required to have ADS-B transponders when operating at SJC.

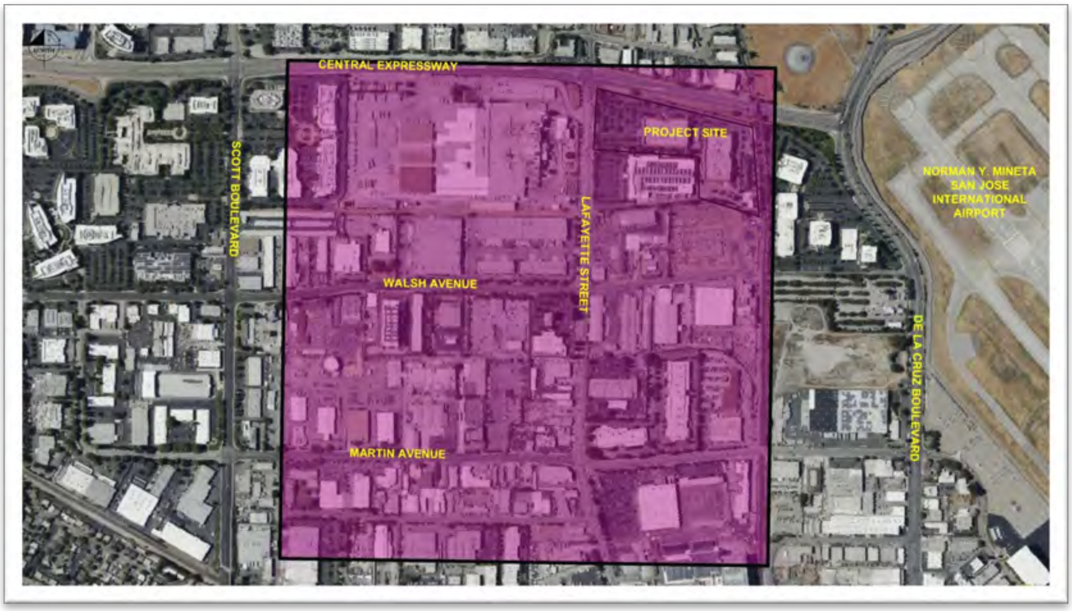


Figure 4 – ADS-B Collection Area

The area examined was larger than the project site because data samples were taken every five seconds by the vendor. The northeast corner of the box was used as the controlling point and the box was stretched west and south to capture as many aircraft pings as possible. The northeast corner of the box was identified as the critical corner and sited to capture the northern limit of the project site and remain clear of the extended Runway 12R/30L centerline. Encroachment on the extended runway centerline could artificially skew the results. Due to limitations, the data vendor could only define data collection boxes that are square and aligned with true north. In other words, a box parallel with the runway centerline could not be used.

Data was collected from March 6, 2020, through November 27, 2022. This was the extent that data was available. Based on feedback from SJC staff, it was determined that small airplanes (aircraft weighing less than 12,500 pounds) and helicopter operations were of concern. Aircraft altitudes from the ground up to 2,600 feet were collected. This was intended to capture aircraft arriving, departing, and conducting pattern work at SJC, while avoiding general SJC overflight traffic. Figure 5 shows the number of operations through the identified box per month, with March 2020 and November 2022 being partial months of data. Figure 6 shows the range of altitudes aircraft were at when transiting this are.

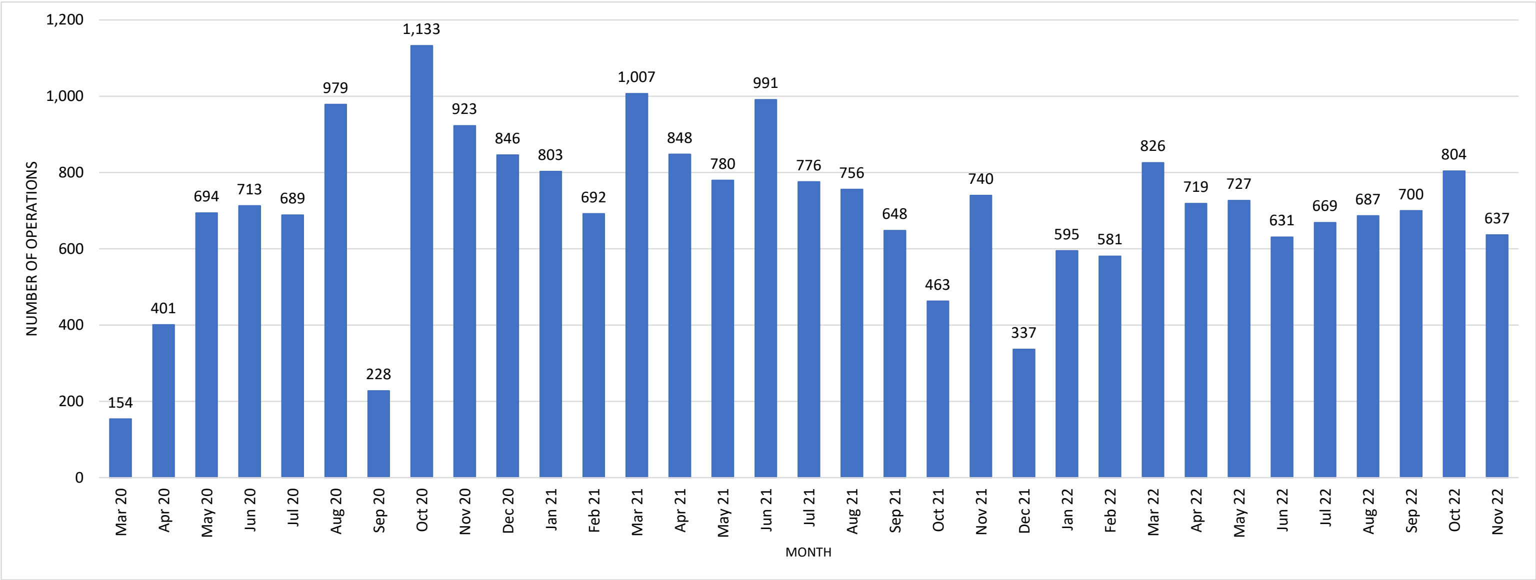


Figure 5 – Number of Aircraft Flying Over the Project Site

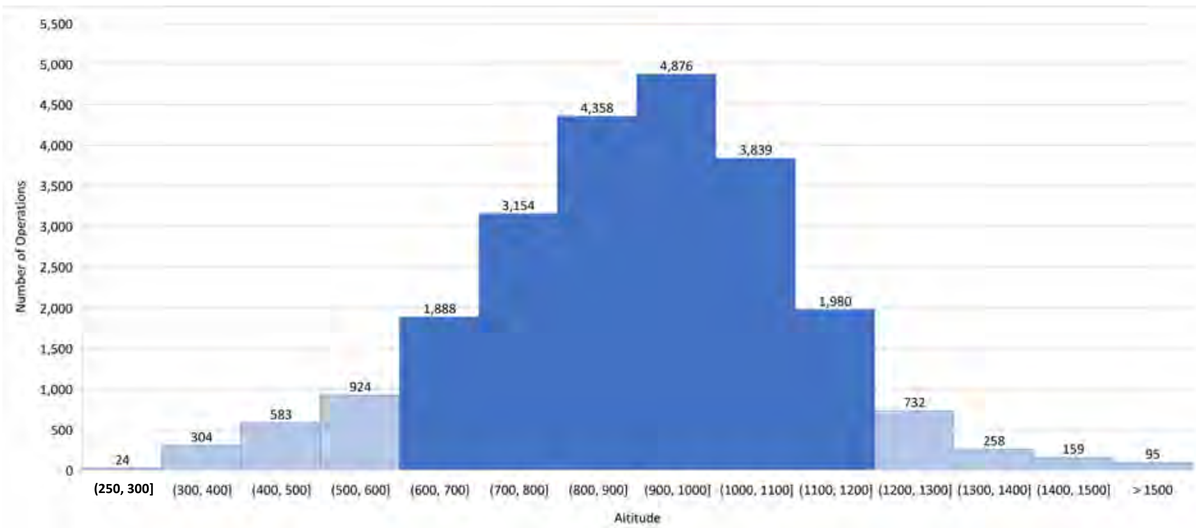


Figure 6 – Altitudes of Aircraft Flying Over the Project Site

On average, about 720 small airplanes overfly the project site monthly. These aircraft are generally at an altitude of 600 feet MSL to 1,200 feet MSL. The lowest altitude observed was 250 feet MSL. All small aircraft overflying this area over the last two and half years were above the maximum plume height of 173 feet MSL.

Conclusions

Table 3 summarizes the results presented in the analysis above. While the plumes will penetrate the Part 77 Transitional Surfaces, they will likely not represent a hazard to air navigation due to no impacts to any published approaches. Also, based on the acquired ADS-B data, no small airplanes or helicopters overfly this site at an altitude that will be affected by the plumes. A portion of the site is within the San Jose VOR/DME critical area. However, the building received a Determination of No Hazard from the FAA which represents a more critical obstruction to the VOR/DME than the thermal plumes as the plumes will not interfere with the VOR/DME radio signals.

Table 3 – Summary of Results

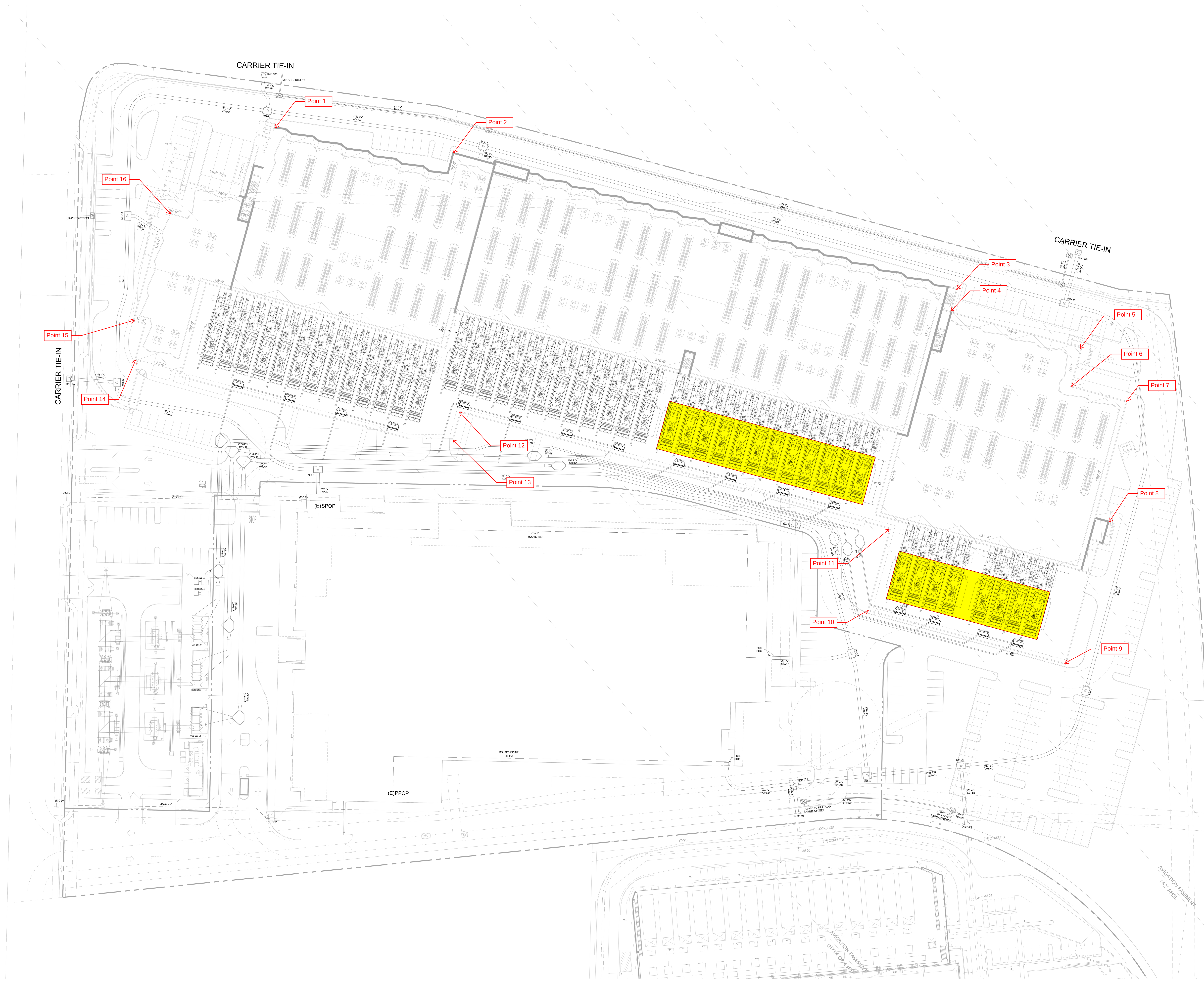
Component Analyzed	Thermal Plume Impacts		Additional Information
	Yes	No	
Part 77		✓	Penetrations are common within the Part 77 Transitional Surface
Airport Design Surfaces		✓	Fixed building was determined to not be a hazard to air navigation
Departure Surface for Runways 30L and 30R		✓	Clear by at least 178 feet.
ILS/LOC RWY 12R		✓	Must remain below 196 feet MSL.
RNAV (GPS) RWY 12R		✓	MSL cannot be increased.
RNAV (RNP) RWY 12R		✓	
RNAV (GPS) RWY 12L		✓	Must remain below 180 feet MSL.
RNAV (RNP) RWY 12L		✓	

Attachments:

A: Project Site Plan
B: Thermal Plume Calculation & Analysis
C: 7460 Notice of Determination

* * * * * * *

Please do not hesitate to contact me at 909.991.4398 (mobile), or Andrew.scanlon@kimley-horn.com to discuss further or if you have any questions or comments.



1 ELECTRICAL SITE PLAN
1" = 40'-0"

N

0 20 40 80
1" = 40'

GENERAL NOTES:

1. NOT USED.

KEYNOTES:

1. NOT USED.

LEGEND

	POWER MANHOLE
	POWER MANHOLE
(N)MH	CAMPUS COMMUNICATION MANHOLE 10FT x 8FT
(N)HH	SVP COMMUNICATION HANDHOLE 6FT x 4FT
(N)MH	SVP COMMUNICATION MANHOLE 10FT x 5FT

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NO.	RECORD	DATE
02	PCC ISSUANCE	06.19.20
01	PCC ISSUANCE	10.07.19

MASTER PLAN

ELECTRICAL
SITE PLAN

PRINCIPAL IN CHARGE MC	PROJECT NUMBER C190280
PROJECT MANAGER CM	DATE XXX
PROJECT ENGINEER XXX	SHEET NUMBER
SCALE NONE	E1.2

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DOCKETED

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Organization:	DayZenLLC
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Vertical Plume Velocity Assessment

Lafayette Backup Generating Facility

Santa Clara, California

Submitted to

California Energy Commission

Submitted by

DIGITAL REALTY

Prepared by

Atmospheric Dynamics, Inc.

ATMOSPHERIC DYNAMICS, INC
Meteorological & Air Quality Modeling

May 2022

Introduction

This report presents the evaluation of the Lafayette Backup Generating Facility (LBGF) source generated plumes from the 46 Cummins diesel engines and 88 rooftop chillers on the effects on airport/aircraft operations. The Normal Y. Mineta San Jose International Airport is located approximately 0.38 miles east southeast of the LBGF. This report is based upon an analysis prepared by Atmospheric Dynamics, Inc. in accordance with the California Energy Commission (CEC) application requirements for a Small Power Plant Exemption (SPPE) pursuant to the power plant siting regulations. This analysis is but one part of a larger analysis, which seeks an SPPE Decision from the CEC.

Based on the stack parameter data, an analysis of the potential plume characteristics from the routine operation the diesel engines and rooftop chillers on vertical winds was prepared and compared to the California Energy Commission (CEC) significance criteria of 5.3 meters per second (m/s) for the average vertical plume velocities as described below.

Atmospheric Dynamics, Inc. (ADI) prepared a screening level plume vertical velocity assessment which are based on the calm wind Spillane methodology outlined in the *"Aviation Safety and Buoyant Plumes"* paper (Peter Best, et. al., presented at the Clean Air Conference, Newcastle, New South Wales, Australia, 2003). This methodology is also recognized as a screening tool for aviation safety set out by the Australian Civil Aviation Safety Authority (CASA) and presented in *"AC 139-5(1) Plume Rise Assessments (CASA, 2012)".*

The aim of this screening assessment is to conservatively determine the potential for turbulence generated by the diesel engines and rooftop chillers waste heat exhaust plumes. Part 139.370 of the Australian Civil Aviation Safety Regulations (1998, 2004) provides that CASA may determine that plume velocities in excess of 4.3 m/s is or will be a potential hazard to aircraft operations. The *Manual of Aviation Meteorology* (Australian Bureau of Meteorology 2003) defines severe turbulence as a vertical wind gust velocity in excess of 10.6 m/s. The assumed critical vertical velocity used as a CEC significance threshold is 5.3 meters per second* (m/s) but it should be noted that the basis of the original CASA derived threshold of 4.3 m/s has been lost in antiquity and that CASA no longer relies on the 1998 and 2004 regulations that established this critical threshold other than to note that a more rigorous analysis, which includes site specific meteorology, should be used if the 4.3 m/s and 10.6 m/s screening thresholds are exceeded. The screening method uses absolute worst-case assumptions of calm winds and neutral atmospheric conditions for the entire vertical extent of the plume to determine these worst-case impacts. It should be noted that these results are extremely conservative in that these worst-case conditions typically only occur during a few hours each year.

The Spillane methodology is generally applied to a limited number of plume source geometry's (turbines, power plant boilers, etc.) with the stacks arranged linearly (in a single straight-line) and separated by distances that typically exceed the individual stack diameters. For the diesel engines, this assumption was maintained. Only one engine stack was modeled consistent with the normal operational testing schedule of the emergency generator engines. For the chiller assessment, a conservative assumption was made in order to use the Spillane methodology on an atypical chiller plume configuration, which is made up of 88 chillers arranged on a two-dimensional surface. Here, the methodology, as described below, assumed that all sixteen chiller cells for each chiller were merged into a single stack with an effective diameter based on the combined area of all sixteen chiller cells. In other words, a single stack was assumed to initially

*For the Puente Power Project (Docket#15-AFC-01, TN#213674, 9/15/2016), "CEC staff … concluded that an average velocity of 5.3 m/s is the appropriate velocity … [for a plume velocity threshold]." The CEC staff "Plume Background Threshold" attached to the docketed document concludes with "…[CEC] staff will use 10.6 m/s peak vertical plume velocity as the new threshold. The altitude at which a plume would have a peak vertical velocity of 10.6 m/s would be the same altitude at which a plume would have an average vertical velocity of half that, 5.3 m/s."

describe the release parameters of the combined chiller cells in each of the 88 individual chillers. The effective plume diameter is appropriate for each individual chiller based on the close proximity and arrangement of the sixteen chiller cells.

Screening Methodology and Vertical Plume Velocity Calculations

The Spillane methodology is based on worst-case calm wind neutral stability conditions to assess the average plume vertical velocity as a function of height. The methodology is based on well-verified laboratory and theoretical treatments of the rise and spread of a buoyant jet, both into a still ambient environment and into a light crosswind. This treatment covers in detail the initial dynamics of the plume as it exits the stack and the entrainment of ambient air into the plume as it rises directly above the stack. In addition to providing clarifications and algebraic solutions to the Spillane methodology, the 2003 Peter Best paper provides additional methodologies that also consider the enhancement of vertical velocities that may occur if the plumes from multiple identical stacks merge and form a higher buoyancy combined plume (referred to here as the enhanced Spillane methodology).

The vertical plume assessment will involve several stages of development. For individual plumes, the stages are:

(a) In the first stage very close to the stack exit, the high plume momentum will result in a short section in which the conditions at the center of the plume are relatively unaffected by ambient and plume buoyancy conditions. This jet phase extends from the stack exit to approximately a distance of 6.25 D above the stack (where D is the stack diameter) in calm conditions. At the end of this stage, the plume-averaged vertical velocity has decreased to half of the stack exit velocity, with a corresponding increase, or doubling, in effective plume diameter.

(b) In the second stage, the plume responds to differences between ambient and plume buoyancy conditions, with much cooler and less turbulent ambient air being entrained into the plume from the outside regions of the plume towards the plume centerline. The momentum and buoyancy of the plume significantly influences plume rise and subsequently the dilution of the stack exhaust to decrease plume vertical velocities. This dilution is very sensitive to ambient wind speed, so the calm wind conditions considered here are extremely conservative.

(c) In the third stage of plume development, plume rise is due entirely to the buoyancy of the plume and continues from some distance until there is an equalization of turbulence conditions within and outside the plume. This final rise is often only achieved at considerable heights/distances from the stack where the effective average vertical velocity is then close to zero. Since there is very little turbulence and near-zero vertical velocities, this stage of plume development is usually not considered for this type of analysis.

In the second stage of development, the analytical solution of the governing equations under these conditions is given by:

$$a = 0.16(z - z_v)$$
$$V = \{(Va)o^{3} + 0.12Fo\,[\,(z - zv)^{2} - (6.25D - zv\,)^{2}]\}^{1/3} / a$$

Where the subscript 'o' refers to values of the parameters at the stack outlet and the variables are:

a	plume radius (m)
V	average vertical velocity (m/s)
z	height above stack top (m)
z_v	virtual source height (m)
D	stack diameter (m)
F_o	buoyancy flux evaluated at the stack outlet (m^4s^{-3})

These are the two primary equations governing the growth of a single plume in the second stage of development under neutral calm wind conditions. Additional equations governing the first stage of single plume development as well as the interaction of multiple plumes in the second stage of development are discussed in detail in the Best paper.

For multiple stacks in the enhanced Spillane methodology, the equations governing the second stage are calculated from the point when the plumes begin to merge until they are fully merged. The plume merging begins at the height where the plume diameters equal the stack separations and the plumes are fully merged at the height where the plume diameters are equal to 2d(N-1)/2 for three or more stacks or 2d for two stacks. At the fully merged height, the merged plume diameter and velocity is enhanced by the fourth root of the number of stacks. Above the fully merged plume height, the enhanced plume diameter and plume velocities follow the regular equations given for the second stage. Below the fully merged plume height for the merging phase, plume velocities are linearly interpolated by height from the single plume velocity at the height where the plumes begin to merge to the enhanced plume velocity at the fully merged plume height.

Vertical Plume Velocity Calculations for the Diesel Engines

The LBGF is comprised of 44 individual large and one (1) small diesel emergency generator stacks. The small diesel emergency generator was not assessed as it would have smaller plume vertical velocities. Generator stack parameter data (plume exit velocity, plume exit temperature and stack exit diameter) were provided by Cummins. Only one (1) engine will be tested during any one hour. While the engines will be tested at minimum loads, the 100 percent load case was utilized for the worst-case plume analysis. For the engine analysis, two ambient conditions were considered: 41.0°F, the minimum monthly mean of daily minimum temperatures, and 84.3°F, the maximum monthly mean of daily maximum temperatures for the San Jose Airport (*"Climatology of the United States No. 81 – Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000 – California"*, February 2002, and *"Climatology of the United States No 20 – Monthly Station Climate Summaries, 1971-2000 – California"*, February 2004). These data is summarized in Table 1.

Table 1 Cummins Diesel Stack Characteristics for Vertical Plume Velocity Analysis		
Case #	1	2
Ambient Temperature (°F)*	41.0	41.0
Stack Diameter (m)	0.7112	0.7112
Exhaust Velocity (m/s)*	31.20	31.20
Exhaust Temperature (K)*	912.0	912.0
Stack Release Height (m)	22.86	22.86
Stack Buoyancy Flux (m^4/s^3)	24.58	23.35
*Stack data provided by Cummins at 100% load		

Screening level vertical plume velocity assessments were made for two ambient temperatures with calm winds and neutral atmospheric conditions for the cases presented in Table 1 which are based on 100 percent load. The results based on the two ambient conditions are presented in Table 2 and the output from the calculation spreadsheet provided in Attachment A.

The initial jet phase extends to a height of about 90 feet above grade level (ft-agl) for both cases. After the jet phase, plume temperature buoyancy characteristics modeled in the Spillane methodology cause a uniform decrease in plume-averaged vertical velocities, with the critical plume-averaged vertical velocity of 5.3 m/s occurring at about 113 ft-agl for both cases

Table 2 Diesel Engine Vertical Plume Velocity Analysis Results for Reference Height		
Case #	1	2
Ambient Temperature (°F)	41.0	84.3
Single Plume Results:		
Plume-Averaged Vertical Velocity at 200 feet-agl (m/s)	2.77	2.73
Height of 5.3 m/s Plume-Averaged Vertical Velocity (feet-agl)	112.8	112.9

These screening results indicate that mechanical and thermal turbulence levels due to the flow from the diesel engine always remain in the light turbulence category and below the significance level of 5.3 m/s at all heights above about 113 ft-agl. Even light wind speeds can dramatically decrease the predicted plume-averaged vertical velocities, so the above results are very conservative indications of adverse conditions. The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year. Theoretical calculations, as shown in the tables above, are likely to overestimate the expected vertical velocities, for the following reasons:

- The wind profile is assumed constant with height with no occurrence of wind-shear when realistically, there is a considerable variation with height, especially in light winds;
- Worst-case scenarios are based on very light-wind, near-neutral atmospheric conditions with maximum loading.

Vertical Plume Velocity Calculations for the Rooftop Chillers

The 88 rooftop chillers are each comprised of 20 individual cells, with a cell fan diameter of 34 inches. The 88 chillers are generally arranged 24 along the longer building length (averaging 15 feet between adjacent chillers) by three along the shorter building width (averaging 15 feet between adjacent chillers). It should be noted that the chillers are arranged differently on the two-story part of the data center (8x2). Based on the groupings of chillers, the single and merged plumes were based on the 24 (3x8) chiller arrangement my merging plumes along the length (3 merged stacks) and width (8 merged stacks). Chiller stack parameter data (exit velocity and temperature) were provided by the applicant. An effective stack diameter for all 20 cells was utilized for each chiller. The chillers will utilize variable speed fans and the number of fans that are operational are dependent upon ambient temperature and plant load. However, to be conservative, all chillers/cells were assumed to be operating at full load. These data are summarized in Table 3 for the same ambient temperatures used for the engine analysis.

Table 3
Chiller Stack Characteristics for Vertical Plume Velocity Analysis

Case #	1	2
Ambient Temperature (°F)*	41.0	84.3
Effective Stack Diameter (m)**	3.86	3.86
Exhaust Velocity (m/s)*	8.06	8.06
Exhaust Temperature (K)*	289.26	313.32
Stack Release Height (m)	23.81	23.81
Stack Buoyancy Flux (m^4/s^3)	11.33	10.45

*Chiller stack data provided by the applicant
** Calculated value based on the cell diameter of 34 inches multiplied by the square of the number of operating cells, or $D_{eff} = 34" * \sqrt{20}$

The Spillane methodology was originally developed to treat multiple individual stacks that are arranged along a linear x or y direction, but not both directions at once, with stack separations much greater than the stack diameters, typical of boilers/turbines at large power plants. As noted above, the 88 chillers are generally arranged in a 3 x 8 pattern. Therefore, the enhanced Spillane methodology was based on calculating the total merging height for the largest linear direction of chiller placements (which is eight chillers spaced 24.6 feet apart along the longer length of the building). The largest grouping of 48 (3x16) chillers were considered in the calculation of vertical velocity plume enhancement (both at and above the totally merged height, and for the interpolation down to the plume touching height. Again, the effective single stack diameter of each chiller was based on the combined 20 cells.

Screening level vertical plume velocity assessments were made for the same ambient temperatures with calm winds and neutral atmospheric conditions as was done for the emergency generator engines. The results are presented in Table 4 and the output from the calculation spreadsheets are provided in Attachment A.

The initial jet phase extends to a height of about 157.3 ft-agl for both cases. The critical plume-averaged vertical velocity of 5.3 m/s occurs in the jet phase at about 132.4 ft-agl for both cases. The plumes touch (begin to merge) at about 246 ft-agl and are fully merged at about 1,233 ft-agl for both cases. Under the enhanced Spillane methodology, the merged plume-averaged vertical velocities never approach 5.3 m/s (either above the totally merged height or when interpolated down to the touching height).

Table 4
Chiller Vertical Plume Velocity Analysis Results for Reference Height

Case #	1	2
Ambient Temperature (°F)	41.0	84.3
Single Plume Results:		
Height of 5.3 m/s Plume-Averaged Vertical Velocity (Within the Jet Phase, feet-agl)	132.4	132.4
Merged Plume Results:		
Plume-Averaged Vertical Velocity at 1,000 feet-agl (m/s)	3.50	3.42

From these results and for each ambient condition, the vertical plume velocities are less than the threshold value of 5.3 m/s for all heights above about 132 ft-agl and above for the chillers. The heights at which plume-averaged vertical velocities exceed 5.3 m/s only occur during the jet phase for both cases. These cases also represent worst-case conditions of calm winds at all levels of a neutral atmosphere.

These screening results indicate that mechanical and thermal turbulence levels due to the flow from the chillers always remain in the light turbulence category and below the significance level of 5.3 m/s at all heights above about 132 ft-agl. Even light wind speeds can dramatically decrease the predicted plume-averaged vertical velocities so the above results are very conservative indications of adverse conditions. The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year. Theoretical calculations, as shown in the tables above, are likely to overestimate the expected vertical velocities, for the following reasons:

- The wind profile is assumed constant with height with no occurrence of wind-shear when realistically, there is a considerable variation with height, especially in light winds;
- Worst-case scenarios are based on very light-wind, near-neutral atmospheric conditions with maximum loading.

Attachment A
Spillane Method Plume Velocity Calculations

SINGLE Plume Average Vertical Velocities for Lafayette Large Emer.Gen Engine, 100% Load, and Maximum Stack Height - Winter Min*

"***Aviation Safety and Buoyant Plumes***," Peter Best, et. al.

"***The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Plume***

from a Gas-Turbine Power Station at Oakey, Queensland, Australia," Dr. K.T. Spillane

Ambient Conditions:					**Constants:**	Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)		
Ambient Potential Temp θ_a	278.15	Kelvins	41.0	°F		0.3048	meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s^2	
Maximum Stack Height h_s	22.86	meters	75	feet-inches	λ	1.11		
Stack Diameter D	0.7112	meters	28	inches	λ_o	~1.0		
Stack Velocity V_{exit}	31.20	m/s	102.37	ft/sec				
Volumetric Flow	12.39	cu.m/sec	26,264	ACFM	$\pi V_{exit} D^2/4$			Sect.2/¶1
Stack Potential Temp θ_s	762.04	Kelvins	912	°F				
Initial Stack Buoyancy Flux F_o	24.5763	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$			Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)			
No.of Stacks N	1			1.000	Multiple Stack Multiplication Factor ($N^{0.25}$)			
Conditions at End (Top) of Jet Phase:								
Height above Stack z_{jet}	4.445	meters*	14.6	feet*	z_{jet} = 6.25D, meters*=meters above stack top			Sect.3/¶1
Height above Ground $z_{jet}+h_s$	27.305	meters	**89.6**	feet				"
Vertical Velocity V_{jet}	15.600	m/s	51.18	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$			"
Plume Top-Hat Diameter $2a_{jet}$	1.422	meters	4.7	feet	$2a_{jet}$ = 2D		Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase								
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:								
Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height			Sect.2/Eq.6
Virtual Source Height z_v	1.760	meters*	5.8	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top			Sect.2/Eq.6
Height above Ground z_v+h_s	24.620	meters	80.8	feet			where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.6042
Vertical Velocity V	**Solutions in Table Below**				$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$			Sect.2.1(6)
Product $(Va)_o$	6.703	m^2/s			$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$			
Solve for plume-averaged vertical velocity at height	**200.0**	**feet**		60.96	meters above ground ($z'+h_s$)			
Gives the following Height above Stack z'	38.100	meters*	125.0	feet*				
Plume Top-Hat Diameter 2a'	11.629	meters	38.2	feet	$2a'=2*0.16(z'-z_v)$			Sect.2/Eq.6
Vertical Velocity V	**2.769**	**m/s**	9.09	ft/sec	$V=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{(1/3)}/(2a'/2)$			Sect.2/Eq.6
Solve for Height of CASC critical vertical velocity V_{crit}	**5.30**	**m/s plume-averaged vertical velocity**					**Critical VV > Top of Jet (Spillane)**	
Find Height above Stack z_{crit}	11.519	meters	37.8	feet	Solve for $x=(z-z_v)$ simultaneously in both eqs. (i.e., Va and a)			
Height above Ground $z_{crit}+h_s$	34.379	meters	**112.8**	feet	for V=4.3 m/s using the cubic equation $ax^3+bx^2+cx+d=0$, where			
					a=1, c=0, and $b=-(0.12F_o)/(4.3^3 0.16^3)$=			-4.8363
Interpolated Height of critical vertical velocity in Jet Phase:					and $d=[0.12F_o(6.25D-z_v)^2-(Va)_o^3]/(4.3^3 0.16^3)$=			-459.00
Find Height above Stack z_{crit}	#N/A	meters	#N/A	feet				http://www.1728.org/cubic.htm
Height above Ground $z_{crit}+h_s$	#N/A	meters	**#N/A**	feet			gives the real solution x = z-zv =	9.7599
							or z(m/above stack) =	11.519
							z(ft/above ground) =	112.8

Table of Plume Top-Hat Diameters (2a) and Plume-Averaged Vertical Velocities starting at end of jet phase:

Height (feet) above ground	(meters) above stack	Plume Radius(m)	SingleStk VertVel(m/s)	Plume Temp(K)		
Stack.Rel.Ht = 75.0	**0.00**	**0.356**	**31.20**			
80.0	1.52	0.477	25.86		**Jet Phase Eqs:**	**5 foot Intervals**
85.0	3.05	0.599	20.52		Linearly interpolated from Stack Rel.Ht to Top of Jet	
Top of jet = 89.6	**4.45**	**0.711**	**15.60**		**Spillane Equations:**	
90.0	4.57	0.450	14.93	465.22	$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3}$ / a	
100.0	7.62	0.938	7.73	361.34	$a = 0.16(z-z_v)$	**10 foot Intervals**
110.0	10.67	1.425	5.62	327.69	$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
Spillane 5.3 m/s Height = 112.8	**11.52**	**1.562**	**5.28**	322.07		
120.0	13.72	1.913	4.64	311.42		
130.0	16.76	2.401	4.09	302.17		
140.0	19.81	2.888	3.72	296.37		**Max<5.30 m/s**
150.0	22.86	3.376	3.46	292.49		
160.0	25.91	3.864	3.26	289.77		
170.0	28.96	4.351	3.10	287.78		
220.0	44.20	6.790	2.61	282.84		**50 foot Intervals**
270.0	59.44	9.228	2.34	280.99		
320.0	74.68	11.667	2.16	280.08		
370.0	89.92	14.105	2.02	279.56		
420.0	105.16	16.543	1.92	279.23		
470.0	120.40	18.982	1.83	279.01		
520.0	135.64	21.420	1.76	278.85		
620.0	166.12	26.297	1.64	278.65		**100 foot Intervals**
720.0	196.60	31.174	1.55	278.53		
820.0	227.08	36.051	1.47	278.45		
920.0	257.56	40.927	1.41	278.39		
1020.0	288.04	45.804	1.36	278.35		
1120.0	318.52	50.681	1.32	278.32		
1220.0	349.00	55.558	1.28	278.29		
1320.0	379.48	60.435	1.24	278.27		
1420.0	409.96	65.311	1.21	278.26		
1520.0	440.44	70.188	1.18	278.25		
1620.0	470.92	75.065	1.15	278.24		
1720.0	501.40	79.942	1.13	278.23		
1820.0	531.88	84.819	1.11	278.22		
1920.0	562.36	89.695	1.09	278.21		
2020.0	592.84	94.572	1.07	278.21		

*Winter Min = Monthly Mean of Minimum Daily Temperatures for 1971-2000 (Lowest in December)

NOAA Sources: Climatography of the United States No.81 *"Monthly Station Normals of Temperatures, Precipitation, and Heating and Cooling Degree Days, 1971-2000 California"* and Climatography of the United States No. 20 *"Monthly Station Climate Summaries, 1971-2000 California"*

SINGLE Plume Average Vertical Velocities for Single LBGF Large Emer.Gen Engine, 100% Load, and Maximum Stack Height - Summer Max*

"***Aviation Safety and Buoyant Plumes***," **Peter Best, et. al.**

"***The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Plume from a Gas-Turbine Power Station at Oakey, Queensland, Australia***," **Dr. K.T. Spillane**

Ambient Conditions:					**Constants:** Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)	
Ambient Potential Temp θ_a	302.21	Kelvins	84.3	°F	0.3048 meters/feet	
Plume Exit Conditions:					Gravity g 9.81 m/s^2	
Maximum Stack Height h_s	22.86	meters	75	feet-inches	λ 1.11	
Stack Diameter D	0.7112	meters	28	inches	λ_o ~1.0	
Stack Velocity V_{exit}	31.20	m/s	102.37	ft/sec		
Volumetric Flow	12.39	cu.m/sec	26,264	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	762.04	Kelvins	912	°F		
Initial Stack Buoyancy Flux F_o	23.3543	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)	
No.of Stacks N	1			1.000	Multiple Stack Multiplication Factor ($N^{0.25}$)	
Conditions at End (Top) of Jet Phase:						
Height above Stack z_{jet}	4.445	meters*	14.6	feet*	z_{jet} = 6.25D, meters*=meters above stack top	Sect.3/¶1
Height above Ground $z_{jet}+h_s$	27.305	meters	**89.6**	feet		"
Vertical Velocity V_{jet}	15.600	m/s	51.18	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$	"
Plume Top-Hat Diameter $2a_{jet}$	1.422	meters	4.7	feet	$2a_{jet}$ = 2D — Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase						
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:						
Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	1.646	meters*	5.4	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	24.506	meters	80.4	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.6297
Vertical Velocity V	**Solutions in Table Below**				$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)}$ / a	Sect.2.1(6)
Product $(Va)_o$	6.987	m^2/s			$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	
Solve for plume-averaged vertical velocity at height	**200.0**	**feet**		60.96	meters above ground ($z'+h_s$)	
Gives the following Height above Stack z'	38.100	meters*	125.0	feet*		
Plume Top-Hat Diameter 2a'	11.665	meters	38.3	feet	$2a'=2*0.16(z'-z_v)$	Sect.2/Eq.6
Vertical Velocity V	**2.731**	**m/s**	8.96	ft/sec	$V=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{(1/3)}/(2a'/2)$	Sect.2/Eq.6
Solve for Height of CASC critical vertical velocity V_{crit}	**5.30**	**m/s plume-averaged vertical velocity**				**Critical VV > Top of Jet (Spillane)**
Find Height above Stack z_{crit}	11.563	meters	37.9	feet	Solve for $x=(z-z_v)$ simultaneously in both eqs. (i.e., Va and a)	
Height above Ground $z_{crit}+h_s$	34.423	meters	**112.9**	feet	for V=4.3 m/s using the cubic equation $ax^3+bx^2+cx+d=0$, where	
					a=1, c=0, and $b=-(0.12F_o)/(4.3^3 0.16^3)$=	-4.5958
Interpolated Height of critical vertical velocity in Jet Phase:					and $d=[0.12F_o(6.25D-z_v)^2-(Va)_o^3]/(4.3^3 0.16^3)$=	-523.34
Find Height above Stack z_{crit}	#N/A	meters	#N/A	feet		http://www.1728.org/cubic.htm
Height above Ground $z_{crit}+h_s$	#N/A	meters	**#N/A**	feet	gives the real solution x = z-zv =	9.9171
					or z(m/above stack) =	11.563
					z(ft/above ground) =	112.9

Table of Plume Top-Hat Diameters (2a) and Plume-Averaged Vertical Velocities starting at end of jet phase:

Height (feet) above ground	(meters) above stack	Plume Radius(m)	SingleStk VertVel(m/s)	Plume Temp(K)		
Stack.Rel.Ht = 75.0	***0.00***	**0.356**	**31.20**			
80.0	1.52	0.477	25.86		**Jet Phase Eqs:**	**5 foot Intervals**
85.0	3.05	0.599	20.52		Linearly interpolated from Stack Rel.Ht to Top of Jet	
Top of jet = 89.6	***4.45***	***0.711***	***15.60***		**Spillane Equations:**	
90.0	4.57	0.468	14.95	480.36	$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3}$ / a	
100.0	7.62	0.956	7.83	383.84	$a = 0.16(z-z_v)$	**10 foot Intervals**
110.0	10.67	1.444	5.67	351.66	$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
Spillane 5.3 m/s Height = 112.9	**11.56**	**1.587**	**5.30**	345.97		
120.0	13.72	1.931	4.66	335.83		
130.0	16.76	2.419	4.08	326.68		
140.0	19.81	2.907	3.70	320.89		**Max<5.30 m/s**
150.0	22.86	3.394	3.43	316.98		
160.0	25.91	3.882	3.23	314.21		
170.0	28.96	4.370	3.07	312.18		
220.0	44.20	6.808	2.58	307.10		**50 foot Intervals**
270.0	59.44	9.246	2.30	305.17		
320.0	74.68	11.685	2.12	304.22		
370.0	89.92	14.123	1.99	303.68		
420.0	105.16	16.562	1.88	303.34		
470.0	120.40	19.000	1.80	303.11		
520.0	135.64	21.438	1.73	302.95		
620.0	166.12	26.315	1.61	302.73		**100 foot Intervals**
720.0	196.60	31.192	1.52	302.60		
820.0	227.08	36.069	1.45	302.52		
920.0	257.56	40.946	1.39	302.46		
1020.0	288.04	45.822	1.34	302.42		
1120.0	318.52	50.699	1.29	302.39		
1220.0	349.00	55.576	1.25	302.36		
1320.0	379.48	60.453	1.22	302.34		
1420.0	409.96	65.330	1.19	302.33		
1520.0	440.44	70.206	1.16	302.31		
1620.0	470.92	75.083	1.13	302.30		
1720.0	501.40	79.960	1.11	302.29		
1820.0	531.88	84.837	1.09	302.28		
1920.0	562.36	89.714	1.07	302.28		
2020.0	592.84	94.590	1.05	302.27		

*Summer Max = Monthly Mean of Maximum Daily Temperatures for 1971-2000 (Highest in July)

NOAA Sources: Climatography of the United States No.81 *"Monthly Station Normals of Temperatures, Precipitation, and Heating and Cooling Degree Days, 1971-2000 California"* and Climatography of the United States No. 20 *"Monthly Station Climate Summaries, 1971-2000 California"*

SINGLE/Approximated Plume Average Vertical Velocities for LBGF Chillers using CEC Staff Methodology - Winter Min*

Based on 48 chillers w/ 20 cells/chiller. Calc' eff.diam for each chiller wiith each cell at 34" ID (220,110 ACFM total for each chiller).

"Aviation Safety and Buoyant Plumes," **Peter Best, et. al.**

"The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Plume from a Gas-Turbine Power Station at Oakey, Queensland, Australia," **Dr. K.T. Spillane**

Ambient Conditions:					**Constants:**	Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)	
Ambient Potential Temp θ_a	278.15	Kelvins	41.0	°F		0.3048 meters/feet	
Plume Exit Conditions:					Gravity g	9.81 m/s^2	
Stack Height h_s	23.81	meters	78 2/12	feet-inches	λ	1.11	
Individual Chiller Stack Diameter D	3.8621	meters	152.1	inches	λ_o	~1.0	
Stack Velocity V_{exit}	8.06	m/s	26.45	ft/sec	$4Vol/(60\pi D^2)$		
Individual Chiller Volumetric Flow	94.44	cu.m/sec	200,110	ACFM	$\pi V_{exit}D^2/4$		Sect.2/¶1
Stack Potential Temp θ_s	289.26	Kelvins	61.0	°F			
Initial Stack Buoyancy Flux F_o	11.3279	m^4/s^3	20.0	ΔT(°F)	$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$		Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)		
Number of Chillers n	48			2.632	Multiple Stack Multiplication Factor ($n^{0.25}$)		
Conditions at End (Top) of Jet Phase:							
Height above Stack z_{jet}	24.138	meters*	79.2	feet*	z_{jet} = 6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground $z_{jet}+h_s$	47.952	meters	**157.3**	feet			"
Vertical Velocity V_{jet}	4.031	m/s	13.22	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$		"
Plume Top-Hat Diameter $2a_{jet}$	7.724	meters	25.3	feet	$2a_{jet}$ = 2D	Conservation of momentum	"

Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase

Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:

Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	0.468	meters*	1.5	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	24.282	meters	79.7	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.9806
Vertical Velocity V	**Solutions in Table Below**				$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)}$ / a	Sect.2.1(6)
Product $(Va)_o$	15.265	m^2/s			$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	
Single Chiller Results:						
Solve for plume-averaged vertical velocity at height	**940.0**	**feet**		286.512	meters above ground ($z'+h_s$)	
Gives the following Height above Stack z'	262.698	meters*	861.9	feet*		
Plume Top-Hat Diameter 2a'	83.914	meters	275.3	feet	$2a'=2*0.16(z'-z_v)$	Sect.2/Eq.6
Vertical Velocity V	**1.092**	**m/s**	3.58	ft/sec	$V=\{(Va)_o^3+0.12F_o[(z'-z_v)^2-(6.25D-z_v)^2]\}^{(1/3)}/(2a'/2)$	Sect.2/Eq.6
Solve for Height of CASC critical vertical velocity V_{crit}	**5.30**	**m/s plume-averaged vertical velocity**				**Critical VV < Top of Jet**
Find Height above Stack z_{crit}	#N/A	meters	#N/A	feet	Solve for $x=(z-z_v)$ simultaneously in both eqs. (i.e., Va and a)	
Height above Ground $z_{crit}+h_s$	#N/A	meters	**#N/A**	feet	for $V=V_{crit}$ using the cubic equation $ax^3+bx^2+cx+d=0$, where	
					a=1, c=0, and $b=-(0.12F_o)/(V_{crit}{}^3 0.16^3)$=	-2.22917
Interpolated Height of critical vertical velocity in Jet Phase:					and $d=[0.12F_o(6.25D-z_v)^2-(Va)_o{}^3]/(V_{crit}{}^3 0.16^3)$=	-4584.19
Find Height above Stack z_{crit}	16.537	meters	54.3	feet		http://www.1728.org/cubic.htm
Height above Ground $z_{crit}+h_s$	40.352	meters	**132.4**	feet	gives the real solution x = z-zv =	17.3892
					or z(m/above stack) =	17.857
					z(ft/above ground) =	136.7

Table of Plume Top-Hat Diameters (2a) and Plume-Averaged Vertical Velocities starting at end of jet phase:

Height (feet) above ground	(meters) above stack	Plume Radius(m)	SingleStk VertVel(m/s)	Plume Temp(K)		
Stack.Rel.Ht = 78.1	**0.00**	**1.931**	**8.06**			
80.0	0.57	1.977	7.97		**Jet Phase Eqs:**	**20 ft Intervals**
100.0	6.67	2.464	6.95		Linearly interpolated from Stack Rel.Ht to Top of Jet	
120.0	12.76	2.952	5.93		**Spillane Equations:**	
Single Jet 5.3 m/s Height = 132.4	**16.54**	**3.254**	**5.30**			
140.0	18.86	3.440	4.91		$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3}$ / a	
Top of Single jet = 157.3	**24.14**	**3.862**	**4.03**		$a = 0.16(z-z_v)$	
160.0	24.95	3.918	3.92	282.49	$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
180.0	31.05	4.893	3.26	282.49	**CEC Staff Equation:**	
200.0	37.15	5.868	2.84	281.49	$V_{mp}=n^{0.25}V_{sp}$	
220.0	43.24	6.844	2.54	280.82	**Brigg's Equation:**	
240.0	49.34	7.819	2.33	280.34	$V_{Brigg's}$ = (2/3) x $1.6^{(3/2)}$ x $F_{mp}{}^{(1/2)}$ x $u^{(-1/2)}$ x $z^{(-1/2)}$	
260.0	55.43	8.795	2.16	279.98	where $F_{mp} = nF_{sp}$	
280.0	61.53	9.770	2.04	279.71		
300.0	67.63	10.745	1.93	279.49		
350.0	82.87	13.184	1.74	279.32		**50 ft Intervals**
400.0	98.11	15.622	1.60	279.01	**Max<5.3 m/s**	
450.0	113.35	18.060	1.51	278.82		
500.0	128.59	20.499	1.43	278.68		
550.0	143.83	22.937	1.37	278.58		
600.0	159.07	25.376	1.31	278.51		
650.0	174.31	27.814	1.27	278.46		
700.0	189.55	30.252	1.23	278.42		
800.0	220.03	35.129	1.16	278.38		**100 ft Intervals**
900.0	250.51	40.006	1.11	278.33		
1000.0	280.99	44.883	1.07	278.30		
1100.0	311.47	49.760	1.03	278.27		
1200.0	341.95	54.636	1.00	278.25		
1300.0	372.43	59.513	0.97	278.24		
1400.0	402.91	64.390	0.94	278.23		
1500.0	433.39	69.267	0.92	278.22		
2000.0	585.79	93.651	0.83	278.21		**500 ft Intervals**
2500.0	738.19	118.035	0.77	278.19		
3000.0	890.59	142.419	0.72	278.17		
3500.0	1042.99	166.803	0.68	278.17		
4000.0	1195.39	191.187	0.65	278.16		
4500.0	1347.79	215.571	0.63	278.16		
				278.16		

*Winter Min = Monthly Mean of Minimum Daily Temperatures for 1971-2000 (Lowest in Dec

NOAA Sources: Climatography of the United

MERGED (along length) Plume Average Vertical Velocities for Lafayette Chillers using CEC Staff Methodology - Winter Min*								
	"Aviation Safety and Buoyant Plumes ," **Peter Best, et. al.**							
	"The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Merged							
		Plume from Two Gas-Turbine Power Station at Oakey, Queensland, Australia ," **Dr. K.T. Spillane**						
Ambient Conditions:					**Constants:**	Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)		
Ambient Potential Temp θ_a	278.15	Kelvins	41.0	°F		0.3048	meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s^2	
Stack Height h_s	23.81	meters	78 2/12	feet-inches	λ	1.11		
Individual Stack Diameter D	3.86213661	meters	152.1	inches	λ_o	~1.0		
Stack Velocity V_{exit}	8.06	m/s	26.45	ft/sec	$4Vol/(60\pi D^2)$			
Individual Volumetric Flow	94.44	cu.m/sec	200,110	ACFM	$\pi V_{exit}D^2/4$			Sect.2/¶1
Stack Potential Temp θ_s	289.26	Kelvins	61.0	°F				
Initial Stack Buoyancy Flux F_o	11.33	m^4/s^3	20.0	ΔT(°F)	$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$			Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)			
Total Number of Stacks n	48							
Average Adjacent Stack Separation d	16.31	meters	53.5	feet	**Calcs based on multiple plume treatment in Peter Best Paper:**			
Number of Stacks along Orientation N	3				**plume velocities increased by $N^{0.25}$ at the height where plumes**			
					fully merged (interp. below ht, single merged stack above ht)			
Conditions at End (Top) of Jet Phase:								
Height above Stack z_{jet}	24.138	meters*	79.2	feet*	z_{jet} = 6.25D, meters*=meters above stack top			Sect.3/¶1
Height above Ground $z_{jet}+h_s$	47.952	meters	**157.3**	feet				"
Vertical Velocity V_{jet}	**4.031**	m/s	13.22	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$			"
Plume Top-Hat Diameter $2a_{jet}$	7.724	meters	25.3	feet	$2a_{jet}$ = 2D		Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet and Merging Phases								
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:								
Single Plume Values: Plume Top-Hat Radius a	**Used in Plume Merging Only**				$a = 0.16(z-z_v)$, or linear increase with height			Sect.2/Eq.6
Virtual Source Height z_v	0.468	meters*	1.5	feet*	$z_v = 6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top			Sect.2/Eq.6
Height above Ground z_v+h_s	24.282	meters	79.7	feet			where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.9806
Single Plume Values: Vertical Velocity V	**Used in Plume Merging Only**				$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$			Sect.2.1(6)
Product $(Va)_o$	15.265	m^2/s			$V_{exit}(D/2)(\theta_e/\theta_s)^{1/2}$			
Plume Merging - Based on Single Plume Calculations where:								Sect.3/¶3
Begin Merging Plume Top-Hat Diameter $2a_{touch}$	16.310	meters	53.5	feet	$2a_{touch}$=d, (or a_{touch}=d/2)			
Height above Stack z_{touch}	51.437	meters*	168.8	feet*	$z_{touch} = z_v+d/(2*0.16)$, meters*=meters above stack top			
Height above Ground $z_{touch}+h_s$	75.251	meters	**246.9**	feet				
Vertical Velocity V_{touch}	**2.268**	m/s	7.4	ft/sec	$V_{touch} = \{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$			
Total Merging Plume Top-Hat **Diameter** $2a_{full}$	32.620	meters	107.0	feet	$2a_{full}$=2d(N-1)/2, (or a_{full}=d(N-1)/2) **FOR 2 STACKS, $2a_{full}$=2d**			
Height above Stack z_{full}	102.406	meters*	336.0	feet*	$z_{full} = z_v+2d/(2*0.16)$, meters*=meters above stack top			
Height above Ground $z_{full}+h_s$	126.220	meters	**414.1**	feet				
Vertical Velocity V_{full}	1.574	m/s	5.2	ft/sec	$V_{full} = \{(Va)_o^3 + 0.12F_o [(z_{full}-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a_{full}$			
Product $(V^3a)_{full}$	64	m^4/s^3						
Conditions at End (Top) of Merging Phase - Define new values for V_{full} and a_{full} in Merged Plume calculations (based on TOTAL number of stacks):								
Merged Plume Values: Plume Diameter 2a	**Solutions in Table Below**				$2a = 2 \times (a_m + 0.16(z-z_{full}))$, or linear increase with height			
Revised Merged Plume **Radius** a_m	42.930	meters	140.8	feet	where $a_m = n^{0.25}a_{full}$ where Total Merging Occurs			
Revised Merged Plume Velocity V_m	**4.143**	m/s	13.59	ft/sec	and $V_m = n^{0.25}V_{full}$ where Total Merging Occurs			
Revised Virtual Source Height z_{full}	102.406	meters*	336.0	feet*	Height above stack where Total Merging Occurs (shown above)			
Revised Vertical Velocity V	**Solutions in Tables Below**				$V=\{n(V^3a)_{full}/a\}^{1/3}$ for heights above total merging elevation			
					$V=V_{touch}+(V_m-V_{touch})*(z-z_{touch})/(z_{full}-z_{touch})$			
Multiple Plume Calculations							for heights below total merging elevation	
Solve for plume-averaged vertical velocity at height		**940.0**	**feet**	286.512	meters above ground $(z+h_s)$			
Gives the following Height above Stack z	262.698	meters*	861.9	feet*	REGULAR EQNS			
Plume Top-Hat Radius a	68.577	meters	225.0	feet	$a=a_m+0.16(z-z_{full})$ **if $z>z_{full}$**			
Vertical Velocity V	**3.544**	**m/s**	11.63	ft/sec	$V=\{n(V^3a)_{full}/a\}^{1/3}$ **if $z>z_{full}$**			
					$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$ **if $z_{touch}<z<z_{full}$**			
					V'=single plume values **if $z<z_{touch}$**			
Solve for Height of CASC critical vertical velocity V_{crit}		**5.30**	**m/s**		BEFORE TOUCHING		**Critical VV < Top of Jet**	
Find Height above Stack z_{crit}	JET	meters	JET	feet	$z_{crit} = z_{full} + \{[n(V^3a)_{full}/(V_{crit})^3]-a_m\}/0.16$ **if $V_{crit}<V_m$**			
Height above Ground $z_{crit}+h_s$	JET	meters	**JET**	**feet**	$z_{crit}=z_{touch}+(z_{full}-z_{touch})*(V_{crit}-V_{touch})/(V_m-V_{touch})$ **if $V_{crit}>V_m$**			
Table of MERGED Plume-Averaged Vertical Velocities starting at Touching Height:					*Single Plume Eqns (see Single Plume spreadsheet)*			
Height (feet)	**(meters)**	**Plume**	**Vert.**		$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3} / a$			
above ground	**above stack**	**Radius(m)**	**Vel(m/s)**		$a = 0.16(z-z_v)$			
Begin Merging (touch) = 246.9	***51.44***	***8.155***	***2.27***		$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$			
260.0	55.43	#N/A	2.42		*Interpolated Layer Eqns*			**20 ft Intervals**
280.0	61.53	#N/A	2.64		$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$			
300.0	67.63	#N/A	2.86					
320.0	73.72	#N/A	3.09					
340.0	79.82	#N/A	3.31					
360.0	85.91	#N/A	3.54					
380.0	92.01	#N/A	3.76					
400.0	98.11	#N/A	3.98					
End Merging (full/mp) = 414.1	***102.40***	***42.930***	***4.14***		*Merged Plume Eqns*			
450.0	113.35	44.681	4.09		$V=\{n(V^3a)_{full}/a\}^{1/3}$			**50 ft Intervals**
500.0	128.59	47.119	4.02		$a=a_m+0.16(z-z_{full})$			
550.0	143.83	49.558	3.95					
600.0	159.07	51.996	3.89					
650.0	174.31	54.434	3.83					
700.0	189.55	56.873	3.77					**100 ft Intervals**
800.0	220.03	61.750	3.67					
900.0	250.51	66.626	3.58					
1000.0	280.99	71.503	3.50					
1100.0	311.47	76.380	3.42					
1200.0	341.95	81.257	3.35					
1300.0	372.43	86.134	3.28					
1400.0	402.91	91.010	3.23					
1500.0	433.39	95.887	3.17					**500 ft Intervals**
2000.0	585.79	120.271	2.94					
2500.0	738.19	144.655	2.76					
3000.0	890.59	169.039	2.62					
3500.0	1042.99	193.423	2.51					
4000.0	1195.39	217.807	2.41					
4500.0	1347.79	242.191	2.33					
5000.0	1500.19	266.575	2.25					

MERGED (along width) Plume Average Vertical Velocities for Lafayette Chillers using CEC Staff Methodology - Winter Min*								
	***"Aviation Safety and Buoyant Plumes,"* Peter Best, et. al.**							
	"The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Merged							
		***Plume from Two Gas-Turbine Power Station at Oakey, Queensland, Australia,"* Dr. K.T. Spillane**						
Ambient Conditions:					**Constants:**	Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)		
Ambient Potential Temp θ_a	278.15	Kelvins	41.0	°F		0.3048	meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s^2	
Stack Height h_s	23.81	meters	78 2/12	feet-inches	λ	1.11		
Individual Stack Diameter D	3.86213661	meters	152.1	inches	λ_o	~1.0		
Stack Velocity V_{exit}	8.06	m/s	26.45	ft/sec	$4Vol/(60\pi D^2)$			
Individual Volumetric Flow	94.44	cu.m/sec	200,110	ACFM	$\pi V_{exit}D^2/4$			Sect.2/¶1
Stack Potential Temp θ_s	289.26	Kelvins	61.0	°F				
Initial Stack Buoyancy Flux F_o	11.33	m^4/s^3	20.0	ΔT(°F)	$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$			Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)			
Total Number of Stacks n	48							
Average Adjacent Stack Separation d	7.50	meters	24.6	feet	**Calcs based on multiple plume treatment in Peter Best Paper:**			
Number of Stacks along Orientation N	16				**plume velocities increased by $N^{0.25}$ at the height where plumes**			
					fully merged (interp. below ht, single merged stack above ht)			
Conditions at End (Top) of Jet Phase:								
Height above Stack z_{jet}	24.138	meters*	79.2	feet*	z_{jet} = 6.25D, meters*=meters above stack top			Sect.3/¶1
Height above Ground $z_{jet}+h_s$	47.952	meters	**157.3**	feet				"
Vertical Velocity V_{jet}	**4.031**	m/s	13.22	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$			"
Plume Top-Hat Diameter $2a_{jet}$	7.724	meters	25.3	feet	$2a_{jet}$ = 2D		Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet and Merging Phases								
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:								
Single Plume Values: Plume Top-Hat Radius a	**Used in Plume Merging Only**				$a = 0.16(z-z_v)$, or linear increase with height			Sect.2/Eq.6
Virtual Source Height z_v	0.468	meters*	1.5	feet*	$z_v = 6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top			Sect.2/Eq.6
Height above Ground z_v+h_s	24.282	meters	79.7	feet			where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.9806
Single Plume Values: Vertical Velocity V	**Used in Plume Merging Only**				$\{(Va)_o^3 + 0.12F_o[(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$			Sect.2.1(6)
Product $(Va)_o$	15.265	m^2/s			$V_{exit}(D/2)(\theta_e/\theta_s)^{1/2}$			
Plume Merging - Based on Single Plume Calculations where:								Sect.3/¶3
Begin Merging Plume Top-Hat Diameter $2a_{touch}$	7.500	meters	24.6	feet	$2a_{touch}$=d, (or a_{touch}=d/2)			
Height above Stack z_{touch}	23.906	meters*	78.4	feet*	$z_{touch} = z_v+d/(2*0.16)$, meters*=meters above stack top			
Height above Ground $z_{touch}+h_s$	47.720	meters	**156.6**	feet				
Vertical Velocity V_{touch}	**4.065**	m/s	13.3	ft/sec	$V_{touch} = \{(Va)_o^3 + 0.12F_o[(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$			
Total Merging Plume Top-Hat **Diameter** $2a_{full}$	**112.500**	meters	369.1	feet	$2a_{full}$=2d(N-1)/2, (or a_{full}=d(N-1)/2) **FOR 2 STACKS, $2a_{full}$=2d**			
Height above Stack z_{full}	352.031	meters*	1155.0	feet*	$z_{full} = z_v+2d/(2*0.16)$, meters*=meters above stack top			
Height above Ground $z_{full}+h_s$	375.845	meters	**1233.1**	feet				
Vertical Velocity V_{full}	0.986	m/s	3.2	ft/sec	$V_{full} = \{(Va)_o^3 + 0.12F_o[(z_{full}-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a_{full}$			
Product $(V^3a)_{full}$	54	m^4/s^3						
Conditions at End (Top) of Merging Phase - Define new values for V_{full} and a_{full} in Merged Plume calculations (based on TOTAL number of stacks):								
Merged Plume Values: Plume Diameter 2a	**Solutions in Table Below**				$2a = 2 \times (a_m + 0.16(z-z_{full}))$, or linear increase with height			
Revised Merged Plume **Radius** a_m	148.058	meters	485.8	feet	where $a_m = n^{0.25}a_{full}$ where Total Merging Occurs			
Revised Merged Plume Velocity V_m	**2.596**	m/s	8.52	ft/sec	and $V_m = n^{0.25}V_{full}$ where Total Merging Occurs			
Revised Virtual Source Height z_{full}	352.031	meters*	1155.0	feet*	Height above stack where Total Merging Occurs (shown above)			
Revised Vertical Velocity V	**Solutions in Tables Below**				$V=\{n(V^3a)_{full}/a\}^{1/3}$ for heights above total merging elevation			
					$V=V_{touch}+(V_m-V_{touch})*(z-z_{touch})/(z_{full}-z_{touch})$			
Multiple Plume Calculations							for heights below total merging elevation	
Solve for plume-averaged vertical velocity at height		**940.0**	**feet**	286.512	meters above ground ($z+h_s$)			
Gives the following Height above Stack z	262.698	meters*	861.9	feet*	LESS THAN TOP OF MERGING PHASE-INTERPOLATE			
Plume Top-Hat Radius a	#N/A	meters	#N/A	feet	$a=a_m+0.16(z-z_{full})$ **if $z>z_{full}$**			
Vertical Velocity V	**2.996**	**m/s**	9.83	ft/sec	$V=\{n(V^3a)_{full}/a\}^{1/3}$ **if $z>z_{full}$**			
					$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$ **if $z_{touch}<z<z_{full}$**			
					V'=single plume values **if $z<z_{touch}$**			
Solve for Height of CASC critical vertical velocity V_{crit}		**5.30**	**m/s**		BEFORE TOUCHING		**Critical VV < Top of Jet**	
Find Height above Stack z_{crit}	JET	meters	JET	feet	$z_{crit} = z_{full} + \{[n(V^3a)_{full}/(V_{crit})^3]-a_m\}/0.16$ **if $V_{crit}<V_m$**			
Height above Ground $z_{crit}+h_s$	JET	meters	**JET**	**feet**	$z_{crit}=z_{touch}+(z_{full}-z_{touch})*(V_{crit}-V_{touch})/(V_m-V_{touch})$ **if $V_{crit}>V_m$**			
Table of MERGED Plume-Averaged Vertical Velocities starting at Touching Height:					*Single Plume Eqns (see Single Plume spreadsheet)*			
Height (feet)	**(meters)**	**Plume**	**Vert.**		$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3} / a$			
above ground	**above stack**	**Radius(m)**	**Vel(m/s)**		$a = 0.16(z-z_v)$			
Begin Merging (touch) = 156.6	***23.92***	***3.750***	***4.06***		$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$			
160.0	24.95	#N/A	4.06		*Interpolated Layer Eqns*			**20 ft Intervals**
180.0	31.05	#N/A	4.03		$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$			
200.0	37.15	#N/A	4.01					
220.0	43.24	#N/A	3.98					
240.0	49.34	#N/A	3.95					
260.0	55.43	#N/A	3.92					
300.0	67.63	#N/A	3.87					**50 ft Intervals**
350.0	82.87	#N/A	3.80					
400.0	98.11	#N/A	3.73					
450.0	113.35	#N/A	3.66					
500.0	128.59	#N/A	3.60					
550.0	143.83	#N/A	3.53					
600.0	159.07	#N/A	3.46					
650.0	174.31	#N/A	3.39					
700.0	189.55	#N/A	3.32					
800.0	220.03	#N/A	3.19					**100 ft Intervals**
900.0	250.51	#N/A	3.05					
1000.0	280.99	#N/A	2.91					
1100.0	311.47	#N/A	2.78					
1200.0	341.95	#N/A	2.64					
End Merging (full/mp) = 1233.1	***352.03***	***148.058***	***2.60***		*Merged Plume Eqns*			
1300.0	372.43	151.322	2.58		$V=\{n(V^3a)_{full}/a\}^{1/3}$			
1400.0	402.91	156.198	2.55		$a=a_m+0.16(z-z_{full})$			
1500.0	433.39	161.075	2.52					
2000.0	585.79	185.459	2.41					
2500.0	738.19	209.843	2.31					**500 ft Intervals**
3000.0	890.59	234.227	2.23					
3500.0	1042.99	258.611	2.16					
4000.0	1195.39	282.995	2.09					
4500.0	1347.79	307.379	2.04					
5000.0	1500.19	331.763	1.98					

SINGLE/Approximated Plume Average Vertical Velocities for Lafayette Chillers using CEC Staff Methodology - Summer Max*								
Based on 88 chillers w/ 20 cells/chiller. Calc' eff.diam for each chiller wiith each cell at 34" ID (220,110 ACFM total for each chiller).	***"Aviation Safety and Buoyant Plumes,"* Peter Best, et. al.**							
	"The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Plume							
		***from a Gas-Turbine Power Station at Oakey, Queensland, Australia,"* Dr. K.T. Spillane**						
Ambient Conditions:					**Constants:**	Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)		
Ambient Potential Temp θ_a	302.21	Kelvins	84.3	°F		0.3048	meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s^2	
Stack Height h_s	23.81	meters	78 2/12	feet-inches	λ	1.11		
Individual Chiller Stack Diameter D	3.8621	meters	152.1	inches	λ_o	~1.0		
Stack Velocity V_{exit}	8.06	m/s	26.45	ft/sec	$4Vol/(60\pi D^2)$			
Individual Chiller Volumetric Flow	94.44	cu.m/sec	200,110	ACFM	$\pi V_{exit}D^2/4$			Sect.2/¶1
Stack Potential Temp θ_s	313.32	Kelvins	104.3	°F				
Initial Stack Buoyancy Flux F_o	10.4540	m^4/s^3	20.0	ΔT(°F)	$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$			Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)			
Number of Chillers n	48			2.632	Multiple Stack Multiplication Factor ($n^{0.25}$)			
Conditions at End (Top) of Jet Phase:								
Height above Stack z_{jet}	24.138	meters*	79.2	feet*	z_{jet} = 6.25D, meters*=meters above stack top			Sect.3/¶1
Height above Ground $z_{jet}+h_s$	47.952	meters	**157.3**	feet				"
Vertical Velocity V_{jet}	4.031	m/s	13.22	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$			"
Plume Top-Hat Diameter $2a_{jet}$	7.724	meters	25.3	feet	$2a_{jet}$ = 2D		Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase								
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:								
Plume Top-Hat Radius a		**Solutions in Table Below**			$0.16(z-z_v)$, or linear increase with height			Sect.2/Eq.6
Virtual Source Height z_v	0.432	meters*	1.4	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top			Sect.2/Eq.6
Height above Ground z_v+h_s	24.246	meters	79.5	feet			where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.9821
Vertical Velocity V		**Solutions in Table Below**			$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)}$ / a			Sect.2.1(6)
Product $(Va)_o$	15.289	m^2/s			$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$			
Single Chiller Results:								
Solve for plume-averaged vertical velocity at height		**1,000.0**	**feet**	304.8	meters above ground ($z'+h_s$)			
Gives the following Height above Stack z'	280.986	meters*	921.9	feet*				
Plume Top-Hat Diameter 2a'	89.777	meters	294.5	feet	$2a'=2*0.16(z'-z_v)$			Sect.2/Eq.6
Vertical Velocity V	**1.040**	**m/s**	3.41	ft/sec	$V=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{(1/3)}/(2a'/2)$			Sect.2/Eq.6
Solve for Height of CASC critical vertical velocity V_{crit}		**5.30**	**m/s plume-averaged vertical velocity**				**Critical VV < Top of Jet**	
Find Height above Stack z_{crit}	#N/A	meters	#N/A	feet	Solve for $x=(z-z_v)$ simultaneously in both eqs. (i.e., Va and a)			
Height above Ground $z_{crit}+h_s$	#N/A	meters	**#N/A**	feet	for $V=V_{crit}$ using the cubic equation $ax^3+bx^2+cx+d=0$, where			
						a=1, c=0, and $b=-(0.12F_o)/(V_{crit}^3 0.16^3)$=		-2.05720
Interpolated Height of critical vertical velocity in Jet Phase:						and $d=[0.12F_o(6.25D-z_v)^2-(Va)_o^3]/(V_{crit}^3 0.16^3)$=		-4704.55
Find Height above Stack z_{crit}	16.537	meters	54.3	feet			http://www.1728.org/cubic.htm	
Height above Ground $z_{crit}+h_s$	40.352	meters	**132.4**	feet			gives the real solution x = z-zv =	17.4707
							or z(m/above stack) =	17.902
							z(ft/above ground) =	136.9

Table of Plume Top-Hat Diameters (2a) and Plume-Averaged Vertical Velocities starting at end of jet phase:

Height (feet) above ground	**(meters) above stack**	**Plume Radius(m)**	**SingleStk VertVel(m/s)**	**Plume Temp(K)**				
Stack.Rel.Ht = 78.1	**0.00**	**1.931**	**8.06**					
80.0	0.57	1.977	7.97				**Jet Phase Eqs:**	**20 ft Intervals**
100.0	6.67	2.464	6.95				Linearly interpolated from Stack Rel.Ht to Top of Jet	
120.0	12.76	2.952	5.93				**Spillane Equations:**	
Single Jet 5.3 m/s Height = 132.4	**16.54**	**3.254**	**5.30**					
140.0	18.86	3.440	4.91				$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3}$ / a	
Top of Single jet = 157.3	**24.14**	**3.862**	**4.03**				$a = 0.16(z-z_v)$	
160.0	24.95	3.924	3.91	306.56			$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
180.0	31.05	4.899	3.25	306.55			**CEC Staff Equation:**	
200.0	37.15	5.874	2.82	305.56			$V_{mp}=n^{0.25}V_{sp}$	
220.0	43.24	6.850	2.52	304.89			**Brigg's Equation:**	
240.0	49.34	7.825	2.31	304.42			$V_{Brigg's} = (2/3) \times 1.6^{(3/2)} \times F_{mp}^{(1/2)} \times u^{(-1/2)} \times z^{(-1/2)}$	
260.0	55.43	8.800	2.14	304.06			where $F_{mp} = nF_{sp}$	
280.0	61.53	9.776	2.01	303.79				
300.0	67.63	10.751	1.90	303.57				
350.0	82.87	13.189	1.71	303.40				**50 ft Intervals**
400.0	98.11	15.628	1.57	303.09			**Max<5.3 m/s**	
450.0	113.35	18.066	1.47	302.89				
500.0	128.59	20.505	1.40	302.75				
550.0	143.83	22.943	1.33	302.66				
600.0	159.07	25.381	1.28	302.58				
650.0	174.31	27.820	1.24	302.53				
700.0	189.55	30.258	1.20	302.48				
800.0	220.03	35.135	1.13	302.45				**100 ft Intervals**
900.0	250.51	40.012	1.08	302.40				
1000.0	280.99	44.889	1.04	302.36				
1100.0	311.47	49.765	1.00	302.33				
1200.0	341.95	54.642	0.97	302.32				
1300.0	372.43	59.519	0.94	302.30				
1400.0	402.91	64.396	0.92	302.29				
1500.0	433.39	69.273	0.89	302.28				
2000.0	585.79	93.657	0.81	302.27				**500 ft Intervals**
2500.0	738.19	118.041	0.75	302.25				
3000.0	890.59	142.425	0.70	302.24				
3500.0	1042.99	166.809	0.67	302.23				
4000.0	1195.39	191.193	0.64	302.22				
4500.0	1347.79	215.577	0.61	302.22				
*Winter Min = Monthly Mean of Minimum Daily Temperatures for 1971-2000 (Lowest in Dec				302.22				
NOAA Sources: Climatography of the United								

MERGED (along length) Plume Average Vertical Velocities for Lafayette Chillers using CEC Staff Methodology - Summer Max*

***"Aviation Safety and Buoyant Plumes,"* Peter Best, et. al.**

***"The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Merged Plume from Two Gas-Turbine Power Station at Oakey, Queensland, Australia,"* Dr. K.T. Spillane**

Ambient Conditions:					**Constants:** Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)	
Ambient Potential Temp θ_a	302.21	Kelvins	84.3	°F	0.3048 meters/feet	
Plume Exit Conditions:					Gravity g 9.81 m/s^2	
Stack Height h_s	23.81	meters	78 2/12	feet-inches	λ 1.11	
Individual Stack Diameter D	3.86213661	meters	152.1	inches	λ_o ~1.0	
Stack Velocity V_{exit}	8.06	m/s	26.45	ft/sec	$4Vol/(60\pi D^2)$	
Individual Volumetric Flow	94.44	cu.m/sec	200,110	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	313.32	Kelvins	104.3	°F		
Initial Stack Buoyancy Flux F_o	10.45	m^4/s^3	20.0	ΔT(°F)	$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)	
Total Number of Stacks n	48					
Average Adjacent Stack Separation d	16.31	meters	53.5	feet	**Calcs based on multiple plume treatment in Peter Best Paper: plume velocities increased by $N^{0.25}$ at the height where plumes fully merged (interp. below ht, single merged stack above ht)**	
Number of Stacks along Orientation N	3					
Conditions at End (Top) of Jet Phase:						
Height above Stack z_{jet}	24.138	meters*	79.2	feet*	z_{jet} = 6.25D, meters*=meters above stack top	Sect.3/¶1
Height above Ground $z_{jet}+h_s$	47.952	meters	**157.3**	feet		"
Vertical Velocity V_{jet}	**4.031**	m/s	13.22	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$	"
Plume Top-Hat Diameter $2a_{jet}$	7.724	meters	25.3	feet	$2a_{jet}$ = 2D — Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet and Merging Phases						
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:						
Single Plume Values: Plume Top-Hat Radius a	**Used in Plume Merging Only**				$a = 0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	0.432	meters*	1.4	feet*	$z_v = 6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	24.246	meters	79.5	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.9821
Single Plume Values: Vertical Velocity V	**Used in Plume Merging Only**				$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	Sect.2.1(6)
Product $(Va)_o$	15.289	m^2/s			$V_{exit}(D/2)(\theta_e/\theta_s)^{1/2}$	
Plume Merging - Based on Single Plume Calculations where:						Sect.3/¶3
Begin Merging Plume Top-Hat Diameter $2a_{touch}$	16.310	meters	53.5	feet	$2a_{touch}$=d, (or a_{touch}=d/2)	
Height above Stack z_{touch}	51.400	meters*	168.6	feet*	$z_{touch} = z_v+d/(2*0.16)$, meters*=meters above stack top	
Height above Ground $z_{touch}+h_s$	75.214	meters	**246.8**	feet		
Vertical Velocity V_{touch}	**2.244**	m/s	7.4	ft/sec	$V_{touch} = \{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	
Total Merging Plume Top-Hat **Diameter** $2a_{full}$	**32.620**	meters	107.0	feet	$2a_{full}$=2d(N-1)/2, (or a_{full}=d(N-1)/2) **FOR 2 STACKS, $2a_{full}$=2d**	
Height above Stack z_{full}	102.369	meters*	335.9	feet*	$z_{full} = z_v+2d/(2*0.16)$, meters*=meters above stack top	
Height above Ground $z_{full}+h_s$	126.183	meters	**414.0**	feet		
Vertical Velocity V_{full}	1.542	m/s	5.1	ft/sec	$V_{full} = \{(Va)_o^3 + 0.12F_o [(z_{full}-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a_{full}$	
Product $(V^3a)_{full}$	60	m^4/s^3				
Conditions at End (Top) of Merging Phase - Define new values for V_{full} and a_{full} in Merged Plume calculations (based on TOTAL number of stacks):						
Merged Plume Values: Plume Diameter 2a	**Solutions in Table Below**				2a = 2 x (a_m + $0.16(z-z_{full})$), or linear increase with height	
Revised Merged Plume **Radius** a_m	42.930	meters	140.8	feet	where $a_m = n^{0.25}a_{full}$ where Total Merging Occurs	
Revised Merged Plume Velocity V_m	**4.058**	m/s	13.32	ft/sec	and $V_m = n^{0.25}V_{full}$ where Total Merging Occurs	
Revised Virtual Source Height z_{full}	102.369	meters*	335.9	feet*	Height above stack where Total Merging Occurs (shown above)	
Revised Vertical Velocity V	**Solutions in Tables Below**				$V=\{n(V^3a)_{full}/a\}^{1/3}$ for heights above total merging elevation	
					$V=V_{touch}+(V_m-V_{touch})*(z-z_{touch})/(z_{full}-z_{touch})$ for heights below total merging elevation	
Multiple Plume Calculations						
Solve for plume-averaged vertical velocity at height	**1,000.0**	**feet**	304.8		meters above ground $(z+h_s)$	
Gives the following Height above Stack z	280.986	meters*	921.9	feet*	REGULAR EQNS	
Plume Top-Hat Radius a	71.509	meters	234.6	feet	$a=a_m+0.16(z-z_{full})$ **if $z>z_{full}$**	
Vertical Velocity V	**3.424**	**m/s**	11.23	ft/sec	$V=\{n(V^3a)_{full}/a\}^{1/3}$ **if $z>z_{full}$**	
					$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$ **if $z_{touch}<z<z_{full}$**	
					V'=single plume values **if $z<z_{touch}$**	
Solve for Height of CASC critical vertical velocity V_{crit}	**5.30**	**m/s**			BEFORE TOUCHING	**Critical VV < Top of Jet**
Find Height above Stack z_{crit}	JET	meters	JET	feet	$z_{crit} = z_{full} + \{[n(V^3a)_{full}/(V_{crit})^3]-a_m\}/0.16$ **if $V_{crit}<V_m$**	
Height above Ground $z_{crit}+h_s$	JET	meters	**JET**	**feet**	$z_{crit}=z_{touch}+(z_{full}-z_{touch})*(V_{crit}-V_{touch})/(V_m-V_{touch})$ **if $V_{crit}>V_m$**	

Table of MERGED Plume-Averaged Vertical Velocities starting at Touching Height:

Height (feet) above ground	(meters) above stack	Plume Radius(m)	Vert. Vel(m/s)	Notes	
				Single Plume Eqns (see Single Plume spreadsheet)	
				$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3} / a$	
				$a = 0.16(z-z_v)$	
Begin Merging (touch) = 246.8	***51.41***	***8.155***	***2.24***	$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
260.0	55.43	#N/A	2.39	*Interpolated Layer Eqns*	**20 ft Intervals**
280.0	61.53	#N/A	2.60	$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$	
300.0	67.63	#N/A	2.82		
320.0	73.72	#N/A	3.04		
340.0	79.82	#N/A	3.26		
360.0	85.91	#N/A	3.47		
380.0	92.01	#N/A	3.69		
400.0	98.11	#N/A	3.91		
End Merging (full/mp) = 414.0	***102.37***	***42.930***	***4.06***	*Merged Plume Eqns*	
450.0	113.35	44.687	4.00	$V=\{n(V^3a)_{full}/a\}^{1/3}$	**50 ft Intervals**
500.0	128.59	47.125	3.93	$a=a_m+0.16(z-z_{full})$	
550.0	143.83	49.563	3.87		
600.0	159.07	52.002	3.81		
650.0	174.31	54.440	3.75		
700.0	189.55	56.879	3.70		**100 ft Intervals**
800.0	220.03	61.755	3.60		
900.0	250.51	66.632	3.51		
1000.0	280.99	71.509	3.42		
1100.0	311.47	76.386	3.35		
1200.0	341.95	81.263	3.28		
1300.0	372.43	86.139	3.22		
1400.0	402.91	91.016	3.16		
1500.0	433.39	95.893	3.10		**500 ft Intervals**
2000.0	585.79	120.277	2.88		
2500.0	738.19	144.661	2.71		
3000.0	890.59	169.045	2.57		
3500.0	1042.99	193.429	2.46		
4000.0	1195.39	217.813	2.36		
4500.0	1347.79	242.197	2.28		
5000.0	1500.19	266.581	2.21		

MERGED (along width) Plume Average Vertical Velocities for Lafayette Chillers using CEC Staff Methodology - Summer Max*

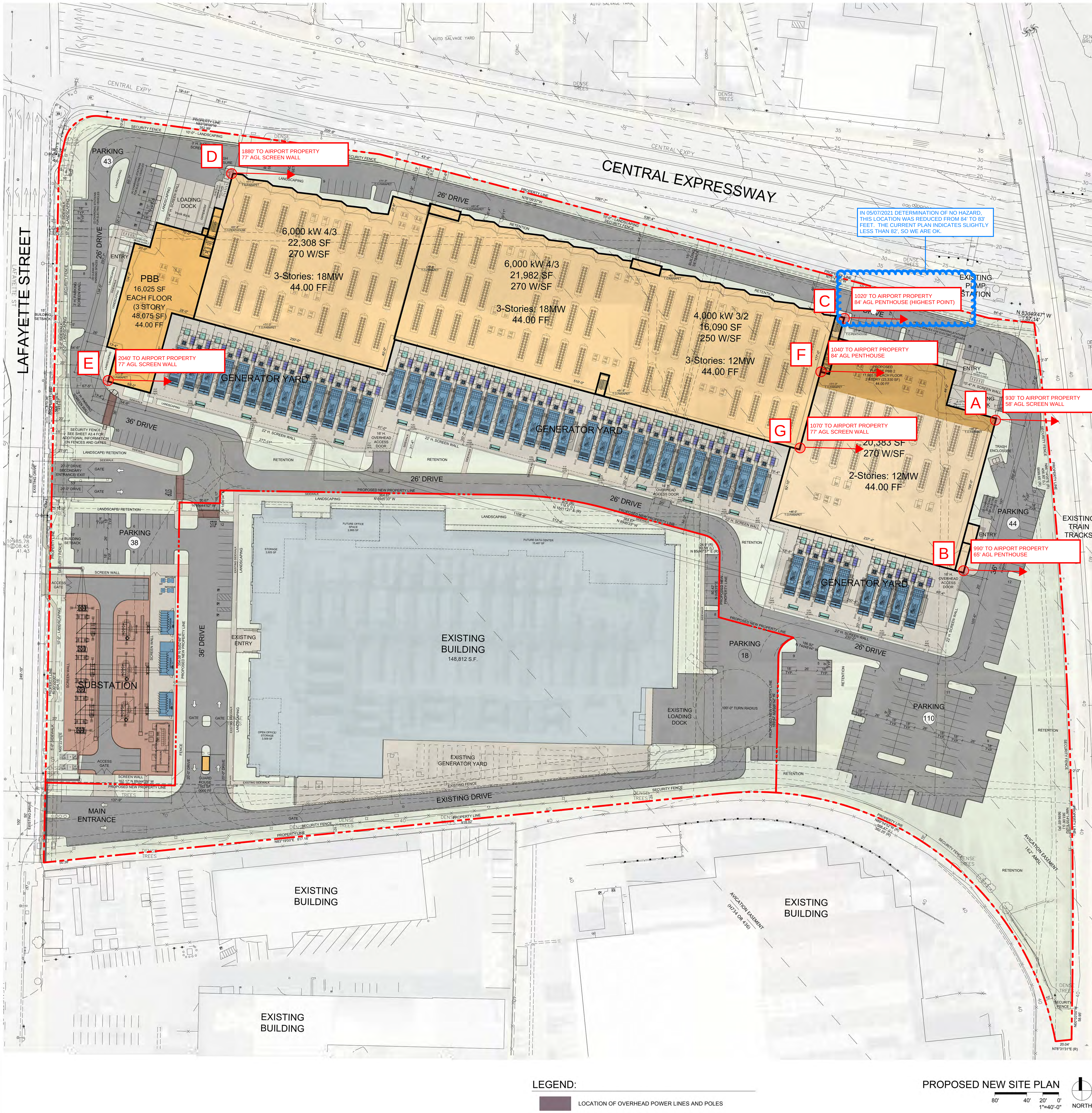
"*Aviation Safety and Buoyant Plumes*," Peter Best, et. al.

"*The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Merged Plume from Two Gas-Turbine Power Station at Oakey, Queensland, Australia*," Dr. K.T. Spillane

Ambient Conditions:					**Constants:** Assume neutral conditions ($d\theta/dz=0$ or $\theta_a=\theta_e$)	
Ambient Potential Temp θ_a	302.21	Kelvins	84.3	°F	0.3048 meters/feet	
Plume Exit Conditions:					Gravity g 9.81 m/s^2	
Stack Height h_s	23.81	meters	78 2/12	feet-inches	λ 1.11	
Individual Stack Diameter D	3.86213661	meters	152.1	inches	λ_o ~1.0	
Stack Velocity V_{exit}	8.06	m/s	26.45	ft/sec	$4Vol/(60\pi D^2)$	
Individual Volumetric Flow	94.44	cu.m/sec	200,110	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	313.32	Kelvins	104.3	°F		
Initial Stack Buoyancy Flux F_o	10.45	m^4/s^3	20.0	ΔT(°F)	$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (see below)	
Total Number of Stacks n	48					
Average Adjacent Stack Separation d	7.50	meters	24.6	feet	**Calcs based on multiple plume treatment in Peter Best Paper:**	
Number of Stacks along Orientation N	16				**plume velocities increased by $N^{0.25}$ at the height where plumes**	
					fully merged (interp. below ht, single merged stack above ht)	
Conditions at End (Top) of Jet Phase:						
Height above Stack z_{jet}	24.138	meters*	79.2	feet*	z_{jet} = 6.25D, meters*=meters above stack top	Sect.3/¶1
Height above Ground $z_{jet}+h_s$	47.952	meters	**157.3**	feet		"
Vertical Velocity V_{jet}	**4.031**	m/s	13.22	ft/sec	$V_{jet} = 0.5V_{exit} = V_{exit}/2$	"
Plume Top-Hat Diameter $2a_{jet}$	7.724	meters	25.3	feet	$2a_{jet}$ = 2D Conservation of momentum	"
Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet and Merging Phases						
Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:						
Single Plume Values: Plume Top-Hat Radius a	**Used in Plume Merging Only**				$a = 0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	0.432	meters*	1.4	feet*	$z_v = 6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	24.246	meters	79.5	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.9821
Single Plume Values: Vertical Velocity V	**Used in Plume Merging Only**				$\{(Va)_o^3 + 0.12F_o[(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)}$ / a	Sect.2.1(6)
Product $(Va)_o$	15.289	m^2/s			$V_{exit}(D/2)(\theta_e/\theta_s)^{1/2}$	
Plume Merging - Based on Single Plume Calculations where:						Sect.3/¶3
Begin Merging Plume Top-Hat Diameter $2a_{touch}$	7.500	meters	24.6	feet	$2a_{touch}$=d, (or a_{touch}=d/2)	
Height above Stack z_{touch}	23.869	meters*	78.3	feet*	$z_{touch} = z_v$+d/(2*0.16), meters*=meters above stack top	
Height above Ground $z_{touch}+h_s$	47.683	meters	**156.4**	feet		
Vertical Velocity V_{touch}	**4.071**	m/s	13.4	ft/sec	$V_{touch} = \{(Va)_o^3 + 0.12F_o[(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)}$ / a	
Total Merging Plume Top-Hat **Diameter** $2a_{full}$	**112.500**	meters	369.1	feet	$2a_{full}$=2d(N-1)/2, (or a_{full}=d(N-1)/2) **FOR 2 STACKS, $2a_{full}$=2d**	
Height above Stack z_{full}	351.994	meters*	1154.8	feet*	$z_{full} = z_v$+2d/(2*0.16), meters*=meters above stack top	
Height above Ground $z_{full}+h_s$	375.808	meters	**1233.0**	feet		
Vertical Velocity V_{full}	0.961	m/s	3.2	ft/sec	$V_{full} = \{(Va)_o^3 + 0.12F_o[(z_{full}-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a_{full}$	
Product $(V^3a)_{full}$	50	m^4/s^3				
Conditions at End (Top) of Merging Phase - Define new values for V_{full} and a_{full} in Merged Plume calculations (based on TOTAL number of stacks):						
Merged Plume Values: Plume Diameter 2a	**Solutions in Table Below**				$2a = 2 \times (a_m + 0.16(z-z_{full}))$, or linear increase with height	
Revised Merged Plume **Radius** a_m	148.058	meters	485.8	feet	where $a_m = n^{0.25}a_{full}$ where Total Merging Occurs	
Revised Merged Plume Velocity V_m	**2.529**	m/s	8.30	ft/sec	and $V_m = n^{0.25}V_{full}$ where Total Merging Occurs	
Revised Virtual Source Height z_{full}	351.994	meters*	1154.8	feet*	Height above stack where Total Merging Occurs (shown above)	
Revised Vertical Velocity V	**Solutions in Tables Below**				$V=\{n(V^3a)_{full}/a\}^{1/3}$ for heights above total merging elevation	
					$V=V_{touch}+(V_m-V_{touch})*(z-z_{touch})/(z_{full}-z_{touch})$	
Multiple Plume Calculations					for heights below total merging elevation	
Solve for plume-averaged vertical velocity at height		**1,000.0**	**feet**	304.8	meters above ground $(z+h_s)$	
Gives the following Height above Stack z	280.986	meters*	921.9	feet*	LESS THAN TOP OF MERGING PHASE-INTERPOLATE	
Plume Top-Hat Radius a	#N/A	meters	#N/A	feet	$a=a_m+0.16(z-z_{full})$ **if $z>z_{full}$**	
Vertical Velocity V	**2.863**	**m/s**	9.39	ft/sec	$V=\{n(V^3a)_{full}/a\}^{1/3}$ **if $z>z_{full}$**	
					$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$ **if $z_{touch}<z<z_{full}$**	
					V'=single plume values **if $z<z_{touch}$**	
Solve for Height of CASC critical vertical velocity V_{crit}		**5.30**	**m/s**		BEFORE TOUCHING	**Critical VV < Top of Jet**
Find Height above Stack z_{crit}	JET	meters	JET	feet	$z_{crit} = z_{full} + \{[n(V^3a)_{full}/(V_{crit})^3]-a_m\}/0.16$ **if $V_{crit}<V_m$**	
Height above Ground $z_{crit}+h_s$	JET	meters	**JET**	**feet**	$z_{crit}=z_{touch}+(z_{full}-z_{touch})*(V_{crit}-V_{touch})/(V_m-V_{touch})$ **if $V_{crit}>V_m$**	

Table of MERGED Plume-Averaged Vertical Velocities starting at Touching Height:

Height (feet) above ground	**(meters) above stack**	**Plume Radius(m)**	**Vert. Vel(m/s)**	*Single Plume Eqns (see Single Plume spreadsheet)*	
				$V_{plume}=\{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3}$ / a	
				$a = 0.16(z-z_v)$	
Begin Merging (touch) = 156.4	***23.86***	***3.750***	***4.07***	$\theta_p=\theta_s(1+(1-(\theta_e/\theta_s))*(V_{exit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
160.0	24.95	#N/A	4.07	*Interpolated Layer Eqns*	**20 ft Intervals**
180.0	31.05	#N/A	4.04	$V'=V_{touch}+(V_m-V_{touch})*(z'-z_{touch})/(z_{full}-z_{touch})$	
200.0	37.15	#N/A	4.01		
220.0	43.24	#N/A	3.98		
240.0	49.34	#N/A	3.95		
260.0	55.43	#N/A	3.92		
300.0	67.63	#N/A	3.87		**50 ft Intervals**
350.0	82.87	#N/A	3.79		
400.0	98.11	#N/A	3.72		
450.0	113.35	#N/A	3.65		
500.0	128.59	#N/A	3.58		
550.0	143.83	#N/A	3.51		
600.0	159.07	#N/A	3.44		
650.0	174.31	#N/A	3.36		
700.0	189.55	#N/A	3.29		
750.0	204.79	#N/A	3.22		
800.0	220.03	#N/A	3.15		**100 ft Intervals**
850.0	235.27	#N/A	3.08		
900.0	250.51	#N/A	3.01		
950.0	265.75	#N/A	2.93		
1000.0	280.99	#N/A	2.86		
1100.0	311.47	#N/A	2.72		
1200.0	341.95	#N/A	2.58		
End Merging (full/mp) = 1233.0	***352.00***	***148.058***	***2.53***	*Merged Plume Eqns*	
1300.0	372.43	151.327	2.51	$V=\{n(V^3a)_{full}/a\}^{1/3}$	
1500.0	433.39	161.081	2.46	$a=a_m+0.16(z-z_{full})$	
2000.0	585.79	185.465	2.35		**500 ft Intervals**
2500.0	738.19	209.849	2.25		
3000.0	890.59	234.233	2.17		
3500.0	1042.99	258.617	2.10		
4000.0	1195.39	283.001	2.04		
4500.0	1347.79	307.385	1.98		



SITE INFORMATION:

PROJECT NAME:	2825 LAFAYETTE STREET
PROJECT DESCRIPTION:	NEW DATA CENTER
PROJECT CONTACT:	CHAD MENDELL ENVIRONMENTAL SYSTEMS DESIGN, INC. 233 SOUTH WACKER DRIVE, SUITE 5300 CHICAGO, ILLINOIS 60606 312-372-1200
OWNER:	DIGITAL LAFAYETTE, LLC 2825 LAFAYETTE STREET SANTA CLARA, CA 95050-2627
PARCEL NUMBER:	NORTH PARCEL: 224-04-093 SOUTH PARCEL: 224-04-094
LOT NUMBER:	NORTH PARCEL: LOT 2 SOUTH PARCEL: LOT 1
TRACT NUMBER:	NORTH PARCEL: 93 SOUTH PARCEL: 94
LEGAL:	BOUNDED BY CENTRAL EXPRESSWAY TO THE NORTH, LAFAYETTE STREET TO THE WEST, 2825 LAFAYETTE STREET (SITE) AND RAILROAD TRACKS TO THE EAST, AND 2805 LAFAYETTE STREET (DLR) TO THE SOUTH COUNTY OF SANTA CLARA: 1.78M POPULATION (2010 CENSUS) TAX ASSESSOR'S PARCEL NUMBER (APN): 224-04-093
ZONING:	MH - HEAVY INDUSTRIAL PROCESSING AND STORAGE USES PERMITTED (MH - ZONING ORD 18.50.030) COMMERCIAL STORAGE AND WHOLESALE DISTRIBUTION
FEMA:	NORTH PARCEL: FLOOD ZONE X SOUTH PARCEL: FLOOD ZONE AH
BUILDING SETBACKS:	FRONT YARD 15'-0" EACH LOT SHALL HAVE A STREET SIDE FRONT YARD OF NOT LESS THAN FIFTEEN (15) FEET IN DEPTH SIDE YARD 15'-0" THE STREET SIDE YARD OF EACH CORNER LOT EXCLUSIVE OF THE FRONT YARD SHALL BE NOT LESS THAN FIFTEEN (15) FEET IN DEPTH REAR YARD 0'-0" SETBACK ADJACENT TO NON-RESIDENTIAL 0' REAR YARD
LANDSCAPE SETBACKS:	FRONT, SIDE YARDS 10'-0" A MINIMUM OF TEN FEET OF THE REQUIRED FRONT AND STREET SIDE YARDS, EXCLUSIVE OF CITY-PERMITTED DRIVEWAY CUTS, SHALL BE DEVELOPED INTO AND PERMANENTLY MAINTAINED AS OPEN LANDSCAPED AREAS SUBJECT TO THE APPROVAL OF THE DIRECTOR OF PLANNING AND INSPECTION.
HEIGHT:	70 FT MAX HEIGHT (ZONING ORD. 18.50.070) MECH AND PARAPETS CAN BE PLACED ABOVE THIS (ZONING ORD. 18.64.010). VARIABLE MAX. HEIGHT BASED ON FAA REGULATIONS.

SITE AREA:	NORTH PARCEL:	691,526.384 S.F.
	SOUTH PARCEL:	299,683.550 S.F.
	TOTAL:	991,209.934 S.F. (22.755 ACRES)
TYPE OF USE:		OFFICE/ DATA CENTER
OCCUPANCY GROUP:		BUSINESS GROUP B (CHAPTER 3, SECTION 304)
TYPE OF BUILDING CONSTRUCTION:		TYPE 2B (FULLY SPRINKLERED) (CHAPTER 6, TABLE 601)
BUILDING AREA:	EXISTING BUILDING - 2805: DATA CENTER:	148,812 S.F.
	NEW BUILDING - 2825: DATA CENTER:	575,401 S.F.
	TOTAL:	724,213 S.F.
GENERATOR YARD:		108,631 S.F.
% LOT COVERAGE:		30 % (209,869/ 691,526.384 = 0.3034)
FLOOR-TO-AREA RATIO (FAR) PROPOSED NEW BUILDING		0.90
PARKING REQUIRED:	DATA CENTER (EXISTING)	38 SPACES
	(1 SPACE PER 4,000 S.F.) (148,812 S.F./ 4000 = 38 SPACES)	
	DATA CENTER (NEW)	144 SPACES
	(1 SPACE PER 4,000 S.F.) (575,401 S.F./ 4000 = 144 SPACES)	
	TOTAL PARKING REQUIRED: DATA CENTER (NEW):	182 SPACES (144 + 38 = 182 SPACES)

PARKING PROVIDED FOR BUILDING 2805:	76 SPACES
PARKING PROVIDED FOR BUILDING 2825:	177 SPACES
TOTAL PARKING PROVIDED:	253 SPACES

* NOTE: THERE ARE **0** COMPACT PARKING STALLS ON THIS SITE.

BICYCLE RACKS REQUIRED:
DATA CENTER (NEW): (CLASS 1 - 5% OF 182 PARKING STALLS) = 10 RACKS
(CLASS 2 - 5% OF 182 PARKING STALLS) = 10 RACKS

BICYCLE RACKS PROVIDED:
DATA CENTER (NEW): CLASS 1 = 10 RACKS
CLASS 2 = 10 RACKS

CHARGING STATION PARKING SPACES REQUIRED:
DATA CENTER (NEW): (6% OF 182 PARKING STALLS) = 11 SPACES

CHARGING STATION PARKING SPACES PROVIDED:
DATA CENTER (NEW): 11 SPACES

CLEAN AIR PARKING SPACES REQUIRED:
DATA CENTER (NEW): (8% OF 182 PARKING STALLS) = 15 SPACES

CLEAN AIR PARKING SPACES PROVIDED:
DATA CENTER (NEW): 15 SPACES

GENERAL NOTES:

1. ALL GATES INSTALLED ON DESIGNATED FIRE DEPARTMENT ACCESS ROADS ARE REQUIRED TO ELECTRICALLY AUTOMATIC POWERED GATES. GATES SHALL BE PROVIDED WITH AN EMERGENCY BATTERY POWER SUPPLY, OR SHALL BE A FAIL-SAFE DESIGN, ALLOWING THE GATE TO BE PUSHED OPEN WITHOUT THE USE OF SPECIAL KNOWLEDGE OR EQUIPMENT. TO CONTROL THE AUTOMATIC GATES A DETECTOR/STROBE SWITCH SHALL BE INSTALLED TO ALLOW EMERGENCY VEHICLES (E.G., FIRE, POLICE, EMS) TO FLASH A VEHICLE MOUNTED STROBE LIGHT TOWARDS THE DETECTOR/STROBE SWITCH, WHICH IN TURN OVERRIDES THE SYSTEM AND OPENS THE GATE. THE GATES SHALL BE EQUIPPED WITH A TOMAR STROBE SWITCH OR 3M OPTICOM DETECTOR TO FACILITATE THIS OVERRIDE.

VICINITY MAP

N.T.S.

NORTH

DIGITAL REALTY
Data Center Solutions

2825 LAFAYETTE STREET
SANTA CLARA, CA
95050-2627

MEP ENGINEER

ESD
Environmental Systems Design, Inc.
233 South Wacker Drive, Suite 5300
Chicago, Illinois 60606
312.372.1200
www.esdglobal.com
DPR License No. 184-000892 IL

ARCHITECT

HKS

STRUCTURAL ENGINEER

PEOPLES ASSOCIATES
STRUCTURAL ENGINEERS

CIVIL ENGINEER

Kimley»Horn

NO.	RECORD	DATE
2	PCC ISSUANCE	06.19.20
1	PCC ISSUANCE	10.28.19

MASTER PLAN

PROPOSED NEW SITE PLAN

PRINCIPAL IN CHARGE MC	PROJECT NUMBER C190280
PROJECT MANAGER CM	DATE 06/19/2020
PROJECT ENGINEER	SHEET NUMBER **A1.1**
SCALE AS NOTED	

C:\Users\swaltenburg\Desktop\Digital - Santa Clara Data Center\CAD\City Submittal Drawings - 2019\DLR - Site Plan - A1_1 - 2020_06_22.dwg 6/22/2020 10:38 AM swaltenburg

Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12505-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette A
Location:	Santa Clara, CA
Latitude:	37-22-22.84N NAD 83
Longitude:	121-56-45.50W
Heights:	41 feet site elevation (SE)
	58 feet above ground level (AGL)
	99 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12505-OE.

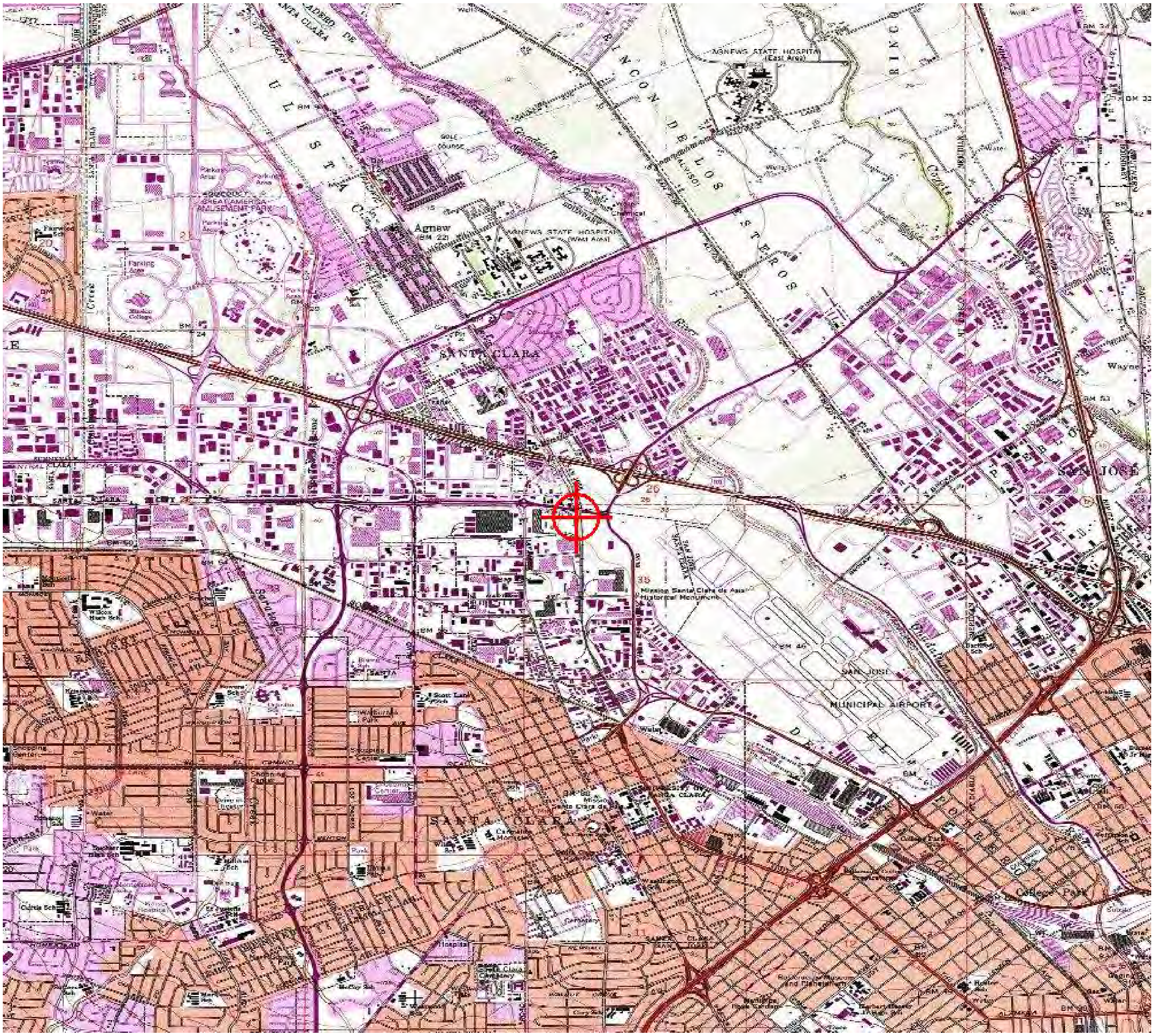
Signature Control No: 455757144-480154406 (DNE)
Daniel Shoemaker
Specialist

Attachment(s)
Additional Information
Map(s)

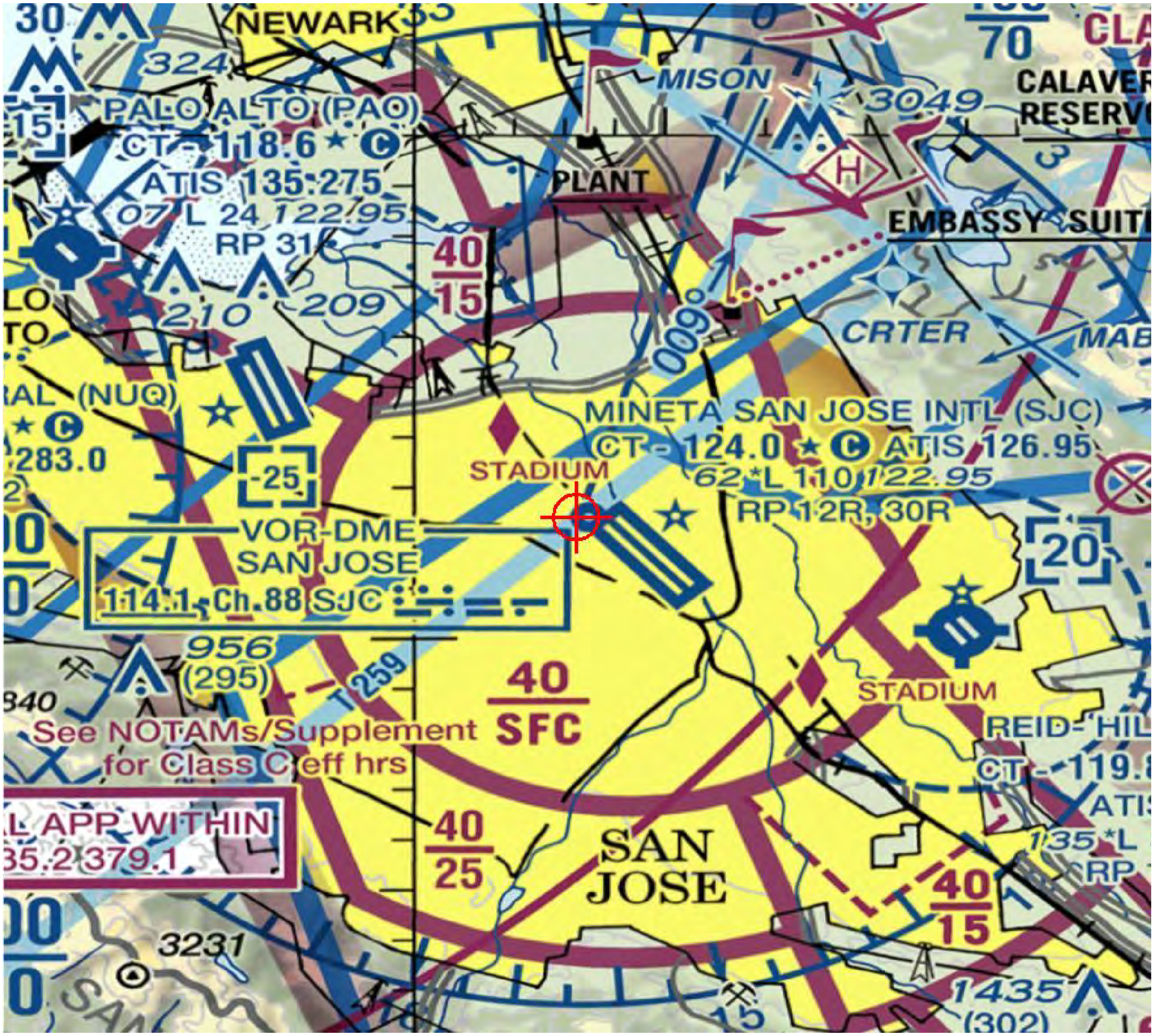
Additional information for ASN 2020-AWP-12505-OE

This building will be located in very close proximity to the threshold of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12505-OE



Sectional Map for ASN 2020-AWP-12505-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12506-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette B
Location:	Santa Clara, CA
Latitude:	37-22-20.89N NAD 83
Longitude:	121-56-45.99W
Heights:	41 feet site elevation (SE)
	65 feet above ground level (AGL)
	106 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12506-OE.

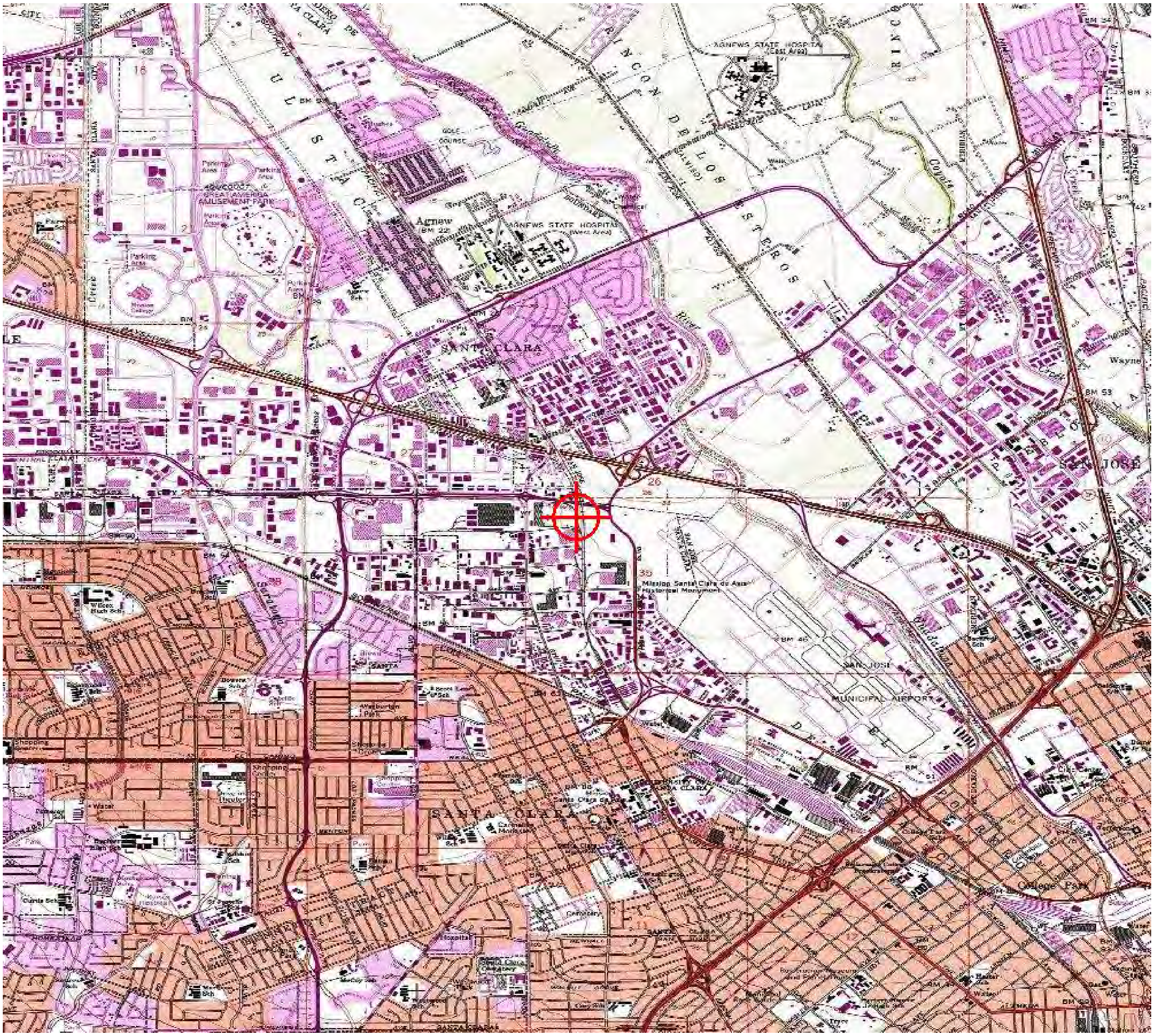
Signature Control No: 455757145-480154409 (DNE)
Daniel Shoemaker
Specialist

Attachment(s)
Additional Information
Map(s)

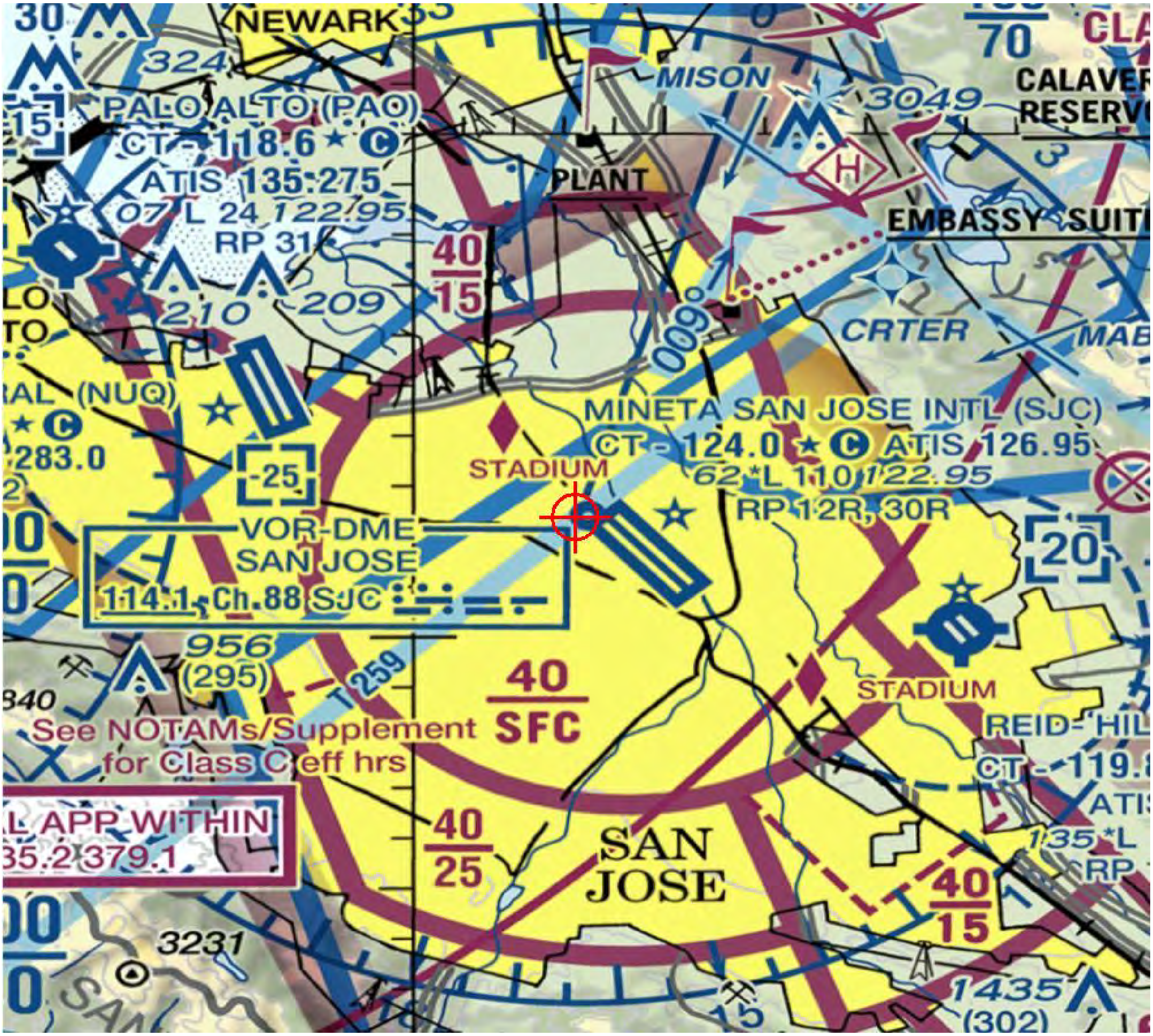
Additional information for ASN 2020-AWP-12506-OE

This building will be located in very close proximity to the threshold of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12506-OE



Sectional Map for ASN 2020-AWP-12506-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12507-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette C
Location:	Santa Clara, CA
Latitude:	37-22-24.05N NAD 83
Longitude:	121-56-47.87W
Heights:	41 feet site elevation (SE)
	83 feet above ground level (AGL)
	124 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

Any height exceeding 83 feet above ground level (124 feet above mean sea level), will result in a substantial adverse effect and would warrant a Determination of Hazard to Air Navigation.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.
(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12507-OE.

Signature Control No: 455757146-480154616 (DNE)
Daniel Shoemaker
Specialist

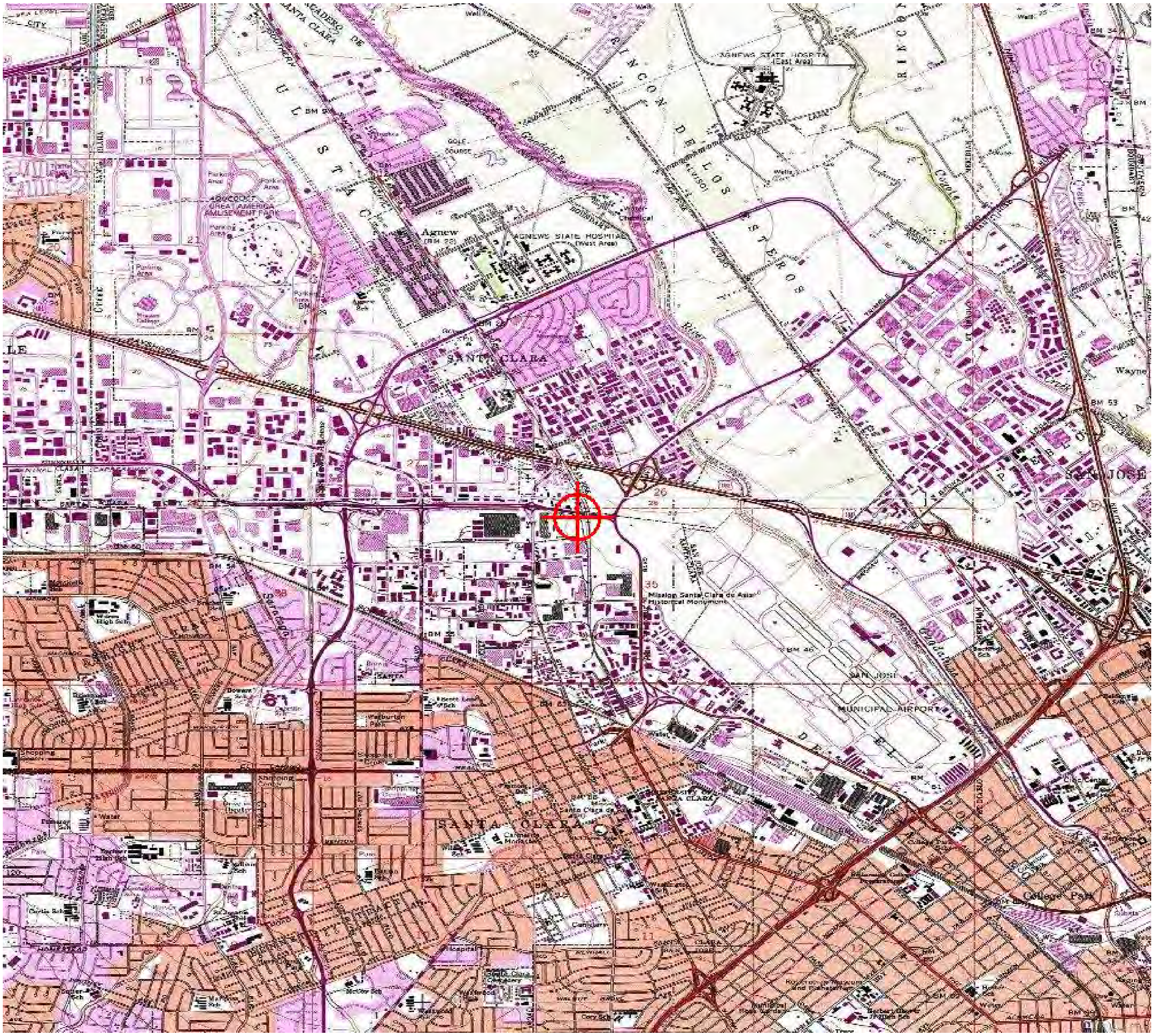
Attachment(s)
Additional Information
Map(s)

Additional information for ASN 2020-AWP-12507-OE

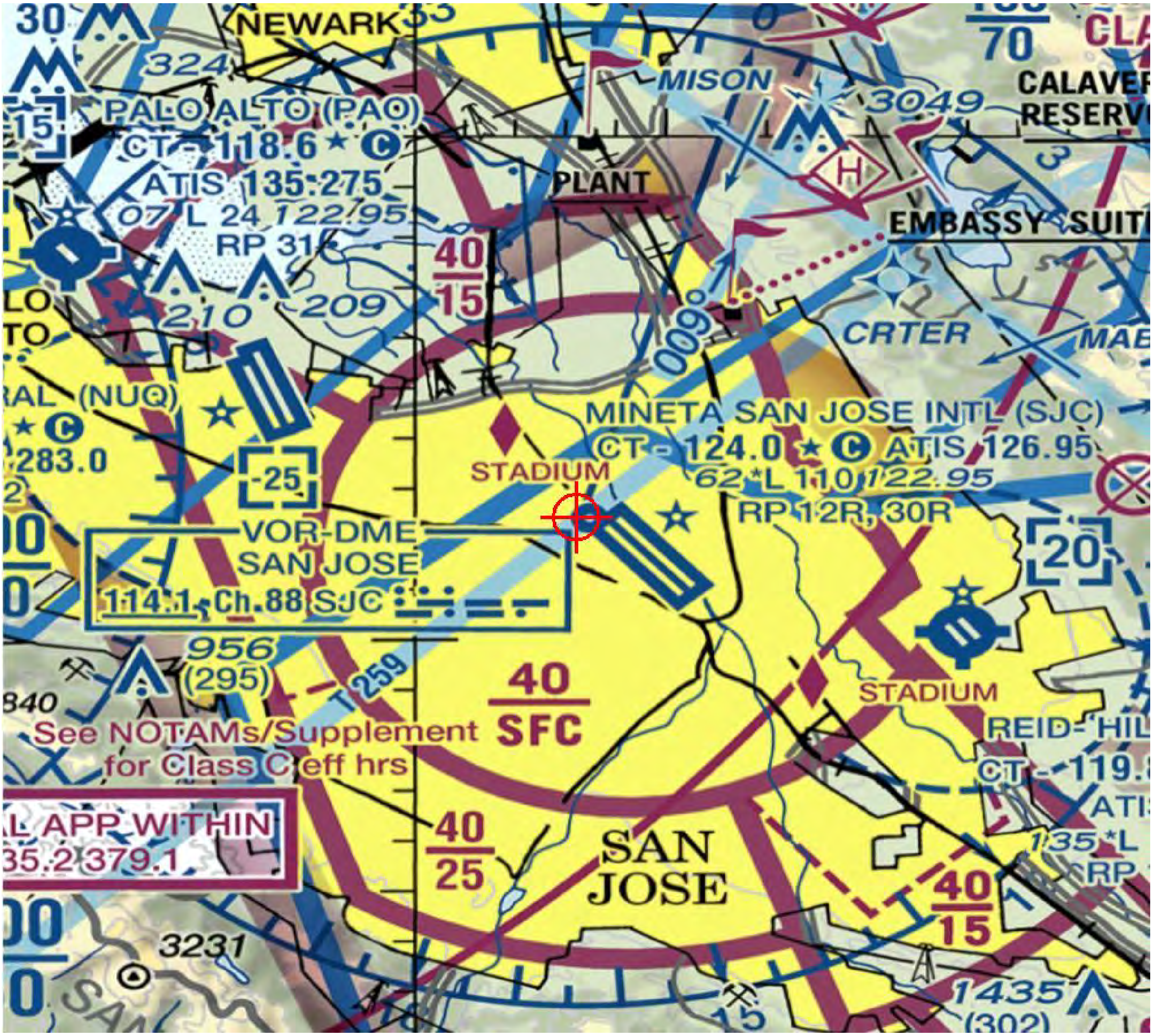
At the negotiated reduced height of 83 feet above ground level (AGL), 124 feet above mean sea level (AMSL), this corner of the building will be at the exact height of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R/30L 14 CFR Part 77 transitional surface. At any height greater than 83 feet AGL/124 feet AMSL, this corner of the building would require circularization for public comment and red obstruction lighting.

This building will be located in very close proximity to the threshold of the SJC RWY 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12507-OE



Sectional Map for ASN 2020-AWP-12507-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12508-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette D
Location:	Santa Clara, CA
Latitude:	37-22-25.73N NAD 83
Longitude:	121-56-57.39W
Heights:	41 feet site elevation (SE)
	77 feet above ground level (AGL)
	118 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12508-OE.

Signature Control No: 455757147-480154408 (DNE)

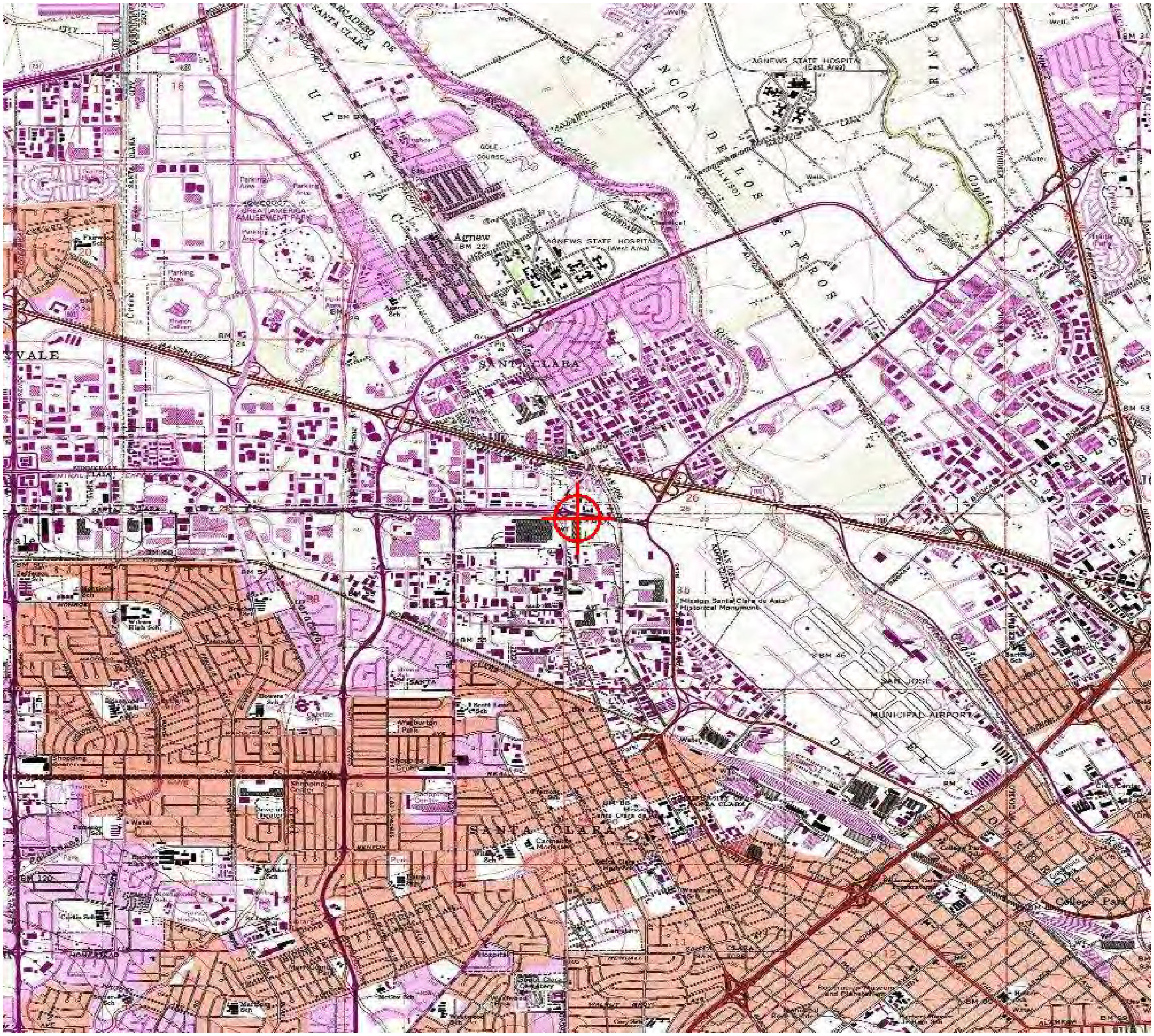
Daniel Shoemaker
Specialist

Attachment(s)
Additional Information
Map(s)

Additional information for ASN 2020-AWP-12508-OE

This building will be located in very close proximity to the threshold of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12508-OE



Sectional Map for ASN 2020-AWP-12508-OE

Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12509-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette E
Location:	Santa Clara, CA
Latitude:	37-22-23.12N NAD 83
Longitude:	121-56-59.45W
Heights:	41 feet site elevation (SE)
	77 feet above ground level (AGL)
	118 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12509-OE.

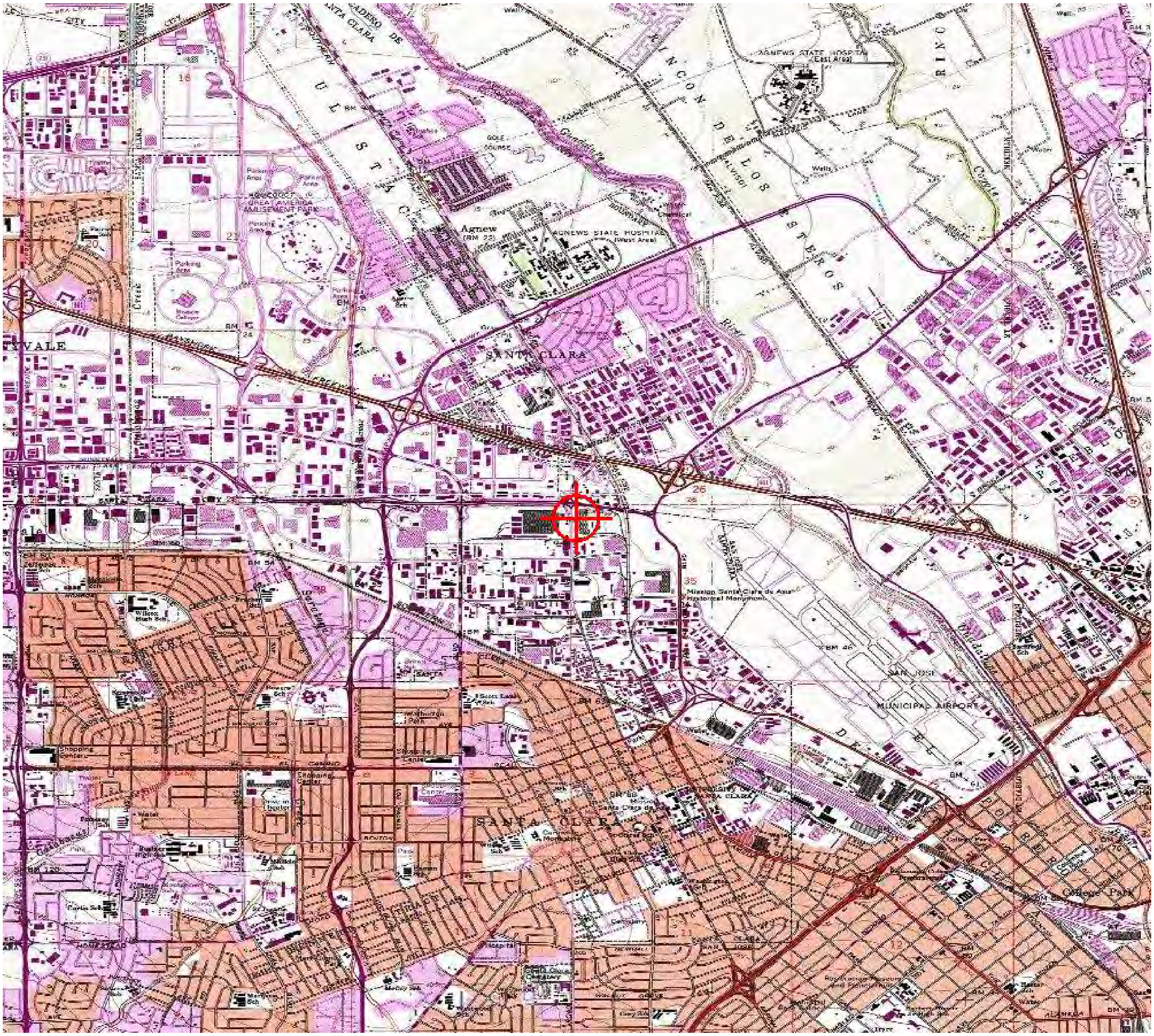
Signature Control No: 455757148-480154410 (DNE)
Daniel Shoemaker
Specialist

Attachment(s)
Additional Information
Map(s)

Additional information for ASN 2020-AWP-12509-OE

This building will be located in very close proximity to the threshold of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12509-OE



Sectional Map for ASN 2020-AWP-12509-OE

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Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12510-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette F
Location:	Santa Clara, CA
Latitude:	37-22-23.40N NAD 83
Longitude:	121-56-48.22W
Heights:	41 feet site elevation (SE)
	84 feet above ground level (AGL)
	125 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12510-OE.

Signature Control No: 455757149-480154407 (DNE)

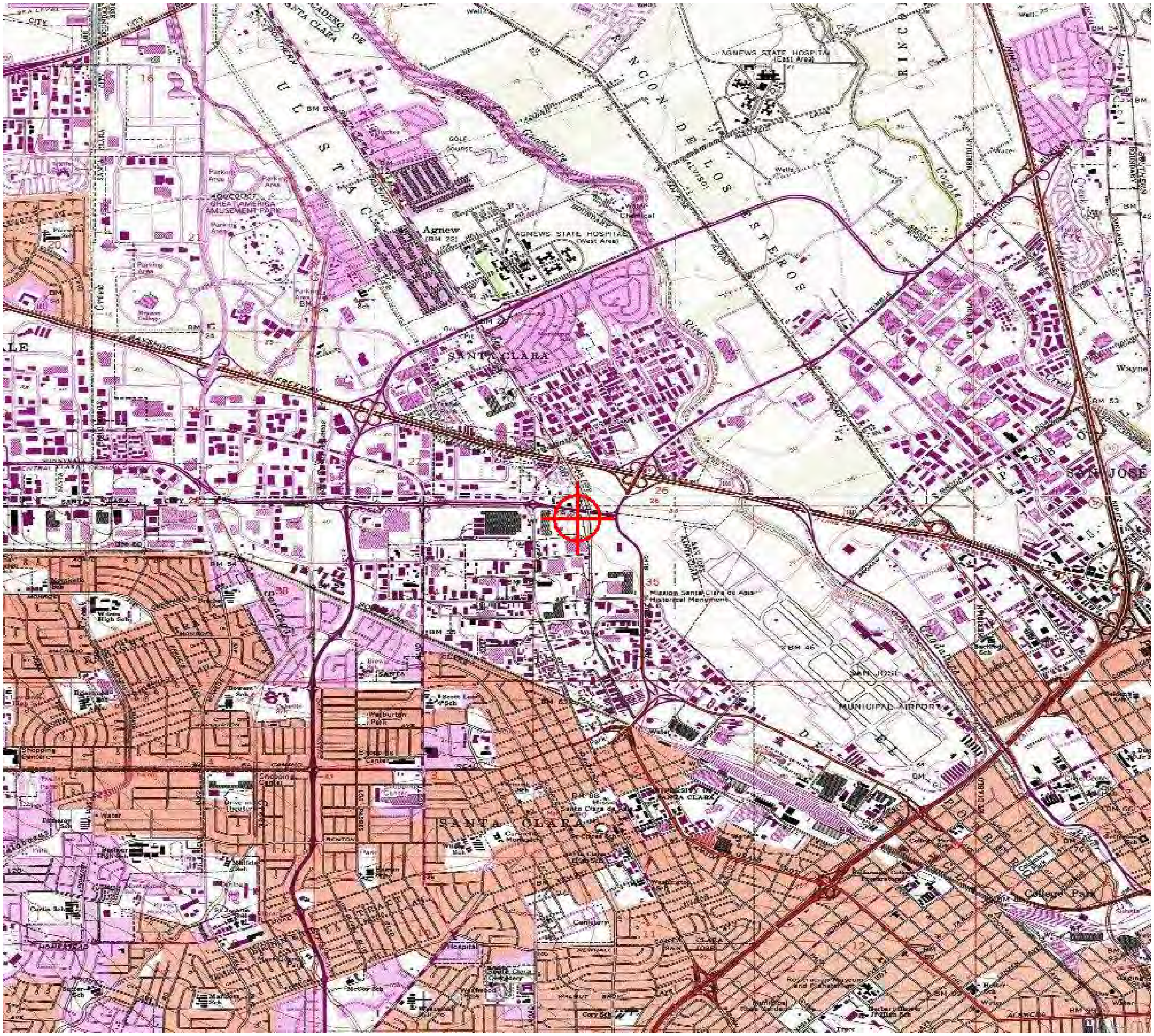
Daniel Shoemaker
Specialist

Attachment(s)
Additional Information
Map(s)

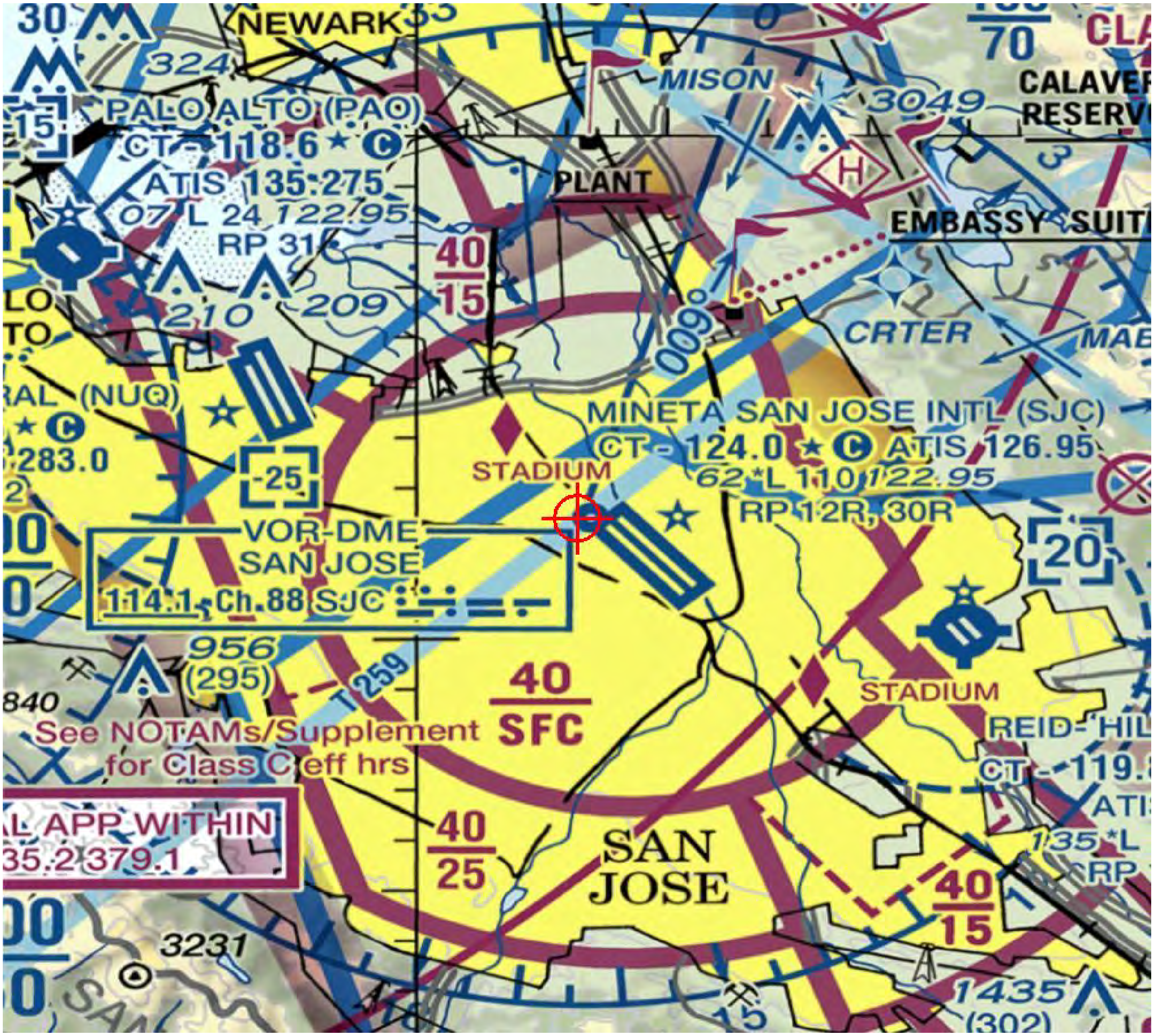
Additional information for ASN 2020-AWP-12510-OE

This building will be located in very close proximity to the threshold of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12510-OE



Sectional Map for ASN 2020-AWP-12510-OE



Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2020-AWP-12511-OE

Issued Date: 05/07/2021

Digital Realty
Rafal Rak
9355 Grand Avenue
Franklin Park, IL 60131

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Building 2825 Lafayette G
Location:	Santa Clara, CA
Latitude:	37-22-22.38N NAD 83
Longitude:	121-56-48.55W
Heights:	41 feet site elevation (SE)
	77 feet above ground level (AGL)
	118 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

_____ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.
Based on this evaluation, marking and lighting are not necessary for aviation safety. However, if marking/ lighting are accomplished on a voluntary basis, we recommend it be installed in accordance with FAA Advisory circular 70/7460-1 M.

The structure considered under this study lies in proximity to an airport and occupants may be subjected to noise from aircraft operating to and from the airport.

This determination expires on 11/07/2022 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

(c) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

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This determination is based, in part, on the foregoing description which includes specific coordinates, heights, frequency(ies) and power. Any changes in coordinates, heights, and frequencies or use of greater power, except those frequencies specified in the Colo Void Clause Coalition; Antenna System Co-Location; Voluntary Best Practices, effective 21 Nov 2007, will void this determination. Any future construction or alteration, including increase to heights, power, or the addition of other transmitters, requires separate notice to the FAA.This determination includes all previously filed frequencies and power for this structure.

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This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

If we can be of further assistance, please contact our office at (206) 231-2989, or dan.shoemaker@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2020-AWP-12511-OE.

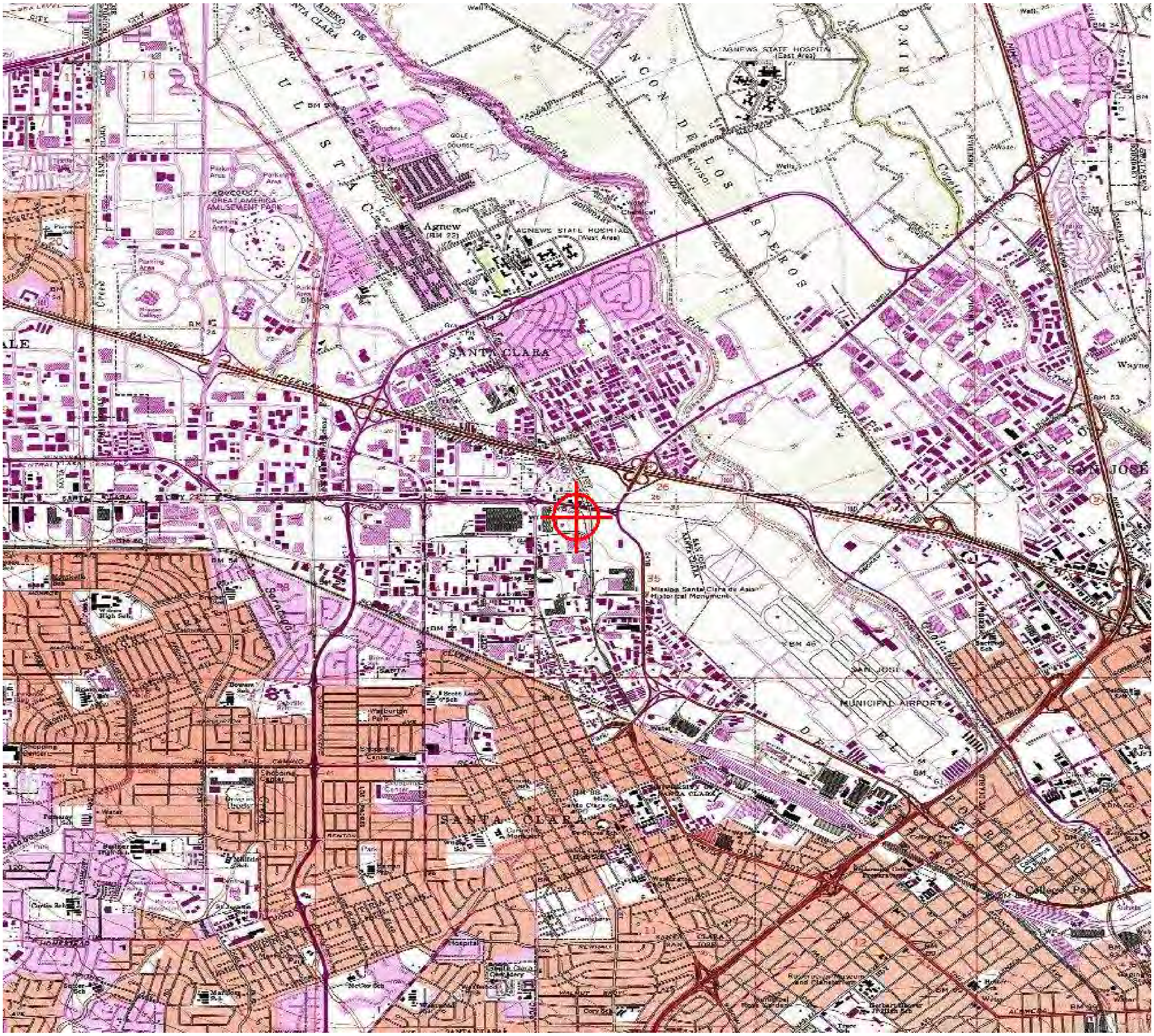
Signature Control No: 455757150-480154411 (DNE)
Daniel Shoemaker
Specialist

Attachment(s)
Additional Information
Map(s)

Additional information for ASN 2020-AWP-12511-OE

This building will be located in very close proximity to the threshold of the Norman Y. Mineta San Jose International Airport (SJC) Runway (RWY) 12R. Occupants and people outside the building will be exposed to frequent loud jet aircraft noise and the sight of large commercial aircraft operating at very low altitudes near the building.

TOPO Map for ASN 2020-AWP-12511-OE



Sectional Map for ASN 2020-AWP-12511-OE