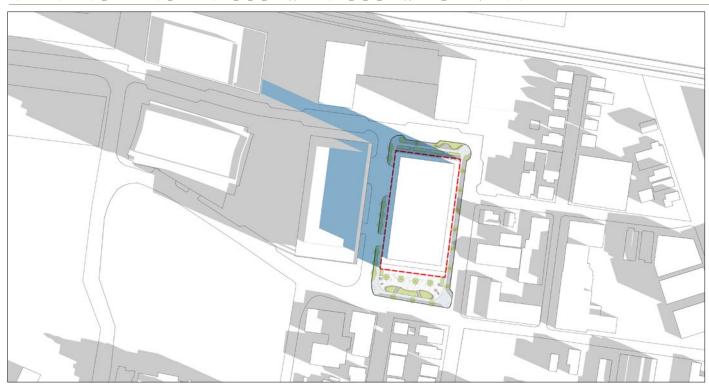
# **APPENDIX B: Environmental**

#### **Contents**

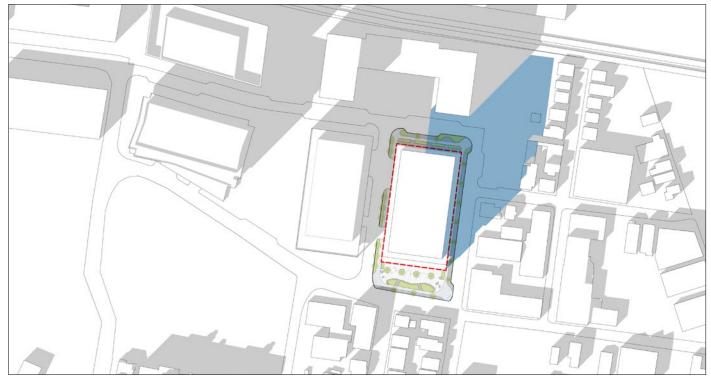
- > Shadow Studies
- > Pedestrian Wind Study
- ➤ Solar Reflection Study

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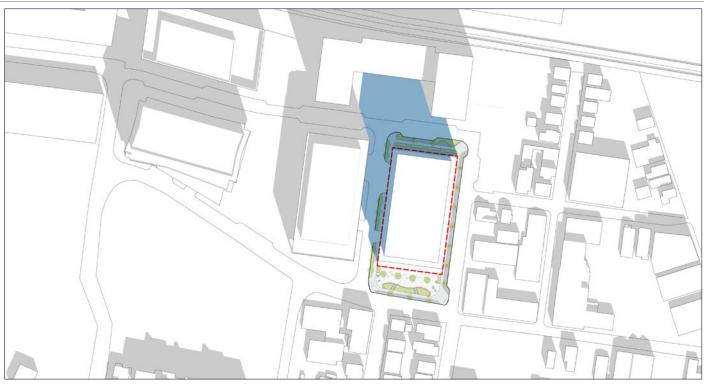
# **SHADOW STUDIES**



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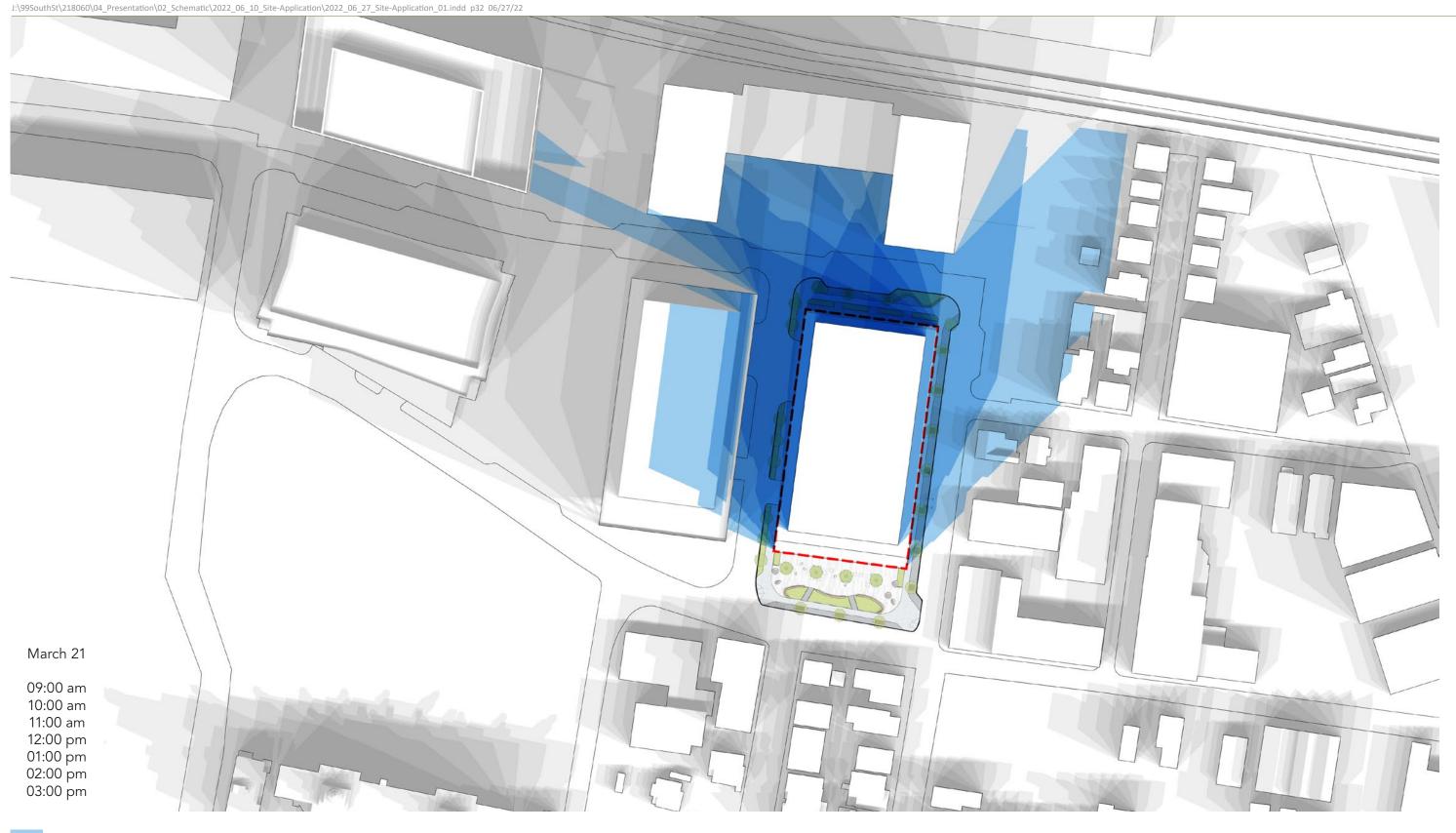
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March 21, 12:00 pm

cbt

Figure B.1 Shadow Studies



NEW SHADOW

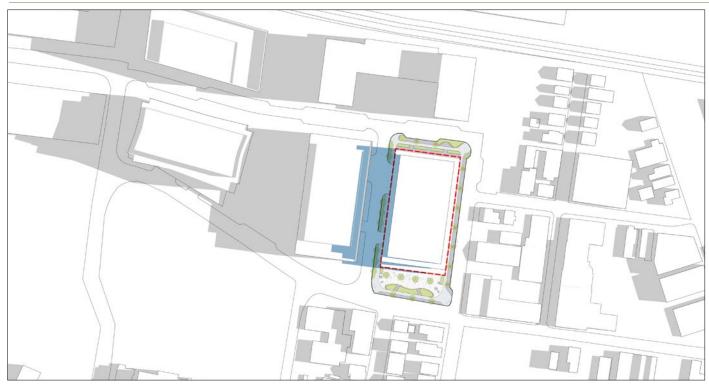
cbt

Figure B.1 Shadow Studies

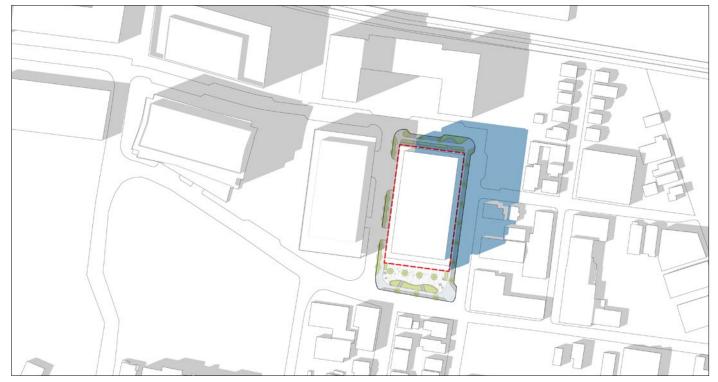
Boynton Yards Building 3 99 South Street Somerville, Massachusetts

EXISTING SHADOW

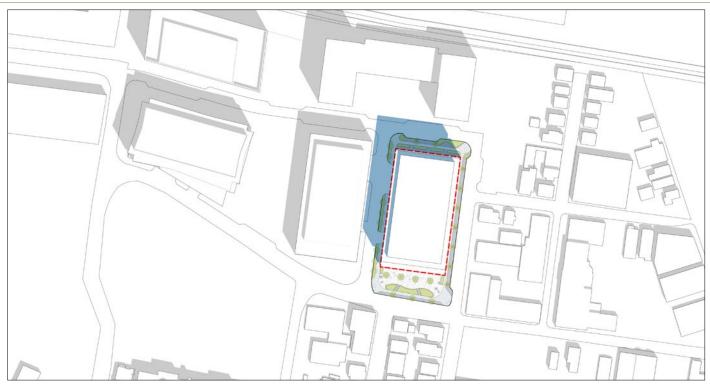
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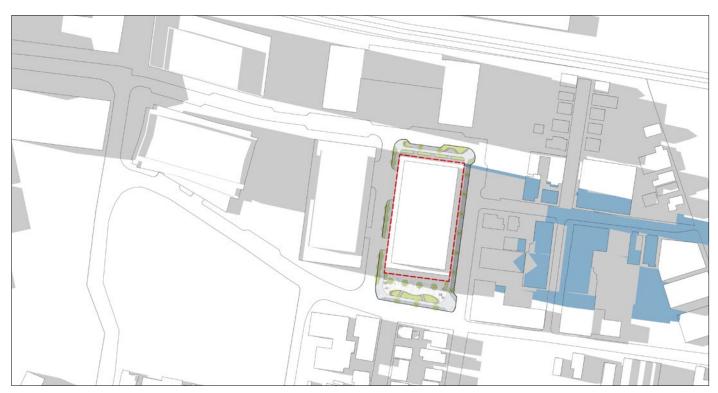
June 21, 9:00 am



June 21, 3:00 pm



June 21, 12:00 pm



June 21, 6:00 pm

cbt

Figure B.1 Shadow Studies

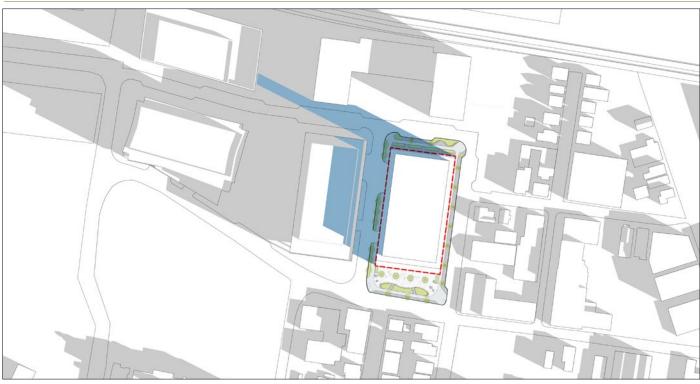
NEW SHADOW

EXISTING SHADOW

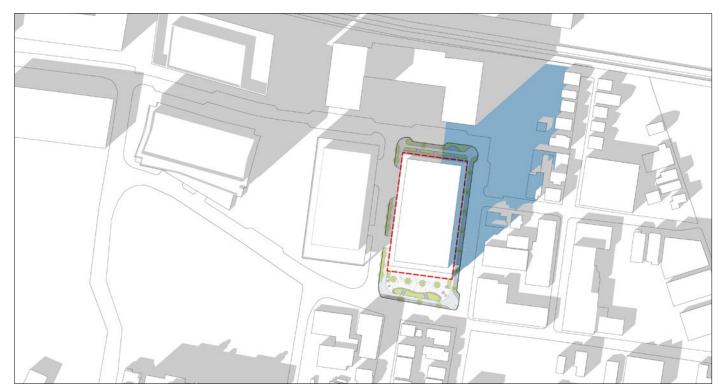
--- PROPOSED NEW BUILDING

cbt

Figure B.1 Shadow Studies



September 21, 9:00 am



September 21, 3:00 pm



September 21, 12:00 pm



September 21, 6:00 pm

cbt

Figure B.1 Shadow Studies

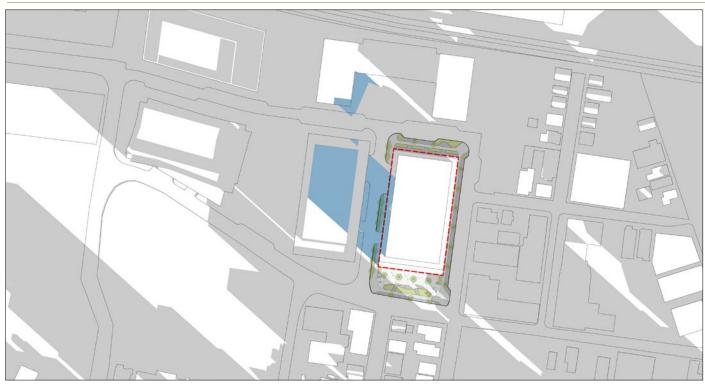
NEW SHADOW

EXISTING SHADOW

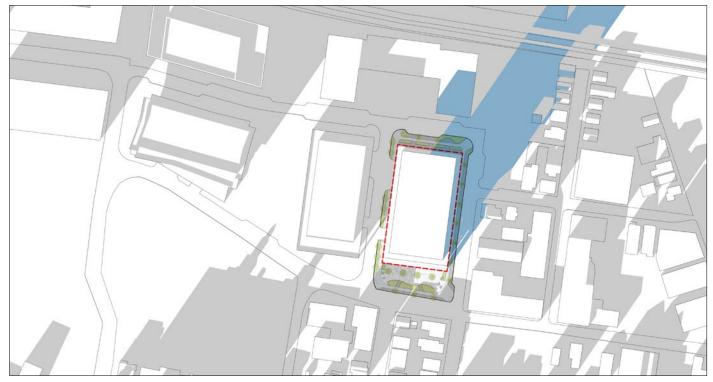
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cbt

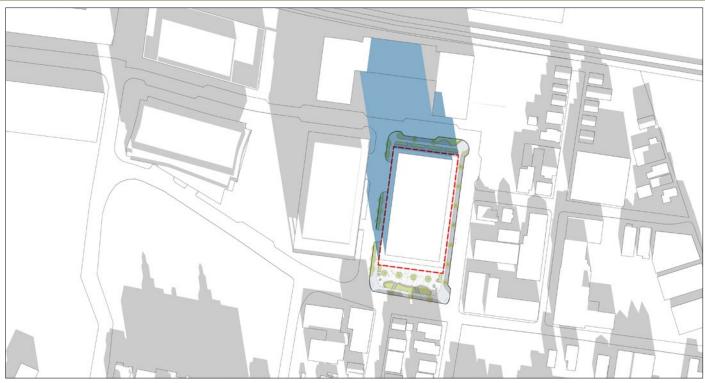
Figure B.1 Shadow Studies



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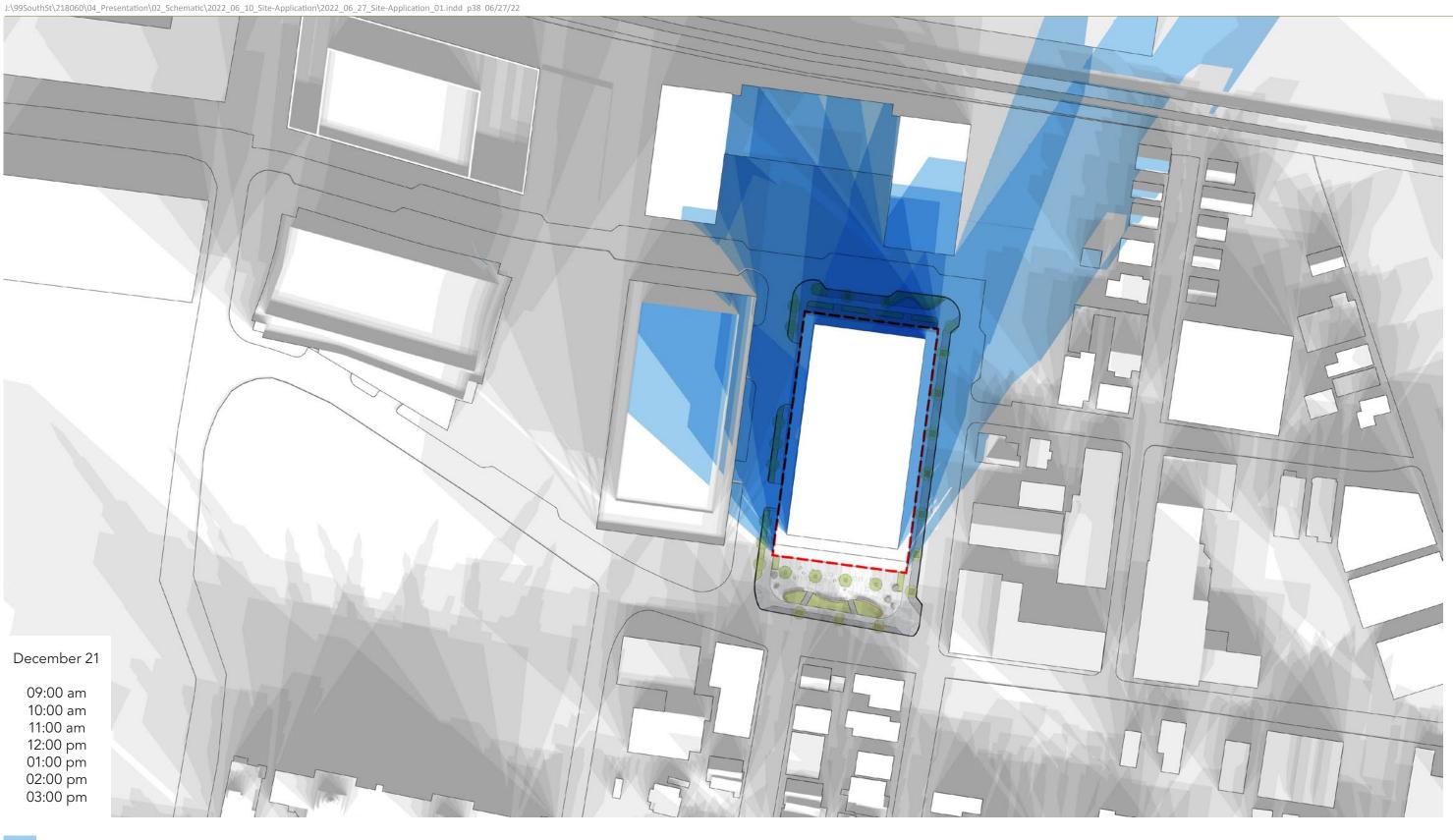
December 21, 3:00 pm



December 21, 12:00 pm

cbt

Figure B.1 Shadow Studies



NEW SHADOW

EXISTING SHADOW

--- PROPOSED NEW BUILDING

cbt

Figure B.1 Shadow Studies

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# **PEDESTRIAN WIND STUDY**

## FINAL REPORT



# 99 SOUTH STREET - BOYNTON YARDS

SOMERVILLE. MA

PEDESTRIAN WIND STUDY RWDI # 2200880 June 16, 2022

#### **SUBMITTED TO**

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### **EXECUTIVE SUMMARY**

RWDI was retained to conduct a pedestrian wind assessment for the proposed 99 South Street – Boynton Yards project in Somerville, MA. The potential wind conditions have been assessed based on wind tunnel testing of the project under the No Build, Build, and Full Build configurations. The wind tunnel data has been combined with the local wind records, and compared to the Mean Speed and Effective Gust criteria adopted by the City of Somerville. The results of the assessment are shown on site plans in Figures 1A through 2C, and the associated wind speeds are listed in Tables 1 and 2. The key findings are summarized as follows:

#### **Effective Gust**

- The effective gust criterion is shown to be met on an annual basis at most locations assessed in the No Build configuration. The exception is a solitary location between the existing buildings to the west of the project site.
- The addition of the proposed building is not anticipated to lead to the exceedance of the effective gust criterion, on an annual basis, at any additional assessed locations as compared to the No Build configuration.
- For the Full Build configuration, the effective gust criterion is anticipated to be met at all assessed locations on an annual and seasonal basis.

#### **Mean Speed**

- For the existing site, mean wind speeds are generally comfortable for the intended usage on and around the project site, except for uncomfortable wind conditions locally in the northwest corner of the existing site, and between the existing buildings to the west of the site.
- The addition of the proposed building is not anticipated to have a significant impact on wind speeds at areas outside of the project site. Wind speeds generally comfortable for the intended usage are anticipated along the sidewalks, at the main entrance, and the outdoor seating areas. Uncomfortable conditions are anticipated at a few of the building corners and are also predicted to persist from the No Build scenario between the existing building to the west of the site.
- In the Full Build configuration, the addition of the future buildings is anticipated to reduce wind speeds
  at most areas, alleviating the uncomfortable conditions occurring along the northern building corners
  of the proposed building and between the existing buildings to the west of site. Also, reduced wind
  speeds comfortable for passive usage are predicted at the outdoor seating areas on the south side of
  the proposed building. Slightly elevated wind speeds are predicted at the outdoor seating areas to the
  north of the building.



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Table 1: Mean Speed and Effective Gust Categories – AnnualTable 2: Mean Speed and Effective Gust Categories – Seasonal



## 1 INTRODUCTION

RWDI was retained to conduct a pedestrian wind assessment for the proposed 99 South Street – Boynton Yards project in Somerville, MA. This report presents the project objectives, background and approach, and discusses the results from RWDI's assessment.

#### 1.1 Project Description

The project (site shown in Image 1) is located on the north side of South Street and between Harding Street and Earle Street on the east and west sides, respectively. It consists of a 14-story lab/office building with an approximate building height of 263 ft.

#### 1.2 Objectives

The objective of the study was to assess the effect of the proposed development on local conditions in pedestrian areas on and around the study site and provide recommendations for reducing adverse effects, if needed. This quantitative assessment was based on wind speed measurements on a scale model of the project and its surroundings in one of RWDI's boundary-layer wind tunnels. These measurements were combined with the local wind records and compared to appropriate criteria for gauging wind comfort and safety in pedestrian areas. The assessment focused on critical pedestrian areas, including building entrances, public sidewalks, grade level outdoor seating areas.



Image 1: Aerial View of Site and Surroundings (Photo Courtesy of Google™ Earth)



#### 2 BACKGROUND AND APPROACH

### 2.1 Wind Tunnel Study Model

To assess the wind environment around the proposed project, a 1:300 scale model of the project site and surroundings was constructed for the wind tunnel tests of the following configurations:

A – No Build: Existing site with existing surroundings (Image 2A);

B - Build: Proposed project with existing surroundings (Image 2B); and,

C – Full Build: Proposed project with existing and future surroundings (Image 2C).

The wind tunnel model included all relevant surrounding buildings and topography within an approximately 1200 ft radius of the study site. The wind and turbulence profiles in the atmospheric boundary layer beyond the modeled area were also simulated in RWDI's wind tunnel. The wind tunnel model was instrumented with 95 specially designed wind speed sensors to measure mean and gust speeds at a full-scale height of approximately 5 ft above local grade in pedestrian areas throughout the study site. Wind speeds were measured for 36 directions in a 10-degree increment. The measurements at each sensor location were recorded in the form of ratios of local mean and gust speeds to the mean wind speed at a reference height above the model. The placement of wind measurement locations was based on our experience and understanding of the pedestrian usage for this site and was reviewed by CBT Architects and LMP.





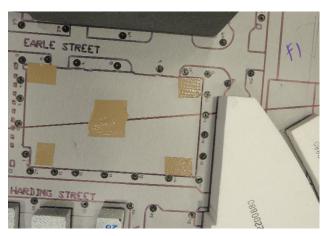
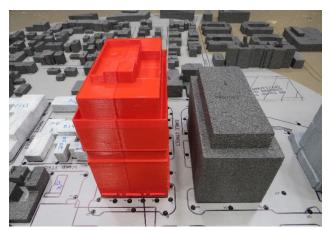




Image 2A: Wind Tunnel Study Model - No Build Configuration







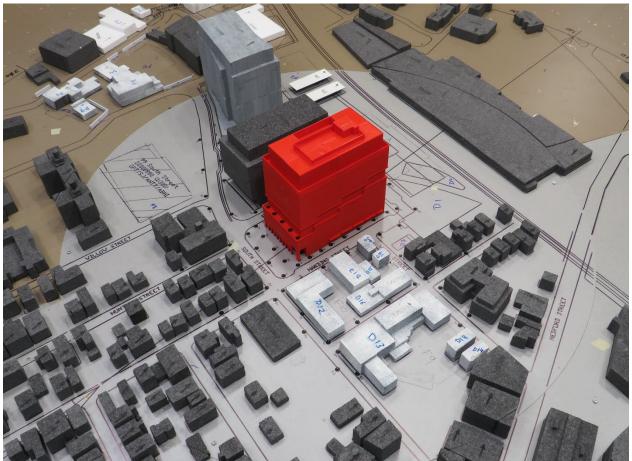


Image 2B: Wind Tunnel Study Model - Build Configuration









Image 2C: Wind Tunnel Study Model – Full Build Configuration



#### 2.2 Meteorological Data

The data from the wind tunnel tests was combined with long-term meteorological data recorded during the years 1995 through 2020 at Boston Logan International Airport to predict full scale wind conditions. The analysis was performed separately for the entire year and for each of the four seasons. Images 3 and 4 present the wind roses summarizing the annual and seasonal wind climates in the Boston area, respectively, based on the data from the airport.

On an annual basis, the most common wind directions are those between north-northwest and south-southwest. Winds from the east-northeast to the east-southeast are also relatively common. In the case of strong winds, west-northwest, northwest, west and northeast are the dominant wind directions. A similar directional distribution is seen in the seasonal wind roses as well (Image 4).

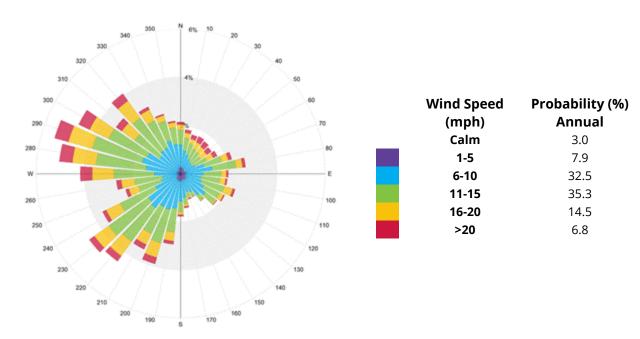


Image 3: Annual Directional distribution of winds approaching Boston Logan International Airport from 1995 through 2020



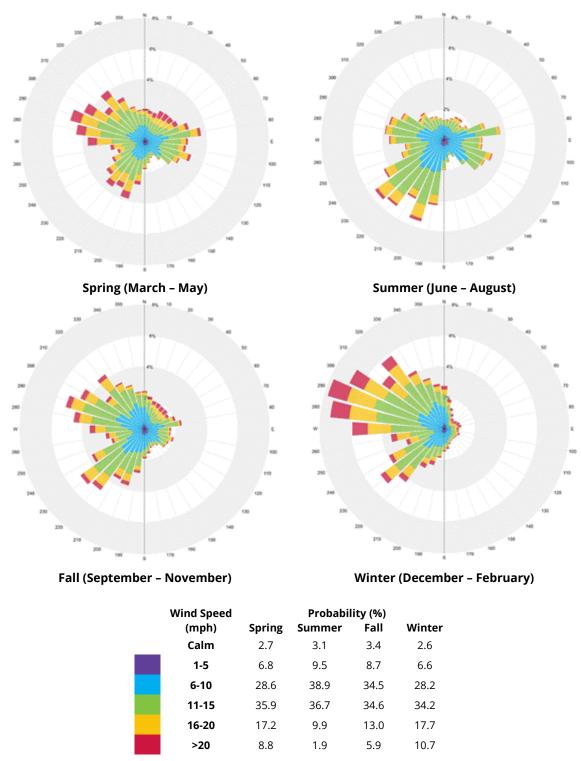


Image 3: Seasonal Directional Distribution of Winds Approaching Boston Logan International Airport from 1995 through 2020



#### 2.3 Pedestrian Wind Criteria

The City of Somerville has adopted two standards for assessing the relative wind comfort of pedestrians. First, the Somerville wind design guidance criterion states that an effective gust velocity (hourly mean wind speed +1.5 times the root-mean-square wind speed) of 31 mph should not be exceeded more than 1% of the time.

The second set of criteria is used to determine the acceptability of specific locations is based on the work of Melbourne. This set of criteria is used to determine the relative level of pedestrian wind comfort for activities such as sitting, standing, or walking. The criteria are expressed in terms of benchmarks for the 1-hour mean wind speed exceeded 1% of the time.

Wind Acceptability	Effective Gust Speed (mph)			
Acceptable	<u>&lt;</u> 31			
Unacceptable	> 31			
Comfort Category	Mean Wind Speed (mph)			
Comfortable for Sitting	< 12			
Comfortable for Standing	<u>&lt;</u> 15			
Comfortable for Walking	<u>&lt;</u> 19			

<sup>\*\*</sup>Effective gust and mean wind speeds are based on a 1% exceedance or 99 percentile wind speeds.

Note that wind speeds which do not meet the comfort criterion (i.e., wind speeds > 19 mph for more than 1% of the time) are identified as "Uncomfortable" in this assessment.

The consideration of wind in planning outdoor activity areas is important since high winds in an area tend to deter pedestrian use. For example, winds should be light or relatively light in areas where people would be sitting, such as outdoor cafes or playgrounds. For bus stops and other locations where people would be standing, somewhat higher winds can be tolerated. For frequently used sidewalks, where people are primarily walking, stronger winds are acceptable. For infrequently used areas, the wind comfort criteria can be relaxed even further. The actual effects of wind can range from pedestrian inconvenience, due to the blowing of dust and other loose material in a moderate breeze, to severe difficulty with walking due to the wind forces on the pedestrian.

This study involved state-of-the-art measurement and analysis techniques to predict wind conditions. Nevertheless, some uncertainty remains in predicting wind comfort, and this must be kept in mind. For example, the sensation of comfort among individuals can be quite variable. Variations in age, individual health, clothing, and other human factors can change a particular response of an individual. The comfort limits used in this report represent an average for the total population. Also, unforeseen changes in the project area, such as the construction or removal of buildings, can affect the conditions experienced at the site. Finally, the prediction of wind speeds is necessarily a statistical procedure. The wind speeds reported are for the frequency of occurrence stated (1% of the time). Higher wind speeds will occur but on a less frequent basis.



## 3 RESULTS AND DISCUSSION

The predicted wind conditions in terms of mean and effective gust speeds pertaining to the tested configurations are graphically depicted on site plans in Figures 1A through 2C located in the "Figures" section of this report. These conditions and the associated wind speeds are presented in Tables 1 and 2, located in the "Tables" section of this report. The following summary of pedestrian wind comfort is based on the annual winds for each configuration tested. Typically, the summer and fall winds tend to be more comfortable than the annual winds while the winter and spring winds are less comfortable than the annual winds.

The following is a detailed discussion of the suitability of the predicted wind comfort conditions for the anticipated pedestrian use of each area of interest. Wind conditions comfortable for walking are appropriate for sidewalks and walkways as pedestrians will be active and less likely to remain in one area for prolonged periods of time. Lower wind speeds conducive to sitting or standing are preferred at main entrances where pedestrians are apt to linger. Wind speeds comfortable for sitting are ideal during the summer for areas intended for passive activities, such as outdoor seating areas.

#### 3.1 No Build Configuration

The mean annual wind speeds are shown to be generally comfortable for walking or more passive use on and around the existing site, including at the assessed sidewalk areas, which is appropriate for the current intended use of the areas (Figure 1A). Winds speeds uncomfortable for walking are predicted in a localized area at the northwest corner of the site, and at a few assessed areas between the existing 101 South and 808 Windsor buildings to the west which is planned to be developed as a civic space in the future (see Locations 57, 58, 68, and 69 in Figure 1A).

The effective gust criterion was met on an annual basis for the majority of locations around the existing site with the exception of one location between the existing 101 South and 808 Windsor buildings to the west (Location 68 in Figure 2A); seasonal exceedances are also predicted in this area (see Locations 68 and 69 in Table 2).

#### 3.2 Build Configuration

The addition of the proposed building is expected to result in similar wind conditions as compared to the No Build scenario at a majority of the assessed areas far from the site; slightly increased wind activity is predicted in the immediate vicinity of the proposed building, especially near the building corners and the sidewalk along Earle Street (Figure 1B). However, apart from the building corners, sitting, standing, or walking conditions are generally predicted at the nearby and surrounding sidewalk areas, which is appropriate for the intended active pedestrian usage. Uncomfortable wind conditions occurring in the area between the existing buildings to the west of site as shown in the No Build scenario are predicted to prevail in the Build scenario (Locations 57, 58, 68, and 69 in Figure 1B).

Wind conditions comfortable for sitting are anticipated at the main entrance of the proposed building (Location 1 in Figure 1B), which is ideal for the intended usage. Wind conditions at a majority of the outdoor seating areas to the north and south of the building are predicted to be comfortable for sitting during the summer (see Locations 2-4, 12-14, 24-26 in Table 2), which is ideal for the anticipated passive usage of the area. If calmer wind speeds ideal for

## PEDESTRIAN WIND STUDY 99 SOUTH STREET - BOYNTON YARDS

RWDI #2200880 June 16, 2022



passive usage is desired in the fall or spring seasons, wind screens or planters at least 6 ft in height can be installed around the targeted seating areas.

The addition of the proposed project is not anticipated to lead to any additional assessed locations that exceed the effective gust criterion, on an annual basis, as compared to the No Build scenario. Wind speeds that exceed the criterion are predicted to occur at the same location (Location 68) as in the No Build Scenario (Figure 2B).

#### 3.3 Full Build Configuration

With the addition of future developments surrounding the site, wind conditions at the project site are predicted to continue to be comfortable for the intended usage in most areas (Figure 1C). Due to the sheltering offered by the future surrounding buildings from the prevailing winds, wind speeds are reduced in most areas around the proposed building, especially in the outdoor seating areas on the south side of the building, with conditions predicted to be comfortable for sitting on an annual basis. Also, wind speeds pertaining to uncomfortable conditions in the Build configuration are shown to reduce to walking conditions near the northern corners of the proposed building, and in the civic space between the 101 South and 808 Windsor buildings to the west. Slightly higher wind speeds are predicted locally in a few assessed areas within the proximity of the future buildings, with conditions primarily comfortable for walking or more passive use in most areas. Also, an increase in wind speeds is observed locally at the outdoor seating areas to the north of the building (Locations 12-14 in Figure 1C), with conditions comfortable for standing during the summer season (Table 2), which is when this area is expected to be used frequently. If lower wind speeds are desired at this outdoor seating space in future, tall planters/wind screens at least 6 ft high can be installed to attain a localized lower-wind zone.

With the reduction in wind speeds in most assessed areas for the Full Build configuration, the effective gust criterion is predicted to be met at all assessed locations on an annual and seasonal basis.

## 4 STATEMENT OF LIMITATIONS

#### **Design Assumptions**

In performing the pedestrian wind assessment (the "Assessment") listed above, RWDI confirms that the assessment was performed by RWDI in accordance with generally accepted professional standards at the time when the Assessment was performed and in the location of the Project. No other representations, warranties, or guarantees are made with respect to the accuracy or completeness of the information, findings, recommendations, or conclusions contained in this Report. This report is not a legal opinion regarding compliance with applicable laws.

The findings and recommendations set out in this report are based on the following information disclosed to RWDI:

 drawings and information listed below were received from CBT Architects and used to construct the scale model of the proposed 99 South Street – Boynton Yards project ("Project Data")

## PEDESTRIAN WIND STUDY 99 SOUTH STREET - BOYNTON YARDS

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File Name	File Type	Date Received (dd/mm/yyyy)
2022_04_25_cbt_218060_99SouthSt_Central_2021	Revit	24/06/2022
2022_05_05_RWDI_Pedestrian Wind & Solar Reflectance Study_background	PDF	05/05/2022
2022.05.11 Boynton Yards Phasing Plans	PDF	12/05/2022
2021_05_17_updates-from-UDC_01	PDF	17/05/2022
2022_05_19_Site	SketchUp	19/05/2022

The recommendations and conclusions are based on the assumption that the Project Data and Climate Data are accurate and complete. RWDI assumes no responsibility for any inaccuracy or deficiency in information it has received from others. In addition, the recommendations and conclusions in this report are partially based on historical data and can be affected by a number of external factors, including but not limited to Project design, quality of materials and construction, site conditions, meteorological events, and climate change. As such, the conclusions and recommendations contained in this report do not list every possible outcome.

The opinions in this report can only be relied up on to the extent that the Project Data and Project Specific Conditions have not changed. Any change in the Project Data or Project Specific Conditions not reflected in this report can impact and/or alter the recommendations and conclusions in this report. Therefore, it is incumbent upon the Client and/or any other third party reviewing the recommendations and conclusions in this report to contact RWDI in the event of any change in the Project Data and Project Specific Conditions in order to determine whether any such change(s) may impact the assumptions upon which the recommendations and conclusions were made.

#### Limitations

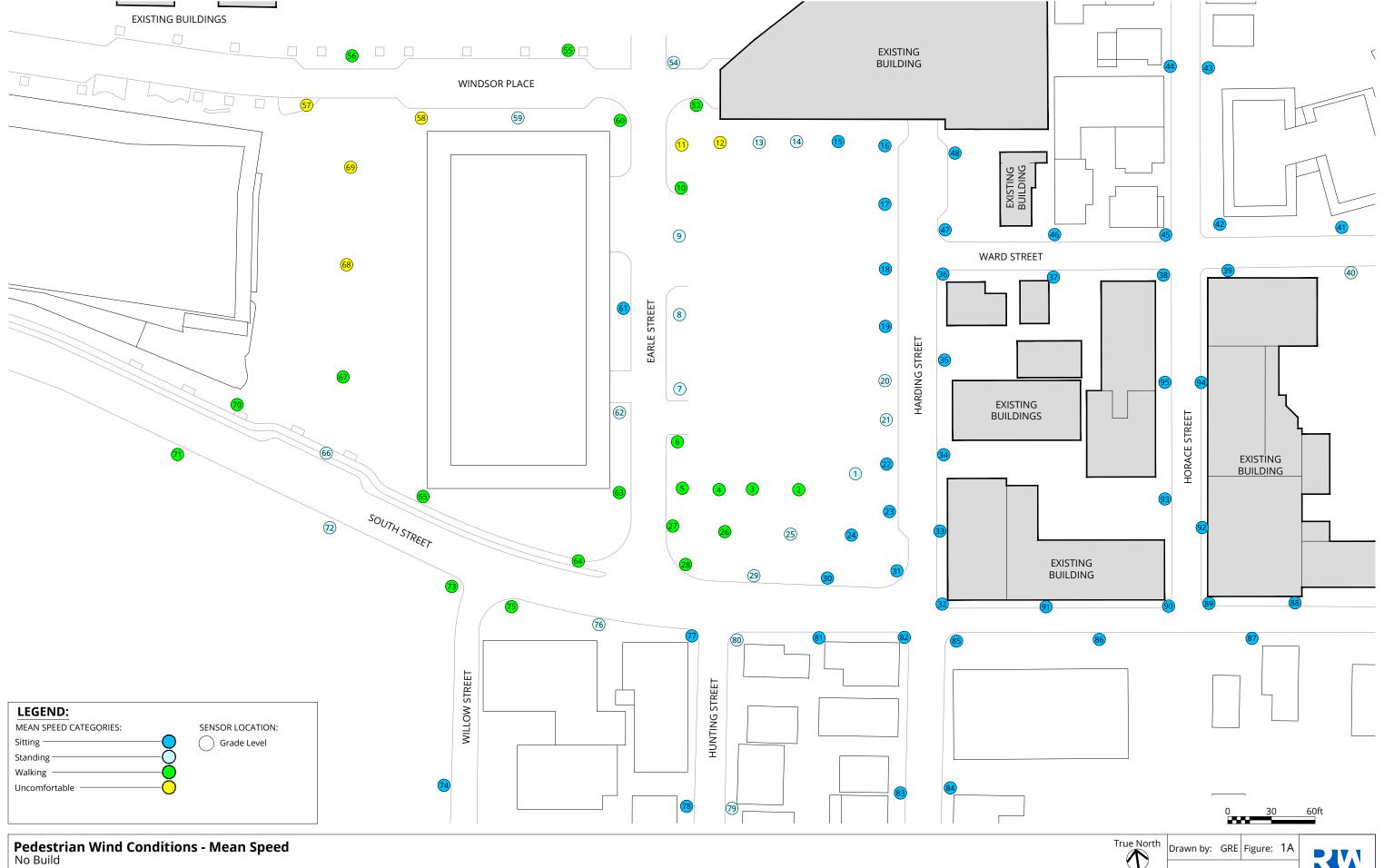
This report entitled 99 South Street – Boynton Yards on 9<sup>th</sup> June, 2022 was prepared by Rowan Williams Davies & Irwin, Inc. ("RWDI") for CBT Architects ("Client"). The findings and conclusions presented in this report have been prepared for the Client and are specific to the project described herein ("Project"). The conclusions and recommendations contained in this report are based on the information available to RWDI when this report was prepared.

The conclusions and recommendations contained in this report have also been made for the specific purpose(s) set out herein. Should the Client or any other third party utilize the report and/or implement the conclusions and recommendations contained therein for any other purpose or project without the involvement of RWDI, the Client or such third party assumes any and all risk of any and all consequences arising from such use and RWDI accepts no responsibility for any liability, loss, or damage of any kind suffered by Client or any other third party arising therefrom.

Finally, it is imperative that the Client and/or any party relying on the conclusions and recommendations in this report carefully review the stated assumptions contained herein and to understand the different factors which may impact the conclusions and recommendations provided.



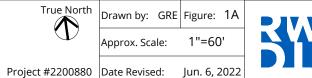
# **FIGURES**

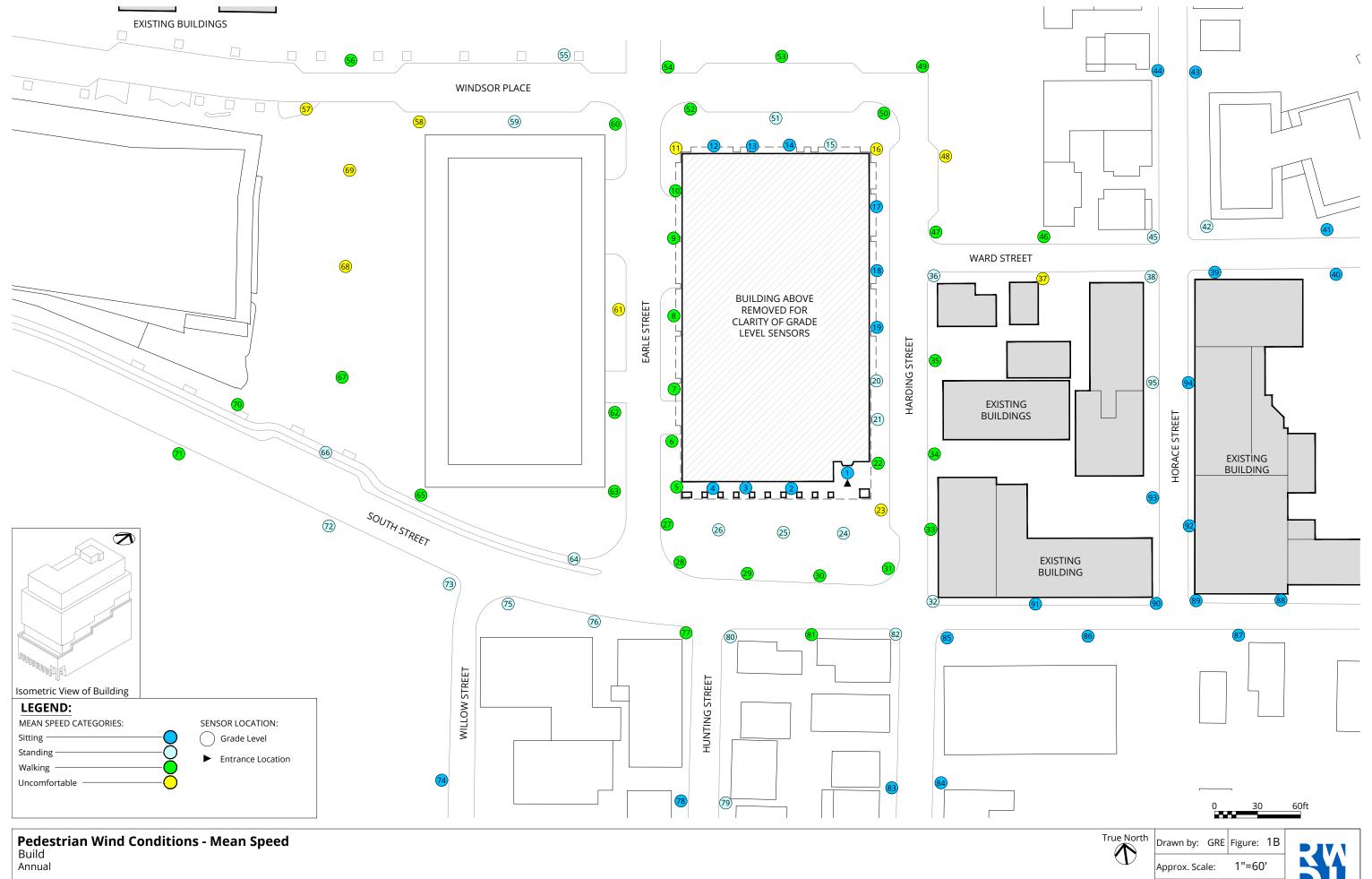


Annual

99 South Street - Boynton Yards - Somerville, MA

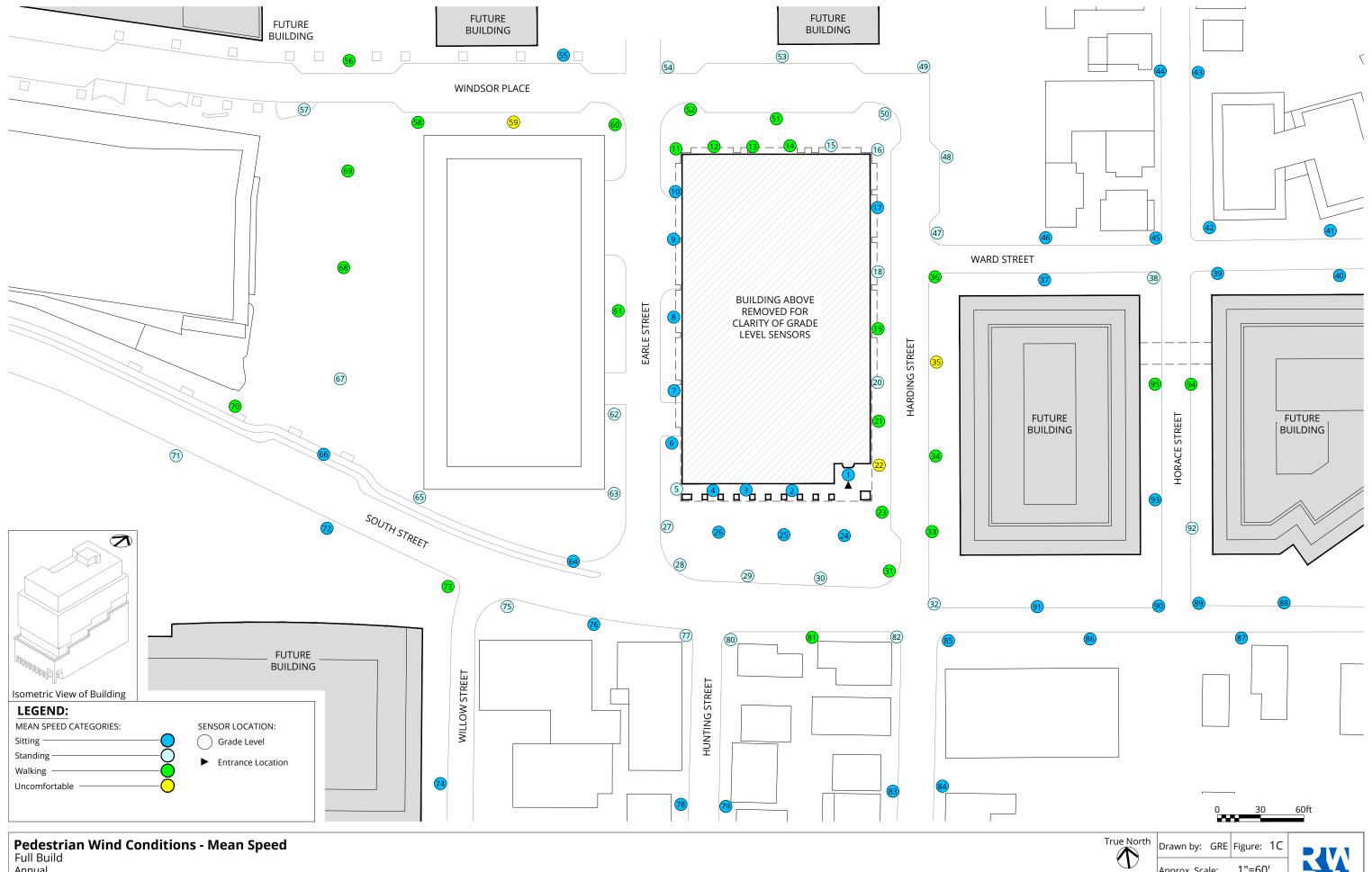
True North Approx. Scale:





Project #2200880 | Date Revised: | Jun. 6, 2022

99 South Street - Boynton Yards - Somerville, MA

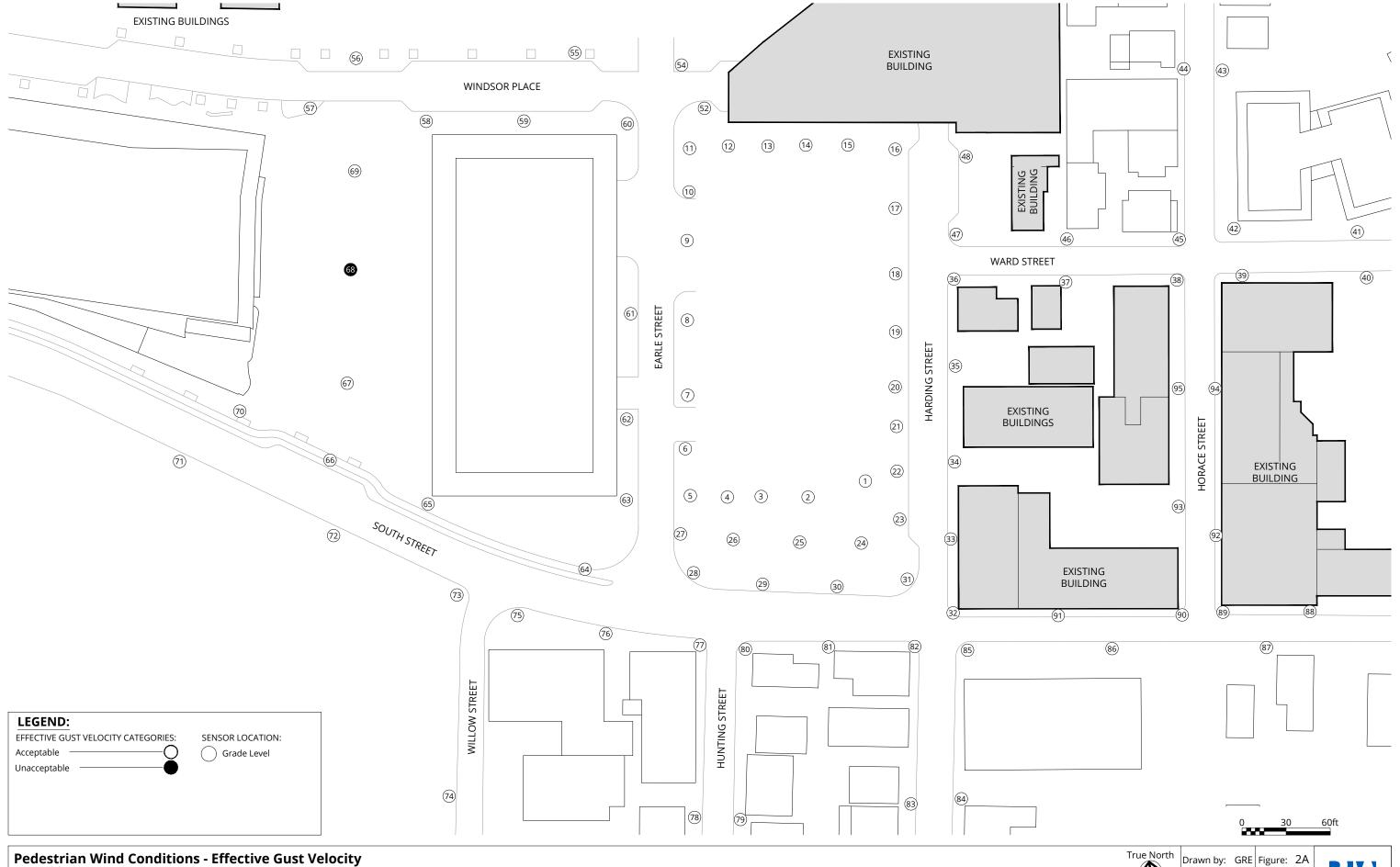


**Pedestrian Wind Conditions - Mean Speed** Full Build Annual

99 South Street - Boynton Yards - Somerville, MA

Approx. Scale: 1"=60' Project #2200880 | Date Revised: | Jun. 6, 2022





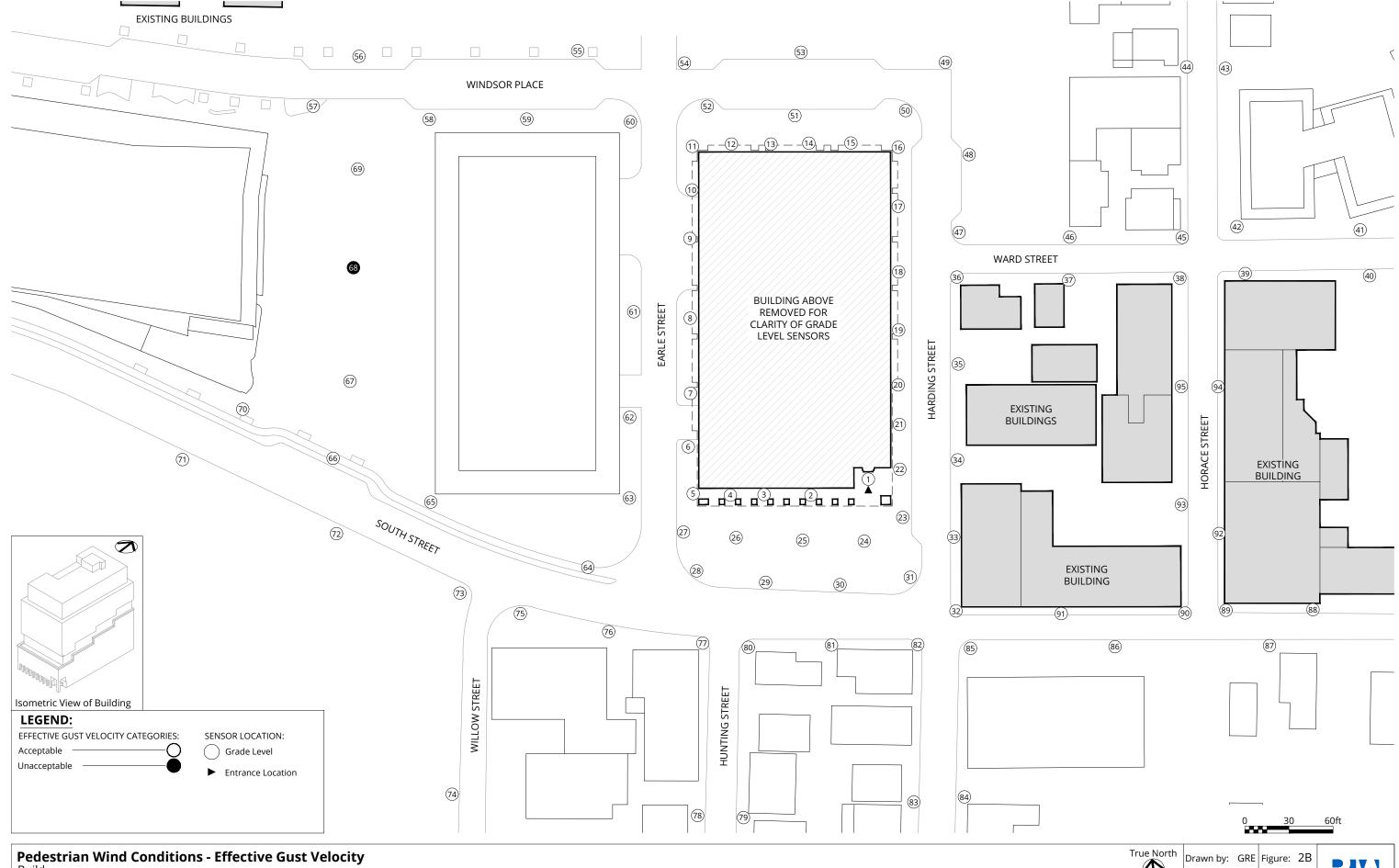
No Build Annual

99 South Street - Boynton Yards - Somerville, MA

True North Approx. Scale: Project #2200880 | Date Revised: Jun. 6, 2022



1"=60'

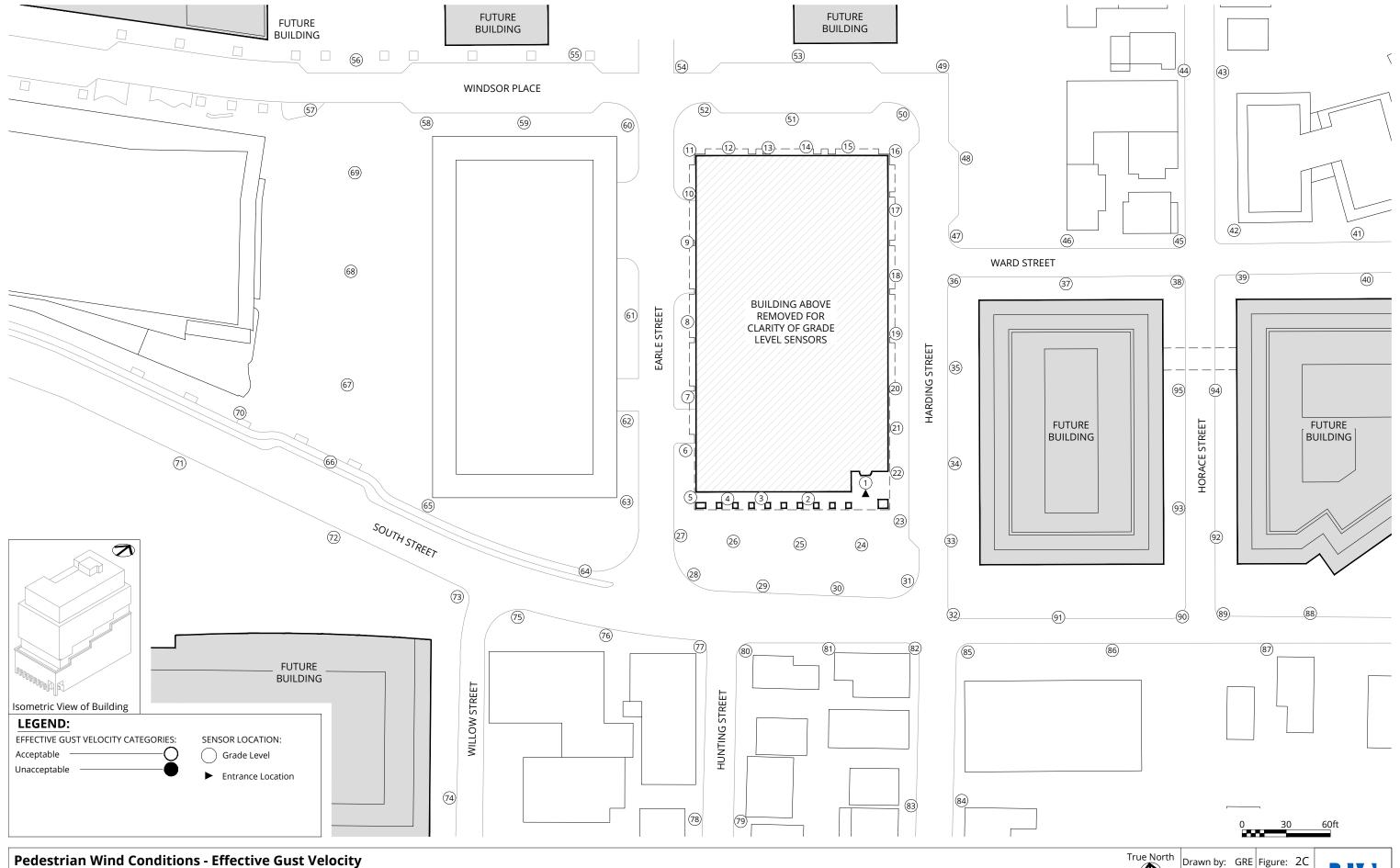


Build

Annual 99 South Street - Boynton Yards - Somerville, MA

True North Approx. Scale: 1"=60' Project #2200880 | Date Revised: | Jun. 6, 2022





**Pedestrian Wind Conditions - Effective Gust Velocity** Full Build

Annual

99 South Street - Boynton Yards - Somerville, MA

True North Approx. Scale: Project #2200880 | Date Revised: Jun. 6, 2022



1"=60'



# **TABLES**



**Table 1: Mean Speed and Effective Gust Categories - Annual** 

			Mean Wind Speed		Effective Gust Wind Speed			
Location	Configuration	Season	Speed	%		Speed	%	
			(mph)	Change	Rating	(mph)	Change	Rating
1	Α	Annual	13		Standing	20		Acceptable
	В	Annual	11	-15%	Sitting	17	-15%	Acceptable
	С	Annual	12		Sitting	17	-15%	Acceptable
2	A	Annual	17	2001	Walking	23	470/	Acceptable
	В	Annual	12	-29%	Sitting	19	-17%	Acceptable
	С	Annual	9	-47%	Sitting	14	-39%	Acceptable
3	A	Annual	18	200/	Walking	25	220/	Acceptable
	В	Annual	11	-39%	Sitting	17	-32%	Acceptable
	С	Annual	9	-50%	Sitting	13	-48%	Acceptable
4	A	Annual	19		Walking	26		Acceptable
	В	Annual	12	-37%	Sitting	18	-31%	Acceptable
	С	Annual	9	-53%	Sitting	13	-50%	Acceptable
5	A	Annual	19		Walking	26		Acceptable
	В	Annual	18		Walking	25		Acceptable
	С	Annual	15	-21%	Standing	21	-19%	Acceptable
6	Α	Annual	19		Walking	26		Acceptable
	В	Annual	16	-16%	Walking	22	-15%	Acceptable
	С	Annual	10	-47%	Sitting	16	-38%	Acceptable
7	A	Annual	14		Standing	21		Acceptable
	В	Annual	18	29%	Walking	24	14%	Acceptable
	С	Annual	11	-21%	Sitting	16	-24%	Acceptable
8	A	Annual	13		Standing	20		Acceptable
	В	Annual	16	23%	Walking	23	15%	Acceptable
	С	Annual	11	-15%	Sitting	16	-20%	Acceptable
9	Α	Annual	15		Standing	23		Acceptable
	В	Annual	18	20%	Walking	27	17%	Acceptable
	С	Annual	12	-20%	Sitting	17	-26%	Acceptable
10	A	Annual	18		Walking	26		Acceptable
	В	Annual	18		Walking	26		Acceptable
	С	Annual	12	-33%	Sitting	18	-31%	Acceptable
11	A	Annual	20		Uncomfortable	26		Acceptable
	В	Annual	20		Uncomfortable	27		Acceptable
	С	Annual	18		Walking	25		Acceptable
12	A	Annual	20	4007	Uncomfortable	26	0701	Acceptable
	В	Annual	12	-40%	Sitting	19	-27%	Acceptable
	С	Annual	16	-20%	Walking	23	-12%	Acceptable
13	A	Annual	13		Standing	21		Acceptable
	В	Annual	12		Sitting	19		Acceptable
	С	Annual	16	23%	Walking	23		Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ctive Gus	st Wind Speed
Location	Configuration	Season	Speed	%		Speed	%	
			(mph)	Change	Rating	(mph)	Change	Rating
14	Α	Annual	13		Standing	19		Acceptable
	В	Annual	12		Sitting	19		Acceptable
	С	Annual	16	23%	Walking	23	21%	Acceptable
15	A	Annual	11		Sitting	17		Acceptable
	В	Annual	14	27%	Standing	20	18%	Acceptable
	С	Annual	13	18%	Standing	19	12%	Acceptable
16	Α	Annual	9		Sitting	15		Acceptable
	В	Annual	20	122%	Uncomfortable	27	80%	Acceptable
	С	Annual	14	56%	Standing	20	33%	Acceptable
17	A	Annual	10		Sitting	16		Acceptable
	В	Annual	11	2621	Sitting	17	4007	Acceptable
	С	Annual	12	20%	Sitting	18	12%	Acceptable
18	A	Annual	12		Sitting	19		Acceptable
	В	Annual	11		Sitting	16	-16%	Acceptable
	С	Annual	13		Standing	18		Acceptable
19	A	Annual	12		Sitting	19		Acceptable
	В	Annual	12		Sitting	18		Acceptable
	С	Annual	16	33%	Walking	21	11%	Acceptable
20	A	Annual	14		Standing	20		Acceptable
	В	Annual	13		Standing	19		Acceptable
	С	Annual	15		Standing	20		Acceptable
21	Α	Annual	13		Standing	20		Acceptable
	В	Annual	15	15%	Standing	21		Acceptable
	С	Annual	16	23%	Walking	21		Acceptable
22	Α	Annual	12		Sitting	18		Acceptable
	В	Annual	19	58%	Walking	25	39%	Acceptable
	С	Annual	20	67%	Uncomfortable	27	50%	Acceptable
23	Α	Annual	11		Sitting	17		Acceptable
	В	Annual	20	82%	Uncomfortable	27	59%	Acceptable
	С	Annual	19	73%	Walking	24	41%	Acceptable
24	A	Annual	11		Sitting	18		Acceptable
	В	Annual	15	36%	Standing	22	22%	Acceptable
	С	Annual	12		Sitting	19		Acceptable
25	A	Annual	14		Standing	21		Acceptable
	В	Annual	13	200/	Standing	20	2 40/	Acceptable
	С	Annual	9	-36%	Sitting	16	-24%	Acceptable
26	А	Annual	16		Walking	23		Acceptable
	В	Annual	13	-19%	Standing	22		Acceptable
	С	Annual	10	-38%	Sitting	17	-26%	Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ctive Gus	st Wind Speed
Location	Configuration	Season	Speed	%		Speed	%	<b>.</b>
			(mph)	Change	Rating	(mph)	Change	Rating
27	Α	Annual	18		Walking	25		Acceptable
	В	Annual	18		Walking	25		Acceptable
	С	Annual	14	-22%	Standing	21	-16%	Acceptable
28	A	Annual	17		Walking	24		Acceptable
	В	Annual	17		Walking	24		Acceptable
	С	Annual	14	-18%	Standing	21	-12%	Acceptable
29	A	Annual	14		Standing	20		Acceptable
	В	Annual	18	29%	Walking	25	25%	Acceptable
	С	Annual	14		Standing	21		Acceptable
30	A	Annual	11		Sitting	17		Acceptable
	В	Annual	18	64%	Walking	26	53%	Acceptable
	С	Annual	15	36%	Standing	22	29%	Acceptable
31	A	Annual	9		Sitting	15		Acceptable
	В	Annual	19	111%	Walking	25	67%	Acceptable
	С	Annual	17	89%	Walking	24	60%	Acceptable
32	A	Annual	10		Sitting	16		Acceptable
	В	Annual	15	50%	Standing	22	38%	Acceptable
	С	Annual	14	40%	Standing	21	31%	Acceptable
33	A	Annual	7		Sitting	13		Acceptable
	В	Annual	17	143%	Walking	22	69%	Acceptable
	С	Annual	16	129%	Walking	22	69%	Acceptable
34	A	Annual	9		Sitting	14		Acceptable
	В	Annual	17	89%	Walking	23	64%	Acceptable
	С	Annual	19	111%	Walking	25	79%	Acceptable
35	Α	Annual	12		Sitting	18		Acceptable
	В	Annual	17	42%	Walking	24	33%	Acceptable
	С	Annual	20	67%	Uncomfortable	27	50%	Acceptable
36	Α	Annual	12		Sitting	19		Acceptable
	В	Annual	15	25%	Standing	21	11%	Acceptable
	С	Annual	17	42%	Walking	24	26%	Acceptable
37	Α	Annual	9		Sitting	15		Acceptable
	В	Annual	20	122%	Uncomfortable	27	80%	Acceptable
	С	Annual	8	-11%	Sitting	14		Acceptable
38	A	Annual	8		Sitting	13		Acceptable
	В	Annual	14	75%	Standing	19	46%	Acceptable
	С	Annual	15	88%	Standing	20	54%	Acceptable
39	A	Annual	9		Sitting	14		Acceptable
	В	Annual	10	11%	Sitting	15		Acceptable
	С	Annual	11	22%	Sitting	17	21%	Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ctive Gu	st Wind Speed
Location	Configuration	Season	Speed	%		Speed	%	- ··
			(mph)	Change	Rating	(mph)	Change	Rating
40	Α	Annual	13		Standing	18		Acceptable
	В	Annual	12		Sitting	17		Acceptable
	С	Annual	8	-38%	Sitting	13	-28%	Acceptable
41	Α	Annual	9		Sitting	14		Acceptable
	В	Annual	9		Sitting	14		Acceptable
	С	Annual	8	-11%	Sitting	13		Acceptable
42	A	Annual	9		Sitting	14		Acceptable
	В	Annual	13	44%	Standing	19	36%	Acceptable
	С	Annual	8	-11%	Sitting	13		Acceptable
43	A	Annual	11		Sitting	17		Acceptable
	В	Annual	10	0=01	Sitting	16	0.407	Acceptable
	С	Annual	8	-27%	Sitting	13	-24%	Acceptable
44	Α	Annual	9		Sitting	14		Acceptable
	В	Annual	7	-22%	Sitting	12	-14%	Acceptable
	С	Annual	6	-33%	Sitting	10	-29%	Acceptable
45	A	Annual	8		Sitting	13		Acceptable
	В	Annual	15	88%	Standing	21	62%	Acceptable
	С	Annual	9	12%	Sitting	14		Acceptable
46	A	Annual	8		Sitting	13		Acceptable
	В	Annual	19	138%	Walking	26	100%	Acceptable
	С	Annual	9	12%	Sitting	15	15%	Acceptable
47	A	Annual	11		Sitting	17		Acceptable
	В	Annual	16	45%	Walking	24	41%	Acceptable
	С	Annual	15	36%	Standing	22	29%	Acceptable
48	A	Annual	8		Sitting	13		Acceptable
	В	Annual	20	150%	Uncomfortable	26	100%	Acceptable
	С	Annual	13	62%	Standing	20	54%	Acceptable
49	Α	Annual	-		-	-		-
	В	Annual	17		Walking	25		Acceptable
	С	Annual	15		Standing	22		Acceptable
50	A	Annual	-			i :		ī
	В	Annual	19		Walking	26		Acceptable
	С	Annual	14		Standing	21		Acceptable
51	A	Annual	-		-	-		-
	В	Annual	14		Standing	22		Acceptable
	С	Annual	17		Walking	24		Acceptable
52	Α	Annual	16		Walking	22		Acceptable
	В	Annual	18	12%	Walking	26	18%	Acceptable
	С	Annual	16		Walking	23		Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ctive Gus	st Wind Speed
Location	Configuration	Season	Speed	%		Speed	%	
			(mph)	Change	Rating	· (mph)	Change	Rating
53	Α	Annual	-		-	-		-
	В	Annual	17		Walking	24		Acceptable
	С	Annual	14		Standing	21		Acceptable
54	A	Annual	13		Standing	19		Acceptable
	В	Annual	17	31%	Walking	25	32%	Acceptable
	С	Annual	15	15%	Standing	22	16%	Acceptable
55	A	Annual	16		Walking	23		Acceptable
	В	Annual	15		Standing	22		Acceptable
	С	Annual	12	-25%	Sitting	19	-17%	Acceptable
56	A	Annual	19		Walking	26		Acceptable
	В	Annual	19		Walking	26		Acceptable
	С	Annual	18		Walking	27		Acceptable
57	A	Annual	20		Uncomfortable	28		Acceptable
	В	Annual	20		Uncomfortable	27		Acceptable
	С	Annual	15	-25%	Standing	23	-18%	Acceptable
58	A	Annual	22		Uncomfortable	29		Acceptable
	В	Annual	22		Uncomfortable	29		Acceptable
	С	Annual	17	-23%	Walking	25	-14%	Acceptable
59	Α	Annual	14		Standing	21		Acceptable
	В	Annual	14	= /	Standing	21	2221	Acceptable
	С	Annual	21	50%	Uncomfortable	28	33%	Acceptable
60	Α	Annual	19		Walking	26		Acceptable
	В	Annual	19		Walking	27		Acceptable
	С	Annual	16	-16%	Walking	24		Acceptable
61	A	Annual	12		Sitting	17		Acceptable
	В	Annual	22	83%	Uncomfortable	29	71%	Acceptable
	С	Annual	18	50%	Walking	24	41%	Acceptable
62	A	Annual	13		Standing	19		Acceptable
	В	Annual	17	31%	Walking	24	26%	Acceptable
	С	Annual	14		Standing	21	11%	Acceptable
63	Α	Annual	19		Walking	26		Acceptable
	В	Annual	17	-11%	Walking	25		Acceptable
	С	Annual	14	-26%	Standing	21	-19%	Acceptable
64	A	Annual	19		Walking	26		Acceptable
	В	Annual	13	-32%	Standing	21	-19%	Acceptable
	С	Annual	12	-37%	Sitting	19	-27%	Acceptable
65	A	Annual	18		Walking	26		Acceptable
	В	Annual	16	-11%	Walking	25		Acceptable
	С	Annual	15	-17%	Standing	21	-19%	Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ctive Gu	st Wind Speed
Location	Configuration	Season	Speed	%		Speed	%	
			(mph)	Change	Rating	(mph)	Change	Rating
66	Α	Annual	15		Standing	23		Acceptable
	В	Annual	14		Standing	23		Acceptable
	С	Annual	11	-27%	Sitting	18	-22%	Acceptable
67	A	Annual	17		Walking	26		Acceptable
	В	Annual	16		Walking	25		Acceptable
	С	Annual	13	-24%	Standing	21	-19%	Acceptable
68	A	Annual	25		Uncomfortable	33		Unacceptable
	В	Annual	25	220/	Uncomfortable	33	270/	Unacceptable
	С	Annual	17	-32%	Walking	24	-27%	Acceptable
69	A	Annual	24		Uncomfortable	31		Acceptable
	В	Annual	24	0=0/	Uncomfortable	31	4.007	Acceptable
	С	Annual	18	-25%	Walking	25	-19%	Acceptable
70	A	Annual	19		Walking	27		Acceptable
	В	Annual	18		Walking	26		Acceptable
	С	Annual	18		Walking	24	-11%	Acceptable
71	A	Annual	16		Walking	25		Acceptable
	В	Annual	16	400/	Walking	24		Acceptable
	С	Annual	14	-12%	Standing	20	-20%	Acceptable
72	A	Annual	15		Standing	23		Acceptable
	В	Annual	14		Standing	23		Acceptable
	С	Annual	12	-20%	Sitting	19	-17%	Acceptable
73	Α	Annual	16		Walking	23		Acceptable
	В	Annual	15		Standing	22		Acceptable
	С	Annual	16		Walking	23		Acceptable
74	A	Annual	11		Sitting	18		Acceptable
	В	Annual	11	270/	Sitting	17	220/	Acceptable
	С	Annual	8	-27%	Sitting	14	-22%	Acceptable
75	A	Annual	17		Walking	24		Acceptable
	В	Annual	14	-18%	Standing	21	-12%	Acceptable
	С	Annual	14	-18%	Standing	20	-17%	Acceptable
76	A	Annual	15		Standing	21		Acceptable
	В	Annual	14		Standing	21		Acceptable
	С	Annual	11	-27%	Sitting	17	-19%	Acceptable
77	A	Annual	12		Sitting	19		Acceptable
	В	Annual	16	33%	Walking	24	26%	Acceptable
	С	Annual	13		Standing	19		Acceptable
78	A	Annual	10		Sitting	15		Acceptable
	В	Annual	9		Sitting	15		Acceptable
	С	Annual	8	-20%	Sitting	12	-20%	Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ective Gus	st Wind Speed
Location	Configuration	Season	Speed	%		Speed	%	<b>.</b>
			(mph)	Change	Rating	(mph)	Change	Rating
79	Α	Annual	13		Standing	19		Acceptable
	В	Annual	13		Standing	19		Acceptable
	С	Annual	11	-15%	Sitting	16	-16%	Acceptable
80	A	Annual	13		Standing	18		Acceptable
	В	Annual	15	15%	Standing	22	22%	Acceptable
	С	Annual	14		Standing	20	11%	Acceptable
81	A	Annual	9		Sitting	14		Acceptable
	В	Annual	18	100%	Walking	25	79%	Acceptable
	С	Annual	16	78%	Walking	23	64%	Acceptable
82	A	Annual	11		Sitting	17		Acceptable
	В	Annual	15	36%	Standing	23	35%	Acceptable
	С	Annual	14	27%	Standing	20	18%	Acceptable
83	Α	Annual	7		Sitting	11		Acceptable
	В	Annual	10	43%	Sitting	15	36%	Acceptable
	С	Annual	8	14%	Sitting	12		Acceptable
84	Α	Annual	11		Sitting	15		Acceptable
	В	Annual	10		Sitting	15		Acceptable
	С	Annual	8	-27%	Sitting	13	-13%	Acceptable
85	Α	Annual	8		Sitting	13		Acceptable
	В	Annual	11	38%	Sitting	17	31%	Acceptable
	С	Annual	10	25%	Sitting	16	23%	Acceptable
86	Α	Annual	9		Sitting	15		Acceptable
	В	Annual	10	11%	Sitting	15		Acceptable
	С	Annual	10	11%	Sitting	17	13%	Acceptable
87	А	Annual	8		Sitting	14		Acceptable
	В	Annual	7	-12%	Sitting	13		Acceptable
	С	Annual	9	12%	Sitting	15		Acceptable
88	А	Annual	7		Sitting	13		Acceptable
	В	Annual	8	14%	Sitting	14		Acceptable
	С	Annual	12	71%	Sitting	19	46%	Acceptable
89	A	Annual	8		Sitting	13		Acceptable
	В	Annual	7	-12%	Sitting	12	240/	Acceptable
	С	Annual	10	25%	Sitting	17	31%	Acceptable
90	A	Annual	8	2001	Sitting	14	4 404	Acceptable
	В	Annual	11	38%	Sitting	16	14%	Acceptable
	С	Annual	11	38%	Sitting	18	29%	Acceptable
91	A	Annual	6		Sitting	10		Acceptable
	В	Annual	7	17%	Sitting	12	20%	Acceptable
	С	Annual	10	67%	Sitting	16	60%	Acceptable

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**Table 1: Mean Speed and Effective Gust Categories - Annual** 

				Mean W	/ind Speed	Effe	ctive Gus	st Wind Speed
Location	Configuration	Season	Speed (mph)		Rating	Speed (mph)	% Change	Rating
92	A B C	Annual Annual Annual	7 8 15	14% 114%	Sitting Sitting Standing	13 12 20	54%	Acceptable Acceptable Acceptable
93	A B C	Annual Annual Annual	9 12 11	33% 22%	Sitting Sitting Sitting	16 18 16	12%	Acceptable Acceptable Acceptable
94	A B C	Annual Annual Annual	9 12 16	33% 78%	Sitting Sitting Walking	14 17 22	21% 57%	Acceptable Acceptable Acceptable
95	A B C	Annual Annual Annual	9 13 16	44% 78%	Sitting Standing Walking	14 17 22	21% 57%	Acceptable Acceptable Acceptable

Configurations	М	ean Wind Criteria Speed (mph)	Effective Gust Criteria (mph)
(A) No Build	<u>≤</u> 12	Comfortable for Sitting	≤31 Acceptable
Existing site and surroundings	13 - 15	Comfortable for Standing	> 31 Unacceptable
(B) Build	16 - 19	Comfortable for Walking	
Proposed project with existing surroundings	>19	Uncomfortable for Walking	
(C) Full Build			
Proposed project with future surroundings			
Maria			

#### Notes

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<sup>1)</sup> Wind Speeds are for a 1% probability of exceedance

<sup>2) %</sup> Change is based on comparison with Configuration A

<sup>3) %</sup> changes less than 10% are excluded



**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		M	ean Wind S	peed (m	oh)	Effect	ive Gust Wi	nd Speed	l (mph)
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
1	A	14	11	13	14	21	17	19	21
	B	12	10	11	11	18	15	16	17
	C	12	11	11	12	18	16	17	17
2	A	17	15	16	18	24	20	23	25
	B	13	11	12	13	21	17	18	20
	C	9	8	9	9	14	12	14	15
3	A	19	16	18	19	26	22	25	26
	B	11	10	11	11	17	15	17	18
	C	9	8	9	9	14	12	13	14
4	A	20	17	19	20	27	23	26	28
	B	12	11	12	13	19	17	18	20
	C	10	8	9	9	14	12	13	14
5	A	20	17	19	20	27	23	26	28
	B	18	14	17	20	26	19	24	28
	C	16	13	15	16	22	17	20	22
6	A	20	17	19	20	27	23	26	27
	B	16	14	15	17	23	19	22	24
	C	11	8	10	11	17	13	16	17
7	A	15	11	14	15	22	18	21	22
	B	18	16	18	19	25	23	24	26
	C	12	9	10	11	17	13	16	16
8	A	15	10	13	14	22	16	21	22
	B	17	13	16	17	25	19	23	24
	C	12	10	11	11	18	14	16	17
9	A	16	11	15	15	24	17	23	24
	B	19	14	18	20	28	21	26	29
	C	13	10	11	12	18	14	17	18
10	A	19	14	18	19	27	20	26	28
	B	18	14	17	19	27	20	25	28
	C	13	10	12	12	20	15	18	19
11	A	21	15	20	22	28	21	26	28
	B	21	16	20	22	29	21	27	30
	C	20	15	18	19	27	20	25	26
12	A	20	15	19	21	27	20	25	28
	B	13	10	12	13	20	15	18	20
	C	18	13	16	17	25	18	23	24
13	A	14	11	13	14	22	17	20	22
	B	13	9	12	14	20	15	19	21
	C	18	13	16	17	25	18	23	23

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		M	ean Wind S	peed (m	oh)	Effect	ive Gust W	ind Speed	d (mph)
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
14	A	13	11	12	13	20	17	19	20
	B	13	9	12	13	20	15	18	21
	C	18	13	16	17	25	18	23	24
15	A	11	10	11	12	18	16	17	18
	B	14	10	13	15	21	15	19	22
	C	15	11	13	14	21	15	19	20
16	A	9	8	9	10	15	13	15	16
	B	21	17	19	22	28	22	26	29
	C	15	12	13	14	21	18	19	21
17	A	11	8	10	11	17	13	16	17
	B	12	9	11	12	18	14	17	18
	C	13	9	12	12	19	14	18	19
18	A	13	11	12	13	20	16	19	20
	B	11	8	11	11	17	12	16	18
	C	15	10	14	13	20	14	19	19
19	A	13	11	12	13	20	16	18	20
	B	14	10	13	13	20	14	18	19
	C	19	13	17	16	23	16	21	21
20	A	14	13	14	15	21	18	20	21
	B	15	10	14	14	21	14	19	20
	C	17	12	16	16	22	15	20	20
21	A	14	12	13	14	21	17	19	21
	B	17	12	16	16	23	16	21	22
	C	18	13	17	17	23	16	21	22
22	A	13	10	12	13	19	15	18	19
	B	21	15	19	20	27	20	25	27
	C	21	17	20	21	28	23	27	28
23	A	11	9	10	11	18	14	16	18
	B	22	17	20	22	28	22	26	28
	C	20	15	18	20	26	20	24	26
24	A	12	10	11	12	19	15	18	19
	B	16	14	15	16	23	19	21	23
	C	13	11	12	13	20	17	18	20
25	A	15	12	14	15	22	18	21	22
	B	13	12	13	14	20	18	19	21
	C	10	8	9	10	17	13	15	17
26	A	17	14	16	18	24	20	23	25
	B	14	11	13	15	22	17	21	24
	C	11	8	10	11	18	14	16	18

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		M	lean Wind S	peed (m	Effect	ive Gust W	ind Speed	l (mph)	
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
27	A	19	16	18	19	26	21	25	27
	B	18	13	17	19	25	19	24	27
	C	15	12	14	15	22	17	21	22
28	A	17	14	17	18	24	20	23	26
	B	18	13	16	19	24	19	23	26
	C	15	12	14	15	22	17	20	22
29	A	14	11	13	15	21	16	19	21
	B	18	14	17	19	26	20	24	28
	C	15	12	13	15	23	18	21	23
30	A	12	8	11	11	18	14	17	18
	B	19	15	17	20	27	21	25	28
	C	16	13	14	16	23	19	21	24
31	A	10	7	9	10	16	11	15	16
	B	21	15	19	20	27	21	25	27
	C	19	14	17	18	26	19	24	25
32	A	11	8	10	10	17	12	16	17
	B	16	12	14	16	23	19	22	24
	C	15	12	14	15	23	18	21	23
33	A	8	6	7	8	13	10	13	14
	B	18	14	16	18	24	18	22	24
	C	17	13	16	17	24	18	22	24
34	A	9	7	9	9	15	12	14	15
	B	18	15	17	18	24	19	22	24
	C	20	17	19	20	26	22	25	26
35	A	12	11	12	12	18	16	18	19
	B	18	15	17	18	26	22	24	25
	C	21	18	20	21	29	24	27	28
36	A	12	11	12	12	19	18	18	20
	B	16	11	15	16	23	17	22	23
	C	18	15	17	18	25	21	24	25
37	A	10	7	9	10	16	12	15	17
	B	21	16	19	22	28	21	26	29
	C	9	7	8	9	15	12	14	15
38	A	9	7	8	9	14	11	13	14
	B	14	12	13	15	20	17	19	21
	C	15	13	14	15	22	18	20	21
39	A	9	7	8	9	15	11	13	14
	B	11	8	10	11	16	12	15	17
	C	12	8	11	11	20	13	18	18

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		M	ean Wind S	Speed (m	oh)	Effect	ive Gust W	ind Speed	d (mph)
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
40	A	14	9	13	13	19	13	18	19
	B	13	9	12	12	19	13	17	18
	C	9	6	8	9	14	10	13	14
41	A	10	7	9	10	15	12	14	15
	B	10	7	9	9	15	12	14	15
	C	9	7	8	8	14	11	13	14
42	A	9	8	9	10	15	12	14	15
	B	14	10	12	15	20	15	18	21
	C	8	7	8	8	14	11	13	14
43	A	11	9	11	12	18	14	17	18
	B	10	8	9	10	16	13	15	17
	C	9	6	8	8	15	10	13	14
44	A	10	7	9	11	14	11	13	16
	B	7	6	7	7	12	11	12	12
	C	6	5	6	6	10	7	9	10
45	A	8	6	8	8	13	10	12	14
	B	16	12	14	17	22	16	20	23
	C	10	8	9	10	15	12	14	15
46	A	8	7	8	9	13	11	13	14
	B	20	15	18	21	27	20	25	28
	C	10	8	9	9	16	13	15	16
47	A	11	10	11	11	17	16	17	18
	B	18	12	16	18	26	18	24	26
	C	16	14	15	16	23	19	22	23
48	A	9	7	8	9	14	12	13	14
	B	21	15	19	21	27	20	25	28
	C	14	11	13	14	21	17	20	21
49	A	-	-	-	-	-	-	-	-
	B	18	14	17	19	26	20	24	27
	C	16	12	14	16	23	18	21	23
50	A	-	-	-	-	-	-	-	-
	B	20	15	19	21	27	20	25	28
	C	15	11	14	15	22	16	20	22
51	A	-	-	-	-	-	-	-	-
	B	15	12	14	16	23	19	21	24
	C	18	14	17	18	26	20	23	26
52	A	16	12	16	16	23	17	22	23
	B	19	14	18	20	27	20	25	28
	C	16	13	15	17	24	19	23	24

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		Mean Wind Speed (mph)			Effective Gust Wind Speed (mph)				
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
53	A	-	-	-	-	-	-	-	-
	B	17	14	16	18	25	20	24	26
	C	14	13	14	15	21	19	21	23
54	A	14	11	13	14	20	16	19	20
	B	18	14	17	19	26	20	24	27
	C	15	12	14	16	23	18	22	24
55	A	16	13	15	17	24	19	22	25
	B	15	11	14	16	23	18	22	24
	C	13	10	12	13	20	16	19	20
56	A	19	17	19	20	27	23	26	28
	B	19	17	18	20	27	23	26	28
	C	20	14	18	20	29	21	26	28
57	A	21	17	20	21	29	24	27	29
	B	20	17	19	21	29	24	27	29
	C	17	12	16	16	25	18	23	24
58	A	22	17	21	23	30	23	28	31
	B	23	18	21	24	31	24	28	31
	C	18	15	17	18	26	20	24	27
59	A	14	10	13	15	21	16	19	22
	B	15	11	13	16	22	16	20	23
	C	21	16	19	22	29	22	27	31
60	A	20	15	19	21	27	20	25	28
	B	20	16	19	21	28	22	26	29
	C	16	13	16	17	25	19	23	25
61	A	12	10	11	12	18	15	17	18
	B	24	17	22	23	32	22	29	30
	C	20	14	17	19	27	19	24	26
62	A	14	10	13	13	21	15	19	19
	B	18	13	17	18	25	18	24	25
	C	15	11	14	15	22	17	21	22
63	A	20	16	19	20	27	21	25	27
	B	17	13	16	18	26	19	24	28
	C	15	11	14	16	22	17	21	23
64	A	20	15	19	21	27	21	26	28
	B	13	11	13	14	21	17	20	22
	C	12	10	12	13	20	15	18	21
65	A	18	14	17	19	27	20	25	28
	B	17	13	16	18	25	19	24	26
	C	15	12	14	16	22	17	20	22

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		Mean Wind Spe		peed (m	ph)	Effective Gust Wind Speed (			d (mph)
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
66	A	16	12	15	16	24	19	23	25
	B	15	11	14	15	24	18	23	24
	C	12	10	11	12	19	16	18	19
67	A	18	13	17	18	27	20	25	27
	B	18	13	16	17	27	20	25	26
	C	13	10	13	14	22	16	20	22
68	A	27	21	25	27	35	28	33	35
	B	26	21	25	27	35	27	32	35
	C	18	15	17	18	26	21	24	26
69	A	25	21	24	25	33	26	31	33
	B	26	21	24	26	33	27	31	33
	C	19	14	17	19	27	20	25	27
70	A	19	16	19	21	28	23	27	30
	B	18	16	18	20	27	23	26	28
	C	19	17	18	19	25	22	24	25
71	A	17	14	16	18	26	21	24	27
	B	16	14	15	17	25	21	23	26
	C	14	12	14	15	21	18	20	22
72	A	15	12	14	16	24	19	23	25
	B	15	11	14	15	24	18	22	24
	C	13	10	13	13	21	16	20	20
73	A	16	13	15	18	24	19	22	25
	B	15	11	14	16	22	17	21	23
	C	17	13	16	17	24	18	23	24
74	A	12	9	11	12	18	14	17	19
	B	11	8	10	12	17	13	16	18
	C	9	8	8	8	15	13	14	14
75	A	17	13	16	18	25	19	23	26
	B	14	11	14	15	21	16	20	22
	C	15	11	14	14	22	16	20	21
76	A	16	12	15	16	22	16	20	22
	B	15	11	14	15	22	17	20	23
	C	12	9	10	12	18	14	17	18
77	A	14	10	12	13	21	15	19	20
	B	16	12	15	18	24	18	22	26
	C	14	11	12	14	21	16	18	21
78	A	11	7	10	10	16	11	15	16
	B	9	7	8	10	15	11	14	16
	C	8	7	7	8	13	11	12	13

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		Mean Wind Speed (mph)			Effective Gust Wind Speed (mph)				
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
79	A	13	10	12	15	19	14	17	21
	B	13	10	12	15	19	14	18	21
	C	11	10	11	11	16	14	16	17
80	A	14	10	13	13	19	14	18	18
	B	16	12	15	17	24	18	22	24
	C	15	12	13	15	22	17	20	22
81	A	10	7	9	9	15	10	14	15
	B	20	14	18	19	26	19	24	26
	C	18	13	16	17	25	18	22	24
82	A	12	8	11	11	19	13	18	17
	B	16	12	15	16	24	17	22	24
	C	15	11	14	15	22	17	20	21
83	A	8	6	7	8	12	9	11	12
	B	11	8	10	10	16	11	14	15
	C	9	7	8	9	14	10	12	13
84	A	11	8	11	11	16	12	15	17
	B	11	8	10	11	16	12	15	16
	C	9	7	8	9	14	11	13	14
85	A	9	6	8	8	14	10	13	14
	B	11	9	10	12	17	14	16	18
	C	11	8	10	11	17	13	16	18
86	A	10	7	9	10	16	12	15	16
	B	11	9	10	11	16	13	15	16
	C	11	9	10	11	17	15	17	18
87	A	8	6	8	9	15	11	14	15
	B	7	6	7	8	13	11	13	13
	C	10	8	9	10	16	13	15	16
88	A	8	6	7	8	13	11	13	14
	B	9	8	8	9	15	13	14	15
	C	13	10	12	13	20	16	19	20
89	A	8	6	7	8	13	11	13	14
	B	7	6	7	7	12	10	12	12
	C	10	9	10	10	17	15	17	17
90	A	9	7	8	9	14	12	14	15
	B	11	10	11	11	17	14	16	17
	C	12	10	11	12	19	17	18	19
91	A	6	5	6	6	11	8	10	11
	B	7	6	7	8	12	10	11	13
	C	10	9	10	11	17	15	16	17

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**Table 2: Mean Speed and Effective Gust Categories - Seasonal** 

		Mean Wind Speed (mph)				Effective Gust Wind Speed (mph)			
Location	Configuration	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
92	A	8	6	7	8	13	10	12	14
	B	8	7	8	8	13	11	12	13
	C	15	14	15	15	21	18	20	20
93	A	10	8	9	10	16	14	15	17
	B	12	11	11	12	18	16	17	19
	C	11	10	11	11	17	15	17	17
94	A	9	8	9	9	15	13	14	15
	B	12	10	11	12	18	16	17	18
	C	18	13	16	17	24	17	22	23
95	A	10	8	9	10	15	12	14	15
	B	13	11	12	13	18	15	17	19
	C	18	13	17	17	24	17	22	23

Seasons	Months	Mean Wind Criteria Speed (mph)		Effective Gust Criteria (mph)					
Spring	March - May	<u>&lt;</u> 12	Comfortable for Sitting	≤31 Acceptable					
Summer	June - August	13 - 15 Comfortable for Standing		> 31 Unacceptable					
Fall	September - November	16 - 19	Comfortable for Walking						
Winter	December - February	>19	Uncomfortable for Walking						
Annual	January - December								
Configuration	S								
(A) No Build	Existing site and surroundings								
(B) Build	Proposed project with existing s	urrounding	S						
(C) Full Build	Proposed project with future surroundings								
Notes	1) Wind Speeds are for a 1% probability of exceedance								

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# **SOLAR REFLECTANCE STUDY**

## DRAFT REPORT



# 99 SOUTH STREET - BOYNTON YARDS

#### **DETAILED SOLAR REFLECTION ANALYSIS**

JUNE 9, 2022 PROJECT #2200880

> SUBMITTED TO Michael Liporto, AIA, NCARB

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## EXECUTIVE SUMMARY



RWDI was retained to investigate the impact that solar reflections emanating from the proposed 99 South Street – Boynton Yards development will have on the surrounding urban realm.

#### **Thermal Impacts on People**

The planar nature of the facades of the proposed development ensure that reflected sunlight will not focus (multiply) in any particular area. Therefore, RWDI does not expect any significant thermal impacts (i.e. risks to human safety or property damage) to occur either on the site or in the surrounding neighborhood.

#### **Visual Glare Impact on Drivers**

As with the addition of any glazed building, drivers traveling in the vicinity of the buildings were predicted to experience an increased level of visual glare impact. This is not unusual for modern buildings. Drivers in proximity and approaching the building from Earle Street, Ward Street, Willow Street, and Hunting Street were predicted to experience reflections from the buildings which can cause a high level of impact. The reflections were predicted to be possible in less than 2% of the daytime annually. RWDI does not predict a significant impact to the trains traveling north of the building.

#### **Visual Glare Impact on Pedestrians and Facades**

Typical levels of visual glare were predicted for pedestrians and building occupants in the vicinity of the development. These types of reflections represent a visual nuisance, as viewers can safely

look away or close blinds. These potential impacts were predicted to be possible throughout the year for residences on Harding Street, Hunting Street, and Ward Street. The design of the facade helped break up the continuity of these reflections compared to a building with a higher window-to-wall ratio. Reflections may also affect pedestrians on the building's balcony and close to the building, however these results are typical and easily remedied with common overhead shading devices like umbrellas and canopies.

#### **Thermal Impact on Facades**

At all studied facade areas, reflections were predicted to be low intensity and short duration. Hence, RWDI would not expect these reflections to lead to a significant additional cooling load for a building. Should an individual choose to expose themselves to the reflected energy, they may feel warm, however this would be a temporary experience and one which would easily be remedied by closing window treatments.

#### **Overall Impact of Reflections**

The predicted impacts of this development on its surrounds are typical of any modern building of this size. Additional details on when reflections were predicted to occur throughout the year, as well as predicted durations and intensities can be found in Appendix A. If mitigation is desired, several strategies to minimize the reflection impacts have been provided. For further details, refer to the Mitigation Suggestions section on page 21.

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## INTRODUCTION

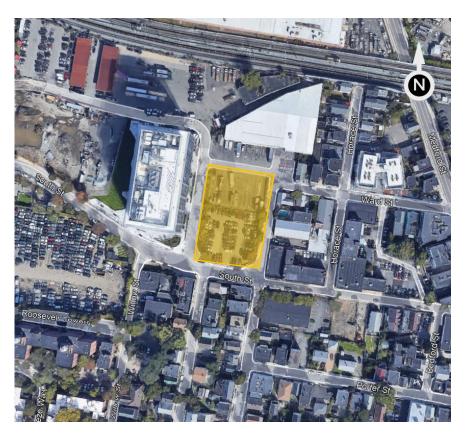


This report provides the computer modeling results of reflected sunlight from the proposed 99 South Street – Boynton Yards in Somerville, MA (as shown in Figure 1). It is our understanding that the development will be surrounded by typical urban spaces such as busy roadways, and other buildings.

RWDI was retained to investigate the impact that solar reflections emanating from the proposed development will have on the surrounding urban terrain.

A preliminary set of simulations was conducted to determine peak reflection intensities and the frequency of reflection occurrence for a broad area around the development. This served to identify areas which may experience high intensity or very frequent reflections. This information informed the selection of sixteen (16) points for a more detailed analysis.

These receptor points represent drivers, pedestrians, and building facades and the detailed results allow us to quantify the frequency, intensity and duration of glare events at the receptors as well as the sources of those reflections.



**Figure 1:** Location of the 99 South Street – Boynton Yards Building (Orange) (Map Credit: Google Earth)



## **Urban Reflections**

While a common occurrence, solar reflections from buildings can lead to numerous visual and thermal issues.

#### Visual glare can:

- Impair the vision of motorists and others who cannot easily look away from the source;
- Cause nuisance to pedestrians or occupants of nearby buildings; and,
- Create undesirable patterns of light throughout the urban fabric.

#### Heat gain can:

- · Affect human thermal comfort;
- Be a safety concern for people and materials, particularly if multiple reflections are focused in the same area; and
- Create increased cooling needs in conditioned spaces affected by the reflections.

The most significant safety concerns with solar reflections occur with concave facades (Figure 2) which act to focus the reflected light in a single area. RWDI does not expect this to be a concern given the form of the project.

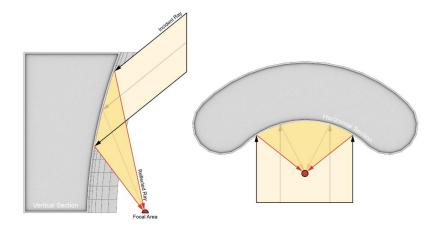


Figure 2: Illustration of Reflection Focusing Due to a Concave Facade



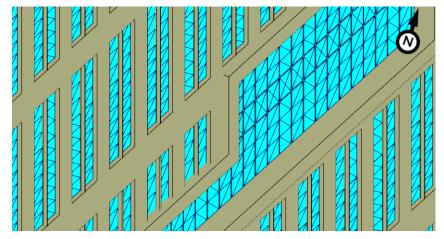
## Methodology

RWDI assessed the potential for reflection impacts using RWDI's in-house proprietary *Eclipse* software, in two phases as per the steps outlined below:

- The Phase 1 'Screening' assessment began with the development of a 3D model of the area of interest (as shown in Figure 3). This was then subdivided into many smaller triangular patches (see Figure 4).
- For each hour in a year, the expected solar position was determined, and "virtual rays" were drawn from the sun to each triangular patch of the 3D model. Each ray that was considered to be "unobstructed" was reflected from the building surface and tracked through the surrounding area. The study domain included the entire pedestrian realm within 1,300 feet of the proposed building.
- The total reflected energy at that hour from all of the patches was computed and its potential for visual and thermal impacts assessed.
- Finally, a statistical analysis was performed to assess the frequency, and intensity of the glare events occurring throughout the year in the vicinity of the project. The criteria used to assess the level of impact can be found in Appendix B of this report.



**Figure 3:** 3D Computer Model of the Proposed Development and Surrounding Context (Existing Buildings are Colored Brown While Future Buildings are Colored Purple)



**Figure 4:** Close-up View of the Model, Showing Surface
Subdivisions

Detailed Solar Reflection Study |



## Methodology (cont'd)

- Based on the findings of the Screening analysis, multiple representative 'receptor points' were selected to undergo the Phase 2 'Detailed' analysis.
- The points were chosen to understand in greater detail how reflections from the building will impact drivers, pedestrians and the rest of the built environment. The selected locations of the points are discussed further in the Detailed Analysis section this report.
- The Detailed analysis process is similar to the Screening analysis, except reflections are analyzed at one-minute increments for the entire year and the source of the reflections is stored for each receptor point.
- In addition to the frequency and duration of reflection impacts, the Detailed analysis allows for the prediction of when impacts can occur, how long they can occur for and the locations of problematic glare sources.



## **Assumptions and Limitations**

#### **Meteorological Data**

This analysis used 'clear sky' solar data computed at the location of Boston Logan International Airport. This approach uses mathematical algorithms to derive solar intensity values for a given location, ignoring local effects such as cloud cover. This provides an assessment of a complete year showing the full extent of when and where glare could ever occur.

#### **Radiation Model**

RWDI's analysis is only applicable to the thermal and visual impacts of solar radiation (i.e. ultraviolet, visible and infrared wavelengths) on people and property in the vicinity of the development. It does not consider the impact of the building related to any other forms of radiation, such as cellular telephone signals, RADAR arrays, etc.

#### **Study Building and Surrounds Models**

The analysis was conducted based on the 3D model and other site information provided by CBT Architects to RWDI up to May 19, 2022.

The surroundings model was developed based on data made available by the City of Boston. The surrounds model includes all buildings which currently exist or are approved for construction by the BPDA, and future developments.

The ground surface and the surrounding buildings were topographically corrected based on a high-resolution LiDAR survey conducted by the National Oceanic and Atmospheric Administration (NOAA) in 2013-2014. NOAA states that the horizontal accuracy of this data set is 16.5 inches at a 95% confidence level. Its vertical accuracy is stated as 4.8 inches at a 95% confidence level.

Potential reductions of solar reflections due to the presence of vegetation or other non-architectural obstructions were not included, nor are reflections from other buildings. Light that has reflected off several surfaces is assumed to have a negligible impact. As such, only a single reflection from the development was included in the analysis.



## **Assumptions and Limitations (cont'd)**

#### **Facade Material Reflectance**

Based on correspondence with CBT Architects on May 5, 2022, several triple pane insulated glazing units (IGUs) are currently under consideration for the vision glass of this project. Upon review of their reflectance characteristics, we have conservatively chosen to model the units with the highest visible and thermal reflectivity (SunGuard SN63 and Interpane Ipasol Ultraselect 62/29 respectively). All glazing on the building has been modeled as these glazing types.

The reflectance properties of the reflective elements are summarized in Table 1. Figure 5 illustrates the location of the reflective materials on the facades.

#### **Applicability of Results**

The results presented in this report are highly dependent on both the form and materiality of the facade. Should there be any changes to the design, it is recommended that RWDI be contacted and requested to review their potential effects on the findings of this report.

This analysis also assumes reasonable and responsible behavior on the part of people in the vicinity of the project. A reasonable and responsible person would not purposely look towards a bright reflection, purposely prolong their exposure to reflected light or heat, or otherwise intentionally try to cause discomfort/harm to themselves or others and/or damage to property.

This report has endeavored to provide a robust and suitably conservative analysis of the potential effects of reflected sunlight, contextualized based on current industry and academic research, and common best practices. Regulation and enforcement of performance requirements is the responsibility of the relevant regional regulatory authority.



## **Assumptions and Limitations (cont'd)**

# NON-REFLECTIVE VISION GLASS

**Table 1:** Nominal Visible and Full Spectrum Reflectance Values of the Reflective Building Elements

Location	Visible Reflectance	Full Spectrum Reflectance		
All Vision Glass	17% (SunGuard SN63)	50% (Interpane lpasol Ultraselect 62/29)		

**Figure 5:** Locations of Reflective Building Elements (Surrounding Context removed for Clarity)



### **Presentation of Results**

This section presents the screening results pertaining to the solar impacts of the development on the surrounding urban area. The following three plots are presented:

#### **Peak Annual Reflected Irradiance**

This plot displays the annual peak intensity of all reflections emanating from the development at a typical pedestrian height (5 feet) above local grade.

Two versions of this plot are included:

- Visible Reflectance (Visual Glare): This plot (Figure 6a)
  displays the intensity of reflected visible light only.
  Depending on the ambient conditions, reflection intensities as
  low as 50 W/m² could be visible to people outdoors.
- Full Spectrum Reflectance (Heat Gain): This plot (Figure 6b) presents the total intensity of a reflection, including both visible light and thermal energy which relates to the risk of excessive heat gain. For full spectrum reflectance, RWDI considers 1500 W/m² as a short-term thermal comfort threshold and reflections above 2500 W/m² as a human safety threshold (refer to Appendix B).

#### **Frequency of Significant Visual Reflections**

This plot (Figure 6c) identifies the locations of the most frequent significant reflections emanating from the facades. In this context a 'significant' reflection is one that is at least 50% as intense as one that would cause after imaging on a viewer (refer to Appendix B).

As this criteria is visually based, the visible reflectance of the facades was used.

In order to attain a complete understanding of the impact that reflections may have on drivers, other factors must be considered, including the duration of the reflections and when they occur. The following plots serve to illustrate the general characteristics of reflections from the development and inform the locations of the receptor points used in the detailed phase of work which will analyze these factors in greater detail.



## **Peak Annual Reflected Irradiance - Visible Reflectance (Visual Glare)**

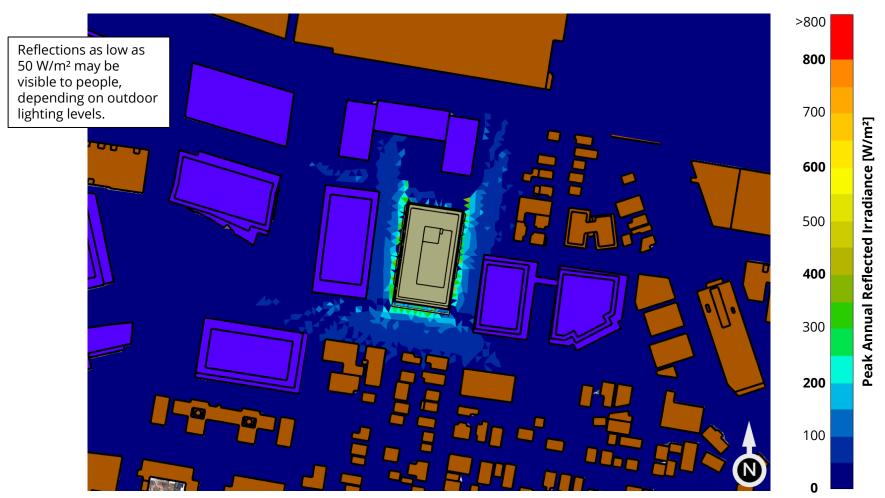


Figure 6a: Maximum Annual Intensity of Visible Reflections at Pedestrian Height



## **Peak Annual Reflected Irradiance - Full Spectrum Reflectance (Heat Gain)**

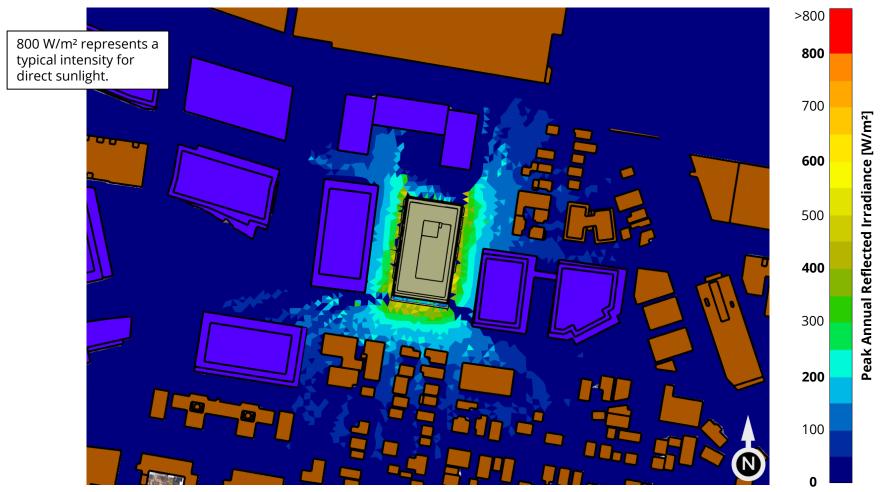


Figure 6b: Maximum Annual Intensity of Full Spectrum Reflections at Pedestrian Height



## **Frequency of Significant Visible Reflections**

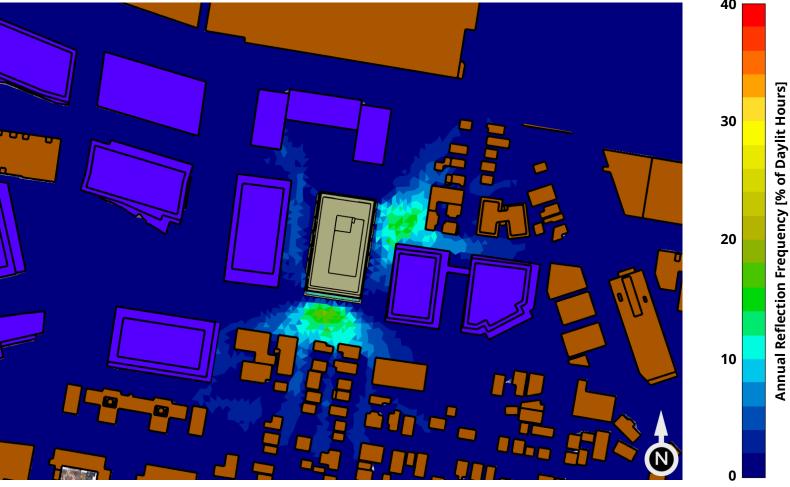


Figure 6c: Frequency (% of Daylit Hours) Where Significant Visible Reflections Can Occur

## SCREENING ANALYSIS OBSERVATIONS



- Like any contemporary building, the reflective surfaces of the proposed development are naturally causing solar reflections in the surrounding neighborhood.
- 2. The planar nature of the facades of the building prevent reflections from focusing (concentrating) in any particular area. Thus, RWDI does not anticipate any heat gain issues on people or property.
- 3. At pedestrian level, reflections were predicted to fall most frequently onto the areas immediately east, south and to a lesser extent, west of the building. The maximum frequency of glare occurrence found at pedestrian level is approximately 19% of daytime hours which is similar to many other buildings RWDI has studied.
- 4. Reflections from the development were predicted to be generally confined to within 400 feet of the building and may impact eastbound drivers turning into Earle Street as well as westbound drivers on Ward Street and northbound drivers on turning onto South Street from Willow Street and Harding Street.

- 5. The occupants of the buildings located close to the development were predicted to experience visible reflections from the development. That being said, the reflections are unlikely to pose a risk to safety. They are likely a nuisance, however occupants can just look away or close blinds.
- Pedestrians in the vicinity of the project were also predicted to have the potential to experience intermittent reflections.
   This condition is common in many urban centers and is unlikely to present a significant safety risk.
- 7. RWDI does not anticipate reflections from this development to have a significant impact on the trains on the rail lines north of the project.
- 8. The exact nature of these impacts are explored further in the following detailed analysis section.

# DETAILED ANALYSIS RESULTS



Based on the findings of the Screening Analysis and the risk levels associated with reflections effecting specific areas, sixteen (16) representative points were selected for the Detailed Analysis. These points are described in Table 2 and illustrated in Figure 7.

Table 2. December Descriptions

Table 2: Receptor Descriptions							
Receptor Number	Receptor Description						
D1	Eastbound driver turning into Earle St. from an assumed future road						
D2-D4	Westbound drivers on Ward St.						
D5	Northbound driver on Willow St. turning onto South St.						
D6	Eastbound driver on South St. turning onto Earle St.						
D7	Northbound driver on Harding St. turning onto South St.						
D8	Westbound driver on South St.						
Р9	Pedestrian on south balcony of 99 South Street Building						
P10	Pedestrian south of 99 South Street Building						
P11	Pedestrian on Hunting St. at South St.						
F12-14	Facades at approximately 2 <sup>nd</sup> floor height of approximately 47, 48, and 46 Hunting St.						
F15	Facade at approximately 2 <sup>nd</sup> floor height of future development on 45 South St.						
F16	Facade at approximately 2 <sup>nd</sup> floor height of future development on 32 Ward St.						



Figure 7: Receptor Locations (Map Underlay Credit: Microsoft Bing Maps) Detailed Solar Reflection Study |

## DETAILED ANALYSIS RESULTS



Table 3 summarizes the level of visual and thermal impact from the development's reflections at each of the studied locations. For each category (visual impact, thermal impacts on people, thermal impacts on facades/property) the point is classified as experiencing one of four impact levels:

- Low impacts indicate that either no reflections reach the receptor, or that reflections which do reach the location are unlikely to lead to visual or thermal concerns.
- Moderate impacts indicate the potential for visual nuisance, minor thermal discomfort to people, or minor heating of materials. Moderate impacts do not indicate a significant safety risk and are common in urban areas. They represent effects such as intermittent visual glare on pedestrians or occupants of adjacent buildings which can be safely self-mitigated.
- High impacts indicate the potential for risks to safety, either through impairing the visual acuity of a vehicle operator or through reflection intensities high enough to cause injury or property damage. When the sun is also in a driver's field of view, RWDI would expect that brightness of the sun to dominate over the less intense reflected light, likely reducing the perceived effect of high impact reflections. This situation is noted in Table 3 where applicable, as are notes on high impact reflection frequencies and durations.

 Very High/Damaging impacts indicate the potential for extreme risks to safety, either due to reflected energy intensities well in excess of RWDI's ceiling exposure limit or visual glare bright enough to damage the retina faster than an individual can blink.

The minute-by-minute results for each point are presented as 'Annual Reflection Impact Diagrams' which distill an entire year's worth of data into a single diagram. The diagrams for each of the receptor points as well as an explanation for how to read the diagrams are provided in Appendix A.

For further detail on RWDI's criteria refer to Appendix B.

The level of mitigation required (discussed further in the Overall Observations and Conclusions section), is determined based on a combination of factors including the predicted level of impact, the frequency and duration of the impacts, and the risk level associated with activities likely to be engaged in at the location.

# DETAILED ANALYSIS RESULTS



**Table 3: Summary of Overall Predicted Impacts on Receptors** 

Receptor Number	Receptor Type	Assumed Activity Risk Level	Assumed Ability to Self-Mitigate	Peak Reflected Light Visual Impact	Duration / Number of Days with High Impact Reflection	Percentage of High Impacts Where the Sun Is Also Visible	Peak Reflected Solar Thermal Impact on People	Peak Reflected Solar Thermal Impact on Facade
D1	Driver	High	Low	High	Longest Duration:  18 minutes Average Duration: 6 minutes No. of days: 95	0%	Low	N/A
D2	Driver	High	Low	High	Longest Duration:  38 minutes Average Duration:  12 minutes No. of days: 92	0%	Low	N/A
D3-D4	Driver	High	Low	Low	N/A	N/A	Low	N/A
D5	Driver	High	Low	High	Longest Duration: 38 minutes Average Duration: 10 minutes No. of days: 123	0%	Low	N/A
D6	Driver	High	Low	Moderate	N/A	N/A	Low	N/A
D7	Driver	High	Low	High	Longest Duration: 17 minutes Average Duration: 9 minutes No. of days: 112	0%	Low	N/A
D8	Driver	High	Low	Moderate	N/A	N/A	Low	N/A
P9-P11	Pedestrian	Low	High	Moderate	N/A	N/A	Low	N/A
F12-F16	Facade	Low	High	Moderate	N/A	N/A	N/A	Low

## OVERALL OBSERVATIONS AND CONCLUSIONS



#### **Thermal Impacts on People**

 The planar facades of the proposed development ensure that reflected sunlight will not focus (multiply) in any particular area. Therefore, RWDI does not expect any significant thermal impacts (i.e. risks to human safety or property damage) to occur either on the site of the development or in the surrounding neighborhood.

#### **Visual Glare Impact on Drivers**

- 2. As with the addition of any glazed building, drivers traveling in the vicinity of the building are expected to experience an increased level of visual glare impact. Some reflections with a high visual impact potential were predicted. Some of these impacts may alter a driver's experience since the glare occurs at times when the sun would not be within a driver's field-of-view. In particular, a driver's experience could be altered when:
  - Traveling east and turning on to Earle St. from an assumed future road (receptor D1) between 5:00 am EST and 6:00 am EST in early May to early August.
  - Traveling west on Ward St. approaching Harding St. (receptor D2) between 6:00 am EST and 7:30 am EST from mid-March to late April and again from mid-August to late September.
  - Traveling north on Willow St. turning into South St. (receptor D5) between 7:00 am EST and 9:00 am EST from mid-October to late February.

 Traveling north on Harding St. turning into South St. (receptor D7) between 2:00 pm EST and 4:00 pm EST from late October to mid-February

The high impact reflections predicted at these locations can last up to 38 minutes per instance, but on average lasted 6 to 12 minutes. This equates to the potential for high impact glare being in 0.5% and 1.7% of the daytime respectively. The design of the build facades reduces the continuity of the reflections much of the time. Resulting in multiple discrete instances compared to a single long duration that can be caused by more glassy buildings.

 For the remainder of the driver receptors, visual glare impacts were predicted to be moderate, and therefore are not expected to pose a significant safety concern to drivers. For further details refer to the visual impact diagrams for all driver receptors (D1-D8) illustrated in Appendix A.

#### **Visual Glare Impacts on Pedestrians and Facades**

4. Moderate levels of visual impact were predicted to fall on most of the pedestrian and facade receptors studied in this analysis. The potential visual impacts noted above do not present a safety risk, but rather a temporary nuisance which can be mitigated by briefly closing blinds or looking away from the glare source.

### OVERALL OBSERVATIONS AND CONCLUSIONS



#### **Thermal Impacts on Facades**

5. The majority of reflected solar energy at the studied facade areas was predicted to be low intensity (less than 250 W/m²) and short duration. Hence, RWDI would not expect these reflections to lead to a significant additional cooling load for a building. Should an individual choose to expose themselves to the reflected energy, they may feel warm however this would be a temporary experience and once which would easily be remedied by closing window treatments.

### MITIGATION SUGGESTIONS



Overall, the reflections emanating from the proposed development onto the surrounding neighborhood are comparable to reflections elsewhere in the city. If, however, there are concerns about the predicted reflection impacts, RWDI offers the following suggestions for further consideration (refer to Figures 8 and 9 on the following pages for a mark-up of these options):

- 1. Glazing Surface Modification: Modifying the exterior surface of sections of the north, east and south facade of the 99 South Street building (highlighted in Figures 8 and 9) to diffuse reflected light (i.e. by "frosting" or roughening the exterior surface) could help in reducing the frequency of reflections predicted at the Earle Street, Ward Street, Willow Street, and Hunting Street receptors.
- 2. Free Standing Shading Devices: A practical approach to intercept some of the reflections falling onto the entrances of the development may be to block reflections closer to pedestrian level. Strategic use of shading devices (umbrellas, canopies, vegetation, etc.) will limit any minor visual or thermal comfort impacts from both direct and reflected light.

# MITIGATION SUGGESTIONS





Figure 8: Markup of East and North Facade Locations Where Exterior Surface Modification Could be Considered

# MITIGATION SUGGESTIONS



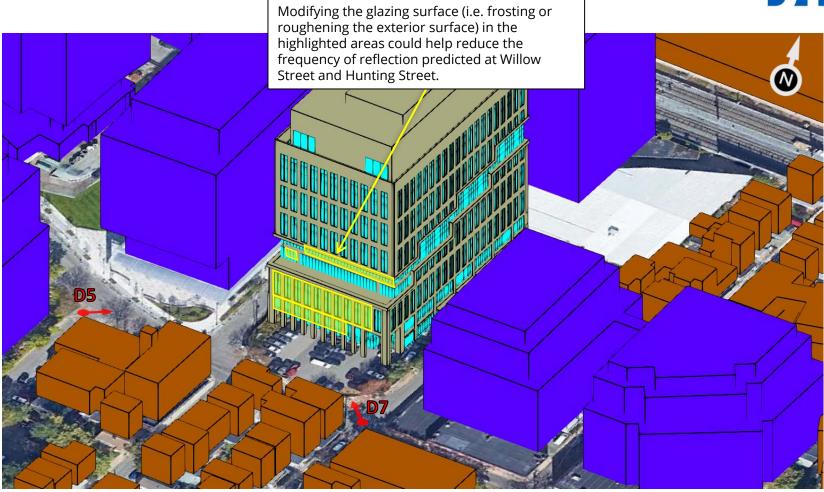


Figure 9: Markup of South Facade Locations Where Exterior Surface Modification Could be Considered

#### GENERAL STATEMENT OF LIMITATIONS



This report entitled 99 South Street – Boynton Yards Detailed Solar Reflection Analysis, dated June 8, 2022 was prepared by Rowan William Davies Irwin Inc. ("RWDI") for CBT Architects ("Client"). The findings and conclusions presented in this report have been prepared for the Client and are specific to the project described herein ("Project"). The conclusions and recommendations contained in this report are based on the information available to RWDI when this report was prepared.

Because the contents of this report may not reflect the final design of the Project or subsequent changes made after the date of this report, RWDI recommends that it be retained by Client during the final stages of the project to verify that the results and recommendations provided in this report have been correctly interpreted in the final design of the Project.

The conclusions and recommendations contained in this report have also been made for the specific purpose(s) set out herein. Should the Client or any other third party utilize the report and/or implement the conclusions and recommendations contained therein for any other purpose or project without the involvement of RWDI, the Client or such third party assumes any and all risk of any and all consequences arising from such use and RWDI accepts no responsibility for any liability, loss, or damage of any kind suffered by Client or any other third party arising therefrom.

Finally, it is imperative that the Client and/or any party relying on the conclusions and recommendations in this report carefully review the stated assumptions contained herein and to understand the different factors which may impact the conclusions and recommendations provided.



# **APPENDIX A**

**ANNUAL REFLECTION IMPACT DIAGRAMS** 



#### **Presentation of Results**

The frequency, duration, and intensity of glare events throughout the year is illustrated using "annual impact diagrams" (see Figure A1 below for the general layout of these plots). The color of the plot for a given combination of date and time indicates the relative impact of any glare sources found. The horizontal axis of the diagram indicates the day of the year, and the vertical axis indicates the hour of the day.

We note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

The following pages present the impact categories for three types of Annual Impact Diagrams: Visual Impact, Thermal Impact on People, and Thermal Impact on Property. More information on RWDI's criteria is available in Appendix B.

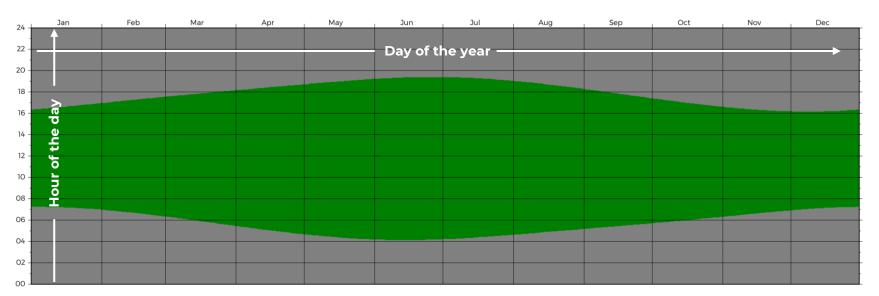


Figure A1: Layout of Annual Reflection Impact Diagram



#### **Visual Impact Categories**

**Low:** Either no significant reflections occur or the reflections will have a minimal effect on a viewer, even when looking directly at the source.

**Moderate:** The reflections can cause some visual nuisance only to viewers looking directly at the source.

**High:** The reflections can reduce visual acuity for viewers operating vehicles or performing other high-risk tasks who are unable to look away from the source, posing a significant risk of distraction.

**Damaging:** The brightest glare source is bright enough to permanently damage the eye for a viewer looking directly at the source.

Hatched areas indicate times and dates when the sun would also be in a driver's field of view.

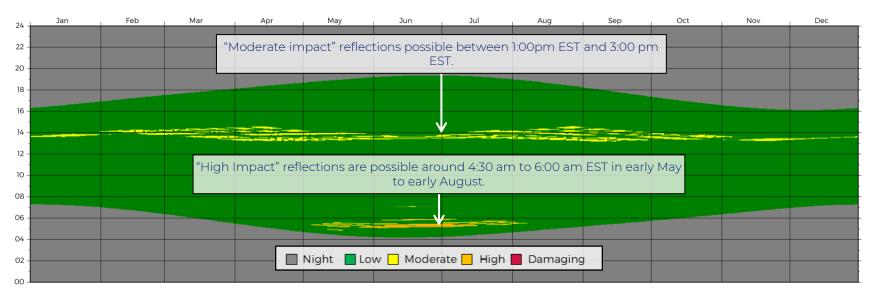


Figure A2: Example of Annual Visual Glare Impact Diagram - Receptor D1



#### **Thermal Impact Categories for People**

**Low:** Either no significant reflections occur or the reflection intensity is below the short-term exposure threshold of 1500 W/m<sup>2</sup>.

**Moderate:** The reflection intensity is above the short-term exposure threshold of 1500 W/m² but below the safety threshold of 2500 W/m². Such reflections would quickly cause thermal discomfort in people.

**High:** The reflection intensity is above the safety threshold of 2500 W/m<sup>2</sup> but below 3500 W/m<sup>2</sup>. This level of exposure to bare skin would lead to the onset of pain within 30 seconds.

**Very High:** Reflection intensity exceeds 3500 W/m<sup>2</sup>. This level of exposure leads to second degree burns on bare skin within 1 minute.

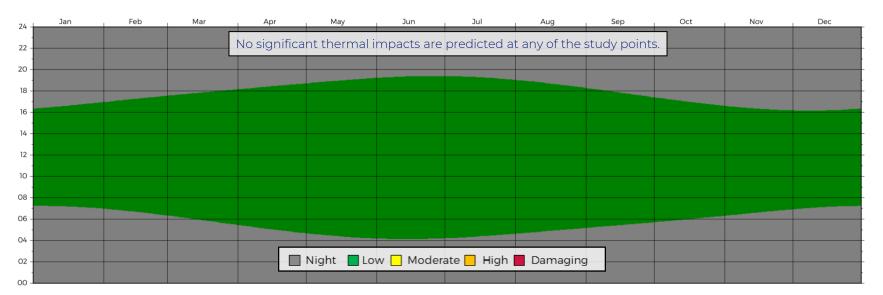


Figure A3: Example of Annual Pedestrian Thermal Impact Diagram – Receptor P9



#### **Thermal Impact Categories for Property**

A different scale is used to illustrate the reflected thermal energy on facades in order to provide further clarity on the potential for heat gain issues. The diagrams illustrate the irradiance levels of all predicted reflection events along with their frequency and duration.

The format of the diagram is similar to the diagrams described in the previous pages. The color of the plot for a given combination of date and time indicates the intensity of the reflected light at that point in time.

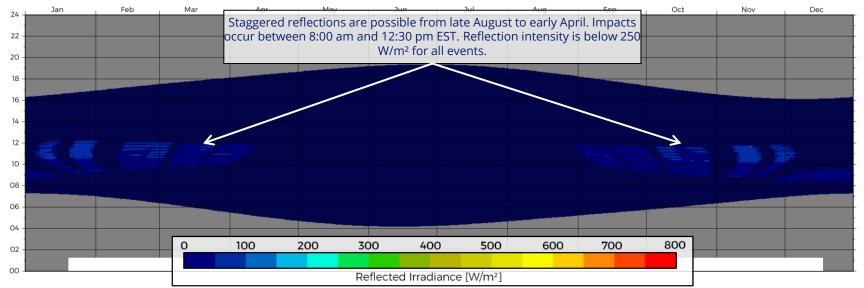
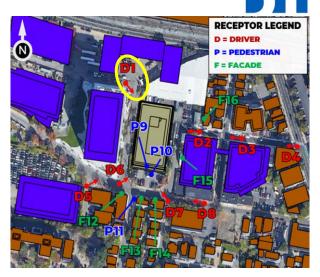


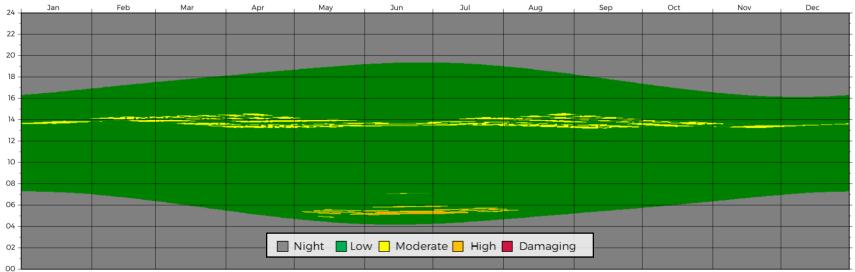
Figure A4: Example of Annual Property Thermal Impact Diagram – Receptor F12 RWDI Project #2200880

June 9, 2022

### **Driver Receptor D1**

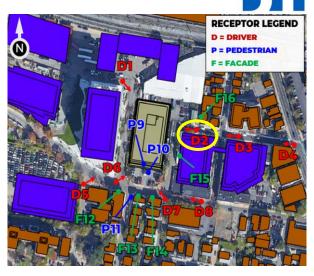
Receptor D1 was chosen to assess the visual impact associated with solar reflections affecting westbound driver turning into Earle St.

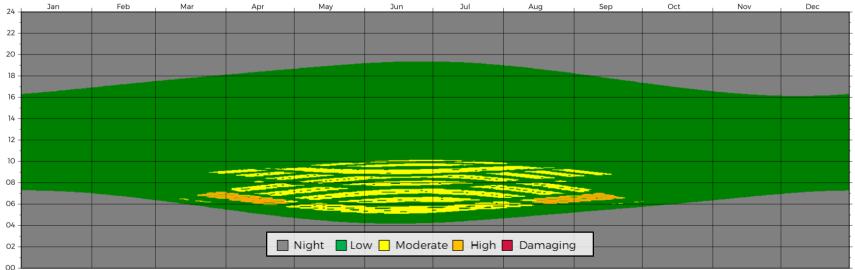




### **Driver Receptor D2**

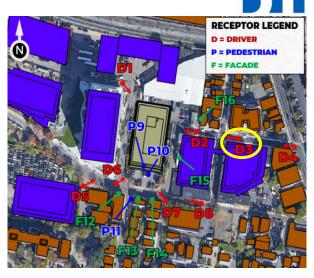
Receptor D2 was chosen to assess the visual impact associated with solar reflections affecting westbound driver on Ward St.

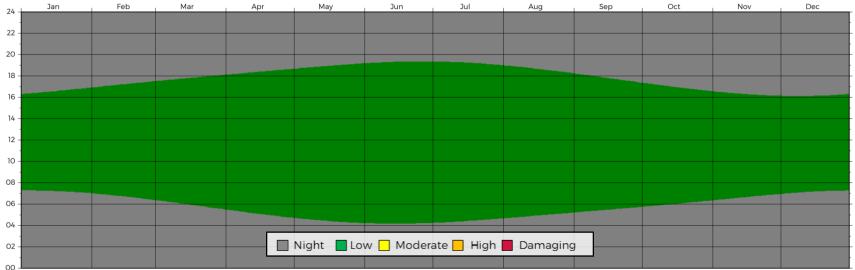




### **Driver Receptor D3**

Receptor D3 was chosen to assess the visual impact associated with solar reflections affecting westbound driver on Ward St.



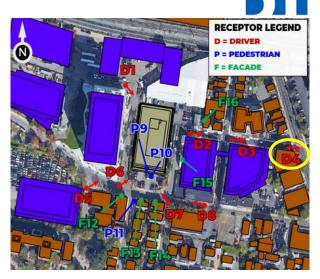


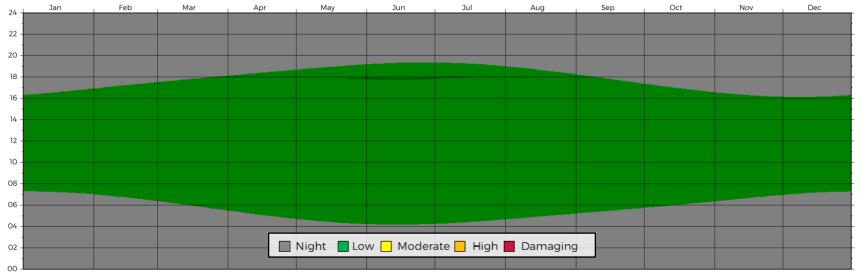
### **Driver Receptor D4**

Receptor D4 was chosen to assess the visual impact associated with solar reflections affecting westbound driver on Ward St.

Please note that the referenced times are in local standard time. In jurisdictions where Daylight Savings Time is used, the time should be shifted by one hour when appropriate.

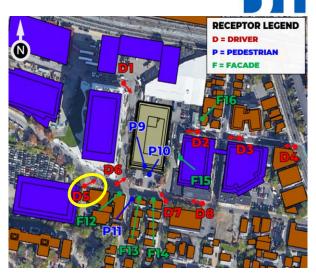
Hatched areas on the plot indicate times when the sun is within a driver's field-of-view.





### **Driver Receptor D5**

Receptor D5 was chosen to assess the visual impact associated with solar reflections affecting northbound driver on Willow St. turning into South St.

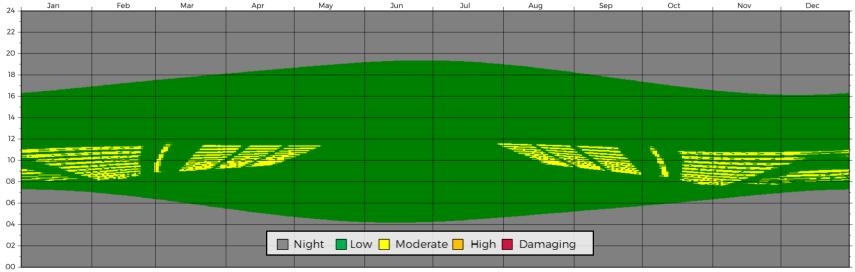




### **Driver Receptor D6**

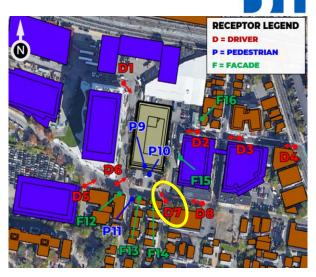
Receptor D6 was chosen to assess the visual impact associated with solar reflections affecting eastbound driver on South St. turning into Earle St.





### **Driver Receptor D7**

Receptor D7 was chosen to assess the visual impact associated with solar reflections affecting northbound driver on Harding St. turning into South St.



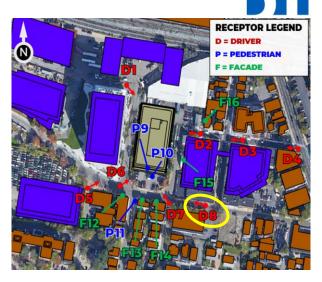


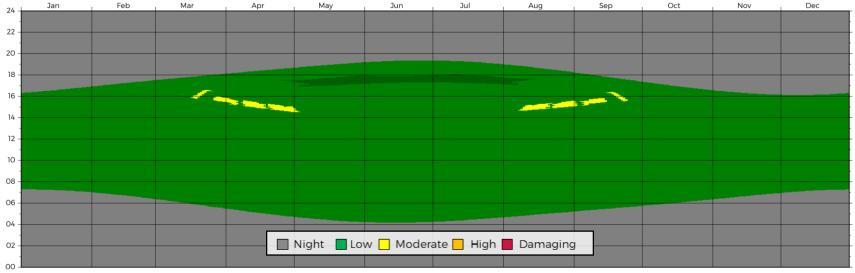
### **Driver Receptor D8**

Receptor D8 was chosen to assess the visual impact associated with solar reflections affecting westbound driver on South St.

Please note that the referenced times are in local standard time. In jurisdictions where Daylight Savings Time is used, the time should be shifted by one hour when appropriate.

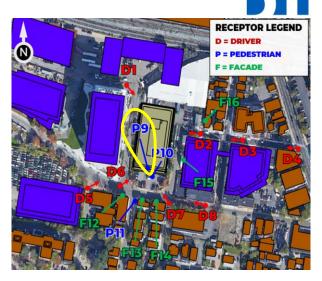
Hatched areas on the plot indicate times when the sun is within a driver's field-of-view.





### **Pedestrian Receptor P9**

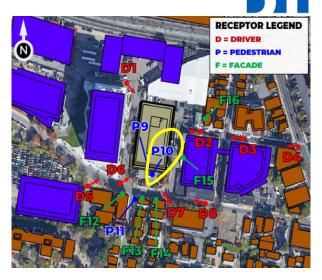
Receptor P9 was chosen to assess the visual impact associated with solar reflections affecting pedestrian on the south balcony of the 99 South Street Building.

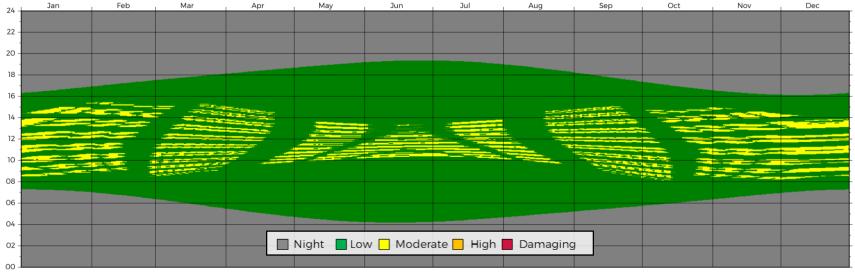




### **Pedestrian Receptor P10**

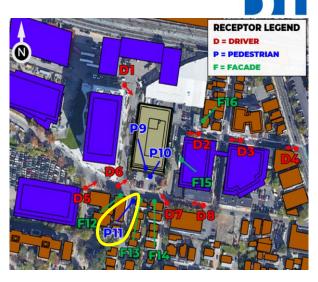
Receptor P10 was chosen to assess the visual impact associated with solar reflections affecting pedestrians south of the 99 South Street Building.





### **Pedestrian Receptor P11**

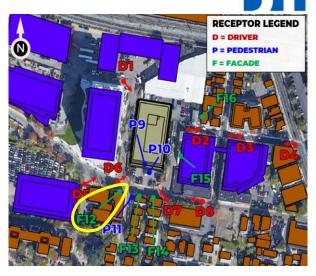
Receptor P11 was chosen to assess the visual impact associated with solar reflections affecting pedestrian on Hunting St. at South St.

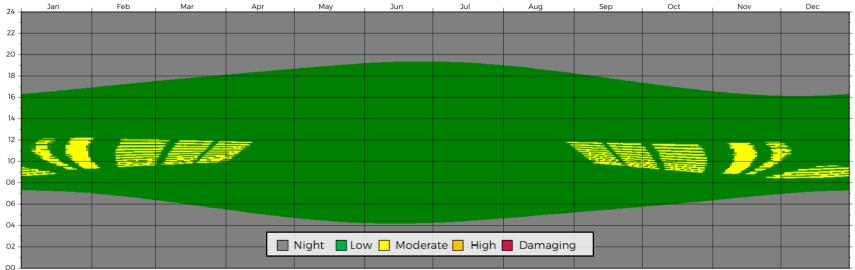




#### **Facade Receptor F12**

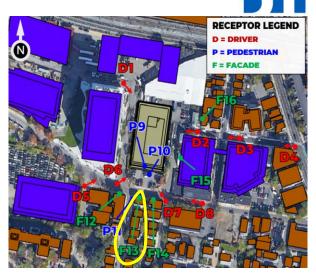
Receptor F12 was chosen to assess the visual impact associated with solar reflections affecting occupants of 47 Hunting St. (Approximately the 2<sup>nd</sup> floor).

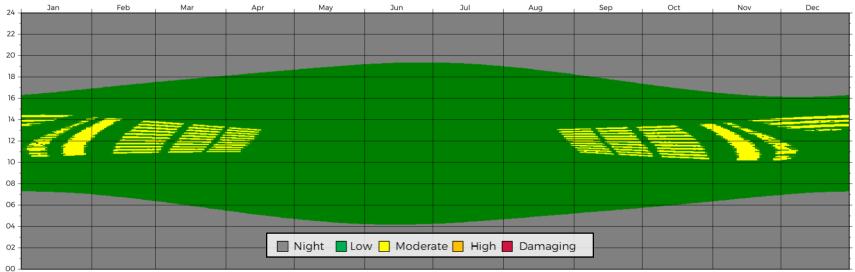




#### **Facade Receptor F13**

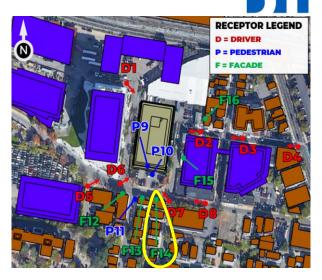
Receptor F13 was chosen to assess the visual impact associated with solar reflections affecting occupants of 48 Hunting St. (Approximately the 2<sup>nd</sup> floor).

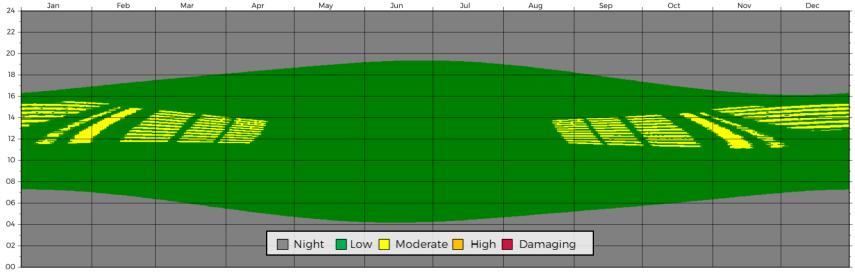




### **Facade Receptor F14**

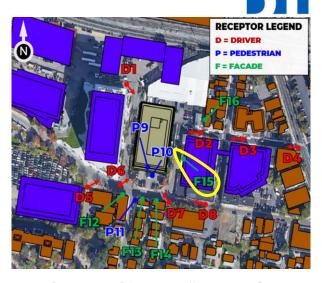
Receptor F14 was chosen to assess the visual impact associated with solar reflections affecting occupants of 46 Hunting St. (Approximately the 2<sup>nd</sup> floor).

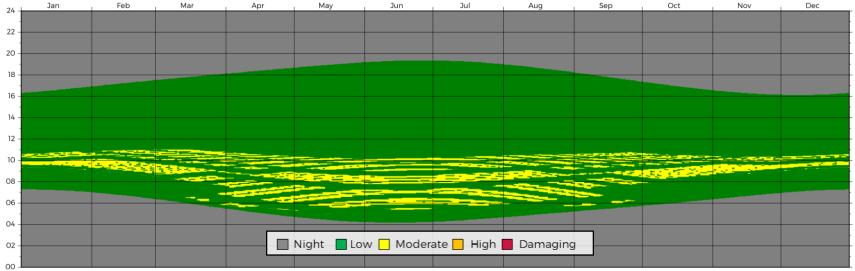




### **Facade Receptor F15**

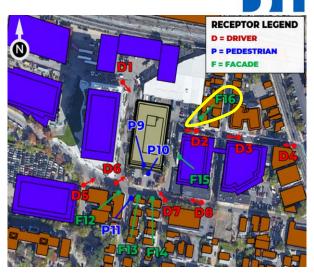
Receptor F15 was chosen to assess the visual impact associated with solar reflections affecting occupants of future 45 South St. (Approximately the 2<sup>nd</sup> floor).

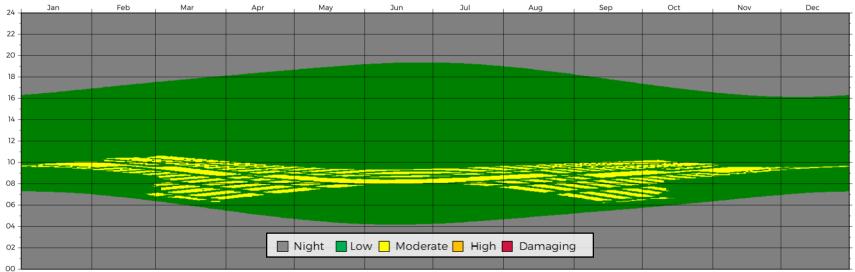




### **Facade Receptor F16**

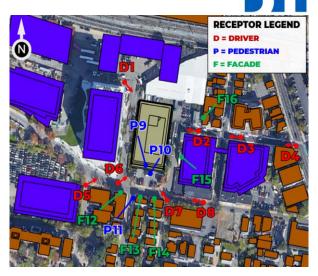
Receptor F16 was chosen to assess the visual impact associated with solar reflections affecting occupants of future 32 Ward St. (Approximately the 2<sup>nd</sup> floor).

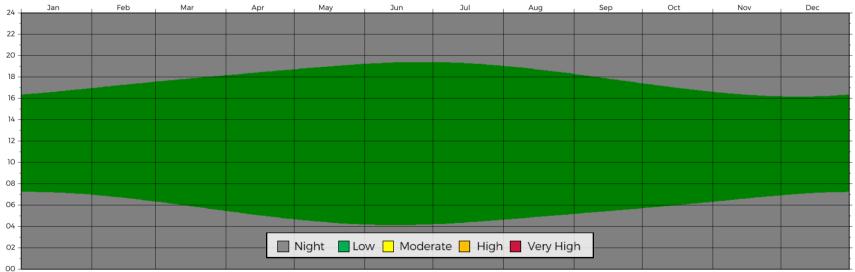




### **All Receptors**

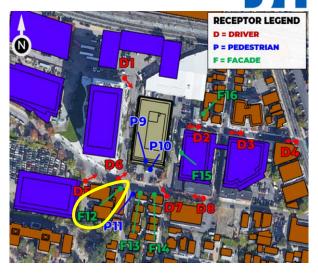
All reflection impacts at all receptors were found to have intensities below RWDI's short-term and human safety threshold values.

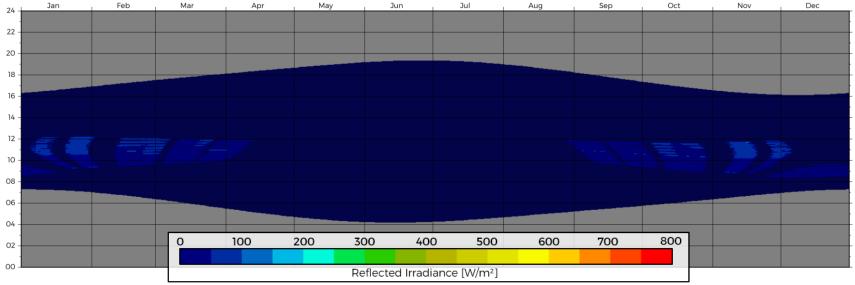




### **Facade Receptor F12**

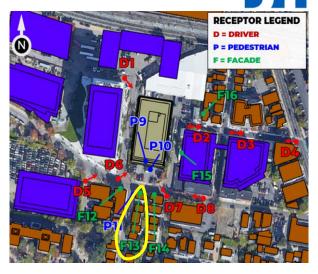
Receptor F12 was chosen to assess the thermal impact associated with solar reflections affecting occupants of 47 Hunting St. (Approximately the 2<sup>nd</sup> floor).

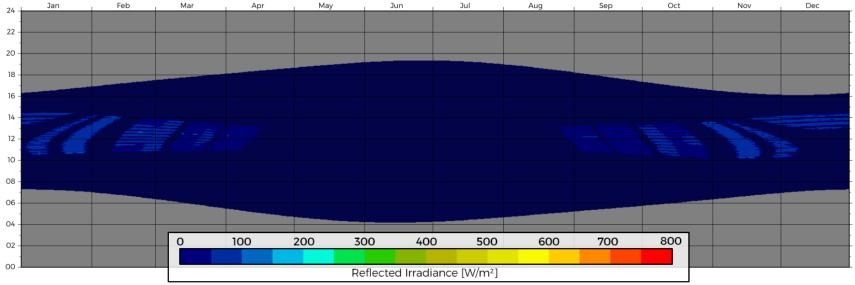




### **Facade Receptor F13**

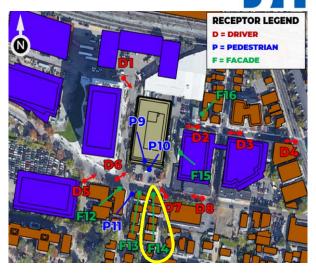
Receptor F13 was chosen to assess the thermal impact associated with solar reflections affecting occupants of 48 Hunting St. (Approximately the 2<sup>nd</sup> floor).

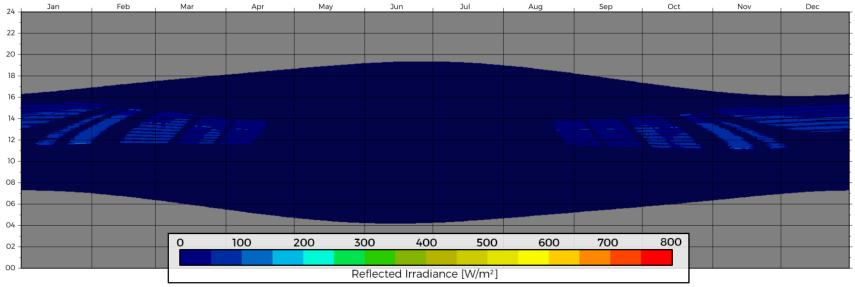




#### **Facade Receptor F14**

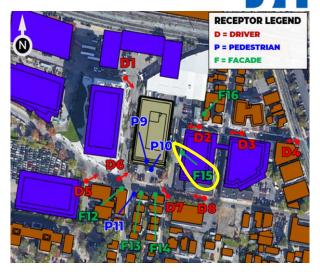
Receptor F14 was chosen to assess the thermal impact associated with solar reflections affecting occupants of 46 Hunting St. (Approximately the 2<sup>nd</sup> floor).

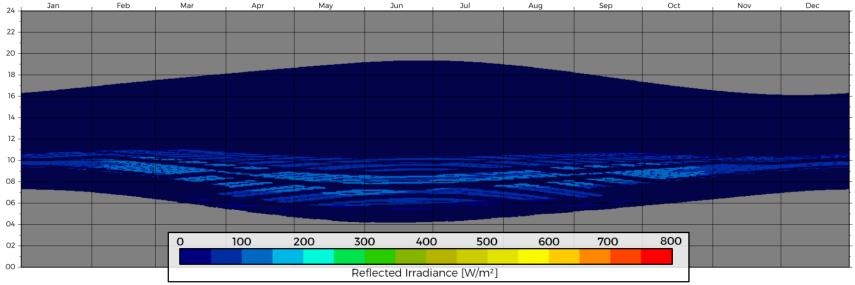




#### **Facade Receptor F15**

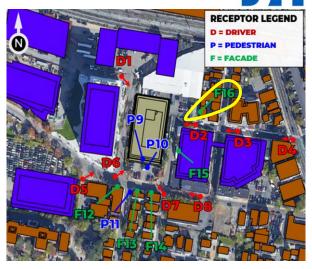
Receptor F15 was chosen to assess the thermal impact associated with solar reflections affecting occupants of future 45 South St. (Approximately the 2<sup>nd</sup> floor).

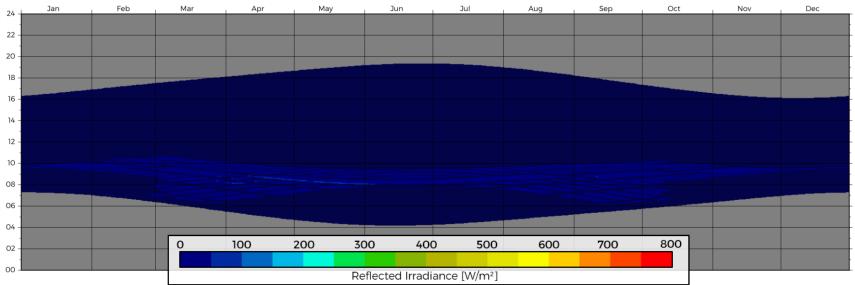




#### **Facade Receptor F16**

Receptor F16 was chosen to assess the thermal impact associated with solar reflections affecting occupants of future 32 Ward St. (Approximately the 2<sup>nd</sup> floor).







# APPENDIX B

**RWDI REFLECTION CRITERIA** 



#### **Visual Glare**

There are currently no criteria or standards that define an "acceptable" level of reflected solar radiation from buildings. RWDI has conducted a literature review of available scientific sources<sup>1</sup> to determine levels of solar radiation that could be considered acceptable to individuals from a visual standpoint.

Many glare metrics are designed for interior use and have been found to not correlate well with the glare impact humans perceive from direct sun or in outdoor environments. RWDI uses the methodology of Ho et al<sup>2</sup>, which defines glare impact based on a physical reaction rather than on a preference-based correlation.

Based on the intensity of the glare source and the size of the source in the field of view (Figure B1), the risk of that source causing temporary flash blindness (i.e. the after images visible after one is exposed to a camera flash in a dark room) faster than a person can reflexively close their eyes can be determined.

If this 'after-imaging' can occur faster than the human blink reflex, it presents an unavoidable effect on a person based on physiology rather than preference. This forms the basis of how we determine if a reflection is 'significant'.

This methodology was previously required by the United States Federal Aviation Administration (FAA) to determine the risk of glare to pilots and other airport staff under FAA Interim Policy 78 FR 63276. While the need to use this exact metric has since been relaxed under FAA Policy 86 FR25801, RWDI still feels that it is appropriate for this work.

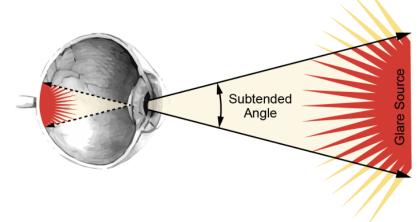


Figure B1: Schematic Illustrating the Subtended Angle of a Glare Source



#### **Visual Glare (cont'd)**

At the screening level, we conservatively take any reflections at least 50% of the intensity required to cause after-images as a "significant" reflection to be counted in the frequency analysis. In the detailed phase of work, we use the typical threshold level.

As a reference, point 1 on Figure B2 illustrates where looking directly at the sun falls in terms of irradiance on the retina (the back of the eye) and the size of the angle that the sun subtends in the sky. This puts it just at the border of causing serious damage before the blink reflex can close the eye.

The other points in Figure B2 correspond to the following:

- 2. Direct viewing of high-intensity car headlamp from 50 feet / 15 m
- 3. Direct viewing of typical camera flash from 7 feet / 2 m
- 4. Direct viewing of high-intensity car headlamp from 5 feet / 1.5 m
- 5. Direct viewing of frosted 60W light bulb from 5 feet / 1.5 m
- 6. Direct viewing of average computer monitor from 2 feet / 0.6 m

Note that the retinal irradiances described on this page are significantly higher than the irradiance levels discussed elsewhere in this report. This is because the human eye focuses the energy on to the retina. The magnitude of the increase is dependent on the geometry of the human eye and the source of the glare, both of which are computed per the Ho et al methodology.

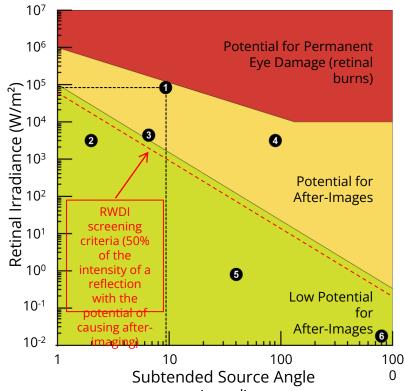


Figure B2: After-Imaging Potential From Various Glare Sources



#### **Visual Glare (cont'd)**

Significant glare impacts on the operators of vehicles or heavy equipment pose a particular risk to public safety due to operator distraction or reduction in their visual acuity. Thus, in the detailed analysis, RWDI assigns an assumed view direction to those engaged in "high-risk" activities (e.g. driving a car or flying a plane) as well as an assumed field of view.

The assigned directions and fields of view acknowledge that an operator is particularly sensitive to reflections emanating from the direction in which they are travelling (and therefore cannot safely look away from) and that the opaque elements of the vehicle will act to obstruct reflections beyond a given angle.

For drivers, the critical angle is taken to be 20° away from the direction of view<sup>3</sup>. Thus, any reflections emanating from within this 20° field of view are considered 'high' impacts, whereas reflections emanating from outside this cone are classified as 'moderate' impacts. This angle is adjusted as needed for impacts on other vehicles such as aircraft<sup>4</sup>, trains<sup>5</sup>, and other heavy equipment<sup>6</sup>.

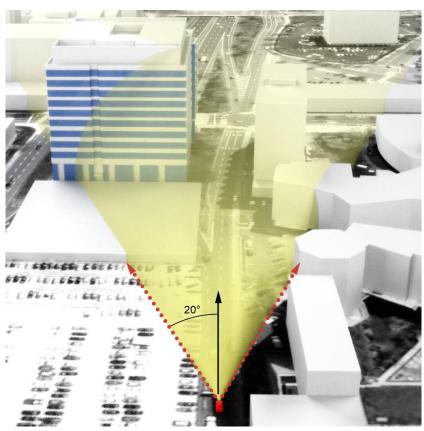


Figure B3: Illustration of a Driver's 20° Field of View



#### Thermal Impact (Heat Gain) on People

The primary sources for exposure limits to thermal radiation come from fire protection literature. However, there is currently inconsistency between different bodies regarding what level of exposure can be reasonably tolerated by people.

The U.S. National Fire Protection Association (NFPA) defines 1,700 W/m² as an upper limit for a tenable egress environment³; i.e. an individual could escape through such an environment successfully, though they would not necessarily emerge unscathed. The British Standards Institution8 sets their limit at 2,000 W/m², which "...is tolerable for ~ 5 min[utes]...". Other researchers9 have found that higher irradiance levels (3,500 – 5,000 W/m²) can be tolerated in outdoor environments for several minutes without issue.

The only current quantitative guideline specific to reflections comes from the City of London's Planning Note on 'Solar Convergence'<sup>10</sup>. Produced in conjunction with the UK Building Research Establishment (BRE), this document indicates that no areas should receive 10,000 W/m² or more for any duration, exposures above 2,500 W/m² should be limited to less than 30 seconds; and that "...areas with reflected irradiances above 1,500 W/m², and preferably those above 1000 W/m², should be minimized."

It should be noted that all these thresholds are guideline values only, and that in reality many factors (skin color, age, clothing choice, etc.) influence how a person reacts to thermal radiation.

Clearly, there are currently no definitive guidelines or criteria with respect to the issue of thresholds for exposure to thermal irradiance in an urban setting. We know this criterion should be lower than the thresholds set in the context of an individual escaping from a fire and greater than typical peak solar noon levels of 1,000 W/m² which people commonly experience.

Therefore, RWDI's opinion at this time, is that reasonable criteria is to establish 2,500 W/m² as a ceiling exposure limit, which reflection intensity should not exceed for any length of time; and 1,500 W/m² as a short term (10 minutes or less) exposure limit.



#### Thermal Impact (Heat Gain) on Property

The impact of solar irradiance on different materials is primarily based on the temperature gains to the material which can cause softening, deformation, melting, or in extreme cases, combustion. These temperature gains are difficult to predict as they are highly dependent on the convective heat transfer from air movement around the object and long-wave radiative heat transfer to the surroundings.

Generally, irradiance levels at or above 10,000 W/m² for more than 10 minutes are required to ignite common building and automotive materials in the presence of a pilot flame. That value increases to 25,000 W/m² when no pilot flame is present¹¹¹,¹²,¹³. However, some materials like plastics and even some asphalts may begin to soften and deform at lower temperatures. For example, some plastics can deform at a temperature of 140°F (60°C), or lower if force is applied. The applied force typically comes from the thermal expansion of the material, the force of gravity acting on the material or an external mechanical force (i.e. someone or something pushing or pulling on it).

Aside from the risk of damage to the material itself, a hot surface poses a safety risk to any person who may come into contact with it. This is particularly important in an urban context as the individual may not expect the object to be heated. NASA<sup>14</sup> defines an upper limit of 111°F (44°C) for surfaces that require extended contact time with bare skin. Surface temperatures below this limit can be handled for any length of time without causing pain.

That said, surfaces within the urban realm are routinely exposed to reflections from windows, metal panels and bodies of water without causing material damage or excessive heating.

Therefore, as this time, RWDI takes a conservative approach and uses a value of 1,000 W/m², consistent with a single (i.e. non-focused) reflection of the sun's peak intensity, as a baseline threshold for reflected irradiance on stationary objects.

However, this is simply a starting point. As noted, depending on the environmental conditions and material properties of the object/assembly other values may be used instead.



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