September 28, 2017

Mr. Brian P. Golden, Director
Boston Planning and Development Agency
One City Hall, Ninth Floor
Boston, Massachusetts 02201

Via: Hand Delivery

Reference: Notice of Project Change – Supplemental Filing
NorthPoint DPIR
Boston, Massachusetts

Dear Director Golden:

As you are aware, DivcoWest Real Estate Investments ("**DivcoWest**") submitted a Notice of Project Change ("**NPC**") for the portion of NorthPoint situated within the City of Boston on September 1, 2017. In that filing, DivcoWest referenced the fact that it would supplement the NPC with the reports on the subject matters of pedestrian wind, solar glare, daylighting and air quality impacts resulting from the Project referenced in the NPC. To that end, on the behalf of DivcoWest, we are pleased to submit the following reports received from Rowan Williams Davies & Irwin Inc. ("**RWDI**") to supplement the NPC:

- Final Report - Pedestrian Wind Study (RWDI # 1703124) for Parcels G and H – NorthPoint Site dated September 26, 2017;
- Final Report - Solar Reflection Study (RWDI # 1703124) for Parcels G and H – NorthPoint Site dated September 8, 2017;
- Final Report – Daylighting Study (RWDI # 1703124) for Parcels G and H – NorthPoint Site dated September 1, 2017; and
- Final Report – Air Quality (RWDI # 1703124) for Parcels G and H – NorthPoint Site dated September 26, 2017.

We offer the following brief overview of the findings of each of the above-referenced Reports:

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Pedestrian Wind:

A pedestrian level wind study was conducted for Buildings G and H, the purpose of which was to assess the effect of Buildings G and H on local wind conditions in the pedestrian areas around the Project Site. The Study involved wind simulations on a 1:3000 scale model for each of Buildings G and H and their respective surroundings. These simulations have been conducted in RWDI's boundary-layer wind tunnel at Guelph, Ontario, for the purpose of quantifying local wind speed conditions and comparing to appropriate criteria for gauging wind comfort in pedestrian areas. The Wind Study shows the 'unmitigated' condition without landscaping and other measures.

As noted in the Wind Study, wind speeds at most areas around the Project Site are expected to meet the wind safety criteria, but in certain limited portions of the ground plane in Cambridge and Somerville wind conditions would be higher than desired for passive pedestrian activity. Since commissioning the Wind Study, DivcoWest has added mitigation measures to the designs, and is in the process of having the Wind Study updated to reflect such mitigation efforts. DivcoWest will submit the updated Report to the BPDA upon its receipt thereof.

Solar Glare

The RWDI Solar Glare Study assessed potential reflection issues using software that determined the visual and thermal impacts of unobstructed solar rays on a 3D model, which provides a "worst case" scenario showing the full extent of when and where glare could ever occur by not taking into account dampening circumstances such as cloud cover and vegetation. A statistical analysis was then performed to assess the frequency and maximum intensity of the solar glare events occurring throughout the year. Based on the results of the screening analysis, 16 receptor points were selected to undergo a more detailed evaluation, with the points having been chosen to understand in detail how reflections from the development will impact drivers and pedestrians. The Study determined that as with any modern development, Buildings G and H naturally will create reflections in the urban realm, but the design of the buildings, including the planar nature of the facades and the low visible reflectance of the glazing, would reduce to severity and frequency of the impacts in the surrounding area and would have predicted impacts to drivers and pedestrians that are typical of any modern building in the urban context.

Daylighting – Sky View

RWDI's daylighting analysis considered the increased daylight construction caused by the construction of proposed Buildings G and H on currently vacant sites. Utilizing the Boston Redevelopment Authority Daylight Analysis ("BRADA") computer program, the Study determined that the impact on daylight of Buildings G and H are typical for an urban area as they are not significantly taller than any of other buildings proposed within the NorthPoint Project or in the surrounding vicinity. In fact, the Study found that the increases in daylight obstruction from

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the Buildings, which ranged from 0% to 66.1% is lower than the daylight obstruction caused by several existing buildings which ranged in their obstruction from 69.8% to 75.9%. Finally, the areas which are impacted see sky view losses of less than 1% and are confined to a radius of 300 feet from the Buildings. The Study determined that the impacts to skyviews are minor and consistent with what is seen elsewhere in the vicinity of the Project Site.

Air Quality

The air quality analysis undertaken by RWDI indicates that, in most instances, the dilution target was met for the emission-producing equipment utilized in each of the Buildings. In the instances where the dilution targets were not met and where potential odor exposures were noted, the Study made specific recommendations for addressing such matters, with which DivcoWest agrees. Additionally, the Air Quality Study noted that further evaluation of tenant specialty and cleanroom exhausts should be evaluated once the nature of such exhausts have been determined. DivcoWest will undertake such evaluations once the nature of the tenant specialty and cleanroom exhausts are better known and will update the Study accordingly.

DivcoWest looks forward to continuing working with members of the public, City leadership, the BPDA Board members and BPDA staff to make this project a success for the residents of Boston.

Very truly yours,

Darren M. Baird
Counsel for and on behalf of
DivcoWest Real Estate Investments

Enclosures

cc: Mark Johnson
John Weigel
John Rappaport
John Gelcich

FINAL REPORT

PARCELS G AND H - NORTHPOINT SITE

CAMBRIDGE, MA

SOLAR REFLECTION STUDY

RWDI # 1703124

September 26, 2017

SUBMITTED TO

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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

RWDI was retained to investigate the impact that solar reflections from the proposed buildings on Parcels G and H of the Northpoint development will have on the surrounding neighborhood.

Thermal Impacts

The planar facades of the proposed buildings on Parcels G and H are not predicted to focus sunlight in any particular area. Therefore, RWDI does not expect any significant thermal impacts (i.e. risks to human safety or property damage) to occur within the development nor in the surrounding neighborhood.

Visual Glare Impacts

Reflection impacts are generally predicted to not create significant impairment trains drivers and most motorists in the vicinity of the site. Some high impact reflections (i.e. those which may occur in a driver's field of view) are predicted to occur on some of the proposed streets immediately adjacent to Parcels G and H. The maximum duration of these impacts is at most 21 minutes and the average duration of the reflection impacts is 7 minutes or less. These impacts are also predicted to only be possible during isolated times and dates. Additionally, many of the impacts occur when the sun is already in the general direction of the driver's field of view, thus experiencing glare would not be an unexpected experience for a driver. The locations of these impacts are also on lower volume local roads rather than on busier streets.

Overall Impact

As with any modern development, the proposed buildings naturally create reflections in the urban realm. However, based on our experience, RWDI considers the predicted impact of these buildings' reflections to be typical of any modern building in an urban context.

2 INTRODUCTION

RWDI was retained to investigate the impact of solar reflections from the proposed Parcels G and H – Northpoint Site (project) in Cambridge, Massachusetts. The project involves the construction of a 250' tall building on Parcel G of the site, and a 179' tall building on Parcel H (Image 1).

RWDI evaluated the full build configuration to determine the combined effect of solar reflections from both Parcels G and H on the surrounding neighborhood.

This final report summarizes the study methodology, design criteria, results and recommendations from our study.

Image 1: Site plan – Aerial view of site and surroundings (courtesy of Google™ Earth)

3 BACKGROUND

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 (Image 2) which act to focus the reflected light in a single area. RWDI does not expect issues with solar focusing from this development as all surfaces on the buildings are planar.

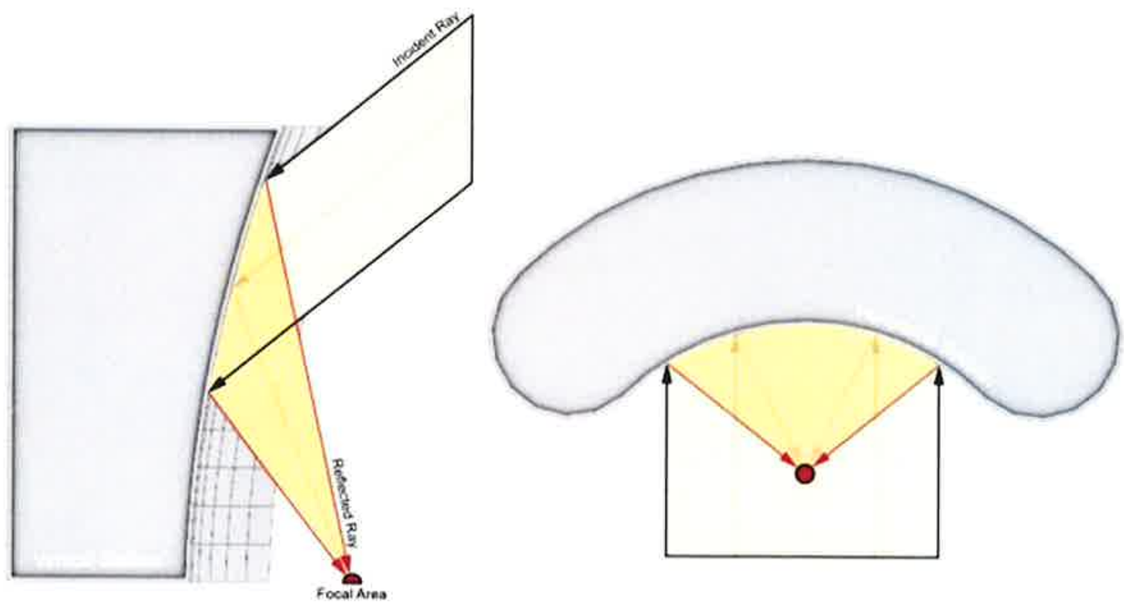


Image 2: Illustration of reflection focusing due to a concave facade shape

4 METHODOLOGY

4.1 Analysis Software

RWDI assessed the potential reflection issues using RWDI's proprietary Eclipse software by first developing a 3D model of the area of interest (as shown in Image 3). The model was subsequently subdivided into many smaller triangular patches, as shown in Image 4.

For each hour in a year, the expected solar position was determined, and "virtual rays" were drawn from the sun's location to each triangular patch of the 3D model. Each ray that was considered to be "unobstructed" was reflected from each building surface onto a horizontal plane 5 feet above ground level. The total reflected energy at that hour from all of the patches was computed and its potential for visual and thermal impacts was assessed.

Finally, a statistical analysis was performed to assess the frequency and maximum intensity of the glare events occurring throughout the year. Based on the results of the screening analysis, 16 representative receptor points were selected to undergo a more detailed evaluation. The points were chosen to understand in greater detail how reflections from the development will impact drivers and pedestrians

For each minute in a year, the expected solar position was determined. Each ray that was considered to be "unobstructed" was reflected from each building surface and tested for impact at each receptor. The detailed analysis allows for the prediction of when reflection impacts will occur, the duration and intensity of the impacts and the source of the reflections.

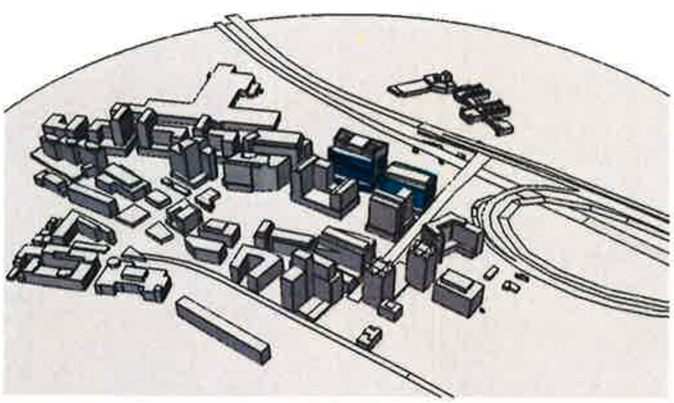


Image 3: Computer model of the proposed development (glazing colored) within the surrounding neighborhood

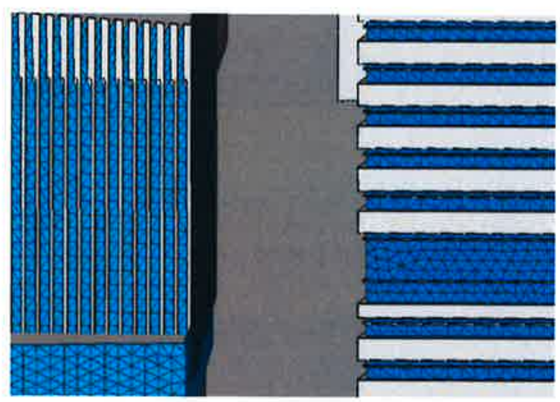


Image 4: Close-up view of the model, showing surface subdivisions

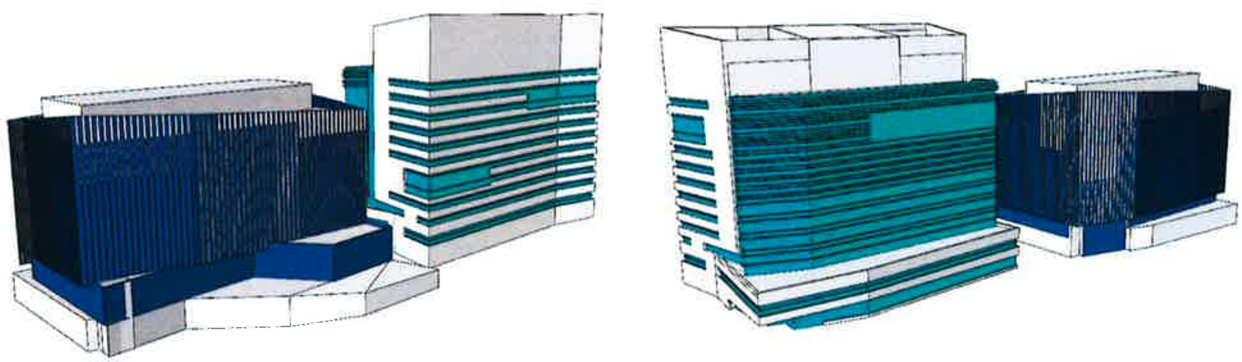
It is important to note that our analysis is based on "clear sky" solar data at the location of Boston Logan International Airport. This approach uses mathematical algorithms to derive solar intensity values for a given location, ignoring local effects such as cloud cover. This provides a "worst case" scenario showing the full extent of when and where glare could ever occur.

The results of our study are also 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.

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.

Only a single reflection from the development was included in the analysis. As such, light that has reflected off several surfaces is assumed to have a negligible impact.

The reflective properties of the glazing for Parcels G and H were determined based on information provided by Perkins + Will and NBBJ up to August 22, 2017. All glazing on Parcel G has been modelled as Viracon VRE1-59 1-1/8" thick insulated glazing units. They have a visible reflectance (relating to visual glare) of 31% and a full spectrum reflectance (which relates to heat gain) of 35%. All glazing on Parcel H has been modelled as Viracon VNE1-63 1-1/8" thick glazing units, with a visible reflectance of 11% and a full spectrum reflectance of 29%. Image 5 shows the location of the reflective materials on the facades. It is RWDI's understanding that all other surfaces on both buildings will not be specularly reflective.



View from east *View from west*

Image 5: Glazed locations on the building facade.

4.2 Criteria

The criteria with which RWDI assesses the impact of solar reflections are included as Appendix B.

5 RESULTS

5.1 Results - Screening Analysis

To understand the large-scale effects of any reflections from this development and to inform the locations of the receptors for the detailed analysis, an initial screening analysis was conducted for a large volume around the buildings.

The surrounding airspace within 1340 feet of Parcels G and H was divided into cubic volumes approximately 7 feet in size. Each volume was tested at hourly increments for an entire year to understand how often significant reflections impact those volumes, and the maximum intensity of reflected energy during the year. 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). Results are presented in Images 6-8 herein:

Peak Annual Reflected Irradiance

Images 6 and 7 display the annual peak intensity of all reflections emanating from the development at a typical pedestrian height (5 feet) above local grade over an entire year. In order to attain a better understanding of the impact of the solar reflections from the development, other factors must be considered such as the frequency and duration of the reflections. These factors are analyzed in detail in the next stage of the study. Two versions are included:

> ***Visible Spectrum Reflectance (Visual Glare):*** Image 6 displays the intensity of reflected visible light only. Depending on the ambient conditions, reflection intensities as low as 150 W/m² could be visible to people.
>
> ***Full Spectrum Reflectance (Heat Gain):*** Image 7 presents the total intensity of a reflection, including both visible light and thermal energy which relates to the overall 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). A typical intensity for direct sunlight is 800 W/m².

Percentage of Daylit Hours (or Frequency) of Reflected Light

Image 8 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 have been caused after imaging on a viewer (refer to Appendix B). As this criterion is visually based, the visible light reflectance of the facades was used.

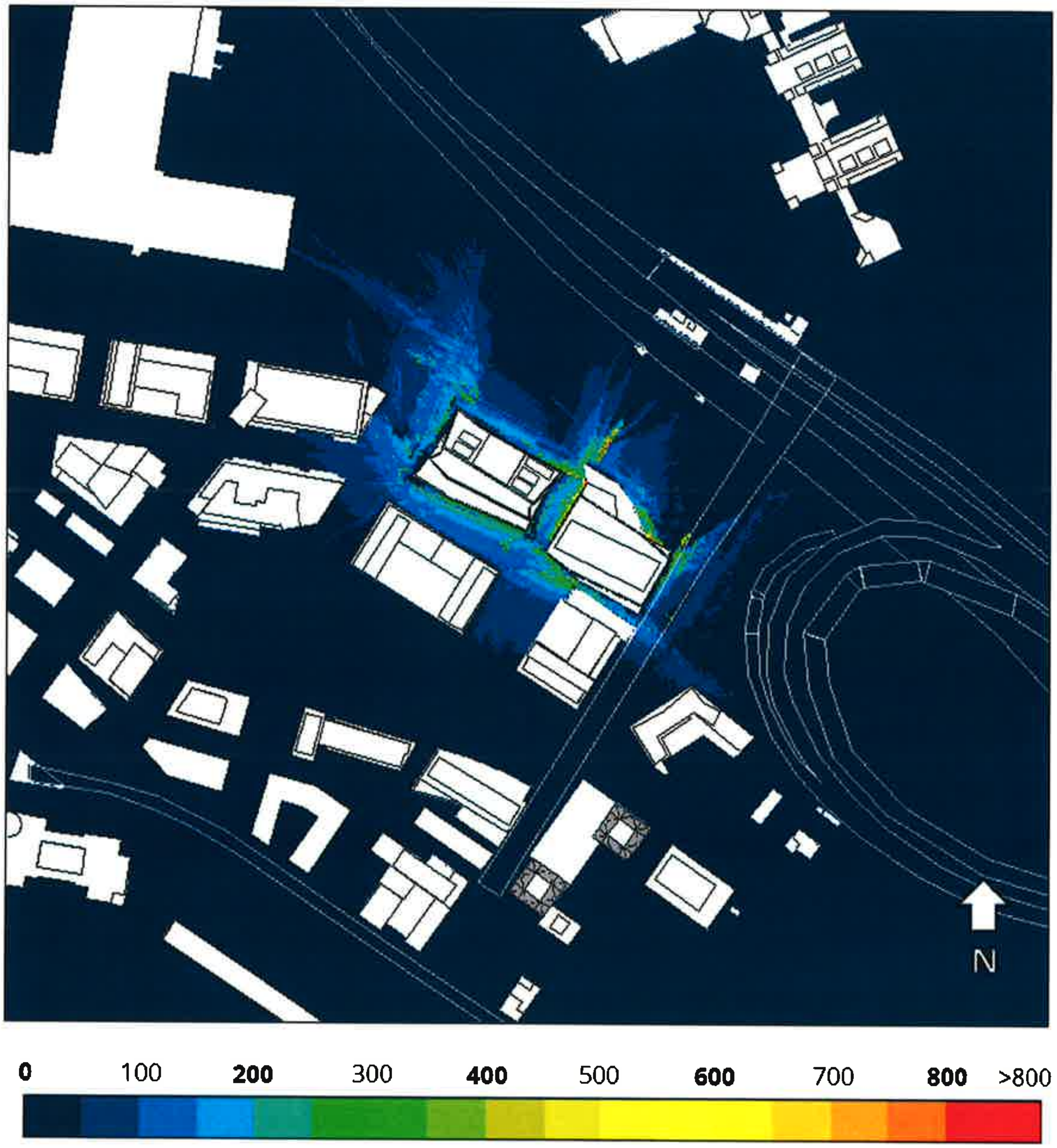


Image 6: Peak annual irradiance of reflected visible light

Note: Reflections as low as 150 W/m² may be visible to people depending on ambient light levels.

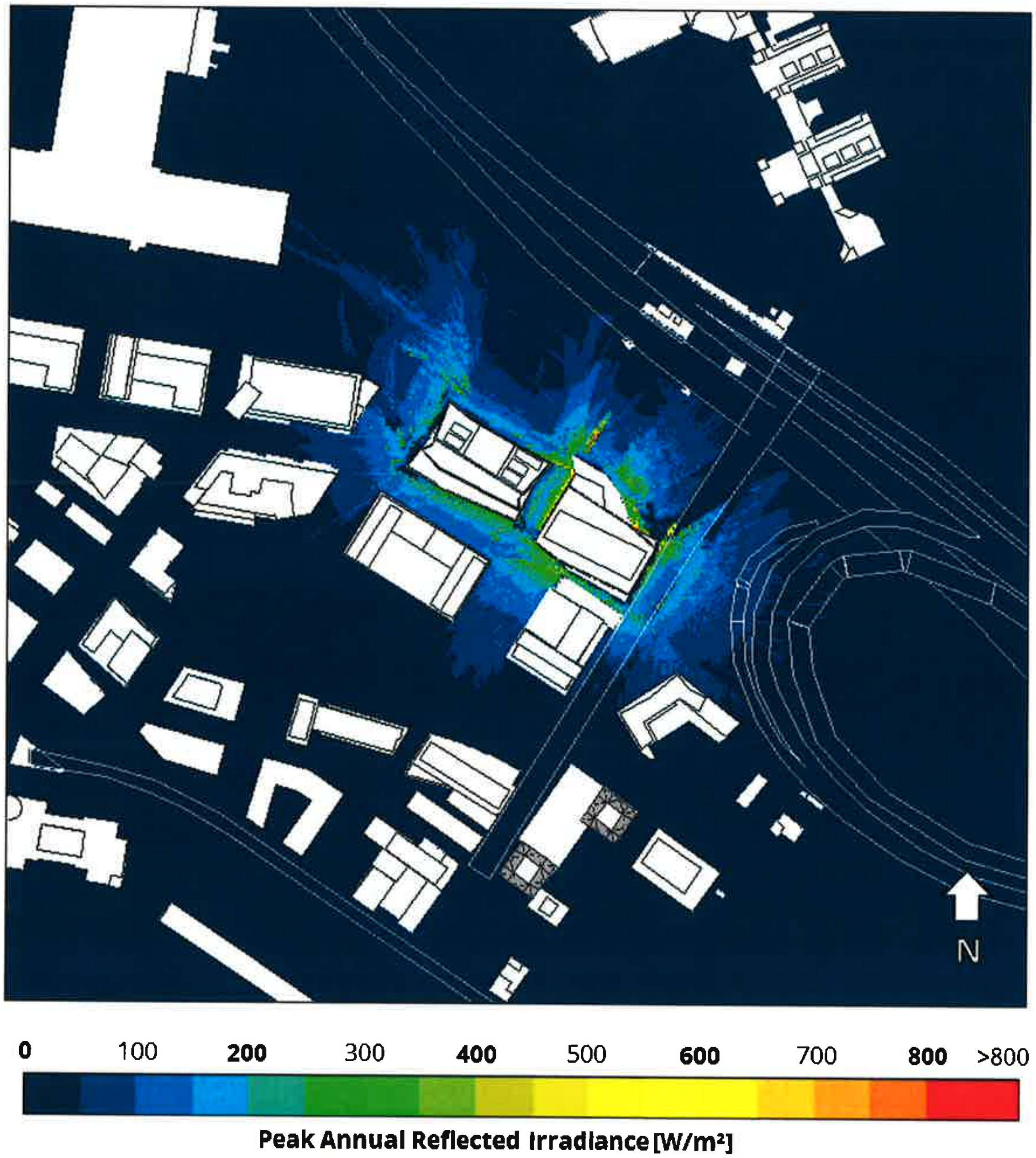


Image 7: Peak annual irradiance of reflected solar energy

Note: 800 W/m² represents a typical intensity of direct sunlight.

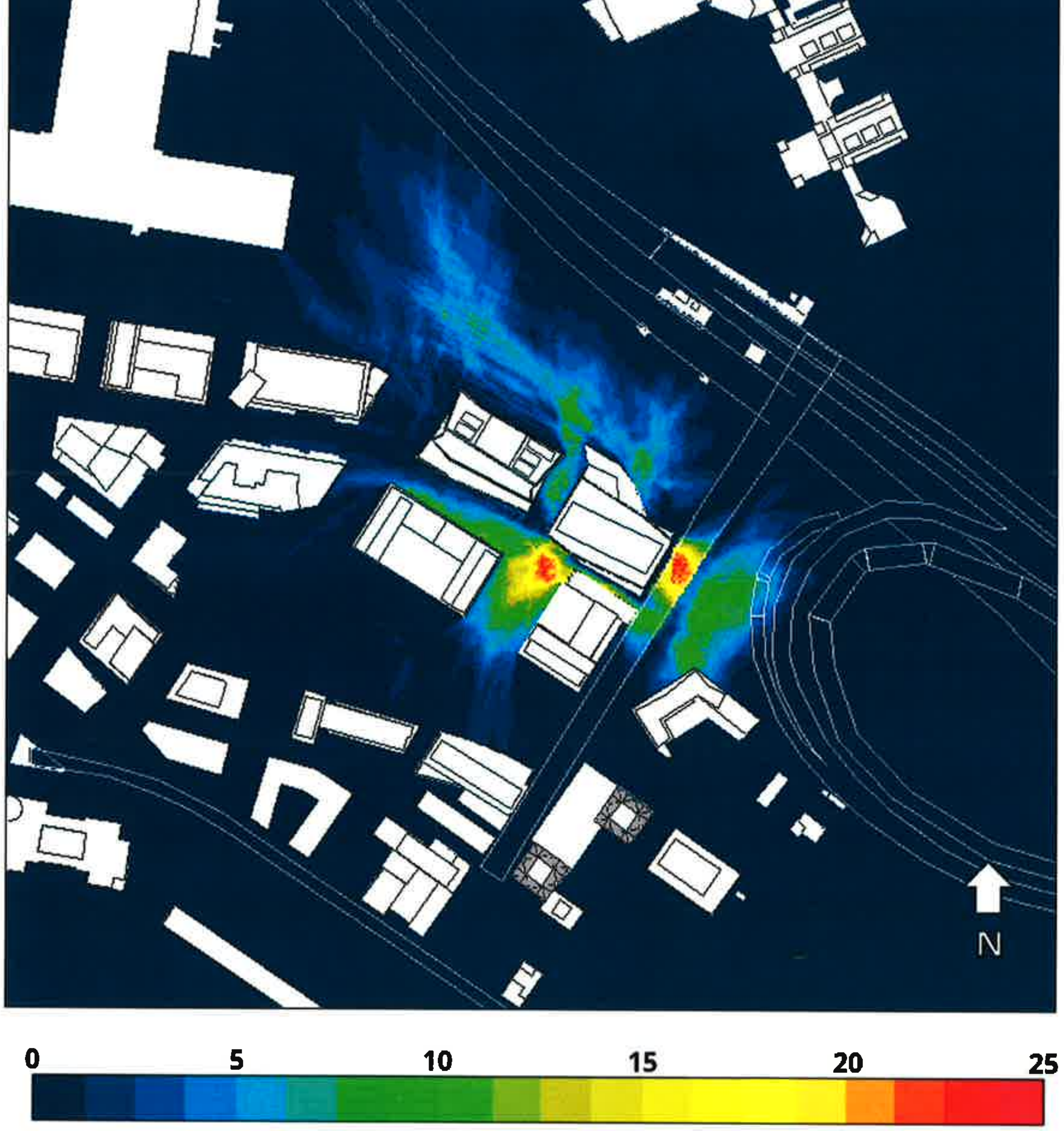


Image 8: Frequency of occurrence significant reflections

Based on this analysis we can make the following preliminary observations:

1. Like any contemporary development, the reflective surfaces of the proposed buildings on Parcels G and H are naturally causing solar reflections in the surrounding neighborhood.

2. The planar nature of the facades of the proposed buildings prevents their reflections from focusing (concentrating) in any particular area. Thus, results of the modeling analysis do not predict any heat gair issues on people or property.

3. Occupants of buildings located in the vicinity of Parcels G and H may experience visible reflections from the development. That being said, they are not predicted to pose a risk to safety, but are more likely to be considered a nuisance as the occupants can easily look away or close blinds.

4. At pedestrian level, reflections are predicted to fall most frequently onto the areas immediately south, southeast, and east of the development. The maximum frequency of glare occurrence found at pedestrian level is approximately 23% of daytime hours.

5. Reflections emanating from the southeast facades of Parcel H are expected to fall onto Gilmore Street. The reflections from this facade may impact drivers travelling south on the bridge as they approach the immediate vicinity of the Parcel H building. Similarly, there may be some impacts on drivers travelling on possible future streets on-site the development. The nature of those impacts is described in Section 5.2.

6. Reflections from the northern and western facades of Parcel G, as well as from northern facades of Parcel H, may affect drivers and passengers of trains travelling eastbound. The westbound trains are less likely to be affected. The exact frequency and duration of any potential impacts are described in Section 5.2.

7. The vertical fins on the current facade of Parcel H are a positive design feature that are predicted to aid in reducing the frequency and intensity of some glancing reflections, particularly to the east and south of the building. Similarly, the deep mullions and the horizontal fins on the facade of Parcel G effectively help in decreasing the frequency and intensity of impacts when sun is high in the sky, particularly to the areas immediately west and south of the development.

5.2 Results - Detailed Analysis

Based on the findings presented in Section 5.1, 16 points were selected for additional detailed investigation. The locations represent areas where the screening simulations predicted frequent reflection impacts or areas of high sensitivity to reflected light that should be studied for due diligence.

The point locations are illustrated in Image 9 and described in Table 1 below. For points that represent people undertaking tasks with a defined direction of view (i.e. drivers who must maintain forward visual contact) the assumed direction of view is indicated with an arrow.

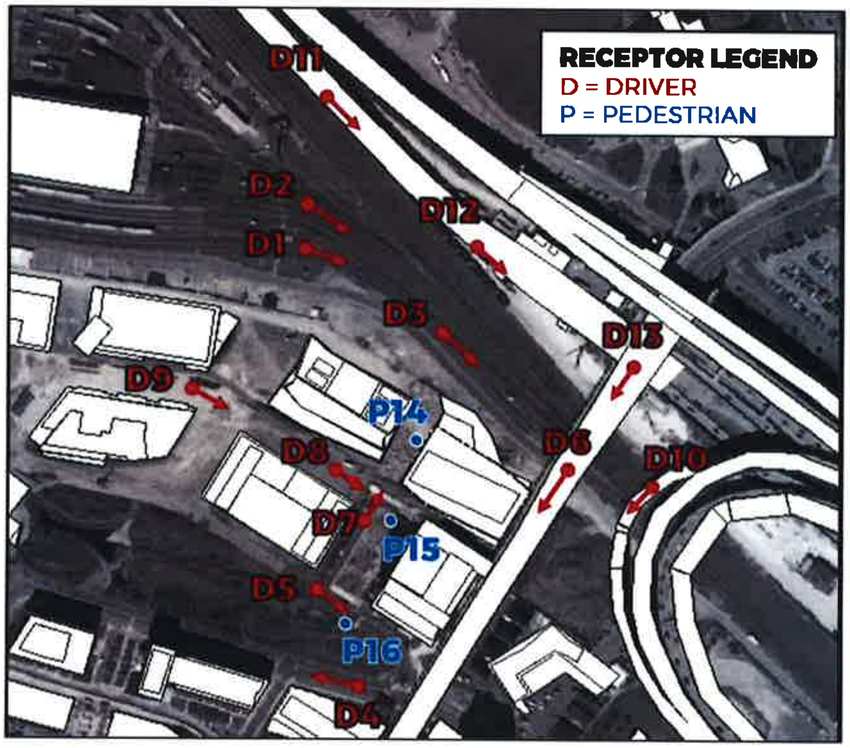


Image 9: Receptor location (For motorists and train divers, the assumed direction of view is indicated with an arrow)

Table 1: Proposed receptor descriptions

Receptor Number	Receptor Description	Receptor Number	Receptor Description
D1-D3	Train drivers traveling southeast	D10	Drivers traveling on Northern Expressway ramp
D4	Drivers traveling west on Northpoint Blvd.	D11-D12	Drivers traveling southeast on Northern Expressway
D5	Drivers traveling southeast on North St.	D13	Drivers traveling southwest or Gilmore Bridge
D6	Drivers traveling southwest or Gilmore Bridge	P14	Pedestrians between the two parcels
D7	Drivers traveling northeast on a possible future street towards the site	P15	Pedestrians in front of Parcel H
D8-D9	Drivers traveling southeast on a possible future street along the site	P16	Pedestrians at a park to the south of the development

The frequency, duration, and intensity of glare events throughout the year computed in the detailed analysis phase is illustrated using "annual glare impact diagrams" The frequency, duration, and intensity of glare events throughout the year computed in the detailed analysis phase is illustrated using "annual glare impact diagrams" (see Image 10 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 date, and the vertical axis indicates the hour of the day.

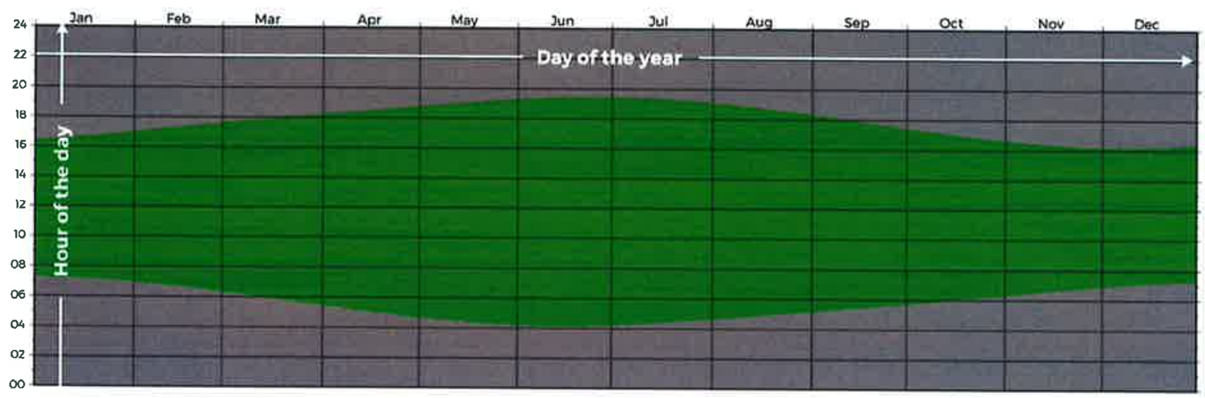


Image 10: Layout of a sample annual glare impact diagram

The full set of diagrams created for each point, along with a more detailed description of how to interpret the plots, is included as Appendix A of this document.

Table 2 summarizes the level of visual and thermal impact the reflections from the proposed Parcels G and H are predicted to have on their surroundings.

Table 2: Summary of overall predicted impacts at the selected receptor points

Receptor Number	Receptor Type	Assumed Activity Risk Level	Assumed Ability to Self-Mitigate	Peak Reflected Light Visual Impact	Sun in Field of View During High Impact Reflection (Y/N)	Duration / Number of Days with High Impact Reflection	Peak Reflected Solar Thermal Impact on People
D1-D6	Driver	High	Low	***Moderate***	N/A	N/A	***Low***
D7	Driver	High	Low	***High****	***No***	Longest Duration: **21 minutes** Average Duration: **7 minutes** No. of days: **81**	***Low***
D8	Driver	High	Low	***High*****	***Yes***†	Longest Duration: **8 minutes** Average Duration: **5 minutes** No. of days: **12**	***Low***
D9	Driver	High	Low	***High*****	***No***	Longest Duration: **5 minutes** Average Duration: **2 minutes** No. of days: **17**	***Low***
D10	Driver	High	Low	***Low***	N/A	N/A	***Low***
D11-D12	Driver	High	Low	***Moderate***	N/A	N/A	***Low***
D13	Driver	High	Low	***Low***	N/A	N/A	***Low***
P14-P16	Pedestrian	Low	High	***Moderate***	N/A	N/A	***Low***

Notes:

* The reflection impacts are typically short in duration and infrequent.

** The reflection impacts are all extremely short in duration and infrequent.

† The high impact reflections all occur when the sun would also be in a driver's field of view, thus reduced the impact that the reflections would likely have on a driver.

Image 11 illustrates the predicted source of the high impact glare at Receptor D7 at selected times. This is not an exhaustive list of all the potential sources of glare at all points, but rather serves to illustrate one of the key findings of this report.

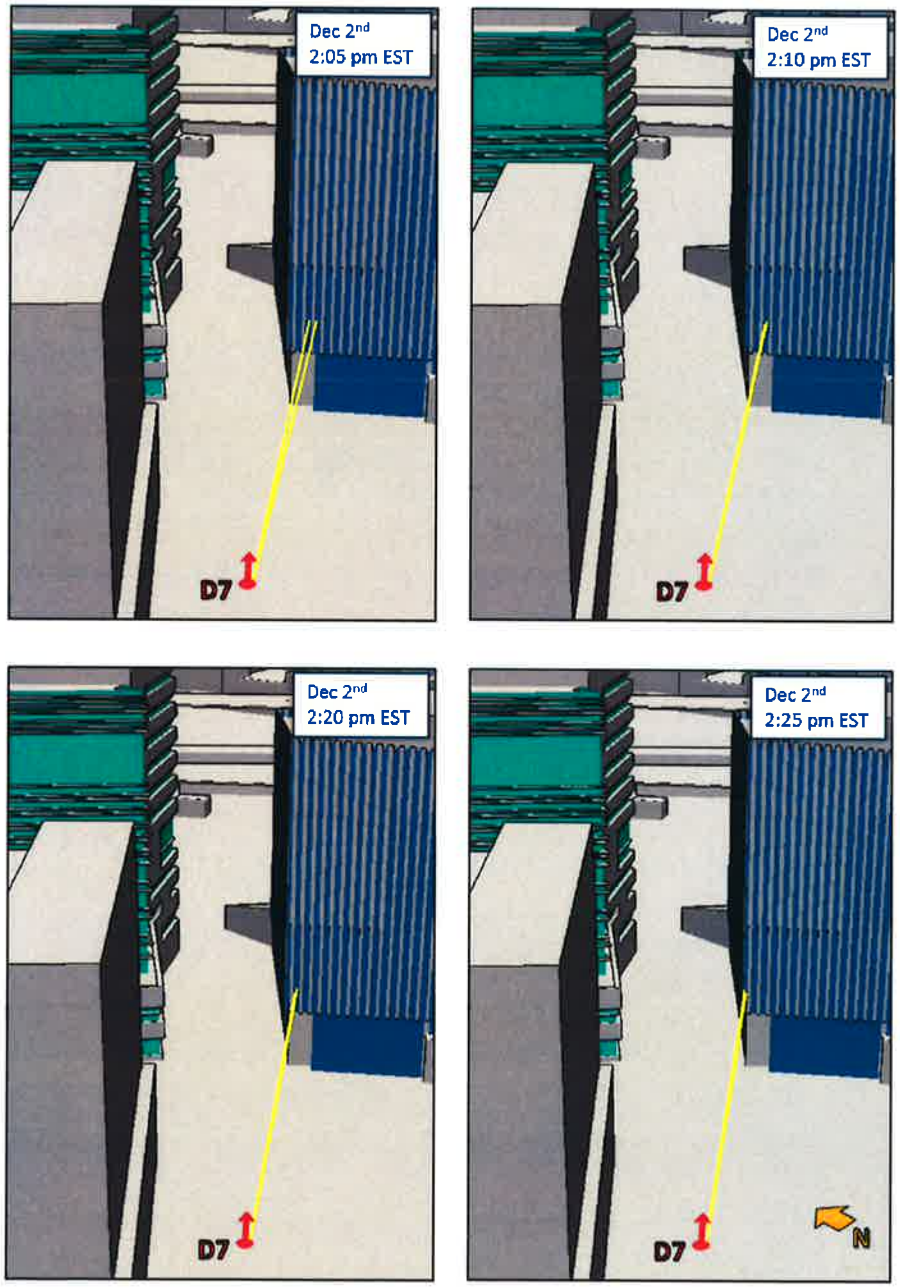


Image 11: Illustration of high impact reflections on Receptor D7 during the afternoon of Dec 2nd.

6 CONCLUSIONS

6.1 Thermal Impacts

The planar facades of the proposed buildings on Parcels G and H are not predicted to cause sunlight to 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 within the development nor in the surrounding neighborhood.

6.2 Visual Impacts

No buildings currently exist on the Parcels G and H sites; therefore, the addition of any glazed buildings will naturally increase the occurrence of reflections in the vicinity. The proposed buildings on Parcels G and H create impacts which RWDI considers typical for a modern building in an urban context. Some reflections with a high visual impact potential were noted. Some of these impacts are expected to alter a driver's experience since the glare occurs at times when the sun would not ordinarily be within a driver's field-of-view. In particular, a driver's experience could be altered when traveling northbound within the Northpoint development towards the Parcels G and H (receptor D7) during some afternoons in January, November, and December (refer to Image 11).

That said, these impacts are predicted to occur 81 days per year at most. They are also predicted to last up to 21 minutes in duration and occur only between 2:00 pm and 3:00 pm EST. It is RWDI's understanding that this road is for local access only, which is expected to experience a lower traffic volume compared to busier streets. Completely eliminating these impacts would require significant alterations to the facade.

Very brief and infrequent reflections with high impacts are also predicted to occur to drivers traveling southeast, immediately south of Parcel G (receptor points D8 and D9). These reflections are very short in duration and are expected to occur only in a few days in the early mornings during the winter months. In addition, the impacts at D8 are not expected to alter the driver's vision as the sun will already be in the driver's line of sight. While the sun is not directly within a driver's field of view during the high impacts at D9, this is due to the sun being shadowed by a surrounding building rather than due to its position in the sky. Thus, in both locations, experiencing glare while driving in that direction and at that time would not be totally unexpected.

Train drivers traveling southeast in the neighborhood of the development (refer to receptors D1-D3 in Appendix A) may experience some reflections from the development. Those reflections are not expected to align with a driver's field of view and thus are unlikely to impair their ability to safely drive.

For other drivers travelling within the vicinity of the development, visual glare impacts are predicted to be moderate at worst, and are not expected to pose a safety concern to drivers. For further details refer to the visual impact diagram for driver receptors D1-D13 illustrated in Appendix A.

Pedestrians within the development and occupants of buildings located in the vicinity of Parcels G and H may experience visible reflections from the development. That being said, they are not predicted to pose a risk to safety.

The vertical fins on the current facade design of Parcel H are a positive design feature that should aid in reducing the frequency and intensity of some glancing reflections, particularly to the east and south of the building. Similarly, the deep mullions and the horizontal fins on the facade of Parcel G effectively help in decreasing the frequency and intensity of impacts when sun is high in the sky, particularly to the areas immediately west and south of the development.

6.3 Overall Impact

As with any modern development, the proposed buildings naturally create reflections in the urban realm. However, the design of the buildings, including the planar nature of the facades and the low visible reflectance of the glazing, acts to reduce the severity and frequency of the impacts in the surrounding area.

Many of the predicted impacts are caused by the natural enhancement of glazing reflectivity due to the angle at which light strikes the glass. Thus, these impacts would likely remain even for glazing with lower visible reflectances. Selecting glazing with a higher visible reflectance would potentially increase the frequencies and durations at which these impacts occur.

Based on our experience, we would consider the predicted impact of this building's reflections to be typical of any modern building in an urban context.

7 APPLICABILITY OF RESULTS

The analysis was conducted based on the geometry provided by Perkins + Will and NBBJ Architects to RWDI up to August 22, 2017. The surroundings model was developed based on data made available by the City of Boston. It should be noted that this study is highly dependent on building geometry, and any significant changes to the building's geometry will likely require a new analysis.

The results presented in this report are highly dependent on both the form and materiality of the facades. Should there be any design changes, including on the facades, RWDI should be contacted and requested to review their potential impact on the conclusions of this report.

APPENDIX A

APPENDIX A: GLARE IMPACT DIAGRAMS

A.1 Presentation of Results - General

The frequency, duration, and intensity of glare events throughout the year computed in the detailed analysis phase is illustrated using "annual glare impact diagrams" (see Figure A.1 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 date, 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.

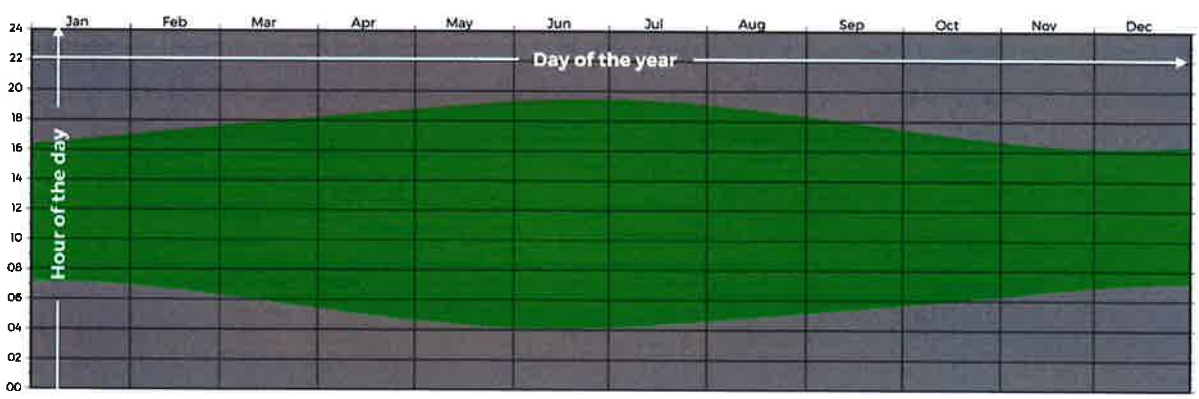


Image A1: Layout of Sample Annual Glare Impact Diagram

A.2 Presentation of Results – Visual Impacts

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.

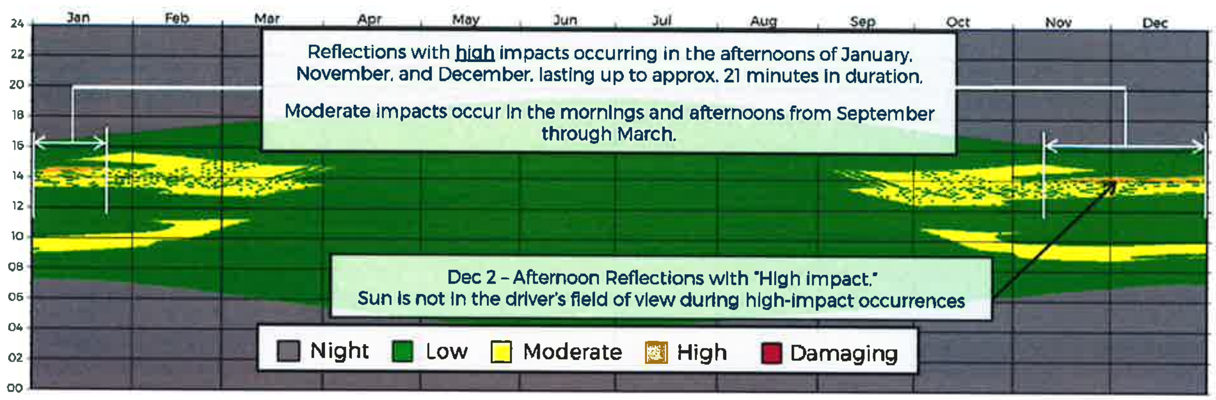


Image A2: Example of Annual Visual Impact Diagram – Receptor D7

A.3 Presentation of Results – Thermal Impacts on People

Low: Either no significant reflections occur or the reflection intensity is below the short-term exposure threshold of 1500 W/m².

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/m² but below 3500 W/m². This level of exposure to bare skin would lead to the onset of pain within 30 seconds.

Very High: Reflection intensity exceeds 3500 W/m². This level of exposure leads to second degree burns on bare skin within 1 minute.

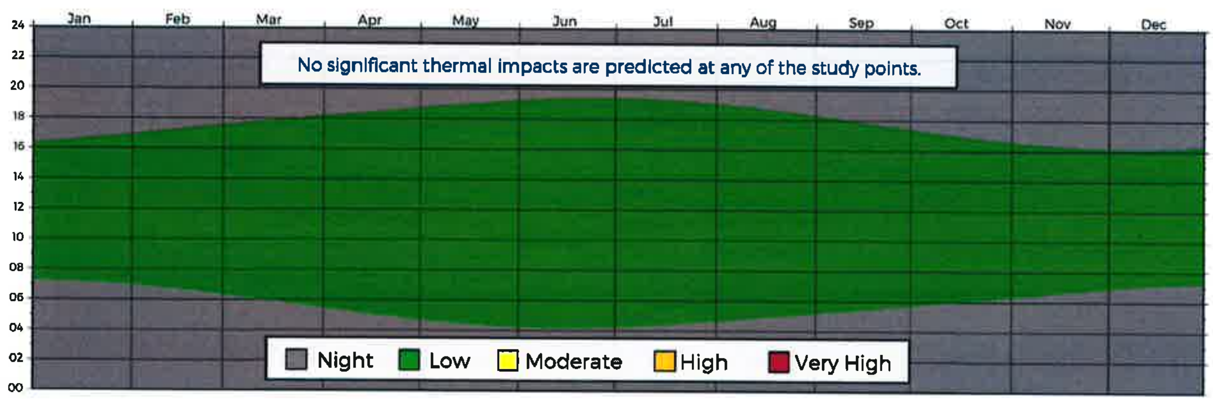
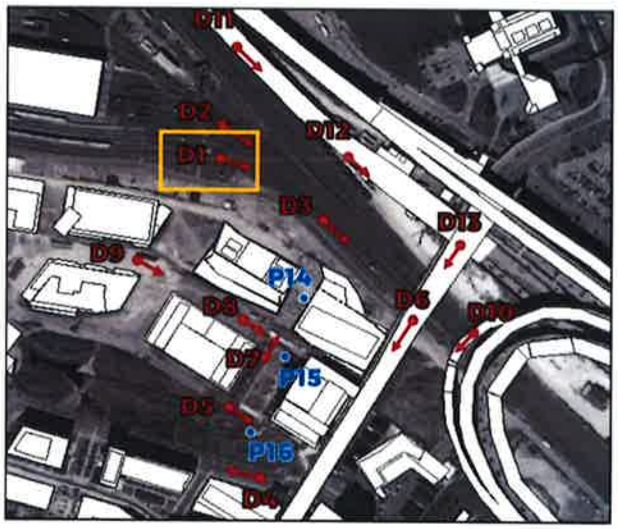


Image A3: Annual Thermal Impact Diagram – All Receptors

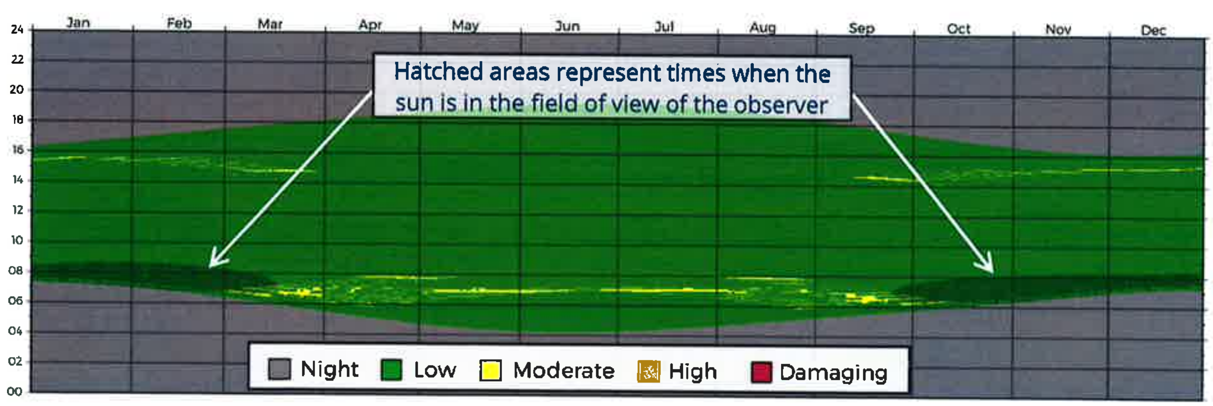
A.4 Annual Visual Impact Plots

A.4.1 Driver Receptor D1

Receptor D1 was chosen to assess the visual risk associated with solar reflections affecting train drivers traveling southeast.

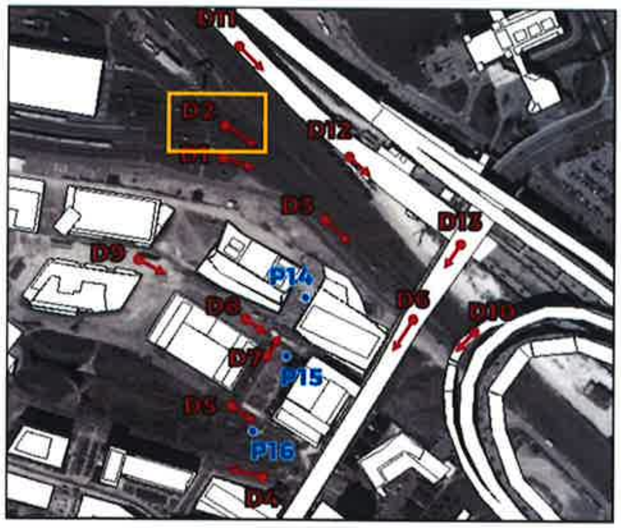


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

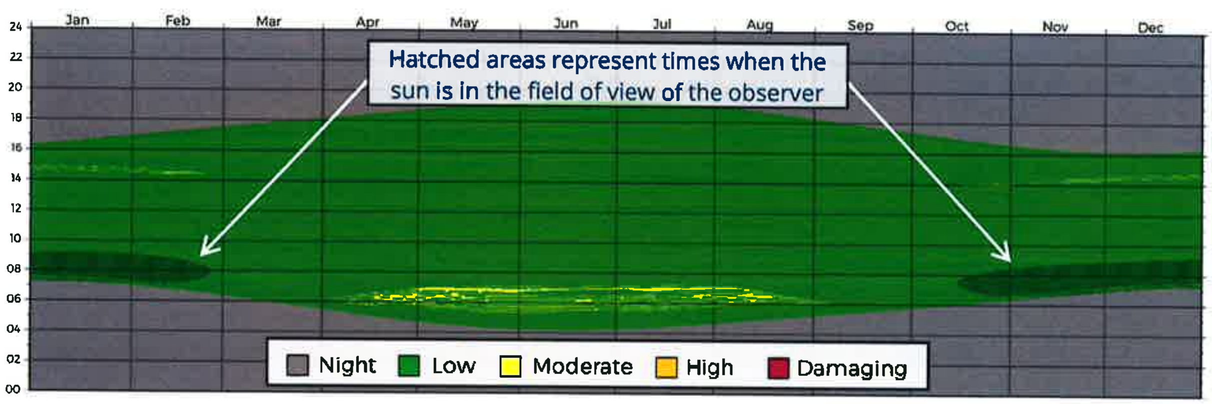


A.4.2 Driver Receptor D2

Receptor D2 was chosen to assess the visual risk associated with solar reflections affecting train drivers traveling southeast.

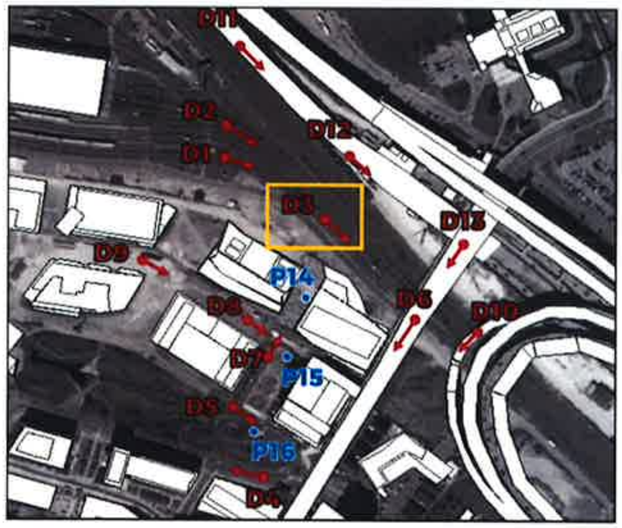


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.



A.4.3 Driver Receptor D3

Receptor D3 was chosen to assess the visual risk associated with solar reflections affecting train drivers traveling southeast.



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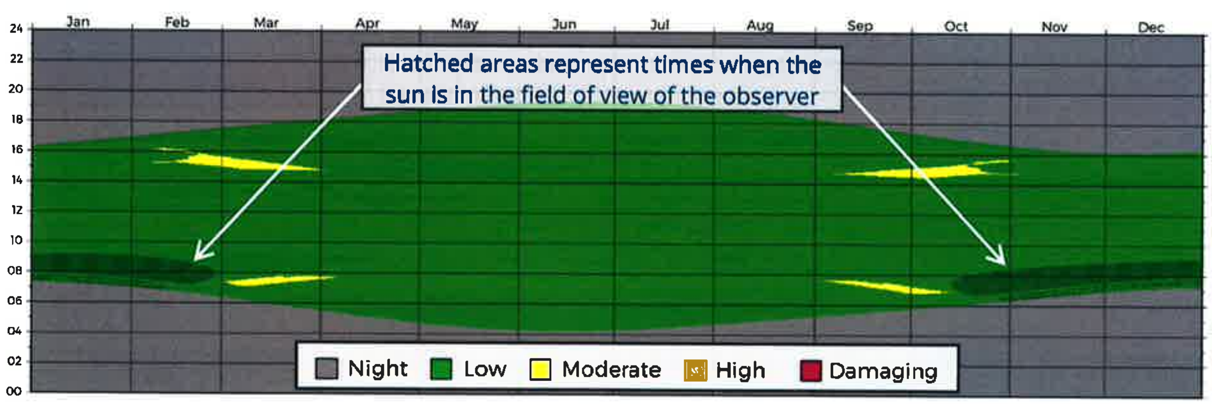
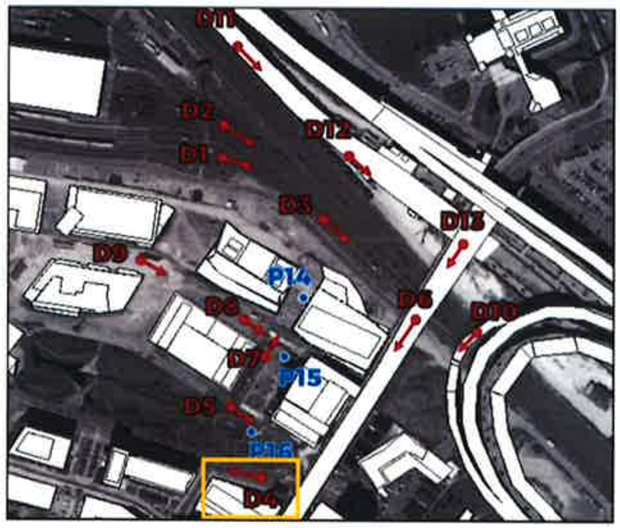


A.4.4 Driver Receptor D4

Receptor D4 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling west on Northpoint Blvd.



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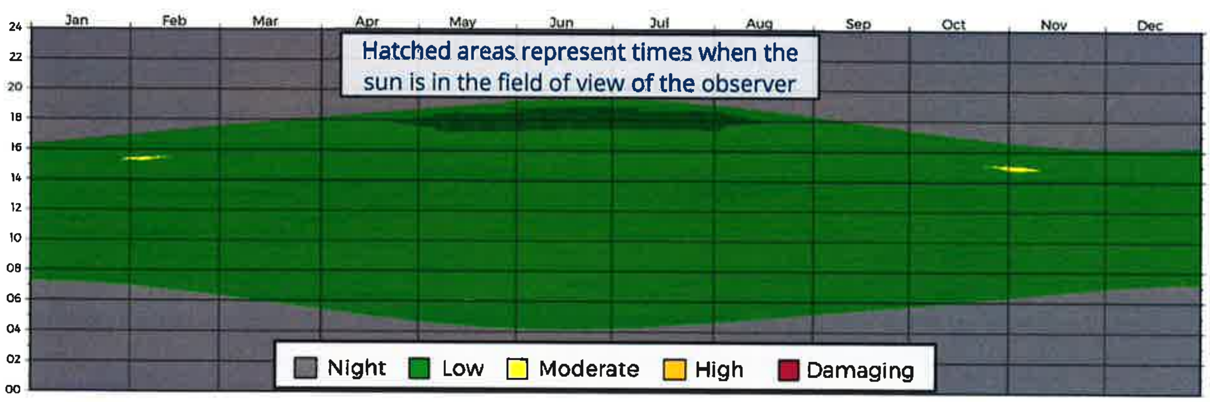
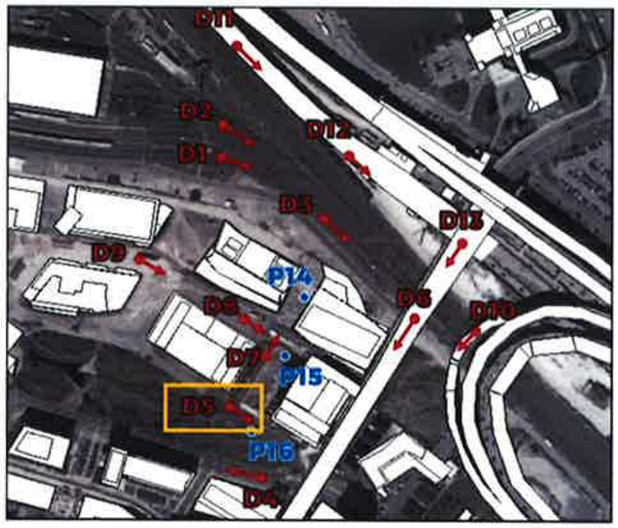
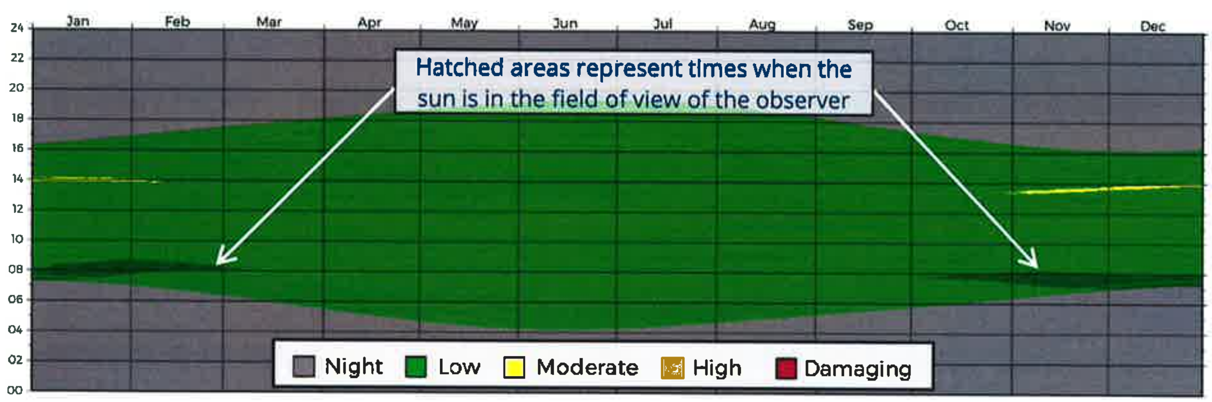


A.4.5 Driver Receptor D5

Receptor D5 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southeast on North St.

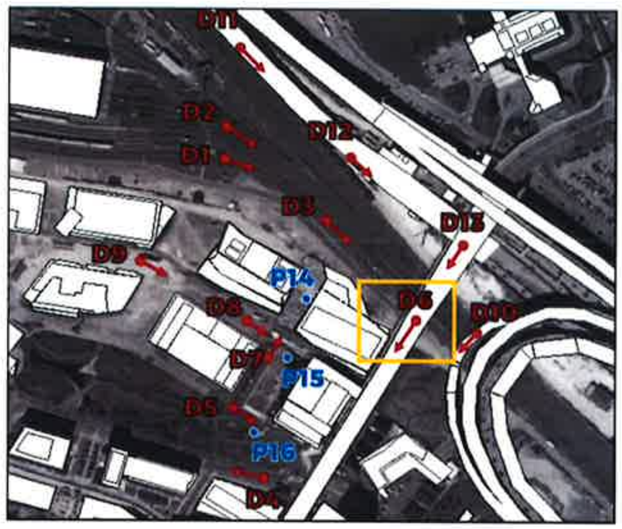


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

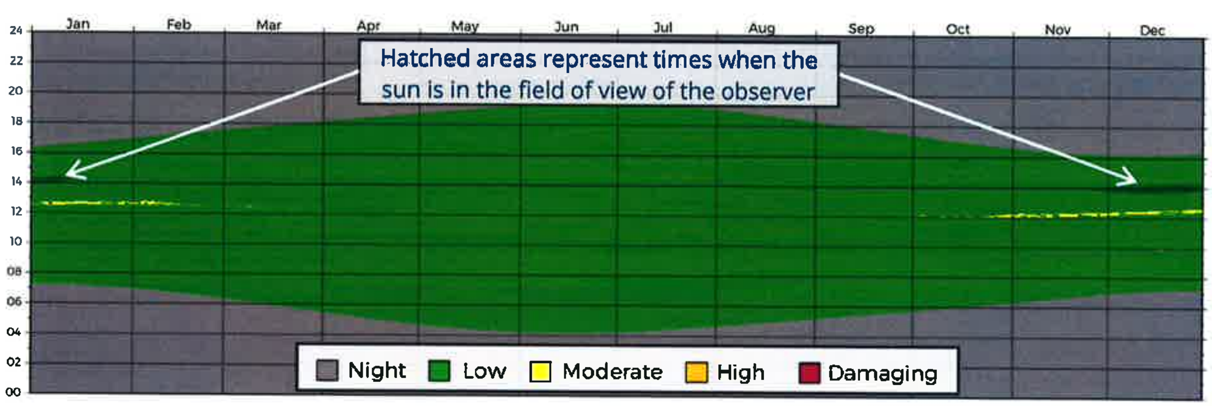


A.4.6 Driver Receptor D6

Receptor D6 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southwest on Gilmore Bridge.

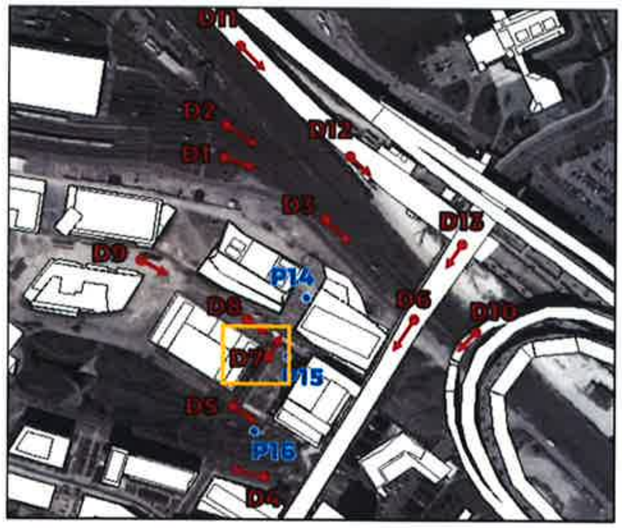


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

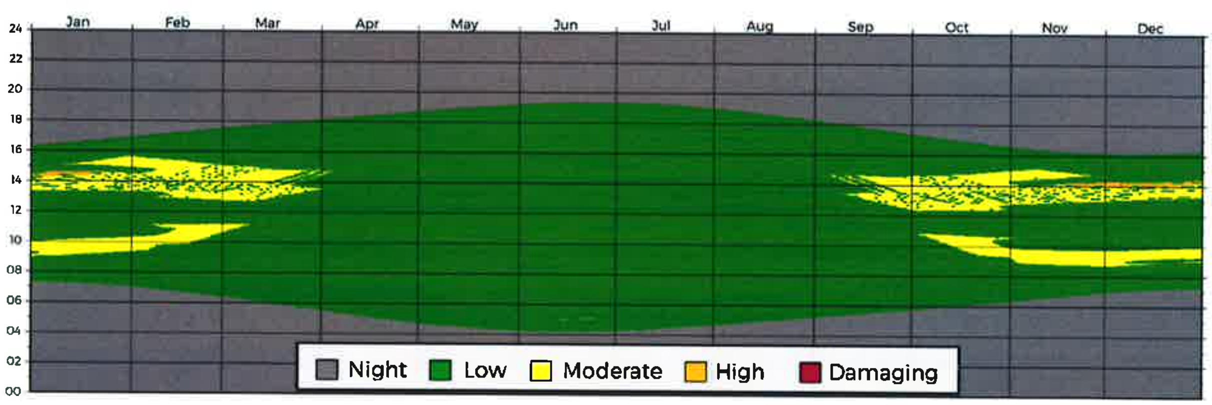


A.4.7 Driver Receptor D7

Receptor D7 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling northeast on a possible future street towards the site.

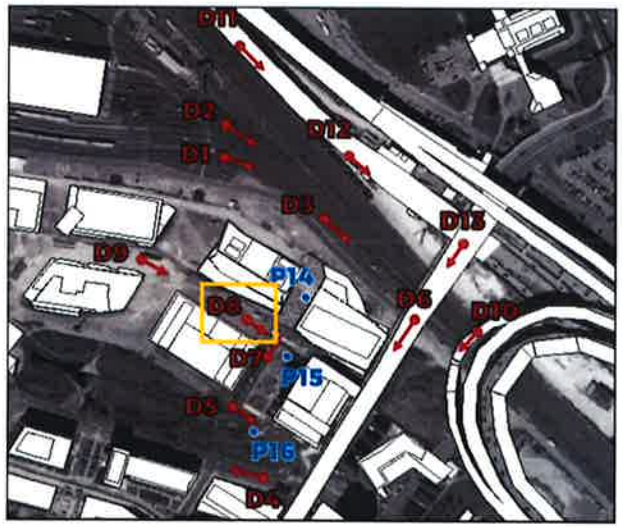


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

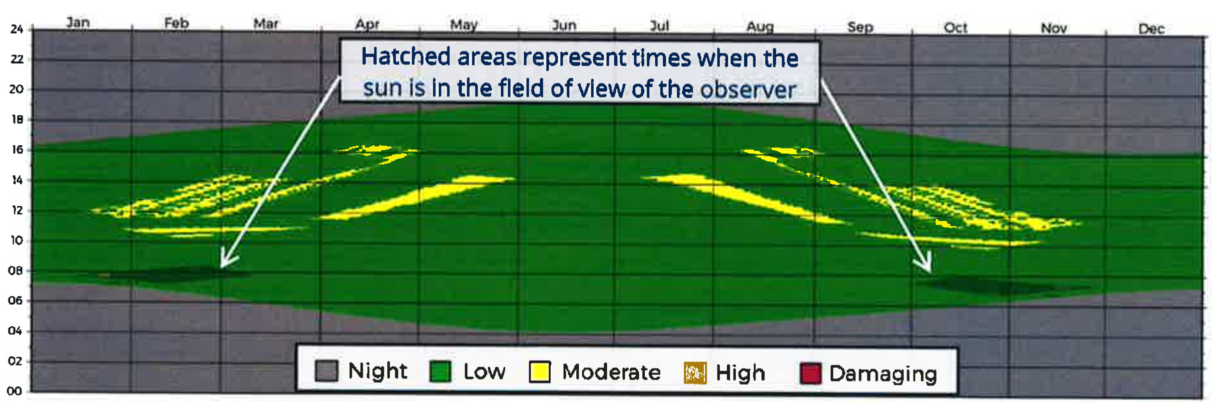


A.4.8 Driver Receptor D8

Receptor D8 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southeast on a possible future street along the site.

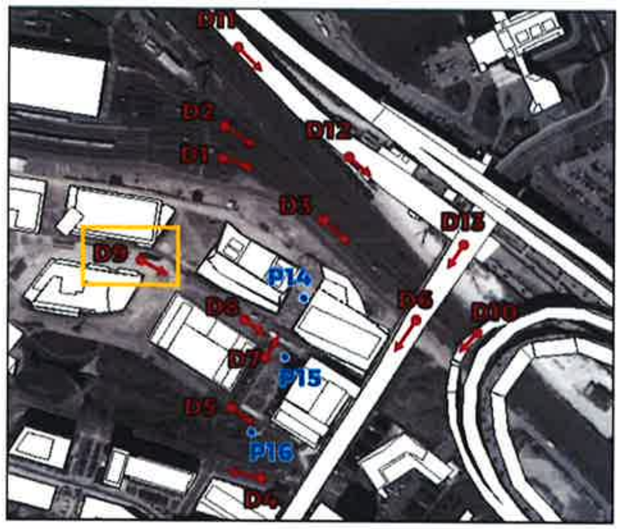


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

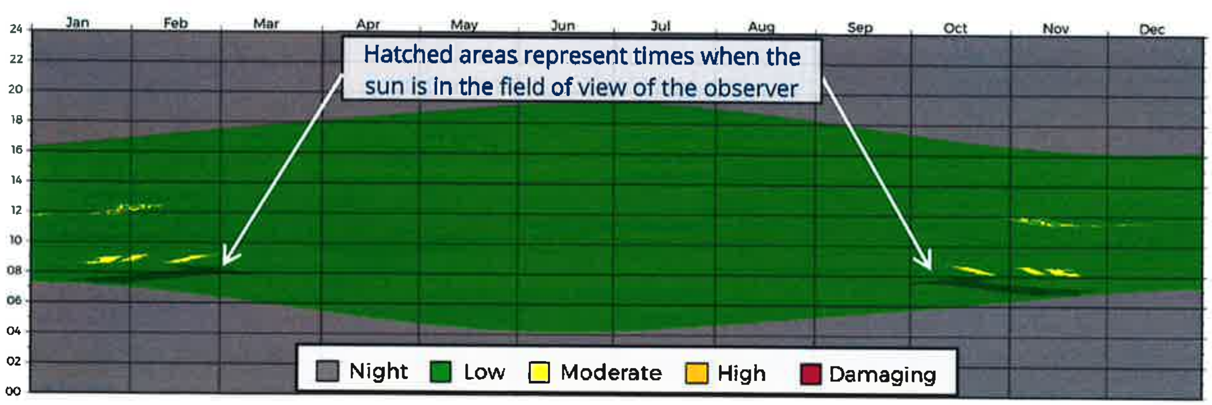


A.4.9 Driver Receptor D9

Receptor D9 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southeast on a possible future street along the site.

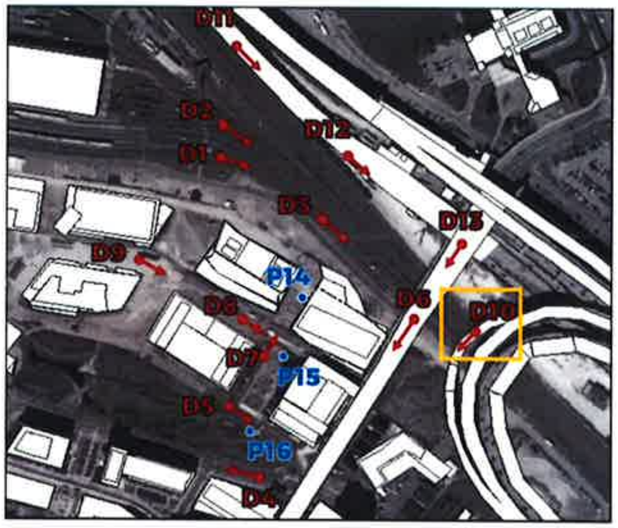


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.



A.4.10 Driver Receptor D10

Receptor D10 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling on Northern Expressway ramp.



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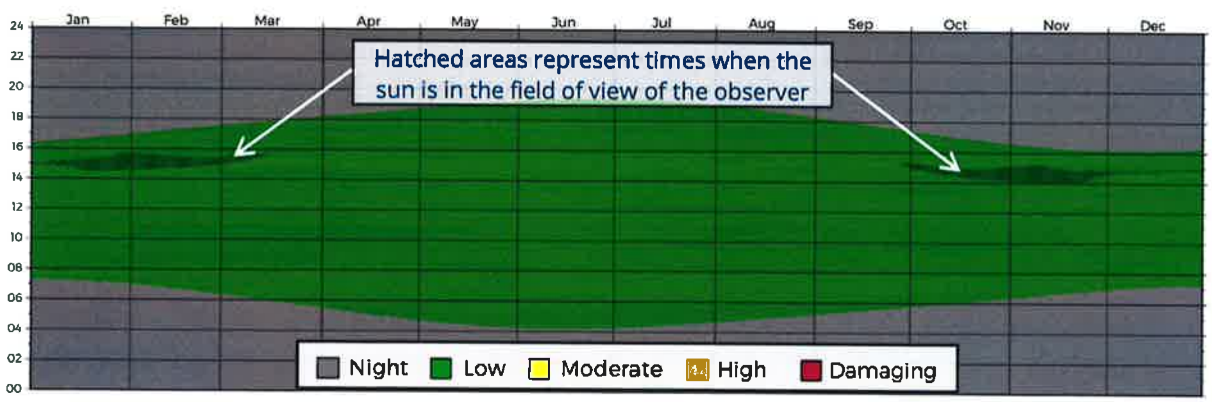
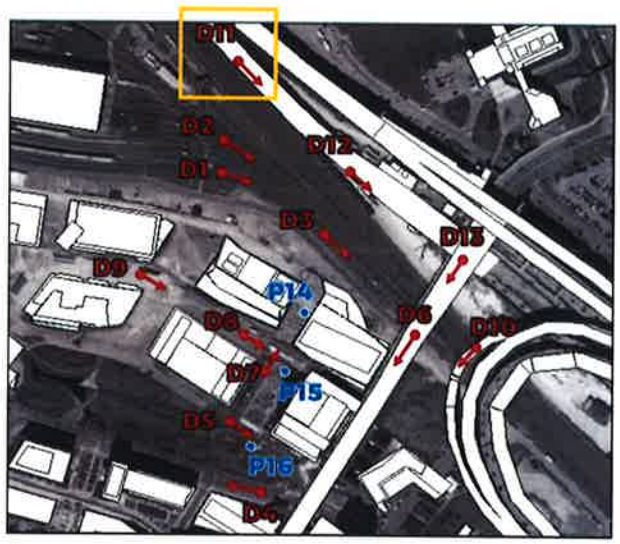


A.4.11 Driver Receptor D11

Receptor D11 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southeast on Northern Expressway.



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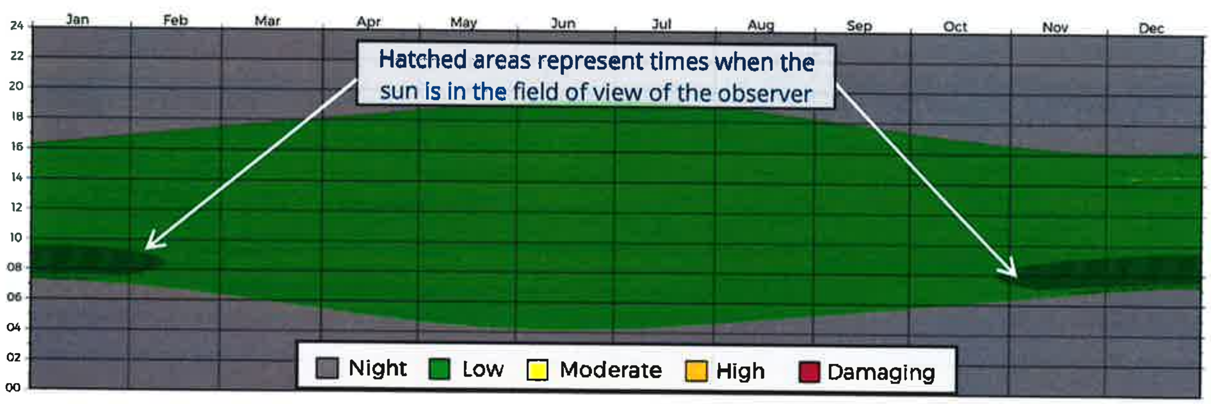
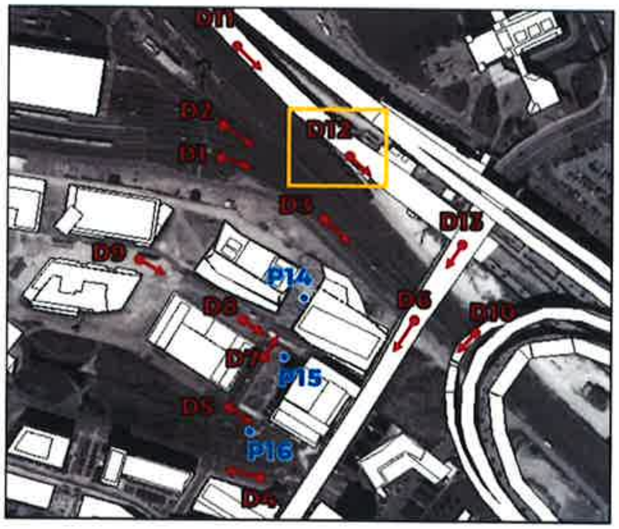


A.4.12 Driver Receptor D12

Receptor D12 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southeast on Northern Expressway.



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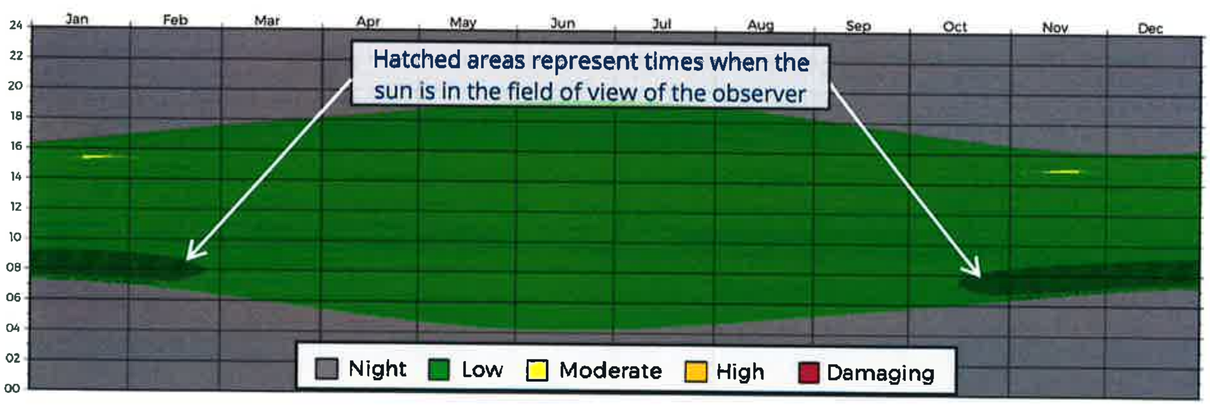
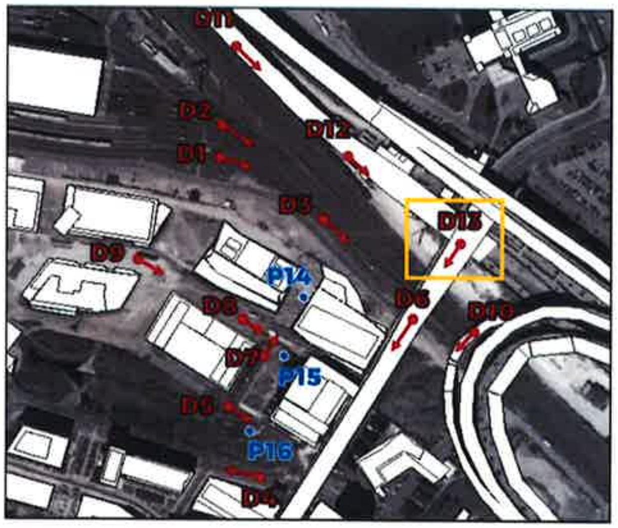


A.4.13 Driver Receptor D13

Receptor D13 was chosen to assess the visual risk associated with solar reflections affecting drivers traveling southwest on Gilmore Bridge.



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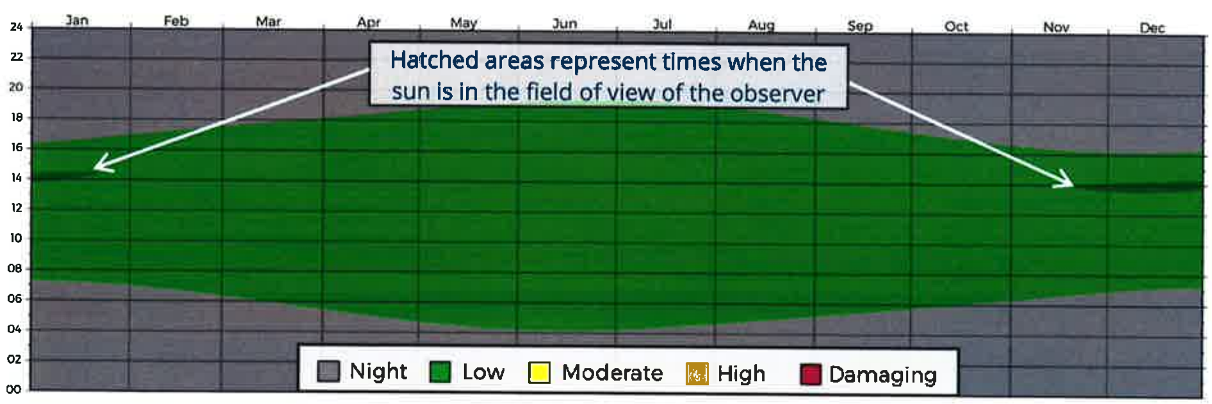
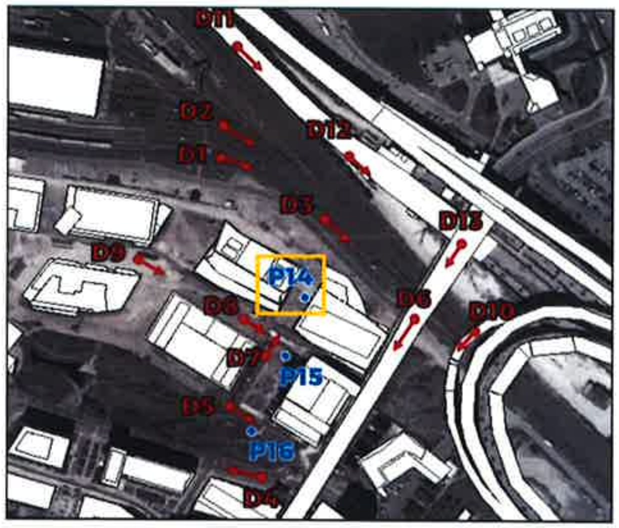
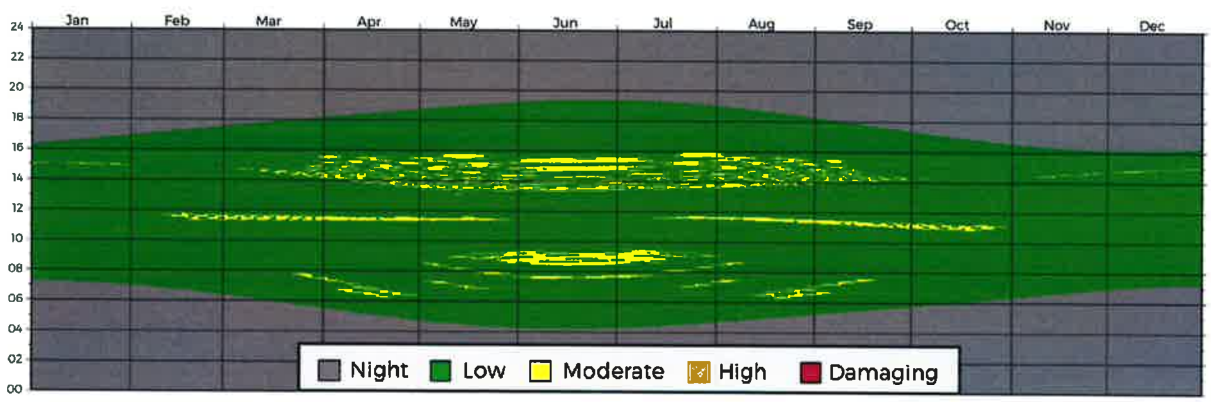


A.4.14 Pedestrian Receptor P14

Receptor P14 was chosen to assess the visual risk associated with solar reflections affecting pedestrians within the development between the two parcels.

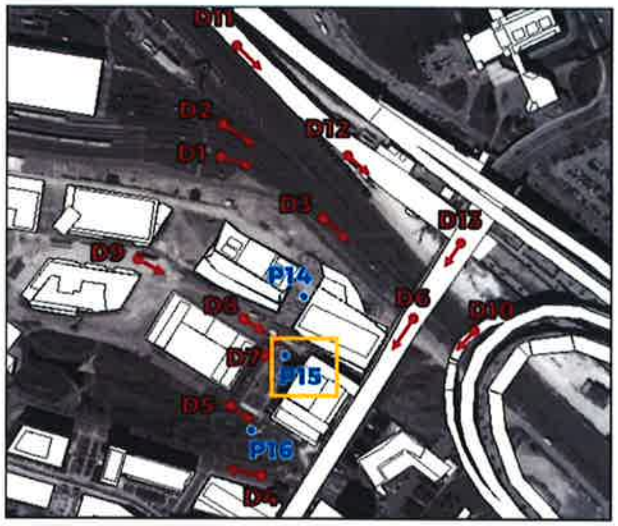


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.



A.4.15 Pedestrian Receptor P15

Receptor P15 was chosen to assess the visual risk associated with solar reflections affecting pedestrians in front of Parcel H building.



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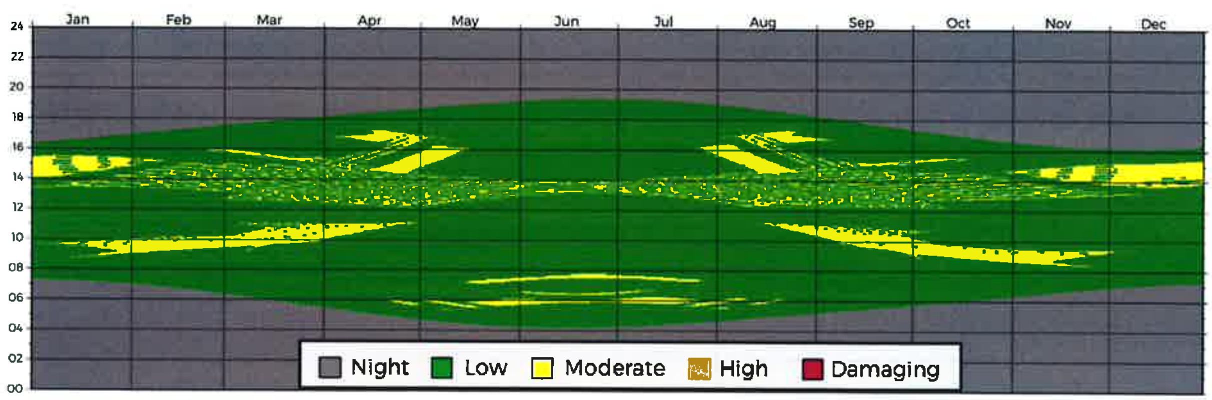
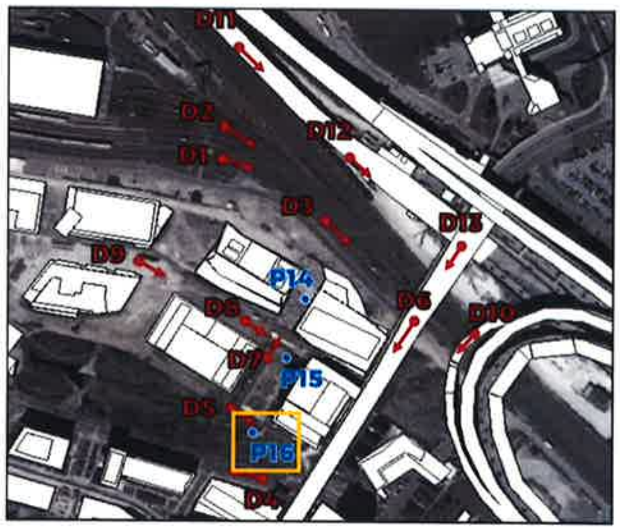
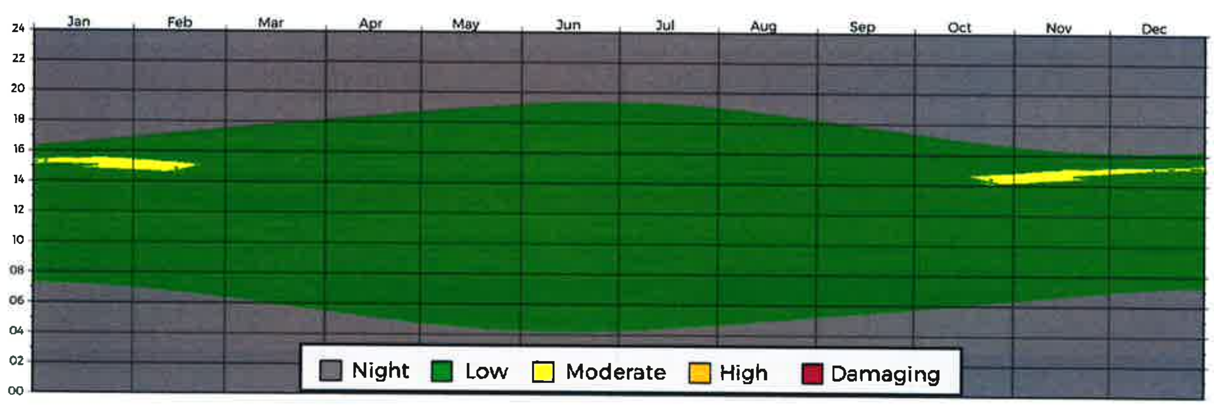


A.4.16 Pedestrian Receptor P16

Receptor P16 was chosen to assess the visual risk associated with solar reflections affecting pedestrians at a park to the south of the development.

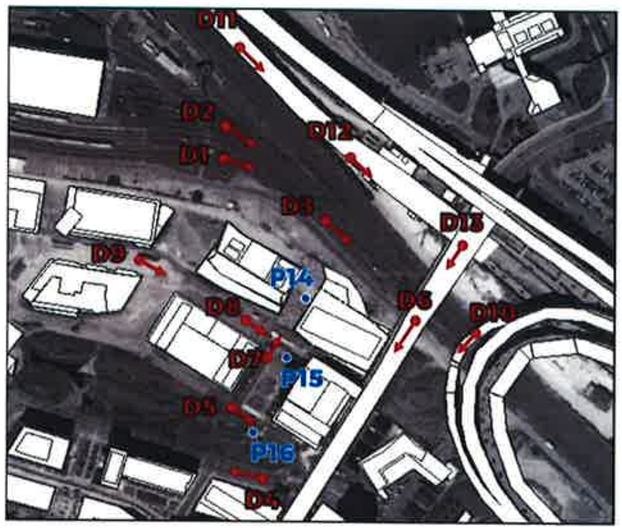


Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.



A.5 Annual Thermal Impact Plots (People)

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



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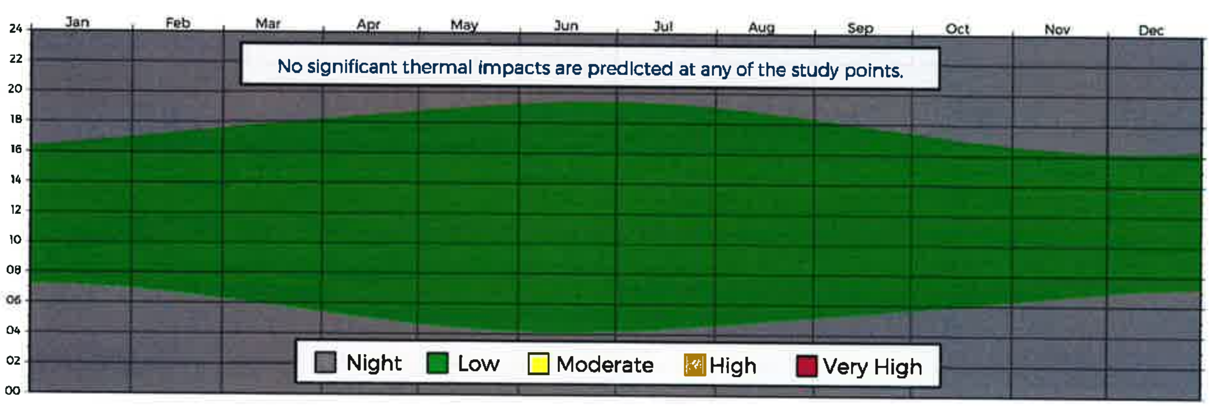

APPENDIX B

APPENDIX B: RWDI REFLECTION CRITERIA

OVERVIEW OF RWDI CRITERIA USED IN THE ASSESSMENT OF SOLAR REFLECTION IMPACTS

B.1 Visual Glare

There are currently no existing criteria or standards that define an "acceptable" level of reflected solar radiation from buildings. RWDI has conducted a literature review of available scientific sources [1] 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 [2], 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 (Image 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) can be determined.

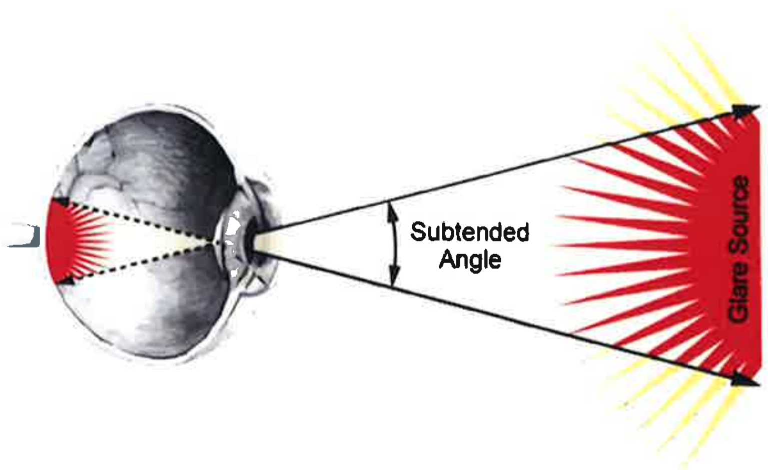

Image B1: Schematic illustrating the subtended angle of a glare source

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 Image B2 on the right illustrates where looking directly at the sun falls in terms of irradiance on the retina (on average about $8x10^4$ W/m²), and the size of the angle that the sun subtends in the sky (about 9.8 milliradians). This puts it just at the border of causing serious damage. This methodology assumes that the exposure time is equivalent to the length of an average person's blink response.

The rest of the points in Figure A2 correspond to the following:

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

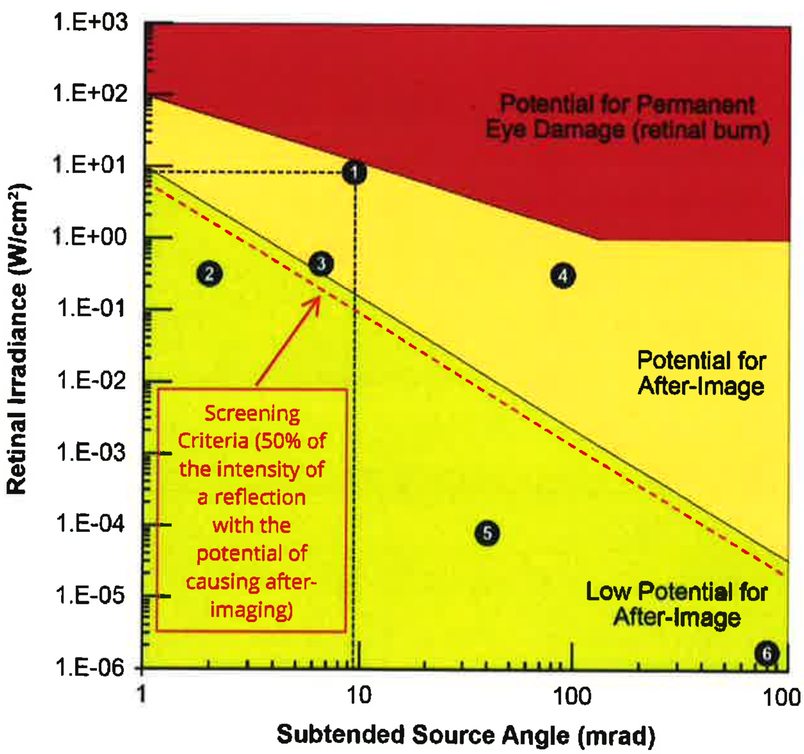

Image B2: Plot showing glare potential for light sources of various sizes and intensities

B.2 Thermal Impact (Heat Gain) on People

The primary sources for exposure limits to thermal radiation come from fire protection literature. The U.S. National Fire Protection Association (NFPA) defines 2,500 W/m² as an upper limit for a tenable egress environment [3]. That being said, while an individual could move through such an environment, they would not necessarily emerge unscathed. Both the British Standards Institution [4] and the U.S. Federal Energy Management Agency [5] indicate that individuals are likely to feel pain within 30 seconds at such exposure levels on bare skin. With second degree burns possible within minutes of exposure. Additionally, this level of additional heat flux can lead to rapid heating of exposed objects which could present a further risk to human safety. It should be noted that these numbers are guideline values only, and that in reality many factors (skin color, age, clothing choice, etc.) influence how a person reacts to thermal radiation.

For our work RWDI has established 2,500 W/m² as a ceiling exposure limit which reflection intensity should not exceed for any length of time.

Lower reflection intensities, while not posing as serious of a risk to human safety, can still negatively impact human comfort. There are no definitive guidelines or criteria with respect to this issue. We know this criterion should be less than 2,500 W/m² and greater than typical peak solar noon levels of 1,000 W/m² which people commonly experience. RWDI's opinion at this time is that a reasonable criterion is to limit reflected irradiance exposure to 1,500 W/m² or less. Based on our assessment, we believe at this level of irradiance most people would be able to tolerate it for several minutes before the onset of discomfort. Additionally, reflections at this intensity level will heat surfaces more slowly.

Thus, we feel reflections below 1,500 W/m² pose a reduced risk to people and should therefore be considered a short term exposure limit. We would conservatively define "short term" as 10 minutes or less which is slightly shorter than the standard 15 minute definition of short term used in the occupational safety context.

B.3 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 present [6-8]. 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).

NASA [9] 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.

Because of the difficult nature of determining material temperatures, RWDI takes a conservative approach and uses a **threshold value of 1,000 W/m² which is approximately the peak intensity of natural sunlight that could be expected to occur over the course of a year**. Intensities beyond this value exceed the levels of irradiance that common exterior building materials are presumably designed for, and depending on the duration, may lead to deformation or damage. Though, as noted this would depend heavily on environmental conditions and the material properties of the exposed object or assembly.

B.4 References

1. Danks, R., Good, J., & Sinclair, R., "Assessing reflected sunlight from building facades: A literature review and proposed criteria." Building and Environment, 103, 193-202, 2016.

2. Ho, C., Ghanbari, C. and Diver, R., "Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation," *J. Sol. Energy Eng.*, vol. 133, no. 3, 2011.

3. National Fire Protection Association. (2003). NFPA 130: standard for fixed guideway transit and passenger rail systems. NFPA.

4. The application of fire safety engineering principles to fire safety design of buildings – Part 6: Human Factors' PD 7974-6:2004, British Standards Institution 2004.

5. Federal Emergency Management Agency, U.S. Department of Transportation, and U.S. Environmental Protection Agency. 1988. Handbook of Chemical Hazard Analysis Procedures. Washington, D.C.: Federal Emergency Management Agency Publications Office.

6. Building Research Establishment: 'Fire spread in car parks' BD2552, Department of Communities and Local Government 2010

7. SFPE Handbook of Fire Protection Engineering 4th Edition NFPA/SPFE 2008 USA

8. V. Babrauskas 'Ignition Handbook' Fire Science Publishers + SFP , 2003

9. E Ungar, K Stroud 'A New Approach to Defining Human Touch Temperature Standards' National Aeronautics and Space Agency , 2010

FINAL REPORT

PARCELS G AND H - NORTHPOINT SITE

CAMBRIDGE, MA

DAYLIGHTING STUDY

RWDI #1703124

September 1, 2017

SUBMITTED TO

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TABLE OF CONTENTS

1 INTRODUCTION

RWDI was retained to assess the obstruction to daylight created by the proposed Parcels G and H – Northpoint Site (project) in Cambridge, Massachusetts (Image 1). The project involves the construction of a 250' tall building on Parcel G of the site, and a 179' tall building on Parcel H.

As part of this evaluation, RWDI investigated the impact of the proposed buildings on the availability of daylight (i.e. light emanating from the sky dome, rather than directly from the sun) to the neighborhood.

This final report summarizes the study methodology (as per Article 80 (Section 80B-2c), using the BPDA's Daylight Analysis Program (BRADA), the design criteria and results.

Image 1: Site plan – Aerial view of site and surroundings (courtesy of Google™ Earth)

2 METHODOLOGY

2.1 BRADA Analysis

Boston, like many major cities around the world, has regulations in place designed to prevent excessive shadows cast by buildings from impacting public spaces. Boston also has an additional requirement to predict how a building will affect the amount of indirect light available at the ground.

The BPDA refers to this indirect light which comes from the sky dome (as opposed to light directly from the sun) as 'daylight', the impact of which is evaluated with a tool known as BRADA.

BRADA was developed in 1985 by the Massachusetts Institute of Technology to estimate the amount of the sky dome visible to a pedestrian based on their direction of view and the surrounding urban context. Given basic geometric information (e.g. building heights, setbacks, location of the viewer, etc.), BRADA produces a two-dimensional 'map' illustrating an approximation of the pedestrian's view as well as a numeric score from 0 to 100% denoting the percentage of the sky dome within a given field of view which is obstructed. The modelling typically uses the midpoint of an adjacent right-of-way as the location of the viewer.

It is RWDI's understanding that Parcels G and H will be constructed at approximately the same time. Thus, the daylight impacts presented here are the cumulative impact of both parcels.

In an urban context, reflective facade materials cause an increase in reflected light, which can act to reduce the perception of a loss of daylight. BRADA can optionally consider the effect of facade reflectivity when calculating the perceived loss of daylight. In this analysis, however, the building facades have been treated as non-reflective in the interest of providing a conservative estimate.

Since the existing condition of the site contains no buildings, the existing daylight obstruction levels will naturally be nil. Thus, additional viewpoints have been selected to provide context to the results of the final condition.

Six points were selected for study in the BRADA analysis. They are summarized below and illustrated in Image 2. Points 1-4 are intended to illustrate the impact of the proposed buildings on daylight access. Points 5 and 6 are included for context. Results of this analysis can be found in Section 5.1.

1. Planned Greenspace – This viewpoint is located at the centerline of a planned greenspace, centered on the western facade of Parcel G.
2. Planned New Street – This viewpoint is located at the centerline of the planned new street, centered on the southern facade of Parcel G.
3. Austin Street – This viewpoint is located at the centerline of the street, centered on the eastern facade of Parcel H.
4. North Street – This viewpoint is located at the centerline of the street, centered on the southern facade of Parcel H.
5. 112 North Point Boulevard – This viewpoint is located at the centerline of the boulevard, centered on the northern facade of an existing building.

6. 123 North Point Boulevard – This viewpoint is located at the centerline of the boulevard, centered on the northern facade of an existing building.

Image 2: Approximate locations of the viewpoints used in the BRADA analysis

2.2 Urban Scale Analysis

To provide additional context to the overall impact that the proposed building will have on daylight availability, RWDI has conducted additional simulations to compute the fraction of the entire sky dome which is visible from the ground under both existing and proposed conditions using RWDI's proprietary Eclipse software.

An area 2400 feet in radius from the proposed buildings was selected for the analysis. The ground surface was subdivided into approximately 425,000 sub surfaces (each representing approximately 35 square feet). The fraction of visible sky was computed by a technique known as ray tracing. Thousands of rays are drawn from each test surface up to the sky which are tested for intersection with buildings and used to derive the fraction of the sky which is visible at each point.

This analysis differs from the standard BRADA evaluation as this approach does not assume a view direction. Rather, it computes the total amount of the entire sky dome which could be seen at each point. It provides a measure of how a proposed building impacts the total amount of daylight falling in a given location, as opposed to BRADA which computes a loss of sky view only for a given direction. This provides increased insight into how a building may impact the illuminance in a space, since the illuminance will come from all parts of the sky, not only from the portion within a given field of view.

2.3 Assumptions and Limitations

2.3.1 Climatic Impacts

BRADA uses a purely geometric analysis for a specific point of view, and does not account for any climatic impacts that can also affect the daylight distribution (e.g. cloud cover, position of the sun, light from "behind" the direction of view, etc.). Therefore, the reduction in daylighting predicted in the BRADA analysis should not be used for any daylight availability assessments beyond the Article 80 requirements.

2.3.2 Study Building and Surrounds Models

The analysis was conducted based on the geometry provided by Perkins + Will and NBBJ Architects to RWDI up to August 22, 2017. The surroundings model was developed based on data made available by the City of Boston. Due to the limitations of BRADA, simplifications to the massing of the parcels was required. Any simplifications made were done in such a way as to create a slightly larger obstruction to daylight in the interest of being conservative.

2.3.3 Facade Material Reflectance

All facades in this analysis were assumed to be entirely non-reflective as a conservative assumption.

2.3.4 Applicability of Results

The results presented in this report are highly dependent on the form of the proposed buildings. Should there be any design changes, RWDI should be contacted and requested to review their potential impact on the findings and conclusions of this report.

3 RESULTS

3.1 BRADA Analysis Results

3.1.1 Viewpoint 1 – Planned Greenspace

The site is currently vacant, thus the current level of obstruction to daylight is 0%. The construction of Parcel G increases the level of obstruction to 60.4%. Parcel H has no impact on the BRADA predicted daylight obstruction from this viewpoint due to its distance from the viewpoint.

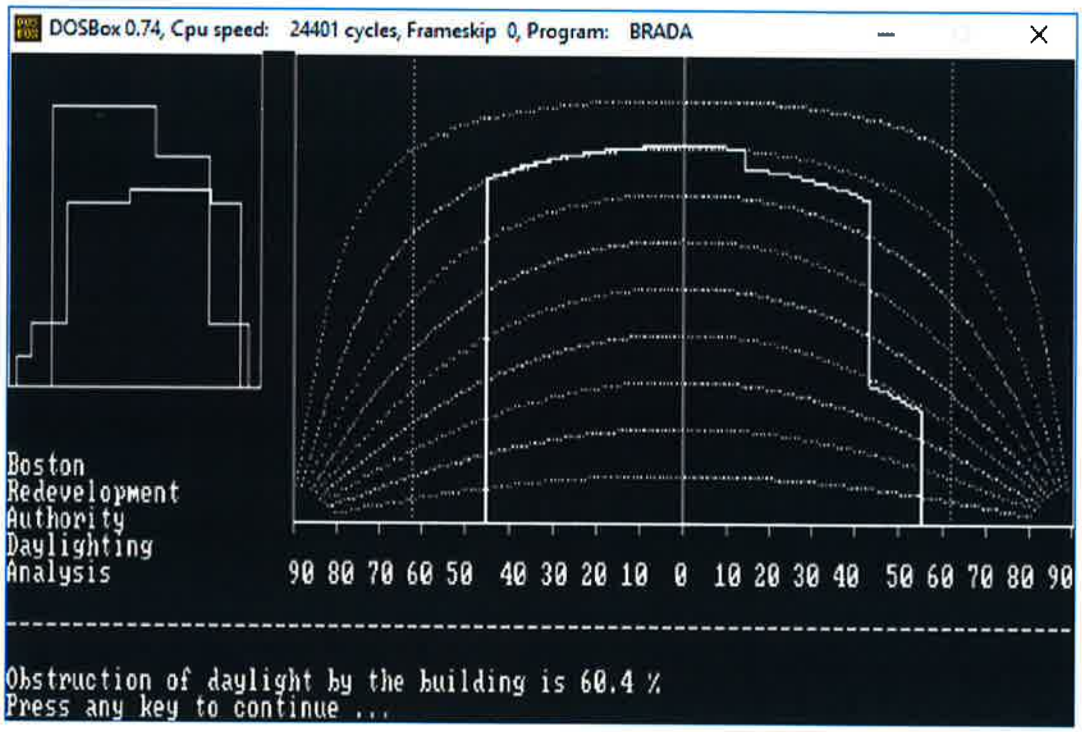


Image 3: BRADA output for Viewpoint 1 under the proposed condition

3.1.2 Viewpoint 2 – Planned New Street

The construction of Parcel G increases the level of obstruction to 66.1% from the current obstruction of 0%. Parcel H has no impact on the BRADA predicted daylight obstruction from this viewpoint due to its location relative to this viewpoint.

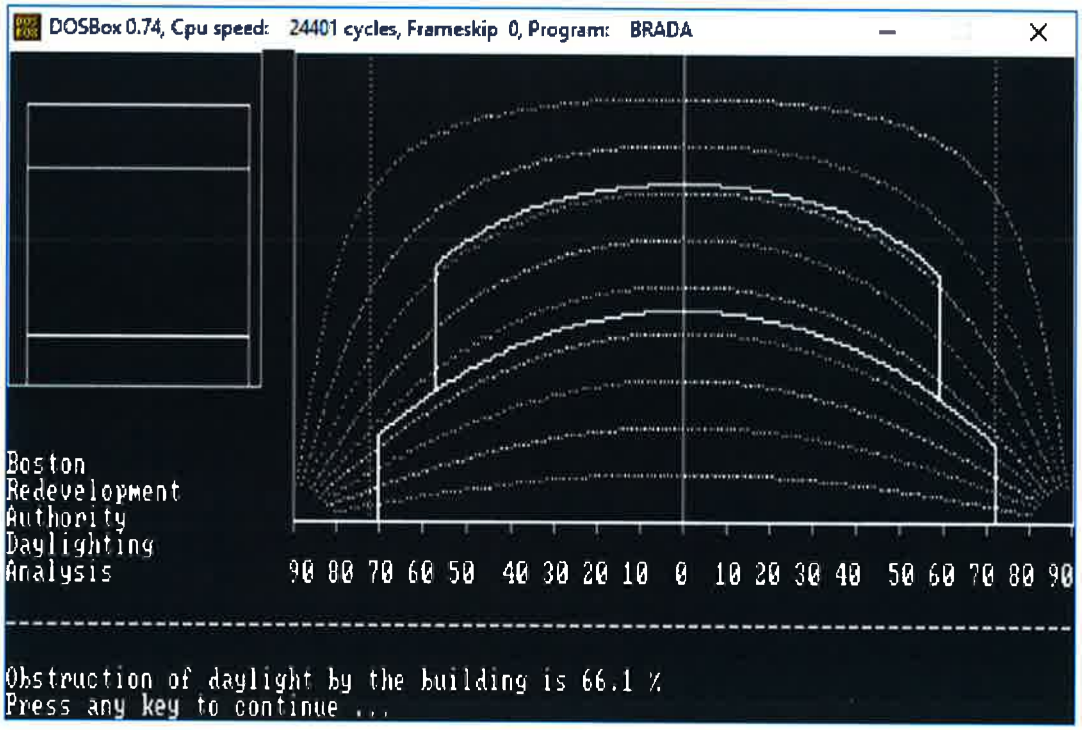


Image 4: BRADA output for Viewpoint 2 under the proposed condition

3.1.3 Viewpoint 3 – Austin Street

The construction of Parcel H increases the level of obstruction to 32.1% from the current obstruction of 0%. Despite being taller than Parcel H, Parcel G has no impact on the BRADA predicted daylight obstruction from this viewpoint due to its distance from this viewpoint.

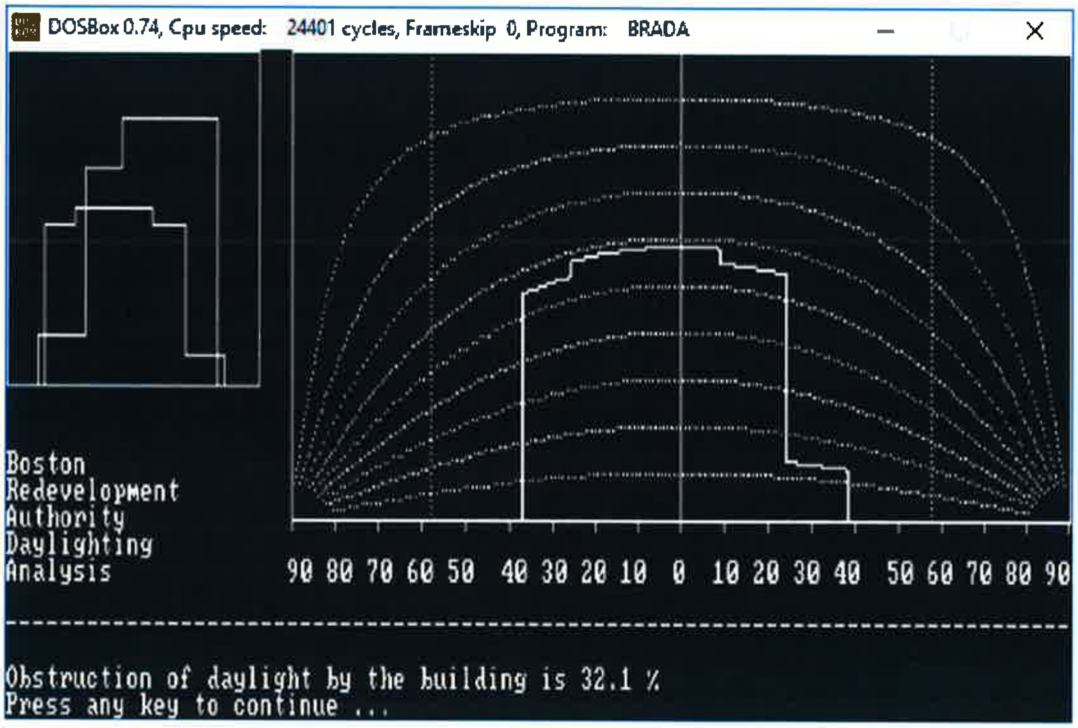
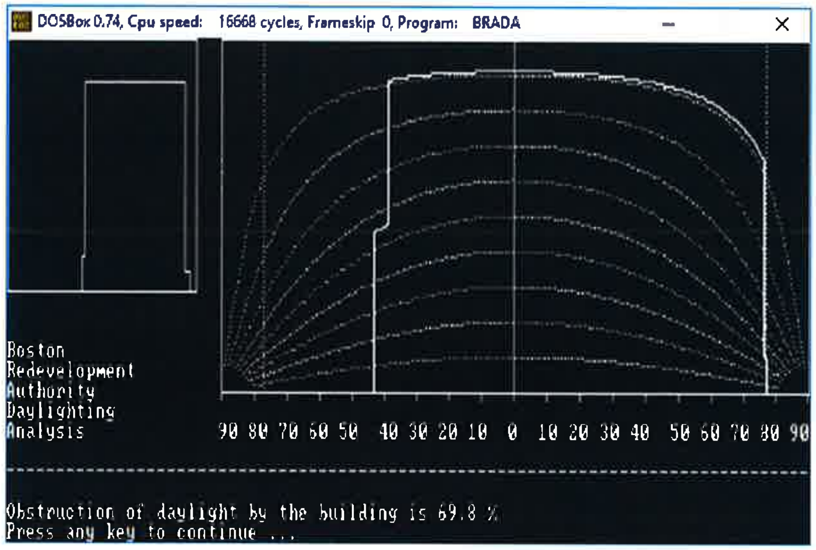


Image 5: BRADA output for Viewpoint 3 under the proposed condition

3.1.4 Viewpoint 4 – North Street

The existing building fronting onto North Street is approximately 240 feet tall and creates a 69.8% obstruction to daylight from this viewpoint. Adding Parcel H, which is approximately 280 feet further away, does not increase the BRADA predicted daylight obstruction, despite the width of the proposed building. Therefore, the increase in daylight obstruction at this location due to Parcel H is 0%. This result also provides context to the level of daylight obstruction created by buildings which already exist in the vicinity of this development.



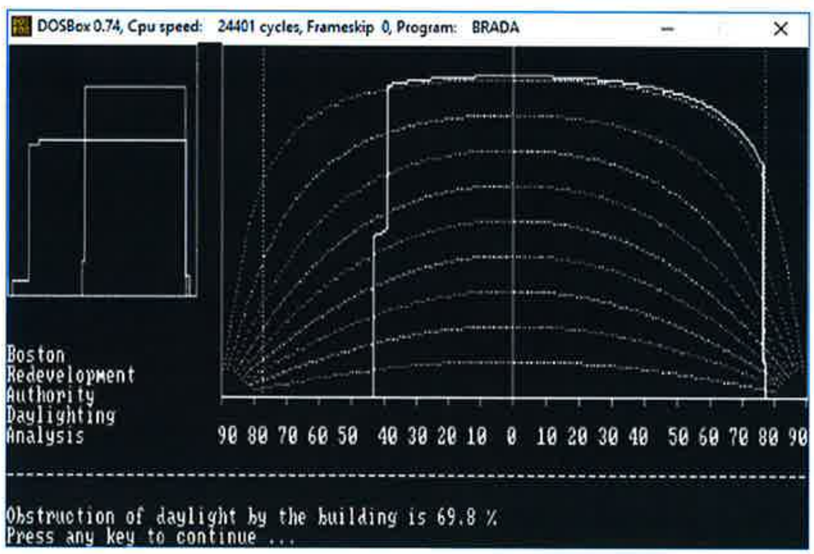


Image 6: BRADA output for Viewpoint 4 under existing (top) and proposed (bottom) conditions

3.1.5 Viewpoint 5 – 112 North Point Boulevard

The existing building at 112 North Point Boulevard is approximately 95 feet tall and creates a 75.9% obstruction to daylight from this viewpoint. This result provides context to the level of daylight obstruction created by buildings which already exist in the vicinity of this development thus no "proposed" condition exists.

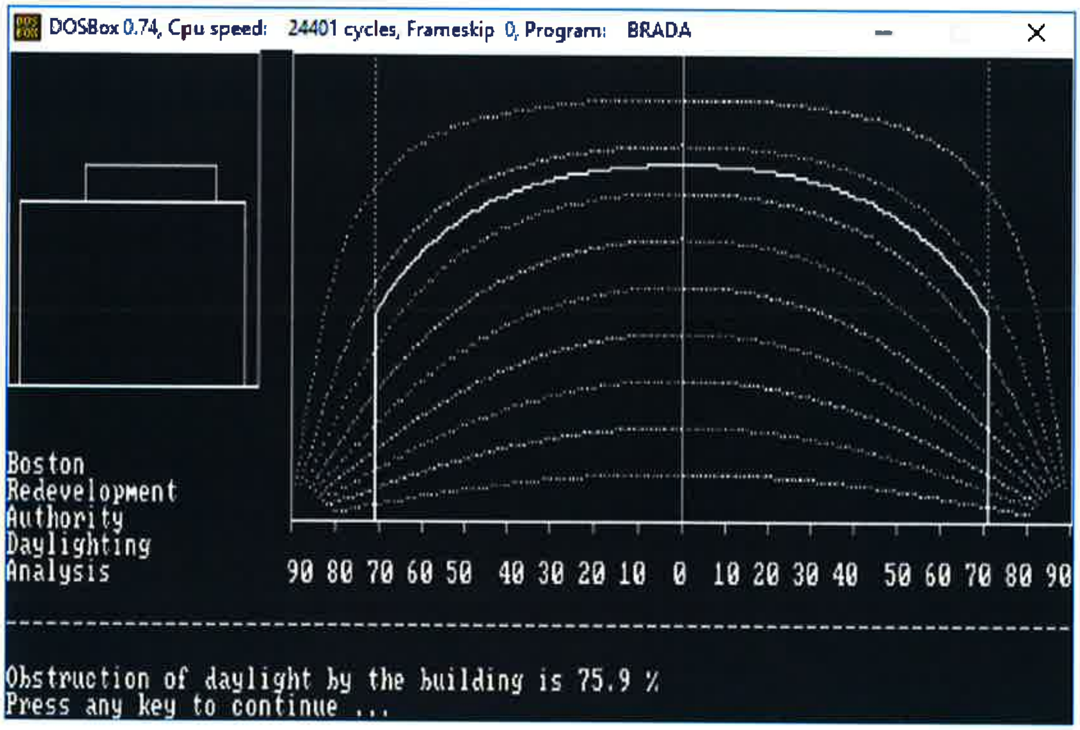


Image 7: BRADA output for Viewpoint 5 under the existing condition

3.1.6 Viewpoint 6 – 123 North Point Boulevard

The existing building at 123 North Point Boulevard is approximately 141 feet tall and creates a 70.4% obstruction to daylight from this viewpoint. This result provides context to the level of daylight obstruction created by buildings which already exist in the vicinity of this development thus no "proposed" condition exists.

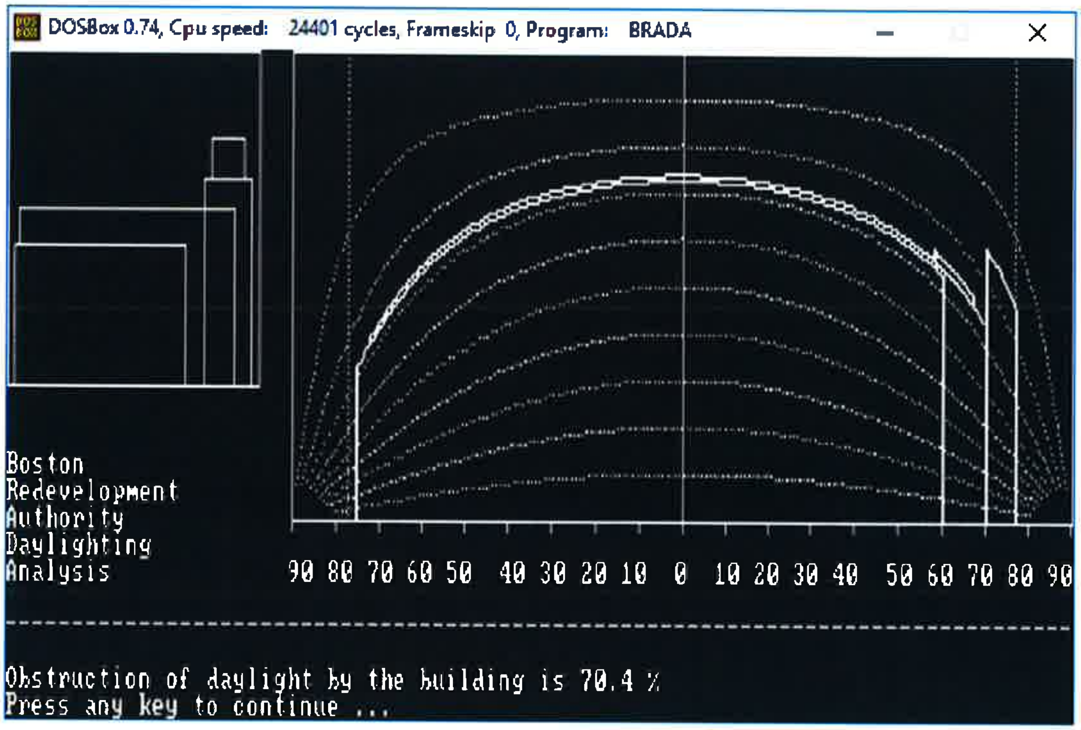


Image 8: BRADA output for Viewpoint 6 under the existing condition

3.2 Urban Scale Analysis Results

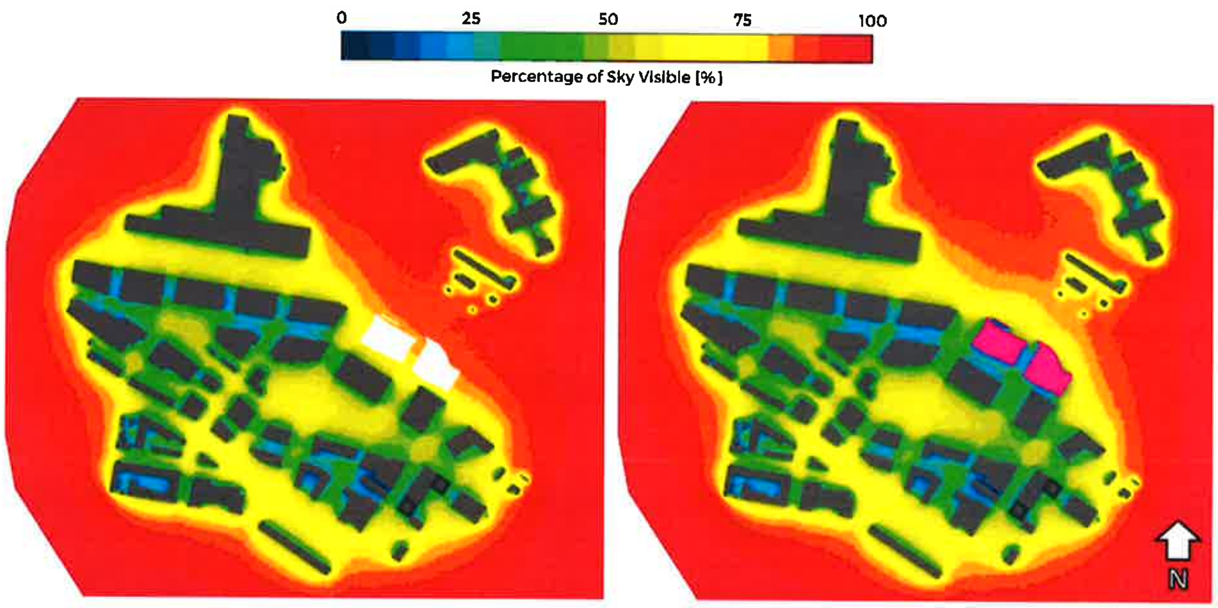


Image 9: RWDI Eclipse output illustrating the percentage of the entire sky visible at each point within 2400 feet of the proposed buildings under existing (left) and proposed (right) conditions

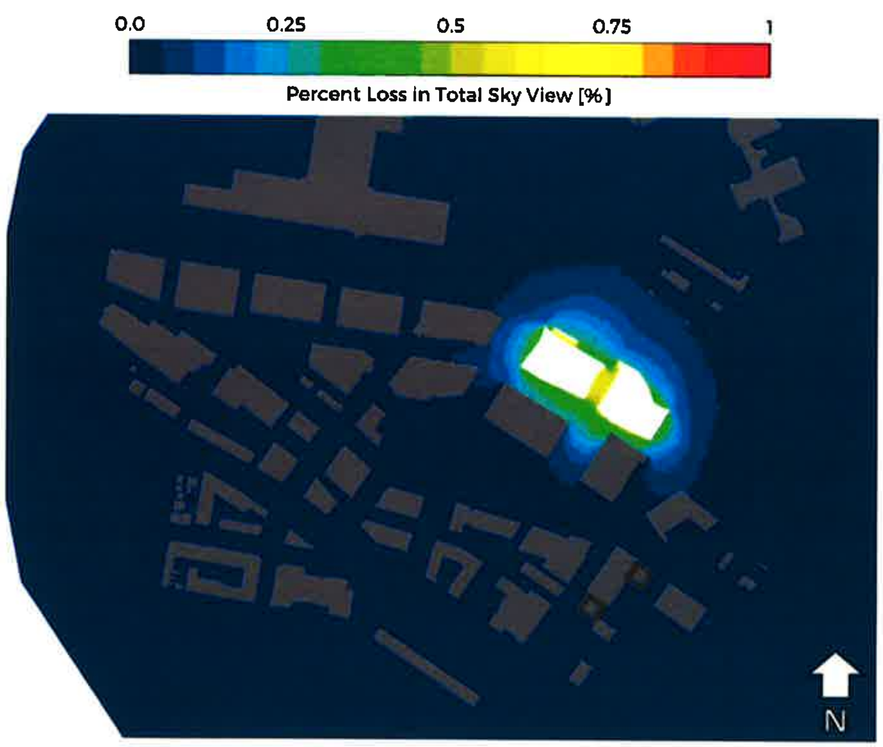


Image 10: RWDI Eclipse output illustrating the net loss in the percentage of visible sky due to the proposed tower

4 CONCLUSIONS

1. As the Parcels G and H sites are currently vacant, the construction of any buildings naturally increases obstruction to daylight.

2. The proposed buildings are not significantly taller than any of the others proposed on the Northpoint site, nor are they significantly taller than the existing buildings in the vicinity. This reduces the relevant impact of the daylight obstruction from the proposed buildings for most potential viewpoints.

3. Increases in daylight obstruction due to Parcels G and H ranged from 0% (Viewpoint 4) to 66.1% (Viewpoint 2). This is lower than the daylight obstruction caused by several existing buildings (Viewpoints 4-6) which rangec from 69.8% to 75.9%.

4. The supplemental urban scale analysis conducted using RWDI's Eclipse tool supports the BRADA based analysis that the impacts of the proposed buildings on daylight availability are generally minor and consistent with what is seen elsewhere in the vicinity.

5. The vast majority of the areas around the proposed buildings see no change in the amount of sky visible. The majority of areas which are impacted see sky view losses of less than 1% and these areas are confined to a radius of approximately 300 feet from the buildings.

6. Overall, the impacts predicted by both BRADA and Eclipse indicate that the level of obstruction to the sky dome due to the proposed buildings is similar to (and in some cases better than) the level of obstruction created by existing buildings in the area.

7. We would consider the impact on daylight of these buildings typical for an urban area.

PARCELS G AND H – NORTHPOINT SITE

CAMBRIDGE, MA

BUILDING AIR QUALITY

RWDI #1703124

September 26, 2017

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EXECUTIVE SUMMARY

Wind tunnel exhaust dispersion modeling was completed to assess air quality conditions and provide recommendations related to the exhaust and intake design of the proposed Parcels G and H – Northpoint Site (Project) in Cambridge, Massachusetts. The primary conclusions and recommendations from the assessment are summarized below.

1. The stack height of the boilers can be reduced to discharge 7 ft above the Parcel G penthouse roof (from vertical flues without rain caps).
2. No design changes are recommended for the Parcel G specialty exhausts. We recommend that impacts from these stacks be evaluated once the nature of these exhausts has been established.
3. Reverse the placement of the base building emergency diesel generator (G1) and the tenant emergency natural gas generator (G2) to reduce frequency of diesel odor impacts during generator operation.
4. Testing of the Parcels G and H emergency diesel generators should be conducted during off-hours to reduce likelihood of diesel odor exposure.
5. We recommend the use of DPF/DOC technology on the Parcels G and Parcel H diesel generators to further reduce odor probability if odors are a concern to the design team.
6. For the clean room, once the nature of the exhaust has been established, the dilution results should be reviewed by the cleanroom consultant to determine whether sufficient dispersion will be achieved to meet appropriate criteria.

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1 INTRODUCTION

Rowan Williams Davies & Irwin Inc. (RWDI) was retained to assess air quality impacts from the proposed Parcels G and H – Northpoint Site (Project) in Cambridge, Massachusetts. The project involves the construction of a 250' tall laboratory building on the Parcel G site, and a 179' tall office building on Parcel H.

This report summarizes the methodology of our wind tunnel study; describes the design criteria applied in our work; and presents the results and recommendations from RWDI's assessment.

2 METHODOLOGY

2.1 Dispersion Modeling

The assessment was accomplished by performing detailed tracer gas wind tunnel dispersion modeling on a 1:300 scale model of the proposed development and surroundings. Wind tunnel modeling is considered to be the most accurate method of replicating airflow patterns around buildings and quantifying the effects these patterns have on exhaust dispersion. Photographs of the scale model in one of RWDI's boundary layer wind tunnels are presented below.

Testing was conducted by releasing a tracer gas of known concentration from each exhaust source and taking measurements at selected receptors under the influence of approaching wind. Mean concentrations of tracer gas at selected receptor locations were measured by drawing samples through flush-mounted tubes leading to a bank of infrared analyzers stationed outside the tunnel. Tests were completed for a range of wind directions and speeds in order to characterize dispersion of the exhaust in the context of the local aerodynamic conditions, including upwind terrain and building effects. Building effects were captured by constructing scale models of all buildings and structures with a 1,200-ft. radius of the Parcels G and H, while upwind terrain conditions were simulated by means of roughness elements and spires.

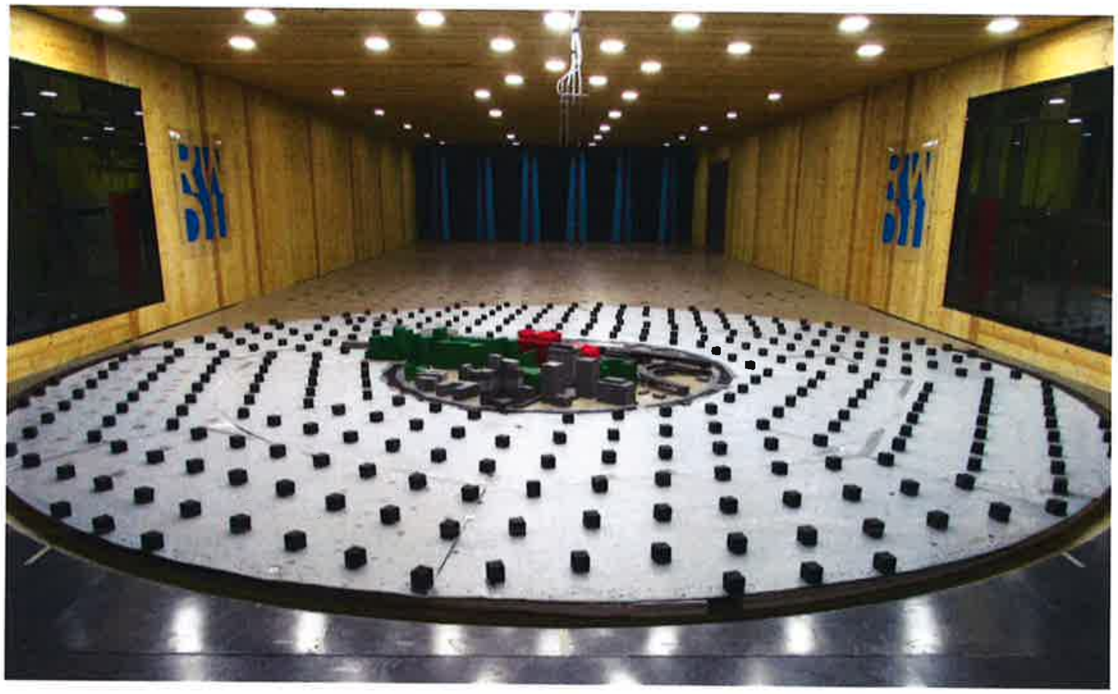


Image 1 - Photograph of Study Model in RWDI Boundary Layer Wind Tunnel

Image 2 - Close-Up Photograph of the of Study Model

2.2 Modeling Parameters

Potential air quality impacts were evaluated from the exhaust sources summarized in Table 1 using detailed dispersion modeling methods outlined above. Air quality impacts are defined as adverse changes to the quality of air that reaches sensitive receptors such as building air intakes, openable windows, sensitive outdoor spaces, sensitive equipment, etc. This could take the form of high pollutant concentrations, strong odors, high temperature, high humidity, etc. The specific impact of interest depends on the source, receptor, and goals of the assessment. Specific details on the exhaust parameters are presented in Section 3. Other proposed sources that were not specifically included in the wind tunnel tests are discussed in Section 4.

Table 1 - Summary of Exhaust Sources Modeled

Source Label	Source Description	Location	Emissions/Impacts of Interest
B1-B18	Proposed Natural Gas Boilers (4,000 MBH, typ. 18)	Parcel G Penthouse Roof	Combustion Pollutants
C	Representative 2,000 cfm Clean Room Exhaust	Parcel H Penthouse Roof	Chemical Emissions
G1	Proposed 1,500 kW Emergency Diesel Base Building Generator	Parcel G Penthouse	Combustion Pollutants, Odors
G2	Future 1,500 kW Emergency Natural Gas Tenant Generator	Parcel G Penthouse	
G3	Proposed 1,500 kW Emergency Diesel Generator	Parcel H Roof	
S1-S2	Representative Future Tenant Specialty Exhausts	Parcel G Penthouse	Various, could include: Chemical Emissions, Kitchen Odors, and Animal Odors

Air quality impacts from sources listed in Table 1 were assessed at receptors that represent either outside air intakes that serve occupied spaces, or operable windows. These receptor locations are summarized in Table 2.

Table 2 - Summary of Receptor Locations Modeled

Receptor Labels	Building	Approximate Elevation Above Sea Level	Location	Description
R1-R4	Parcel G	230	Northern Penthouse Facade	Proposed Outside Air Intake Louver
R5-R8	Parcel H	175	East and West Roof	Representative Operable Windows
R9-R10	Parcels L+M	240	Northern Facades	Representative Outside Air Intakes or Operable Windows
R11	Twenty/20	225		
R12			West Facade	
R13		240	Roof	
R14			North Facade	

Note: [1] Grade at the MBTA tracks is 22' asl. as per the 170802_Parcel G.pdf elevations provided on August 2, 2017.

The locations of the exhaust sources and receptors are illustrated on Figure 1.

2.3 Dilution Criteria

For design purposes, RWDI applies dilution criteria to assess air quality impacts from various types of exhaust sources. Exhaust dilution (*D*), is defined as the ratio of source concentration (C_o) to the concentration predicted at a receptor (*C*). In other words:

$$D = \frac{C_o}{C}$$

Dilution criteria for good design practice are developed for each exhaust source, and are based on based on specific pollutant and/or odor emissions, air quality exposure limits, and/or odor thresholds. The design objective is for exhaust to be well diluted, at a level equal to or greater than the criteria, at all important receptors to achieve acceptable air quality. The dilution criteria applied for each of the exhaust sources are summarized in Table 3, and discussed in detail in Appendix A.

Table 3 - Summary of Dilution Criteria Applied

Source Label(s)	Exhaust Type	Recommended Dilution Criterion	Basis
B1-B18	Natural Gas Boilers (4,000 MBH)	10:1 (Health)	• Dilution to meet US EPA 1-hour NAAQS of 188 μg/m³ for nitrogen dioxide (NO_2) based on continuous use. NO_2 is the critical pollutant. • Based on low-NO_x burner (9 ppm).
C	Clean Room	-	• Activities in clean room have not been established. No criteria are applied.
G1, G3	Stand-by Diesel Generator (1,500 kW)	350:1 (Health)	• Dilution to meet recommended 1-hour not-to-exceed threshold for nitrogen dioxide (NO_2) of 338 μg/m³. NO_2 is the critical pollutant. • Based on an EPA Tier-2 certified engine with NO_2 emissions of 6.6 g/bhp-hr when operating at 100% load. Stand-by only.
		3,000:1 (Odor Detection)	• Dilution required to meet a 50% odor detection threshold for modern (post-2005) diesel generators.
G2	Stand-by Natural Gas Generator (1,500 kW)	50:1 (Health)	• Dilution to meet recommended 1-hour not-to-exceed threshold for nitrogen dioxide (NO_2) of 338 μg/m³. NO_2 is the critical pollutant. • Based on an EPA Tier-2 certified engine with NO_2 emissions of 1.0 g/bhp-hr when operating at 100% load. Stand-by only.
S1-S2	Tenant Specialty Exhausts	-	• Specialty program not established. No criteria are applied.

2.4 Meteorological Data

RWDI reviewed wind data from the Boston Logan International Airport, the closest meteorological station with a substantial and recent data set used to estimate wind conditions at the site. A summary of the directional distribution of winds over a period from 1986 to 2016 is shown below. The wind directions in the figure refer to the direction from which the wind blows, while the annual frequency of a given wind direction is shown as a distance radially from the center.

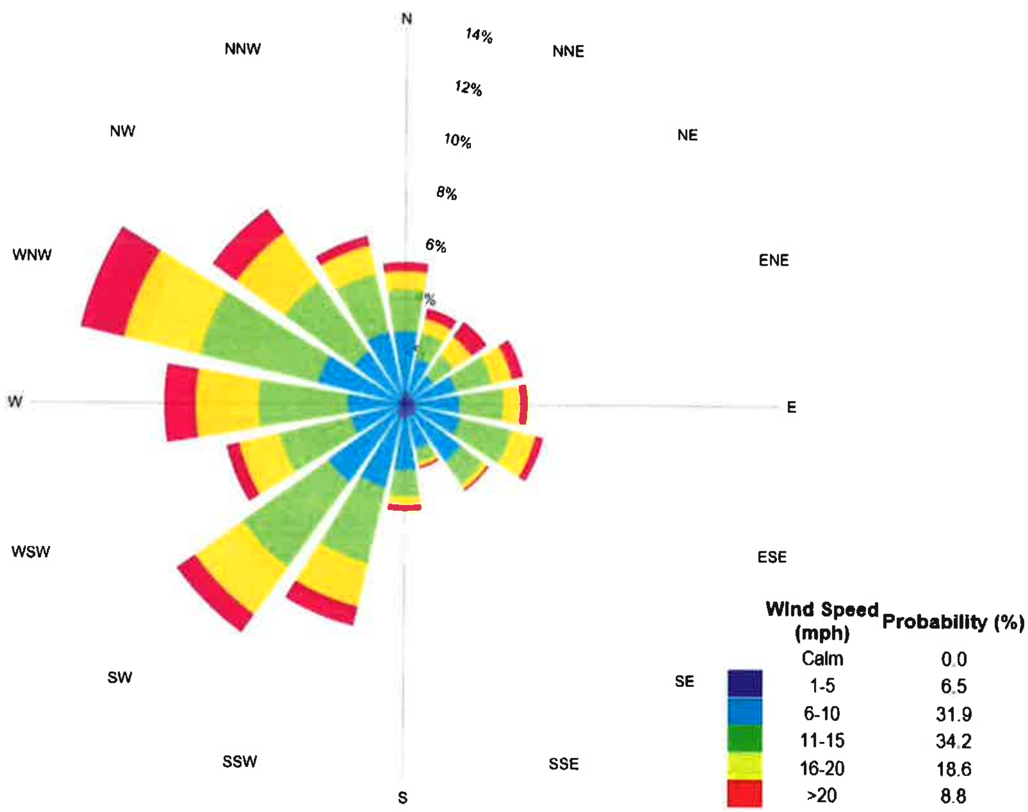


Image 3 - Directional Distribution (%) of Winds from the Boston Logan International Airport (1986 – 2016)

The wind data was used to estimate of the percent of time that wind conditions resulting in dilution levels less than the indicated dilution criteria are expected to occur, using a statistical analysis of the wind tunnel results combined with the hourly meteorological data from the Boston Logan International Airport. Frequency is defined as the annual percentage of wind conditions that may result in dilution levels less than the given criterion at a receptor. For example, a 50% frequency means that there is a 1 in 2 chance of winds that will result in the indicated dilution criterion not being met. In this example, 50% of winds represents approximately 4,380 hours per year (i.e. 8,760 x 50%).

3 RESULTS AND RECOMMENDATIONS

Dispersion modeling results are presented and discussed on a source-by-source basis in the following sections. Results are presented in the form of worst-case predicted dilution and compared to criteria. Also presented are results from frequency analyses where appropriate.

Recommendations for modification to design or operating parameters are provided in situations where recommended exhaust dilution criteria are not met.

3.1 Parcel G Sources

3.1.1 Proposed 4,000 MBH Natural Gas Boilers (Source B1-B18)

We understand that eighteen 4,000 MBH natural gas boilers will discharge above the penthouse roof of Parcel G from vertical uncapped stacks. The boilers were evaluated for the worst-case operation of all eighteen boilers firing at 100% capacity. The modeling results are presented in Table 4.

Boiler Exhaust parameters modelled:

Boiler Model:	Patterson-Kelley New P-K Sonic SC-4000 NG
Exhaust Flow rate (per flue):	990 cfm
Stack Exit Velocity (per flue):	1,260 fpm (based on a 12' flue diameter)
Stack Height:	5 ft above the top of the screen
Maximum Operation Scenario:	18 @ 100% load each
Dilution Criterion Applied:	10:1 (Health-based dilution target)

Table 4 - Summary of Modeling Results for Proposed Natural Gas Boilers (Source B1-B18)

Boiler Stack Height Modeled	Worst-Case Dilution Level (Receptor)	Criterion Met?
5 ft above the top of the screen	240:1 (R9)	*Yes*
Flush with the top of the screen	220:1 (R9)	

3.1.1.1 Discussion

The recommended health-based dilution criterion was met at all receptor locations evaluated with stacks terminating at least 5 ft above the top of the screen. The recommended health-based dilution target would also be met if the stacks were reduced in height to be flush with the top of the screen wall.

Although not explicitly evaluated, based on the positive dispersion results shown in Table 4, we believe that the boiler stacks can be safely reduced in height to discharge 7 ft above their penetration points on the Parcel G penthouse roof from vertical flues without fixed rain caps.

3.1.1.2 Recommendations

The boiler stacks can terminate 7 ft above their penetration points on the Parcel G penthouse roof assuming that no rain caps are used.

3.1.2 Proposed Parcel G Emergency Generators (Sources G1-G2)

We understand that two 1,500 kW emergency generators will be located at the penthouse level of Parcel G. The base building generator (Source G1) will be a diesel unit while the tenant generator will be natural gas (Source G2). Detailed results are provided in Table 5 for individual operation of either unit at 100% of their rated loads. Frequency results are presented for both the G1 and G2 locations to assess whether re-locating the diesel unit to G2 would be beneficial. Simultaneous operation of the generators is discussed in Section 3.1.2.1.

Generator Exhaust parameters modelled:

Generator Model	CAT 3512C unit with EPA Tier 2 emissions
Exhaust flow rate:	11,734 cfm
Stack exit velocity:	8,400 fpm [1]
Stack Height:	Flush with above the top of the screen
Maximum Operation Scenario:	100% load each
Dilution Criteria Applied:	350:1 (Health-based dilution target for diesel operation)
	3,000:1 (Odor-based dilution target for diesel operation)
	50:1 (Health-based dilution target for natural gas operation)

Note: [1] Parameter estimated based on typical values for sources of this type.

Table 5 - Summary of Modeling Results for Proposed Parcel G Emergency Generators (Sources G1-G2)

Receptor Label	Receptor Description	Worst-Case Dilution Level		Frequency of Wind Conditions Expected to Result in Dilution Levels Below 3,000:1 Diesel Odor Criterion[1]	
		G1 Location	G2 Location	G1 Location	G2 Location
R1-R4	Parcel G Proposed Outside Air Intake Louvers	1,210:1 (R3)	2,180:1 (R3)	*15%*	*7%*
R5-R8	Parcel H Proposed Outside Air Intakes	730:1 (R6)	950:1 (R6)	*14%*	*14%*
R9-R10	Parcels L+M Representative Outside Air Intakes or Operable Windows	1,830:1 (R9)	1,190:1 (R9)	*3%*	*6%*
R11-R12	Twenty/20 Building Representative Outside Air Intakes or Operable Windows	920:1 (R12)	950:1 (R12)	*7%*	*7%*

Note: [1] The odor criterion is not applicable for natural gas engines.

3.1.2.1 Discussion

The recommended health-based dilution targets were met at all receptor locations assessed when the generators operate either individually or simultaneously.

The dilution target for diesel odors was however not met at varying frequencies. For a diesel unit at the G1 location, it was found that approximately 15% and 14% of wind conditions were problematic for impacts on Parcel G and on surrounding buildings (worst-case at Parcel H), respectively. If the diesel unit was located to G2, the probability of dilutions below target drop to 7% at Parcel G and remain similar off-site. No odor concerns are expected from a gas unit.

In order to significantly reduce the odor frequency beyond the values shown in Table 6, stacks at either G1 or G2 would need to extend at least 15 ft above the Parcel G screen wall, or that emission controls be used.

3.1.2.2 Recommendations

We recommend the following to reduce odor-related impacts:

- Reverse the location of the G1 and G2 generators. Locate the diesel unit in the G2 location and natural gas unit in the G1 location;
- Test the diesel generator during building off-hours; and/or
- Use emission controls in the form of a Diesel Particulate Filter and Diesel Oxidation Catalyst combination unit (DPF/DOC) if further odor potential reduction is desired (e.g., to achieve as close to 'no odor' as possible without major stack increases).

3.1.3 Future Parcel G Tenant Specialty Exhausts (Sources S1-S2)

We understand that twelve future tenant specialty exhaust are planned above the penthouse level on Parcel G. RWDI modeled tenant specialty exhausts at two representative locations; one for each of the two groupings of six shown as S1 and S2 on Figure 1. The nature of the specialty exhausts has not yet been defined at this stage in the design process. Without the emissions known, no dispersion criteria for the specialty exhaust has been defined. Comments are provided for various emission sources, while modeling results are presented in Table 6.

Exhaust parameters modelled:

Exhaust flow rate:	4,000 cfm
Stack exit velocity:	3,000 fpm[1]
Stack Height:	Flush with the top of the screen
Maximum Operation Scenario:	Constant Volume Operation

Note: [1] Parameter estimated based on typical values for sources of this type.

Table 6 - Summary of Modeling Results for Future Tenant Specialty Exhausts (Sources S1-S2)

Receptor Label	Receptor Description	Worst-Case Dilution Level	
		S1 Location	S2 Location
R1-R4	Parcel G Proposed Outside Air Intake Louvers	>10,000:1	>10,000:1
R5-R8	Parcel H Proposed Outside Air Intakes	2,030:1 (R6)	1,780:1 (R6)
R9-R10	Parcels L+M Representative Outside Air Intakes or Operable Windows	2,540:1 (R9)	1,580:1 (R9)
R11-R12	Twenty/20 Building Representative Outside Air Intakes or Operable Windows	3,370:1 (R12)	2,640:1 (R12)

3.1.3.1 Discussion

A worst-case dilution result of 1,580:1 was obtained between the top of the stack and the Parcels L+M operable windows. No benefit was applied to possible internal system dilution.

Based on the modeled results, the future tenant specialty exhausts in their current configuration may achieve sufficient dilution to meet the RWDI recommended design criteria for the following sources:

- Common Fume hoods;
- Vivaria;
- Biosafety cabinets;
- Perchloric acid hoods; and,
- Kitchen exhaust hoods (based on a single 4,000 cfm kitchen exhaust, the result would be acceptable for a maximum of three 4,000 cfm kitchen exhausts).

Other higher hazard activities/equipment/operations may require more dispersion and dilution than predicted here.

3.1.3.2 Recommendations

Impacts from the future tenant specialty exhausts should be evaluated once the nature of these exhausts has been established.

3.2 Parcel H Sources

3.2.1 Representative Parcel H Clean Room Exhaust (Source C)

We understand that an approximately 5,000 ft^2 clean room may be located within Parcel H, which would require an estimated exhaust of 2,000 cfm. The programming for the cleanroom has not yet been established and therefore no information on emission profile was available at the time of this assessment. No dispersion criteria for clean room exhaust has been defined since the emissions can be highly variable and in some cases highly toxic. The worst-case dilution results for a representative exhaust are presented in Table 7.

Clean Room Exhaust parameters modelled:

Exhaust flow rate:	2,000 cfm
Stack exit velocity:	3,030 fpm[1]
Stack Height:	10 ft
Operation Scenario:	Constant Volume Operation
Dilution Criterion Applied:	TBD after emissions are known

Note: [1] Parameter estimated based on typical values for sources of this type.

Table 7 - Summary of Modeling Results for Representative Clean Room Exhaust (Source C)

Receptor Label	Receptor Description	Worst-Case Dilution Level (Receptor)
R3-R4	Parcel G Proposed Outside Air Intake Louvers	4,530:1 (R4)
R5-R8	Parcel H Proposed Outside Air Intakes	1,990:1 (R7)
R10	Parcels L+M Representative Outside Air Intakes or Operable Windows	7,950:1
R11-R14	Twenty/20 Building Representative Outside Air Intakes or Operable Windows	680:1 (R11)

3.2.1.1 Discussion

A worst-case dilution result of 680:1 was obtained between the top of the exhaust stack and the Twenty/20 Building residential operable windows, which was the worst impacted receptor. No internal system dilution benefit was applied.

The dilution results at Twenty/20 would not meet the dilution criterion for fume hood emissions, and may represent elevated risk for a cleanroom depending on the activities conducted and anticipated emissions.

3.2.1.2 Recommendations

We recommend that once the nature of the exhaust has been established, the dilution results should be reviewed by the cleanroom consultant to determine whether sufficient dispersion will be achieved to meet appropriate criteria for those emissions.

3.2.2 Proposed Parcel H Emergency Diesel Generator (Source G3)

We understand that a 1,500 kW emergency diesel generator will be located at the penthouse level on Parcel H. At this stage in the design process there in flexibility in the location of the generator on roof. RWDI recommended and evaluated a generator located at the northeast corner of the penthouse; this location maximizes the separation distance from the Twenty/20 building and is desirable from an architectural perspective as the screen wall is raised shielding the generator from view. The generator was assessed at 100% of rated load as a worst-case operating condition with the stack discharging vertically above the penthouse roof (Source G on Figure 1). The modeling results are presented in Table 8

Generator Exhaust parameters modelled:

Generator Model	CAT 3512C unit with EPA Tier 2 emissions
Exhaust flow rate:	11,734 cfm
Stack exit velocity:	8,400 fpm[1]
Stack Height:	10 ft above top of penthouse roof
Maximum Operation Scenario:	100% load
Dilution Criteria Applied:	350:1 (Health-based dilution target)
	3,000:1 (Odor-based dilution target)

Notes: [1] Parameter estimated based on typical values for sources of this type.

Table 8 - Summary of Modeling Results for Proposed Parcel H Emergency Diesel Generator (Source G3)

Receptor Label	Receptor Description	Worst-Case Dilution Level (Receptor)	Frequency [1] of Wind Conditions Expected to Result in Dilution Levels Below Odor Criterion (3,000:1)
R2-R4	Parcel G Proposed Outside Air Intake Louvers	850:1 (R3)	7%
R5-R8	Parcel H Proposed Outside Air Intakes	490:1 (R7)	13%
R10	Parcels L+M Representative Outside Air Intakes or Operable Windows	1,820:1	5%
R11-R14	Twenty/20 Building Representative Outside Air Intakes or Operable Windows	550:1 (R13)	5%

3.2.3 Discussion

The recommended health-based dilution target was met at all receptor locations assessed. The most significant odor impacts (in terms of strength and frequency) were predicted at the Parcel H outside air intakes (13% wind frequency not meeting target and worst-case dilution level indicating odor strength could be recognizable to most). Similar odor strength of lower frequency were predicted at the Parcel G intakes and at Twenty/20.

A stack height in excess of 30 ft above the Parcel H penthouse roof would be required to achieve the desired dilution target for odors. Alternatively, the use of emission controls could also be considered.

3.2.4 Recommendations

We recommend the following to reduce odor related impacts:

- Test the diesel generator during building off-hours.
- If further odor potential reduction is desired (e.g., to achieve as close to 'no odor' as possible without major stack increases), we recommend the use of emission controls in the form of a Diesel Particulate Filter and Diesel Oxidation Catalyst combination unit (DPF/DOC).

4 OTHER DESIGN COMMENTS

Screening-level numerical modeling was performed for other proposed exhaust sources identified during the test plan phase of RWDI's work. Based on positive modeling results, wind tunnel evaluation was not deemed necessary for:

- Parcel G General Building and Fume Hood Exhaust (16)
- Parcel G Cooling Towers (4,000 Ton over 5 cells)
- Parcel H Boilers (4)
- Parcel H Cooling Towers (3 cells)

Design guidance for these sources was provided in RWDI's test plan document dated September 7, 2017 and is repeated below.

Proposed Parcel G General Building and Fume Hood Exhaust (16)

It is assumed that the general building air exhaust from the eight stacks above each penthouse level air handling unit could contain fume hood exhaust. The following design guidance is only necessary if there is fume hood exhaust in the air stream.

- The stacks should discharge flush with the top of Parcel G Northern Penthouse Façade (elev. 271' asl.).

- The discharge velocity while at 100% flow rate (50,000 cfm) should be a minimum of 3,000 fpm. With this exit velocity, up to 50% flow rate turndown is possible (down to 25,000 cfm and 1,500 fpm per stack) while still meeting recommended dilution criteria at building air intakes.

Proposed Parcel G Cooling Towers (4,000 Ton over 5 cells)

- Cooling towers should discharge flush with the top of Parcel G Northern Penthouse Façade (elev. 271' asl.).
- The cooling towers should be maintained according to industry best practices such as those outlined with Cooling Technology Institute (CTI) and ASHRAE.

Proposed Parcel H Boilers (4)

- Boilers should be low-NOx (<30 ppm) natural gas units with boiler flues discharging vertically a minimum of 7 ft above the penthouse roof without fixed rain caps.

Proposed Parcel H Cooling Towers (3 cells)

- Cooling towers should discharge at a height at least as tall as the Parcel H penthouse roof or surrounding screen wall, whichever is taller.
- The cooling towers should be maintained according to industry best practices such as those outlined with Cooling Technology Institute (CTI) and ASHRAE.

4.1 MBTA Locomotives on Existing Tracks

Metro Boston Transit Authority (MBTA) rail ways are located to the north of Parcels G and H. These tracks are traversed by diesel-fuelec trains as they move to and from the MBTA station.

Screening level numerical modeling indicates that there are no health-based risks associated with the train traffic, but that diesel odors could reach the intakes of Parcels G and H. This condition is more problematic for Parcel G as the intakes are on the northern façade facing the tracks. The frequency of train traffic on the tracks is not currently known. In general, a larger frequency of trains passing by Parcels G and H would also coincide with an increased potential for diesel odors to reach the building intakes.

Without detailed modeling, we recommend that a "wait-and-see" approach be adopted at Parcels G and H; this approach would involve the allocation of space for activated carbon filters within the building handling units. If diesel odors from the trains become problematic, then activated carbon can be installed at the affected intakes.

5 SUMMARY OF RECOMMENDATIONS

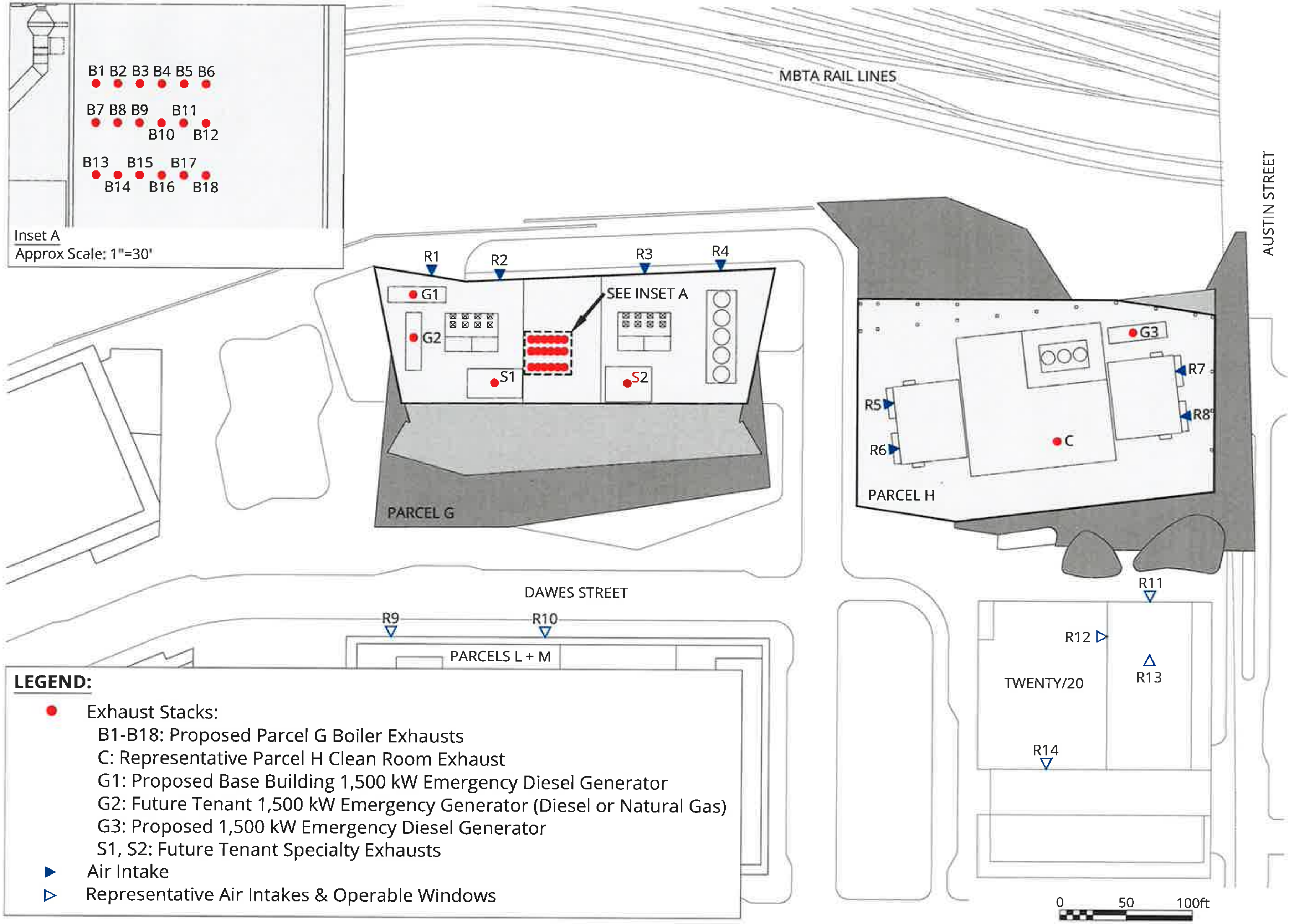
Based on the wind tunnel dispersion modeling results and discussion above, the following design and operational recommendations are suggested:

1. The stack height of the boilers can be reduced to discharge flush with the Parcel G northern penthouse façade (from vertical flues without rain caps).
2. No design changes are recommended for the Parcel G specialty exhausts. We recommend that once the nature of these exhausts has been established, they are reviewed to determine whether sufficient dispersion will be achieved to meet appropriate dilution criteria.
3. Swap the placement of the base building emergency diesel generator (G1) and the tenant emergency natural gas generator (G2) to reduce frequency of diesel odor impacts during generator operation.
4. Testing of the Parcel G and H emergency diesel generators should be conducted during off-hours to reduce likelihood of diesel odor exposure.
    a. Consider the use of DPF/DOC technology on the Parcel G and Parcel H diesel generators to further reduce odor probability if results from RWDI study are concerning to the design team and/or owner.
5. For the clean room, once the nature of the exhaust has been established, the dilution results should be reviewed by the cleanroom consultant to determine whether sufficient dispersion will be achieved to meet appropriate criteria.

6 APPLICABILITY OF RESULTS

The results and recommendations presented in this report pertain to the proposed Parcel G and H development as detailed in the architectural design drawings listed in Appendix B, mechanical drawings and information received up to and including September 15, 2017, the exhaust parameters presented in Section 3, and the exhaust and receptor locations shown in Figure 1. Should there be any design changes that deviate from these parameters, the building and local air quality conditions may change. It is therefore recommended that RWDI be contacted and requested to review the potential effects of design changes. Also, note that the work described herein was conducted for the purposes of providing design guidance only. Modeling and/or other work in support of regulatory requirements was not conducted and may require separate study.

FIGURES



LEGEND:

- Exhaust Stacks:
  - B1-B18: Proposed Parcel G Boiler Exhausts
  - C: Representative Parcel H Clean Room Exhaust
  - G1: Proposed Base Building 1,500 kW Emergency Diesel Generator
  - G2: Future Tenant 1,500 kW Emergency Generator (Diesel or Natural Gas)
  - G3: Proposed 1,500 kW Emergency Diesel Generator
  - S1, S2: Future Tenant Specialty Exhausts
- ▶ Air Intake
- ▷ Representative Air Intakes & Operable Windows

Location of Exhaust Sources and Receptors

Parcel G & H - Northpoint Site - Boston, MA

True North

Project #1703124

Drawn by: DBB | Figure: 1

Approx. Scale: 1"=100'

Date Revised: Sept. 22, 2017

APPENDIX A

APPENDIX A: DISCUSSION OF DILUTION CRITERIA

Combustion Exhausts

The primary pollutants associated with combustion exhausts are nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM) and sulfur dioxide (SO_2). Odor is also a concern for exhaust sources that use diesel or jet fuel, such as generators, trucks, buses, and helicopters. Gasoline and natural gas combustion sources have negligible odor emissions.

Health Criteria

Occupational and ambient air quality standards should be considered when determining the health based criteria for combustion exhaust. It is our opinion, however, that the application of occupational standards may not be sufficiently stringent for the higher risk demographic that can be found in the general population including children, the elderly, or other individuals that are more susceptible to respiratory ailments or other health effects of poor air quality (e.g., those with chronic obstructive pulmonary disorder (COPD) or asthma). In most cases NO_2 is the limiting pollutant, meaning that it has the highest ratio of source concentration to allowable concentration and requires the most dilution. By designing to meet the recommended target for NO_2, recommended thresholds for other criteria pollutants would also be met.

Several studies, as summarized by the California Environmental Protection Agency[1,2], have been published citing the acute health effects of NO_2 in humans exposed to varying concentrations in non-occupational settings. These studies demonstrated that short-term exposure of individuals with compromised respiratory systems to concentrations of NO_2 as low as 338 μg/m³ affected airway responsiveness. Based on this evidence, RWDI recommends applying a not-to-exceed target of 338 μg/m³ for NO_2 emissions from intermittent combustion exhaust sources unless a stricter national or state standard exists.

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1 California Environmental Protection Agency (CalEPA), Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA). January 2007. Review of the California Ambient Air Quality Standard for Nitrogen Dioxide. Technical Support Document Available online at http://www.arb.ca.gov/research/aaqs/no2-rs/no2tech.pdf

2 California Environmental Protection Agency (CalEPA), Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA). January 2007. Review of the California Ambient Air Quality Standard for Nitrogen Dioxide. Staff Report. Available online at http://www.arb.ca.gov/research/aaqs/no2-rs/no2staff.pdf

For continuously operating sources such as boilers, co-generation systems, or generators that are used for peak shaving, we recommend applying a stricter 1-hour standard of 188 µ/m³ due to the potential for longer-term exposure. This is equivalent to the 1-hour National Ambient Air Quality Standard (NAAQS) established by the US Environmental Protection Agency (EPA), and is stricter than both RWDI's recommended 338 µg/m³ target for intermittent sources, and applicable longer-term (e.g., 24-hour and annual) air quality standards for criteria pollutants. Note that for intermittent sources, the EPA has expressed the view that the 1-hour standard of 188 µ/m³ for NO_2 may be too strict and not necessarily applied to such sources as generators that are only used for emergency purposes[3]. For NO_2 and intermittent sources, the not-to-exceed target of 338 µg/m³ is recommended instead as discussed above.

While the thresholds and limits imposed by regulatory standards have been consulted to establish design criteria, it is important to note that regulatory modeling has not been undertaken, and we are not aware of specific requirements that may apply. We recommend that the permitting aspect be considered, as different criteria, modeling procedures, and background air quality levels may need to be considered.

Emergency Generators

For the 1,500 kW Tier 2 emergency diesel generators the exhaust must be diluted by a factor of 350:1 to meet the suggested short-term limit of 338 µg/m³. This health-based dilution criterion was developed using the specified CAT 3512C engine with EPA Tier 2 emissions with a specific 'not-to-exceed' nitrogen oxides (NO_x) emission rate of 6.6 g/bhp-hr at 100% load.

For the 1,500 kW Tier 2 natural gas emergency generator, the exhaust must be diluted by a factor of 50:1 to meet the suggested short-term 338 µg/m³ NO_2 limit. This health-based dilution criterion was developed using typical emissions for CAT G3516C engines with a nitrogen oxides (NO_x) emission rate of 1.0 g/bhp-hr.

Boiler Exhaust

For the proposed 4,000 MBH boilers operating on natural gas, the exhaust must be diluted by a factor of 10:1 in order to meet the short-term 188 µg/m³ NO_2 limit, which is applicable to continuously operating sources. This health-based dilution criterion was developed based on the low-NO_x (9 ppm) emissions provided for the proposed boilers.

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[3] U. S. Environmental Protection Agency. "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" Tyler Fox, Leader, March 1, 2011

Odor Criteria

Odor is very subjective, and there is a varying degree of sensitivity within the human population. It is often very difficult to eliminate odors entirely. Instead, design targets can be used for minimizing detection and recognition of the odorous exhaust. In order to do so, RWDI recommends designing to reduce the strength of odors from combustion exhausts such as diesel generators to a 50% detection level, which is recognized as an industry standard target for reducing odors to a generally acceptable level. By designing to meet this level, approximately 50% of the population will be able to detect an odor, while fewer people would be able to recognize the odor or find it objectionable. Combustion sources are very odorous, and require significantly more dilution to meet odor thresholds compared to meeting health-based air quality standards.

Diesel Generator Odor

To address odor from diesel generator exhaust, RWDI recommends designing to achieve an exhaust dilution of 3,000:1 at nearby receptors of concern (i.e., the exhaust is diluted 3,000 times before reaching the receptor location). This design target is based on odor panel testing conducted previously by RWDI using field samples from modern (post-2005) diesel generator exhausts operating on ultra-low sulfur diesel (ULSD) fuel.

The 3,000:1 target corresponds to a 50% detection level and also to a 20% recognition level (i.e., approximately 20% of the population will be able to recognize the diesel odor at this dilution level). Table A1 provides the approximate levels of response that could be expected at various levels of dilution for diesel odor based on the odor panel testing.

Table A1: Approximate Levels of Population Response to Diesel Odor

Level of Exhaust Dilution	Diesel Odor Detection Response (% of population)	Diesel Odor Recognition Response (% of population)
1,000:1	95%	60%
2,000:1	70%	30%
3,000:1	50%	20%
5,000:1	15%	<10%

The information in the above table can be used to demonstrate the expected strength of diesel odors at various levels of exhaust dilution. Stronger odors elicit higher levels of response, while milder odors elicit lower levels of response. For example, with a dilution on the order of 1,000:1, nearly everyone exposed to the odor can be expected to detect it with 60% of people able to recognize it correctly as diesel. At this odor level, one might expect a strong correlation with odor-driven complaints. In general, very high levels of dilution are required in order to minimize the level of response to diesel odors.

APPENDIX B

APPENDIX B: DRAWING LIST FOR MODEL CONSTRUCTION

The drawings and information listed below were received from Perkins + Will and NBBJ and were used to construct the scale model of the proposed Parcels G and H – Northpoint Site. Should there be any design changes that deviate from this list of drawings, the results may change. Therefore, if changes in the design are made, it is recommended that RWDI be contacted and requested to review their potential effects on wind conditions.

File Name	File Type	Date Received (dd/mm/yyyy)
101970.00 Divco West NorthPoint Parcel H-penthouse.rvt	.rvt	8/24/2017
2017 08 18-101970.00 Divco West NorthPoint Parcel H.rvt	.rvt	8/22/2017

FINAL REPORT

PARCELS G AND H – NORTHPOINT SITE

CAMBRIDGE, MA

PEDESTRIAN WIND STUDY
RWDI #1703124
September 26, 2017

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EXECUTIVE SUMMARY

The wind conditions around the proposed Parcels G and H – Northpoint Site developments are discussed in detail within the content of this report and are summarized as follows:

- Wind speeds at most areas around the project site are expected to meet the RWDI wind safety criterion except for two areas – locations around Baldwin park and the service road between Parcels G and H;
- Wind conditions at grade level around Parcels G and H are generally predicted to be appropriate for the intended usages during the summer months;
- Seasonally higher wind speeds during the winter are predicted to result in grade level wind conditions that are primarily suitable for the intended usages. However higher than desired wind speeds are anticipated around the entrance plaza of Parcel G, the west areas around Parcel G;
- Wind speeds at the upper level terraces and podiums of Parcels G and H are expected to be higher than desired for passive pedestrian activity during the summer. Recommended wind control measures have been provided in the report in order to improve wind conditions.

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1 INTRODUCTION

RWDI was retained to assess and consult on the pedestrian wind conditions on and around the proposed Parcels G and H – Northpoint Site (Project) in Cambridge, Massachusetts (**Image 1**). The project involves the construction of a 250' tall building on Parcel G of the site, and a 179' tall building on Parcel H.

This report summarizes the methodology of wind tunnel studies for pedestrian wind conditions, describes the RWDI pedestrian wind comfort and safety criteria, presents the local wind conditions and their effects on pedestrians and provides conceptual wind control measures, where necessary.

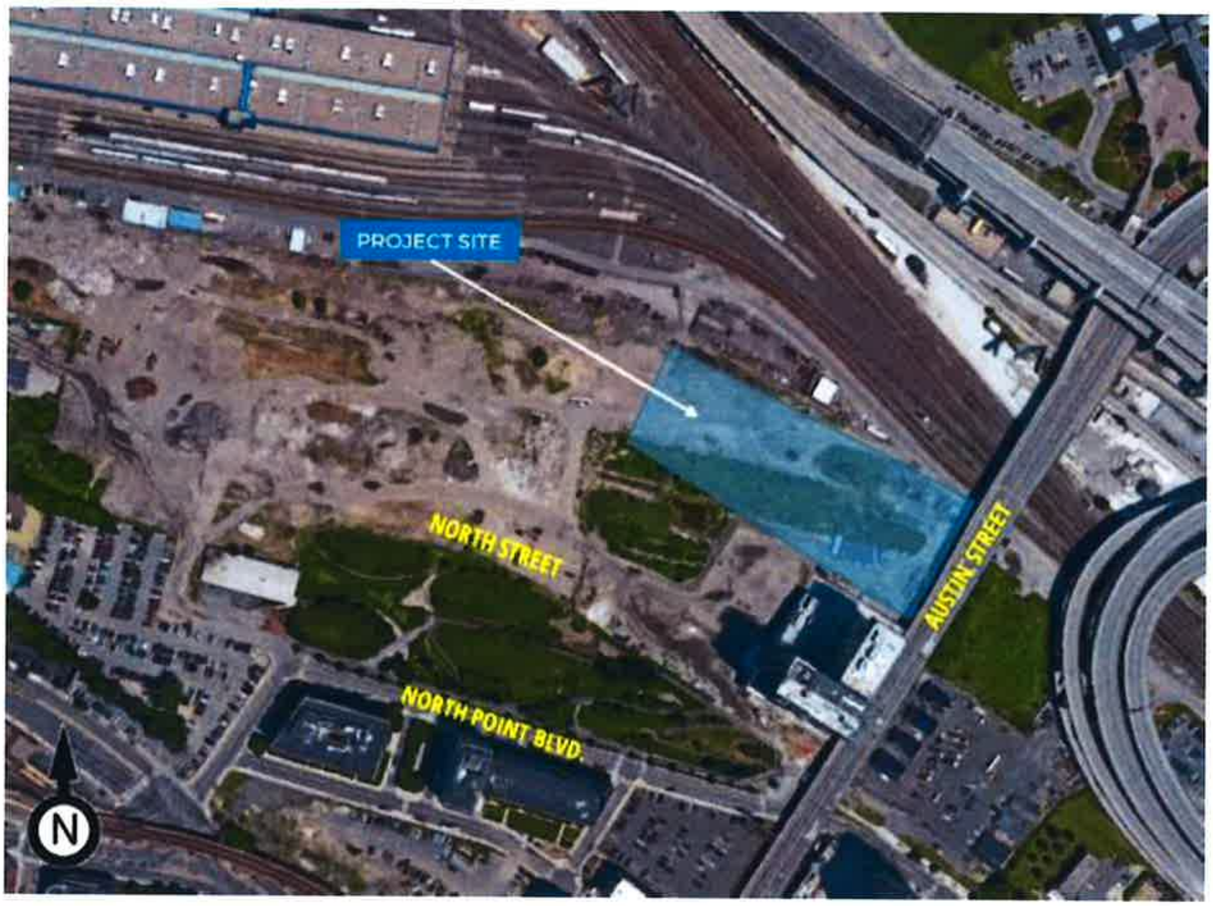


Image 1: Site plan – Aerial view of site and surroundings (courtesy of Google™ Earth)

2 METHODOLOGY

2.1 Test Configuration

To assess the wind environment around the proposed project, a 1:300 scale model of the project site and existing surroundings, including buildings that are approved and anticipated to be added in the future, was constructed for the wind tunnel test.

The scale model of the proposed project (as shown in Image 2) was constructed using the design information and drawings listed in Appendix A. The wind tunnel model included all relevant surrounding buildings and topography within approximately 1200 ft. radius of the study site. The boundary-layer wind conditions beyond the modelled area were also simulated in RWDI's wind tunnel. The wind tunnel model was instrumented with 63 wind speed sensors to measure mean and gust wind speeds at a full-scale height of approximately 5 ft. The placement of wind measurement locations was based on our experience and understanding of the pedestrian usage for this site. These measurements were recorded for 36 equally incremented wind directions.

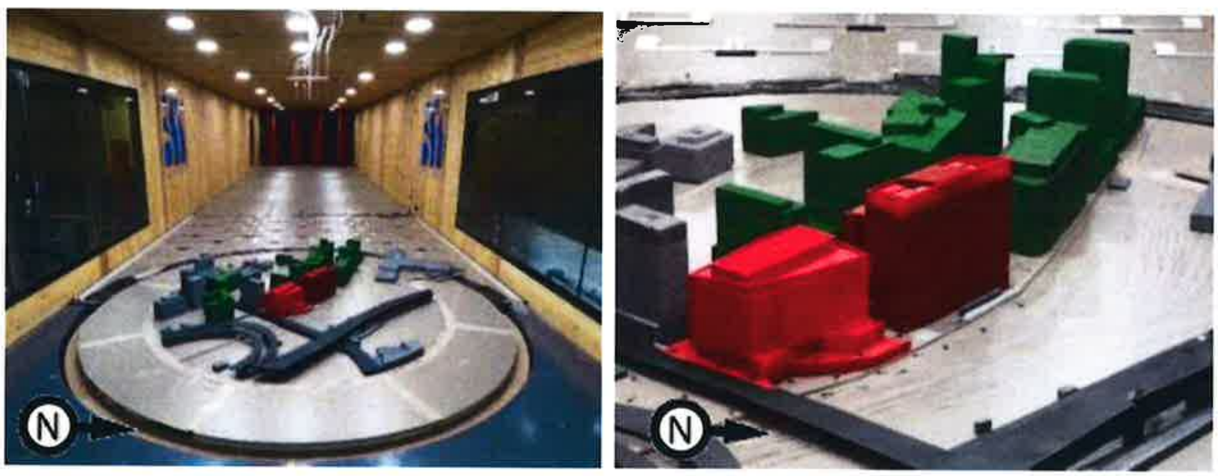


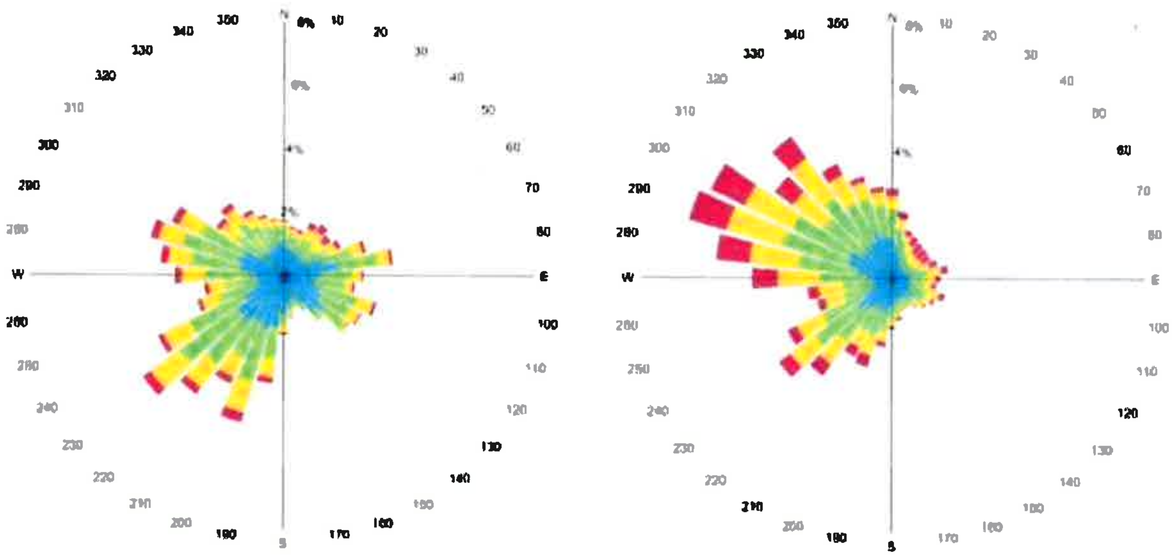
Image 2: Wind tunnel study model - future configuration

2.2 Meteorological Data

Wind statistics recorded at Boston Logan International Airport between 1986 and 2017, inclusive, were analyzed for the Summer (May through October) and Winter (November through April) seasons. Image 3 graphically depicts the directional distributions of wind frequencies and speeds for the two seasons.

Winds are frequent from the southwest and northwest quadrants during the summer, with secondary winds present from the east. During the winter, the prevailing winds are from the northwest quadrant, with secondary winds from the southwest quadrant, as indicated by the wind roses. Strong winds of a mean speed greater than 20 mph measured at the airport (at an anemometer height of 30 ft) occur more often in the winter (12.5%) than in the summer (4.8%).

Wind statistics from Boston Logan International Airport were combined with the wind tunnel data to predict the frequency of occurrence of full-scale wind speeds. The full-scale wind predictions were then compared with the RWDI criteria for pedestrian comfort and safety.



Summer (May – October) **Winter (November – April)**

Wind Speed (mph)	Probability (%) Summer	Winter
Calm	2.4	2.1
1-5	7.2	5.4
6-10	35.3	27.0
11-15	35.0	31.9
16-20	15.3	21.0
>20	4.8	12.5

Image 3: Directional distribution of winds approaching Boston Logan International Airport from 1986 to 2016

2.3 Wind Criteria

The RWDI pedestrian wind criteria are used in the current study. These criteria have been developed by RWDI through research and consulting practice since 1974 (References 1 through 6). They have also been widely accepted by municipal authorities as well as by the building design and city planning community (References 7 through 11).

RWDI Pedestrian Wind Criteria

Comfort Category	GEM Speed (mph)	Description
Sitting	≤ 6	Calm or light breezes desired for outdoor restaurants and seating areas where one can read a paper without having it blown away
Standing	≤ 8	Gentle breezes suitable for main building entrances, bus stops, and other places where pedestrians may linger
Strolling	≤ 10	Moderate winds that would be appropriate for window shopping and strolling along a downtown street, plaza or park
Walking	≤ 12	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
Uncomfortable	> 12	Strong winds of this magnitude are considered a nuisance for all pedestrian activities, and wind mitigation is typically recommended

Notes: (1) Gust Equivalent Mean (GEM) Speed = max(mean speed, gust speed/1.85) ; and;
(2) GEM speeds listed above based on a seasonal exceedance of 20% of the time between 6:00 and 23:00.

Safety Criterion	Gust Speed (mph)	Description
Exceeded	> 56	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

Notes: Based on an annual exceedance of 9 hours or 0.1% of the time for 24 hours a day.

A few additional comments are provided below to further explain the wind criteria and their applications.

- Both mean and gust speeds can affect pedestrian comfort and their combined effect is typically quantified by a Gust Equivalent Mean (GEM) speed, with a gust factor of 1.85.
- Instead of standard four seasons, two periods of summer (May to October) and winter (November to April) are adopted in the wind analysis, because in a cold climate such as that found in Cambridge, there are distinct differences in pedestrian outdoor behaviors between these two-time periods.
- Nightly hours between midnight and 5 o'clock in the morning are excluded from the wind analysis for comfort since limited usage of outdoor spaces is anticipated, while wind safety analysis is conducted for a 24-hour period.
- A 20% exceedance is used in these criteria to determine the comfort category, which suggests that wind speeds would be comfortable for the corresponding activity at least 80% of the time or four out of five days.

- Only gust wind speeds need to be considered in the wind safety criterion. These are usually rare events, but deserve special attention in city planning and building design due to their potential safety impact on pedestrians.

- These criteria for wind forces represent average wind tolerance. They are sometimes subjective and regional differences in wind climate and thermal conditions as well as variations in age, health, clothing, etc. can also affect people's perception of the wind climate. Comparisons of wind speeds for different building configurations are the most objective way in assessing local pedestrian wind conditions.

3 PREDICTED WIND CONDITIONS

The predicted wind comfort and safety conditions pertaining to the configuration assessed are graphically depicted on a site plan in Figures 1 through 3. These conditions and the associated wind speeds are presented in Table 1, located in the Tables section of this report.

3.1 Pedestrian Wind Safety

Wind speeds at most areas on and around the site are expected to meet the wind safety criterion. Exceptions are: the area to the northwest of Parcel G (Locations 6 and 18 in Figure 5), and the area between Parcels G and H (Locations 9, 23 and 24 in Figure 5). These conditions are caused by exposure to the northeasterly winds and acceleration of winds around the building corners.

Wind control features are recommended to control wind safety issues around the Parcels G and H. The landscaping recommended for improving wind comfort (discussed in subsequent sections) is expected to reduce gust wind speeds around the site. Alternatively, the use of wind screens or canopies at the north and northeast corners of Parcel G can be used to improve wind conditions (presented in Image 4).

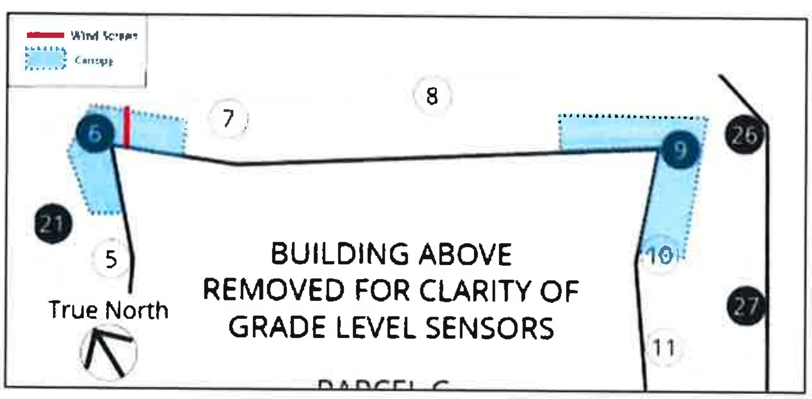


Image 4: Areas for recommended wind screens and canopies

Wind speeds at all locations on the elevated terraces and podiums of the two Parcels are expected meet the wind safety criterion (Figure 3).

3.2 Pedestrian Wind Comfort

3.2.1 Grade Level (Locations 1 through 47)

Wind conditions comfortable for walking or strolling are appropriate for sidewalks.

Wind speeds at the entrance plaza of Parcel G (Locations 1 through 3 in Figure 1) are expected to be suitable for standing, which is desired for an entrance. During the winter, wind speeds in this area are expected to increase and become conducive to strolling (Locations 1 through 3 in Figure 2), which may be higher than desired for building entrances along the façade of this plaza. Winter wind conditions in this area can be improved using localized wind control features. The use of wind screens, or tall, coniferous planters, are recommended along the plaza's west perimeter. This is recommended to reduce the impact of winds accelerating through the undercut of the building. Examples of these mitigation measures are presented in Image 5.

Image 5: Examples of recommended mitigation measures

The main entrance to Parcel H was identified at Location 26 in Figures 1 through 3. Wind conditions in this area are predicted to be conducive to standing throughout the year, which is ideal.

Wind conditions west of Parcel G are predicted to be primarily acceptable for walking, strolling and standing during the summer (Locations 3 through 5, 17 and 18 in Figure 1). These wind speeds are higher than desired for passive activity during the summer months, which is due to the acceleration of the southwesterly through northwesterly and northeasterly winds between Parcel G and the future building west of the site. During the winter, winds in this area will be uncomfortable for any pedestrian activity (Figure 2). These conditions may be acceptable to Divco provided that this area is not frequently used during the winter season.

Wind conditions around the west area of Parcel G can be improved using landscaping (highlighted green areas in Image 6), which will assist in diffusing winds across the park area. If an improvement in wind conditions is desired for the winter season, we recommend that coniferous landscaping be planted.

Pedestrian areas surrounding Parcel G and Parcel H consist of a commuter rail area north of the site; a parking lot and highway underpass east of the site; a service road between Parcels G and H; and future Parcel developments along the south and west areas. The summer wind conditions in these areas are primarily expected to be suitable for standing along the north and east, with slightly windier conditions around the south and west areas. Wind conditions around all the surroundings are expected to increase during the winter to become suitable for strolling or walking (acceptable for pedestrian pathways). Isolated areas of uncomfortable winds were identified between Parcels G and H (Location 24 in Figure 2). Based on the landscaping plan presented in Image 6, evergreen trees are planned along the north corner of Parcel G, as well as the sidewalk between Parcels G and H. This is predicted to improve uncomfortable wind conditions around the proposed development.

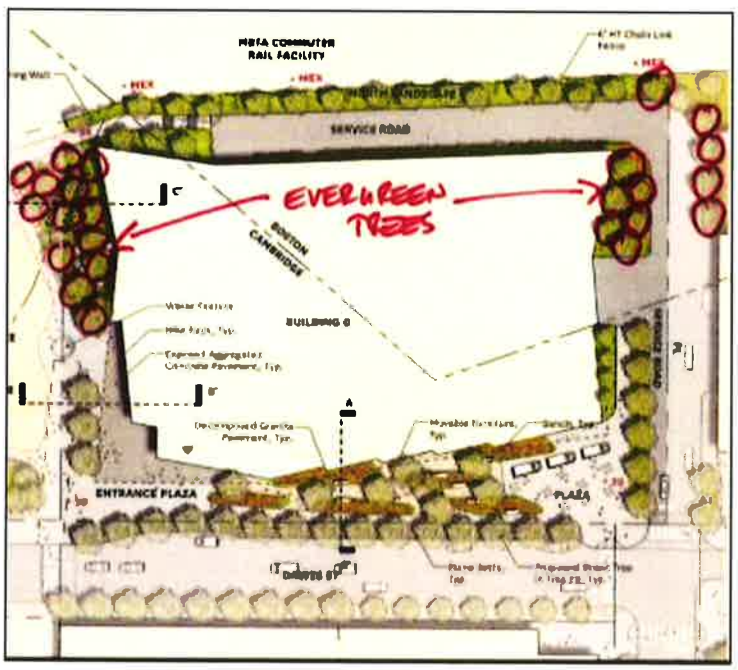


Image 6: Landscaping plan

3.2.2 Terrace and Roof Levels (Locations 48 through 63)

It is generally desirable for wind conditions on terraces intended for passive activities to be comfortable for sitting more than 80% of the time in the summer. During the winter, the area would not be used frequently and increased wind activity would be considered appropriate.

Parcel G has potential amenity spaces on Level 3 (Locations 48 through 54), and wind speeds on this level are predicted to be comfortable for walking or strolling during the summer (Figure 1), which is higher than desired for pedestrian activities.

On the Parcel H development, wind speeds are generally predicted to be unsuitable for passive activities on the south terrace (Locations 55 through 59) during the summer, with isolated areas of calmer wind conditions on along the east area of Level 2 (Location 60 through 62 in Figure 1). As pedestrians are unlikely to use these spaces during the winter, windy conditions across the terraces may be considered acceptable.

Wind comfort on the elevated levels of both Parcels G and H can be improved by installing guardrails (ideally 20-30% porous), or trees of a height greater than 6 ft. around their perimeter. Additionally, the use of localized mitigation features such as planters, wind screens or trellises can further help to improve the conditions. It is recommended that planters be 4 - 6 ft. in height. Examples are presented in Image 7.

Image 7: Examples of recommended mitigation features on terraces

4 APPLICABILITY

The wind conditions presented in this report pertain to the proposed Parcels G and H – Northpoint Site as detailed in the architectural design drawings listed in Appendix A. Should there be any design changes that deviate from this list of drawings, the wind condition predictions presented may change. Therefore, if changes in the design are made, it is recommended that RWDI be contacted and requested to review their potential effects on wind conditions.

5 REFERENCES

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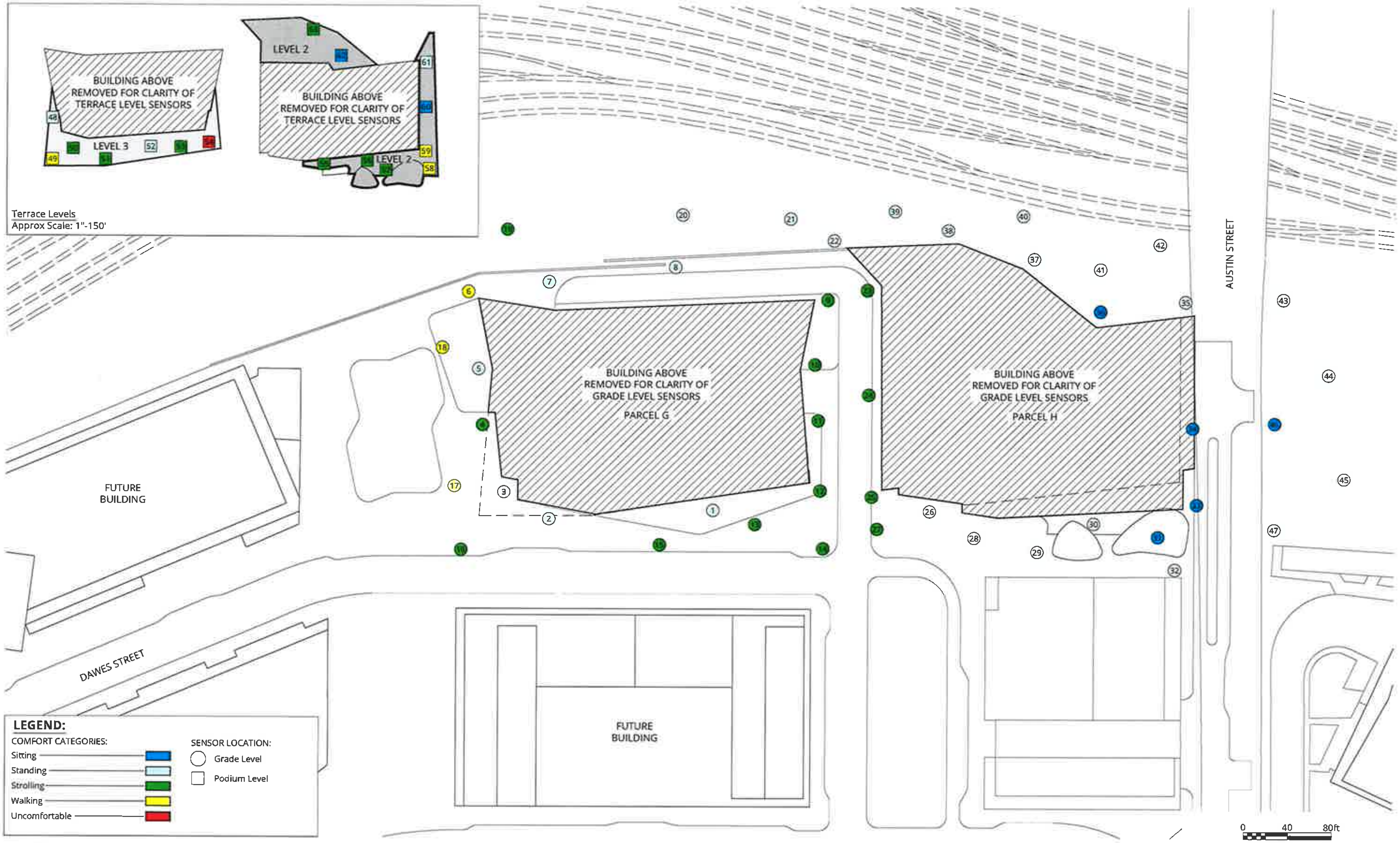
FIGURES



Pedestrian Wind Comfort Conditions
Future Configuration
Summer (May to October, 6:00 to 23:00)

Parcel G & H - Northpoint Site - Cambridge, MA

True North

Project #1703124

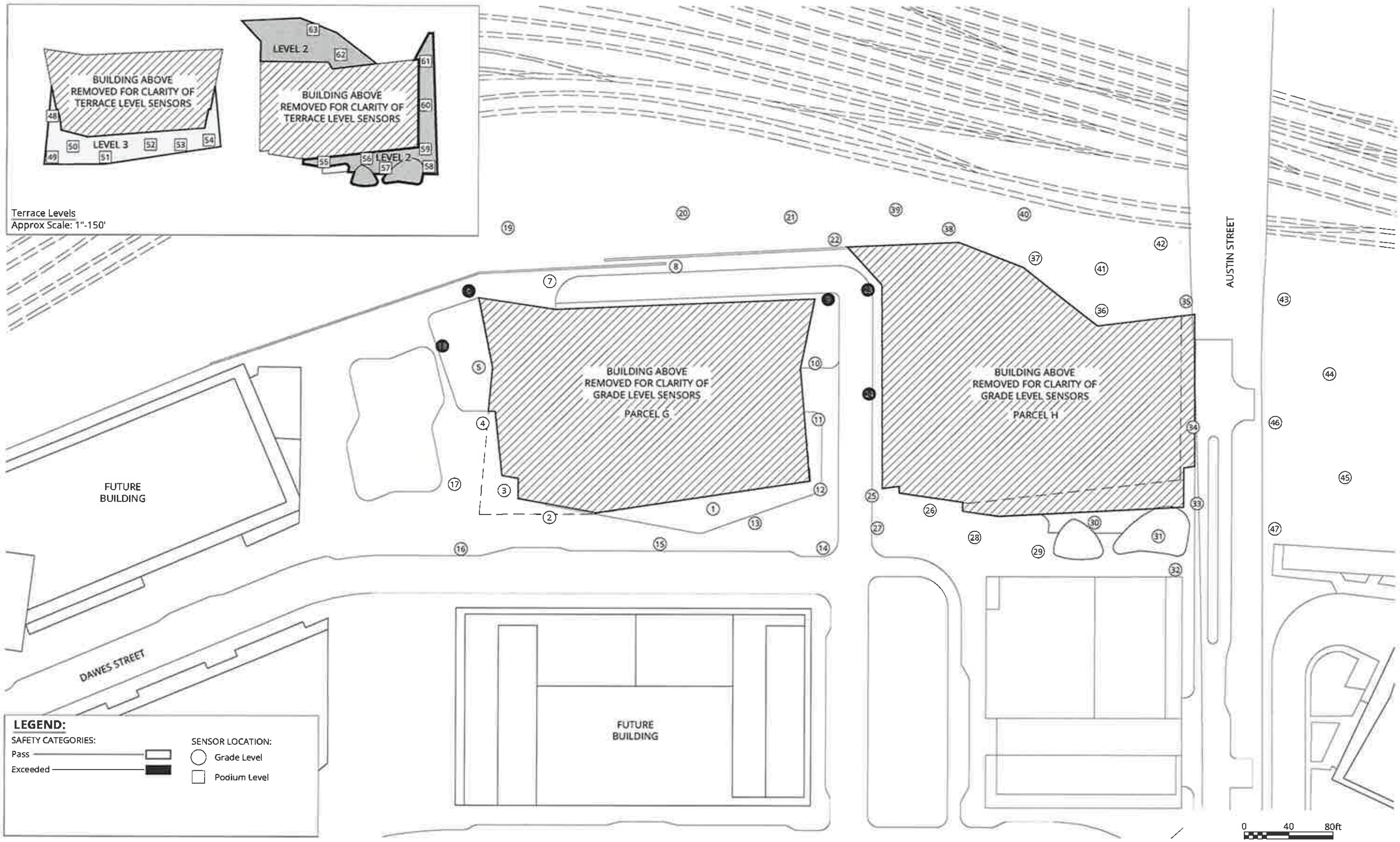
Drawn by: DBB | Figure: 1
Approx. Scale: 1"=80'
Date Revised: Sept. 26, 2017

Pedestrian Wind Comfort Conditions
Future Configuration
Winter (November to April, 6:00 to 23:00)

Parcel G & H - Northpoint Site - Cambridge, MA

Project #1703124

Drawn by: DBB	Figure: 2
Approx. Scale:	1"=80'
Date Revised:	Sept. 26, 2017



Pedestrian Wind Safety Conditions
Future Configuration
Annual (January to December, 0:00 to 23:00)

Parcel G & H - Northpoint Site - Cambridge, MA

True North

Project #1703124

Drawn by: DBB	Figure: 3
Approx. Scale:	1"=80'
Date Revised:	Sept. 26, 2017

RWDI

TABLES

Table 1: Pedestrian Wind Comfort and Safety Conditions

Location	Wind Comfort				Wind Safety	
	Summer		Winter		Annual	
	Speed (mph)	Speed (mph)	Speed (mph)	Rating	Speed (mph)	Rating
1	8	Standing	9	Strolling	39	Pass
2	8	Standing	9	Strolling	41	Pass
3	6	Sitting	8	Standing	35	Pass
4	8	Standing	11	Walking	40	Pass
5	7	Standing	8	Standing	40	Pass
6	12	Walking	14	Uncomfortable	54	Pass
7	7	Standing	10	Strolling	44	Pass
8	7	Standing	8	Standing	34	Pass
9	9	Strolling	11	Walking	54	Pass
10	8	Standing	10	Strolling	40	Pass
11	10	Strolling	11	Walking	47	Pass
12	10	Strolling	11	Walking	48	Pass
13	8	Standing	10	Strolling	39	Pass
14	9	Strolling	10	Strolling	45	Pass
15	8	Standing	11	Walking	43	Pass
16	10	Strolling	12	Walking	46	Pass
17	11	Walking	14	Uncomfortable	48	Pass
18	11	Walking	13	Uncomfortable	55	Pass
19	9	Strolling	12	Walking	46	Pass
20	8	Standing	10	Strolling	43	Pass
21	8	Standing	10	Strolling	44	Pass
22	8	Standing	11	Walking	45	Pass
23	9	Strolling	10	Strolling	65	Exceeded
24	10	Strolling	13	Uncomfortable	57	Exceeded
25	10	Strolling	12	Walking	48	Pass
26	7	Standing	8	Standing	32	Pass
27	8	Standing	10	Strolling	40	Pass
28	7	Standing	8	Standing	34	Pass
29	7	Standing	8	Standing	33	Pass
30	8	Standing	10	Strolling	39	Pass
31	6	Sitting	7	Standing	33	Pass
32	6	Sitting	6	Sitting	37	Pass
33	4	Sitting	4	Sitting	21	Pass
34	5	Sitting	6	Sitting	19	Pass
35	6	Sitting	8	Standing	46	Pass
36	5	Sitting	6	Sitting	28	Pass
37	7	Standing	9	Strolling	42	Pass
38	7	Standing	10	Strolling	41	Pass
39	8	Standing	10	Strolling	43	Pass
40	8	Standing	10	Strolling	43	Pass
41	7	Standing	9	Strolling	37	Pass
42	7	Standing	9	Strolling	39	Pass
43	7	Standing	8	Standing	42	Pass
44	7	Standing	8	Standing	34	Pass

Table 1: Pedestrian Wind Comfort and Safety Conditions

Location	Wind Comfort				Wind Safety	
	Summer		Winter		Annual	
	Speed (mph)	Speed (mph)	Speed (mph)	Rating	Speed (mph)	Rating
45	8	Standing	9	Strolling	40	Pass
46	6	Sitting	7	Standing	29	Pass
47	7	Standing	8	Standing	35	Pass
48	8	Standing	10	Strolling	42	Pass
49	11	Walking	14	Uncomfortable	53	Pass
50	8	Standing	10	Strolling	40	Pass
51	9	Strolling	11	Walking	40	Pass
52	8	Standing	9	Strolling	37	Pass
53	8	Standing	10	Strolling	39	Pass
54	13	Uncomfortable	14	Uncomfortable	53	Pass
55	8	Standing	10	Strolling	40	Pass
56	8	Standing	10	Strolling	39	Pass
57	10	Strolling	12	Walking	41	Pass
58	11	Walking	12	Walking	45	Pass
59	11	Walking	12	Walking	47	Pass
60	6	Sitting	6	Sitting	38	Pass
61	7	Standing	6	Sitting	48	Pass
62	6	Sitting	6	Sitting	29	Pass
63	8	Standing	10	Strolling	46	Pass

Seasons	Hours
Summer = May - Oct	6:00 - 23:00 for comfort
Winter = Nov - April	0:00 - 23:00 for safety

Configurations	
Future	Proposed project with future surroundings

Comfort Speed (mph)	
(20% Seasonal Exceedance)	
≤ 6	Sitting
7 - 8	Standing
9 - 10	Strolling
11 - 12	Walking
> 12	Uncomfortable

Safety Speed (mph)	
(0.1% Annual Exceedance)	
≤ 56	Pass
> 56	Exceeded

APPENDIX A

Drawing List for Model Construction

The drawings and information listed below were received from Perkins + Will and NBBJ and were used to construct the scale model of the proposed Parcels G and H – Northpoint Site. Should there be any design changes that deviate from this list of drawings, the results may change. Therefore, if changes in the design are made, it is recommended that RWDI be contacted and requested to review their potential effects on wind conditions.

File Name	File Type	Date Received (dd/mm/yyyy)
101970.00 Divco West NorthPoint Parcel H-penthouse.rvt	**Revit**	**8/24/2017**
2017 08 18-101970.00 Divco West NorthPoint Parcel H.rvt	**Revit**	**8/22/2017**