The Distribution and Effects of Borrowed Daylight in the Atrium of the Van Nuys Medical Science Building

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Case Study Participants

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Jeff Culp - Operations Manager

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and the faculty and staff of the Van Nuys Medical Science whose cooperation and assistance was critical to the success of this study.

James B. Hill

Senior Vice President

Architectural Concepts and Design

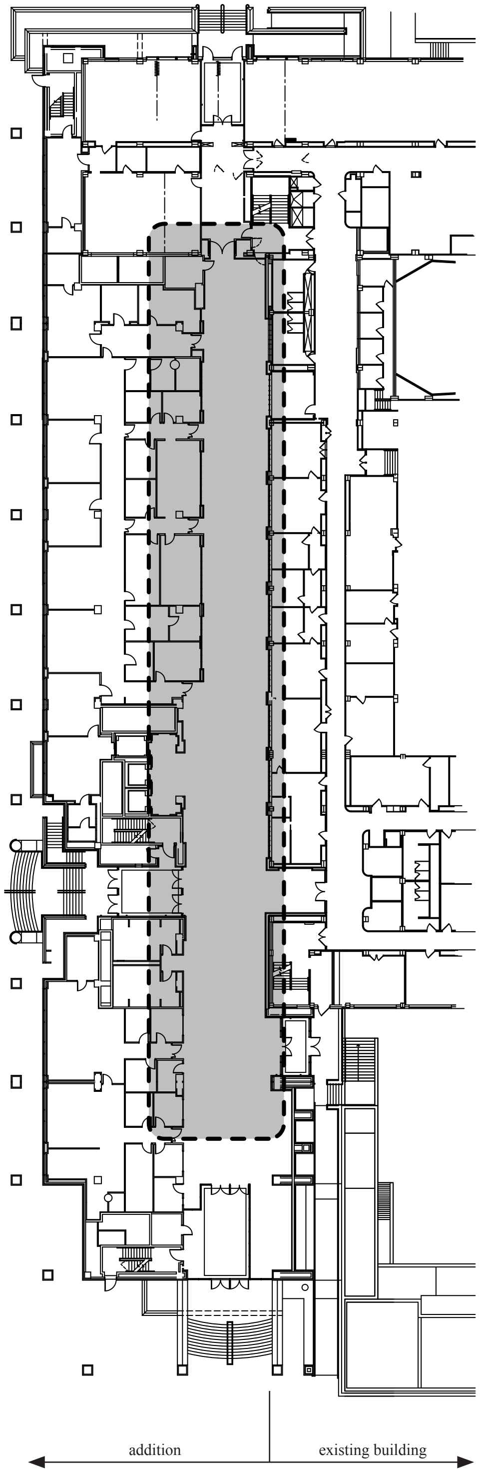
Project Management/Client Champion

BSA Design

on the cover: image showing the mirror wall and glazed atrium roof

Contents

View through atrium facing north



Plan with the atrium highlighted.

Abstract

This report describes the methodology, collected results, conclusions of and design recommendations based upon the planning and execution of a eight-week field study of the luminous environments of the atrium and offices (highlighted in the image to the right) of the addition to the Van Nuys Medical Science Building at IUPUI in Indianapolis, Indiana.

The focus of this report is the office spaces themselves and the ability of the users of these spaces to perform tasks in daylit and artificially lit conditions. The process for deriving the conclusions involved discussions with the project manager and the faculty of the science building, field based and non-field based research of the spaces involved in the study, the analysis of the data collected in the field, and the drafting of design guidelines based upon specific shortcomings found in the daylighting scenarios in the addition as designed and constructed. A post occupancy evaluation was also created and distributed to compile the opinions of a number of the users of the offices on the daylighting conditions in their offices.

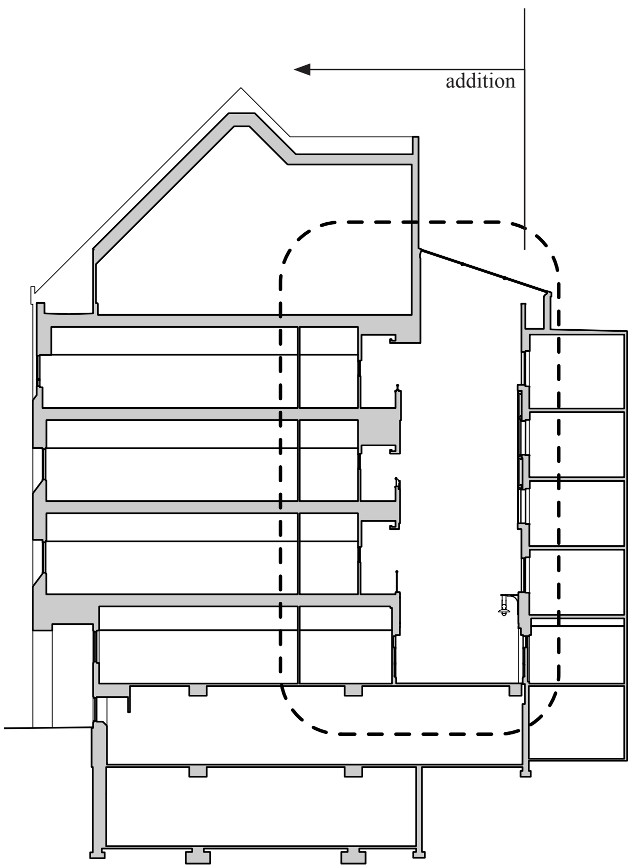
Vital Signs Background

The intent of the Vital Signs program is to investigate the post-occupancy environmental conditions of a building such as lighting design, air quality, etc, in order to better understand those design methodologies and approaches that maximize the benefits for the building's occupants and improve the efficiency of the building as a living machine. The purpose for identifying these methodologies is the development of standards that will inform design decisions for contemporary and future architectural and engineering professionals.

In this seventh series of the Vital Signs program studies through the CERES department at Ball State University, lighting conditions at the Van Nuys Medical Science Building in Indianapolis, IN were being examined.
This building was chosen because of its classification under Vital Signs guidelines as a 'generic building type' laboratory building. By studying the daylighting conditions within this facility, comparing them to national standards, and considering their effects on the building's users, one can identify similarities and differences between the intent of the building's designers and the consequences of their design decisions. This type of analysis allows the development of daylighting guidelines and suggestions for other designers encountering similar design situations whether inside or outside the realm of this building type.

Image from the fifth floor balcony, showing the connection between the addition and the existing building

James B. Hill, BSA Design
Project Manager



Section with the area of the study highlighted

Project Background

Provided by James B. Hill, BSA Design

The Van Nuys Medical Science Center Phase 1 is an addition to the existing Medical Science Building originally constructed in the mid-1950s on the IUPUI campus. James B. Hill of BSA Design was the project manager for the project. BSA Design provided architectural, MEP engineering and lab planning design services for the project. Design work on the addition was initiated in 1992, but due to budget delays and the eventual inclusion of the State Board of Health laboratories to the program, the design was not completed until April 1996. Construction on the project was completed in May of 1998 at a cost of $34 million. The project added 167,000 gross square feet to the existing laboratory building, bringing the total square footage for the complex to 462,000 gross square feet.

A prominent feature of the Van Nuys Medical Science Building addition is a narrowly proportioned atrium space, oriented north-south, which links it to the existing laboratory building. The atrium space functions as an “interior street,” maintaining existing campus circulation patterns and serves as an orientation space for clarifying access to the new and old wings of the building. Also, by using this building configuration, the architect was able to obtain a variance allowing for a one-hour fire barrier to be used between the new and old construction where four-hour fire rated construction would otherwise be required. A curtainwall system using mirrored glass was installed on the existing building façade along the east side of the atrium. The highly reflective wall system was chosen because it concealed the discrepancy in floor to floor heights between the existing structure and the addition, visually doubled the narrow, 20’ atrium space and reflected natural light to the corridor zones along the west side of the atrium. Behind the mirrored wall in the existing building are offices that overlook the atrium. On the west side of the atrium are the new laboratory suites. Apertures in the west wall of the atrium provide visual relief for the researchers. Originally, the spaces were going to be separated from the atrium by a wall that was to be entirely glazed. However, privacy concerns and the researchers’ need for large quantities of wall space demanded that the amount of glazing be kept to a minimum.

Research Methodology

The following pages will show the results of two types of research used in determining the quality and effects of the lighting in the Van Nuys Medical Science Building.

The *field based research* performed in the development of this report can be divided into three phases. These phases are based upon the increasing level of engagement on the part of the researchers as the hypotheses are developed and tested.

Indicative research is based upon the initial assessment of the researchers on the first visit to the building. By making notes and observations of the space in the field after talking with the architect about the basic ideas behind the design, the team is able to assemble a strong first impression of the space. This qualitative first impression leads to the initial development of the hypotheses.

Investigative research involves the use of instantaneous field based light measurements to develop a better understanding of the quantitative aspects of the spaces considered in the initial hypotheses. This aids in the refinement of these hypotheses, which allows for the development of a plan for testing the hypotheses in the third phase of field based research.

Diagnostic research involves the use of long term light measuring devices to examine how the conditions observed in the investigative phase vary over time -- in this case a two week period in November 2002. Large quantities of data are collected in this phase and must be organized carefully to draw appropriate conclusions.

The non-field based research performed in the development of this report falls into two categories:

Diagnostic research using a *daylight study model* was performed to see how the daylighting conditions in the atrium may change throughout the year.

A *post occupancy evaluation* questionnaire was created and distributed to gain a qualitative understanding from the point of view of the building's daily users.

Image from first floor showing mirror wall

Indicative Research

Procedure

The indicative research is simply an initial visit to the building to make observations about the building and its lighting conditions. This trip was conducted one week after the interview with the architect, during which the design intents and other more general issues pertaining to the project were discussed. The team arrived in the afternoon on a clear day and recorded the following first impressions through field notes, photographs, and sketches.

Image showing detail of mirror wall

Observations

Our first impression of the atrium of the Van Nuys Medical Science Building was that it was a bright, well-lit space, even in overcast sky conditions. A large, 90% reflective mirror mostly covered the east wall, the ceiling was completely glazed, and most of the finishes in the space were light colored. The mirror wall gave a broken reflection of the wall opposite to it. There was some concern that the mirror could cause a glare problem due to its west facing orientation. A number of offices adjacent to the atrium had some form of visual filter or barrier such as black felt cloth placed in the glazed apertures.

A large amount of electrical illumination was also provided. Indirect decorative fluorescent luminaries and direct floodlight fluorescent luminaries provide illumination for the first floor. The intensity of the floodlight-style luminaries created a lot of visual discomfort for individuals on the first floor of the space. Indirect fluorescent luminaries and direct incandescent luminaries provided illumination on the second, fourth, and fifth floor balconies. It appeared that none of the electrical illumination in the atrium was regulated by a photocell and/or rheostat.

Hypotheses

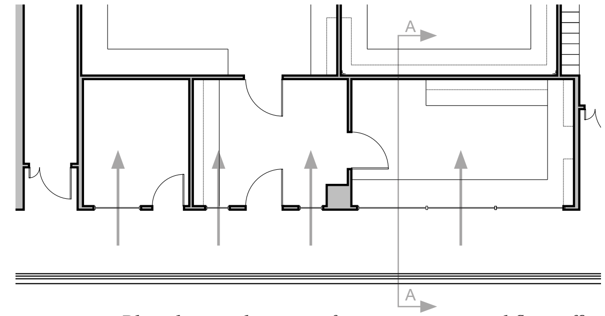
These hypotheses were first formed loosely based upon the team's first impressions of the building from the indicative research done during the first visit to the building and the interview with James Hill. They were refined during the early investigative phases of research.

> The borrowed daylight entering the offices and laboratories adjacent to the atrium provides an adequate amount of illumination according to IES standards for the tasks performed within those spaces.
>
> The borrowed daylight entering the offices adjacent to the atrium causes no visual impairment or distraction for the users in those spaces.

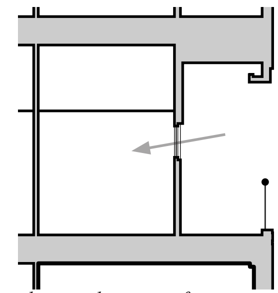
IES Standards

IES standards are recommendations published by the Illuminating Engineering Society outlining suggested ranges of illumination in footcandles for specific tasks. They were used as the guidelines for quantitatively proving or disproving the first hypothesis.

For the "performance of visual tasks of high contrast or a large size," which is the category of tasks performed in the office spaces, the IES calls for 20 to 50 footcandles at the location of the task. Therefore, the borrowed daylight entering the offices studied must provide at least 20 footcandles of illumination at the location of the task to be sufficient for the tasks involved.



Plan showing location of apertures in second floor offices


Section showing location of apertures in second floor offices


View of apertures from hallway


View of apertures from inside office

HOBO Light Intensity Logger

Stowaway Light Intensity Logger

GE Light Meter

Sylvania Light Meter

Minolta Spot Luminance Meter

Tools

These tools were used in the investigative research and diagnostic research portions of the project.

Instrumentation

Onset Instrument’s HOBO Light Intensity Data Logger

Onset Instrument’s StowAway Light Intensity Data Logger

These instruments are used to measure light intensity over a period of time. They are set to take measurements at prescribed intervals over a specific time period. They record data in lumens/ft^2 that can be downloaded to a personal computer. The StowAway has a range from 0.001 to 1000 footlamberts and the HOBO has a range of 0.01 to 15,000 footlamberts. They are partially cosine corrected but are not color corrected.

GE Analog Light Meter model 217

A handheld device used for measuring footcandles of light falling on a surface. This device has a range of 0 to 10,000 fc and is cosine and color corrected.

Sylvania Digital Light Meter model DS-2000

A handheld device used for measuring footcandles of light falling on a surface. This device has a range of 0 to 2,000 fc and is color and cosine corrected. It is also more precise and more accurate than the GE analog meter.

Minolta Luminance Spot Meter model LS-100

This device measures the luminance of a surface within a one-degree acceptance angle within a nine-degree field of view. It has a range of sensitivity from 0.001 to 87,530 footlamberts and is both cosine and color corrected.

Nikon N80 Camera

Pentax K-1000

Related Software

Onset Instrument’s Boxcar Pro 4.0

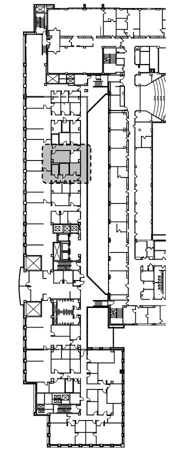
This software activates the HOBO and StowAway instruments for field measurements and downloads the data recorded by the devices once measurements are recorded.

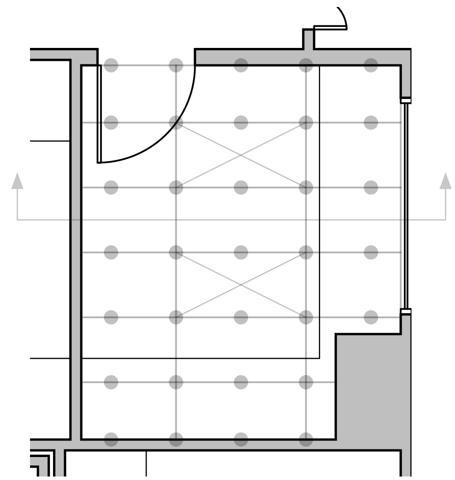
Investigative Research

Procedure

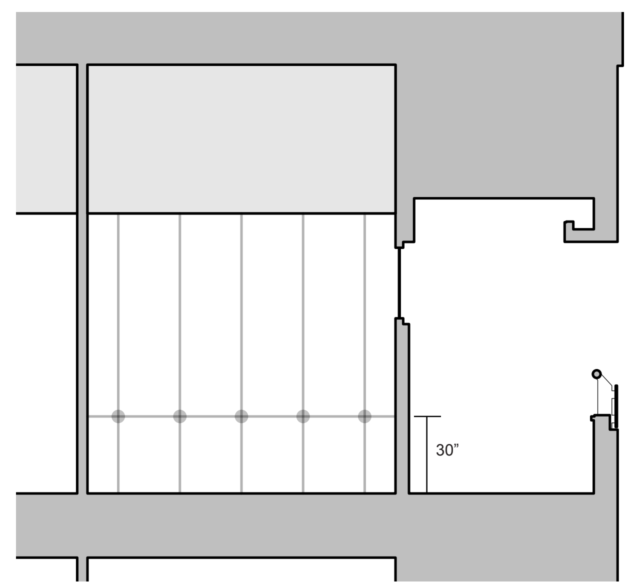
The purpose of the investigative phase of analysis was to determine the distribution of daylight throughout Office C with and without artificial lighting. Measurements were taken with the lights in the room turned on and turned off, with the door to the room shut to restrict any interference from artificial light in the adjacent corridor. Office C was divided into a 2' square grid referenced to the 2' x 4' acoustic ceiling tile grid as a guide to provide a matrix onto which the readings could be plotted (indicated by gray circles on the figures to the right). Readings were then taken with the Sylvania digital light meter at 30 inches above the floor. The researchers were careful not to enter the attenuated angle of the light meter, which would distort the device's readings, while operating the light meter.

These measurements were taken at 11:00 A.M., which the data from the StowAways and the daylighting model tests suggested would be the time of day at which the most amount of daylight would enter the office spaces in the winter. Therefore, taking measurements at this time would reveal the best case scenario of daylight penetration into the space.





Plan of room C showing the reflected ceiling grid and location of Sylvania light meter readings (as gray circles)

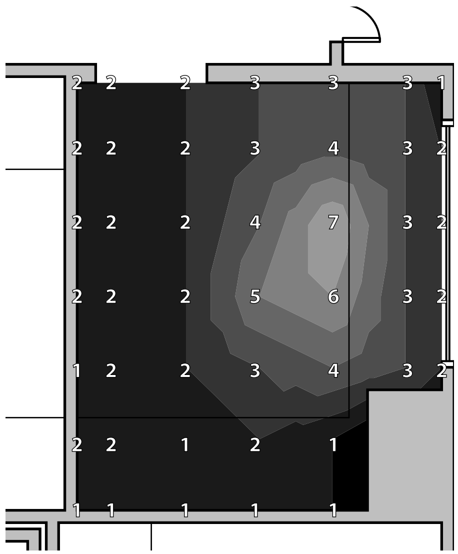


Section of room C showing the 30” height of the Sylvania light meter readings

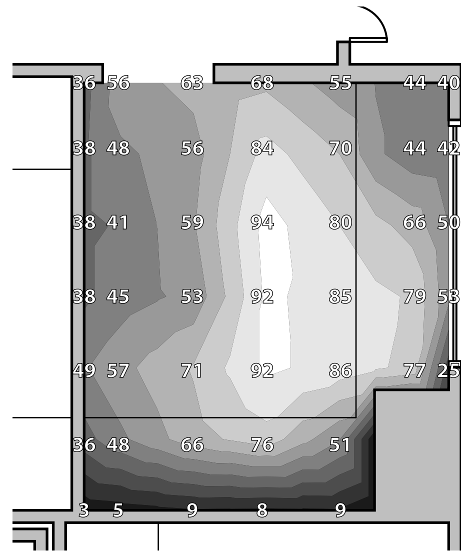
Investigative Research

Results

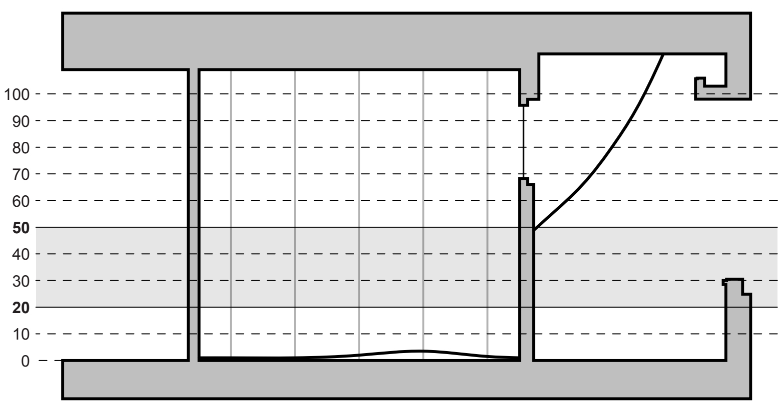
The data gathered indicates a sharp contrast between artificially lit and daylit conditions in Office C. As indicated in the isolux plot and illumination cross-section on the left, the amount of daylight entering the room does not provide 20-50 footcandles at the task level, which is the IES requirement for this work space. However, the graphics on the right indicate that these requirements are exceeded with the use of electric lighting. Furthermore, the graphs drawn through the balcony show that an overly sufficient amount of light exists in the circulation zone between the atrium and the office zone.



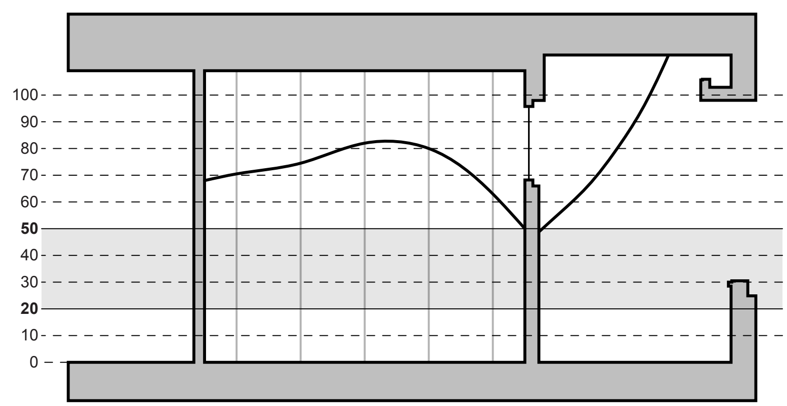
Isolux plot of Office C showing values at grid points without artificial light



Isolux plot of Office C showing values at grid points without artificial light



Section of Office C showing artificial lighting with the 20-50 fc IES recommended zone



Section of room C showing artificial lighting with the 20-50 fc IES recommended zone

Investigative Research

Conclusions

By examining the isolux plots and illumination sections on the previous page, three conclusions can be drawn.

The first conclusion is that the amount of light falling on the task surfaces in Office C is more than adequate when the lights in the room are turned on. This is because the lighting on these surfaces exceeds the 20-50 footcandle requirement set by the IES standards for the tasks performed in this space.

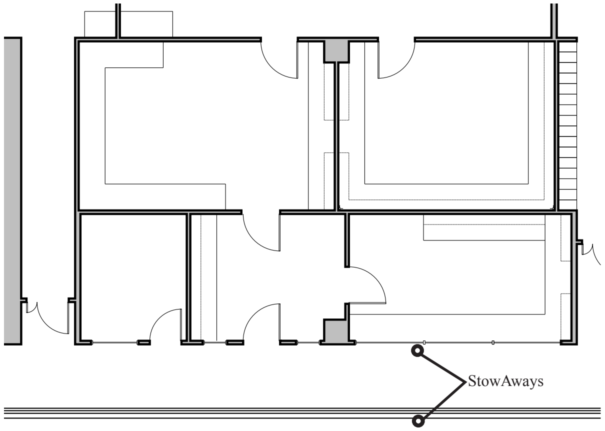
The second conclusion is that the amount of light falling on the task surfaces in Office C is inadequate when the lights in the room are turned off. This is because the lighting on these surfaces falls below the 20-50 footcandle requirement set by the IES standards for the tasks performed in this space.

The third conclusion is that if the daylighting condition in this space was improved so that the task surfaces would receive the required 20-50 footcandles, then less artificial light would have to be used. This would also improve the quality of light in this space, because most individuals prefer natural daylight over artificial light, and reduce the building's energy consumption and lower energy costs.

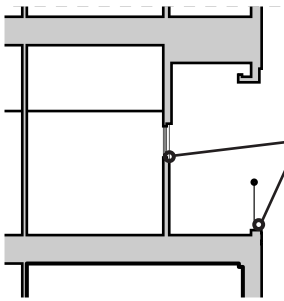
Redirection of the light producing the extreme levels of illumination in the balcony spaces could aid in achieving this goal. This idea is reinforced by the results of the diagnostic research with StowAways (p.20) and the conclusions drawn from the daylighting model studies (p.23). Methods for resolving this problem are described more thoroughly on page 27.

Image showing office C with the lights on

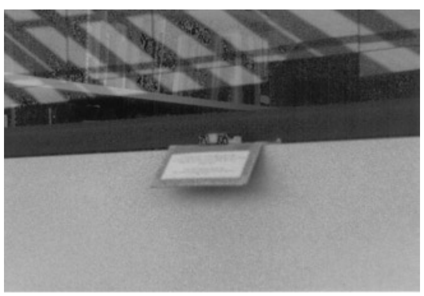
Image showing office C with the lights off



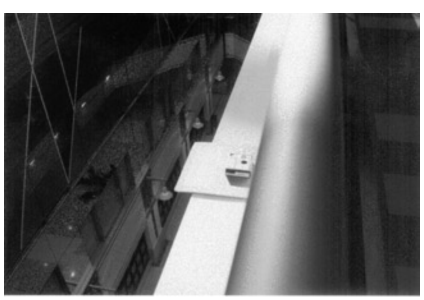
Plan showing location of StowAways at Office B



Section showing location of StowAways at Office B



Location of StowAway on sill



Location of StowAway on balcony ledge

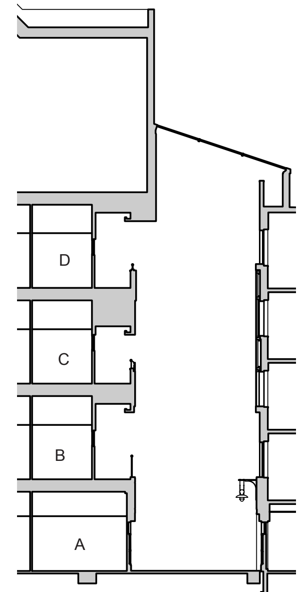
<u>Diagnostic Research: Field Measurements</u>

Procedure

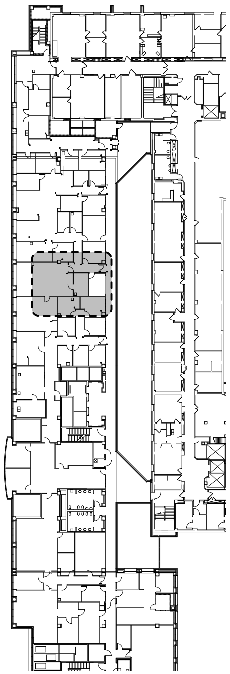
Six Stowaway illumination meters were used for the study. These devices were placed in the following locations:

- inside of Office A (first floor) adjacent to the window looking into the atrium
- outside of Office B (second floor) adjacent to the window overlooking the atrium and on the ledge of the balcony overlooking the atrium
- on the inside of Office C (fourth floor) adjacent to the window overlooking the atrium and on the ledge of the balcony overlooking the atrium
- and outside of Office D (fifth floor) adjacent to the window overlooking the atrium and on the ledge of the balcony overlooking the atrium

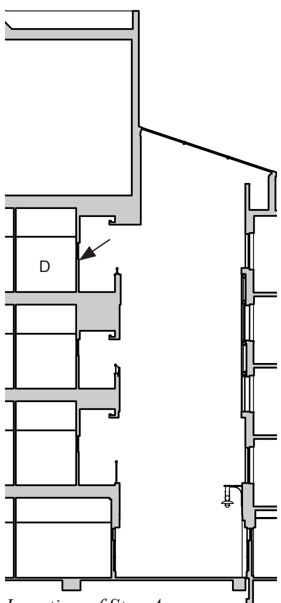
These devices were programmed using the Boxcar software to take readings for two weeks and record illumination levels at fifteen-minute intervals. During this period of time weather conditions recorded were obtained from the national weather service.



Location of Offices A-D



Location of Office D



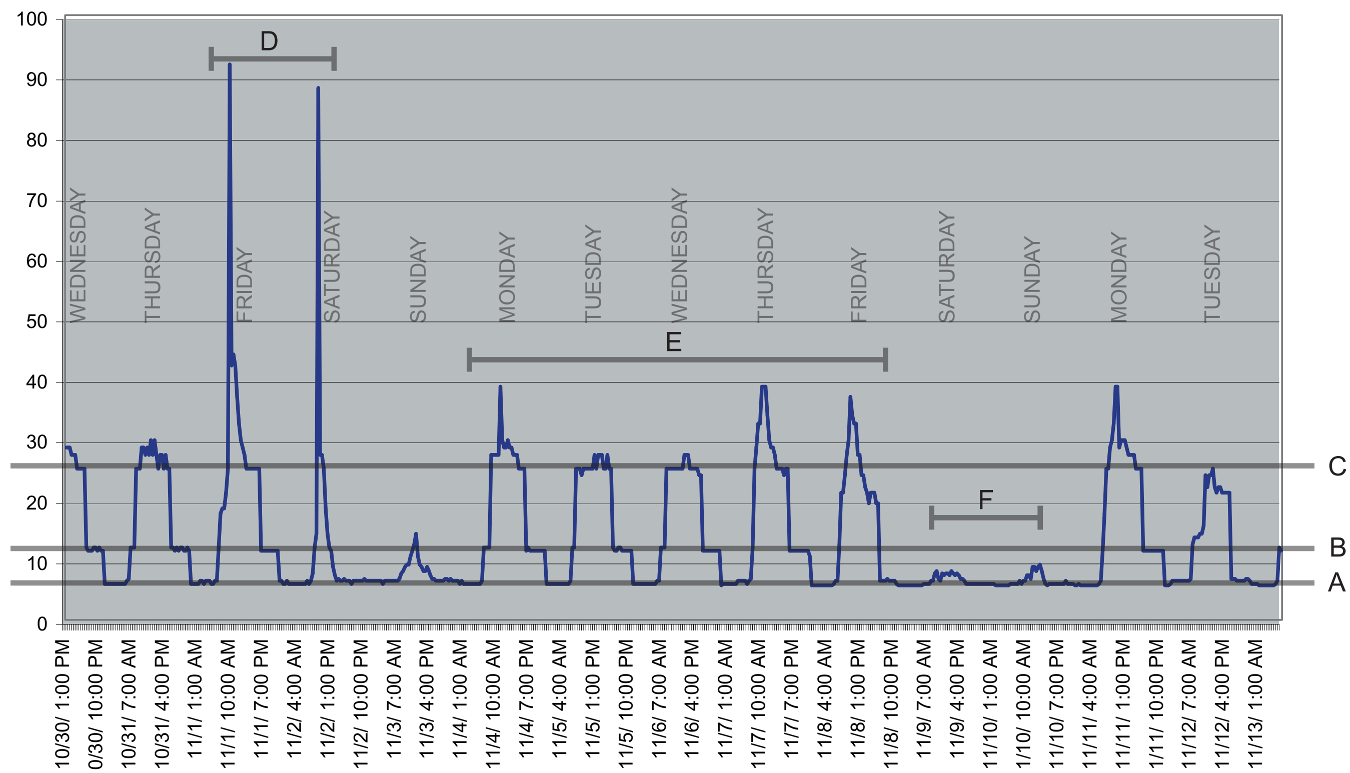
Location of StowAway

Diagnostic Research: Field Measurements

Introduction: Interpreting the Data

Below is a sample of the data recorded by the StowAway light meters. This is taken from the StowAway placed on the aperture sill outside of Office D. By looking at this example, one can identify clear patterns of the lighting in this space. Verifying these trends with the weather conditions recorded over the two week study period lends credibility to the results of these tests.

- Reference line A indicates artificial light given off by safety lighting that runs 24 hours a day in the building's hallway.
- Reference line B indicates artificial light given off by the lighting in the coves in the hallways between the atrium and the offices.
- Reference line C indicates artificial light given off by the ceiling lights inside of the offices.
  Daylight falling upon the StowAway is indicated by the peaks that rise above reference line C.
- Zone D indicates natural light peaks on the clearest days of the study.
- Zone E indicates the average lighting falling on the aperture sill during a mostly overcast week.
- Zone F indicates the natural light falling upon the StowAway on a rainy weekend.
  The readings in this zone are much lower than the others because of low illumination levels from the lack of most artificial light except safety lighting and the overcast sky conditions.



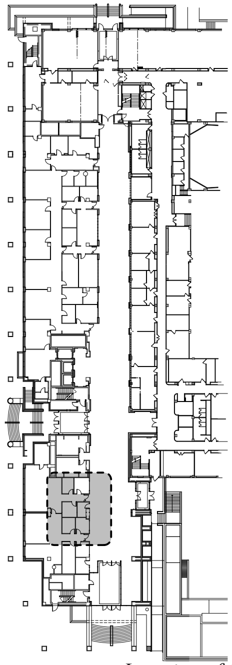
Diagnostic Research: Field Measurements

Data

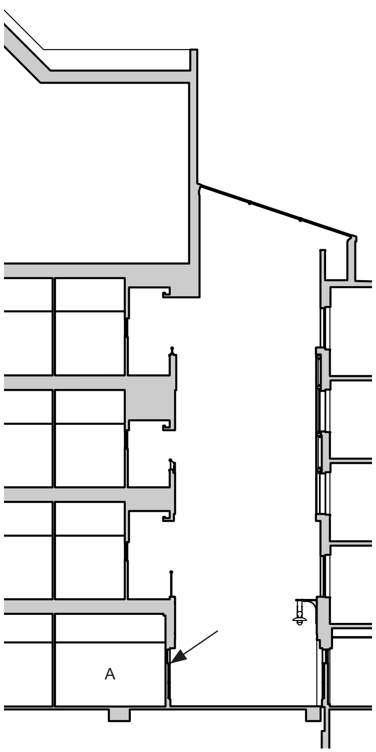
Pages 16-19 show graphs of the data retrieved from the seven StowAways programmed to take measurements from October 30, 2002 through November 13, 2002. The sections to the right of the graphs indicate the location of the devices.

Larger scale images of the graphs are available in Appendix A (p.30) for a more detailed analysis of the data.

Conclusions based upon comparisons drawn from the information displayed in the graphs is available beginning on page 20.

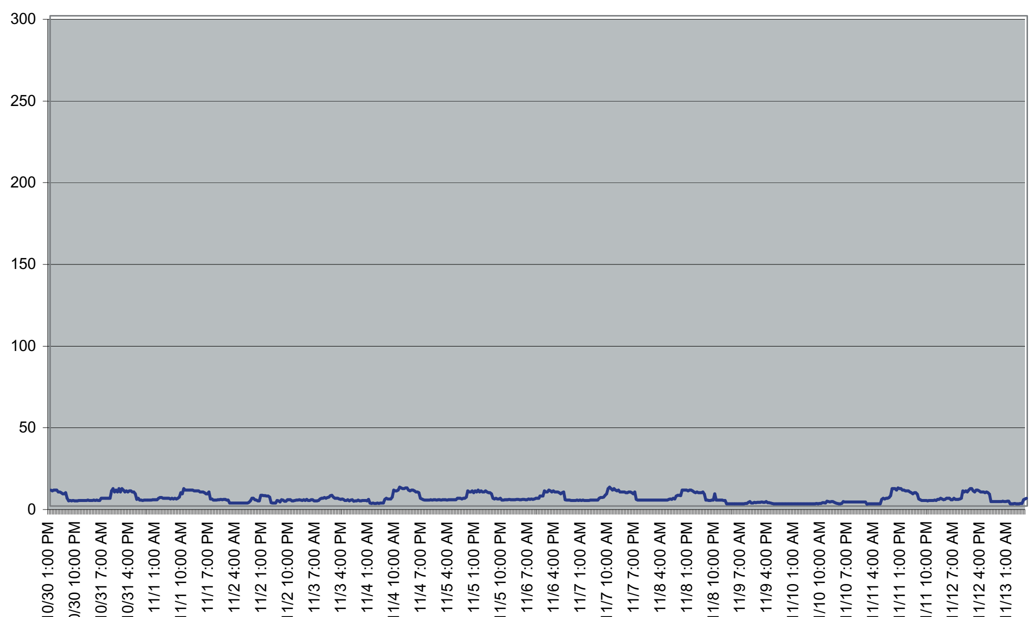


Location of Office A



Location of StowAway

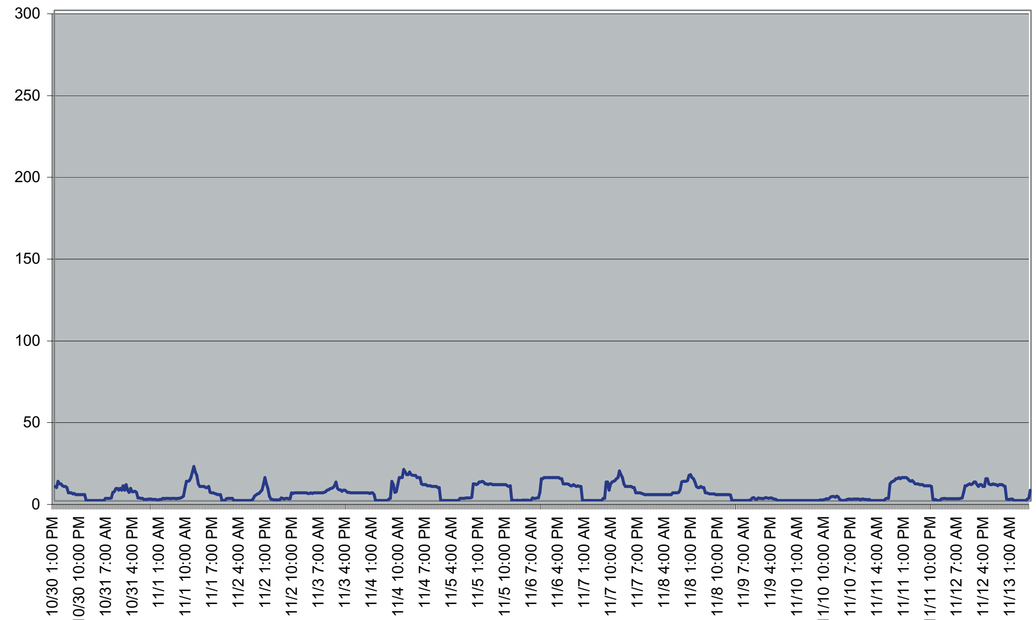
Office A - First Floor



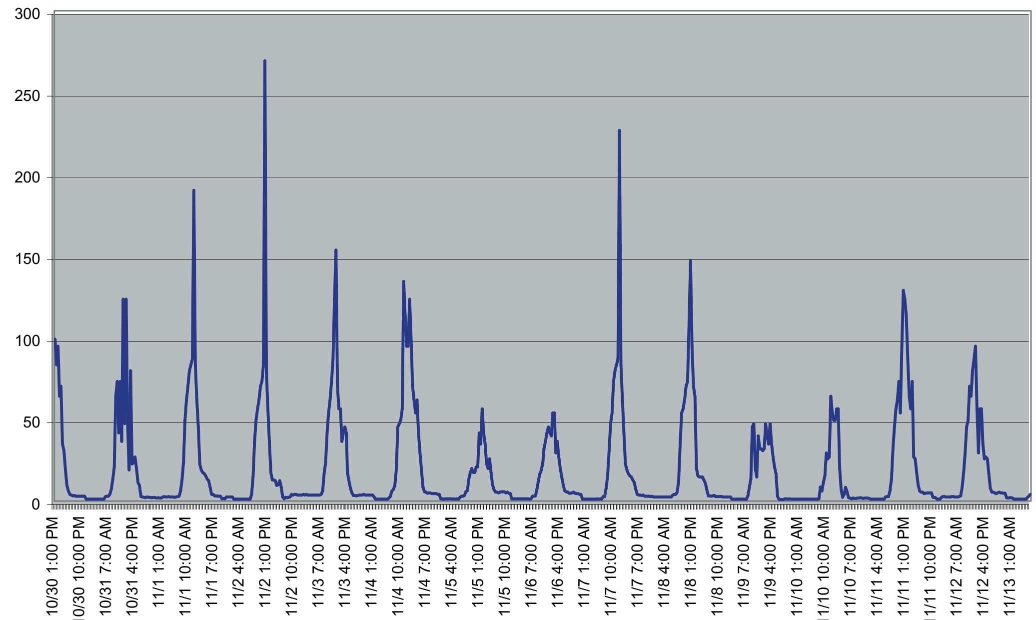
StowAway located on aperture sill

Diagnostic Research: Field Measurements

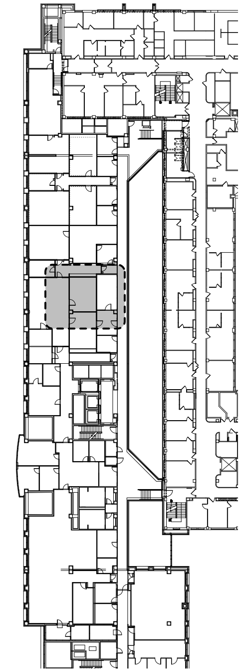
Data: Office B - Second Floor



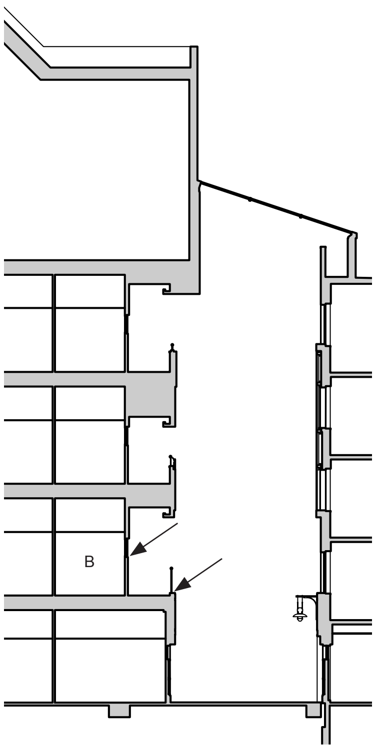
StowAway located on aperture sill



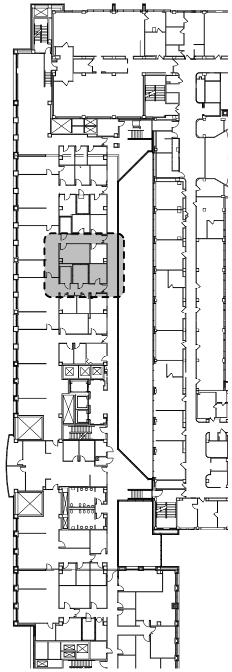
StowAway located on balcony ledge



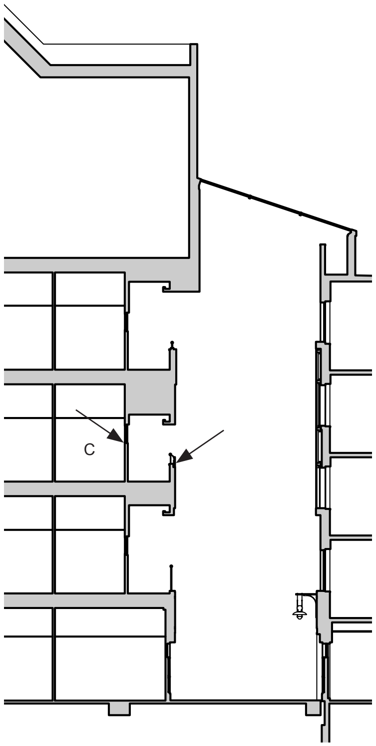
Location of Office B



Location of StowAways



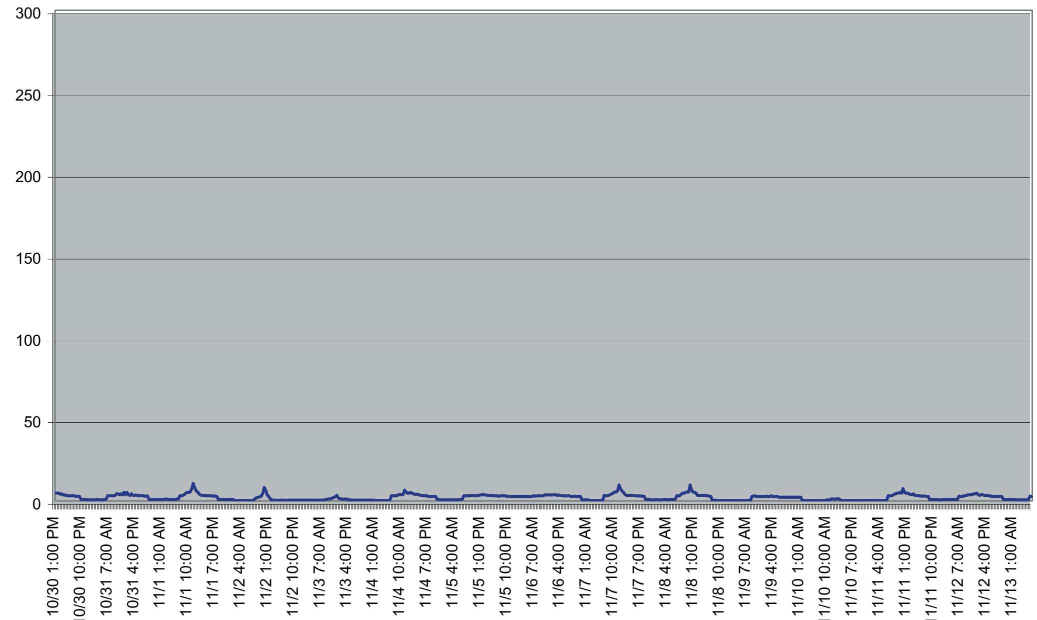
Location of Office C



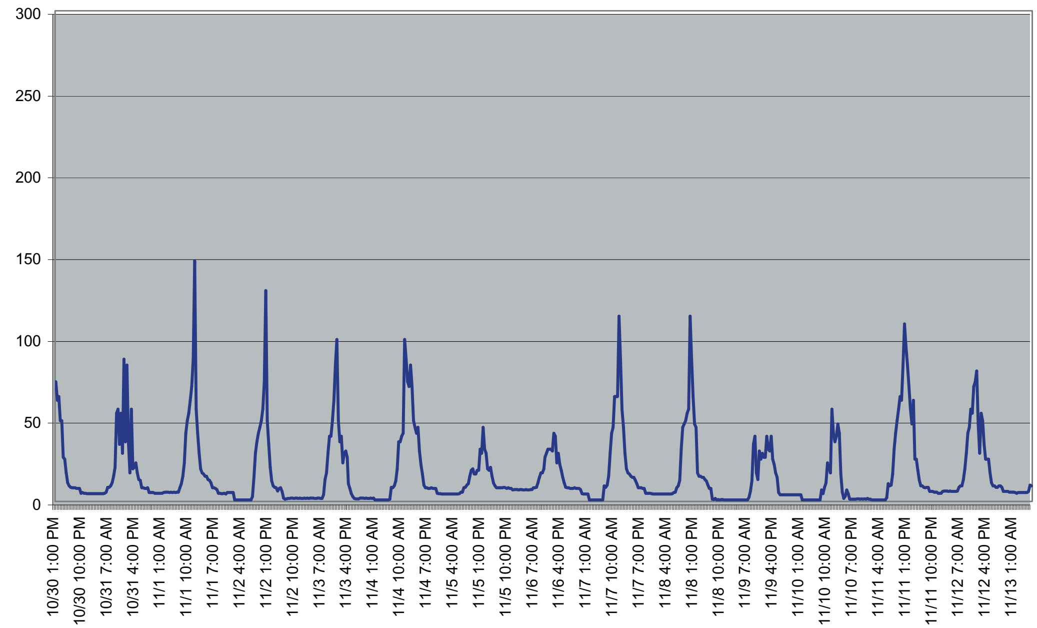
Location of StowAways

Diagnostic Research: Field Measurements

Data: Office C- Fourth Floor



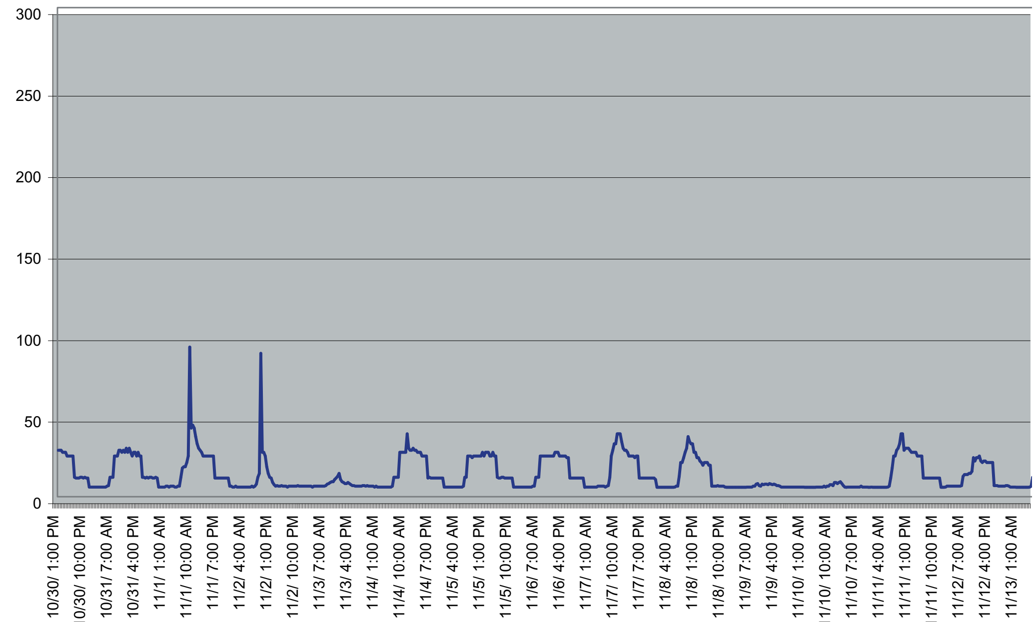
StowAway located on aperture sill



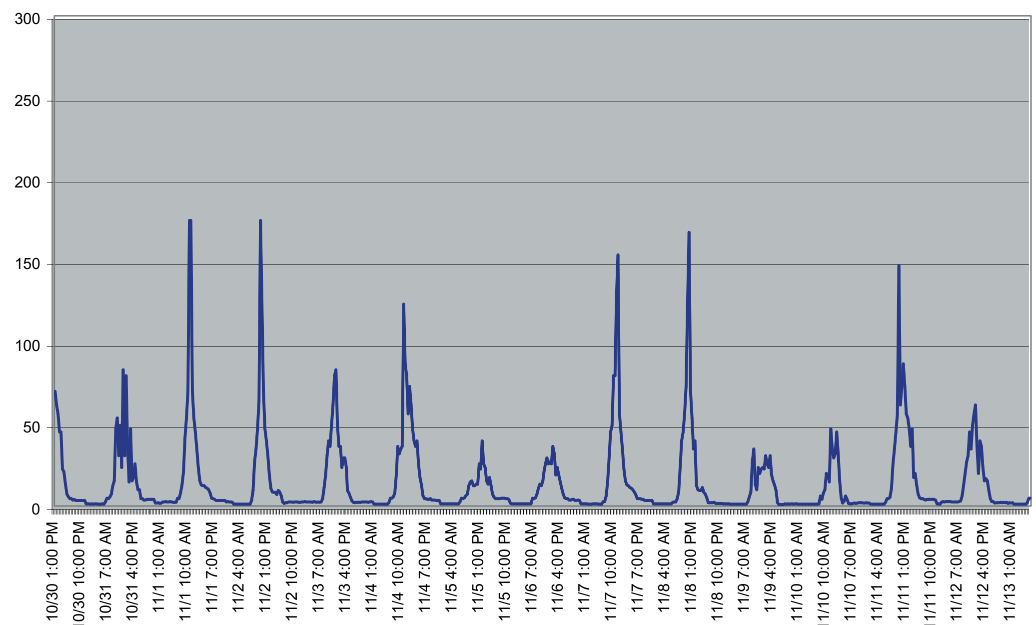
StowAway located on balcony ledge

Diagnostic Research: Field Measurements

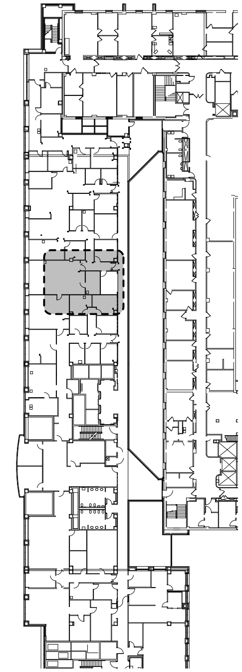
Data: Office D - Fifth Floor



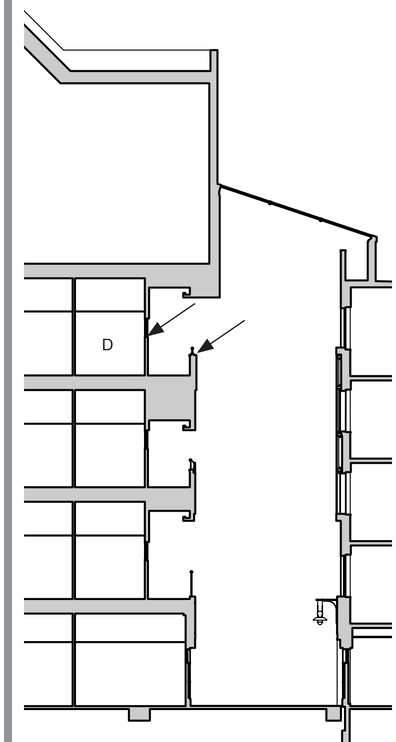
StowAway located on aperture sill



StowAway located on balcony ledge

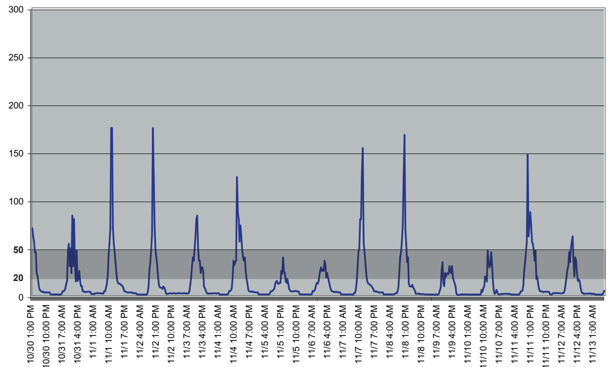


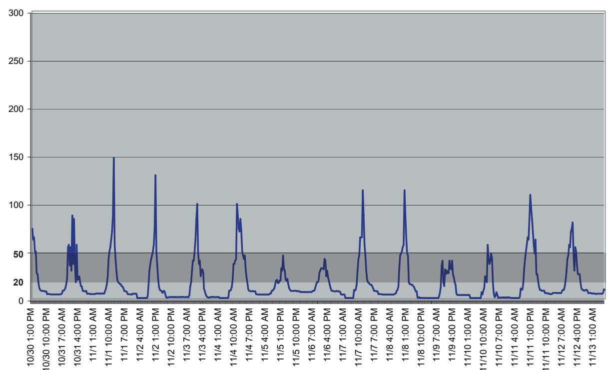
Location of Office D

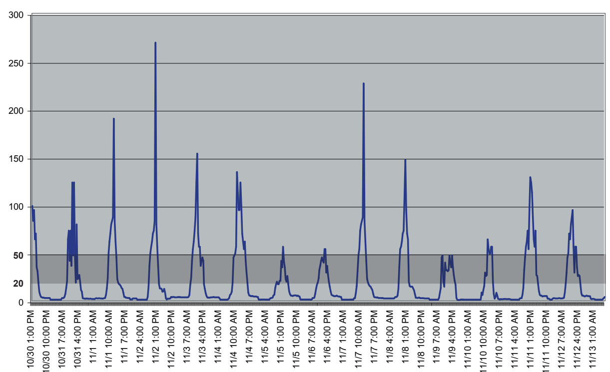


Location of StowAways

Diagnostic Research: Field Measurements







Conclusions

The three graphs to the right represent data recorded from the balcony edges on the fifth, fourth, and second floors. These readings indicate that the combination of natural light entering through the roof of the atrium and the artificial light under the balcony walkways typically provides a level of illumination exceeding the 20-50 footcandle range (indicated bar the darker grey bar) required by IES standards for the tasks performed in the office spaces adjacent to the balconies. Even on overcast days the illumination levels peak near the 50 footcandle line, as far down as the second floor balcony. Because of this information, as with the investigative research we can conclude that sufficient if not over sufficient daylight is entering into the atrium and could potentially be redirected into the office spaces.

These graphs also demonstrate the limited amount of time each day that the atrium receives direct beam daylight, as will be discussed with the results of the daylighting model study on page 23. Solutions for increasing the length of time on a typical day that the atrium receives such light are discussed in the design recommendations beginning on page 27.

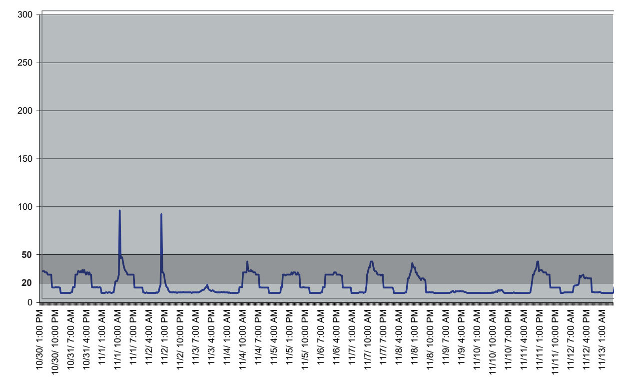
Diagnostic Research: Field Measurements

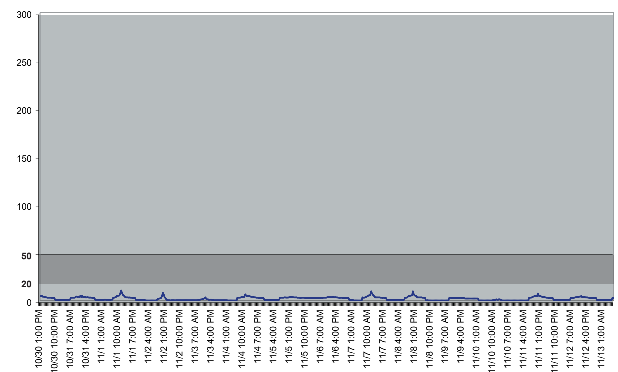
Conclusions

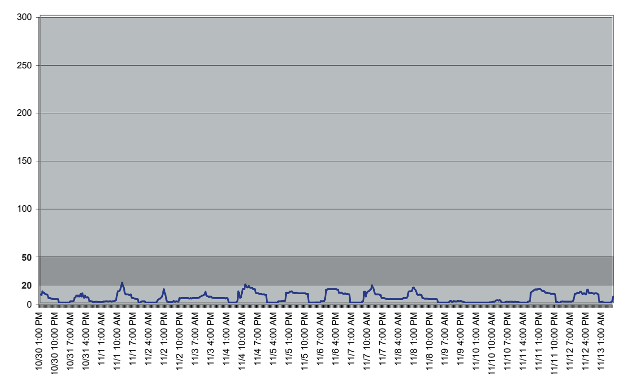
The three graphs to the right represent data recorded from the aperture sills of offices on the fifth, fourth, and second floors. These readings indicate that despite the large amount of natural light falling upon the balcony ledges just six feet away, an inadequate amount of natural light is reaching the sills of the offices on these floors according to the 20-50 footcandle range required according to the IES standards for the tasks performed in the office spaces.

As has been shown through the investigative research (pp. 11-13) and in the daylighting model studies which follow (pp. 22-23), the conclusion can be drawn that although the light reaching the corridor zone of the addition produces sufficient illumination in that space, it is not being properly redirected to reach and pass through the apertures of the office spaces.

The design recommendation on page 27 examine this problem and propose solutions to it.







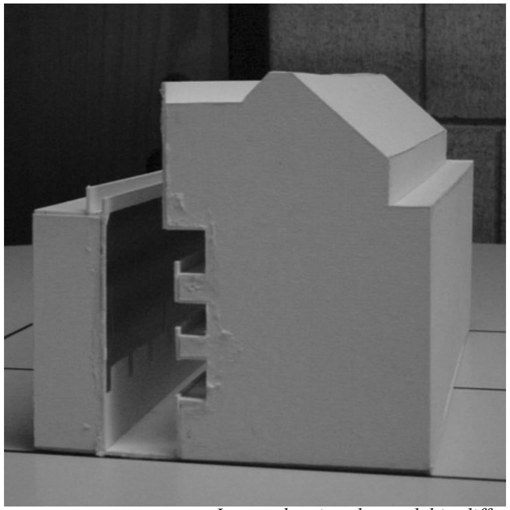


Image showing the model in diffused light

Image showing the heliodon, model placement, and tripod location

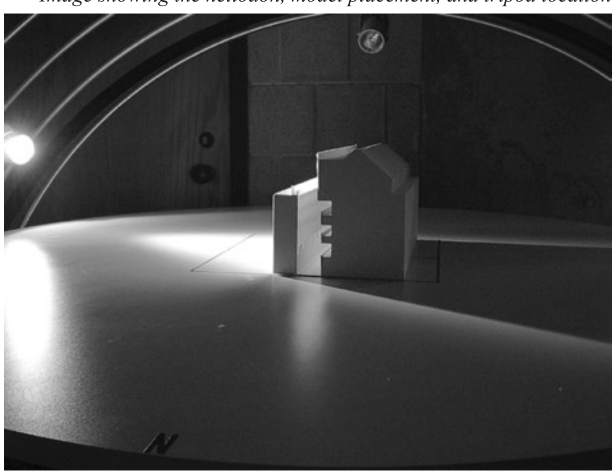


Image showing the model placement on the heliodon with light simulating daylight in the background

Diagnostic Research: Daylight Model Studies

Procedure

In order to study how beam light illuminated the atrium and caused glare throughout the year, a 1/16" = 1'-0" model was constructed. The model was restricted to this size because the heliodon used required it to fit within a 12"x12"x6" rectangular volume. The reason for the size restriction is because the beam light produced by the multiple reflector lamps used on the heliodon are not as parallel as the beam light from the sun, and the test results of any model exceeding the size restrictions will be distorted. An 84% reflective crescent board was used to represent the white painted gypsum board walls of the space, and a 95% reflective chrome foil was used to represent the mirror.

Results

The model study indicated that beam light entering the atrium was most intense from 9:00 a.m. to 12:00 p.m. At this point, the sun was at an angle that allowed beam light to enter the atrium space directly. The tall west wall reflected beam light into the atrium as soon as the sun rose above the horizon. However, the west wall began to block beam light at 1:00. This was undesirable for the purposes of illumination as the atrium was only gathering skyvault illumination. Nonetheless it did prevent glare problems during the late afternoon and evening. The model studies also indicated that the apertures between the atrium and the offices never received direct beam light because the balconies and overhangs shaded them.

There was a dramatic change in illumination throughout the seasons. The south wall blocked much of the light entering the atrium during late fall and winter, shortening the period of time that the atrium received beam light.

<u>Diagnostic Research: Daylight Model Studies</u>

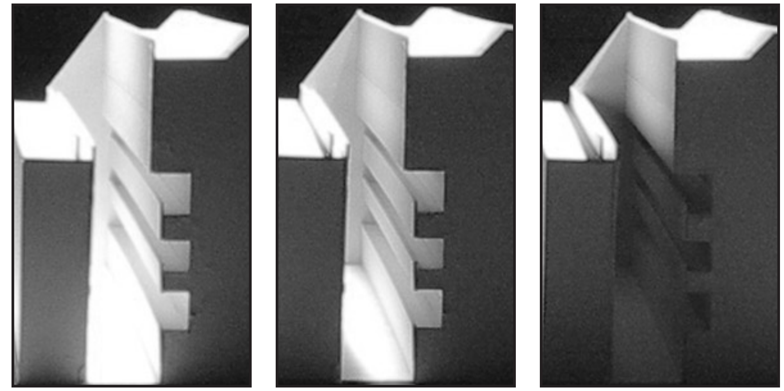
Conclusions
Two conclusions can be made based upon the results of the daylighting model studies.

The first conclusion is that although from 9:00 a.m. to 12:00 p.m. a significant amount of daylight enters the atrium space, the balconies in the corridor zone between the atrium and the offices prevents the majority of this light from reaching the office apertures. This problem could be potentially resolved by redirecting the light around the balconies or moving the corridor zone out from between the atrium space and the office zone.

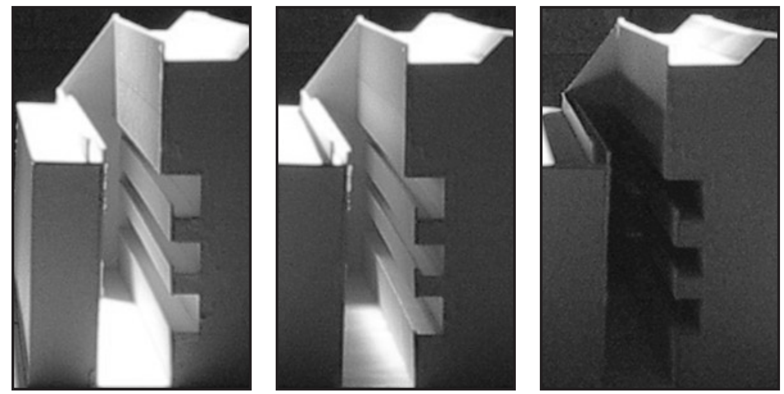
The second conclusion is that although from 9:00 a.m. to 12:00 p.m. a significant amount of daylight enters the atrium space, it is cut off at 1:00 for all seasons. This is caused by the location of the high wall to the west of the atrium, which blocks the sun after it reaches its peak at 12:00 p.m. This problem could potentially be resolved by increasing the attenuated angle of the atrium, exposing it to more skyvault light, or by re-proportioning the volume of the atrium.

Both of these ideas are discussed graphically and in more detail on page 27.

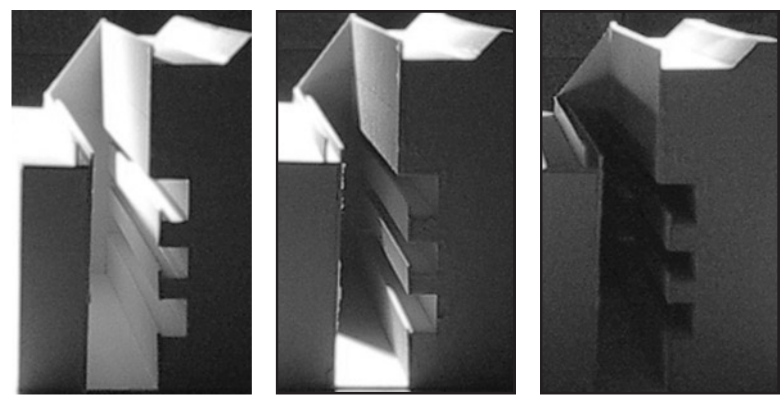
The complete series of these images can be seen in Appendix C beginning on page 38.



11:00 *12:00* *1:00*
June - West Wall



11:00 *12:00* *1:00*
March/September - West Wall



11:00 *12:00* *1:00*
December - West Wall

Qualitative Research

Procedure
Since highly sensitive experiments were being conducted at the Van Nuys Medical Science building throughout the duration of the study, we only had access to a limited number of spaces. Therefore, a questionnaire was developed to broaden the sample base in order to derive a better understanding of how the occupants utilize the offices adjacent to the atrium, how natural and artificial lighting in the space affects them, and how they feel about the apertures that provide the daylighting. This questionnaire as it was distributed can be seen in Appendix B (p. 37).

Interpretations
Question 1 was developed in order to ascertain the types of tasks performed in the offices. This is key in determining if the users are being provided with adequate quantities of illumination. 88% percent of the respondents stated that they performed reading and writing tasks within the space, 100% performed computer tasks, 47% used the offices for group work, 52% utilized the office for meetings, 7% used the office to make phone calls, and 7% used the office space in order to conduct experiments.

Question 2 was also intended to aid the diagnostic process in that it could indicate whether the occupants generally felt that the illumination within the offices was adequate for the tasks they performed. 94% of the respondents indicated that they had no problem with the lighting conditions in their offices.

Question 3 was included because fatigue becomes an issue when people work in spaces for long periods of time, and because people that work for long periods of time within a space generally become more accustomed to and accomodate for its characteristics. 94% of the respondents spent 7 hours or more within the offices.

Question 4 asked if it was necessary for the occupants to take periodic breaks to rest their eyes throughout the workday. An illumination problem would have been indicated if the occupants indicated that they spent short periods of time within the offices and needed to take breaks to rest their eyes. 65% of the respondents indicated that they took periodic breaks to rest their eyes. However, an illumination problem was not clearly indicated since nearly all the respondents indicated that they spent long periods of time within the offices.

Question 5 was incorporated to determine the number of occupants that used supplemental lighting to assist in the performance of their tasks. 76% of the respondents indicated that they used supplemental lighting, which implies that either the quantity of illumination provided by the combined electric and natural lighting was too low, or that the geometry of the illumination sources was problematic relative to task areas.

Question 6 indicated that both quantity and geometry might be problems. One respondent stated that he/she used supplemental lighting for all tasks performed in the office, while the other respondent indicated that he/she used supplemental lighting while working with a fume hood.

Questions 7 and 8 were incorporated as a means of determining whether the quantity of natural illumination entering the offices was sufficient to allow the occupants to perform their tasks without the use of electric illumination. In every case, the respondents indicated that they used electric illumination while working in the offices. This is a strong indication that the quantity of natural light entering the spaces was too low for them to perform their tasks.

Question 9 was also incorporated as a means of determining whether the quantity of natural illumination entering the offices was sufficient to allow the occupants to perform their tasks without the use of electric illumination. 44% of the respondents indicated that it was possible to perform the tasks in the offices without the use of electrical illumination. However, since the respondents invariably used the ceiling mounted luminaries, and the majority used some form of supplemental illumination, it seems unlikely that it was comfortable for them to perform tasks using only the natural light provided by the apertures.

Questions 10 and 11 were included to determine if glare problems were prevalent while the occupants were using electrical illumination. In both cases, 82% of the respondents indicated that they had no difficulty reading glossy printed materials or computer screens in their offices.

Questions 12 and 13 were included to determine if glare problems were prevalent while the occupants were not using electrical illumination. Only 53% of the respondents indicated that they found it difficult to read glossy printed materials, while 88% indicated that they had no problem reading computer screens in their offices. The reason that 47% of the respondents indicated that they found it difficult to read glossy printed materials may be attributable to low quantities of illumination within the offices or glare produced by the contrast of the relatively small, bright aperture against the dark office walls.

Question 15 was incorporated to determine whether the occupants felt the quality of illumination entering the apertures in the offices was comfortable or uncomfortable. 57% of the respondents indicated that the illumination entering their offices was either comfortable or very comfortable, while 25% indicated that they were indifferent to the illumination provided by the apertures. Only 3 respondents stated that the illumination was uncomfortable or very uncomfortable.

Questions 14 and 16 were incorporated to gauge whether issues extraneous to the study influenced the occupant responses. It was decided that the two most likely non-illumination related problems associated with the apertures were related to privacy and distractions. However, 88% of the respondents stated that they felt that the apertures did not pose a threat to their privacy, and 86% stated that the apertures were not distracting. Therefore, it seems unlikely that issues of privacy or distraction influenced the occupant's responses.

Conclusions

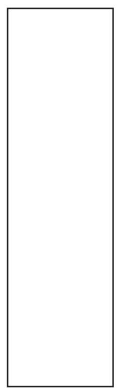
In summary, it can be determined that the daylighting in these spaces is not adequate, from the standpoint of the users, for the tasks that they perform in these spaces. This agrees with the conclusions drawn from the investigative and diagnostic research (pp.13,20) and the daylighting model studies (p.23). The fact that 76% use supplemental lighting disagrees with the results from the investigative research, which shows that artificial lighting levels in the offices exceed the IES requirements for illumination in these spaces. Again, the use of supplemental lighting could be a result of improper between geometry of the tasks performed and the sources of illumination.

The indication of the respondents that most of them had little to no trouble viewing their computer monitors or reading glossy material in the offices indicates that the apertures do not cause visual impairment for the tasks performed in these spaces. Their further indication of the illumination entering through the apertures as either comfortable or very comfortable reinforces these findings.

Proof of Hypotheses

Hypothesis 1 was that the borrowed daylight entering the offices adjacent to the atrium provides an adequate amount of illumination according to IES standards for the tasks performed within those spaces. Based upon the conclusions drawn from the investigative research (p.13), the diagnostic research (p.20), and the daylighting model studies (p.23), this hypothesis has been proven false. See page 27 for design recommendations to solve these problems.

Hypothesis 2 was that the borrowed daylight entering the offices adjacent to the atrium causes no visual impairment or distraction for the users in those spaces. Based upon the results of the questionnaire (p.25), this hypothesis has been proven to be true.



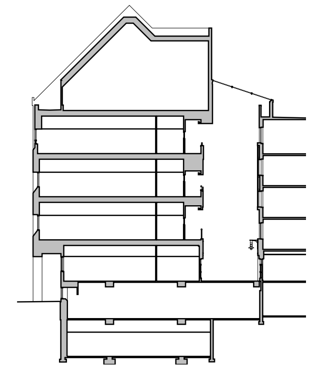
3.6:1 Aspect Ratio

Design Recommendations

The atrium of the Van Nuys Medical Science Building was designed primarily as a circulation space. Daylight distribution was never a driving force in the design of the atrium. As a result, the atrium does not effectively distribute daylight. The apertures are too small to allow adequate quantities of illumination to pass through to the offices, and they are shaded by the balconies. On a clear day in December, 280 foot candles of illumination were recorded at the handrail of the balcony. 48 foot candles were recorded at the sill of the apertures, and only 1-3 foot candles were recorded at the work surfaces.

The atrium in the Van Nuys Medical Science Building is a tall, narrow space, with an aspect ratio of 3.6 : 1 (height : width). The mirror on the east wall of the atrium has an attenuated angle of 12.7° at the base. The apertures in the offices on the west side of the atrium are fairly small, with a 5’-8” sill height and a 8-0” head height. This gives an exposure to the mirror of only 3.3 for an individual seated in the center of the room. As previously stated, beam light never reaches the apertures, as the balcony above shades it.

Solution A was intended to more efficiently redirect the light within the atrium while maintaining the existing relationships between the office, laboratory, and circulation spaces. First, the depth of the balconies was reduced and the height of the ceiling was increased from 9’-0” to 12’-0. This might be possible because the volume required for ducts and other support systems is much smaller for an office space than a laboratory. The head height of the aperture was then increased to 11’-9”, while the sill height remained at 5’-8” because of privacy concerns. Raising the head height increased the attenuated angle for an individual seated in the center of the office from 3.3° to 10.5°. In addition, light shelves were added to direct beam light from the atrium into the apertures.



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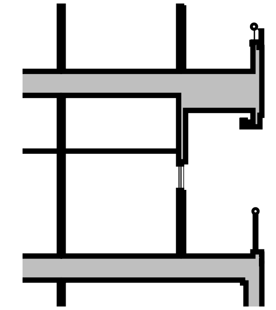
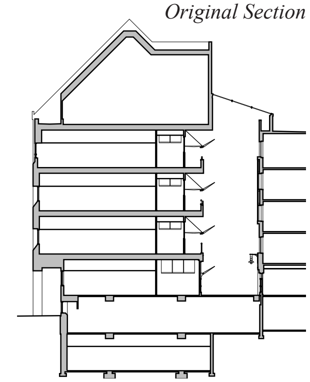
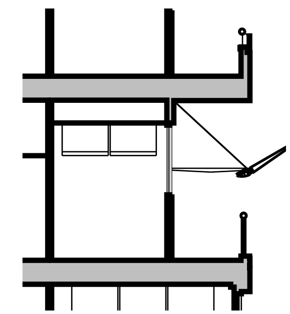


Detail



Solution A



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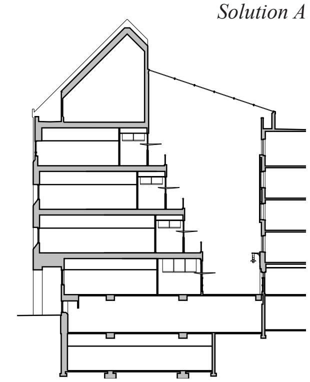
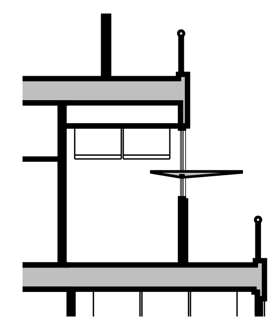
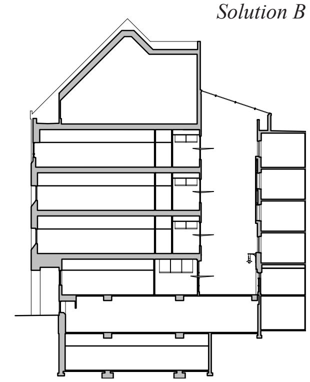


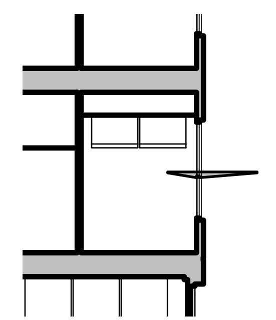
Solution B



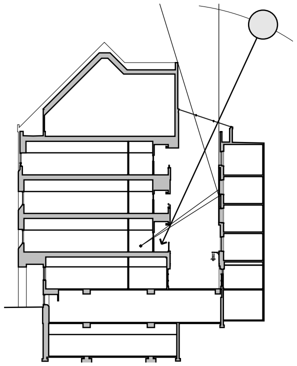
Detail



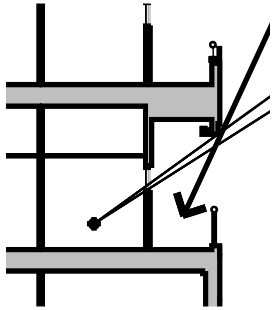
Solution C



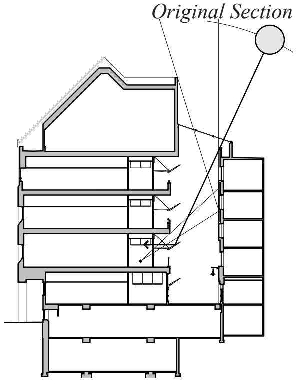
Detail



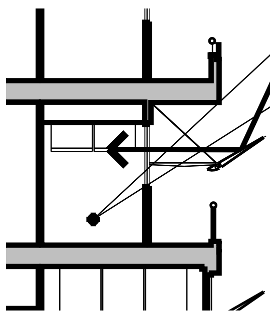
Original Section



Detail



Solution A



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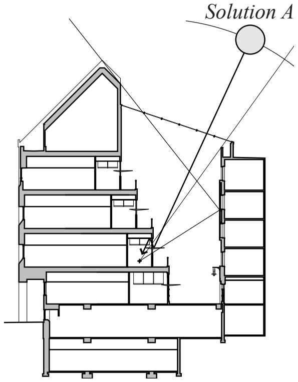
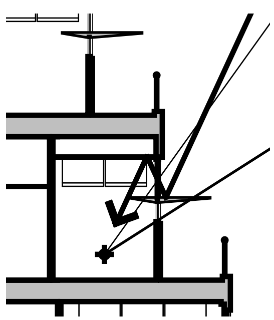


Solution B



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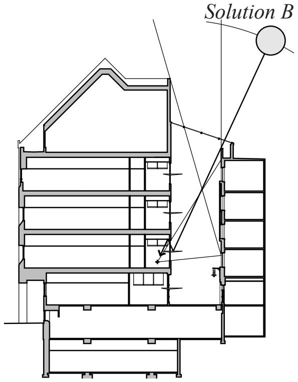
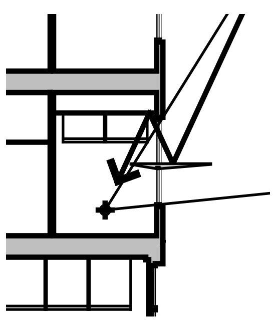


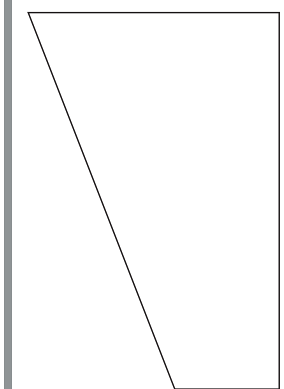
Solution C



Detail

Solution B was intended to increase the quantity of beam and skyvault light entering the atrium. The aspect ratio of the atrium is reduced to 1.5 : 1. The head and sill heights remain the same as in solution A. The atrium steps back the width of the balconies every floor, allowing skyvault light to penetrate deep into the space in more easily, and allows beam light to be utilized for a longer period of time. This solution gives an individual seated in the center of the space an aspect ratio of 21.9°. The attenuated angle of the mirror was increased from 3.3° at the base to 12.7° at the base, thus allowing it to reflect more light into the apertures. Again, light shelves are utilized to distribute beam light. Light shelves are useful because they reduce the difference between the brightest area of a room and the darkest area of a room. They also reflect light onto the ceiling of a room, making it the brightest surface. This is very comfortable to the eye, because the sky is normally much brighter than the ground. Solution B was admittedly an idealized solution, as it ignored the site and programmatic constraints placed on the architects of the Van Nuys Medical Science building. However, this is a good solution to distribute daylight when programmatic and site conditions allow it to be implemented.

Solution C attempts to locate spaces according to the quantity of light required by the tasks performed within them. The pedestrian walkways were relocated from the edge of the atrium to an area between the offices and the laboratories. This both removed the balconies that shadowed the apertures and solved the privacy concerns. This allowed the sill of the aperture to be dropped to 3’-0”, while the head remained at 11’-9”. This gave an individual seated in the center of the room an attenuated angle of 52.3°, along with a greater degree of visual relief. Light shelves were also integrated for the distribution of beam light.



3.6:1 Aspect Ratio

Appendices

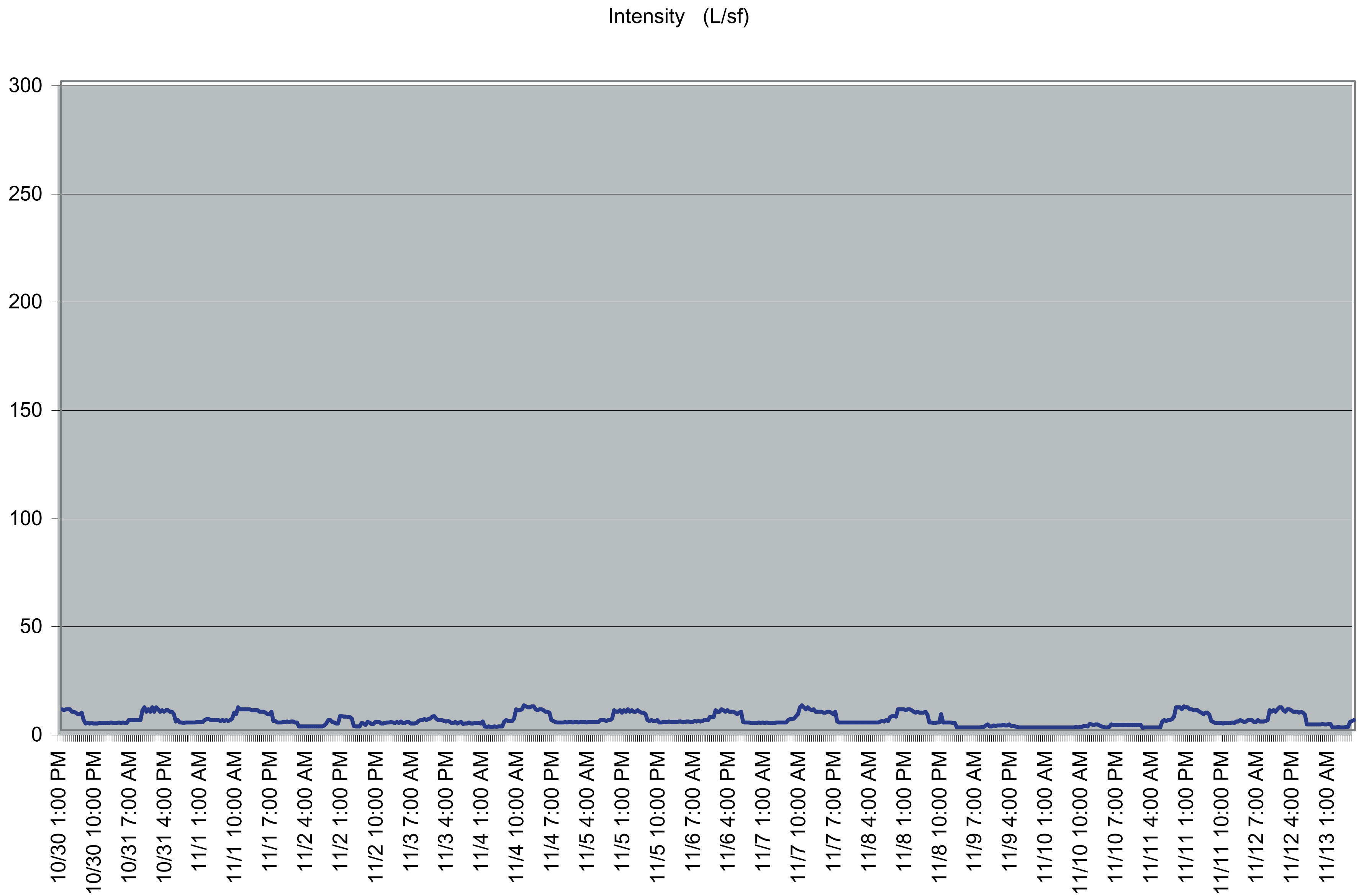
Introduction
The remaining pages of this document provide support information for the subjects discussed in the main body of this report.

Appendix A provides larger graphs of the data recorded by the seven StowAway illumination devices without additional commentary.

Appendix B shows a copy of the questionnaire as it was distributed to the users of the office spaces.

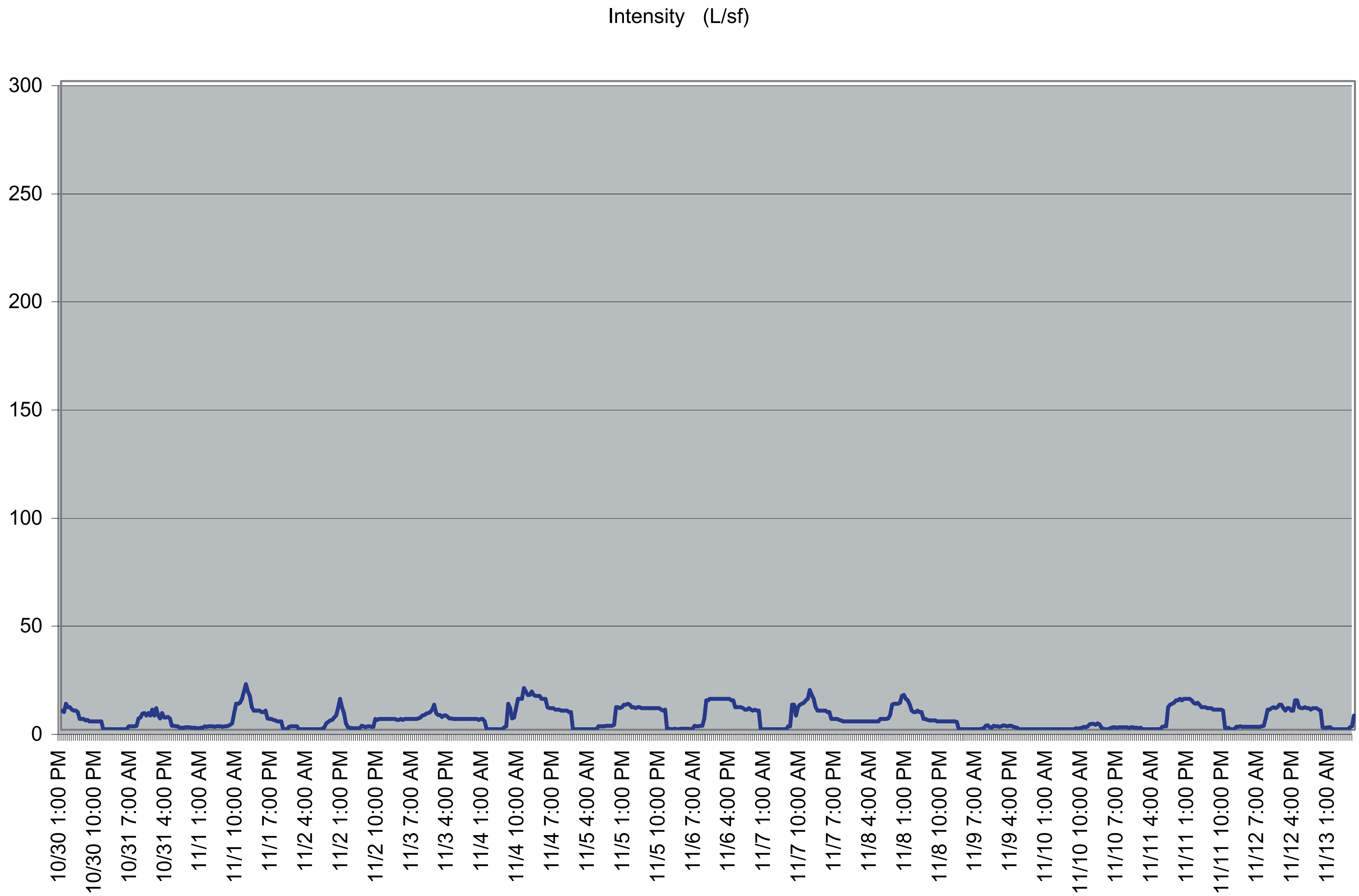
Appendix C shows all of the images recorded in the daylight study model research performed with the heliodon.

Appendix A: Light Intensity Graphs



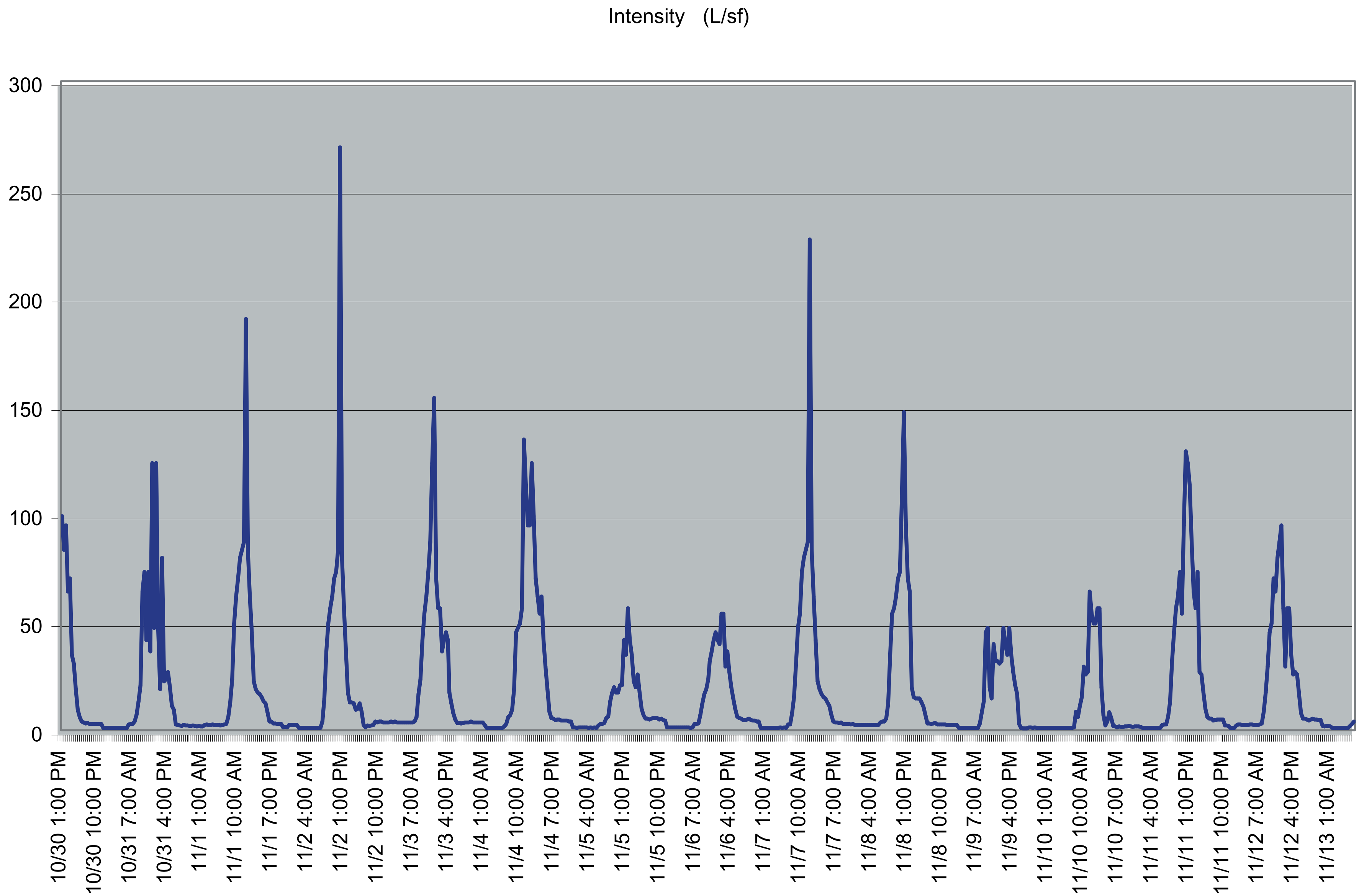
Intensities at First Floor Sill Location

Appendix A: Light Intensity Graphs



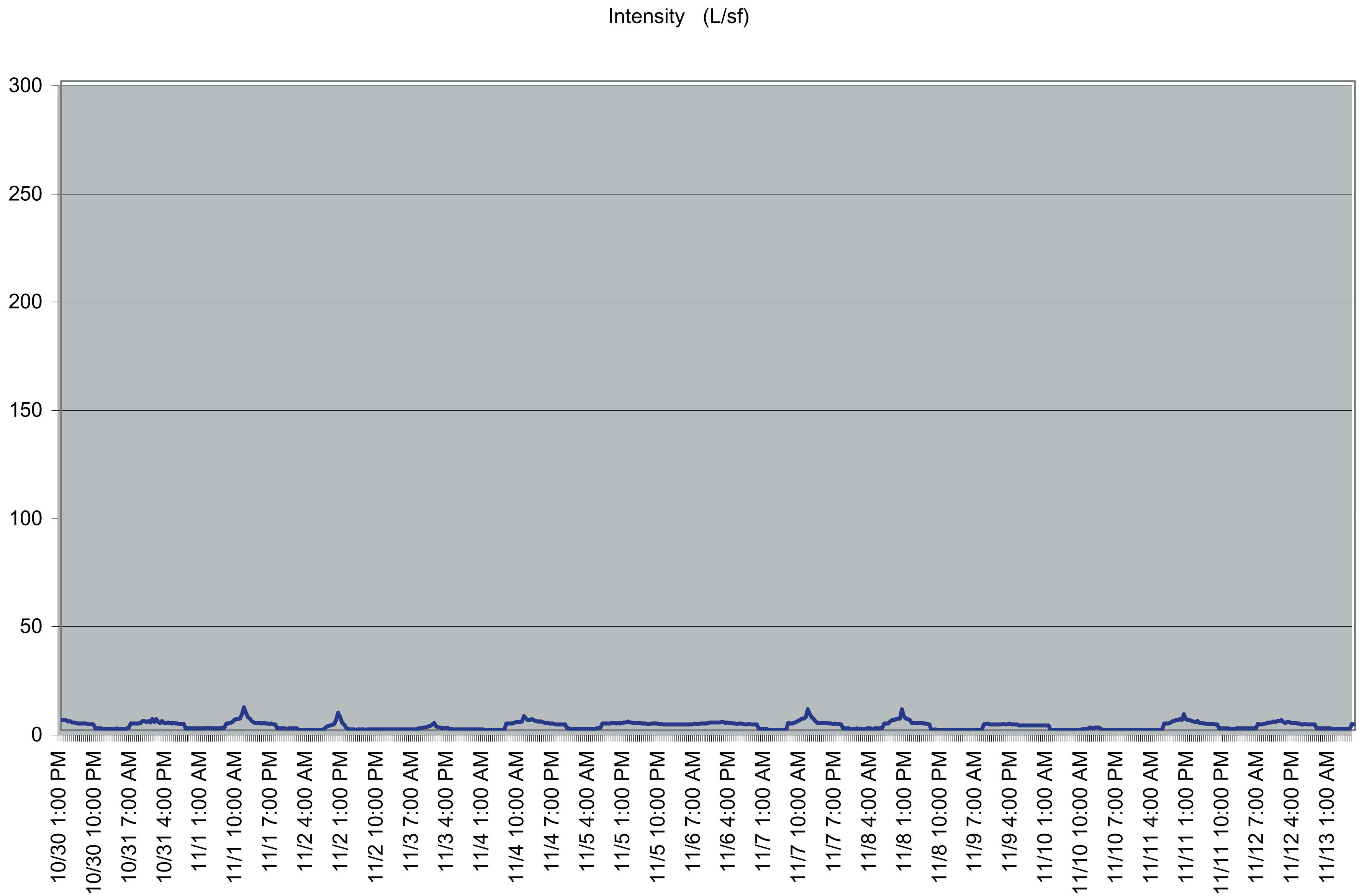
Intensities at Second Floor Sill Location

Appendix A: Light Intensity Graphs



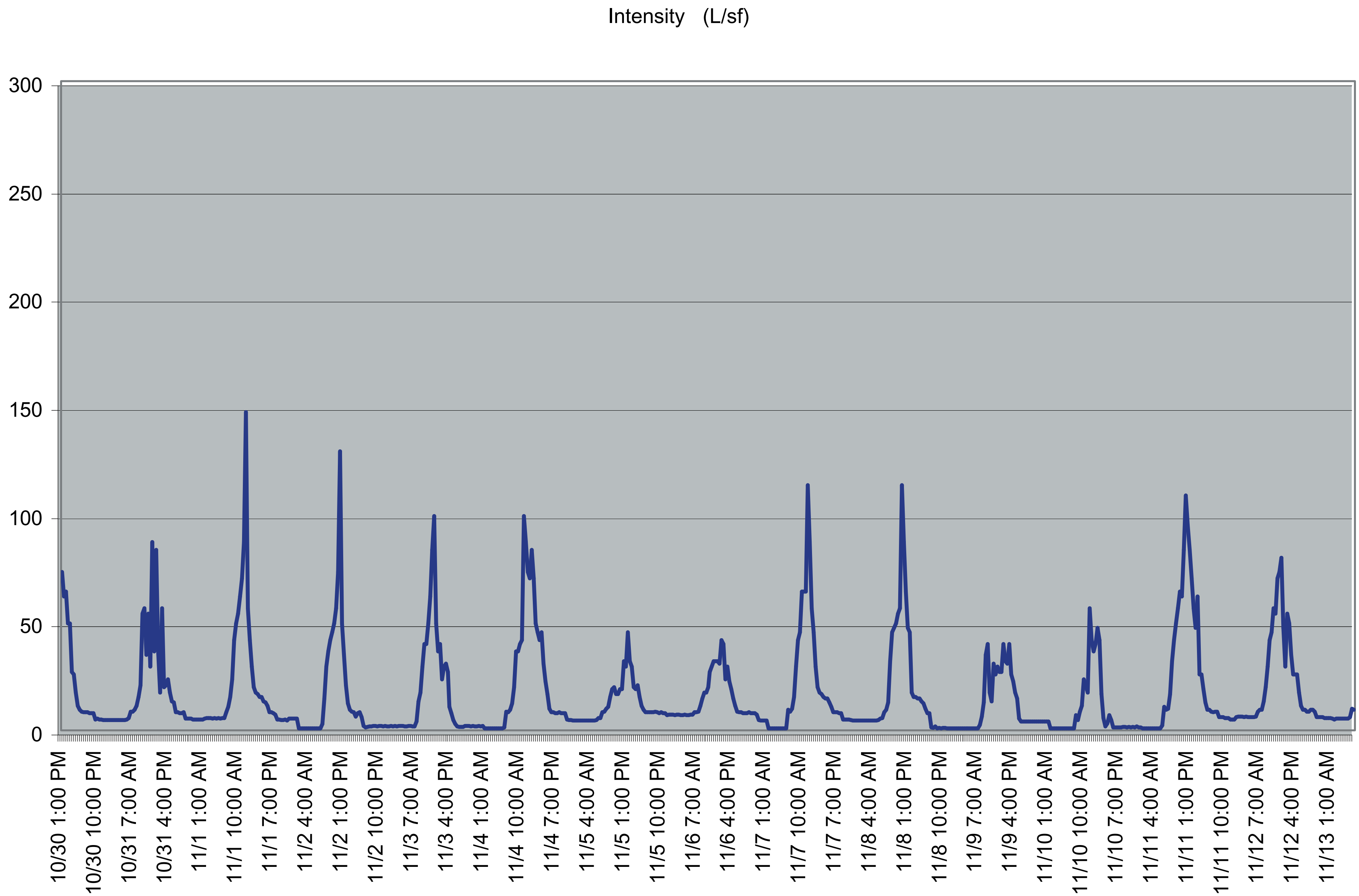
Intensities at Second Floor Balcony Location

Appendix A: Light Intensity Graphs



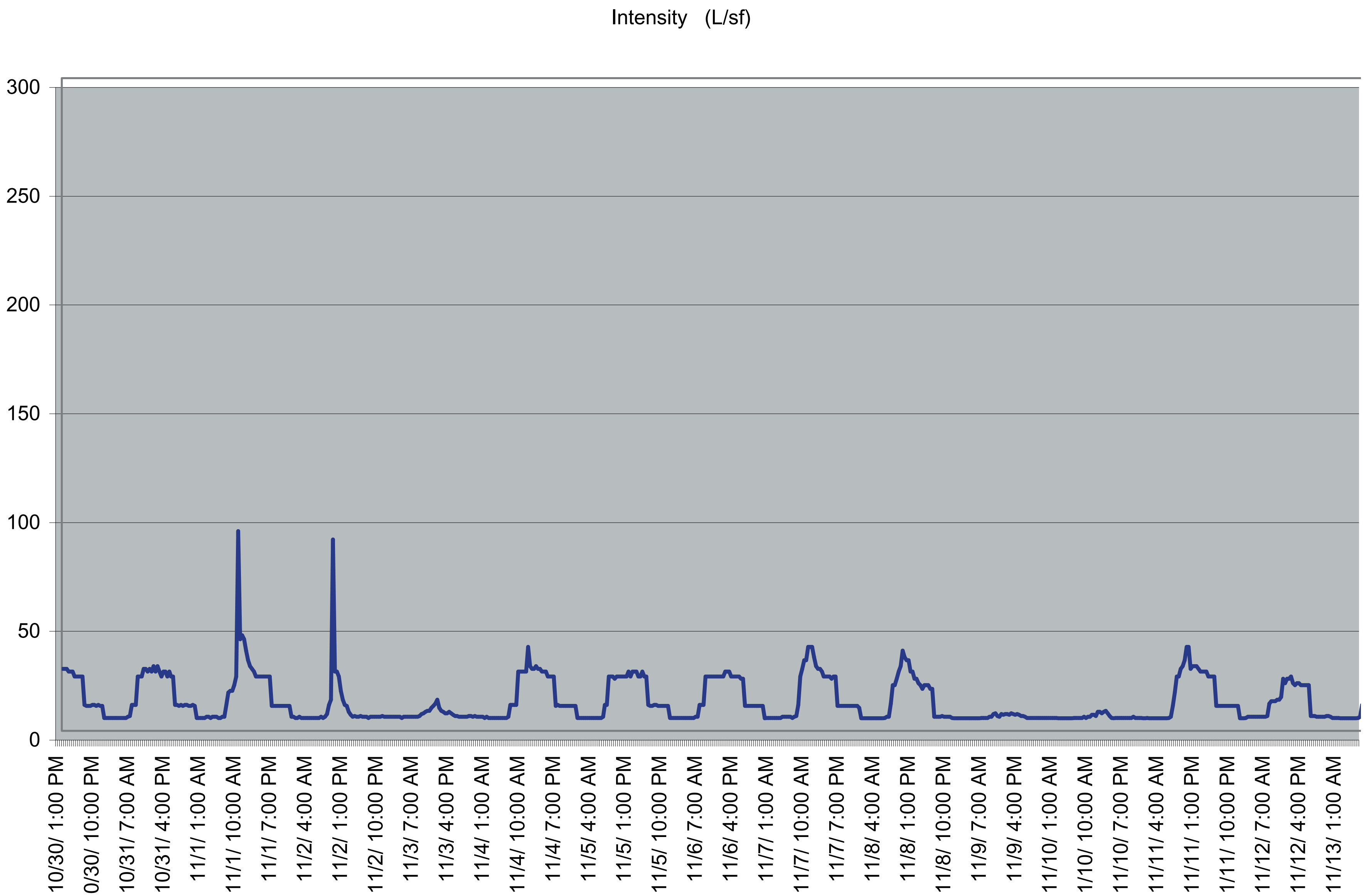
Intensities at Fourth Floor Sill Location

Appendix A: Light Intensity Graphs



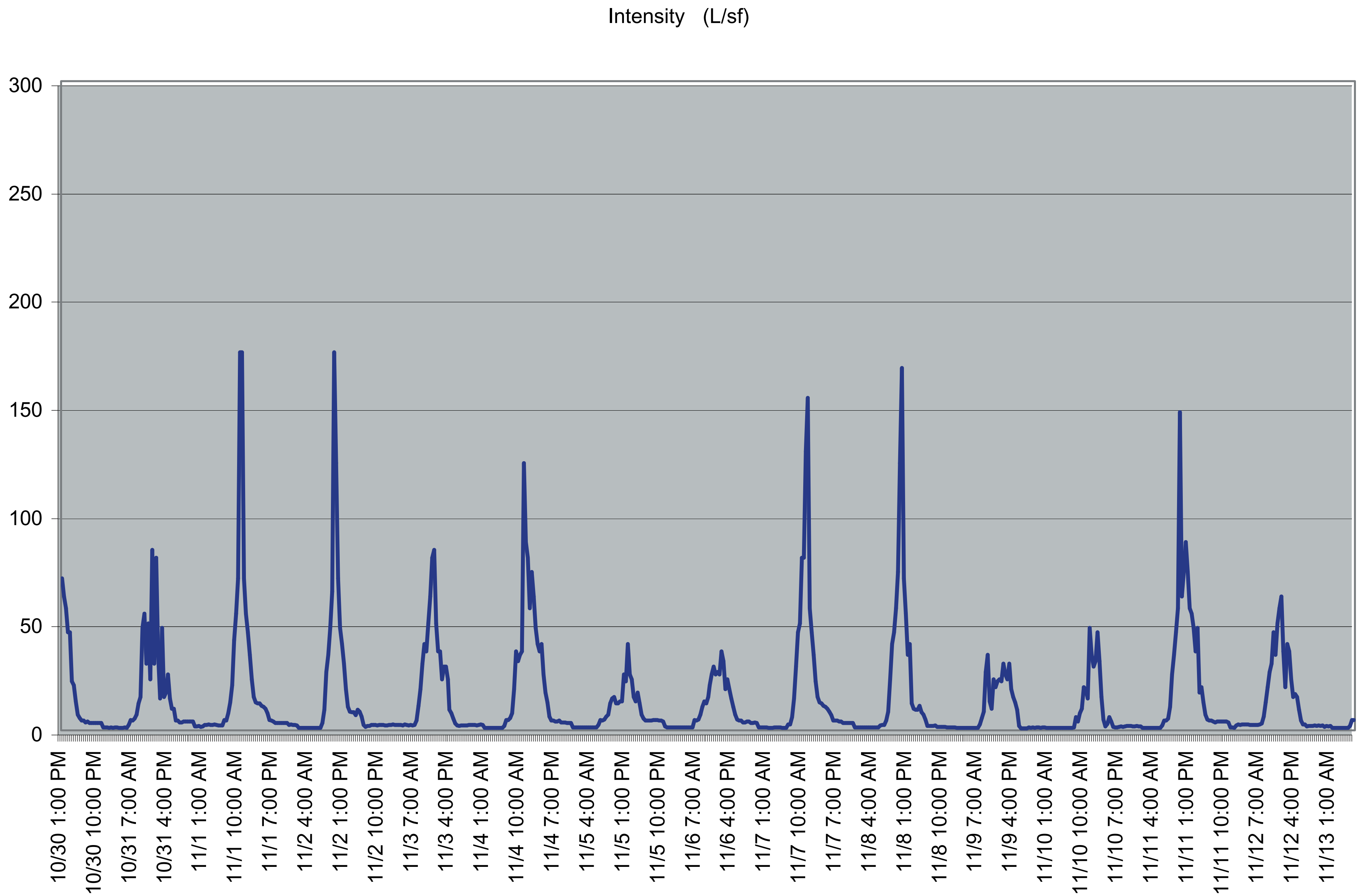
Intensities at Fourth Floor Balcony Location

Appendix A: Light Intensity Graphs



Intensities at Fifth Floor Sill Location

Appendix A: Light Intensity Graphs



Intensities at Fifth Floor Balcony Location

Appendix B: Lighting Questionnaire

the questionnaire as it was distributed:

Van Nuys Medical Science Building Lighting Questionnaire

1. What tasks do you normally perform in your office? (check all that apply)

☐ Reading	☐ Group Work
☐ Writing	☐ Meetings
☐ Computer Tasks	☐ Other__________________________

2. Is it difficult to perform any of these tasks due to the lighting conditions in your office? Y N
   If so, which tasks present difficulty?

3. How many hours per day do you typically spend in your office performing these tasks? ______hrs/day
4. Do you find it necessary to take periodic breaks in order to rest you eyes? Y N
5. Do you use supplemental or additional lighting in order to perform some tasks? Y N
6. What types of tasks require supplemental lighting?

7. At what hour of the day do you typically turn the lights in your office on?

8. At what hour of the day do you typically turn them off?

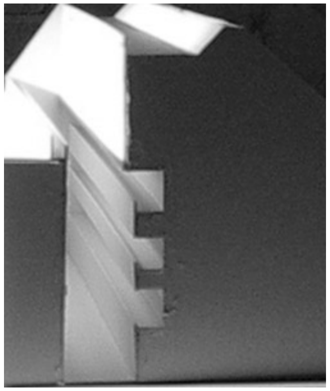
9. Is it possible for you to perform tasks within your office with the lights turned off? Y N
10. Do you find it difficult to read glossy print material in your office with the lights on? Y N
11. Do you find it difficult to read a computer screen in your office with the lights on? Y N
12. Do you find it difficult to read glossy print material in your office with the lights off? Y N
13. Do you find it difficult to read a computer screen in your office with the lights off? Y N
14. Do you feel that the windows in your office compromise your privacy? Y N
15. Rate the comfort of the light entering through the windows: (circle one)
    Very Comfortable Comfortable No Opinion Uncomfortable Very Uncomfortable
16. Are the windows in your office distracting? (circle one)
    No Opinion Somewhat Distracting Distracting Very Distracting

17. Is the lighting in the labs comfortable for the tasks that you perform at lab stations? Y N
18. Is it difficult to perform tasks on a computer at your desk? Y N
19. Do you require supplemental lighting in order to perform tasks at your desk? Y N
20. Are there conditions of glare at: (circle all that apply)
    Lab Stations Desks Computer Screens
21. How often are the blinds into your lab space open?
    Always Frequently Sometimes Seldom Never

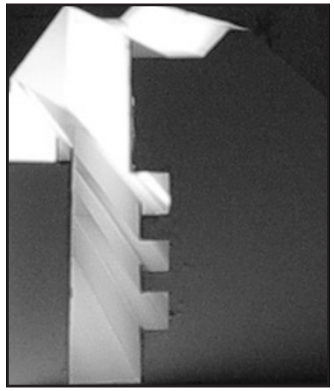
Interior Illuminance/ Daylight Control/ Occupants' Response Ball State University Vital Signs Class

Appendix C: Heliodon Atrium Daylighting Studies

June-West Wall

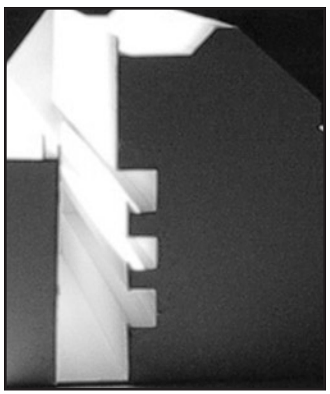


6:00 am

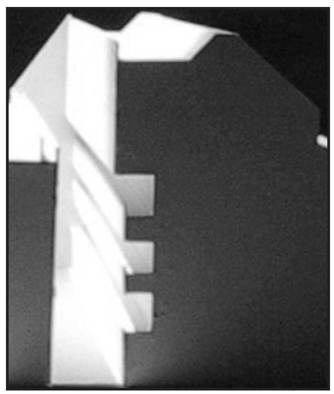


7:00 am

8:00 am



9:00 am



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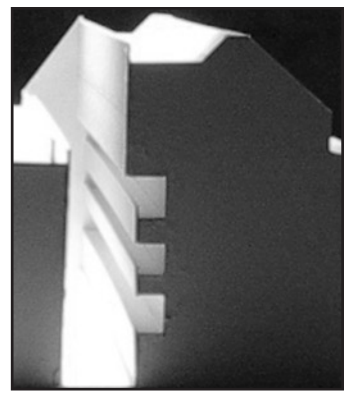
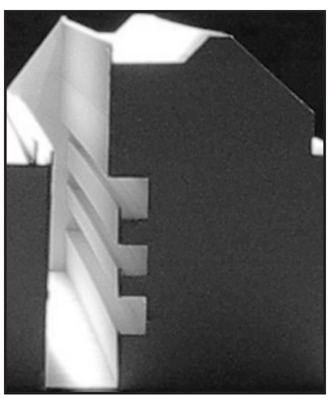
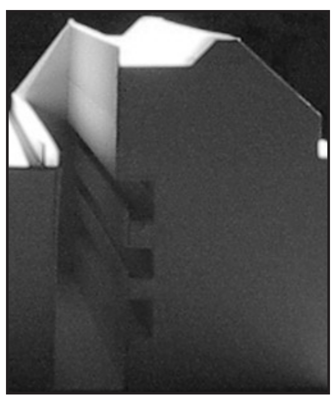


11:00 am



12:00 p.m.



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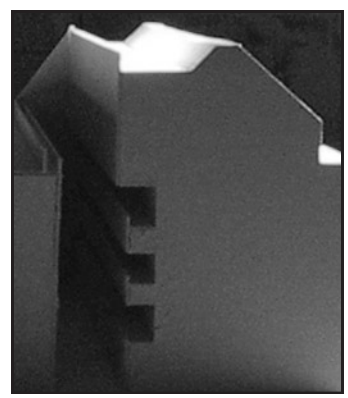
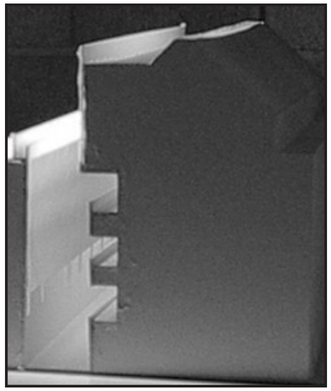


2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

June-East Wall



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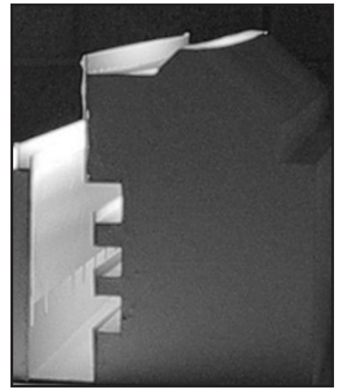

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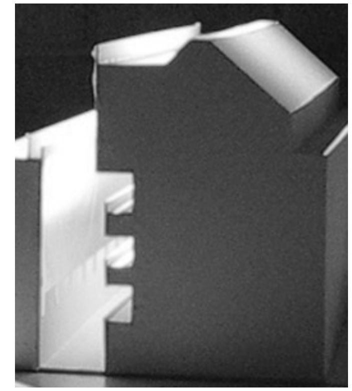

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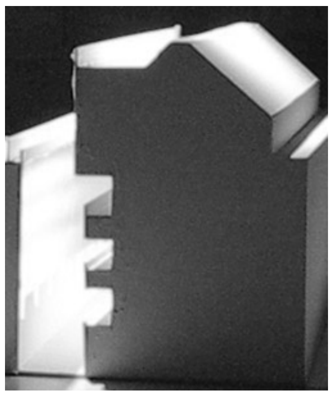

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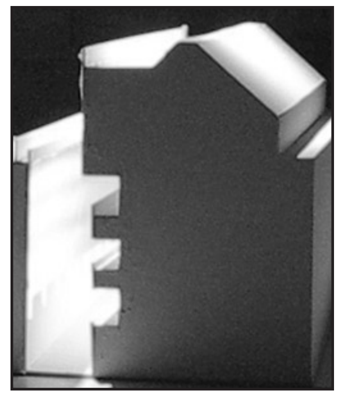

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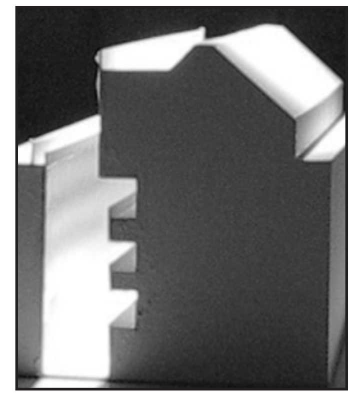

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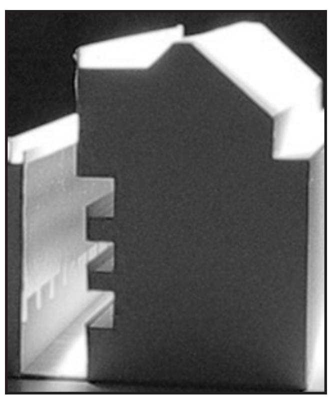

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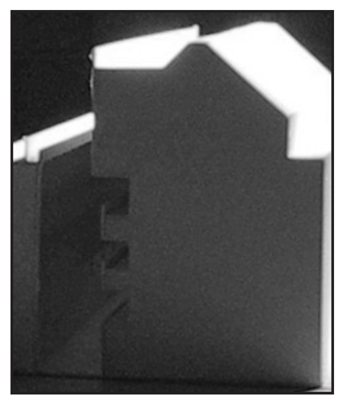

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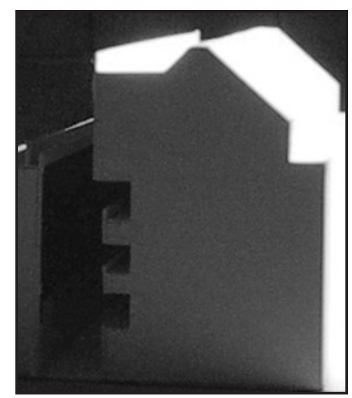
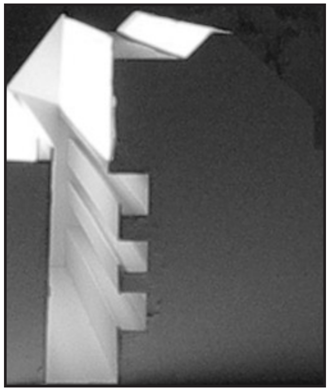


2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

May/July-West Wall



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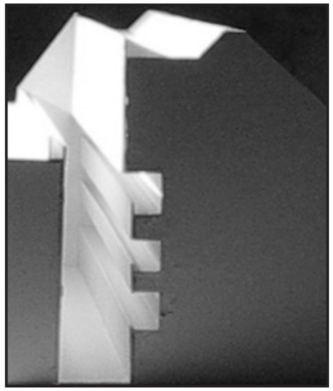

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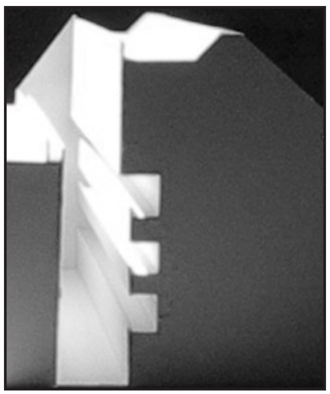
8:00 am



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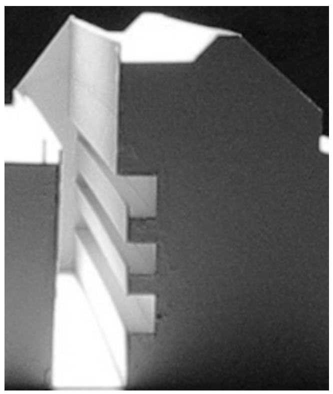

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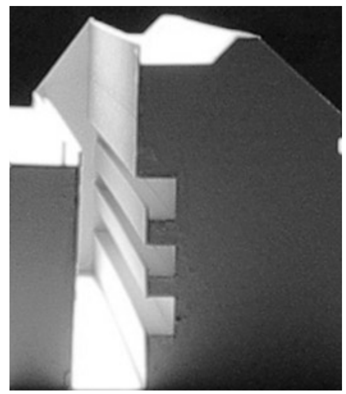

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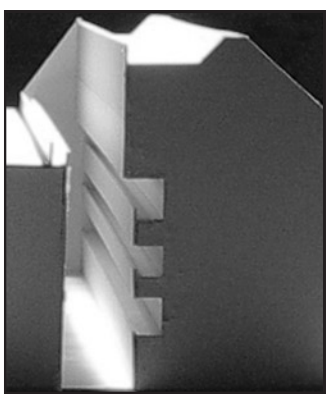

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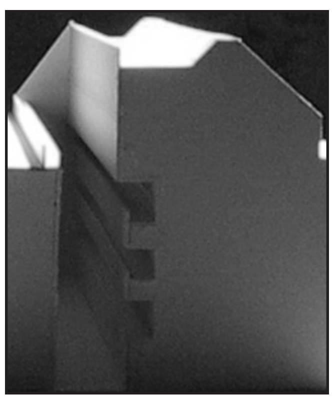

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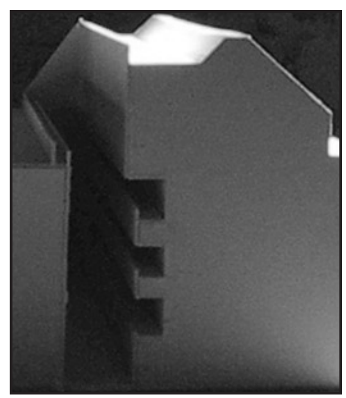
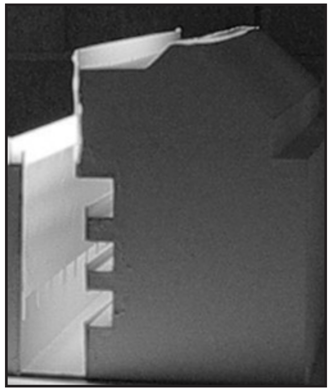


2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

May/July-East Wall



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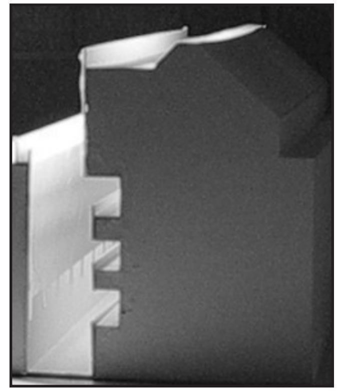

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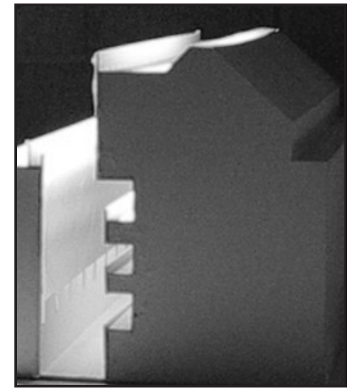

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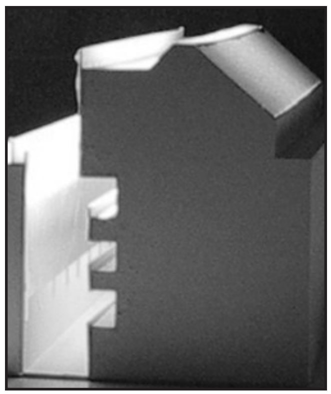

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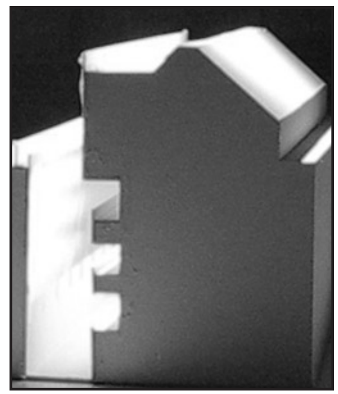

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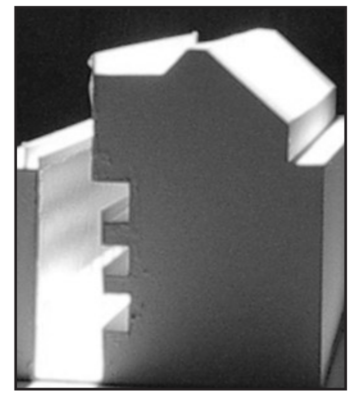

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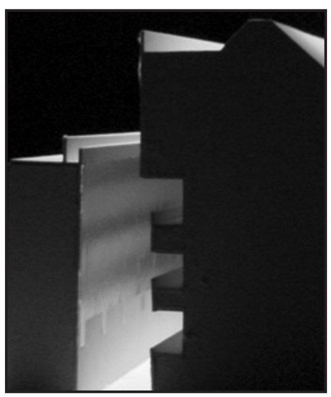

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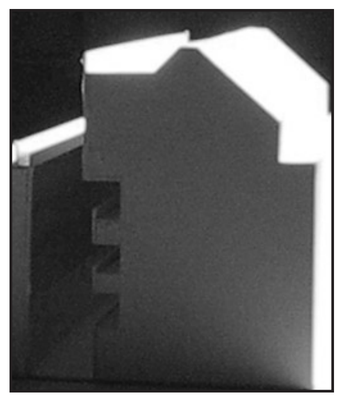

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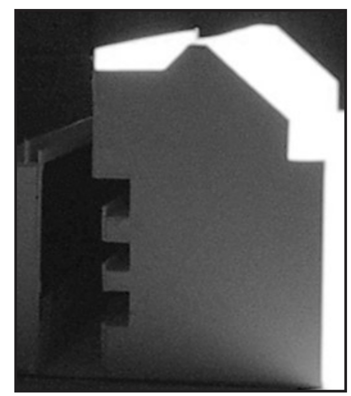
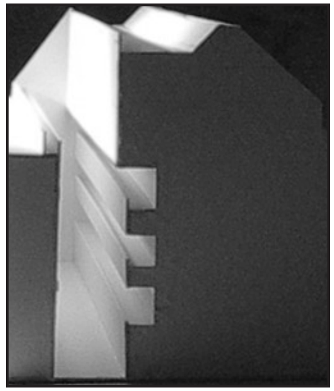


2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

April/August-West Wall

6:00 am



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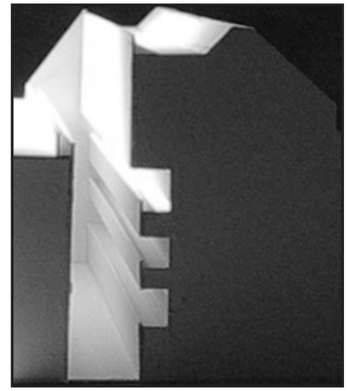

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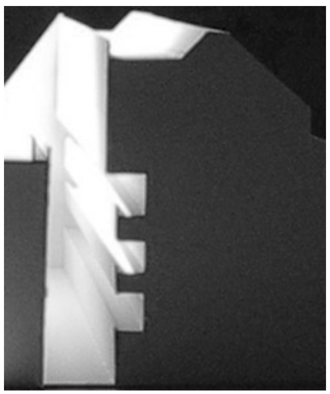

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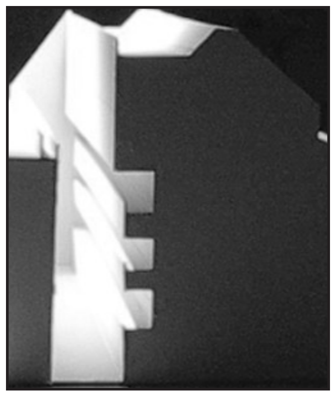

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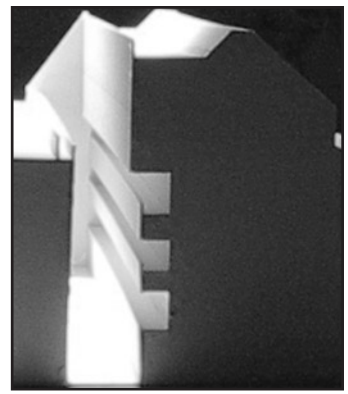

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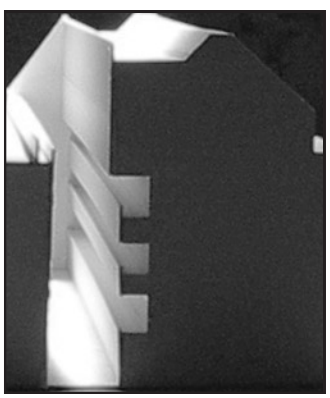

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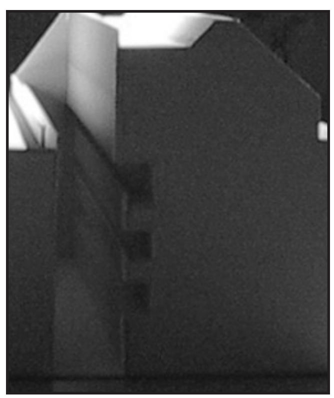

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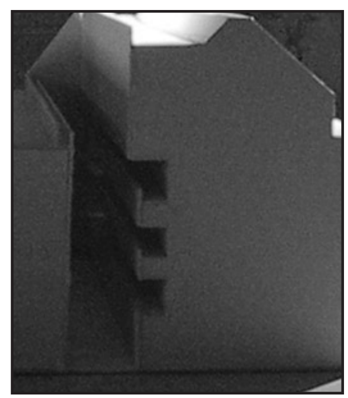
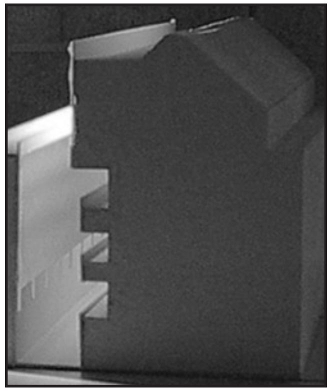


2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

April/August-East Wall



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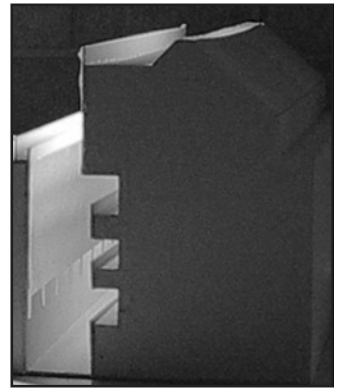

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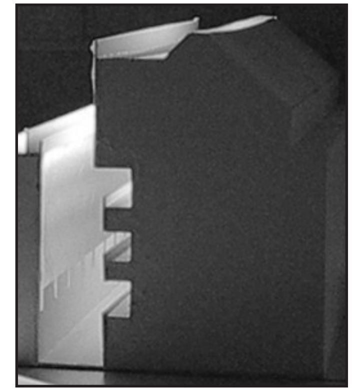

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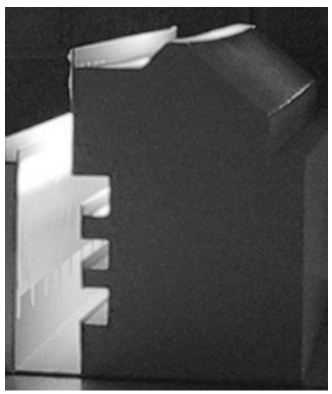

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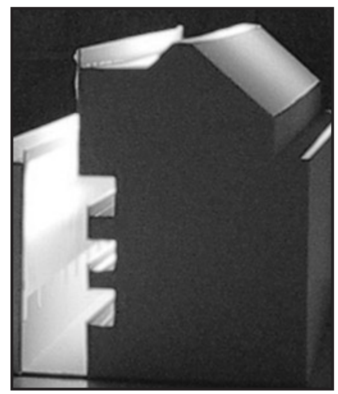

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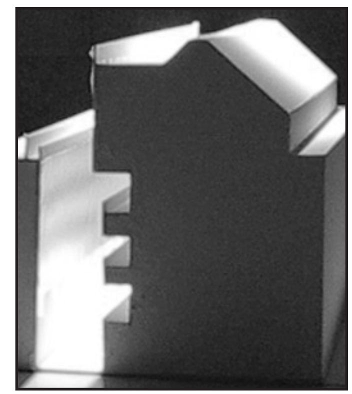
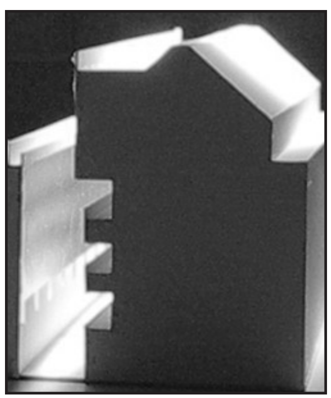


11:00 am



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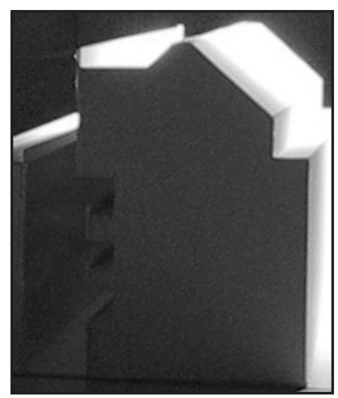
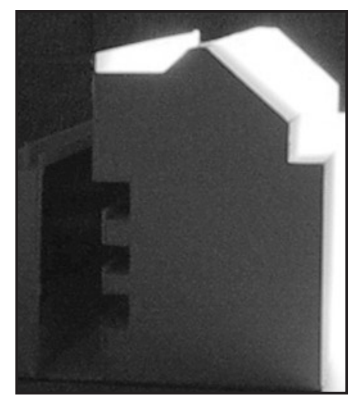


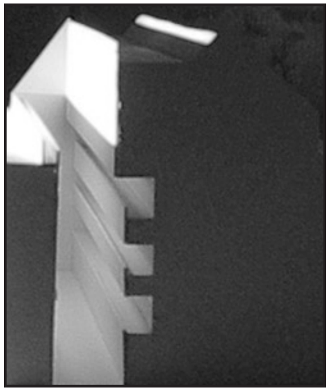
1:00 p.m.



2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

March/September-West Wall



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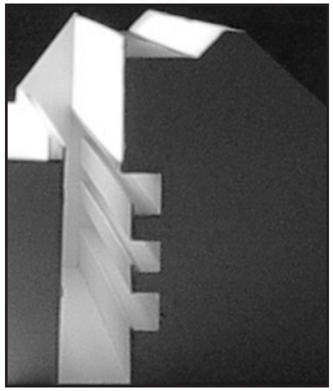
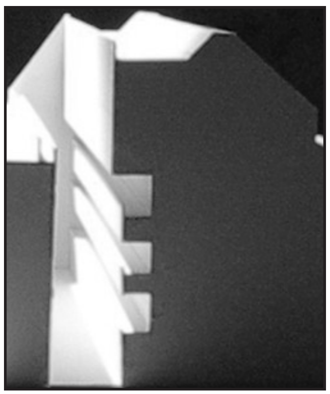
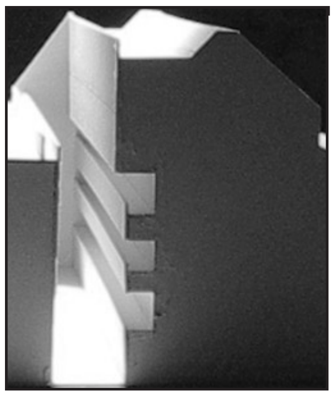


7:00 am

8:00 am



9:00 am



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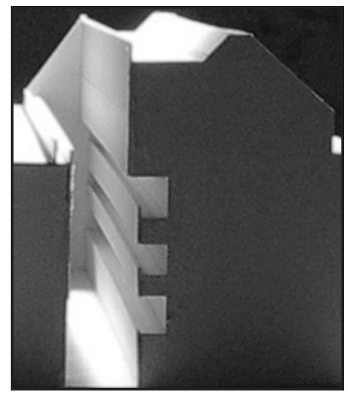
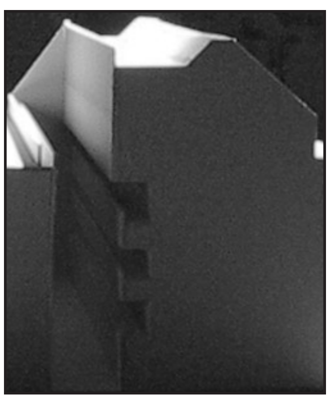


11:00 am



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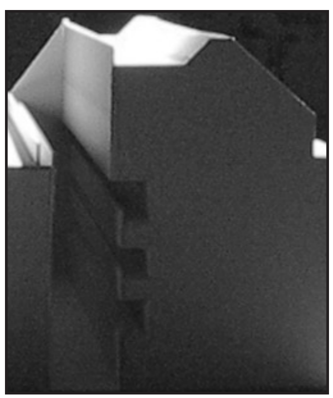

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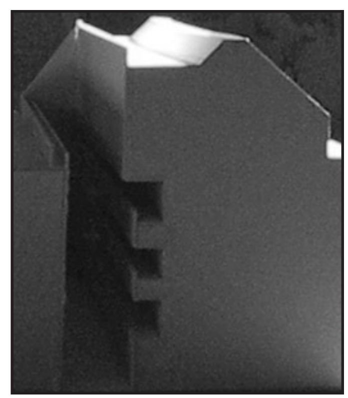
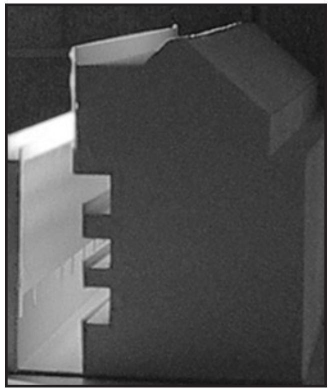


2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

March/September-East Wall



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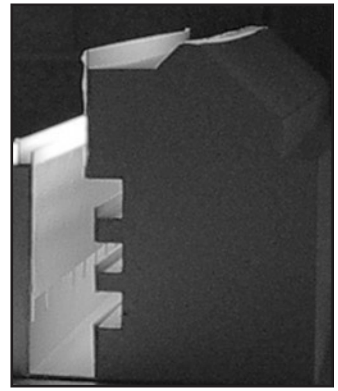

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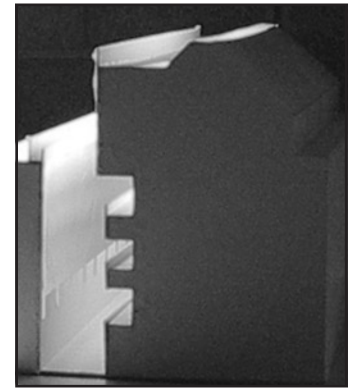

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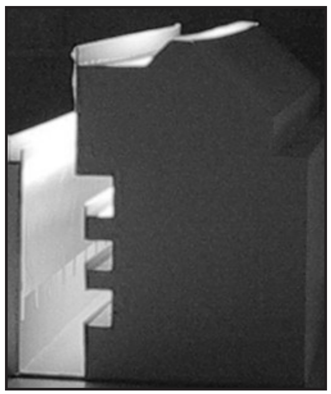
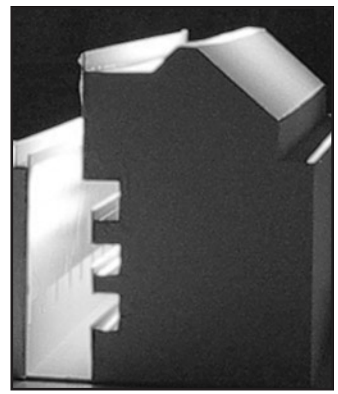


9;00 am



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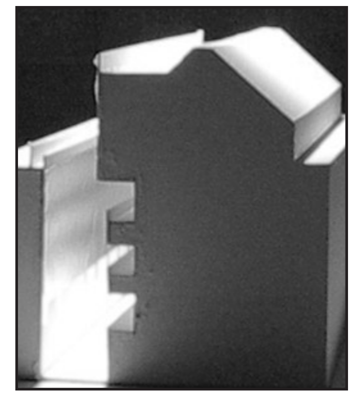
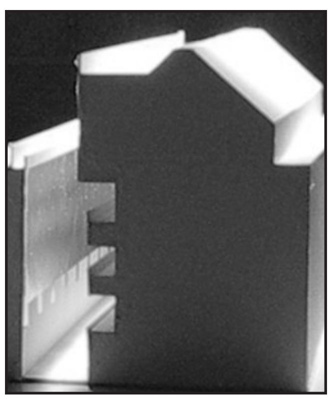
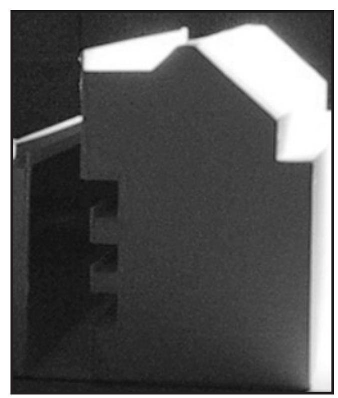


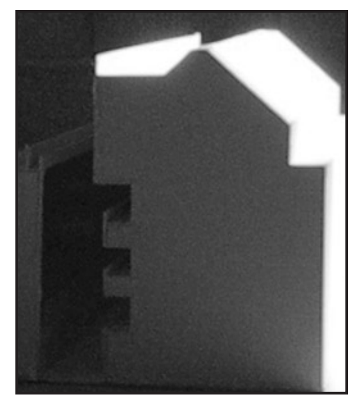
11:00 am



12:00 p.m.



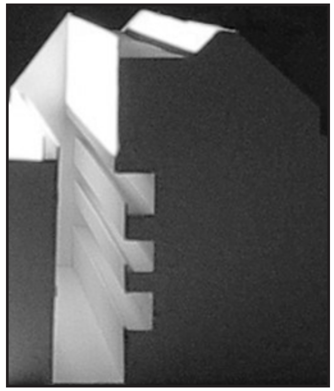
1:00 p.m.



2:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

February/October-West Wall



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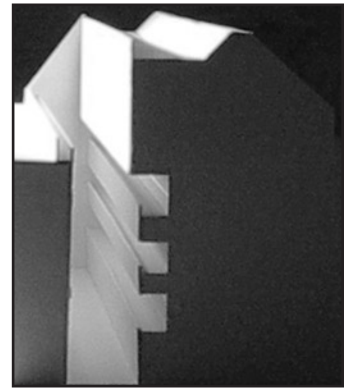

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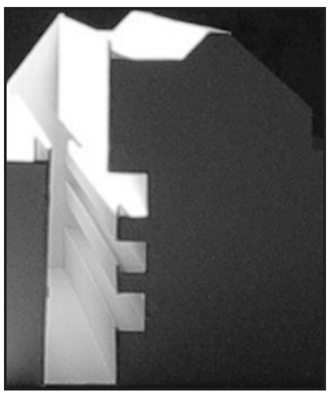
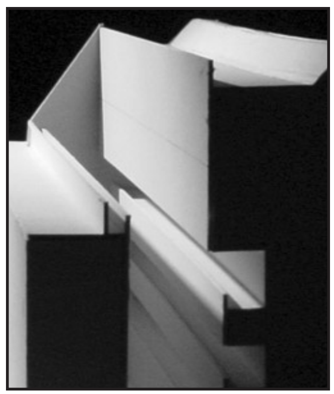


9:00 am



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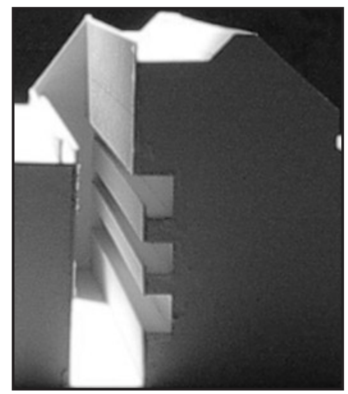

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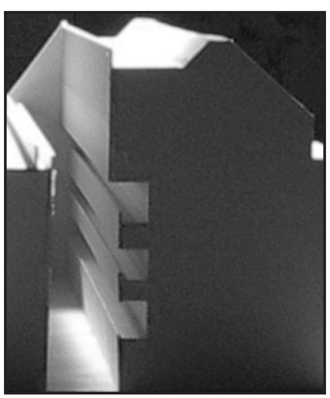

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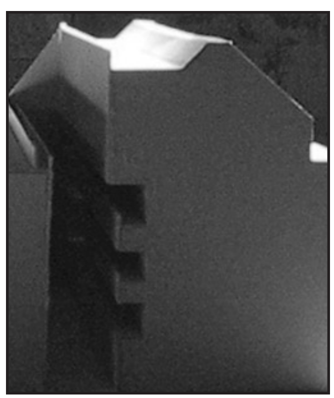
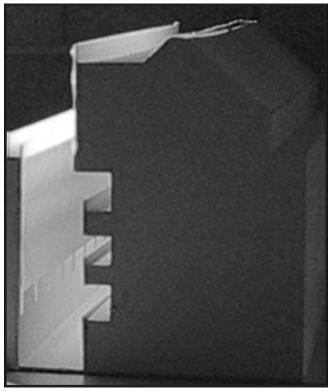


1:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

February/October-East Wall



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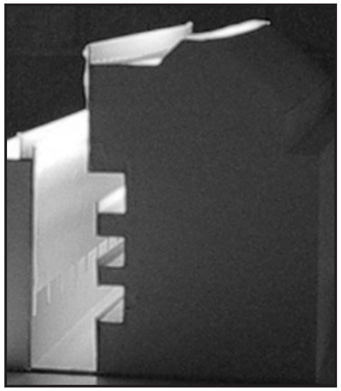

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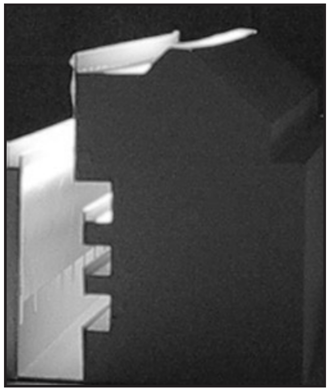

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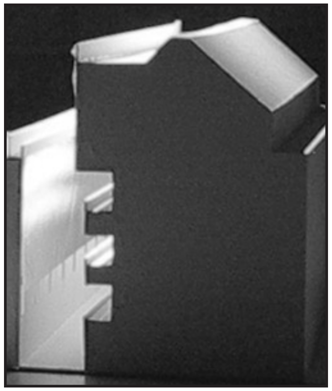

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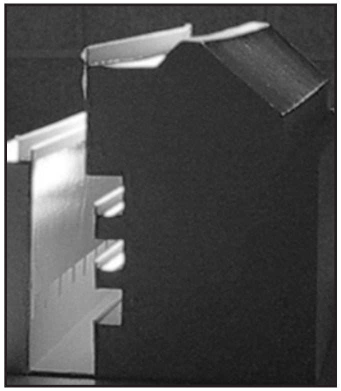

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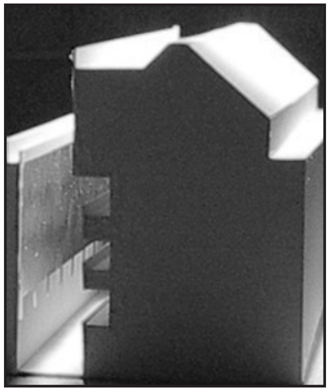

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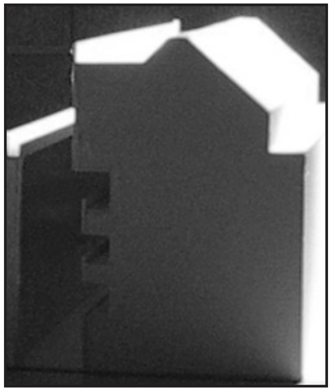
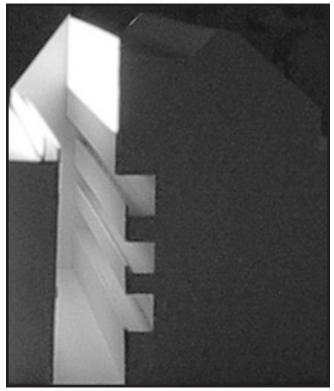


1:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

January/November-West Wall



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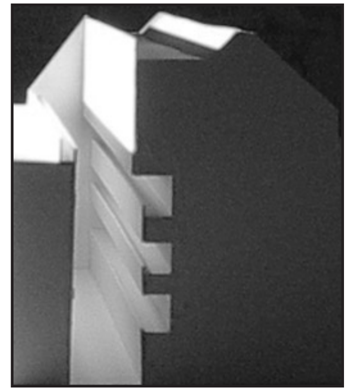

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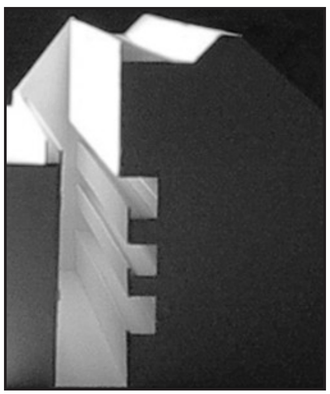

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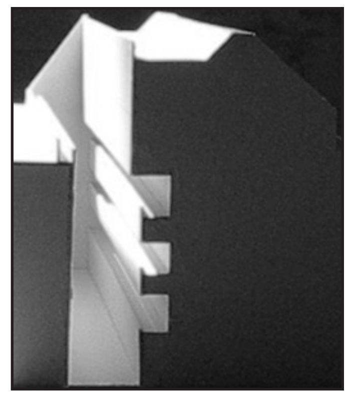

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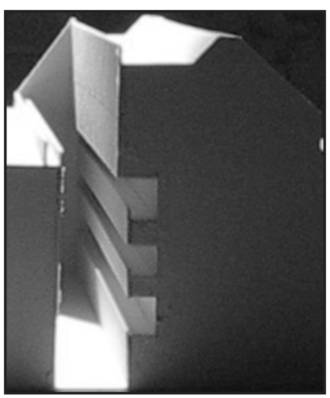

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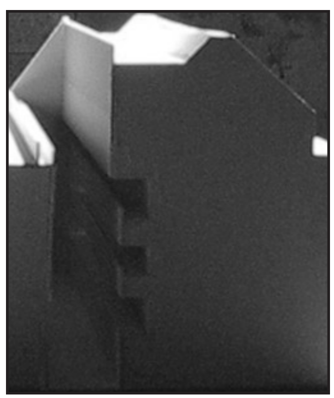
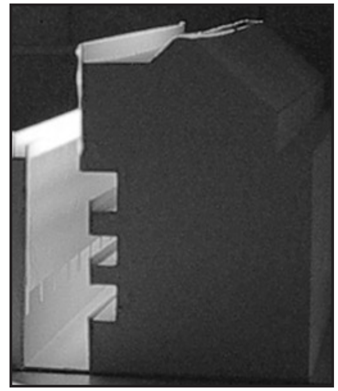


1:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

January/November-East Wall



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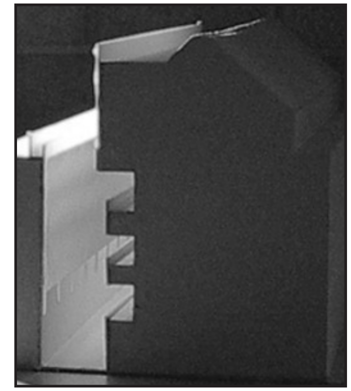

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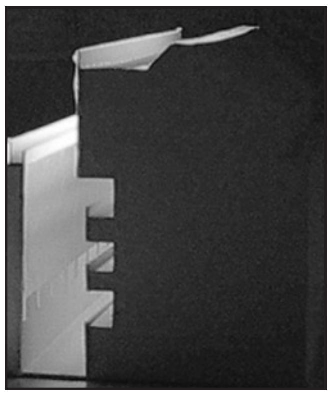

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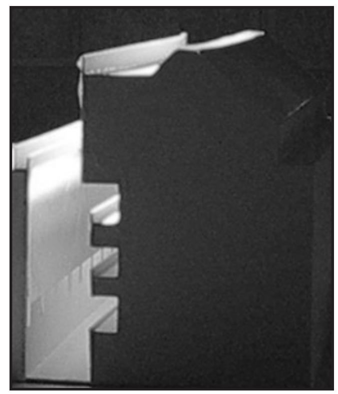

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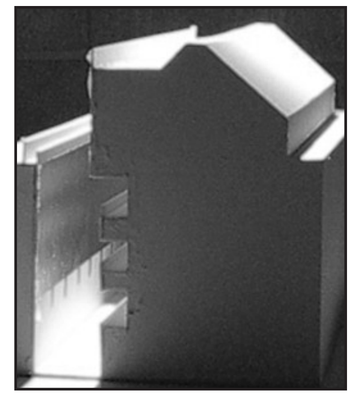

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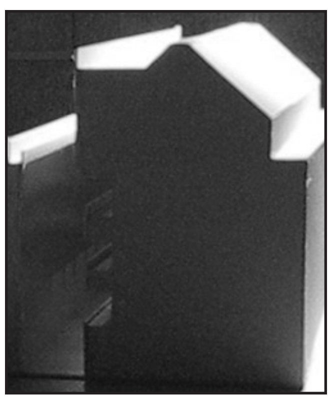

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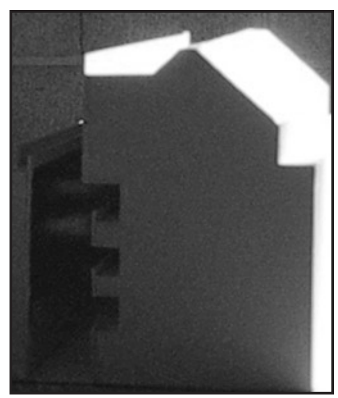
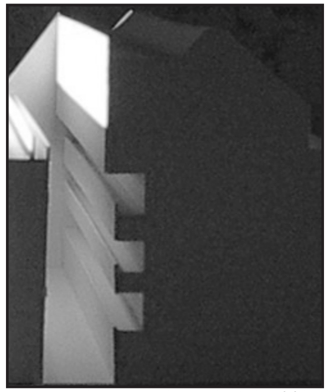


1:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

December-West Wall



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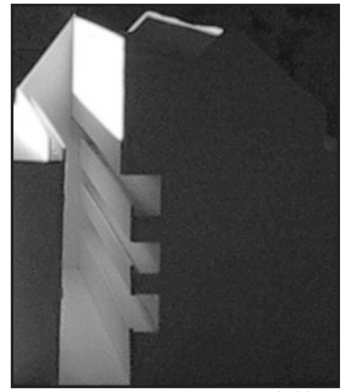

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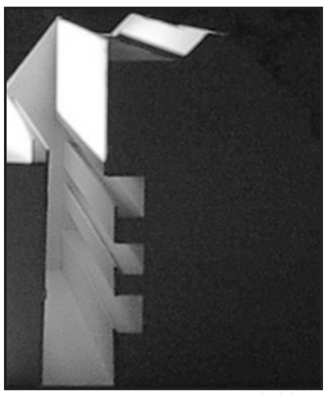

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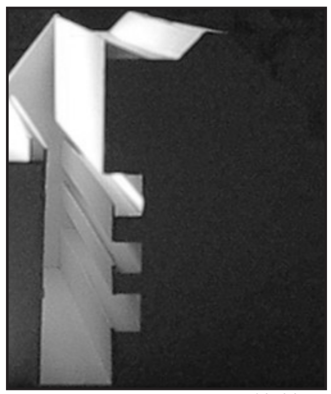

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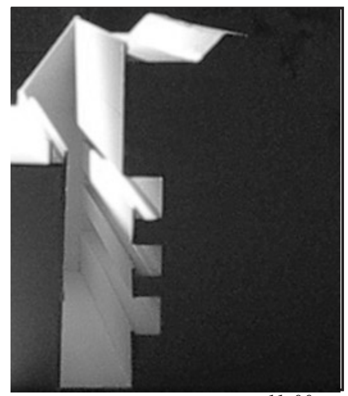

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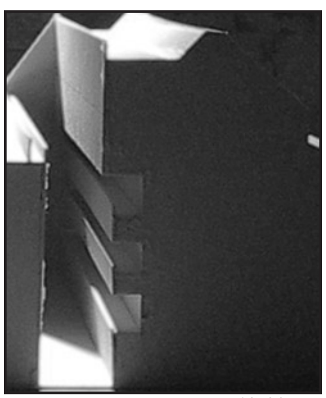

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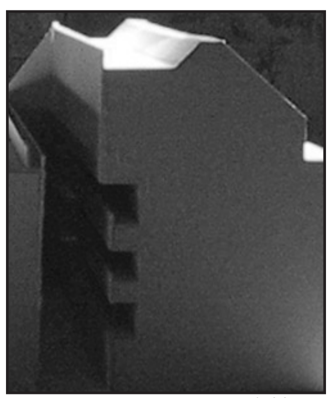
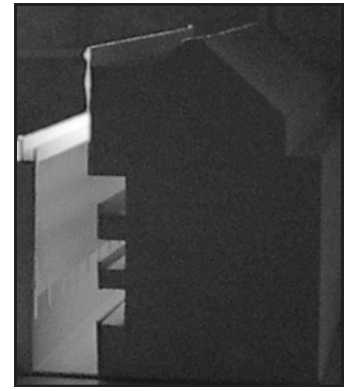


1:00 p.m.

Appendix C: Heliodon Atrium Daylighting Studies

December-East Wall


7:00 am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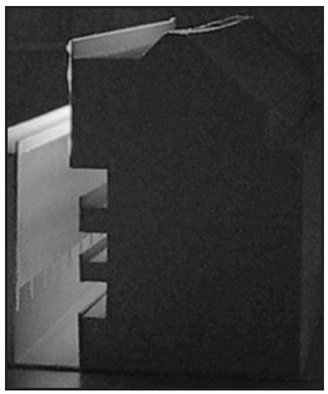
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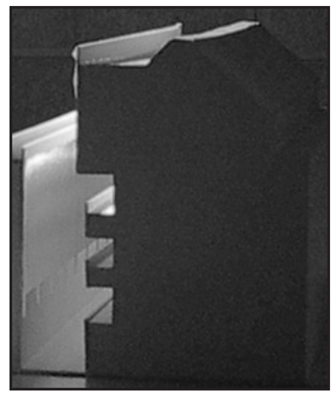
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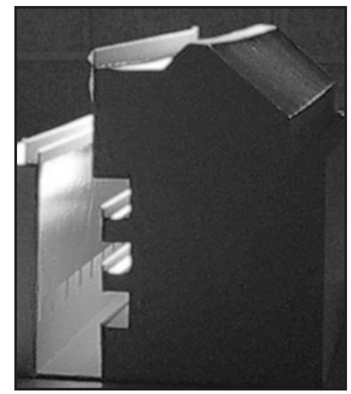
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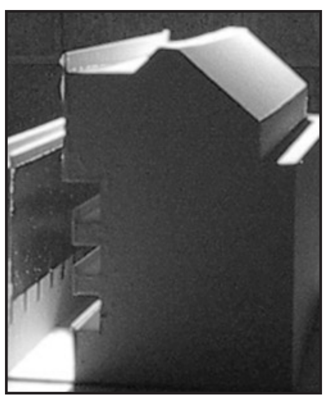
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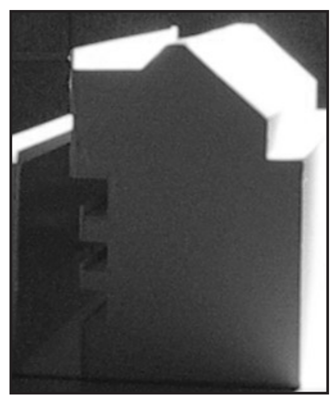
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