VITAL SIGNS

A BUILDING WORKUP

THE CLEO ROGERS MEMORIAL LIBRARY

COLUMBUS, INDIANA

SUBMITTED BY
THE
VITAL SIGNS CLASS
CERES STUDENT SCHOLARS
CENTER FOR ENERGY RESEARCH/EDUCATION/SERVICE
BALL STATE UNIVERSITY

AUGUST 1996

Preface

The Vital Signs Curriculum Materials are being used as the backbone to a sequence of course offerings initiated in the spring of '96 at Ball State University through the Center for Energy Research/Education/Service (CERES). The first class made use of the *Interior Illuminance, Daylight Control and Occupant Response* curriculum module. The intent of the ongoing course offering is to integrate the participation of students as *CERES Student Scholars* under the mentorship of both the CERES staff and those faculty and/or professionals participating as *CERES Visiting Scholars*. The field research will continue to utilize the architecture of Columbus, Indiana.

Acknowledgements

The Vital Signs Project is managed through the Center for Environmental Design at the University of California, Berkeley under the direction of Chris Benton, Gail Brager, Bill Burke, and Alison Kwok. The Vital Signs Project is funded by the Energy Foundation, the National Science Foundation, Pacific Gas and Electric Company, and the University of California, Berkeley.

Additional support for the research presented in this report was provided by Ball State University through CERES.

Table of Contents

Preface.....i
Acknowledgments.....i

I. Vital Signs Initiative at Ball State
- Vital Signs Class.....VS-1.1
- Instructional Team.....VS-1.2
- Visiting Scholars.....VS-1.2
- Student Scholars.....VS-1.2
- Project Selection.....VS-1.3

II. Cleo Rogers Memorial Library Building
- Research Structure.....CR-1 1
- Original Building.....CR-1.2
- New Addition.....CR-1 3
- Building System Findings CR-1-4

III. Executive Summary of Lighting Systems Assessment
- Main Area/Lobby.....ES-2 1
- Mezzanine Level.....ES-2. 3
- Galleria.....ES-2 . .5
- New Addition.....ES-2. 8
- Children's Library.....ES-2.10

IV. Detailed Team Reports
- Main Area/Lobby.....APP A
- Mezzanine Level.....APP B
- Galleria.....APP C
- New Addition.....APP D
- Childrens Library.....APP E

VS-1-1

The Vital Signs Initiative at Ball State

The Vital Signs Class

The Vital Signs Class was offered as an interdisciplinary educational opportunity and comprised Honors College students from disciplines across campus, e.g., architecture, landscape architecture, urban planning, zoology, political science, etc.

The majority of students had widely varying, previous exposure to the subject content of the course and little or no familiarity with the scientific method. The course was structured largely to follow the sequencing of materials presented in the curriculum packet to properly equip the students to engage in fundamental field research; certain lab-based research exercises (e.g., physical modeling) were not undertaken, but reviewed for information purposes only.

Instructional Team

The *Instructional Team* for the student research summarized in this report included faculty on the staff of the Center for Energy Research/Education/Service:

Jeffrey D. Culp, Operations Manager; William W. Hill, PhD, Senior Researcher; Robert A. Fisher, Resident Fellow; and Robert J. Koester, Director

Visiting Scholars

The *CERES Visiting Scholars* who contributed to the educational effort and provided critique of the student work included faculty and professionals from around the country:

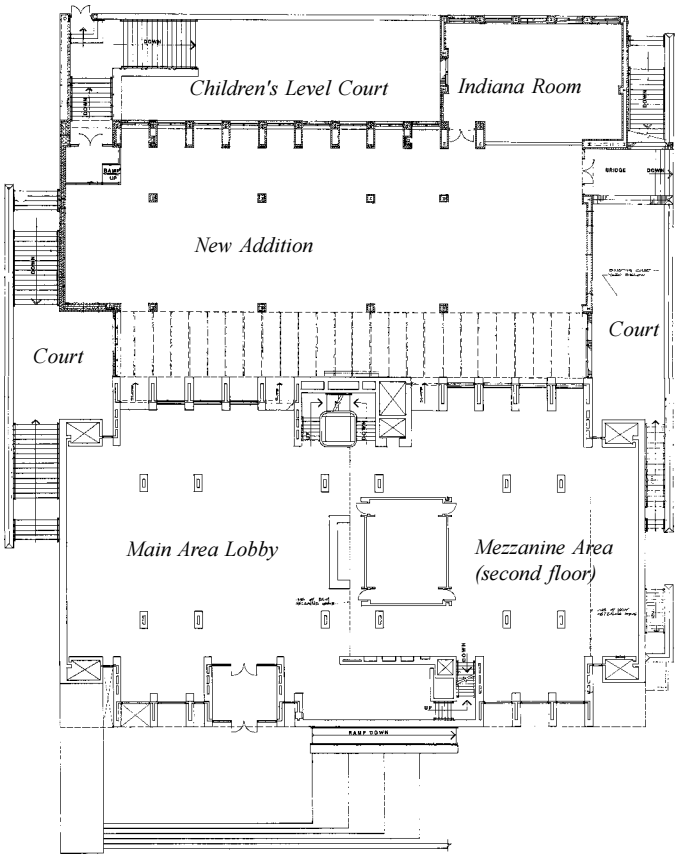
Cris Benton, University of California, Berkeley; Marietta Millet, Department of Architecture, University of Washington; Fuller Moore, Department of Architecture, Miami University; Wolf Preiser, Department of Architecture, University of Cincinnati; Claude Robbins, ERC International Consultants Inc., Denver; and, Marc Schiler, Department of Architecture, University of Southern of California.

Student Scholars

The *CERES Student Scholars* for this innaugural research effort included:

John Barker, Architecture; Robin Bass, Architecture; Mark Beebe*, Architecture; Rebecca Chorzempa, Landscape Architecture; Jenni Confer, Landscape Architecture; Joel Dunning, Architecture; Michele Ehlers, Architecture; Jared Forte, Urban Planning; Jeffrey Gehring, Architecture; Bill Grossnickle, Architecture; Heather Kuhne, Architecture; Emily Linderman, Architecture; Rachel Minnery, Architecture; Paul Pogue*, Political Science; Scott Redelman, Architecture; Aaron Rosenau, Architecture; Jeff Sailer, Zoology; Kevin Singh, Architecture; Erica Stepler, Architecture; Karen Thome*, Urban Planning; Robert Whiteamire*, Architecture.

** Denotes students who continued to participate during the summer months to help complete the expanded final report.*



Plan View
Cleo Rogers Memorial
Library
Columbus, Indiana

Project Selection

Many unique architectural works available in the Columbus Indiana environs readily fit at least one of the four candidate categories for a Vital Signs *building workup*:

architecturally significant,
energy efficient,
generic building type,
historically significant.

We chose to engage a *building type* study using the Cleo Rogers Memorial Library. Selection of this building type offered a chance to use a similar facility on campus as a trial site for application of field research protocol -- testing and refining techniques in a more accessible setting. Techniques included visual survey and site documentation, instrument placement, hypotheses building, questionnaire survey development and evaluation, and data collection and assessment.

Cleo Rogers Memorial Library Building **CR-1-1**
research structure

The Research Structure

This report summarizes the field-based research findings regarding the Cleo Rogers Memorial Library in Columbus, Indiana. The report discusses in general the integration of lighting technologies with the other building systems -- heating, ventilating, air conditioning, window glazing and structure. And the report discusses in detail natural and artificial lighting illuminance levels, the isolux distribution patterns, the energy density, lamp type and fixture type, and occupancy factors.

The findings presented are sequenced to reflect the levels of increasing research engagement developed during the semester-long field study.*

Indicative assessments reflect preliminary visits to the library at which time the students were framing an awareness of the facility design and looking for field-research opportunities.

Investigative assessments reflect more detailed fact-finding and field-measured data gathering using short-term instrument sampling. Such work was conditioned on the experience of the first visits and reflected a fuller understanding of the lighting and building technologies in use.

Diagnostic assessments reflect the use of longer-term data acquisition and more in-depth examination of such information. This phase of the research was conditioned by hypotheses about lighting performance and required significant field research and data analysis ability.

Team Reports which resulted yield a comparison of building design approach: the inventive integration of building systems in the *original design*-- including heating, ventilating, air conditioning, glazing, structure and lighting -- vis á vis the more conventional isolation of systems in the *new addition*; and the significance of uncontrolled daylighting and inconsistent artificial lighting on illuminance levels and occupant response throughout the facility.

** these categories of increasingly sophisticated research activity are adopted from Post Occupancy Evaluation by Preiser/Rabinowitz/White*

CR-1-2 **Cleo Rogers Memorial Library Assessment**
facility description

Original Building

The Cleo Rogers Memorial Library was designed by IM Pei. It was commissioned in 1963 and occupied in 1967. The building comprises brick-clad, waffled-pan, fixed-glazing construction technologies with centralized floor-integrated air supply/return using terminal distribution and capture at window mullions. The floor construction includes a secondary concrete slab located above the primary (waffled) structure. Metal baffles placed between these slabs are used for patterning air supply and air return pathways. Waste heat from the incandescent lighting fixtures, placed within the structural pan coffers, is designed to provide a substantial portion of the winter-time space heating.

Cleo Rogers Memorial Library Assessment **CR-1-3**
facility description

Figure 2 Interior view of galleria looking east, showing glazing system, and globe and track lighting fixtures.

New Addition

The *original building* was expanded in 1987; the architects of the *new addition* respected the original parti and mimicked the material selection and patterning used by Pei. The new wing, however, uses primarily fluorescent rather than incandescent lamps, has acoustical ceiling tiles over major spaces and uses hydronic baseboard convectors at the window glazing. The physical linkage between the two buildings, comprises a galleria space with north facing, sloped glazing overhead and window walls at the east and west ends.

Building Systems

A number of generalized building system descriptions are provided along with the more detailed presentation of lighting system research findings. These more global building system discussions are provided as a means to begin linking this *Building Work Up* on *Interior Illuminance and Occupant Response* to those other educational/research/content modules of the Vital Signs Curriculum Materials Packet. These *indicative* level descriptions of building systems can thus serve as a platform from which further research might be undertaken.

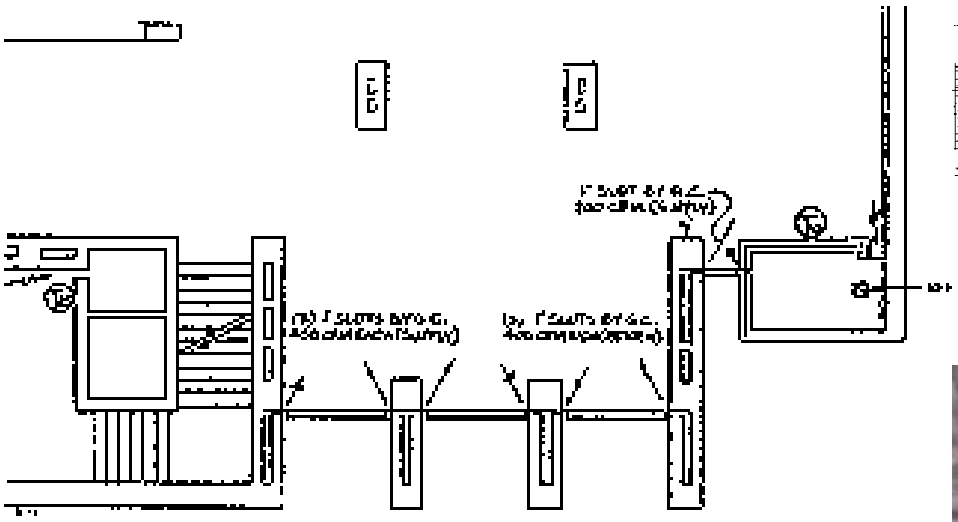


Figure 3 Constuction drawing of the "air shaft" glazing mullion showing patterns of supply and return air flow.

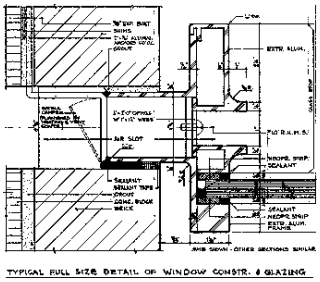


Figure 4 Constuction drawing of the "air shaft" through the glazing mullion.

Figure 5 Fixed glazing mullion with integral air supply/air return channel.

Window Glazing

The original building employed $^{1}/_{2}$" thick full height single pane fixed glass panels, set in steel mullions. These mullions have integral air supply and air return slots which bathe the glass in a continuous horizontally flowing air stream. The mullion air shafts are supplied by vertical duct runs set within the structural brick piers of the building. The glass is not spectrally selective and no attempts were made to insulate the "air slot" mullion against thermal loss to the outside ambient air.

Cleo Rogers Memorial Library Building **CR-1-5**
building systems findings

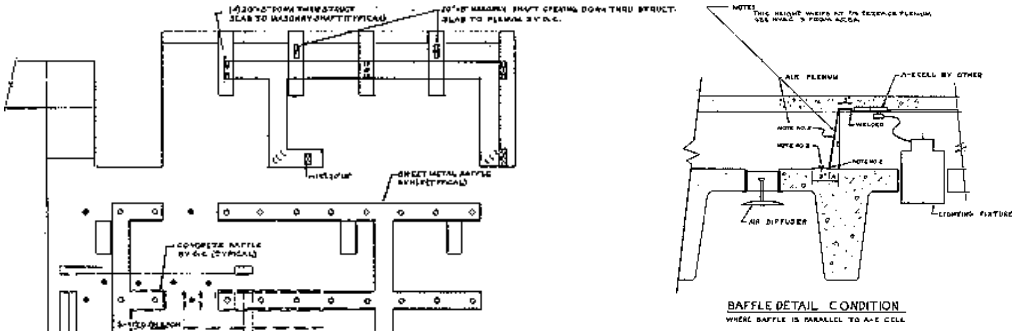


Figure 6 Construction drawing of air plenum baffling above light fixtures.

Figure 7 Constuction drawing of the typical ducting and baffling patterns between the topping and structural floors.

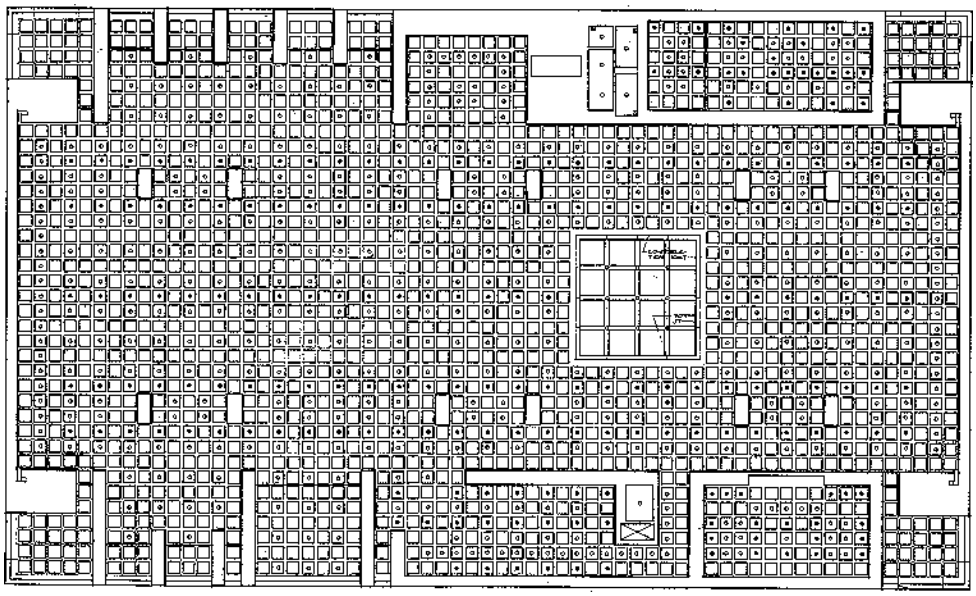


Figure 8 Reflected ceiling plan of original building, showing integration of lighting fixtures and air diffusers with waffle pan coffers.

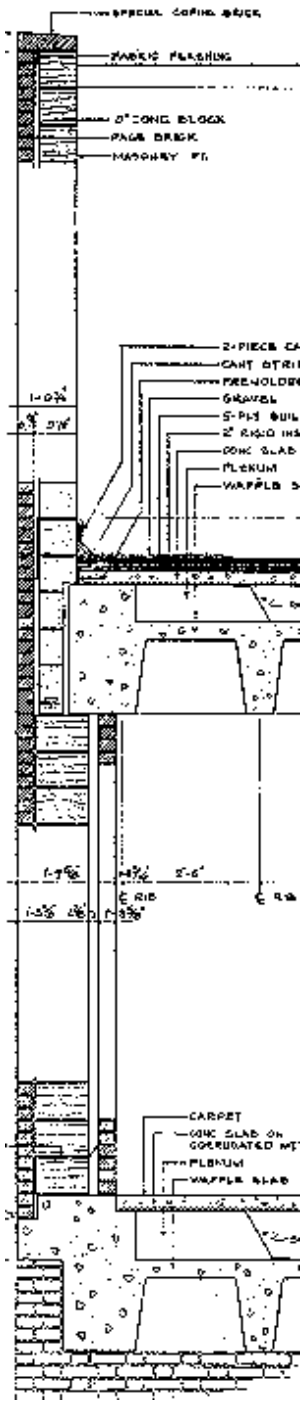


Figure 9 Constuction drawing of the lower and upper floor double slab air plenum with baffling.

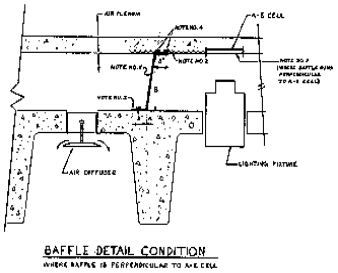


Figure 10 Detail drawing of air supply diffuser "fit" into structural concrete waffle slab.

Air Flow / Original Building

All ventilation in the *original building* is provided by constant volume, forced mechanical delivery. The building has no passive ventilation potential through operable windows. The zones of mechanical service and air flow rates are:

Plaza Level /Mezzanine	19600 cfm
Building Perimeter	13550 cfm
Lower Level South	11750 cfm
Lower Level North	18150 cfm

Pneumatic and electric thermostats are placed in perimeter locations, near major return air plenums in the main lobby of the Plaza Level and in central locations on the Lower Level. Cooling is provided by a split-system heat pump. The four mechanical zones have supplementary heaters in the mixing plenums and at each hot deck.

Fresh air intake is provided at the central air handling systems. Natural convective currents result in heat stratification in the high bay spaces of the original building; this produces unpleasant temperatures on the Mezzanine level. Fresh air intake for the constant volume air handling system of the *original building* occurs through the penthouse.

Cleo Rogers Memorial Library Building **CR-1-7**
building systems findings

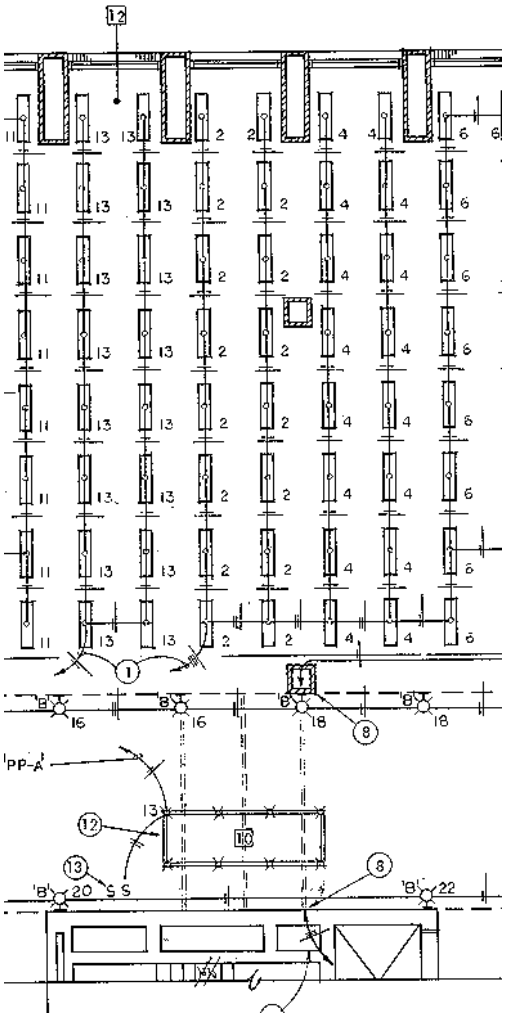


Figure 11 Partrial reflected ceiling plan of the new addition and galleria, showing patterning of the fluorescent, globe and track lighting fixtures..

Figure 12 View of the diffuser cover placed over the original mullion location at the Galleria connection to the main library space in the original building.

Figure 13 View of the baseboard convector units located below the north-facing glass of the addition.

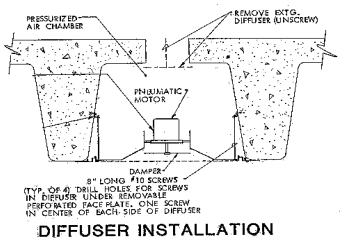


Figure 12 Constuction drawing of the motorized damper replacement for the lower level ceiling areas in the original building.

Air Flow / New Addition

The *new addition* utilizes a variable air volume (VAV) delivery system, serving the east and west halves, respectively. The Indiana Room to the northeast is part of the eastern zone. Thermostats are located in the Galleria Space, the Stack Area and the Indiana Room. Return air is drawn over fluorescent lighting fixtures located within the ceilings. Hydronic baseboard units are provided at the perimeter of the building, at the base of all window glazing. The original ceiling diffusers in the lower level of the original facility have been retrofitted with pneumatic, motor-driven dampers. Fresh air intake for the VAV handlers in the *new addition* occurs through the roof.

Indoor Air Quality

Filtration of return air is provided in the return air leg of the constant volume air handling of the *original building* system and in the variable air volume air handling system of the *new addition.* These static filters are replaced on a scheduled basis. No additional evaluation of air quality was undertaken. The likelihood of off-gassing or contaminant contribution to the occupied space in the *original building* and the *new addition* is primarily vested in carpet and furniture material sources. Humidity levels are also controlled by the respective central mechanical systems. Since the building is without operable windows, fresh air intake is provided as part of the air handling system; this coupled with the filtration allows for conventional control of indoor air quality.

More detailed analysis of the heating, ventilating, and air conditioning system was not undertaken as part of this Vital Signs Study.

Thermal Mass

The *original building* and *new addition* contain considerable thermal mass -- in the brick, concrete block, concrete waffle slab and secondary construction. The affect of using a secondary concrete slab over the structural waffle system as an air plenum return allows for considerable air stream temperature stabilization and energy storage in both masses. This is not part of the operational design scheme; no evaluation was made of the effect of this thermal capacitance or that of the brick piers and exposed concrete on the thermal qualities of the occupied spaces in either wing.

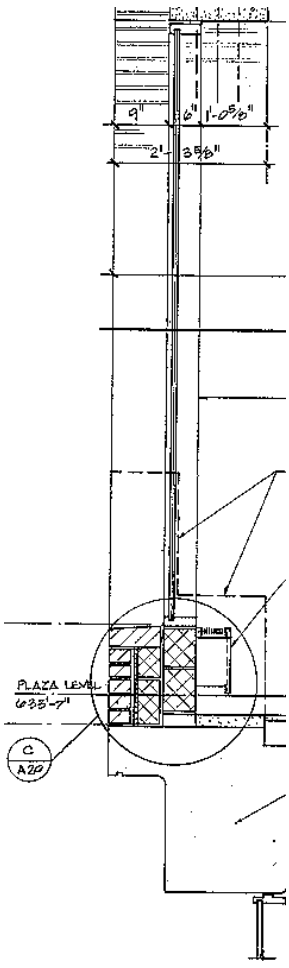


Figure 13 Constuction drawing of baseboard convecting units below glazing in the new addition.

Illumination Systems

Illumination at the building apertures is substantially higher than throughout the rest of the facility.

Natural lighting penetrates the spaces significantly in the *original building* on the southern side of the main lobby and east end of the Mezzanine through full-height fixed window glazing; the glazing is not spectrally selective. Substantial shadows are cast by the adjacent brick piers. The brightness ratios between those zones receiving direct sun as compared to artificially lit zones are extreme, causing glare.

The atrium construction over the Mezzanine level in the original building provides substantial levels of natural illumination; the presence of the trees filter and modulate the direct sun.

Daylight penetration on the below-grade level occurs through exterior courts. The interior spaces receive substantial northern skyvault and reflected southern beam illumination off the walls of these light courts.

Daylighting in the *new addition* occurs along the southern edge through the sloped glazing over the galleria and along the north face through vertical fixed glazing. Morning and evening sunlight (during all seasons of the year) reach the Galleria through the eastern and western window walls, respectively. Substantial light intensity and shadow casting conditions occur throughout the Galleria on clear days.

Artificial illumination of the primary spaces of the *original building* is provided with incandescent lamps in reflective housings located within the concrete ceiling coffers of the structure. The artificial illumination of the *new addition* is provided primarily by parabolic reflector/fluorescent fixtures.

Preliminary instantaneous measurement of illuminance values in the *original building* range from 20 to 600 footcandles under clear sky conditions. The average clear sky illumination in the *new addition* is 70 footcandles.

The furniture placement within the respective areas does not appear to be organized in response to the natural illumination. Seating areas to the south of the main entry level, lobby and stack area, undergo intense direct beam illumination. Glare factors are substantial. Seating areas on the Mezzanine level undergo considerable illumination intensity swings. Carrels throughout the building experience substantial shadow conditions from the mix of artificial and natural light sources.

Measurement of illumination and luminance levels in the primary zones of the building indicate modest surface reflectances. The building design which uses unpainted brick and concrete as primary interior finish materials provides a highly absorptive surface for impinging light. Reflectances range from a low of 11% for the brick walls to a high of 55% for the exposed concrete.

The fixture placement and count taken from the construction documents indicate that energy densities in the *original building* range from 5.6 to 10.6 Watts/SF. The energy density of the *new addition* ranges from .89 to 2.2 Watts/SF.

The research findings based on longer-term data gathering, as premised on specific hypotheses for each of the five primary usage zones in the building, are discussed and illustrated in the following Executive Summary. Each of the spaces is significantly different in its physical configuration and resulting illuminance performance. The spaces experience a range of illumination levels which fall well below or well above IES recommendations that existed at the time of construction.

The five areas studied in detail by the Student Scholar research teams are:

Main Lobby
Mezzanine Level
Galleria
New Addition
Children's Library

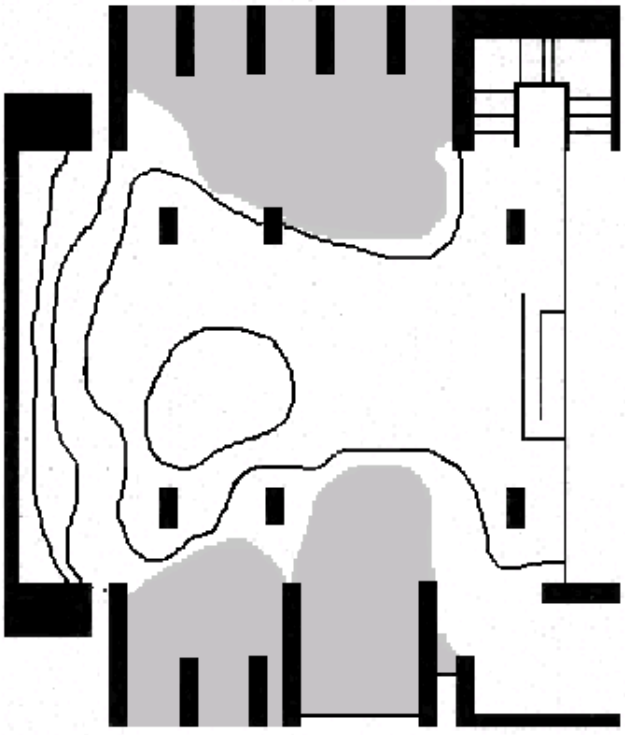
The full research reports submitted by the student teams are included as appendices.

Main Area/Lobby Space

The sequence of space illumination studies for the main area/lobby of the library, are summarized in this section; they are detailed in **Appendix A**. The isolux map (**figure 15**) illustrates that the majority of the space contains illumination levels which fall below IES recommendations for reading--between 35 and 50 footcandles. The areas adjacent to the windows provide substantially more illumination during the daytime only. During the evening hours and when natural daylight is not entering the room, the entire space contains fairly uniform but low illumination levels. This finding is supported by data samples taken across the building sections. Two plots, taken near the west wall of the space are illustrated. The first chart (**figure 16**) is from a sunny day, March 30, where natural light was filling the space. The second chart (**figure 17**) was taken during an overcast day, March 31, when natural light was minimal. It is safe to say that the data for March 30th and 31st are dramatically different due primarily to outside weather conditions.

Figure 14 Main lobby space looking east.

Figure 15 Isolux map of the main lobby area.



meets or exceeds IES minimum recommendations

ES-2-2 Executive Summary of Lighting Systems Assessment
main lobby

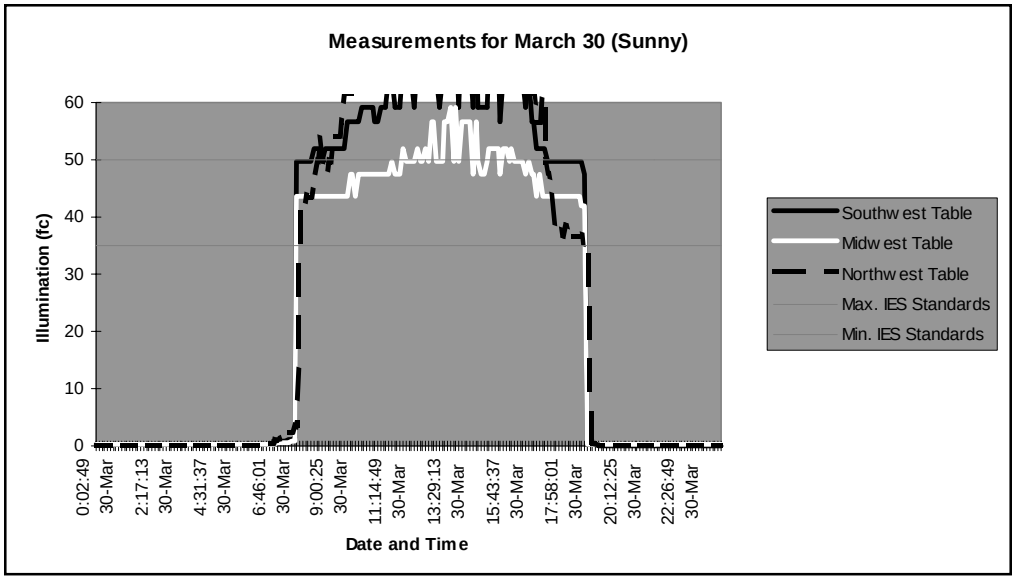


Figure 16 Measurments taken along the west wall during a sunny day.

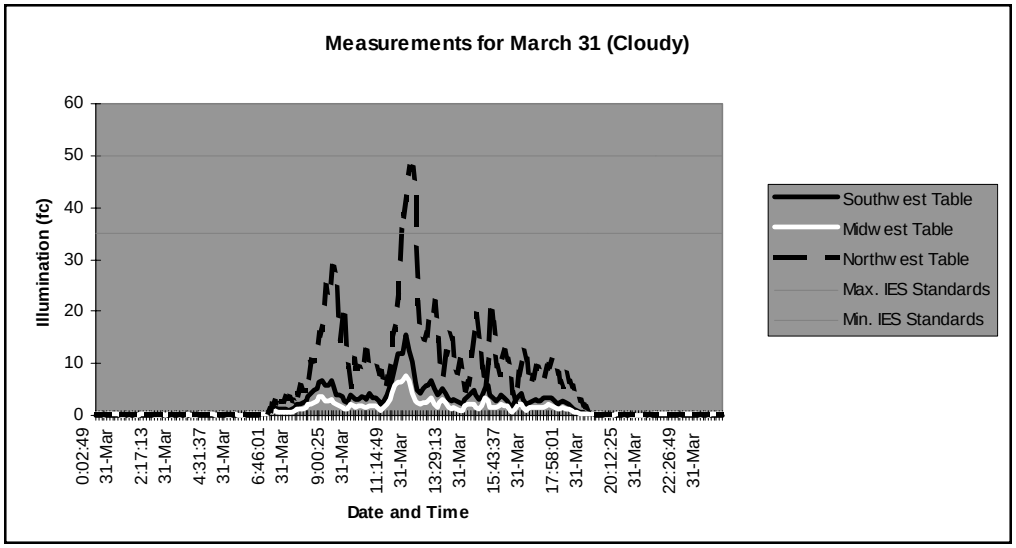


Figure 17 Measurements taken along the west wall during an overcast day.

Mezzanine Level

The study of the mezzanine level, as detailed in **Appendix B** is summarized below. A primary issue addressed is the illuminance recommendations from the IES for 'finding and reading' books. Illuminance readings were taken throughout the stack area. Sample measured values on the surfaces of 'west to east' and 'north to south' book stacks are presented in **figures 19** and **20**, respectively. These display considerable variations from the top to the bottom of the stacks. Clearly the lighting in the space is not sufficient to evenly illuminate the entire area. It is interesting to note that the ends of the stacks nearest the light well (west in **figure 19** and north in **figure 20**)generally have a higher footcandle reading than do the opposite ends of the same stacks. This illustrates that the light

Figure 18 Stacks and the skylight of the mezzanine area.

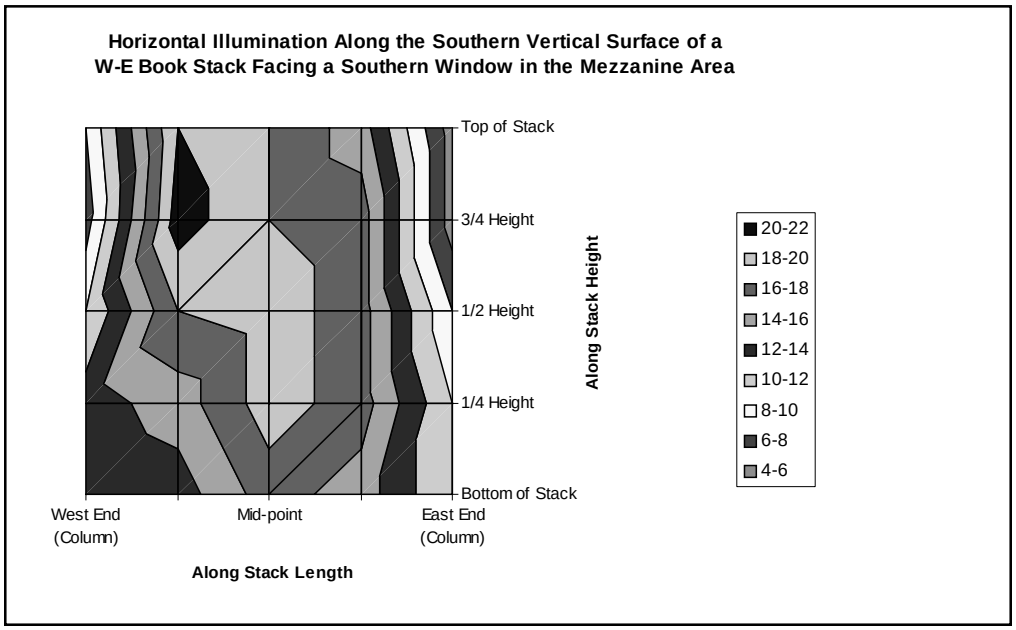


Figure 19 Illuminance measurements on a 'west to east' oriented stack.

well does allow daylight to enter the space. Figure 23 also illustrates the effects of the overall low reflectance scheme in the library as brick columns adjacent to each end of the stack diminish the illumination levels on the books at the end of the stacks.

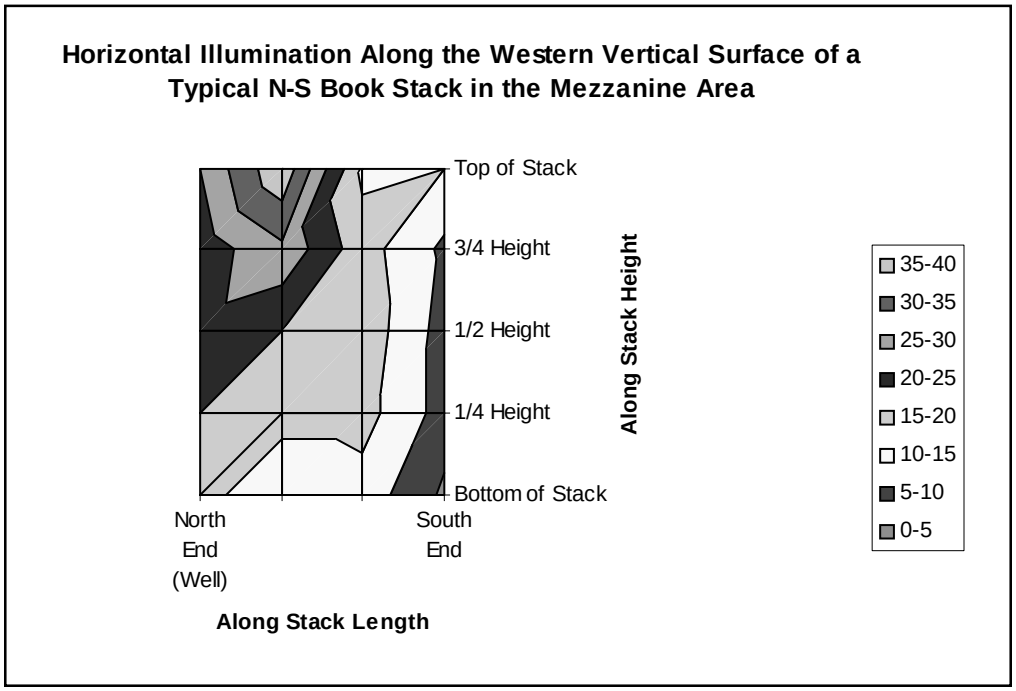


Figure 21 Illuminance measurements taken on a 'north to south' oriented stack.

Galleria

Detailed information on the studies of the Galleria space can be found in **Appendix C**. This space connects the *original building* with the *new addition*. Daylighting -- from an overhead skylight and floor-to-ceiling windows at the east and west ends of the space -- provides the dominant illumination during daytime hours; wall-mounted metal halide lamps in globe-shaped housings are the primary sources of lighting during evening and nighttime operating hours. The reference desk situated in the center of the space is supplementaed with a lighting rack containing eight incandescent fixtures. Lack of daylighting control results in excessive illumination levels during the day; at night, the artificial lighting is inadequate for achieving comfortable reading illumination levels. This day/night illumination difference is represented in **figure 22** and **figure 23**. In **figure 22**, each 'row' of illumination measurements represents a section taken from west to east through the space. Row 1 is the southernmost section, taken nearest the old portion of the library, while Row 7 is the northernmost string of data, taken near the brick wall of the library addition. **Figure 6** displays the instantaneous daytime illuminance levels; throughout the majority of the space on a partly cloudy day, illumination levels are well over 150 footcandles. However, data in Row 7 remains fairly constant at approximately 40-75 footcandles. This is due to the readings being taken near/under the ceiling of the new addition; they are influenced more by artificial lighting than by daylighting.

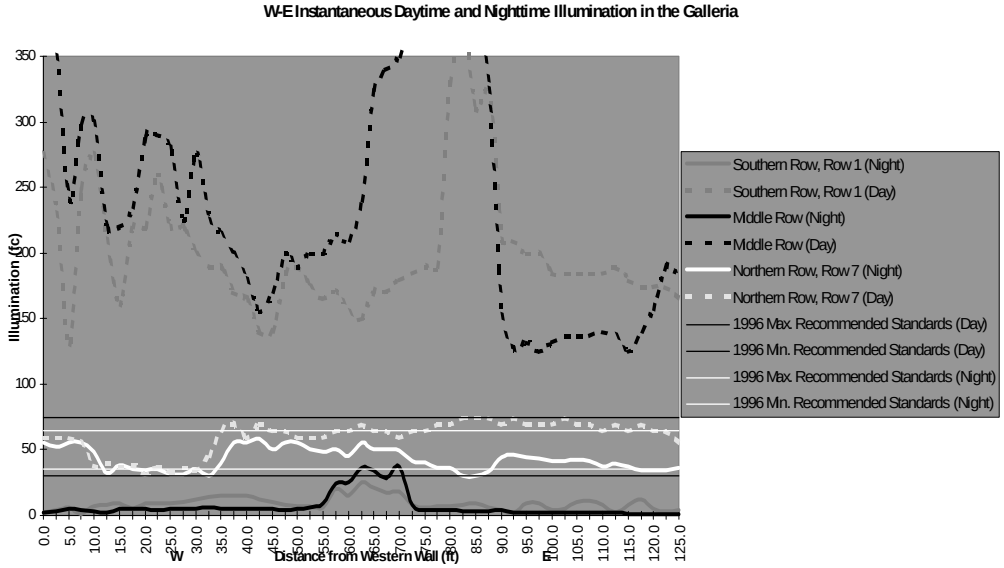


Figure 22 Illuminance measurements from a W-E section that runs the length of the galleria.

The measurements for the space fluctuate widely, but with the exception of Row 7, they display an internal consistency; that is, they rise and fall at roughly the same time. The fluctuations of the readings illustrate the effect of daylighting on the space in two important manners -- the influence of the east and west windows and the influence of weather conditions.

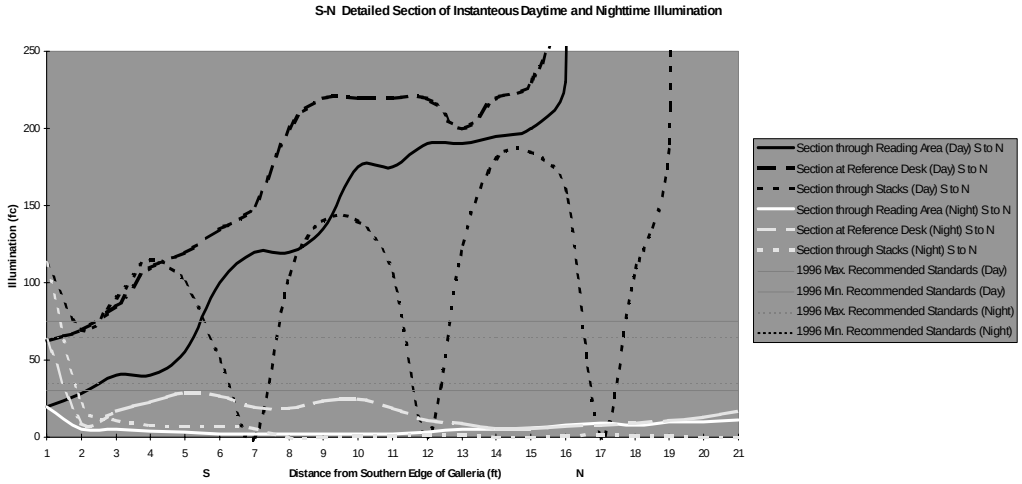


Figure 23 Illuminance measurements from a section that runs the width of the galleria.

On the west portion of the graph -- 0-35 feet -- the readings begin at 400 footcandles, and steadily drop at greater distances from the window. At 95 feet, the readings increase, reaching a peak of 600 footcandles. The influence of weather is displayed in the measurements taken between the 65 and 95 feet distances. As the day was partly cloudy, the measurements for the first 65 feet were taken under a cloud cover; at 65 feet, the cloud cover began to break, opening to beams of direct sunlight. At this point measurements were still being taken, and they show a sharp increase, reaching a peak of 450 footcandles at the 80 foot mark. The clouds began to close again, and by the time the measurements at the 95 foot mark were taken, the direct sunlight had been obscured.

The instantaneous nighttime illuminance level graph displays a dramatic decrease in the light level wherein the highest reading barely reaches 50 footcandles. The spikes in the nighttime graph in Row 3 from the 55 through 75 foot markers represent the illuminance from the eight fixtures in the lighting rack above the reference desk.

The instantaneous daytime illuminance readings taken on a south/north axis as shown in **figure 23** provide more information regarding the effect of daylight on the space. Starting on the south end, where the galleria connects with the *original building*, and working across the 20 foot long galleria to the *new*

addition, readings were taken every foot. This was done at three spots--the reference stacks on the east end, the reference desk in the center, and the study carrels on the west end. In all three cases the readings showed remarkable consistency for the first 14 feet from south to north; then, at the 15 foot mark, the readings jump to over 250 footcandles for the study carrels and reference desk, and the reference stacks show a similar increase at 18 feet. This can be explained by the steep angle of the skylight; the sun is in the south portion of the sky, and the north-facing skylight is angled to present a smaller surface to the south. This restricts much of the sunlight; however, the angle does allow direct sunlight to come in and fall on the north edge of the galleria, accounting for the high readings in that section.

Figure 24 Looking east in the galleria space.

New Addition

The illumination study of *new addition* to the library which is summarized below is presented in detail in **Appendix D**. The spaces in the addition include a general stack area, a table/study area, a series of study carrell bays along a line of north-facing windows, and the Indiana Room, located in the north-east corner of the plan. The issue evaluated in these areas is the effect of different lighting conditions on the usage of the space by patrons. While the other building space studies focused predominantly on the match of lighting levels with IES recommendations, this study focuses primarily on patron usage. A formulation of space-use-percentage was determined by dividing the average number of people studying by the total number of available seats/stations. While many of the spaces are well lit, it was found that space usage and illumination level are not positively correlated. For example, **figure 25** shows that as the intensity of light declined, the percent of space usage increased. Another example is evident in the analysis of the main area of the library which was used as a comparison against the spaces in the *new addition*. As mentioned earlier in the study of the Main Area, the light levels often fall below the recommended standards, yet this area has received as high as an 18% usage as shown in **figure 26**.

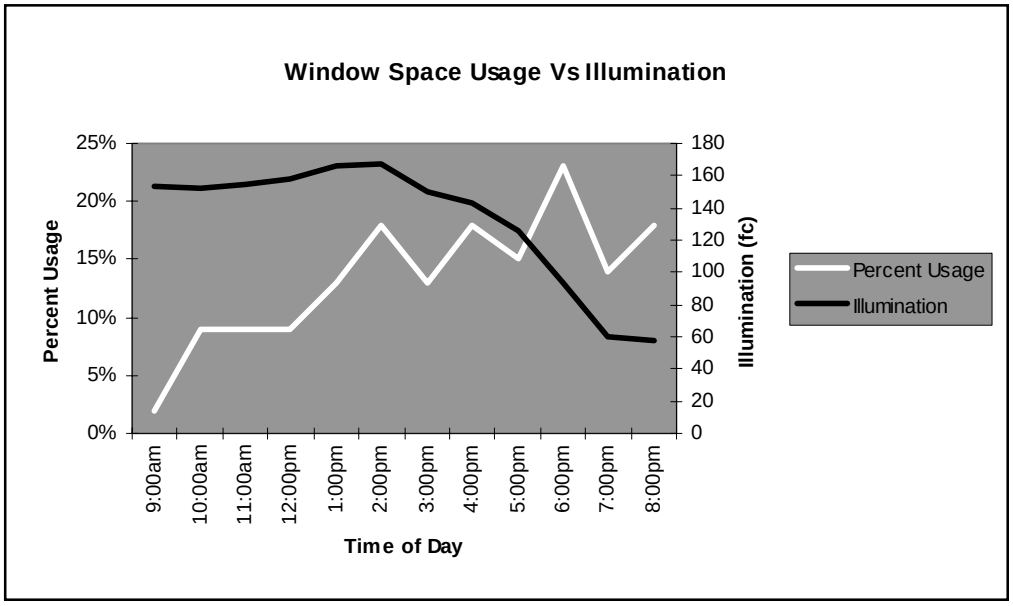


Figure 25 Relationship between the illumination and the space usage.

Finally, analysis of the Indiana Room revealed the most positive correlation between percent usage and illumination.

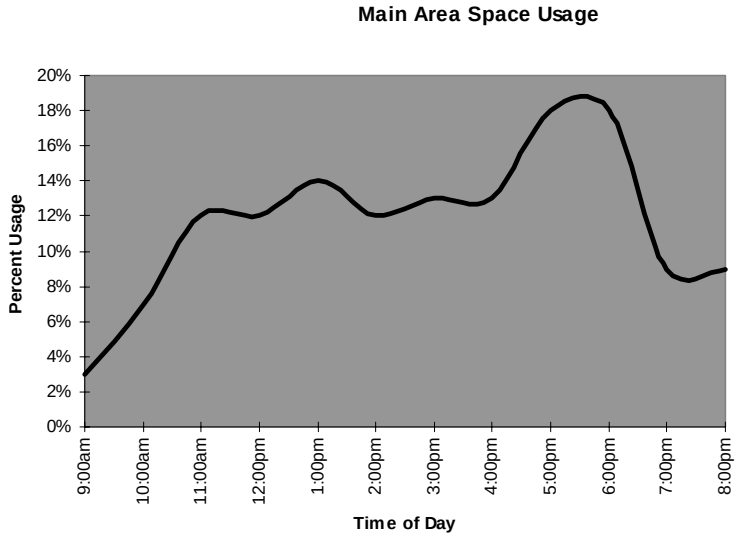


Figure 26 Percent usage of the main space of the new addition.

Because the patrons were interviewed, reasons were found as to why they chose to sit in a particular location. Quoted from **Appendix D**, the "patrons' most popular response as to the reason they chose to sit in a particular location was privacy and...quiet." The second most popular response was..."the reference materials they were interested in were located near the seating they were using." Other answers varied from "needing a particular type of table, liking the comfort of a chair, to even selecting a place [from which] to watch people." When the patrons were asked about lighting in terms of their decision to select particular seating, the answers indicate that people are aware of lighting [even if subconsciously] and react accordingly. For example, one patron mentioned "needing to adjust the blinds to remain in a space..." One patron mentioned "the overall darkness of the library" while still another person talked about "how the lighting is pretty good everywhere."

Figure 27 View of the stacks in the addition.

Children's Library

Figure 28 Some patrons of the children's area.

The children's library study is detailed in **Appendix E**. This space is on the lower level and was part of the *original building*; it has an external sunken plaza, below street level to the north. This is the direction from which the majority of natural light enters the space. However, it was found that the natural lighting does not reach far into the space. **Figure 29** shows that daylight contributes significantly to the illumination of the children's library but for only about a five foot depth into the space. Throughout the space, illumination levels are barely above the minimum IES recommendations . The 3-D isolux graph shown in **figure 30** illustrates the low illumination levels as well as the variations across the depth of space.

It was also discovered that the electric lighting in the space creates variations in illumination levels at different working heights throughout the space. The coordination of patterning of the lighting fixtures with the waffle slab structure of the ceiling, and the light distribution characteristics of the 'can' fixtures, causes a pooling of cones of light to be produced which yields noticible variation in the intensities of light -- 'cold' and 'hot' spots occur at eye level. At the operational task level of 24", however, these blend to produce a more uniform illumination.

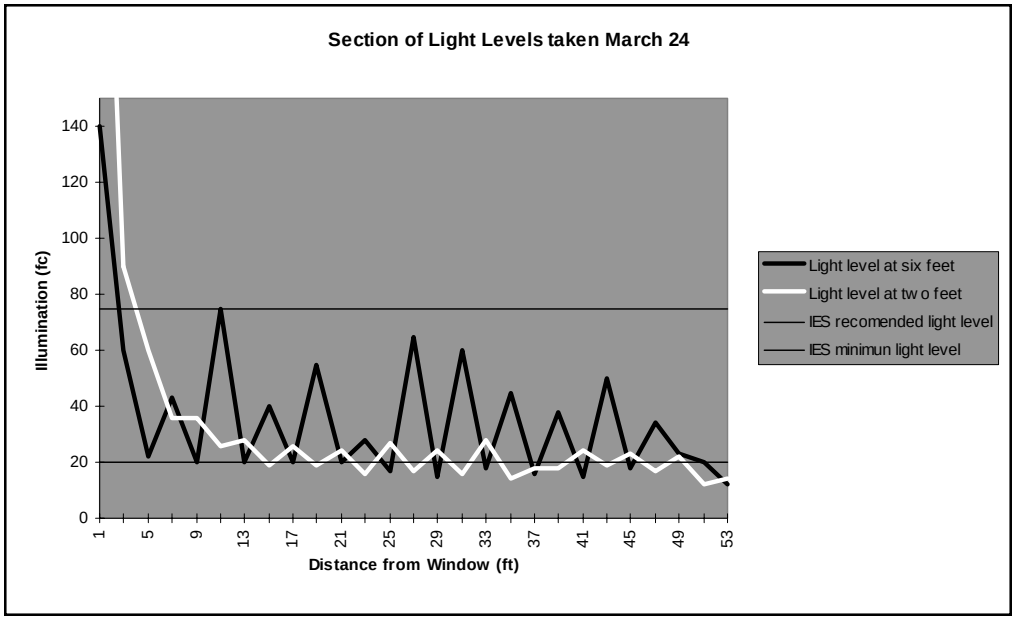


Figure 29 Illuminance measurements taken from a single section through the space.

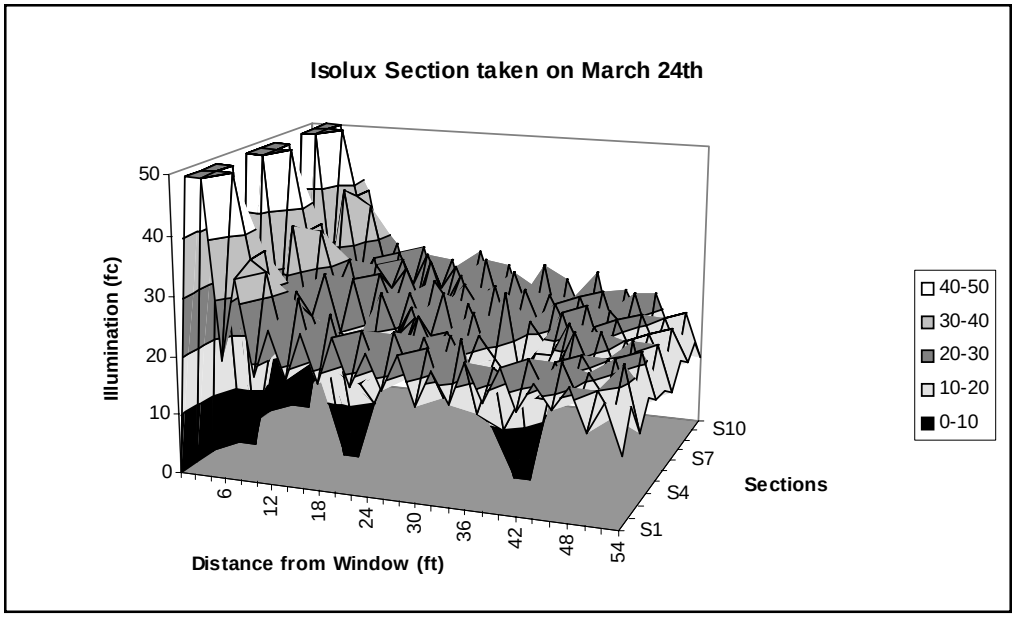


Figure 30 Isolux taken across a broader band of sections through the space at 24" task height.