Lighting Depth

Introduction

The TCES owners are dedicated to providing the most eco-friendly and efficient building they possibly can. Because of this, they made sure that the lighting design for the building was extremely efficient, not only to gain LEED points but also in an effort to actively conserve energy. They see the building not only as a place where students can come to learn, but want it to also be a teaching point itself. By designing a green building, they can demonstrate how it can be done and hopefully guide other developers to do the same. Due to their extraordinary efforts, lower power densities will be hard to achieve but I will make every attempt to do so.

The four spaces that I will be investigating during this lighting design will be the exterior, the main lobby, the case study classroom, and one of the chemistry laboratories. The exterior is the main point of interaction between the public and the building. A long arcade along the North facade of the building will be the focus for the redesign. The next space the public encounters is the lobby. The lobby serves as the main circulation space as well as the reception area and display gallery. A three-story atrium stands in the center of the lobby, providing light to the hallways up on the 2nd and 3rd floors as well as part of the lobby below. Adjacent to the lobby is the case study classroom, which will be used by visiting professors to have their work reviewed, as well as for lectures and possibly classes. Above all of this on the second floor are the lab spaces. One of the chemistry labs has been chosen in order to reduce the power density in a spaces that is overlit. Spaces chosen for producing finalized renderings are the lobby and the chemistry classroom.

Design Goals

Power densities that are lower than the current power densities are desired. Since the power density in the chemistry lab is above what is allowed, a major goal of mine will be to bring it down to a level below what ASHRAE 90.1 allows. Throughout all the spaces it is important for me to choose fixtures which will integrate with the simple yet beautiful architecture. The fixtures should reflect this simplicity and beauty, and should not be a prominent feature of the architecture but merely a part of the architecture. Of course, neither should they be an eye sore. In addition, I will obtain proper light levels as defined by the IES in all spaces and an appropriate level of control for each space is desired. For individual design goals and criteria for each space, please see below.

Design Solution

To achieve the low power densities that are desired, I have chosen efficient fixtures and sources. In the lobby, I attempted to use daylight from the lightwells during the day when possible. I chose simple fixtures that do not detract from the architecture because they are either too elaborate or too displeasing to look at. In many instances, I have made an effort to find a fixture that can be used in multiple locations, drastically reducing the number of fixtures needed on the project.

General Information

Overall Design Concept

After I visited the site and took in the views of the mountains, the lake, and all the trees surrounding the building, I couldn't help but come away with a sense of what the owners of TCES wanted to help preserve. As such, nature provided me with two main design concepts. The first is the idea of sustainability to ensure that the views that I enjoy are there for future generations. The second is the idea of “Beauty in Simplicity” that comes from observing how simply things in nature seem to interact and respond to one another. As such, I will chose fixtures to blend and compliment the architecture of the building in addition to being efficient and energy-saving. Much like nature, I will attempt to avoid waste and at the same time create a visually pleasing experience. Also, to relate rooms to one another I will choose a minimal amount of fixtures to serve the spaces, meaning that the fixtures chosen must be usable in many settings. This will also promote sustainability in that fewer fixture types means fewer lamp types, fewer manufacturers producing fixtures, and fewer man-hours spent installing fixtures since the contractor will only have to learn to install a limited amount of fixtures.

Fixture Schedule

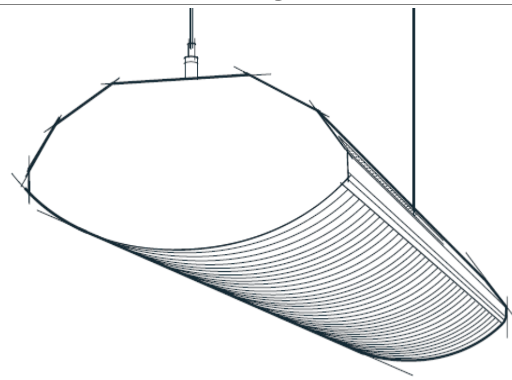
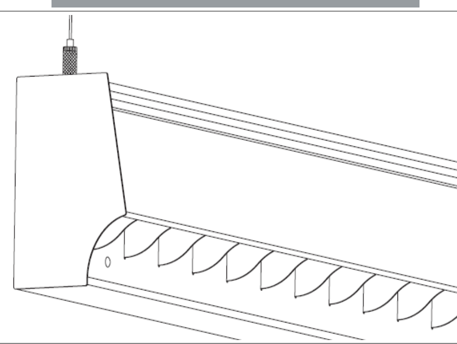
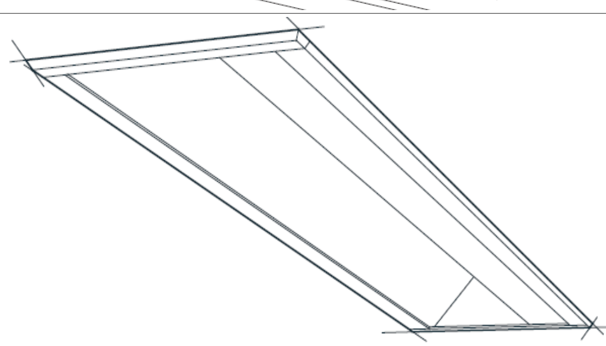
Fixtures are grouped together by letter if the physical housing of the fixture is the same. Variations on the mounting, lamping, ballasts, etc. are denoted by a number following the letter. See figure 1.1 below for fixture types and descriptions. Full fixture cutsheets are available for viewing in Appendix A-CD. Images of each fixture type can be found in figure 1.2.

LIGHT FIXTURE SCHEDULE

TYPE	MOUNTING	MODEL	LAMP	BALLAST	FINISH	DESCRIPTION / NOTES
A1	Surface	Prudential PRU-7 surface mounted 4'-0” linear semi-direct fluorescent fixture.	Philips F32T8 835 ALTO	E	Galvanized	Ceiling Mounted Semi-Direct
A2	Suspended	Prudential PRU-7 suspended 4'-0” linear semi-direct fluorescent fixture.	Philips F32T8 835 ALTO	E	Galvanized	Suspended Semi-Direct
A3	Suspended	Prudential PRU-7 suspended 4'-0” linear semi-direct fluorescent fixture.	Philips F32T8 835 ALTO	ED	Galvanized	Suspended Semi-Direct
B1	Track	Erco JILLY track mounted floodlight.	Philips CDM-T 35W 830 T6	M	Cast Aluminum	Flood Light
C1	Surface	Finelite X2-R surface mounted 4'-0” linear wallwasher.	Philips F32T8 835 ALTO	E	Galvanized	Surface Mount Wallwasher
D1	Recessed	Prudential P-5900 4'-0” recessed linear fluorescent wallwasher.	Philips F32T8 835 ALTO	E	Painted Aluminum	Recessed Wallwasher
E1	N/A	Erco LUCY adjustable arm compact fluorescent task light.	Philips PL-T 18W 835 4P ALTO	E	Anodized Aluminum	CFL Tasklight
F1	Surface	Fail-Safe HDSCR surface mounted metal halide downlight.	Philips CDM 50W 830 ED17	M	Stainless Steel	Wet Location Downlight

Ballast Codes:	
E	= Electronic
ED	= Electronic Dimming
M	= Magnetic

Figure 1.1

Type	***Image***
A1, A2, A3	
B1	
C1	
D1	

Type	*Image*
E1	
F1	
	Figure 1.2

Ballast Schedule

Ballasts and lamps used for each fixture type are listed in figure 1.3. For ballast and lamp cutsheets please see Appendix A-CD.

BALLAST INFO							
TYPE	BALLAST	E/M/D	LAMP	NUM LAMPS	WATTS	AMPS	VOLTAGE
A1	Advance Transformer RCN-3P32-SC	E	32W T8	(2)	65	0.54	120
A2	Advance Transformer RCN-3P32-SC	E	32W T8	(2)	65	0.54	120
A3	Lutron FDB-4827-120-2	ED	32W T8	(2)	69	0.57	120
B1	Advance Transformer 71A5005P	M	35W MH	(1)	55	0.5	120
C1	Advance Transformer RCN-3P32-SC	E	32W T8	(2)	65	0.54	120
D1	Advance Transformer RCN-3P32-SC	E	32W T8	(2)	65	0.54	120
E1	Advance Transformer RCF-2S18-M1-LS-QS	E	18W CFL	(1)	20	0.17	120
F1	Advance Transformer 71A5105P	M	50W MH	(1)	69	1.55	120

Figure 1.3

Light Loss Factors

Light loss factors and the assumptions used to get them are listed in figure 1.4 below. The IESNA Handbook, ninth edition, was used to determine appropriate values.

LIGHT LOSS FACTORS						
TYPE	CAT.	BF	LLD	RSDD**	LDD	TOTAL LLF
A1	II	1.03	1*	0.95	0.95	0.93
A2	II	1.03	1*	0.95	0.95	0.93
A3	II	1	1*	0.95	0.95	0.9
B1	IV	1	1*	0.95	0.89	0.85
C1	II	1.03	1*	0.95	0.95	0.93
D1	IV	1.03	1*	0.95	0.89	0.87
E1	II	1.05	1*	0.95	0.95	0.95
F1	IV	1	1*	0.78	0.82	0.64

Notes:
* Mean lumens used, so LLD is 1
** Based on 12 month cleaning cycle

Figure 1.4

Controls

Unless otherwise noted, switches are to be standard 2-pole throw switches. Exceptions include the use of Lutron dimming switches (Nova 3PS – see Appendix A-CD for cutsheet) in the case study classroom, and the use of a smartwire switching system for several lobby fixtures as well as exterior fixtures, in addition to them being controlled by regular 2-pole throw switches. See figure 1.5 below for smartwire switching system schedule.

SMARTWIRE SWITCHING SYSTEM RELAY SCHEDULE			
RELAY #	BREAKER	LOAD DESCRIPTION	CHANNEL
-01	1L1-13	LOBBY AREA LIGHTS	A
-02	1L1-15	LOBBY WALLWASHERS	A
-03	1L1-17	LOBBY FLOODLIGHTS	A
-04	1L1-18	EXTERIOR LIGHTS	B

SMARTWIRE SWITCHING SYSTEM NETWORK CLOCK SCHEDULE			
CHANNEL	GROUP	AUTOMATION SCENARIO	DATA
A	LOBBY	SCHEDULED ON/OFF	M-F 8AM-10PM SAT-SUN 8AM-6PM
B	EXTERIOR	ASTRO (DARK) ON/OFF	SWITCH OVERRIDE

Figure 1.5

Motion Detector Schedule

Motion detectors are used in all spaces to automatically shut off the lights when the spaces are unoccupied for a certain period of time. Refer to reflected ceiling plans for models used in each room. See figure 1.6 below for details, as well as Appendix A-CD for cutsheets.

MOTION DETECTOR SCHEDULE				
TYPE	MOUNTING	MODEL	VOLTAGE	COVERAGE
U1	Ceiling	The Wattstopper Ultrasonic Model UT-355-2	120V	1000sf
U2	Ceiling	The Wattstopper Ultrasonic Model UT-355-3	120V	2000sf
D	Wall	The Wattstopper Dual-tech Model DT-200	120V	2000sf

Figure 1.6

Exterior Design

Design Concept

The exterior of the building is covered by an arcade the length of the building. The arcade is a triangular shaped roof structure that can easily hide fixtures from passersby and serve to cut down on the amount of light trespass to adjacent properties. I will highlight the front door to indicate to visitors where they should enter, and I will maintain safe illuminance levels (as set forth by the IES) along the arcade walkway to ensure proper illuminance for walking as well as facial feature identification.

Design Criteria

Reflected Glare:

Glare reflected in the windows can be distracting and due to low ambient light levels at night, can have a blinding effect since the eye is not accommodated to higher light levels. For safety reasons, I will avoid glare in glazing whenever possible.

Direct Glare:

Glare coming directly from fixtures is also a problem for the same reason that reflected glare is problematic. The luminaires will be mounted 12-15ft in the air, however, so this may not be a problem.

Light Trespass:

In order to meet LEED standards, no direct light may leave the property. This means that fixtures must be chosen carefully so as not to create light trespass onto neighboring properties.

Dark Sky:

To satisfy LEED criteria full cutoff fixtures must be used to avoid light pollution into the sky. Full cutoff fixtures do not put out light above the horizontal plane, so no light can escape into the sky where it would be useless.

Illuminance Criteria:

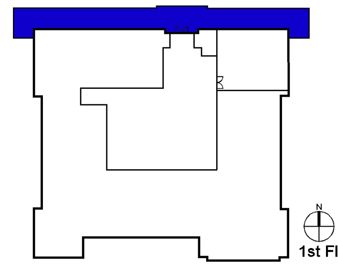
Horizontal:
Walkways: IES .5fc
Vertical:
Facial Recognition: IES 3fc
Importance:

Vertical and horizontal illuminances must be increased in order to accomplish the tasks that the space requires. Right now, the space is underlit per IES recommendations and should probably be increased both for ease of accomplishing tasks and for safety reasons.

Power Density:

ASHRAE 90.1 allowance:
- 30 w/lf main entrance
- 20 w/lf other doors
- 1.25 w/sf canopies

Reflected Ceiling Plan



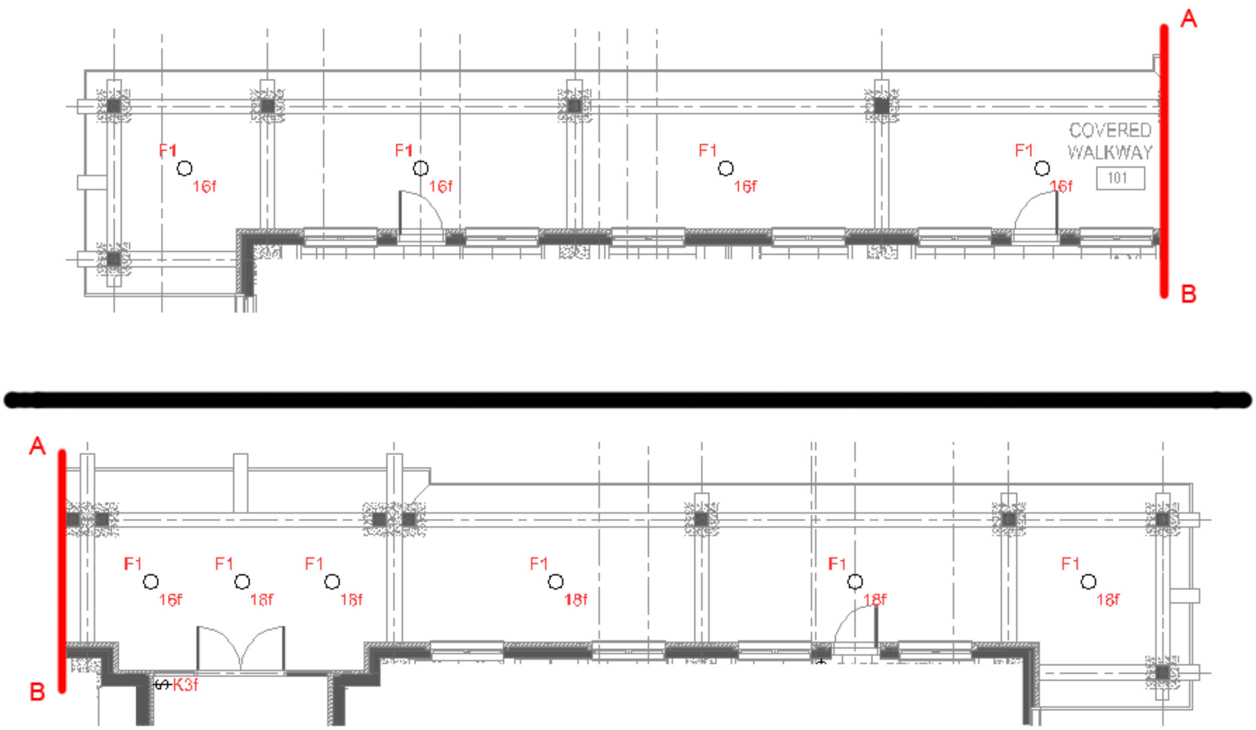


Figure 1.7 – Circuit all fixtures to PNL-1L1 (see figure 1.10)

Power Density Calculations

The exterior power densities came in below ASHRAE 90.1, and while the main door power density is above the existing power density, the others are below. Calculations are shown in figure 1.8 below.

EXTERIOR POWER DENSITY					
TYPE	BALLASTS	WATTS	TOT. WATTS	AREA	CHECK
F1	2	69	138	Main Door	
F1	2	69	138	Other Door	
F1	6	69	414	Canopy	
Main Door LF			6		
Other Door LF			9		
Canopy SF			1897		
Allowed Main Door W/LF			30		
Allowed Other Door W/LF			20		
Allowed Canopy W/SF			1.25		
Main Door Density			**23**		**OK**
Other Door Density			**15.33**		**OK**
Canopy Density			**0.22**		**OK**

Figure 1.8

Controls

The exterior lights are controlled by the smartwire switching system (see figure 1.5) on an astronomic time clock that turns the lights on at dusk and off at dawn. The users can override the system by using a key-controlled switch just inside the vestibule leading to the lobby. All of the lights in the space will be controlled together.

Electric Light Illuminance Calculations

AGI was used to determine values for the floor and vertical facial illuminance. Figure 1.9 below shows a calculation summary for the lobby area. For complete AGI32 output and files please see Appendix A-CD.

Horizontal Average: 3.26fc
Vertical Average: 1.86fc

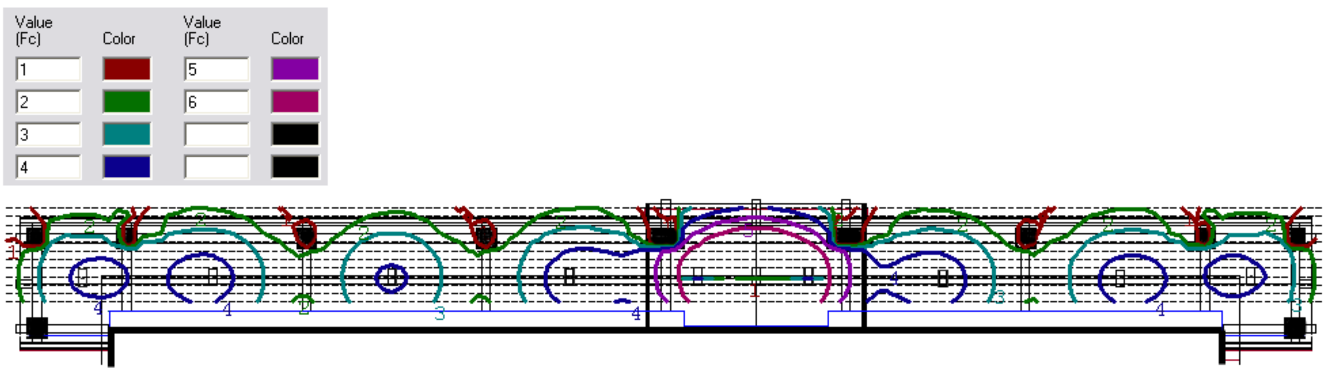


Figure 1.9

Conclusions

I achieved appropriate horizontal light levels along the exterior, and an increased light level was obtained at the entrance to set it apart from the rest of the facade. A full cutoff fixture was used to comply with dark sky ordinances. The power densities I achieved were less than that required by ASHRAE 90.1 while still maintaining acceptable horizontal light levels by IES standards. The space could further save energy by using a lower wattage source since the horizontal illuminance is higher than is needed, however the vertical illuminance, which is already slightly below recommended levels, would be decreased as well.

Lobby Design

Design Concept

As the visitors enter the building, I will draw their attention to three things in a very particular order. First, I will highlight the receptionist desk and emphasize it the most since that is where people will go if they need directions, have a meeting, or wish to contact someone in the building. Second, they will notice the highlighted walls that contain various research materials and information about the building that explain what TCES is all about and what sort of research is conducted there. Third, I will highlight the stairs in an attempt to encourage people to walk and use the stairs. I will deliberately not highlight the elevator in an attempt to draw even more attention to the stairs. Since bare concrete can be found all throughout the lobby, I have chosen industrial, galvanized metal fixtures to complement the architecture.

Design Criteria

Daylight Integration:

Due to the lightwell present in the center of the lobby, daylight integration must be considered. The well provides an opportunity to bring daylight into the space, but it may not be as efficient as it could be. Redesigning the skylight and lightwell to bring more light into the space is required.

Green Design:

Since TCES is designed to be a LEED platinum project, energy efficient design and general "green design" is of utmost importance. The power density is already low, but could be lower with the successful integration of daylight and the possible use of more efficient light sources such as linear fluorescents instead of compact fluorescents.

Fixture Appearance:

With the exposed concrete slab, there is little possibility of using recessed fixtures, so surface or pendant mounted fixtures must be used. Fixtures must be chosen that will compliment the architecture and will not detract from it. Finding a unifying theme for all fixtures chosen (such as shape, finish or style) may help the fixtures to not detract from the space, and to not distract the users.

Glare:

The main source of glare in the lobby would be from the light well. Because the skylights are so high up, it may not be a problem as far as direct glare onto the floor is concerned. Also, direct sunlight that may fall on the walls can be desirable in the lobby as it adds visual interest and a connection to the outdoors. As for electric lighting, because of the polished nature of the concrete floor fixtures will need to be carefully selected to avoid reflected glare off the floor.

Accent Lighting:

As this will be a space to display various research projects, accent lighting is essential. Because the exhibits will be changing fairly frequently, a solution that can cover a wide range of objects and exhibit types is desirable. The lightwell should not interfere too much with accent lighting as the areas to be accented are between 10 and 20 feet away from the lightwell and the ceilings are only about 11 feet high.

Highlighting:

People will need visual cues as to where to go when they enter the building. As such, the receptionist desk will be highlighted, as well as the walls and stairwell. Additional layers of light will be used to lead people to various rooms and displays, but the visual hierarchy will first be composed of the receptionist, then the walls and stairwell.

Illuminance Criteria:

Horizontal:

Reception:	IES 10fc
Gathering:	IES 10fc
Circulation:	IES 5fc

Vertical:

Reception:	IES 5fc
Gathering:	IES 5fc
Illuminated Walls:	IES 30fc

Importance and Hierarchy:

Vertical and horizontal illuminances must be maintained in order to accomplish the tasks that the space requires. Horizontal illuminances must also be met to meet local egress code requirements for light levels. Currently, everything is fairly flat, with the walls being the main accent points. The hierarchy of objects in the space will need to be looked at and the illuminances and luminances varied accordingly so that objects will be noticed in order of importance.

Power Density:

ASHRAE 90.1 allowance (school/university lobby): 1.8 W/sf

An additional 1W/sf can be added for decorative wall sconces and highlighting exhibits, but will most likely not be used.

Reflected Ceiling Plan

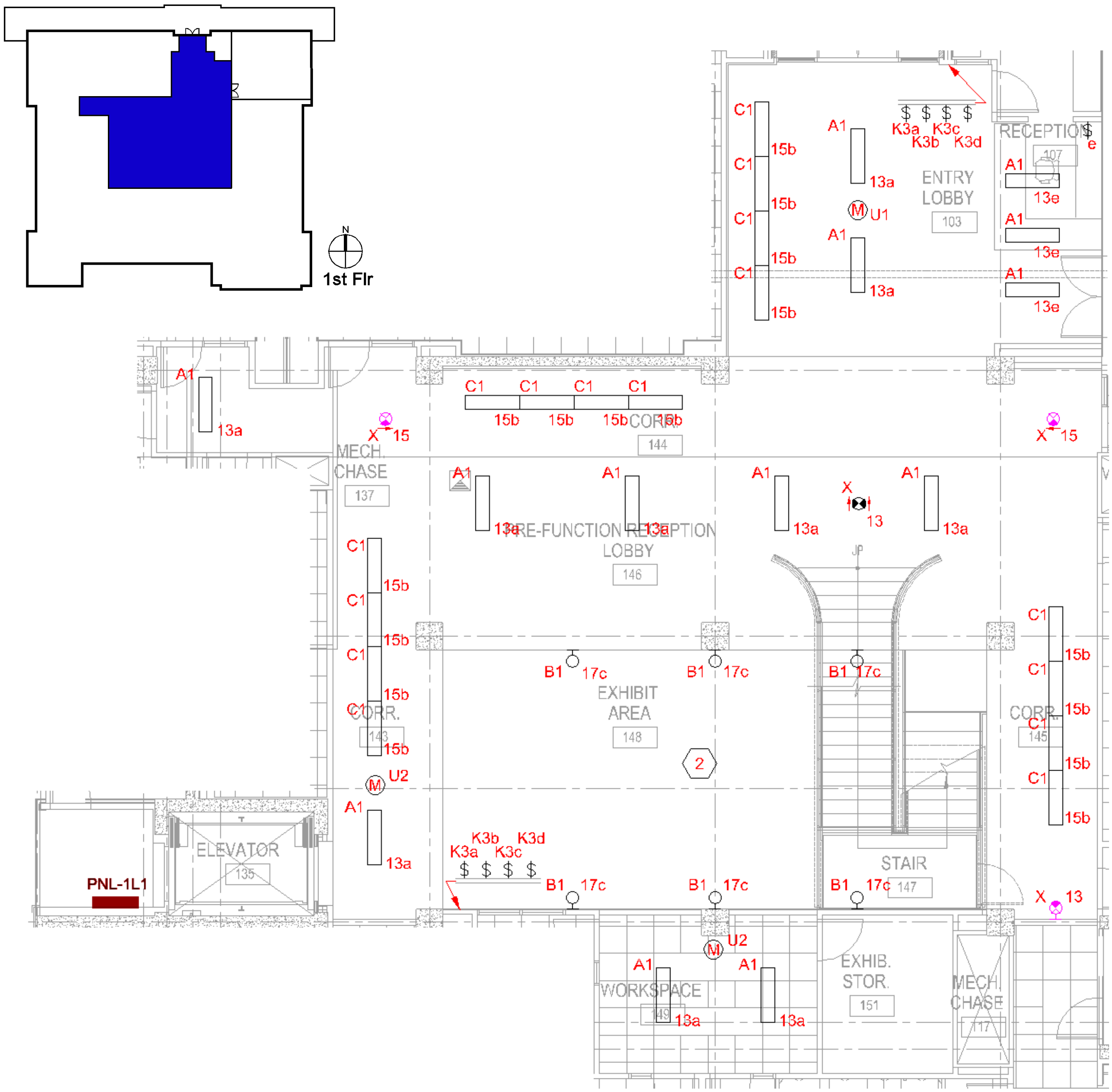


Figure 1.10 - All fixtures circuited to PNL-1L1

Power Density Calculations

The existing power density of .978 W/sf was well below the allowed 1.8W/sf, but after calculating the new power density I was able to reduce that even more while maintaining proper light levels. See figure 1.11 below for calculation details.

LOBBY POWER DENSITY				
TYPE	**BALLASTS**	**WATTS**	**TOT. WATTS**	**CHECK**
A1	13	65	845	
B1	6	55	330	
C1	8	65	520	
Total:			1695	
Area:			3070	
Allowed:			1.8	
Density:			**0.55**	**OK**

Figure 1.11

Controls

The control scheme that I decided to use for the lobby is a scheduled on/off using a smartwire switching system (see figure 1.5 for details) and a series of relays. Based on known building occupancy schedules, on Monday through Friday the lobby lights will be turned on at 8am and off at 10pm, unless overridden using the manual switching by the user. On Saturday and Sunday the lobby lights will be on from 8am to 6pm, unless overridden. The lobby will also have ultrasonic occupancy detectors which will shut off lights when the space is unoccupied in addition to 3-way switching that will control the fixtures. The area lights, wallwashers and floodlights can all be controlled separately.

Electric Light Illuminance Calculations

AGI was used to determine values for the floor, the receptionist desk, and vertical facial illuminance. Figure 1.12 below shows a calculation summary for the lobby area. For complete AGI32 output and files please see Appendix A-CD.

Floor Average:	18.43fc
Vertical Average:	13.37fc
Wall Average:	24.94fc
Desk Average:	32.5fc

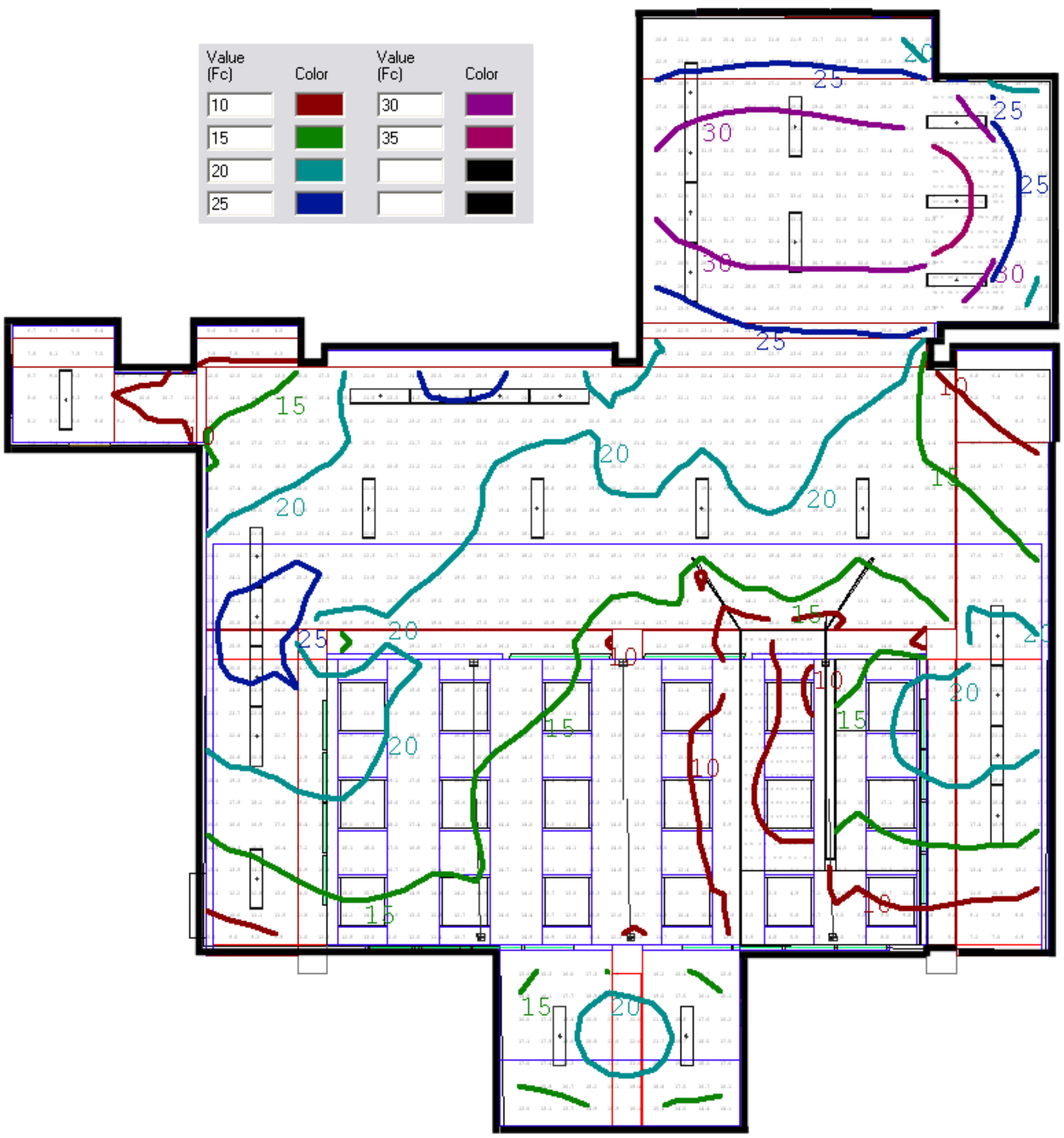


Figure 1.12

Skylight Redesign

Introduction

The atrium in TCES is a 3 story tall structure in the center of the building. At the top of the atrium are 18 skylights (3 rows of 6 skylights) that provide light to the inner circulation spaces on the upper floors and part of the lobby below. I will use TracePro to determine efficiency of the current skylight as well as to explore efficiencies of new designs. Radiance, and in particular the rtcontrib program, will then be used to determine illumination levels at the lobby floor (see "Daylight Analysis" on page 29).

Design Goals

Since the lobby floor is three stories below the skylights, the main goal of this analysis is to improve the efficiency of the skylight lightwells to achieve as much light on the floor as possible. The current solution is analyzed along with my own designs to find the most efficient design that will fit with the current structure and glazing systems.

Design Solution

The lightwells currently consist of completely vertical walls, and the skylights are tilted at a 30 degree angle toward the south. The new designs to be tested involve splayed wells and a different degree of tilt to attempt to get the efficiency up as high as possible. Once the highest efficiency is established, Radiance's rtcontrib program is used to find daylight levels for January 21st, March 21st, and May 21st since those dates can closely approximate the average for the months around the winter solstice, the equinox, and the summer solstice, respectively.

Analysis

After examining the structural system supporting the skylight well (see Appendix A-CD for detailed notes on the structural system) I determined that the skylight could be splayed by an additional 6" on each side at the bottom while maintaining the same size at the top. This width allowed me to keep the same structural supports in place while gaining extra light. Simply splaying the well was the first alternate solution I investigated. The second solution was to splay the well and tilt the skylight to 39 degrees. The optimal angle for light gathering is equal to the latitude at the location of installation, which is how I arrived at 39 degrees. Below are the TracePro irradiance maps of the exit point in the lightwell (figures 1.13 – 1.18) for the conditions and times I chose (December 21st and June 21st since those are the points where the sun is at its most extreme angles). The images shown are the rays leaving the lightwell. For a more detailed view of the rays incident on the glass and larger views of the rays exiting the wells, please see Appendix A-CD.

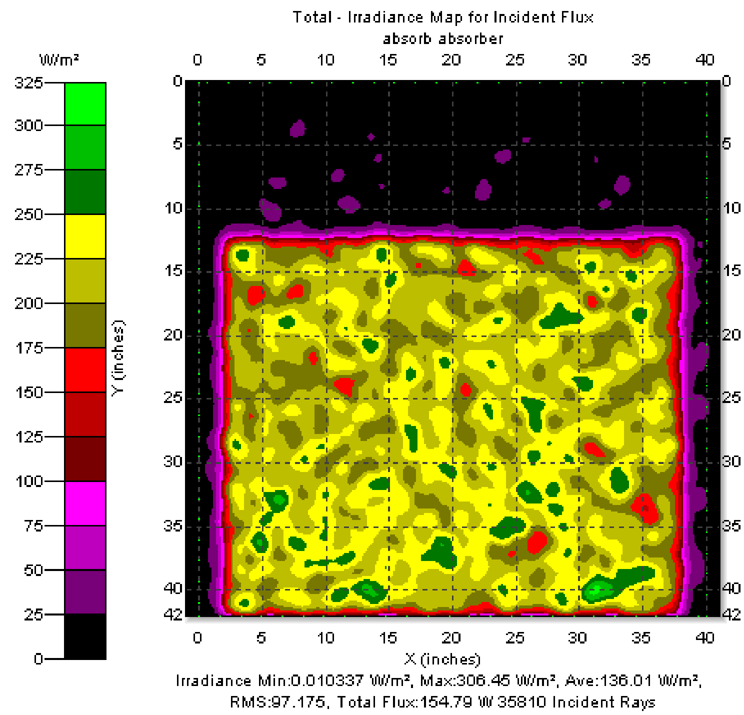


Figure 1.13 - Summer, Original Design

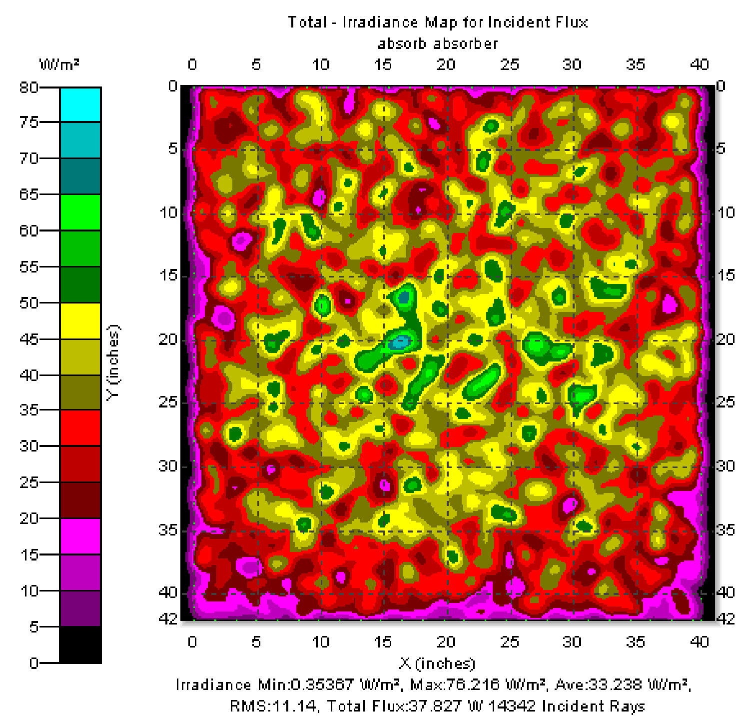


Figure 1.14 - Winter, Original Design

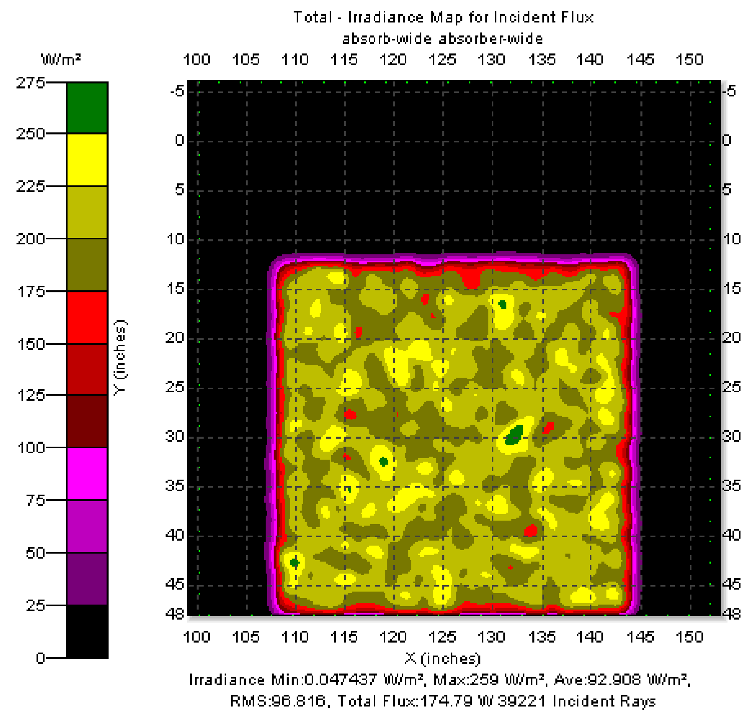


Figure 1.15 - Summer, Splayed

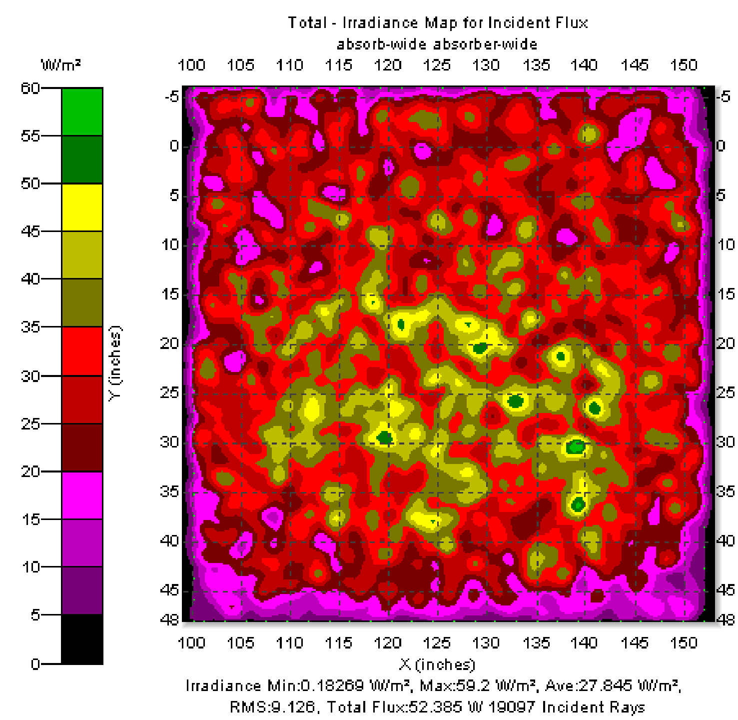


Figure 1.16 - Winter, Splayed

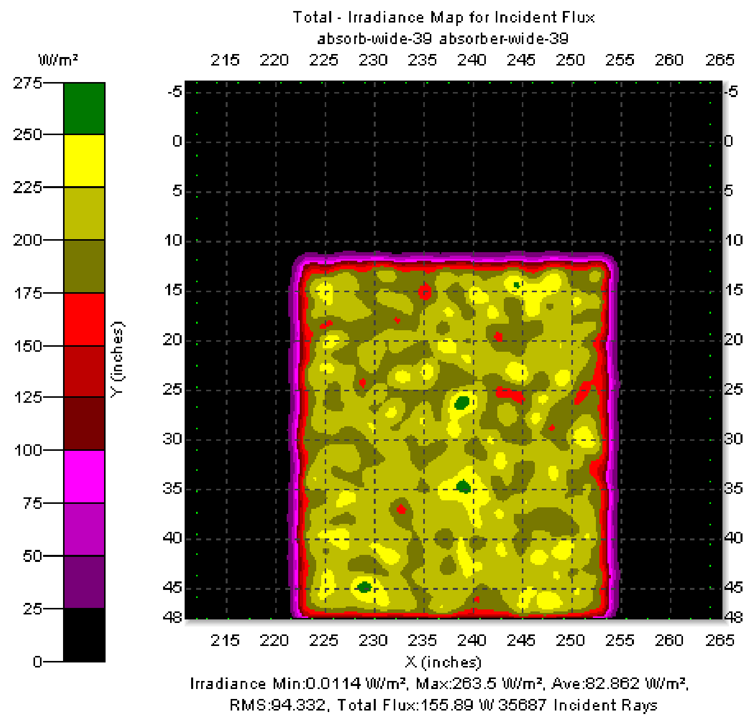


Figure 1.17 - Summer, Splayed & Tilted

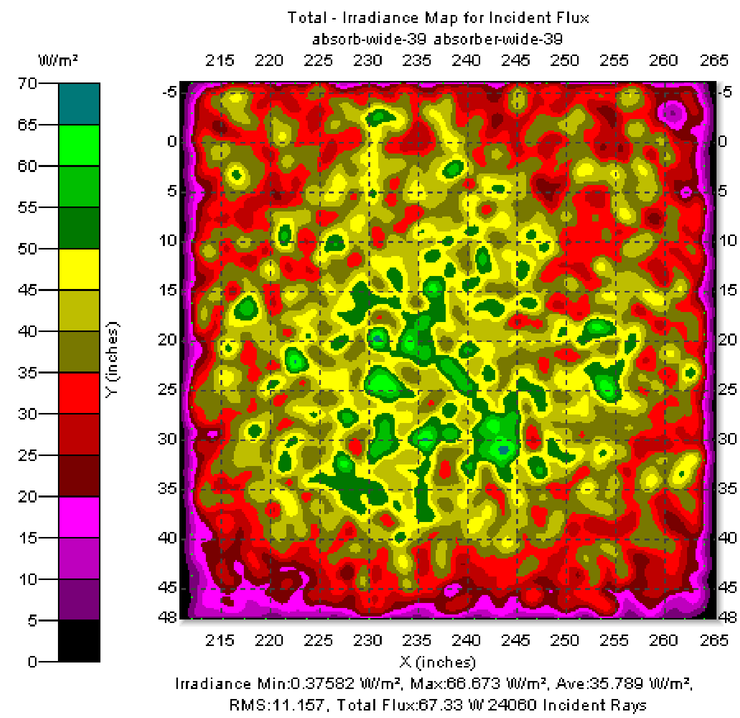


Figure 1.18 - Winter, Splayed & Tilted

Results from the TracePro runs are summarized in table 1.19. The number of rays that were incident on the glass was compared with the number of rays exiting the lightwell. The ratio of rays exiting the well over the rays incident on the glass covering the well is the efficiency. Both of the splayed options performed similarly, and we're better than the original design by quite a bit. The additional tilt placed on the skylight actually decreased the performance, especially in the summer time when the sun is the highest since the more extreme tilt may cause the higher sun angle to effectively be blocked.

Lightwell Efficiency Calculations			
Summer		***Winter***	
Original Design		**Original Design**	
Glass	= 51,540 rays	Glass	= 68,266 rays
Absorber	= 35,810 rays	Absorber	= 14,342 rays
efficiency	= 70.5%	efficiency	= 14.7%
Splayed		**Splayed**	
Glass	= 44,292 rays	Glass	= 65,648 rays
Absorber	= 39,221 rays	Absorber	= 19,097 rays
efficiency	= 84.2%	efficiency	= 24.2%
Splayed & 39 Deg		**Splayed & 39 Deg**	
Glass	= 46,472 rays	Glass	= 77,376 rays
Absorber	= 35,687 rays	Absorber	= 24,060 rays
efficiency	= 76.4%	Efficiency	= 23.9%

Table 1.19

Daylight Analysis

Introduction

I used Radiance's rtcontrib program to determine daylight levels from 8am to 6pm on January 21st, March 21st and May 21st. The program calculates the amount of light that different skypatches contribute to a set of points that you wish to find the illuminance at. These contributions can then be multiplied by the luminances of the skypatches (determined by the rtrace program) to determine the illuminances at each point. I then analyzed the data to determine if there is a significant amount of light available within the space. For reasons which will become clear during the analysis, I then ran several runs of AGI32 to study the daylight in the space as well.

Design Goals

The main goal of the analysis is to determine if the floodlights placed in the atrium are necessary throughout the day or if they can just be switched on via a timer. Daylight levels comparable to those achieved with just the electric lighting are desirable in order for this to be plausible. Because the fixtures used are metal halide, dimming is not a cost-effective option. Switching the fixtures on and off may be possible, but with the warm-up time and the re-strike time of metal halide the option I will shoot for is to be able to have the lights on during the day and turned off via a timer at night since it will be unoccupied.

Design Solution

Because of the difficulties involved with dimming or switching metal halide, the most likely solution is to keep the floodlights on during the day, however the daylighting study may show that this is unnecessary.

Scripts Used

See Appendix A-CD for the actual scripts listed below.

sensors.cgi – program to output a list of sensor points and an array of values to input into excel to view the final illuminances in a more usable form
gensky.sh – script to create sky definition files for clear, cloudy, and intermediate sky conditions based on criteria entered such as latitude and longitude
skylum.sh – script to calculate the skypatch luminances based on the sky definitions created by gensky.sh
rtcontrib.cgi - program to read in the contributions and multiply them by the appropriate luminance to determine the illuminance at each sensor input point

Analysis

All files mentioned herein are available for viewing in Appendix A-CD. First, the radiance scene of the lobby was set up and sensor points (sensors.inp) were established to determine the illuminance at the (x,y,z) coordinates listed. Sky definitions for each time, day, and condition desired were created using the gensky.sh script. After that, rays were traced to each of the 145 skypatches to help determine the luminance of each patch using the skylum.sh script.

```
rtrace -h -ov -ab 3 -ad 1000 -ar 3000 -as 20 -aa 0.1  sky.oct < skypatch.inp | \
rcalc -e '$1=179*($1*0.265+$2*0.67+$3*0.0648)' > sky.lum
```

I then used the rtcontrib program to calculate the contributions from each skypatch.

```
rtcontrib -I+ -b tbin -ab 6 -ad 26000 -ar 30000 -aa .1 -as 100 -lw 0.00001  \
-o rt.out -m sky_glow -f tregenza.cal overall.oct < sensors.inp
```

The output was then run through the rtcontrib.cgi program to get the illuminance values, which were then put into excel to analyze. An example graph can be seen in figure 1.20.

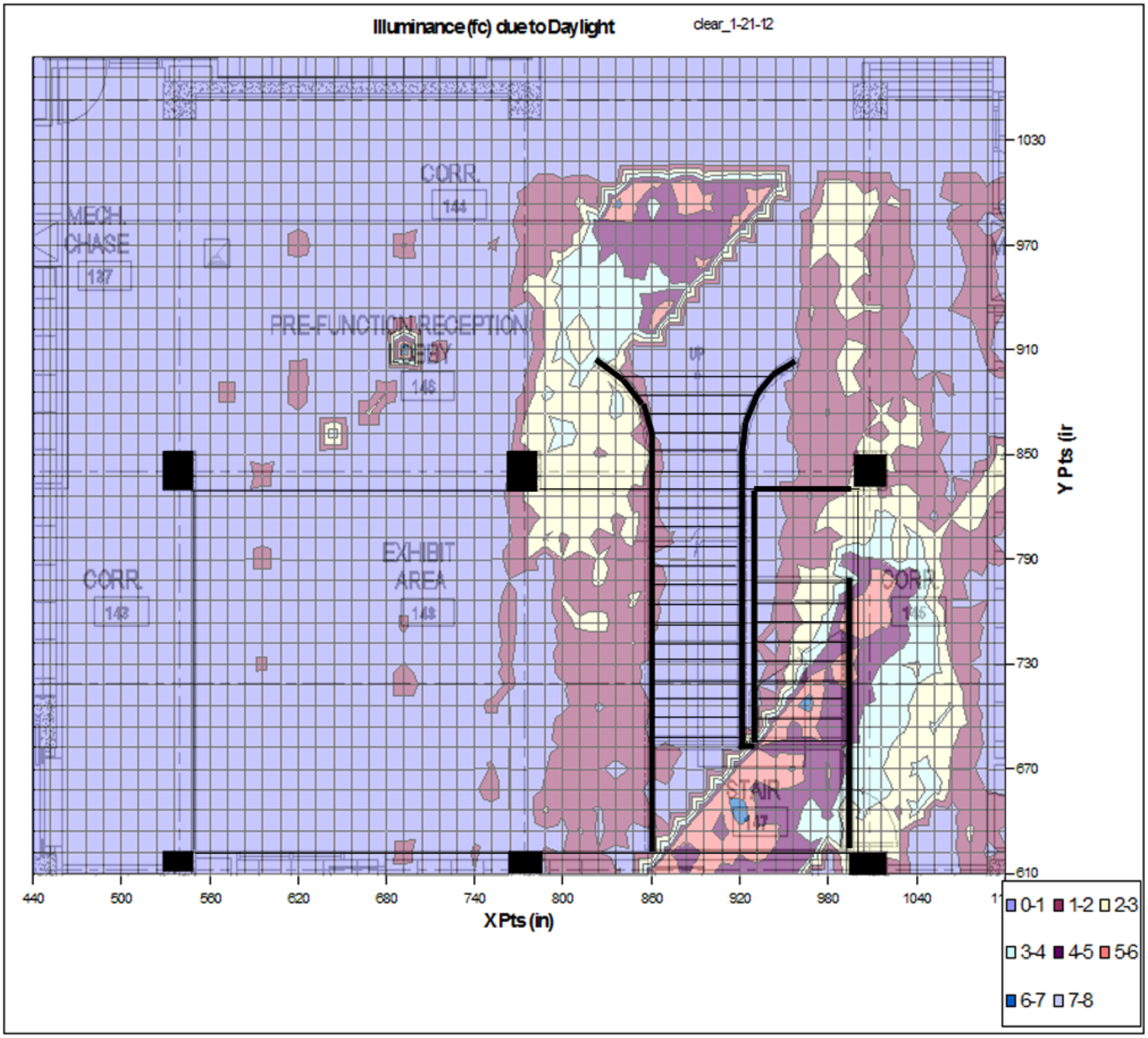


Figure 1.20 – Radiance: Jan 21st, 12pm, Clear Sky

After analyzing the results, I noticed that they did not seem to make much sense. Why is there so much light underneath the stairs on the right? Why is a good amount of light reaching far back into the space, but not is not present in the lightwell itself? After reviewing my scripts and comparing them with several other people's algorithm's used, I determined that the strange results were not due to a fault in the algorithm. Investigations into the rtcontrib output files, however, revealed that many of the skypatches were not contributing anything to quite a few of the illuminance points (the output can be found in rt.out in Appendix A-CD). Perhaps this was due to settings that were too low in the rtcontrib program.

In an effort to determine whether these results were indeed valid or not, I ran a series of clear sky conditions in AGI32 to compare the results. See figure 1.21 below.

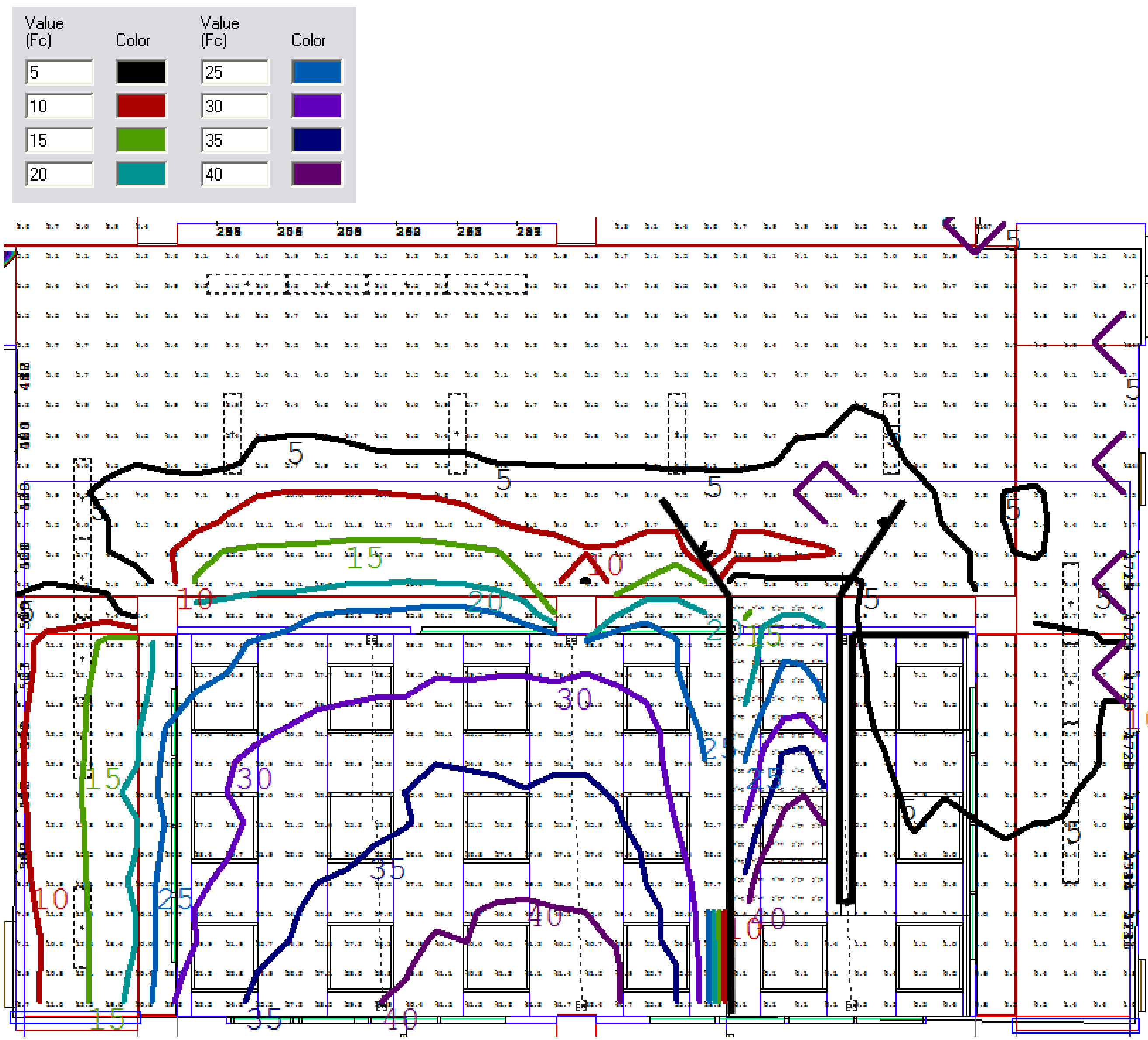


Figure 1.21 - AGI32: Jan 21st, 12pm, Clear Sky

The AGI32 calculations produced much more reasonable results, showing a good amount of light in the lightwell and less as you move into the room. For complete Radiance and AGI32 results please see Appendix A-CD.

Renderings

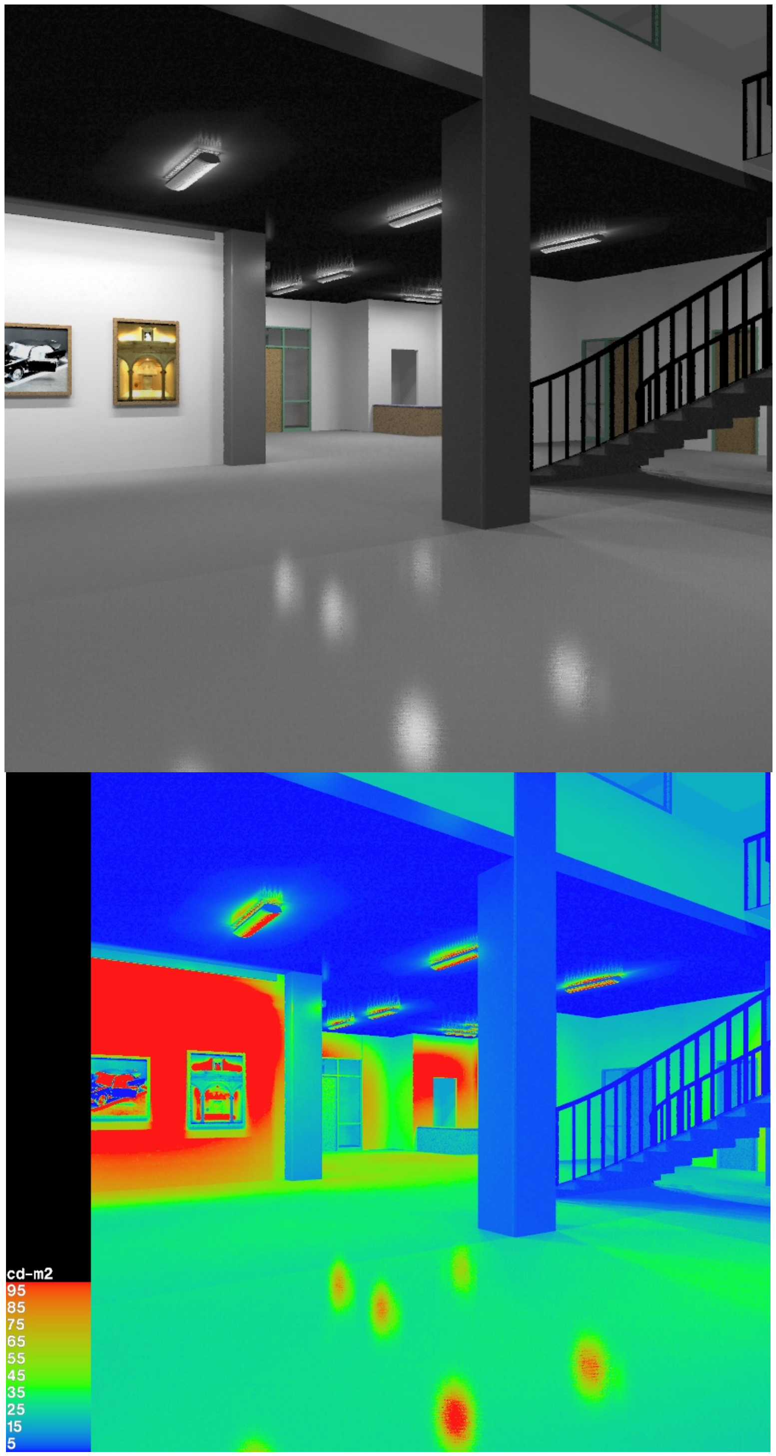


Figure 1.22

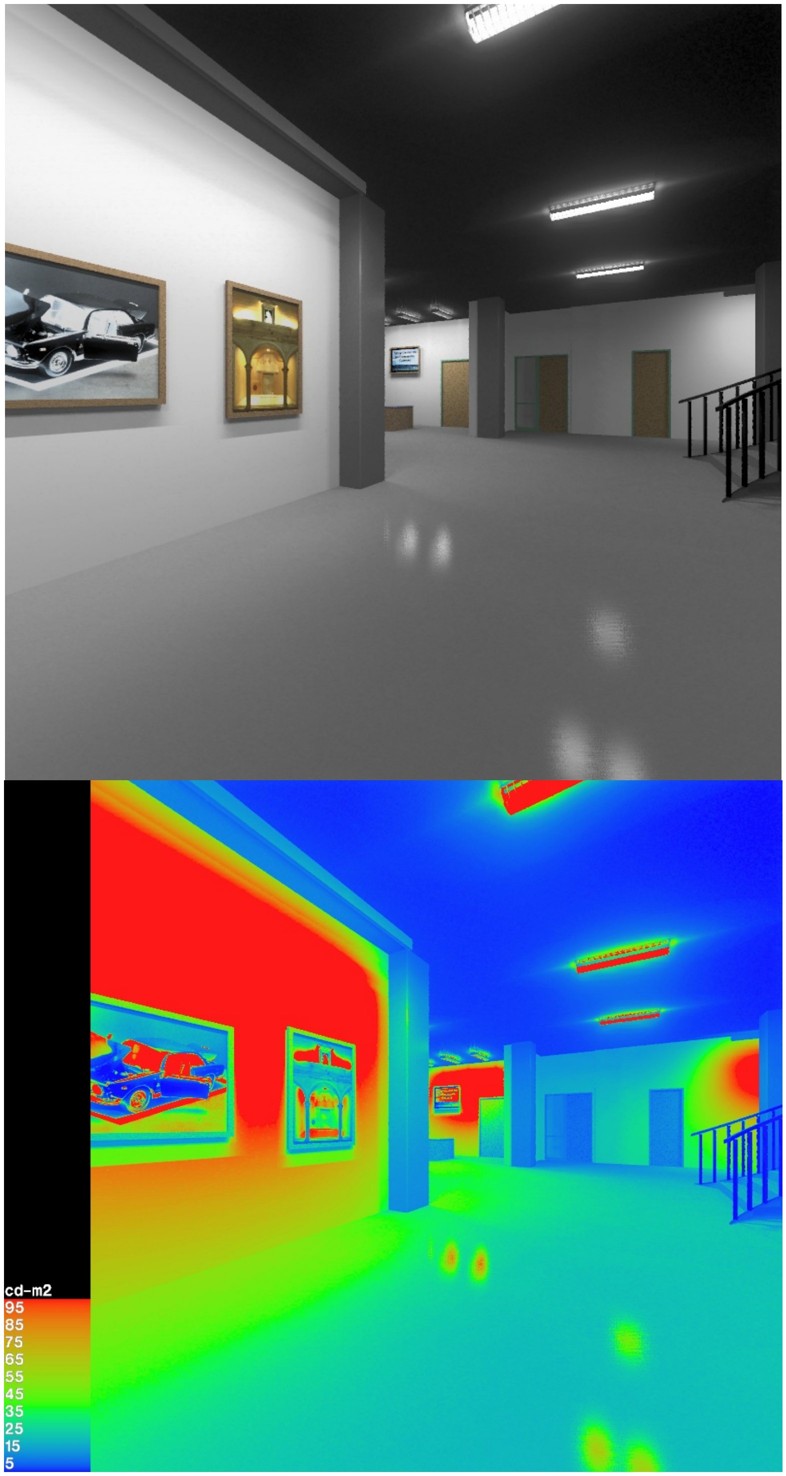


Figure 1.23

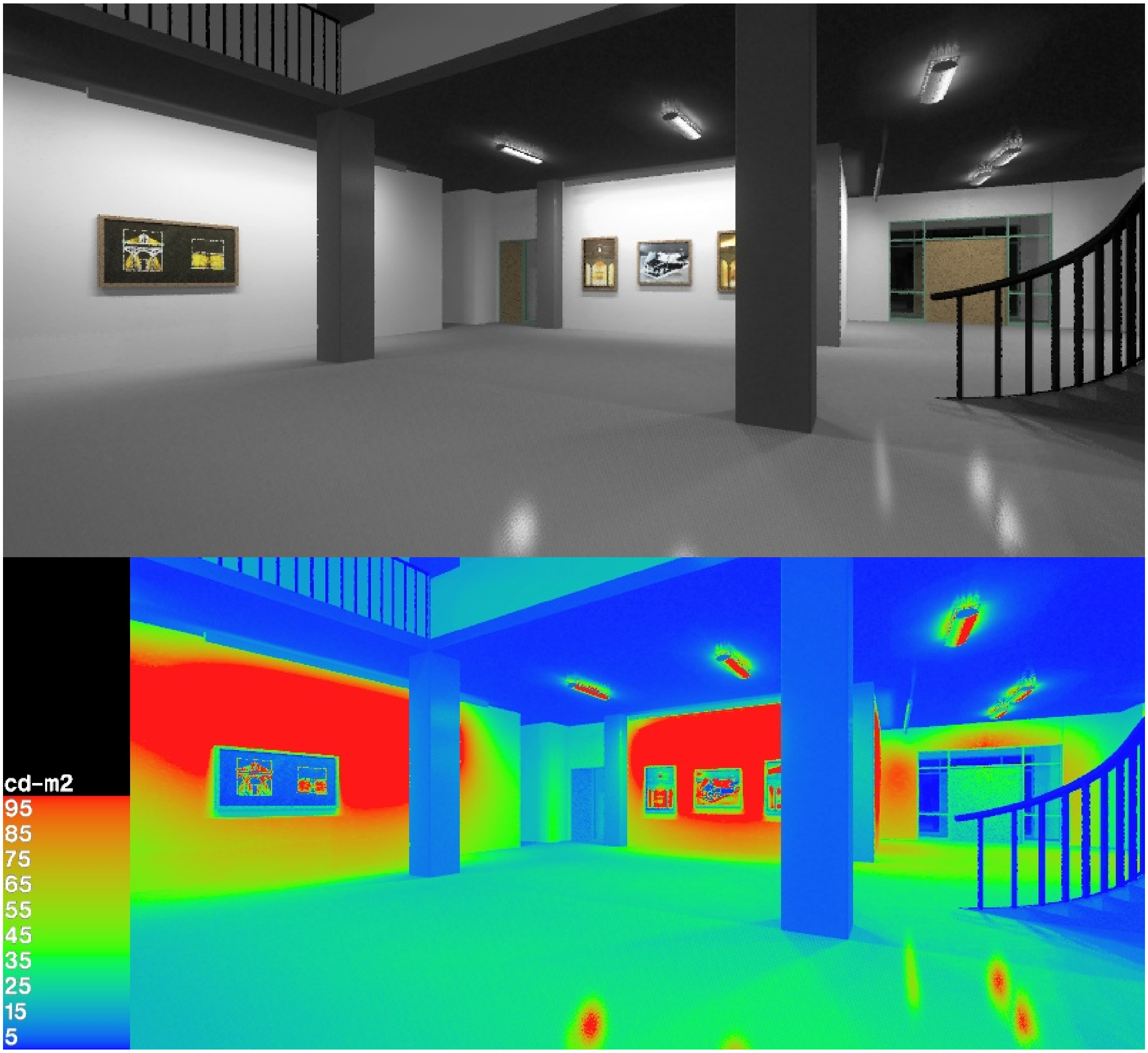


Figure 1.24

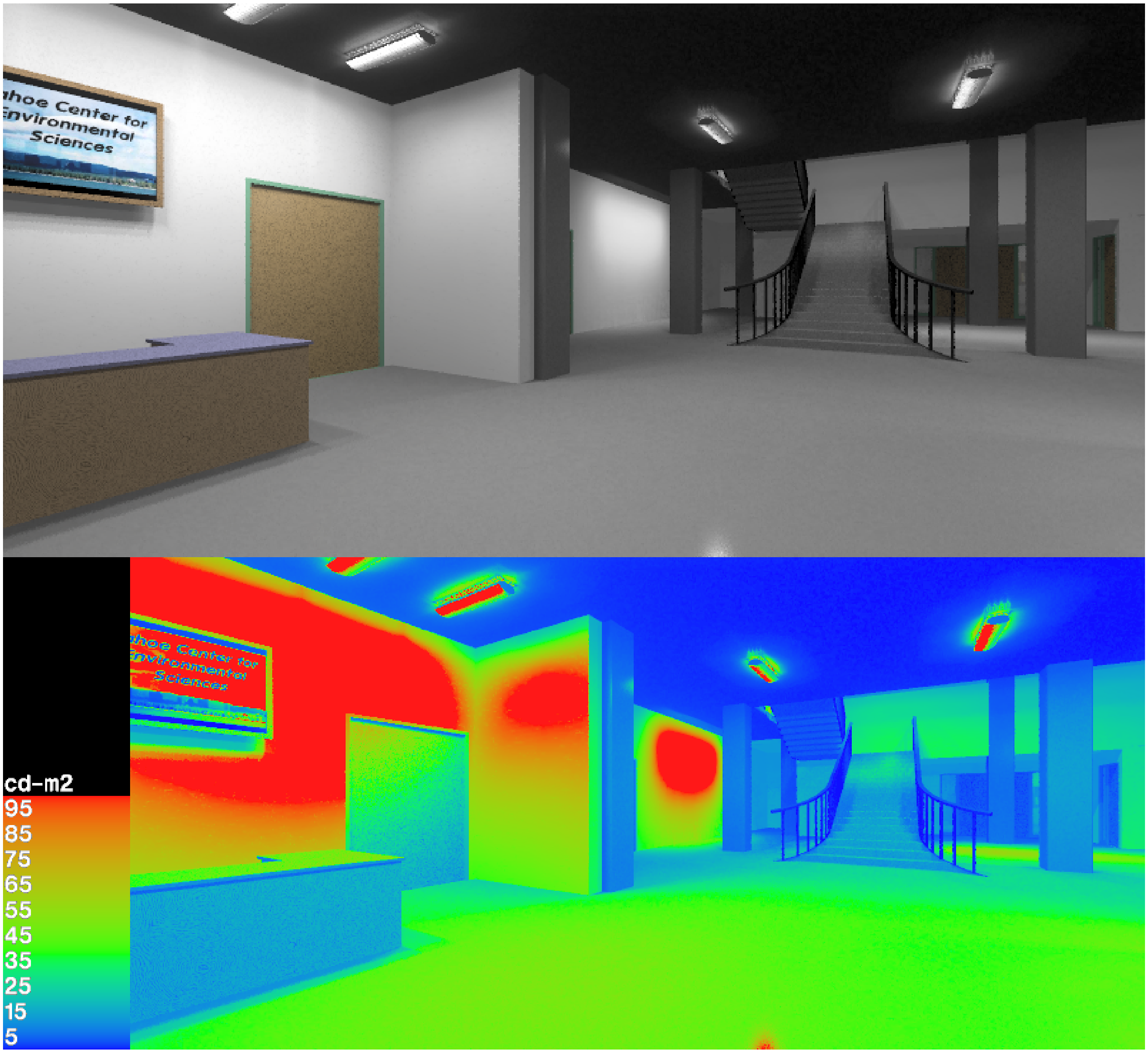


Figure 1.25

Digital copies of each rendering can be found in Appendix A-CD.

Conclusions

The lobby was designed with integration and sustainability in mind. The fixtures chosen were more efficient than those previously chosen, leading to a decreased power density that was well below ASHRAE 90.1 while at the same time maintaining light levels. A clear hierarchy of spaces and features can be seen in the renderings as your eye is drawn to the brighter areas first. Also seen in the renderings are how the fixtures compliment the architecture well. They neither draw unnecessary attention to themselves, nor do they appear out of place. The controls system offers a simple way to control the lights in the space and contains several safe-guards to ensure that the lights are not left on when the space is unoccupied, resulting in a loss of energy. The daylighting analysis led to mixed results when using Radiance and AGI. Based on the Radiance output, the best control scheme for the floodlights would be to have them on during the day, with an optional switch control to turn them off. The AGI calculations, however, show much more light in the space with a much more reasonable distribution of light. I would still recommend having the lights on all day due to the uncertainty of available light and the long warm-up and re-strike times for metal halide.

Case Study Classroom Design

Design Concept

Since the case study classroom will be used for a variety of things, including professional lectures and regular classes, an easy to use but flexible system is desired. To accomplish this, I will use simple controls to interface with the lights. The main overhead lights in the room will be dimmable for adjusting light levels for various presentations and classes. The front of the room will be used for everything from writing on the blackboard to displaying printed material to projecting digital presentations. As such, I will include wallwashers which can be controlled separately from the main lights overhead to provide light for those types of presentations that may require it.

Design Criteria

Reading Tasks:

Since a majority of the time in this room will be devoted to reading one form of material or another, priority should be placed on vertical and horizontal light levels that are appropriate for reading various types of media. Since the types of media can vary between pamphlets, papers, slides (PowerPoint and the like) and posters, the lighting system must be flexible enough to allow for all these types of materials to be easily read.

Fixture Appearance:

Since the main use of the room is to teach people and to help the flow of information from speaker to listener, the fixtures must not be distracting to the occupants. Both the speaker and the listeners must not be distracted by obnoxious looking fixtures or fixtures that may interfere with a listeners line of sight. The fixture must also complement the architecture well.

Accent Lighting:

Some forms of media such as posters may need to be accented, while other forms such as computerized slides, will not benefit from being accented. As such, a versatile and controllable accenting system should be implemented that allows the speaker to easily highlight whatever they wish while at the same time not washing out slides they may be using. The controls should be simple enough for visiting presenters who are unfamiliar with the system to understand.

Illuminance Criteria:

Horizontal:

Reading - Desk: IES 30fc

Demonstration: IES 100fc

Vertical:

Front Wall: IES 30fc

Importance:

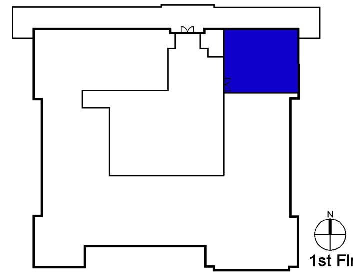
Vertical and horizontal illuminances must be maintained in order to accomplish the tasks that the space requires. While this space may be used for demonstrations that require very fine work, that will not be it's primary use, so the 100fc that the IES recommends may be a bit high for something that isn't required very often.

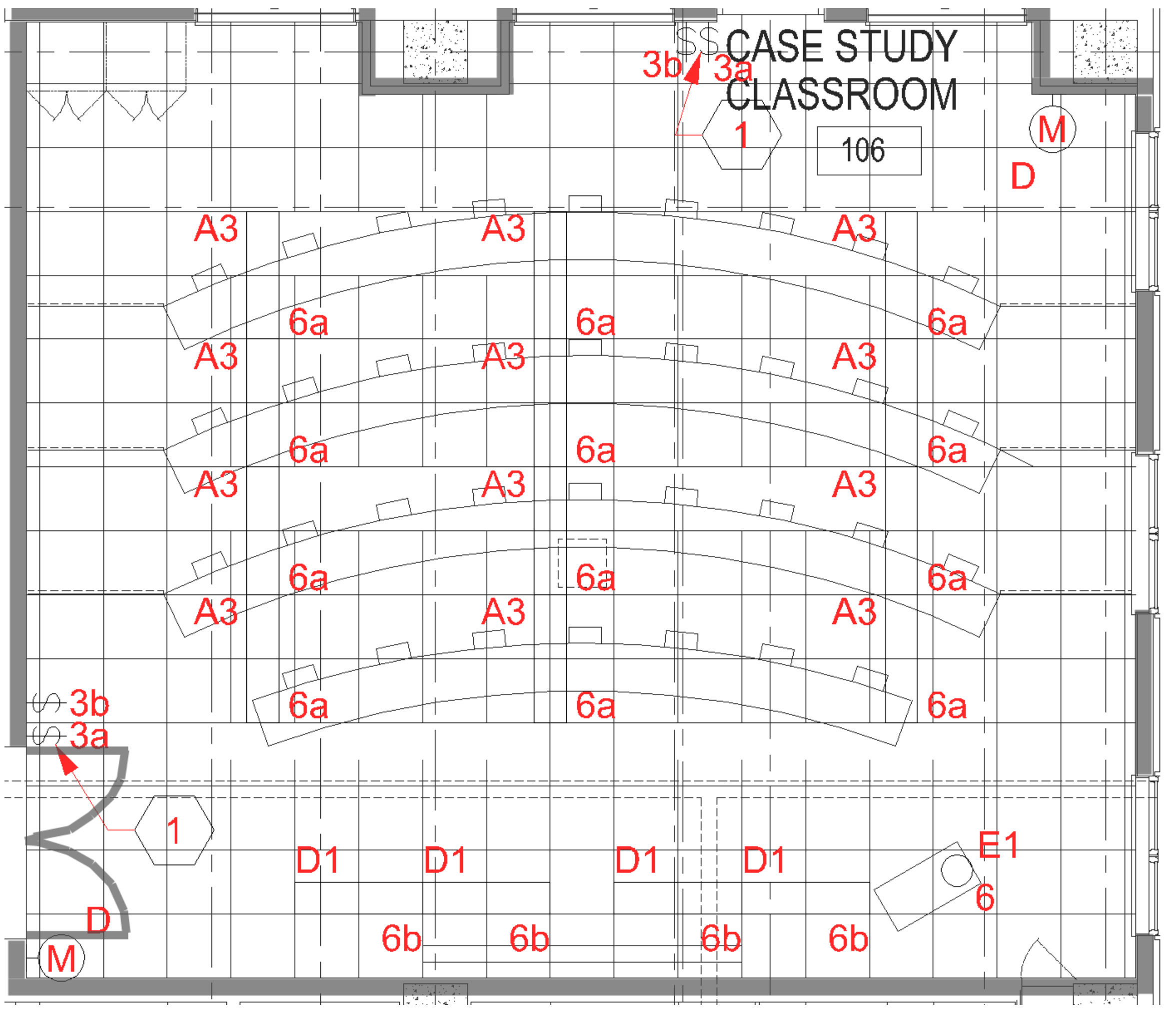
Power Density:

ASHRAE 90.1 allowance (school/university lecture hall): 1.6 W/sf

An additional 1W/sf can be added for decorative wall sconces and highlighting artwork, but will not be used.

Reflected Ceiling Plan





1 – *Provide Lutron sliding dimmer switch model NOVA 3PS*

Figure 1.26 – All fixtures circuited to PNL-1L1 (see lobby plan, figure 1.10)

Power Density Calculations

The existing power density of 1.3 W/sf was below the allowed 1.6 W/sf, but after designing the new system the power density is even lower, leading to even more energy savings. See figure 1.27 below for details of calculations performed.

CASE STUDY POWER DENSITY				
TYPE	**BALLASTS**	**WATTS**	**TOT. WATTS**	**CHECK**
A3	12	65	780	
D1	2	65	130	
E1	1	20	20	
Total:			930	
Area:			1015	
Allowed:			1.6	
Density:			**0.92**	**OK**

Figure 1.27

Controls

Dimming was a desired feature of the main lights in the room for when presentations are given, and since the system should be usable by anyone walking into the room, I decided to use a simple sliding dimmer switch (Lutron model Nova 3PS) as the main means of control for the semi-direct light fixtures. The wallwashers are on standard 2-pole throw switches, and the the task lamp is controlled by a switch on the fixture itself. The room also contains dual-tech motion sensors, meaning that they use ultrasonic and infrared to determine if people are in the room, leading to less false-offs.

Electric Light Illuminance Calculations

AGI was used to determine values for the desk, the wall, and podium illuminance. Figure 1.28 below shows a calculation summary for the lobby area. For complete AGI32 output and files please see Appendix A-CD.

Desk Average: 77.75fc
Wall Average: 59.68fc
Podium Average: 59.08fc

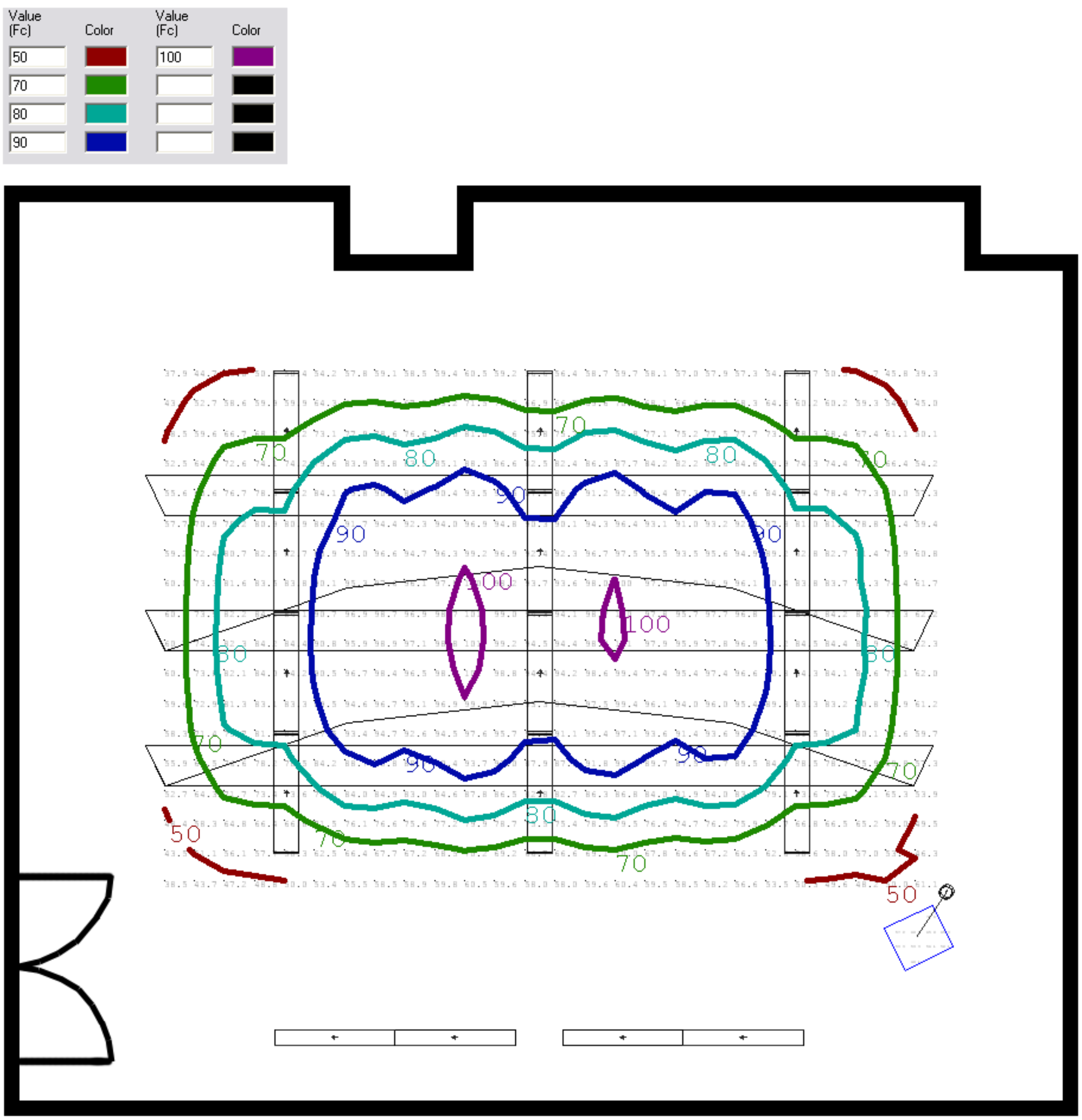


Figure 1.28

Conclusions

The flexibility and ease of use of the system achieved a nice balance, using very simple controls to gain a good amount of flexibility. The wallwashers provide a good amount of light for printed material or for writing on the blackboard, but can be switched separately from the main lights during a presentation. The relatively high amount of light on the desktops normally can be used for finer tasks but can be dimmed while taking notes or during a presentation. The ability of the speaker to control their own podium light is advantageous and easy for the speaker to use and adjust to their liking.

Chemistry Laboratory Design

Design Concept

Because of the dangerous nature of some lab experiments, I will design the space with safety in mind. The fixtures chosen will lead to a minimal amount of glare for the students. The room will not only be used for experiments, however, and will function as a regular classroom as well. As such, I will allow for multiple light levels so that a high light level can be had during fine task work such as experiments, while a lower ambient light level, suitable for taking notes, will be available as well. Simple bi-level switching will provide this control. The blackboard at the front of the class will be used for teaching at times, so wallwashers will be provided to illuminate the board.

Design Criteria

Reflected Glare:

The high level of risk involved in some chemistry experiments necessitates reducing the amount of glare and the number of glare sources in the space. Since there will be large amounts of glass in the space in the form of windows, beakers and jars, elimination of glare sources is essential.

Direct Glare:

As with reflected glare, direct glare from the fixtures cannot be tolerated as it may pose a safety hazard to those in the lab as they work on experiments.

Fixture Appearance:

Since the main use of the room is to teach people and to help the flow of information from speaker to listener, the fixtures must not be distracting to the occupants. Both the speaker and the listeners must not be distracted by obnoxious looking fixtures or fixtures that may interfere with a listeners line of sight. The fixture must also complement the architecture well.

Illuminance Criteria:

Horizontal:
- Workstation: 102fc (IES 50fc)

Vertical:
- Workstation: 47fc (IES 30c)
- South Wall: 46fc (IES 30fc)

Importance:

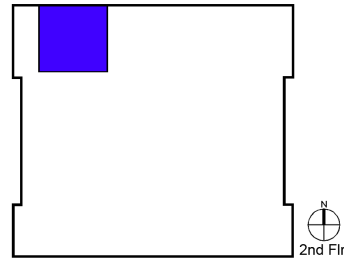
Vertical and horizontal illuminances must be maintained in order to accomplish the tasks that the space requires. Right now, the space is overlit per IES recommendations, and perhaps some over lighting is called for, but in order to bring the power density down the lighting levels may need to be dropped. The importance of the tasks, however may dictate that the power allowance not drop much below that of ASHRAE 90.1. By reducing the horizontal illuminance for ambient lighting the power densities may be reduced, and by adding task lighting for fine tasks, the 100 footcandles currently designed may be reached without greatly increasing the power density.

Power Density:

ASHRAE 90.1 allowance (school/university classroom):1.6 W/sf

An additional 1W/sf can be added for decorative wall sconces and highlighting artwork, but will not be used.

Reflected Ceiling Plan



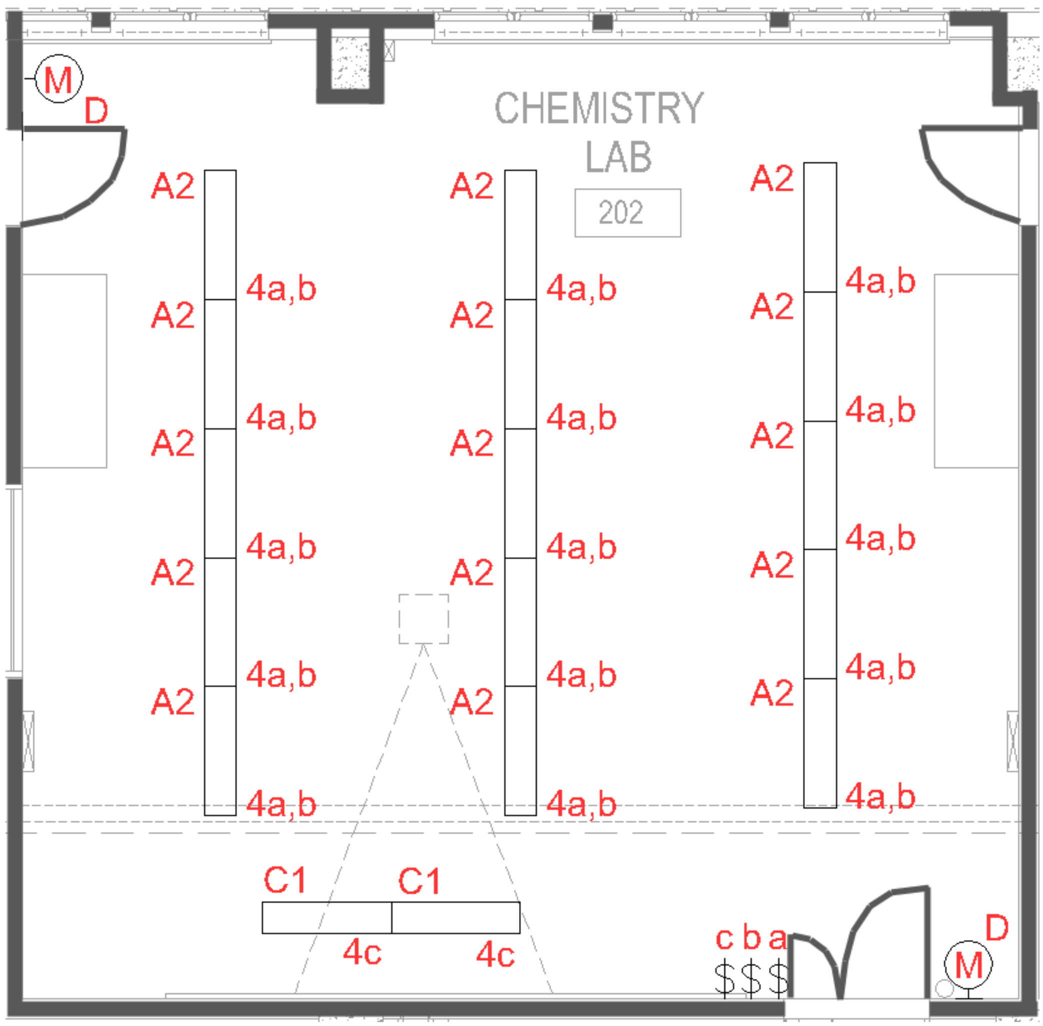


Figure 1.29

Power Density

The current power density in the chemistry lab is 1.7 W/sf, which exceeds the 1.6 W/sf allowed by ASHRAE 90.1. In the new design, the power density is significantly smaller, as is seen in figure 1.30 below.

CHEMISTRY LAB POWER DENSITY				
TYPE	**BALLASTS**	**WATTS**	**TOT. WATTS**	**CHECK**
A2	15	65	975	
C1	1	65	65	
Total:			1040	
Area:			907	
Allowed:			1.6	
Density:			**1.15**	**OK**

Figure 1.30

Controls

Simple bi-level switching will control the main lights in the room, with the wallwashers having their own dedicated switch for when they are needed. In addition, dual-tech occupancy sensors monitor the room for people and switch lights off when no one is there.

Electric Light Illuminance Calculations

AGI was used to determine values for the desk, facial and the wall illuminances. Figure 1.31 below shows a calculation summary for the lobby area. For complete AGI32 output and files please see Appendix A-CD.

Desk Average:	71.38fc
Wall Average:	72.06fc
Vertical Average:	55.69fc

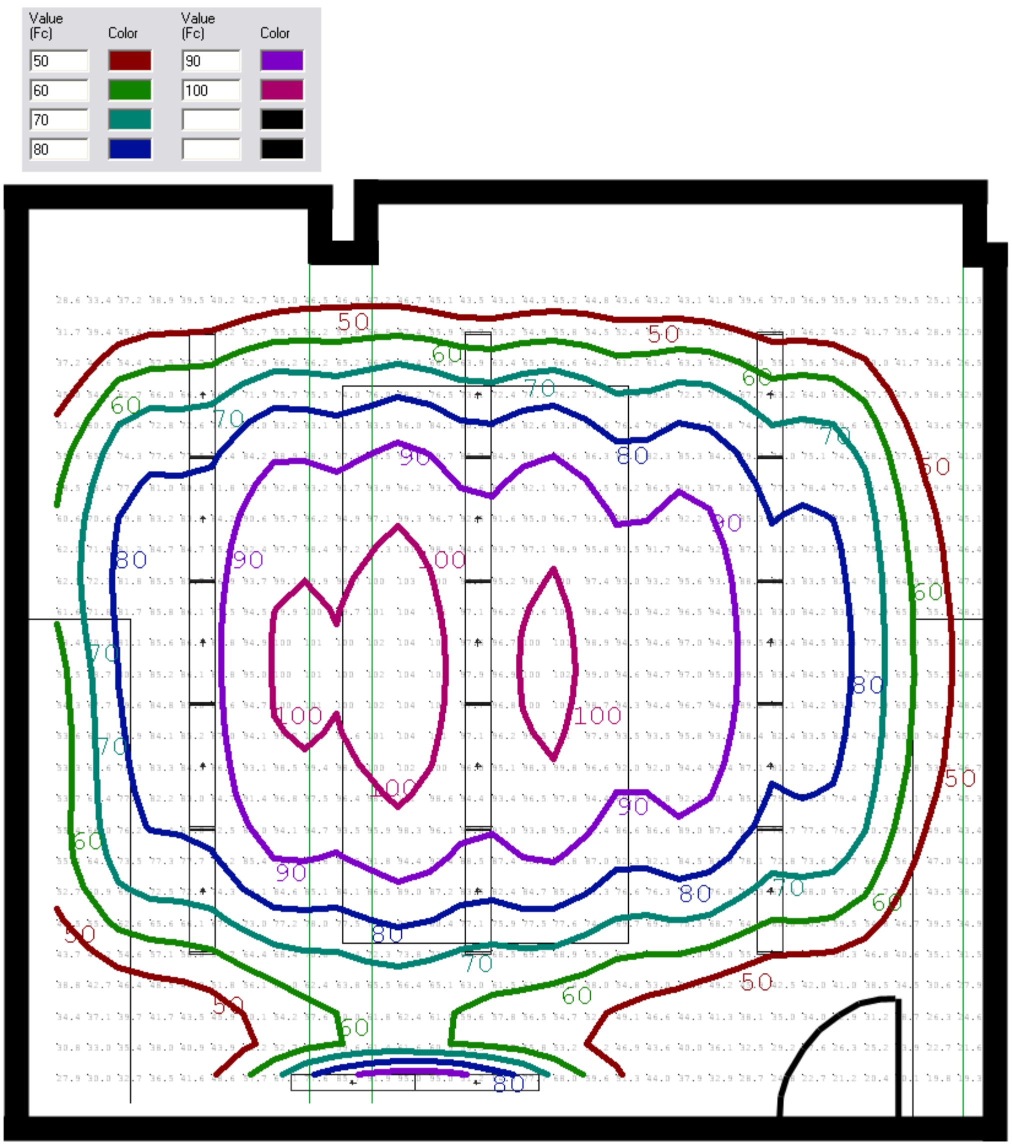


Figure 1.31

Renderings

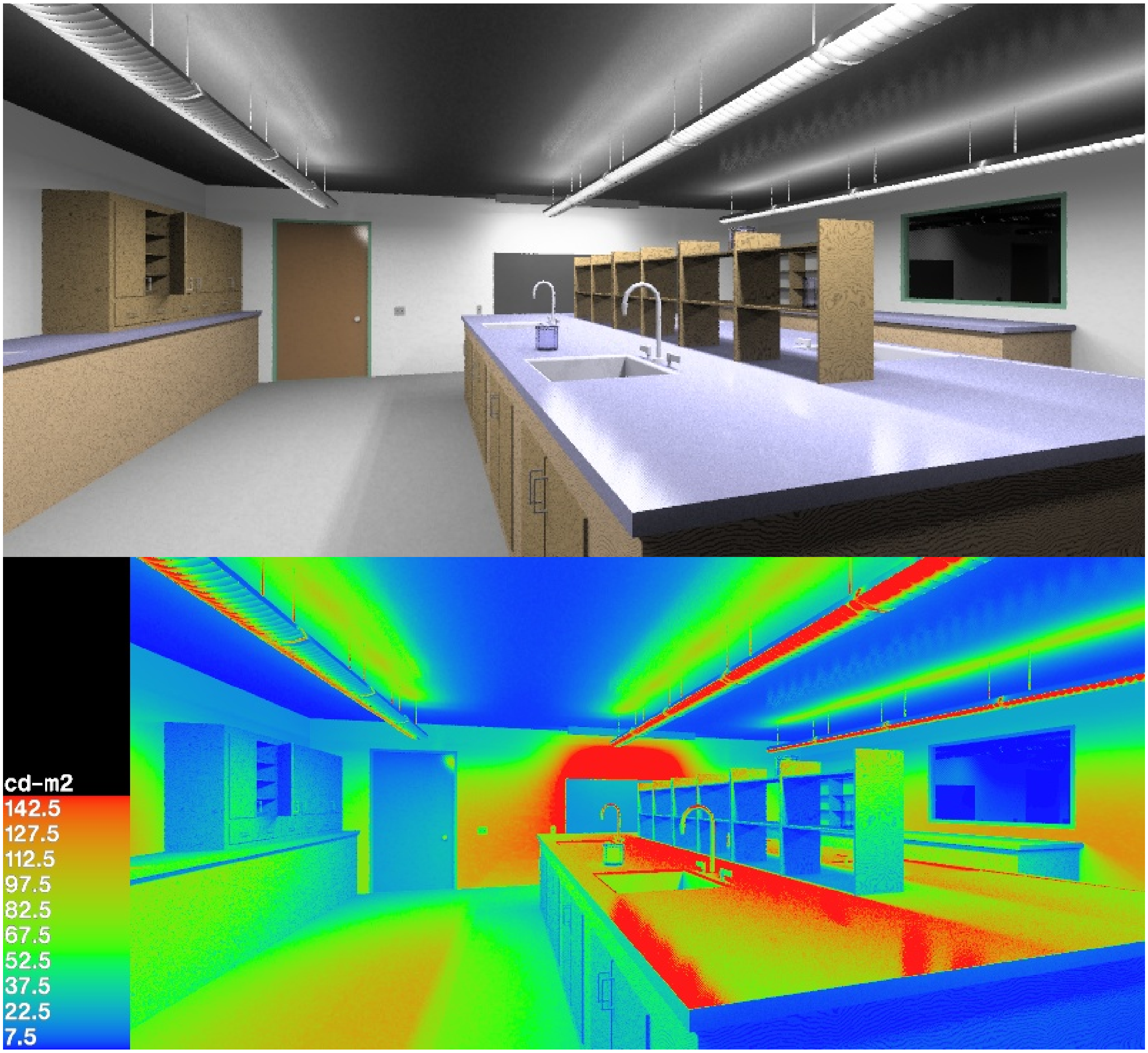


Figure1.32

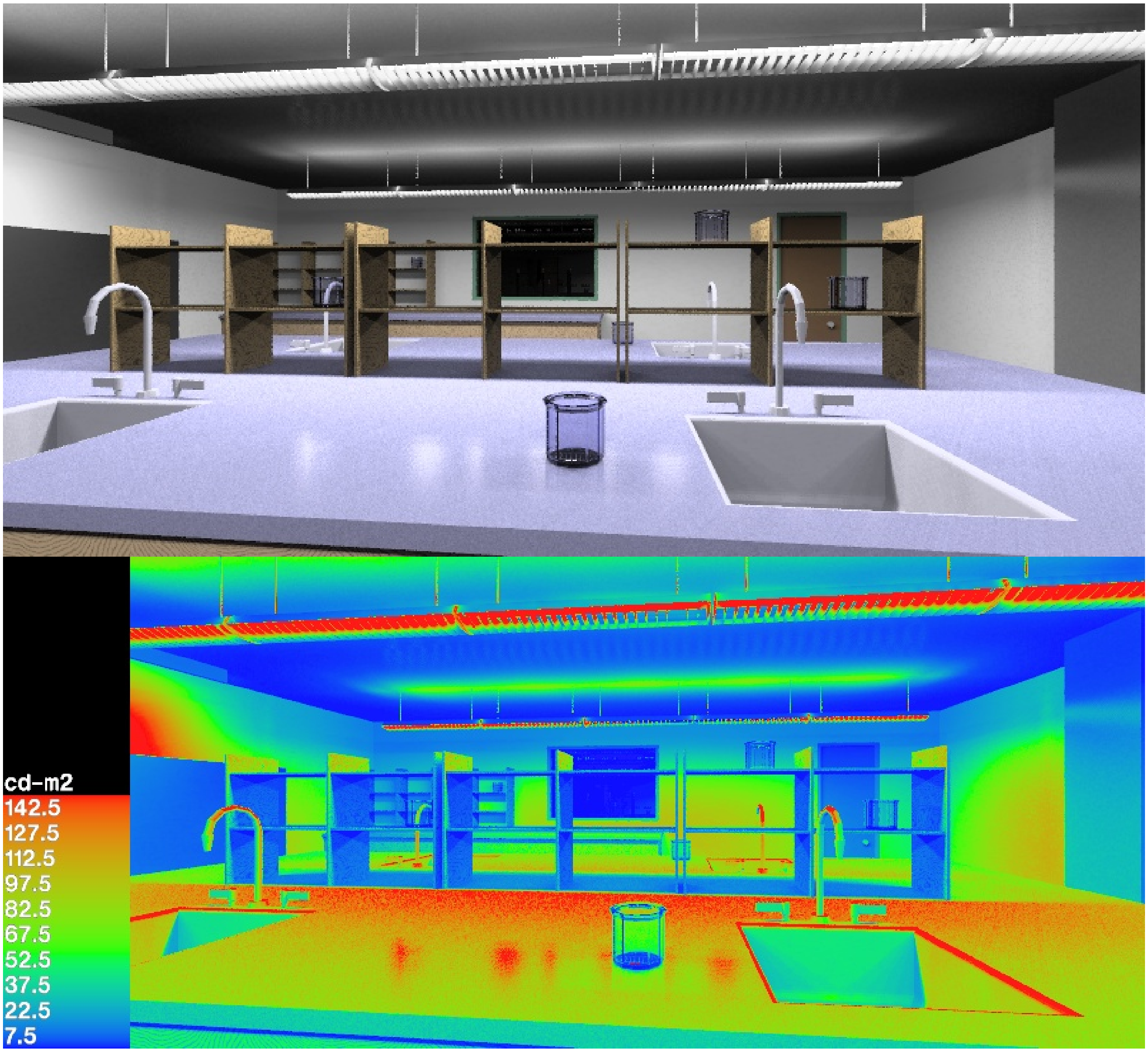


Figure 1.33

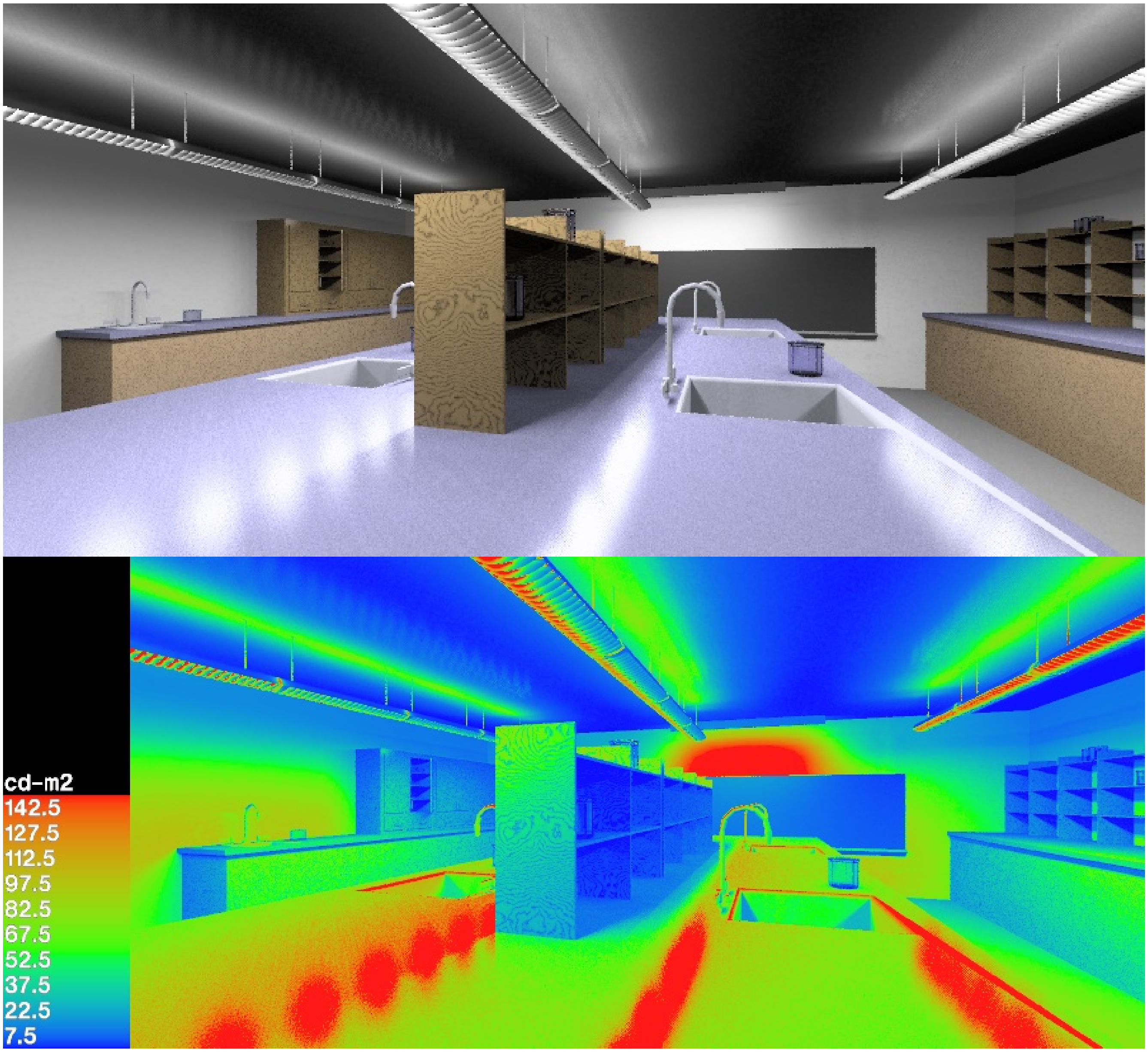


Figure 1.34

Conclusions

The chemistry lab space is a highly specialized space that required a lot of care. Too much glare in the room could be hazardous due to the caustic chemicals sometimes used. For this reason, fixtures that would not produce much glare were chosen. Also of importance is the ability to control the light level for when fine task work is necessary and for when reading and note taking are the tasks, so the bi-level switching effectively solves that problem. The multiple uses for the board at the front of the room led to the use of wallwashers in that area to light the blackboard, which accomplish the task of lighting the wall nicely.