SENIOR THESIS

Prince Frederick Hall, University of Maryland

PSU Architectural Engineering CM

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9 April 2014

Prince Frederick Hall

University of Maryland
State College, MD

Building Statistics

Area: 185,522 gsf
Stories: 7 above grade
Cost: $59 Million
Delivery: Design – Build
Use: Dorms/ Offices
Occupant: Student

Project Team

Owner: University of Maryland
Contractor: Clark Construction Group, LLC
Architect: WDG Architecture PLLC
Structural: Cagley & Associates Inc.
MEP: WFT Engineering Inc.
LEED: EMO Energy Solutions, LLC
Civil: Site Resources Inc.
Lighting: C.M. Kling & Associates Inc.
Geotechnical: KCI Technologies, Inc.

Structural

- Reinforced Concrete for slab & foundations
- Reinforced Concrete Frame
- Masonry Sheer Walls
- Non-load bearing walls are masonry
- The height of the top structural slab is 216'3"

Mechanical

- 6 Interior Air Handling Units of variable Supply
- 2 Roof-top Units with 11,000 CFM airflow

Electrical

- 2 External 3000 KVA pad mounted transformers
- 1 gas 350 KW Roof Generator

Telecommunications

- All doors have card swipe access
- All critical areas have security cameras
- Oversees AV systems for advanced classrooms
- Wireless internet access throughout

LEED

- Currently Gold qualified
- 63 credits
- Low emission material used
- Smart Storm water management

Architecture

- Georgian Red Brick
- Curtain Walls for daylight
- Adheres to University Master Plan

Lauren Kandt - Construction Management
www.engr.psu.edu/ae/thesis/portfolios/2014/ljk5096/index.html

Executive Summary

Introduction

The purpose of this thesis is to investigate potential alternatives to current systems and to seek potential improvements to the current interactions with Prince Frederick Hall. Since Prince Frederick Hall is already mostly completed, this building will be used as a reference for the rest of the Universities campus. By applying these alternative systems to Prince Frederick Hall the University can see side by side comparisons for the proposed system and the current systems. This information can be used to consider these systems for future buildings on campus.

Infinity System Investigation

The Infinity System proved to be a quickly installed and cost effective alternative to cast-in-place concrete. This system should be further investigated by the University as an alternative structural system in future buildings.

Greywater System Investigation

This investigation revealed that a greywater system is not a cost efficient sustainable solution for Prince Frederick Hall. Focusing the system on reusing water from the sinks and showers of the communal bathrooms provided over a million gallons of greywater per year. The toilets that would use this water only require 390,000 gallons per year. Since plumbing is very expensive to install and water is very cheap, the amount of water reused would not justify the cost of installation. I recommend focusing on other building systems to improve for sustainability, even for future projects.

Photovoltaic Window System Investigation

The investigation revealed that Pythagoras Solar could provide functional and practical photovoltaic windows for buildings on campus. However the ROI was discovered to be about 20 years. While this should be considered over the lifetime of a building I recommend that the University consider Pythagoras Solar photovoltaic windows on a case by case basis.

Building Information Transfer Investigation

This investigation pursued a means to prevent information loss as a building changes hands once complete. It was found that the University itself was a highly experienced owner and was able to gather all the information it desired on a building. However the information was not filtering down to the building occupants. Therefore I suggest implementing an app to educate the student populations and serve the maintenance crews with quick and up to date information.

Acknowledgments

I'd like to extend my sincerest gratitude to the following:

Justin Hollier for patiently aiding me in gathering information.

For use of Prince Frederick Hall.

Jeffrey B.Hundley for being so willing to help me investigate their system.

Brad Kerser for letting me wander around his job site on a busy day.

Alex Burg for being the person most enthusiastic about this project.

And to everyone who helped me finish this Thesis.

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Project Overview

Client Information

Prince Frederick Hall is being built by the University of Maryland to provide more living space for on campus students and high school campers. The University is a public research University in College Park, Maryland. The building will have offices, classrooms and a computer lab for STEM camps that the University hosts along with four different types of dormitory room.

University projects have unique challenges and expectations that are addressed in the project specifications. The University has fairly strict regulations for building appearance on campus. They are well known for red-brick Georgian buildings and intends to keep it that way. The University also wants to cultivate a studious environment for its students. Noise pollution is extensively addressed as well as no-work days surrounding exam periods and commencement days.

Project Description

Prince Frederic Hall is a 7-story dormitory building with mixed use floors. It is a fairly typical dorm with security, campus services, and a sustainable focus. The total cost is $59,392,361.00 and the building is expected to be ready for occupancy on 13 May 2014.

Constructability Concerns

Notice to Proceed arrived May 5, 2012. Clark Construction immediately began working this project. They placed the target milestone for occupancy on May 11th, 2014. This provides two years to prepare the site and construct Prince Frederick Hall. Due to the project being located in a residential part of campus there are many concerns surrounding the student population. To address this the contract included clauses to limit or forbid construction during finals weeks and on commencement days. The university expects construction to respect the academic calendar and the schedule was created to reflect this concern. Once the building is enclosed construction will speed up due to the repetitive nature of the higher dormitory floors. The University reserves the right to occupy and install equipment in completed areas of the project before substantial completion. It also plans to maintain full occupancy in the buildings surrounding the worksite.

The job site is located in the south section of campus. It is has replaced an existing parking lot and is surrounded on all sides by other dormitory buildings. Unfortunately this means that not only is an entire road closed but large populations of student pedestrians need to be redirected at all hours around the job site. Fortunately the pedestrian paths are conductive to guiding students around the site. Needless to say, safety is heavily emphasized in scheduling and site layout.

Prince Frederick Hall is an advanced and modern building due to the technology camps planned to be hosted within the dorm and a desire to provide students with technology friendly living spaces. Telecommunications and security will be managed by Lenel On Guard system. They will assist with the programing behind the security devices, however Clark is expected to install most of the actual equipment. The concrete, masonry, stud and curtain wall construction is fairly typical. The excavation however, is worth noting. The site needed to be cleared of Building 066 and a parking lot. Once cleared, erosion became a construction concern due to the sandy nature of the Coastal Plains soil. Storm water management and reinforced excavation walls seem to solve this adequately.

Cost

The project has a total cost of Prince Frederick Hall is $59,392,361.00 or $550.09 per square foot. This is more than the RS Means estimate of $25,447,748.80. This could be explained by the mixed use estimate being divided differently. This estimate divided the top 6 floors as residential, while the lower 2 floors were estimated as office space. It is also explained by the lack of accounting for the telecommunications materials and the 'classroom like' environments.

System Design Overview

Structural

Prince Frederick Hall is a cast-in-place concrete structure with masonry shear walls. Due to the height of the structure a crane is be required for elevating the concrete hose and then lifting the exterior elements up to the correct floor. The boom of the crane will need to be able to swing over the four story building just to the north of the site. Since Prince Frederick Hall is seven stories tall this should not be an issue. The excavation was limited to be as close to the building as possible. The access ramp runs along the north side of the building footprint, forming a straight down –up ramp.

Enclosure

The watertight milestone was not reached until partway through MEP rough in for the lower floors. Because of this the site plans account for having both the tower crane and material elevators on site at the same time. Should the crane leave sooner than expected then the elevators would simply have more room to work. The elevators are positioned to be able to each handle a wing of the structure. The shape of the site provides plenty of turnaround space for forklifts near each elevator. The forklift paths depend on the excavation being refilled up to the building so the weight of the forklifts can begin to compact the soil.

Figure 1: Prince Frederick Hall as of 15 Oct 13

Electrical

There are several electrical rooms scattered throughout Prince Frederick Hall. The electrical system was designed to be able to handle high loads of the security system, student electronics, computer lab, offices, and all general building loads without being interrupted. To address this two external 3000KVA pad mounted transformers are attached to the building. There is also a gas 350KW roof generator to ensure the load demands will be met.

Telecommunications

Since Prince Frederick Hall is a university dorm building a great deal of emphasis is placed on student safety. To achieve this critical areas of the building have security cameras and all doors have card swipe access to unlock them. All of this data is processed through an interior telecommunications room to ensure student safety. This building also includes advanced lecture halls with interactive AV systems. A modern computer lab is also placed near the lecture halls to provide easy access to the resources students and technology campers would need. The entire building has wireless access to simplify student dorm life by not tying students down to a single wall outlet.

Lighting

Since Prince Frederick Hall is a repetitive design for floors 2-7, the lighting follows similar patterns. Due to the simplistic and minimalist nature of dorm rooms Typical Resident Bedroom Recessed 2x2 Double Basket lights are used, two per room. Recessed 2x2 Double Baskets are used in the social areas while Typical Unit Vanity Lights and Recessed CLF Lensed Downlights are used in the bathrooms. For the first floor far more effort was placed in painting with the light to create a pleasant atmosphere and thus a far greater variety of light fixtures were used. A great deal of emphasis was also placed on adequate lighting for the exterior since Prince Frederick Hall will feature a lawn with many walking paths bordering it.

Mechanical

Since Prince Frederick Hall is a densely occupied dormitory building, excellent climate control is desired. The HVAC system must provide air to all rooms as well as several high tech lecture halls and a computer lab. It also must to ventilate the bathrooms on each floor and ensure fumes do not enter the building from the road to the east of the Hall. To achieve the variable supply demand 6 interior Air Handling Units are installed across Prince Frederick Hall. To ensure there is enough air to fill the building there are 2 roof-top Units with 11,000CFM airflow placed on the building, well clear of fumes from the passing road.

Structural

Prince Frederick Hall is a cast in place concrete structure with masonry sheer walls. Each floor is an 8" concrete slab reinforced with rebar mats. The foundations are mostly rectangular footings of variable sizes about 2' below the SCUB slab. The concrete columns grounded on the footings carry the floor loads from the entire building. Most of the interior walls are not load bearing and do not require reinforcing if they are shorter than 12'. The exterior is a mixture of brick masonry and glass curtain wall to present the desired architectural appearance of consistency with the rest of the campus.

Fire Protection

Due to the density of the building population a clear and efficient fire system is critical. Thus the fire alarm system is designed to provide a zoned evacuation. This means that upon activation the fire alarm system will first require evacuation of the floor on which the alarm was pulled as well as the floors above and below. The remaining floors will be sent a message telling the occupants to stay put until otherwise instructed. This system is in place to ensure each alarm is as undisruptive as possible without putting occupants to needless risk.

Transportation

There are four elevator shafts total within Prince Frederick Hall. Of those four, three are used to provide student movement from the 1st floor up to the 7th floor. The remaining elevator is a service elevator used to access the basement levels. There are three stairwells, two at each end of the building and one at the center of the building elbow, that also provide occupant mobility throughout the building.

Project Cost

Structural Estimate

The majority of the building structure is concrete; however there was no small and predictable bay that served to represent the entire building. Due to this an entire floor was selected to serve as the example assembly estimate.

Floor three was selected since its floor plan was mirrored on all above floors. Unfortunately this did not account well for the lower floors due to the extensive telecom systems. This is part of why hangers and inserts were not included in this estimate; to ensure the focus remained on the structural system and to reduce the variations between floors. The non-load bearing walls were also left out of this estimate to reduce variance and because they are not impactful on the structural system beyond being a load.

Curiously the floor structural system was entirely concrete and rebar. The few steel beams were relegated to the roof and an outdoor overhang. This monotony in material greatly simplified the estimate. The total cost came to around 23 million for the floor, higher than the expected estimate for floor. This could be due to the cheaper concrete options in the DC area. It could also be due to less conservative rebar estimates and more creative cost categorization.

General Conditions Estimate

The General Conditions Estimate erred on the side of caution for most every item listed. Due to the catch all nature of the category it seemed prudent to try to cover all the expected and unexpected costs. To that end the general conditions presented a weekly operating cost of $26k.

Costs for general conditions are typically pulled from past experience. The site staffing pay chart was derived from wage averages presented on the internet to protect their privacy.

The Insurance costs were also derived from outside sources. Several other costs, such as traffic control measures were provided more funding to ensure the site entrance would always be ready for materials and other traffic. Utilities are all in one category due to the University providing much of such services for the job site

Existing Conditions

Site Orientation

The site of Prince Frederick Hall was a parking lot. The University concluded that the growing student body would be better served by a large dormitory and thus the space purpose changed. The open lawn area to the west of the parking lot is a valued space on the campus and Prince Frederick Hall was designed with the intent of expanding that lawn area for more student use. The job site has a very close proximity to several dorms around the intended location for Prince Frederick Hall.

Demolition

To prepare the site for construction the parking lot, road and Building 66 all needed to be demolished and removed. While the parking lot and road are easily removed and reused as aggregate, Building 66 presented more of a challenge. The Utility line to Building 66 would be extended to service Prince Frederick Hall, as well as the trailers during construction. This utility re-use demands that care be taken while demolition building 66 and laying down the future road path.

Noise Concerns

Due to the location of the site, construction noise and vibration will impact a large number of students in the surrounding dormitory buildings. Because of this the University requested that construction not occur during finals weeks and on commencement days. However, since students would hopefully desire to be studious all the time, additional measures can be taken to minimize noise disruption. Scheduling noisier site activities for later in the day is a simple means to ensure the student population stays content and happy.

Additionally, use of absorptive materials along the site fencing or around a particularly noisy activity such as pile driving could significantly decrease the noise present on the site. Unfortunantly absorptive fencing would add a great deal of cost and should be used as a last resort.

Equipment	Sound Level at Operator	
	Average	Range
*Background**	86	
Earth Moving:		
Front End Loader	88	85-91
Back Hoe	86.5	79-89
Bull Dozer	96	89-103
Roller	90	79-93
Scraper	96	84-102
Grader	<85	
Truck	96	89-103
Paver	101	100-102
Material Handling:		
Concrete Mixer	<85	
Concrete Pump	< 85	
Crane	100	97-102
Derrick	<85	
Power Units:		
Generators	<85	
Compressors	<85	
Impact:		
Pile Driver (diesel and pneum.)	98	82-105
Pile Driver (gravity, bored)	82.5	62-91
Pneumatic Breaker	106	94-111
Hydraulic Breaker	95.5	90-100
Pneumatic chipper	109	
Other Equipment:		
Poker Vibrator	94.5	87-98
Compressed Air Blower	104	
Power Saw	88.5	78-95
Electric Drill	102	
Air Track Drill	113	
Noise Standards		**Noise Level**
OSHA (at workers ear)		90 dB (A)
Day Time Community (at property line)		65 dB (A)

Figure 2: Construction Noise in Decibels and Acoustic Fencing

Site Security

Due to the location of the site, there will be pedestrian traffic passing by at all hours of the day and night. This creates concerns for the site security, especially if tipsy or sleep deprived students decide through the site is a faster route than around the site. While the site itself will be periodically shut down for the University mandated non-construction days, there will need to be some sort of presence on site to prevent trespassers.

Fortunately, there are many options for security. The University of Maryland could lend its police force to the task but they may not be willing to station someone at the site for the full night. Another option is to hire a security service such as Maryland Security Professionals to secure the site in the absence of construction work.

Site Layout

The site for Prince Frederick Hall is located on the southwest quadrant of campus. Unfortunately this location means there is very limited road access. This resulting in needing to ensure that nothing blocks the access route to the site due to lack of proper back up. As you can see on the map below, where the site is highlighted in red, there are only two roads to bring materials in through. However, Preinkert Drive is being used to provide parking for the students and thus not for material uses unless there is an emergency. To ensure the access road stays open staff should familiarize themselves with the campus that they will be driving though. Weekly updates on heavy traffic days should aid drivers in moving quickly and efficiently to and from the site.

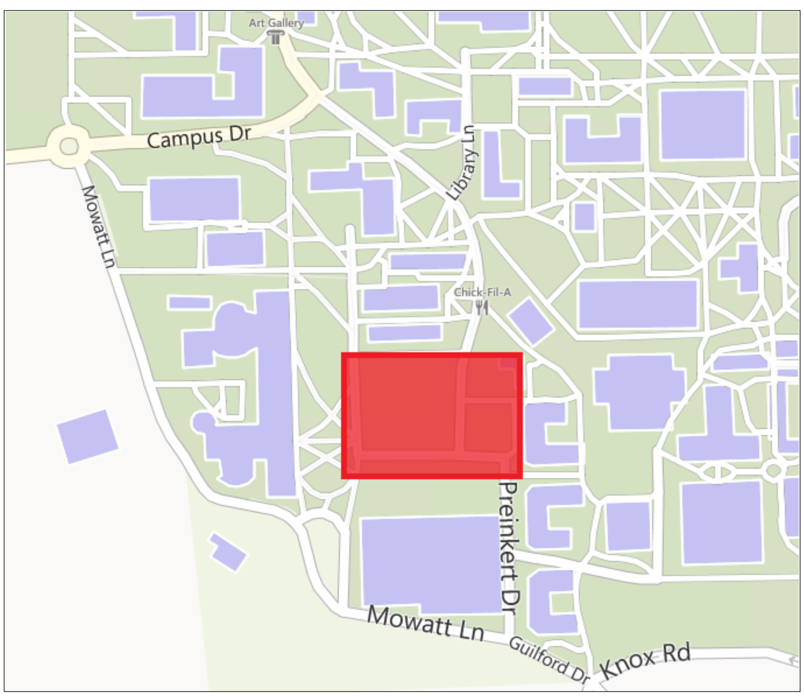


Figure 3: Location of Site highlighted in Red

Project Schedule

Extensive site work and excavation begin during mobilization and continue through to the completion of phase one. These activities include demolition and excavation, demanding a linear schedule due to the site-wide nature of these tasks. Once Phase two begins this linear approach changes to a much faster staggered method, neatly fast tracking the project. Instead of having a task impact the whole site, tasks are broken up floor by floor. On site this sort of schedule demands heightened focus and attention from management to ensure each task is completed in a timely manner. This schedule, though difficult to manage, does greatly increase productivity day to day and can cut months or more off a project. This faster pace ensures Prince Frederick Hall is completed in time for occupation.

Critical Path

Due to the overlapping tasks and limitation of 200 tasks, a critical path was quite difficult to select and instead milestones are the driving force of the project. However, to demonstrate the flow of work the second floor was selected to represent the expected progress of each floor and thus presented as the critical path to completion. This floor was selected because it is the first floor devoted to dorm rooms without extensive offices as well. In the schedule the second floor has trade specific tasks listed for the entirety of the project to demonstrate what is occurring as each trade finishes a task.

Had there not been a limit of 200 tasks, then the trades would be broken down into half floors to better map the critical path to completion.

Unexpected Variations

When compared to Clark Construction's schedule, this schedules occupancy milestone fell one day later. This variation could be due to generalizing and grouping tasks to meet task number criteria for this report.

Acceleration

The schedule for Prince Frederick Hall is truly controlled by the University of Maryland. They request there to be no work on commencement days and near final exams. Then request for work to occur at 'reasonable' times of the day was requested due to the proximity of the site to student housing. Despite this Clark Construction is still able to accelerate the schedule by having the trades overlap as they go through each floor.

Prince Frederick Hall is repetitive dormitory floors from the third floor up. Clark Construction was able to take advantage of this repetition to accelerate the schedule slightly. As one trade moved from the third floor up to the fourth, a new trade can move into the third floor. The repetitive nature of the floors will help each crew to become more efficient as they rise up the building. Unfortunately this will result in a large number of labors on site at any given time. Their safety is thus put back in the spotlight to ensure this method to accelerate the schedule doesn't accidentally delay it further due to injury.

Delay Factors

Another means of "accelerating" a schedule is to have contingency plans for unexpected events. These events can range from weather to site injury to student riots. Each location can contribute unique delay factors.

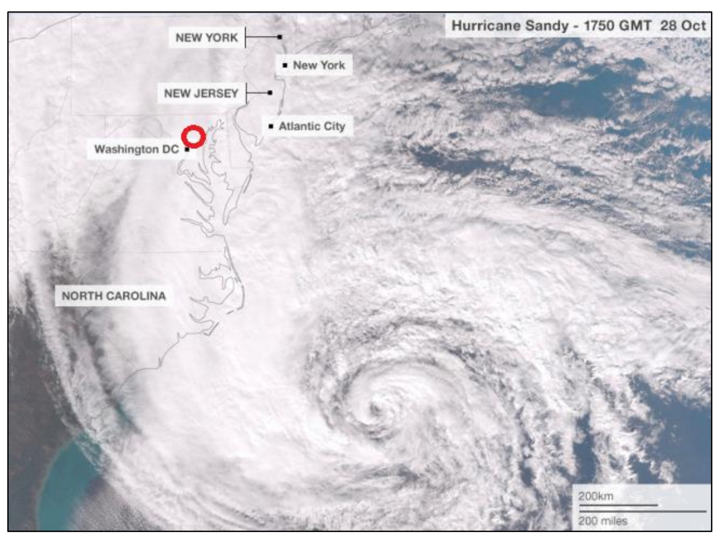


Figure 5: Hurricane Sandy with site location marked.

Weather and other acts of God wouldn't normally require a unique plan beyond the typical to get back on schedule. However, within the last five years the Washington D.C. area has not only experienced being in the direct path of Hurricane Sandy but also felt a 5.8 magnitude earthquake in 2011. There is no reason not to expect a repeat event. Having a plan for each phase to prepare the site would help prevent delays from material damage. Following up with a contact tree to ensure clear communication to contractors, staff and laborers would also ensure work resumes as soon as is safe.

Unique to a college campus is potential delays from the student body. Riots, celebration and other spontaneous evens could pose a risk to the construction schedule and the safety of the site due to the proximity to student residences. Prince Frederick Hall is being built right next to four currently inhabited dorm buildings. Though riots are not common at the University of Maryland they generally occur on Route 1, thankfully a far distance from the site. However the student residents in the south quad of campus, if moving in a direct line to Route 1, go right over the site.

LEED

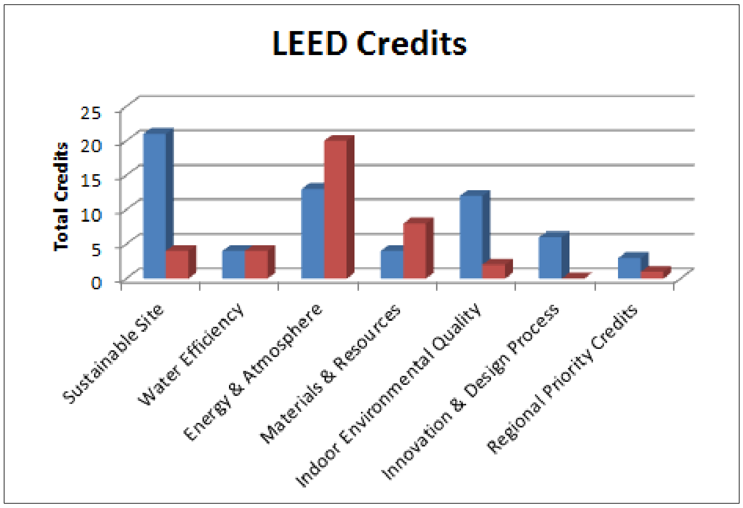


Figure 6: Leed Credits

Prince Frederic Hall was contracted to hold a Silver LEED rating by the University of Maryland. This would have required 50-59 points to achieve. The current LEED credit count places Prince Frederick Hall as a Gold rated building. The LEED Point Sheet can be found Appendix B.

Sustainable Sites

This category focuses on the methods used to minimize the building impact on the environment and ecosystems around it. To this end it includes points such as alternative transportation and development density, both quite simple to pick up on a bike filled, pedestrian packed dormitory block. This category also includes open space development and storm water design. The University desired to create a lawn space near Prince Frederick Hall, easily filling the open space credit. The soil on site is very fine and sandy, demanding a plan to avoid extensive erosion and run-off. Due to this plan an extra credit was picked up for Quality Storm water management.

Water Efficiency

This category provides incentive to focus on water in all ways. While reducing water use helped to pick up credits in this category it was largely ignored due to the desire for an attractive landscape for the life of the building.

Energy and Atmosphere

This category places emphasis on energy performance. Since this building is new construction there were several credits available to be picked up for optimized energy performance. However a large number of credits were lost due to lack of on-site renewable energy in favor of maintain the Universities' architectural appearance.

Materials and Resources

This category presents an opportunity to gain huge benefits from smart construction efforts. Since the University decided to spare no expense there was very little recycled or re-used material. However construction waste management and regional material use made up for the lack of recycling and helped to earn credit back.

Indoor Environment Quality

This category is where the architectural and building lifespan are able to earn LEED credit. With its focus on indoor air quality and demand for daylight and view Prince Frederick

Hall is a clear case study for this category. The dorm was designed with a long sustainable life in mind. To this end high quality HVAC systems were selected and efficient systems were put in place. It was also designed to provide each dorm room with equal access to light, creating a building with very few spaces without a window. As mentioned earlier, the University spared no expense, using high-quality, low-emission materials to better serve the students who will occupy the building. The rest of the credits were earned with well documented construction practices.

Innovation and Design

This category addresses all the sustainable aspects of the building and its construction that are not covered in any of the other categories.

Summary

Prince Frederick Hall is a LEED Gold modern dorm designed to serve its inhabitants in comfort and ease. It is well designed in its systems and in the methods used in construction. However, for the University to see even better buildings, Prince Frederick Hall must be examined and evaluated when compared to the following proposed alternative systems.

Analysis 1: Infinity Structural System Investigation

Problem Identification

Due to the academic nature of Prince Frederick Hall the completion date is very important to the University. They need to be able to house students in Prince Frederick Hall by Fall 2014. This project has a very tight schedule to reflect this. However, erecting the structural system for Prince Frederick Hall took about half of the project duration time. Finding a method to decrease the time spent erecting the structural system would help to ensure that completion dates are met for future construction on the University campus. This investigation will compare and contrast the alternative structural system with the current cast-in-place structural system for Prince Frederick Hall.

Potential Solutions

One of the fastest structural systems to place is modular framing. There are several options for what type of modular construction to actually use. Precast concrete is an obvious alternative since Prince Frederick Hall is currently cast-in-place concrete. However the planning and lead time for precast concrete is fairly long, making it unsuitable for University project timelines.

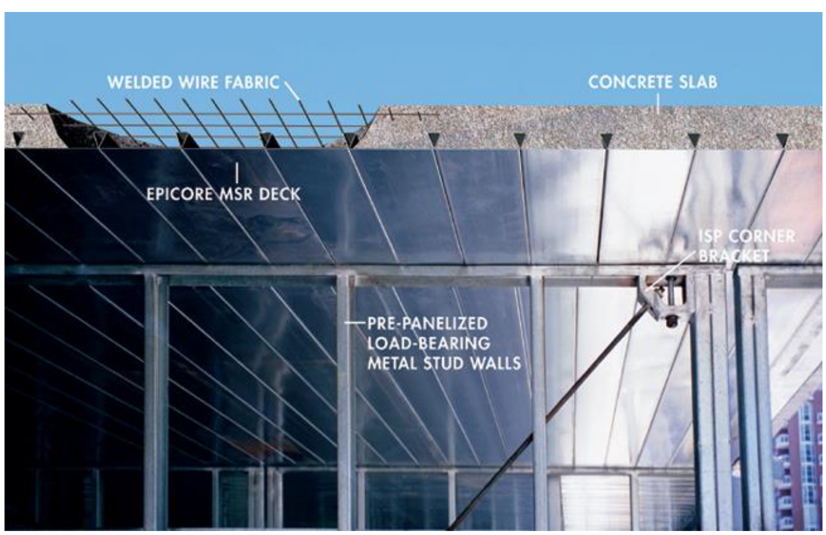


Figure 7: Infinity System Labeled

Another option is structural stud wall panels and decking, such as the Infinity System. The Infinity Structural System is a framing system that combines structural metal stud wall panes with Epicore MSR Composite Floor Systems. This system is commonly used in large repetitive structures like Hotels and Dorms, making it a promising alternative for Prince Frederick Hall. The Infinity Structural System is deceptively simple. The Pre-Panelized metal stud walls serve as the load bearing part of the system. Some of these panels are Infinity Shear Panels (ISP) that serves to handle lateral loads on the building. The Epicore MSR Deck serves to support the floor systems. It is designed to also serve as the ceiling of the area below the deck should the owner wish to save money in that area.

Investigation

The Infinity Structural System is at its best when mixed with other structural systems. For example, on the Shafer and Grace Project, the Infinity System sat on top of a cast-in-place foundation. It also had a I-beam system to support the roof instead of using Epicore deck. For this investigation, the Infinity System will be applied to the 2nd through 7th floors. The foundation, basement and first floor will remain cast-in-place concrete to best account for the unique mechanical loads and layout. To account for wind loads, shear panels (ISP) will be used in the stairwells.

Schedule

The main strength of the Infinity Structural System is speed. For example, on the Shafer and Grace project, a 14000 square foot floor could be finished in 9 days. Two days for panel installation, four for deck prep and one day to pour. Assuming that crews on Prince Frederick Hall could work at a similar pace, then a floor could be structurally completed in 15 days. By this estimate, the Infinity System could be placed for Prince Frederick Hall in 90 days. The original duration for this is 114 days. The Infinity Strucutral System would save 24 days on site. This time could be used to account for float, or to give more time to the MEP rough in.

Duration Estimates					
Project	Floor Area	Days/ Floor		Structural Durations (2-7 floors)	
Shafer and Grace	14000	9		Cast-In-Place	114 days
Prince Frederick Hall	22512	15		Infinity	90 days
				Duration Difference	24 days

Figure 8: Estimate based on similar residential project

Logistics

That said, one of the potential bottlenecks is the access road to the site. Prince Frederick Hall is located on the South west corner of campus, surrounded with inhabited dorms. The only road with access crawls downhill along several curves. The flatbeds used to deliver the panels can navigate this road, but the risk of a crash occurring or a semi-truck getting stuck is possible. To mediate this risk, delivery times should be carefully coordinated so workers could help direct the delivery driver to and from the site along the access road.

Figure 9: Flatbed delivering Infinity Panels on site.

This coordination will not be difficult. The Infinity Structures team believes in just-in-time delivery. To do this, they schedule each delivery with the intent of driving the flatbed to the site where the panels will be lifted off of the flatbed and directly placed on the building. This method serves to minimize materials on site and can greatly benefit a site with limited space. While Prince Frederick Hall is not the smallest site, it is still tight. Using this just –in-time delivery will help to keep the site clear for other materials as the Infinity Structural System is placed.

Ensuring the panels are loaded onto the flatbed in the correct order should also be coordinated. Depending on weather the panels with be moved from the truck right onto the building. If they will be moved to a waiting area before being lifted onto the building then this reverses the order that the panels need to be stacked in.

Constructability Concerns

While the Infinity system is an excellent choice for speed, it does have several potential construction drawbacks. Most of these can be predicted and easily corrected.

The first concern is the warping of the concrete decks. Ideally the concrete on the decking is completely flat. In reality it can dip and have gradual rises and falls. These cause the panel frames to tilt, causing the next deck to not have a flat surface to rest on, causing dips in the concrete. This carries errors up to the top of the building. Keeping an eye out and ensuring the tolerances are maintained will account for this.

Figure 10: Panels tilted by Uneven Concrete, Up.

Figure 11: Panels tilted by Uneven Concrete, Down.

Another concern is severe weather. Weather is not a major concern for installation of the panels themselves. It can however possibly delay the delivery of materials, resulting in the project being behind schedule. Severe winter weather can also ice the hoist, causing further delays in installation. Wind can be a concern during installation. It is swiftly corrected with temporary wood bracing.

Another relatively unlikely concern is from the production of the panels themselves. The panels can on occasion arrive from the factory already warped. This is a quality control issue that can be addressed and assessed on the site as the panels are lifted into place. The warping is normally not structurally compromising but may present problems for MEP installation and hanging drywall. Noting any warping and giving a heads up to these contractors will correct the issue of warping.

Most of these errors are fairly easy to correct for. Especially since most are purely cosmetic and within tolerances. The drywall installers can help to compensate for these cosmetic gaps between panels and imperfect alignments.

Fire Rating

Prince Frederick Hall requires 2 hour fire protection on all interior load bearing walls. The EPCOR MSR has a rating between 1-2 hours depending on slab depth and concrete type.

The Metal Stud Wall have a 1 hour rating with a single layer of fire code drywall. With multiple layers of fire code drywall however, the Metal Stud Walls can have a 3 hour rating. The exterior WalPanel is rated to 1 hour. To ensure that the Infinity System meets the 2 hour requirement, all Metal Stud walls will have two layers of fire code drywall hung on them. This will unfortunately add some expense to construction.

Cost Saving

Prince Frederick Hall was designed with non-load bearing masonry to serve as interior walls. This simplified construction by ensuring those walls only needed a coat of paint to be finished. Fortunately, the Epicor decking is designed to serve as a ceiling. Painting the ceiling and dry walling the walls for the Infinity Structural System will help compensate for the change from painting the walls and tiling the ceiling for the current cast-in-place concrete system.

Sound Characteristics

Sound transference is an important factor in dorm buildings due to the 24/7 activity. Different students are active at different times. This can lead to extremely disrupted sleep from sound transmittance. The EPCOR MSR STC (sound transmission class) is 54-58 depending on floor coverings.

MEP advantages

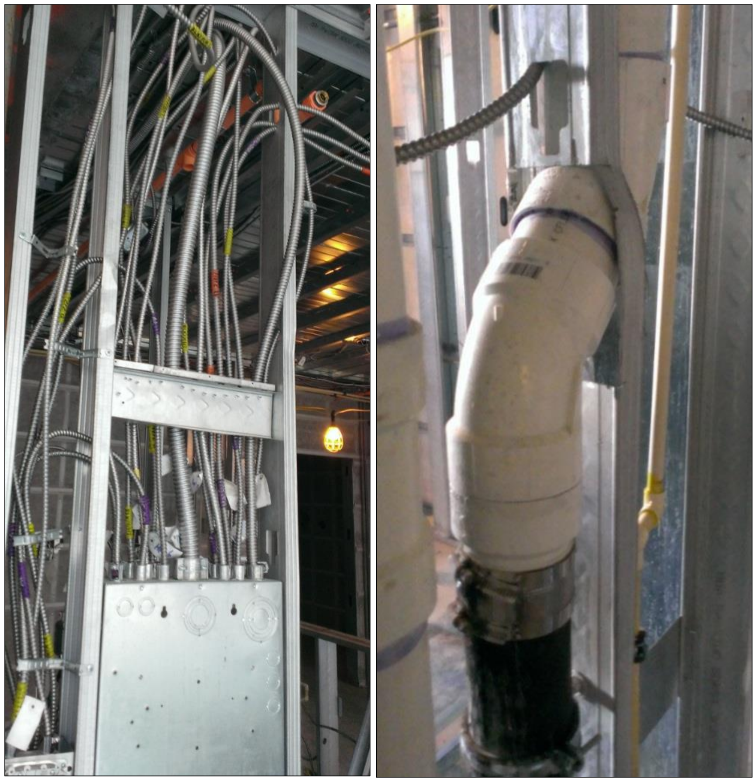


Figure 12: Examples of MEP Construction with Infinity

The Infinity Structural System provides many MEP rough in advantages. Due to its similarities to stud wall, it can be assembled with spaces for MEP. This can however backfire if proper coordination did not occur. For example, when a 4 inch pipe needs to be threaded between infinity system studs, as happened here. Interestingly the MEP is even further simplified when stud walls serve as the non-load bearing walls as well.

LEED

The Infinity Structural System offers many advantages to gaining LEED Credit. Due to the LEED requirements for Prince Frederick Hall in contract, many of these LEED points have already bin earned though smart construction practices. There are still points to be gained to earn the Platinum LEED rating though. The Infinity System offers possible credit in sustainable sites, energy and atmosphere, materials and resources, and indoor environmental quality.

Cost Comparison

Cost Comparison between Concrete Columns/Decking and Infinity Panels/Decking										
Floor 4 only										
	#	unit	Material/Unit	Material Total	Labor/ Unit	Labor Total	Equipment/ Unit	Equipment total	Total plus O&P	Total
Infinity Panels	2507.02	LF	$ 11.30	$ 28,329.33	$ 13.05	$32,716.61	$ -	$ -	$ 32.50	$ 81,478.15
ISP	223.2	LF	$ 11.30	$ 2,522.16	$ 13.05	$ 2,912.76	$ -	$ -	$ 32.50	$ 7,254.00
EPICOR Metal Decking	22512	SF	$ 1.65	$ 37,144.80	$ 0.41	$ 9,229.92	$ 0.03	$ 675.36	$ 2.59	$ 58,306.08
Rebar	6	Ton	$ 1,050.00	$ 6,300.00	$ 540.00	$ 3,240.00	$ -	$ -	$ 2,025.00	$ 12,150.00
Concrete	22512	SF	$ 1.97	$ 44,348.64	$ 0.85	$19,135.20	$ 0.28	$ 6,303.36	$ 3.75	$ 84,420.00
Totals:			Material	$ 118,644.93	Labor	$67,234.49	Equipment	$ 6,978.72	Grand Total	$243,608.23
								Original Cost 4th floor Concrete		$377,000.00
									Difference	$133,391.77

To narrow down the cost comparison a single floor was selected. Floor four was chosen for having a typical floor plan when compared to the floors above and below. The cost comparison focused on the cost of cast-in-place concrete and Infinity Panels. To try and keep as focused on that as possible, non-load bearing walls were ignored as well as all wall, floor, and ceiling finishes. The cost of the original concrete for this floor was pulled from PFH February Cost Report. Surprisingly the Infinity Panels appear cheaper by over $100,00.

There are several possible explanations for this. The cost difference could be from the labor needed to place and remove the molds and forms for the cast-in-place concrete. Another possible reason for the difference is the fact that drywall was not included. Drywall will need to be applied to every single Infinity Panel, while concrete can be finished with a coat of paint.

Recommendation

This investigation concludes that the Infinity Structural System is a viable and practical alternative to cast-in-place concrete for campus building. The Infinity System can improve the project schedule with is speed to place. This is especially important when all construction is constrained to the academic school year. The infinity system also has the advantage of being easy and cheap to finish since the EPICORE Metal Deck can serve as the ceiling and the concrete can be finished so it may serve as the floor. Above all, the Infinity System is a cheaper alternative that should be considered for future construction on the University campus.

Structural Breadth: Integrity post Changes

Problem Identification

The Infinity System is a very practical structural system for repetitive unit buildings like hotels and dorm. However it is still prudent to ensure that the system can support the expected dead and live loads upon it.

Investigation

Design Parameters

The investigation must being with understanding the loads a dormitory building. Since this is a dormitory building, residential load standards will be used.

Live Load:

Rooms = 40 psf

Hallways = 100 psf

Dead Load:

Rooms = 5psf (ceiling) + 20 psf (partitions) = 25 psf

Hallways = 5 psf (ceiling) = 5 psf

Regular Weight Concrete = 150 Lb/cuft

Minimum Concrete Compressive Strength = 4000 lb/sq.in.

EPICORE MRS Steel Minimum yield = 45000 lb/sq.in.

Reinforcing rebar steel minimum yield = 60000 lb/sq.in.

Deck Deflection is a minor concern due to the use of EPICOR MRS decking when compared to a solid concrete slab reinforced with rebar. Rebar is normally placed one inch above the bottom of the slab. EPICOR MRS Decking places steel at the very bottom of the deck, helping to control tension at the bottom of the slab.

Calculations

Deck Orientation

The deck orientations are marked on the plan in Appendix depicting the locations of Infinity Panels on Floor 4. It will be a continuous span across Dorm Rooms and Corridor.

Span Lengths

Room Span = 22.5 ft → L= 23 ft

Corridor Span = 5.5 ft → L=6 ft

Slab Depth

Since original design called for 8 inches and Prince Frederick Hall is close to the maximum height for Infinity System, use 7.5 inches for depth.

Loads

Slab Weight = 150 (7.5-2+1.833)/12 = 91 psf

Total Load

Dorm= 40psf + (91+25)psf = 156 psf

Corridor = 100psf + (5+91) psft = 196psf

Ultimate Load

Dorm = 1.7(40psf) + 1.4(91+25psf) = 230.4 psft

Corridor = 1.7(100psft) + 1.4(91+5psf) = 304.4 psf

Dorm Design

Deflection Check

$$E_c = (150)^{1.5}(33)*(4000)^{.5} = 3834250 \text{ psi}$$

$$I_{eff} = 299.3 \text{ in}^4/\text{ft}$$

$$Defl_{max} = [.0084*(156)*23^4(1728)] / (3834250 * 299.3) = .552 \text{ in}$$

$$Defl_{lim} = 23/360 = .76 \text{ in}$$

Check : .76 > .55

Shear Check

$$d = 7.5 - .46 = 7.04 \text{ in}$$

$$d_1 = 7.5 – .75 – (.625/2) = 6.437 \text{ in}$$

Flexural Shear

$$V = (1.15*156*23) / (2 – 156*(6.437/12)) = 1979.42 \text{ lb}$$

$$V_o = 1979.42/.85 = 2328.75 \text{ lb}$$

$$V_u = 2328.75/ (12*6.437) = 30.148 \text{ psi}$$

$$V_c = 2*4000^{.5} = 127 \text{psi}$$

Check : 127 psi > 30.15 psi

Flexural Reinforcement

Positive Steel Area Check

$$156*(23^2)/ 11 =.9[A_s*45000*7.04 – (A_s^2 *45000^2) /(2*12*.85*4000)]$$

$$A_s= .0237 \text{ in}^2/\text{ft}$$

Check: 22 gauge works

Negative Area Steel Check

$$156*(23^2)/ 9=.9[A_s*45000*7.04 – (A_s^2 *45000^2) /(2*12*.85*4000)]$$

$$A_s = .025 \text{ in}^2/\text{ft}$$

Check: $A_s = .3*L = .3*23*12 = .575 \text{ in}^2/\text{ft} > .025 \text{ in}^2/\text{ft}$

Welded Mesh size = 6x6 – W7.9xW7.9

Corridor Design

Deflection Check

$$E_c = (150)^{1.5}(33)*(4000)^{.5} =3834250 \text{ psi}$$

I_{eff} =299.3 in^4/ft

$Defl_{max}$=[.0084*(196)*6^4(1728)] / (3834250 * 299.3) = .0497 in

$Defl_{lim}$ = 6/360 = .2 in

Check : .2 > .05

Shear Check

d = 7.5 - .46 = 7.04 in

d_1 = 7.5 – .75 – (.625/2) = 6.437 in

Flexural Reinforcement

Positive Steel Area Check

196*(6^2)/ 8 =.9[A_s*45000*7.04 – (A_s^2 *45000^2) /(2*12*.85*4000)]

A_s= .037 in^2/ft

Check: 22 gauge works

Flexural Shear

V = (196*6) / (2 – 196*(7.04/12)) = 473.013 lb

V_o= 473.013/.85 = 556.486 lb

V_u = 556.486/ (12*7.04) = 6.58 psi

V_c = 2*$4000^{.5}$ = 127psi

Check : 127 psi > 6.58 psi

Flexural Shear Bond

u = (196*6)/[7.5*1.7(7.04– (.037 *45000) /(2*12*.85*4000)] = 13.15 psi

Allowable = 80 psi

Check: 80 psi > 13.15 psi

Recommendations

This breadth investigation of the structural stability of the Infinity System proves that it is viable in Prince Frederick Hall.

Analysis 2: Grey Water System Investigation

Problem Identification

The University of Maryland has an intensive focus on sustainability across their campus. As stated before, Prince Frederick Hall was contracted as a Silver Rated LEED building, and now has managed to reach Gold. The idea of pushing this dorm building even further to Platinum LEED Rating was well received by the University. Unfortunately the construction was sustainability focused from the start, and thus has few credits left to earn. That means the best areas to improve for LEED credit are sustainable systems over the life of Prince Frederick Hall, such as the plumbing system.

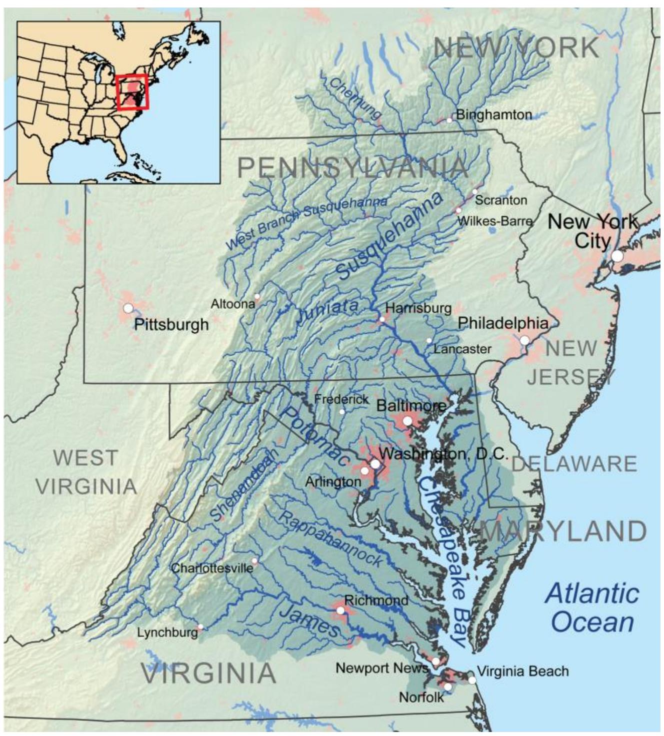


Figure 13: Map of the Chesapeak Watershed

The University of Maryland is part of the Chesapeake watershed. On the map the University of Maryland is located between Washington D.C. and Baltimore. The Chesapeake watershed is approximately 64000 square miles along the eastern coast and up through Pennsylvania and New York. Currently this watershed is home to 17 million people. Within this watershed, what one area does to the water impacts everywhere else downstream. Since Prince Frederick Hall is going to have a high concentration of human occupants, it will produce a great deal of waste water and sewage. While one building will not single handedly destroy the ecosystem of the watershed, good stewardship to everyone downstream demands investigation into possible reductions in water consumption. However, there are sustainable systems that could offset the amount of water used or resourcefully reuse water. These systems are more commonly called Greywater Systems.

Potential Solutions

There are two major Greywater systems to consider; Rain Water Harvesting and Grey water Reuse. Both of these systems discern between cleanwater, greywater and blackwater. Greywater is defined as “household wastewater (as from a sink or bath) that does not contain serious contaminants (as from toilets or dippers)”. Blackwater is defined as “polluted water: water contaminated with animal, human or food waste”. Water collection systems have been in use for centuries, but the modern interpretations and terms were popularized in the 1970’s.

Rain Water Harvesting is the process of collecting rainwater, lightly treating it and then using it as greywater. This system is dependent on being located in an area that has sufficient rainfall to actually contribute to the water use of a building. It is also dependent on being able to collect water from a significantly sized area. The filtration process consists of a screen to remove sticks, leaves and other large particles. The second part of the filtration system requires chemical treatment of the water to ensure it will not grow algae or bacteria. This filtration is not as extensive as for clean drinking water, but it is necessary to keep the holding tank clean and the water from turning to blackwater.

Greywater Reuse is the process of collecting greywater from sinks and showers, lightly treating it, and then the collected greywater for appropriate tasks. This system has the advantage of reusing water that has already been used within a building as opposed to depending on the weather and sizable harvesting equipment. It does however require a significant addition of plumbing to deal with the three classifications of water within the system. The filtration system is very similar to the Rain Water Harvesting filtration system, but with less focus on particle filtration and more focus on chemical treatment to prevent growth within the holding tanks.

Both of these systems have significant advantages and disadvantages. For the purposes of this investigation a validation check will discern which system is viable and which will have the greatest impact on Prince Frederick Hall's water consumption.

Investigation

Initial Check

This investigation must begin with what the estimated water consumption is for Prince Frederick Hall without a grey water system. The calculations can be found in Appendix E. The estimated water consumption for Prince Frederick Hall came out to 4,454,000 gallons per year.

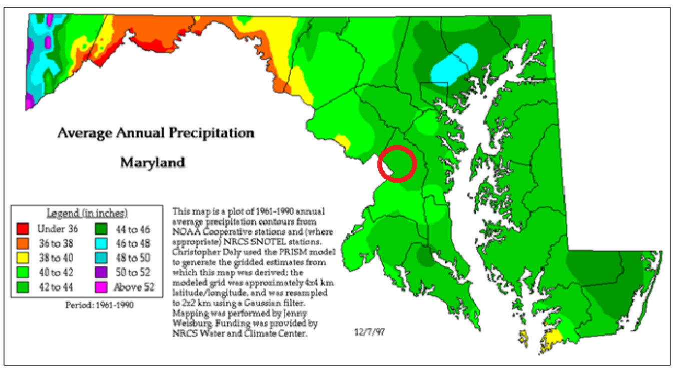


Figure 14: Average Annual Rainfall

The rainfall collection estimate depended on assuming that the entire roof area could be converted to collect water. With that square foot area in mind the next step was to see what sort of rainfall should be expected in southern Maryland. The approximate location of the University of Maryland is marked on the map with a red circle. Using this data the estimated Rainwater collected was 546,000 gallons per year.

The Greywater reuse estimate originated from the assumption that the only fixtures that would use greywater are urinals and toilets. It is also assumed that only showers and bathroom sinks would generate greywater. This is because showers and sinks produce easy to filter and treat waste water while custodian sinks and laundry machines produce waste water with harsh chemicals in it.

Initial Results		
	Gallons	
	Per Day	Per Year
Origninal Building Totals	12203.2	4454168
Rainwater Collected		546324
Adjusted Building Total		3907844
Greywater Reuse	1879.2	685908
Adjusted Building Total	10324	3768260

Figure 15: Initial Check Data

System Installation

This Initial rundown proves that of the two systems, the Greywater Reuse system will provide a greater return over the lifetime of the building. Incorporating the greywater system into Prince Frederick Hall requires a storage container, slump pumps, the filtration system, the control system and additional plumbing for the removal and return of the water.

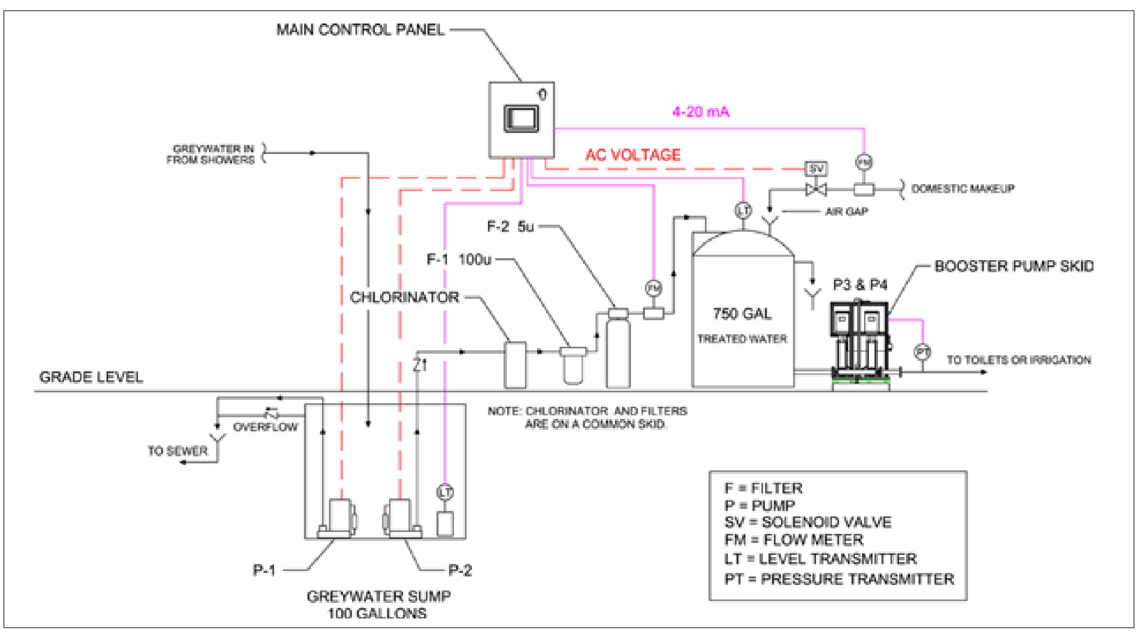


Figure 16: Diagram of a Greywater System

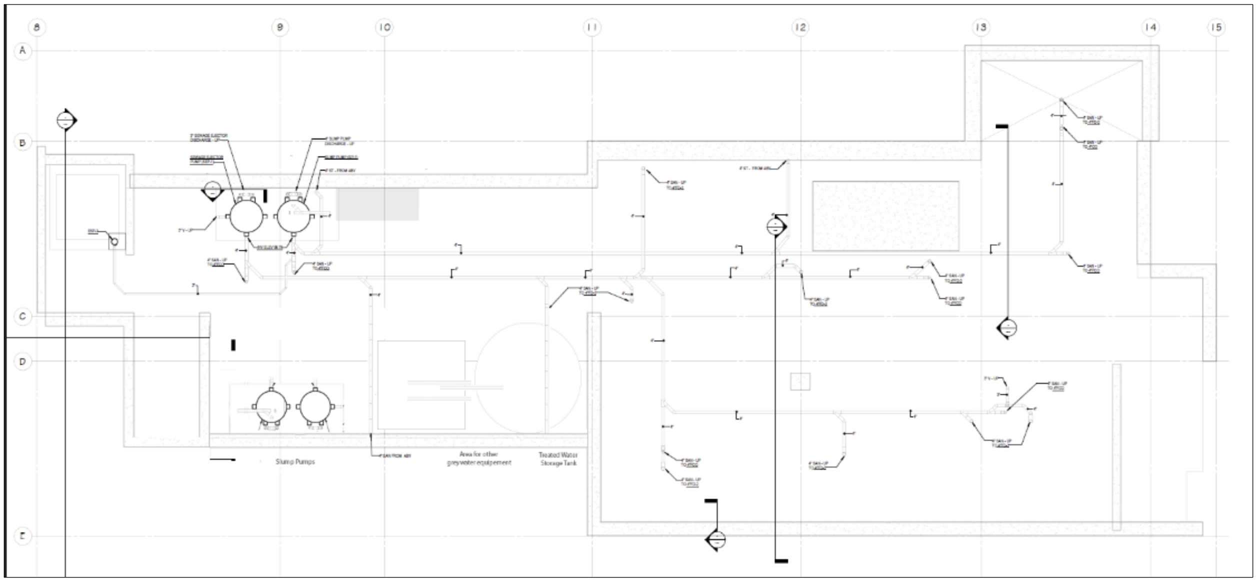


Figure 17: Expanded Scub Slab Plans

Fortunately there is a scub under slab already devoted to plumbing and other system machinery. By expanding this slab in the area across from the original plumbing slump pump space for the greywater pumps, filters and storage tank is opened up. This also ensures the slump pumps for the greywater system are located fairly close to the riser locations for the communal bathrooms.

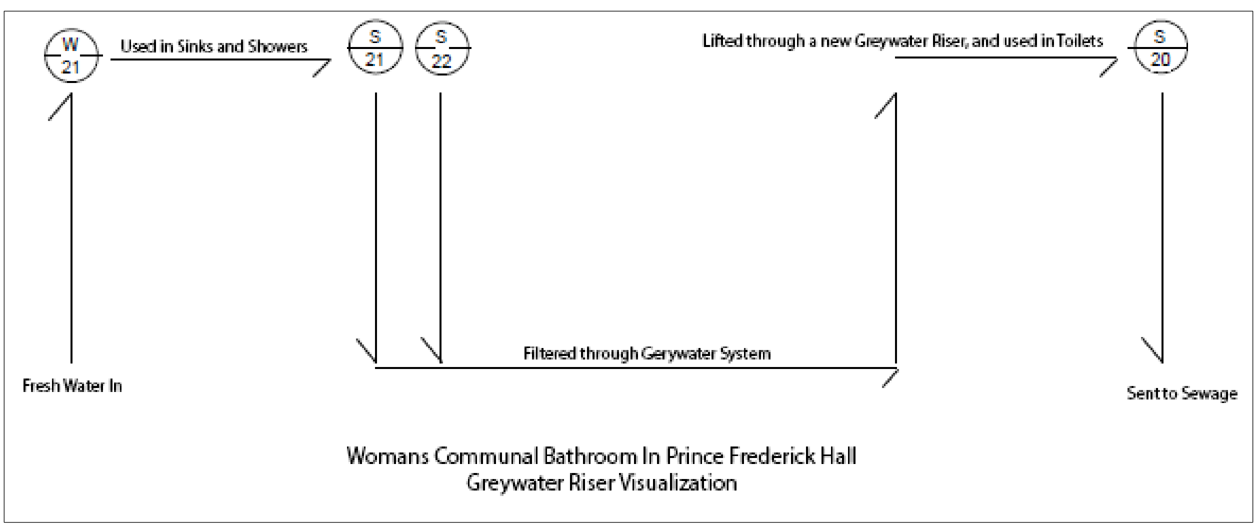


Figure 18: Water Path Diagram

Adding new risers and pipes to a system is always a bit intimidating due to the size of pipes and the gradients and space required. Surprisingly, the current arrangement of the water system is fairly friendly toward the modifications required for the greywater system to work. In the communal bathrooms for example, the sanitary risers already separate shower waste from toilet sewage. As see on the water path diagram above, modifying the first floor plan so that the grey water from S22 and S21 are directed to the filtration system instead of straight to sewage will not severely contribute to the building cost. Things do get a bit trickier once the greywater is to be returned to the bathrooms for use in the toilets. The clean water risers have showers, toilets and sinks all drawing from the same pipe system.

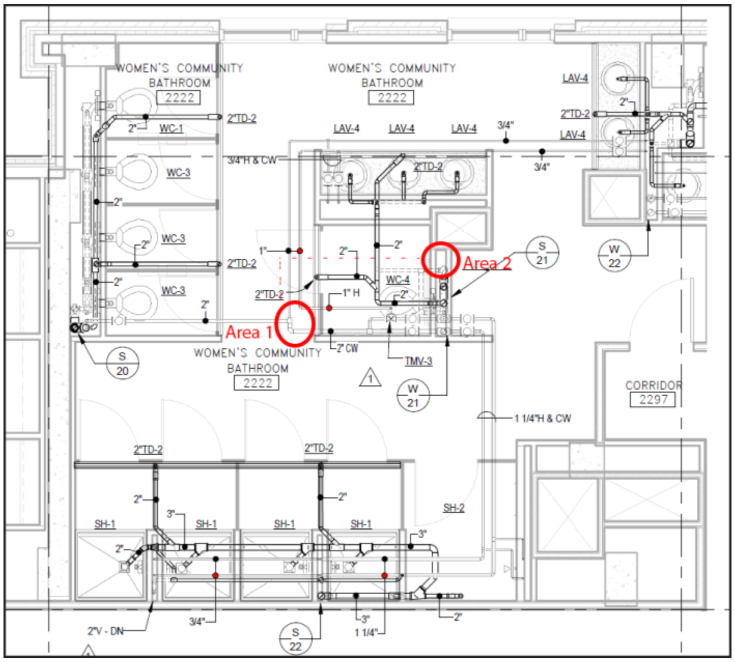


Figure 19: Plumbing Modifications Highlighted on Plan

For the greywater system to work, a vertical riser will need to be installed just for the toilets. On the plans however, this is clearly not a major redesign. Area 1 highlights the original connection between W-21 and the toilets. By simply disconnecting that and reconnecting it to the greywater riser, the toilets are removed from the clean water and ready to be fully connected to the greywater system. The Greywater riser will fit neatly into the wall space highlighted by Area 2 on the diagram. This will place it beside the other risers, ensuring that any plumbing work is minimally invasive to the building. The mens communal bathroom mirrors the womans bathroom and has the same riser space for their own greywater riser. A larger version of this marked plan is avalible in the appendix.

Cost

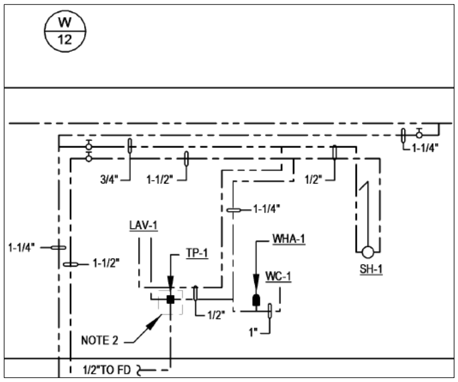


Figure 20: Example Riser for Individual Bathroom

The cost problems begin to arise when the individual bathrooms are considered. This is because both the clean water risers support all three bathroom fixtures, and the sewege risers drain from all three. This means that for each of these individual room bathrooms the greywater system will need two additional risers installed. Since this seems to be straying from the practical a rough estimate was run to ensure the greywater system is still cost efficient for the University.

Since the Individual Bathrooms would add a significant amount to the cost of Prince Frederick Hall from material alone, they will be excluded from the greywater system. Instead the greywater system will focus on the communal bathrooms.

Rough Estimate Risers Material Cost							
	Bld Height (ft)	# Risers Grey	# Repeats	# total Risers	LF Pipe	Cost/LF	Material Total Cost
Communal Bathroom	100	1	2	2	200	99	19800
Individual Bathrooms	100	2	16	32	3200	99	316800

Figure 21: Rough Estimate for Riser Material Cost

Running an estimate on the communal bathroom water consumption reveled an unfortunate surprise. The greywater produced from the sinks alone could cover the greywater required for the toilets to use without the supplement from the rainwater. Unfortunately the amount of water reused would be about 390000 gallons per year. The sinks produce over a million gallons per year. This means that of the greywater filtered through the system, less than half will actually be reused before being directed into the sewage system.

Estimated Greywater Source and Use											
Source		#/floor	#/Floors 2-7	# Students	Students/ Floors 2-7	Unit /Day/Student	Unit	Gallons/Unit	Gallon/Day/Student	Gallon/Day	Gallon/Year
Sink	Female	3	18	22	132	5	Minutes	2.2	11	1452	529980
	Male	3	18	22	132	5	Minutes	2.2	11	1452	529980
Shower	Female	4	24	22	132	10	Minutes	1.5	15	1980	722700
	Male	4	24	22	132	5	Minutes	1.5	7.5	990	361350
									Total Sink Greywater		1059960
									Total Shower Greywater		1084050
									Total Source Greywater		2144010
Use											
Toilets	Female	4	24	22	132	3	Flush	1.6	4.8	633.6	231264
	Male	2	12	22	132	0.5	Flush	1.6	0.8	105.6	38544
Urinals	Male	2	12	22	132	2.5	Flush	1	2.5	330	120450
									Total Used Greywater		390258

Figure 22: Estimated Greywater Use in Communal Bathrooms Only

The excess greywater could be redirected to serve the watering system in the lawn associated with Prince Frederick Hall. However, college students often use such lawns for outside study, sunbathing and pick-up games. This varied usage college lawns receive is a great deal more tactile than most lawns. Using greywater from sinks and showers on the grass lawn creates a risk of a student's coming into direct contact with the lightly treated greywater. The potential medical risks should be evaluated by biologists and bio-engineers before implementation.

Recommendation

I cannot recommend Prince Frederick Hall adopt a greywater system. For the individual bathrooms, the cost of modifying the risers is simply not worth the return. For the communal bathrooms, it is fairly simple to install such a system, but the amounts of water actually reused do not justify the cost of installation. Since Prince Frederick Hall sits in the Chesapeake watershed, water is a resource worth noting and monitoring. It is also very plentiful and cheap. Thus, due to installation costs and such small amounts of water reused, Prince Frederick Hall would do more ecological good investigating another building system to improve.

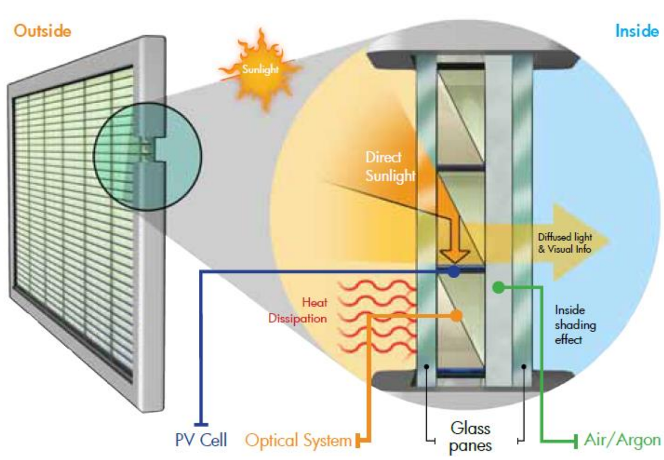
Analysis 3: Photovoltaic Cell Investigation

Problem Identification

The University of Maryland has an intensive focus on sustainability across their campus. As stated before, Prince Frederick Hall was contracted as a Silver Rated LEED building, and now has managed to reach Gold. However the idea of pushing this dorm to Platinum Rating was well received, if difficult to achieve since sustainable construction efforts to gain LEED certification has been mostly been implemented. The best areas left to improve on are sustainable systems over the life of Prince Frederick Hall. Since Prince Frederick Hall is a dorm building, it will have a large energy load since students often have more than one electrical device. One of the best ways to offset this load is to harness solar power. While the roof of Prince Frederick Hall has a relatively small surface area, the southern facing façade has a much larger area, and thus provides a greater possible contribution to addressing the energy demands of this dorm.

Potential Solutions

Solar power has been around in some form since cavemen first took naps in the sunshine. More recently solar panels have been implemented on roofs and in vast fields to attempt to permanently harness the power of the sun. Since these approaches require a massive amount of land for a relatively small return, solar companies have begun to explore more subtle means of incorporating solar power into buildings. One of these solutions is using the window area as solar panels. Solar companies across the board have found a workable idea for how to do this. The windows would be designed to let appropriate amounts of light into the building while at the same time reflecting direct sunlight onto photovoltaic cell surfaces embed in the



window. Pythagoras Solar, a company founded in 2007, seems to have found the greatest success in creating such windows so far.

Investigation

Viability

Solar Panels have not become standard because they are simply not that great at converting sunlight to power yet. The Space Station's solar panels, essentially the most advanced and celebrated solar panels available, are only 40% efficient. The Pythagoras Solar PVGU windows are about 12% efficient. While this sounds low, it is above average for commercial solar panels. The technical specifications for these windows provided annual energy yield estimates for different cities in the United States. For Prince Frederick Hall, the most comparable city on the list is Atlanta, another Eastern City.

Estimated Energy Consumption					
Unit	Avg. Consumption /Unit (KwH)	# of Unit	Consumption Total (KWH)	$/KWH	Annual Cost
Students	505.74	388	196227.12	0.129	25313.3
SqFt	24	22300	535200	0.129	69040.8
		Building Total	731427.12	0.129	94354.1

Estimated Energy Gain Annual					
	KWH/SF	SF	KWH Total	$/KWH	Savings
Dorm Windows	9.63	5675.88	54658.72	0.13	7050.98
Curtain Wall	9.63	6685.00	64376.55	0.13	8304.57
		Total KWH	119035.27	Total Savings	15355.55

Figure 23: Energy Estimates

For this viability study assume all southern windows and most eastern and western facing windows are converted to the photovoltaic cell system. Combining the area assumption with the data above, the Pythagoras Solar Window system could generate about 119,000 KWH annually. This could save the University more than 15 thousand dollars annually. Granted this amount feels small when compared to the estimated annual energy cost of 943 thousand dollars to operating Prince Frederick Hall. That said; this amount of energy savings should be considered over the course of the lifetime of the building. And it will most likely cover the cost of installation within about 4 years. The viability study proves this is worth investigating further.

Window transparency

Figure 24: View through a Pythagoras Solar Window

One of the main drawbacks of the Pythagoras Solar Window system is that it can interfere with a windows main purpose, to provide a clear view of the outside. Since the photovoltaic cells are parallel with the earth, it is still easy to see out of the window. It is actually comparable to looking out through venetian blinds. However the cells reflect and glint, a possible annoyance for the inhabitants of Prince Frederick Hall. Once information is distributed on the windows and the Pythagoras Solar System the inhabitants of Prince Frederick Hall will most likely grow accustomed to and possibly appreciate the unique look of these photovoltaic windows.

Constructability Concerns

Pythagoras Solar designed these windows to be very easy to install. Simply place and connect to the electrical system. Though the company describes this a simple for the sake of possible owners, this requires a level of coordination between the electrical engineer, the architect and the CMs that needs to be addressed early in the design process to ensure that every group is ready to help install these windows efficiently. Depending on the experience of the installation teams, some level of MEP rough in may be needed as the windows are installed to ensure connecting them to the electrical system is not hampered later in construction.

As mentioned in the Infinity Structural System Investigation, the logistics of delivering materials to the Prince Frederick Hall work site needs to be well coordinated with site supervisors. Just-in-time delivery may be just as applicable here as it was with the Infinity system. Pythagoras Solar custom constructs each window before delivery to the site. Since they are already aware of where each window goes on the building, loading the flatbeds in such a way that the crane can lift the appropriate windows directly off the flatbed onto the building could leave a great deal of space free on site. This approach requires a high level of coordination between the CM and Pythagoras Solar for deliveries, but it would also ensure the Pythagoras Solar Windows would not be left siting in ready areas on site where they may be damaged.

HVAC Concerns

It would be a sad thing to replace all of Prince Frederick Hall's windows with energy creating windows only to have more energy lost due to heat than is produced by the windows themselves. Fortunately Pythagoras Solar addressed this in their specifications.

GLAZING SPECIFICATIONS	
Outer Glass**	6mm (1/4") ultra-clear
Inner Glass**	6mm (1/4") low-e coated
U-Value*	0.30
Solar Heat Gain Coefficient (SHGC)***	0.14 (for angles > 25° above normal) 0.41 (for angles < 25° above normal)
Visual Light Transmittance (VT)***	0.00 (for angles > 25° above normal) 0.49 (for angles < 25° above normal)
UV Transmittance (UVT)***	0.00 (for angles > 25° above normal) 0.28 (for angles < 25° above normal)

Figure 25: Specifications from Pythagoras Specs

The windows themselves are double pane by nature, ensuring that if nothing else, an air buffer will help to maintain heat within Prince Frederick Hall.

Cost

The Pythagoras Solar Windows system can be built in custom sizes to fulfill each unique project's needs. That said, having consistent window sizes on the façade will decrease the cost of construction. Please refer to the architectural breadth section for further analysis of this. The common window size designed in the architectural breadth will be used in the following cost estimate. The new window area found an additional one thousand square feet for the photovoltaic windows.

Energy Gains Annual - New Windows					
	KWH/SF	SF	KWH Total	$/KWH	Savings
Dorm Windows	9.63	6149	59214.87	0.129	7638.72
Curtain Wall	9.63	6685	64376.55	0.129	8304.57
		Total KWH	123591.42	Total Savings	15943.3

Cost

The curtain wall for Prince Frederick Hall cost $178,030 while the per floor cost of Window material came out to above $65,000. These numbers were pulled from the PFH February cost report. Photovoltaic windows are a great deal more expensive than normal windows due to the photovoltaic cells, the custom construction, and the multiple panes and electronics required. That said, the Photovoltaic cell windows can return the cost of investment over time. The north façade of Prince Frederick Hall will not have photovoltaic windows since it does not face south, but will use the common window size to aesthetically match the front of Prince Frederick Hall.

Photovoltaic Material Cost Estimate								
	Amount	Unit	Material/Unit	Material Total	Labor/Unit	Labor Total	Total/ Unit	Total
Photovoltaics	172	ea	$ 390.00	$ 67,080.00	$ 53.50	$ 9,202.00	$ 443.50	$ 76,282.00
Curtain Wall Photovoltaics	60	ea	$ 390.00	$ 23,400.00	$ 53.50	$ 3,210.00	$ 443.50	$ 26,610.00
North Windows	114	ea	$ 390.00	$ 44,460.00	$ 98.50	$11,229.00	$ 488.50	$ 55,689.00
North Curtain Walls	3017.433	sqft	$ 50.00	$ 150,871.65	$ 7.55	$22,781.62	$ 57.55	$173,653.27
						Material Total		$332,234.27

The data for photovoltaics were found using RSMeans 2014 for Green Building. There was no photovoltaic window cell specification to work from. This could explain the suspiciously low cost for these photovoltaic windows. Comparing this cost to the estimated energy gains results in ROI in about 20 years.

Recommendation

The University of Maryland would be able to implement photovoltaic windows into future buildings or renovations with a guaranteed return of investment eventually. That said, for these Photovoltaic windows to work their best they would ideally have a large open space to the south, such as Prince Frederick Hall's extensive lawn. At certain locations on campus these windows would serve as an excellent sustainable system. At other more dense areas of campus, the windows would simply not generate enough power to justify their implementation. This Investigation concludes that the University should consider and implement photovoltaic windows on a case by case basis for each building.

Architectural Breadth: Increasing Window Area

Problem Identification

The Pythagoras Solar photovoltaic cells are designed to sit between window panels. To increase their expected output, the window area needs to be expanded. However, the University of Maryland has strict architectural standards to maintain the university's academic appearance and feeling. Prince Frederick Hall is no exception. There are currently three different sizes for dorm room windows used on the southern, eastern and western facing walls of Prince Frederick Hall. If these could be merged into one common size of window while still adhering to the architectural expectations of the University, then a great deal of cost could be saved on materials and the potential window area for the Pythagoras Solar system increased.

Investigation

Architectural Standards

The University of Maryland wants to present an air of tradition, academia and unity through its architecture across campus. This is especially important in the dorms where many potential students and their parents are taken on tours. Prince Frederick Hall attempts to bring a touch of modernity to the traditional architecture with beautiful curtain walls accenting the buildings height and entrances.

The goal of this investigation is to look instead at the dorm room windows. Since the curtain wall already accents the modern aspect of the aesthetic if falls to the façade over the dormitory parts of the building to maintain the University standards; brick and stone with punch out windows for every dorm room. By making these dorm windows uniform and slightly expanding their size, greater energy gains are possible without compromising the architectural standards for Prince Frederick Hall.

Current Window Conditions

As marked on the elevations below, the windows over the dorm rooms come in many different shapes. This is because of the four different types of dorm room present in Prince

Frederick Hall. Interestingly, all the dorm rooms facing the elevations of interest fluctuate between 11’1 ¼” and 12’ 10 5/16”. Also between sets of D1 and A1 windows are a series of louvers. These are mostly architectural for the purpose of drawing the eye vertically at that point in the façade.

Figure 26: Original Elevations with Potential Photovoltaic Windows marked in Red

Proposed Window Size

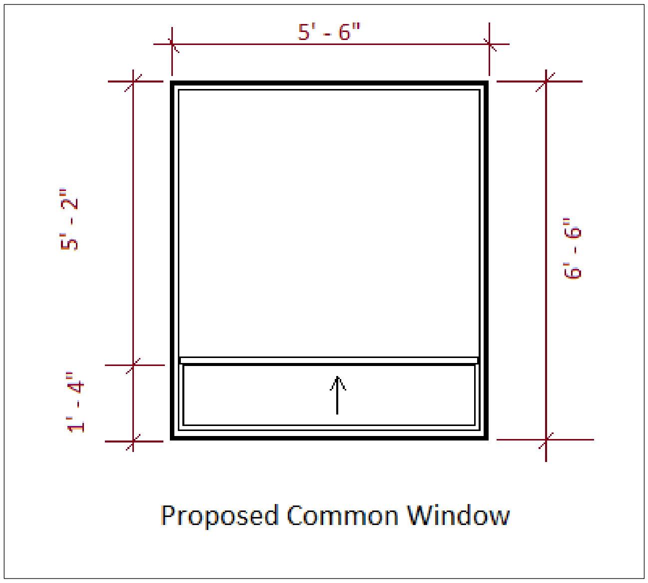


Figure 27: Proposed Common Window for Dorm Rooms

To maximize the potential area for Photovoltaic Windows I propose this common window design for all dorm room windows. This window has a small opening panel so inhabitants of Prince Frederick Hall can still open their windows to enjoy fresh air as they desire. Its width is 5’6” to ensure that it fits comfortably between the walls of each dorm room. This width will seem tightest when replacing the B1 windows on the corner dorm rooms beside the southern stairwell on the South Elevation. The height of 6’6” was selected to present the feeling of a square window when viewed from inside of the building. The one foot difference in height makes its biggest impact on the outside, where it creates a rectangular shape. This taller rectangle shape serves to emphasize the height of Prince Frederick Hall, though a bit more subtly than its predecessors window types.

Brick lintels are used above all of the dorm room windows to create a unified appearance on the façade. This simplicity also helps to keep the eye drawn to the modern curtain walls instead of focusing on the dorm room windows.

The louvers between windows were removed and replaced by more brick façade. Instead of the louvers breaking up the façade and creating a more visually busy building, they have been moved to sit on top of the east-west wing roof. This relocation results in the appearance of a two tiered crown atop Prince Frederick Hall. The step appearance of the rise also helps to draw the eye to the tallest point of Prince Frederick Hall and the largest curtain wall. All of the adjusted elevations are available in the Appendix G.

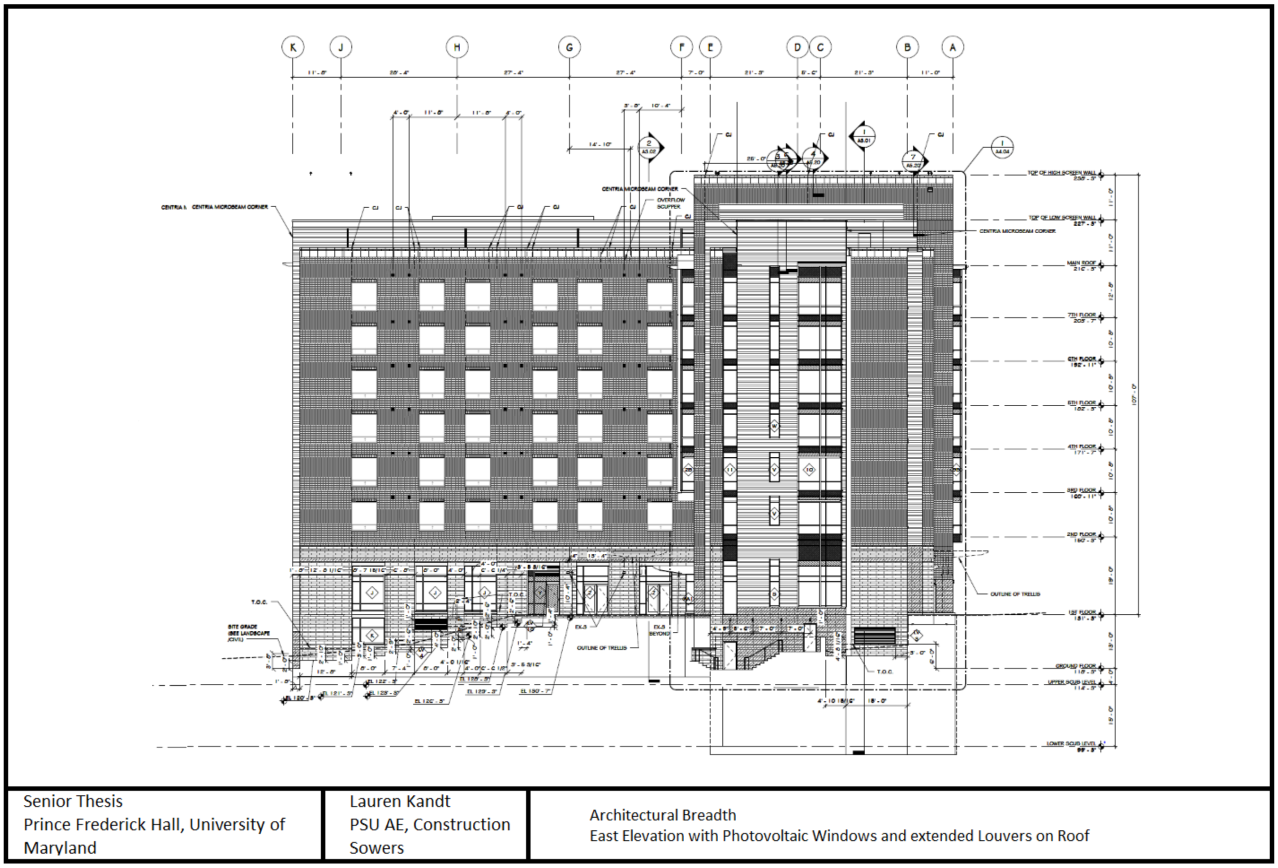


Figure 28: Modified East Elevation

Window Area

The common window size was not just to unify and simplify the appearance of Prince Frederick Hall. It was also designed to help expand the window area on the three elevations that can be converted to the Pythagoras Solar photovoltaic Windows. The common window size, only replacing the dorm room window, increased the total window area by 1013 square feet.

Window Areas					
New Design					
		Height	Width	ea	Total Area
Curtain	1	87.33	7.33	1	640.13
	2.1	60	6.33	1	379.80
	2.2	25.5	14.66	1	373.83
	2A.1	54	17.16	1	926.64
	2A.2	54	3.25	1	175.50
	3	86.66	7.33	1	635.22
	4	96	6	1	576.00
	5	88.83	13.08	1	1161.90
	5A	88.83	5.33	1	473.46
	6	68.33	19.66	1	1343.37
Dorms	P	6.5	5.5	172	6149.00
			Total Window Area		12834.84

Figure 29: New Window Areas

Recommendation

I recommend using the common window size when designing with photovoltaic windows in mind. While it is not as architecturally appealing as having a variety of window shapes, it is extremely functional, provides a great deal of light to student inhabitants of dorms and provides an extra one thousand square feet of photovoltaic surface area. This common window size does not detract from the academic architecture of the University of Maryland, and it can improve its sustainability.

Analysis 4: Building Transfer Research

Problem Identification

Prince Frederick Hall is a very modern building. Its systems are all reasonably efficient and it is designed with the current demands of a student; computer labs, spacious bathrooms, and plenty of electrical outlets in the dorm rooms. These systems set Prince Frederick Hall apart from many of the 100 year old buildings also present on campus. That said, the University of Maryland must maintain hundreds of multi-use buildings on their main campus alone. Because of the sheer number of buildings some of the unique details of certain buildings can be lost in the system. Loosing track of what makes each building unique homogenizes maintenance efforts. This may seem like a reasonable thing, but a 100 year old building does not need the same type of care and repair as a 10 year old building. This knowledge loss may result in a new building's systems not getting the care they need since it performs better than an older building by default. Locating and correcting the spots where details and information about campus buildings get lost could help campus UPP service each unique building's needs.

Potential Solutions

One of the critical Knowledge loss times is the transition from the constructors to the owner. For Prince Frederick Hall this is the handoff of Prince Frederick Hall from Clark Construction to the University of Maryland. A potential solution is creating a checklist or information package describing the unique systems of each building that Clark Construction could present the University. This checklist could reduce information loss as it is distributed from the office of the physical plant down to the maintenance workers and custodians who actually work with the campus buildings on a daily basis. This information could also take the form of a program or app to simplify distribution efforts.

Investigation

Research revealed that the information loss was not in the building handoff to the owner. The University is a very experienced owner. Because of this they know exactly what they want to know at each point in the construction process. However, there is still some level of information loss from the University down to the individuals who daily interact with the building. From unofficial information gathering, most building inhabitants and custodians cannot describe the differences between one building and the next on campus. Somewhere between the highly experienced owner and the employees who actually maintain the building, information is obviously lost.

To better pin down where information may be lost, a survey was created and sent out to custodians and residential assistants at the University of Maryland and Penn State. The survey was created on SurveyMonkey.com and is listed in Appendix H. There were only three responses. They were, however, very enlightening responses.

The three responses all came from Residential assistants. Their responses were surprisingly consistent in appreciation, hatred, or bewilderment. Unsurprisingly all three held negative views of the HVAC system within their respective dorm building. Their interaction with the Electrical system amounted to “call OPP”. Please note; this survey was intended more for custodians and maintenance than RA’s.

The answers to the LEED question greatly surprised me.

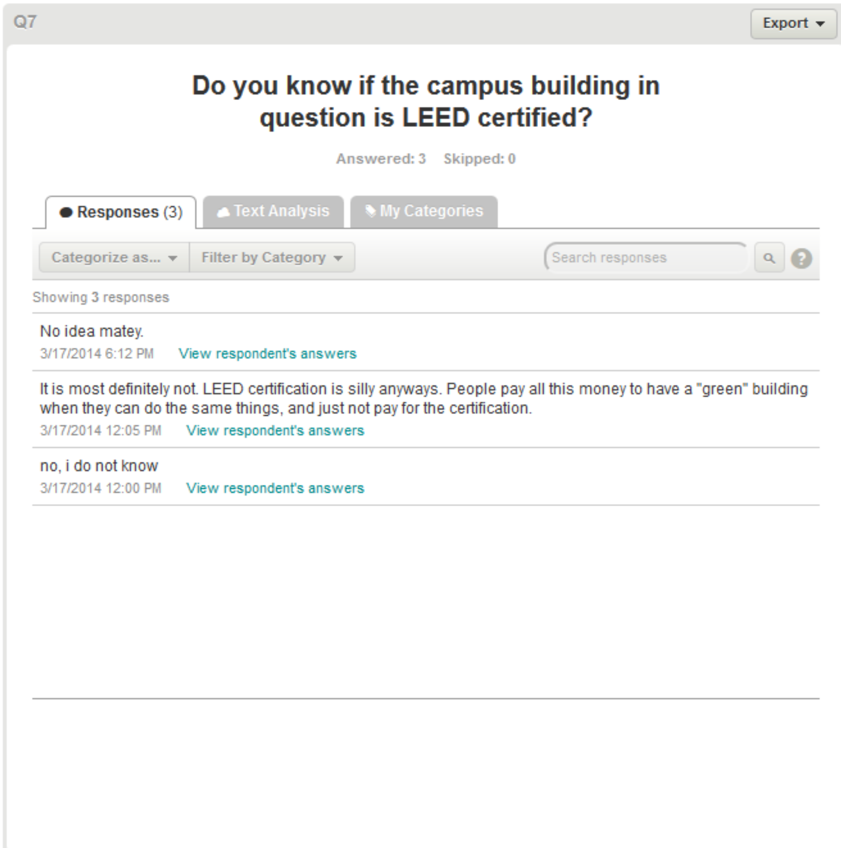


Figure 30: Survey Answers for LEED Question

The University of Maryland takes a great deal of pride in their sustainability programs across campus. They have several LEED certified buildings. Prince Frederick was always contracted to be LEED Silver at least. So here is a clear knowledge loss from Owner to occupant since the Univeristy is so proud of this sustainablity effort and yet the students dissmiss it from ignorance.

It is entirely possible to present such building information to students. Almost every student has a smart phone and is familiar with apps. An App could be created to inform students about the buildings on campus and what the Universities sustainability efforts look like. Since almost every university requires an account and password, that could serve unlock the app that lists the buildings and their sustainability features.

The App

Audience

The target audience of such an app would be the engineering students, architectural students, Residential Assistants, campus tour directors and any individuals associated with the University with a curiousity about campus buildings. This app could turn buildings into living classrooms for these student groups.

Engineering students could use this app to be able to pull up data on buildings so they may use them as real world examples of the different systems discribed inthier courses. Architectural students could use this app in much the same way. Residential Assistants and tour directors could use this app to be able to quickly and accuratly answer questions about buildings on campus, such as their age and occupancy. And of course, any individuals associated with the university with a passion for sustainablity would be able to use this app to see what buildings on campus are LEED certified.

Figure 31: The first Screen of the App

Screen Interaction

All the screens are avalible in Appendix H.

When opening the app, the first image presented to the user is a log in, to ensure that information is only distributed to individuals with accounts associated with the University.

The second screen is a list of campus maps for the Univsersity. One the user selects a campus, that preference can be recorded so once the app is reopened, it will open immediately to the third screen. This screen would then be accessible through a menu.

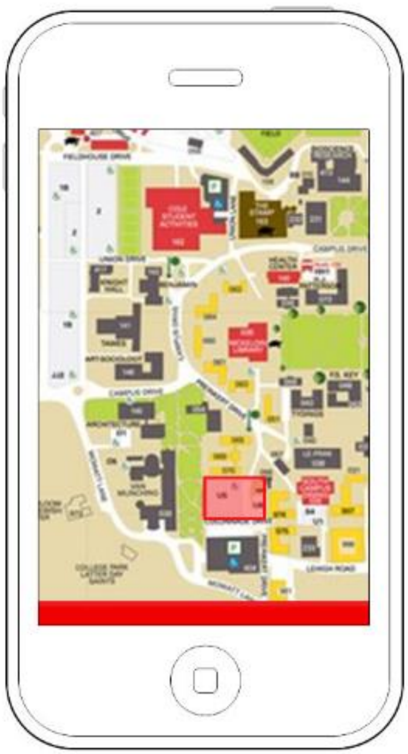


Figure 33: The Third Screen

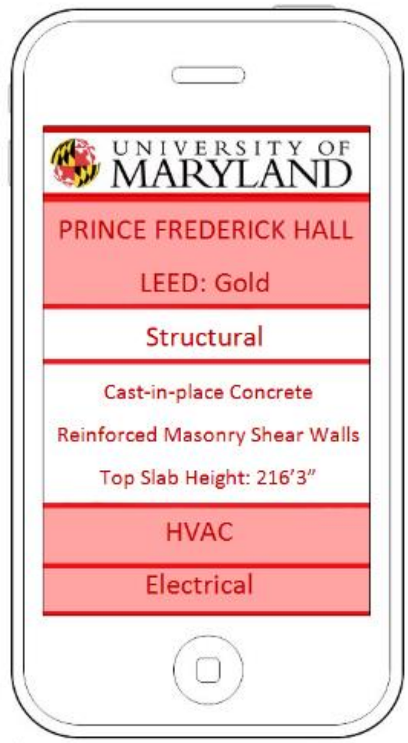


Figure 32: The Fourth Screen

The third screen is a map of the campus selected. The user can click on a buildign and select it and move forward to the fourth screen.

The fourth screen is the menu for the selected building. As you can see, the user can click on a system to pull up more information.

Further Possibilities

This app, on it's surface, is a simple information distribution tool. It can be modified for many other purposes at the discretion of the University.

For example, if two dorm building are engaged in a competition, like a trash reduction competition. This app could add the data on each buildings trash reduction efforts to the respective building, creating a better competition since it would be easy to see who was in first place.

This app could also be used to mark construction on campus. As construction areas block of walkways, this app could update its map to reflect the current situation on campus. This could have the added side effect of limiting the number of students who walk right next to a contruction area, helping to protect the student population from harm.

Another possible app expansion is for the Univerisities OPP. By creating a feedback system from the building this app could collect water, HVAC and electrical data and attach it directly to the correct building. Then this information could be collected and presented in on easy to access app. The log in screen could be modified so only OPP employees are able to access this level of detal on a building. If someone calls in that the temperature is to high or cold in a particular building, this app could give quick feedback as to what the problem may be.

This isn't limited to building systems either. This app could list building opening and closing times all in one easy to find place. Campus security could use this app to mark which building have been locked each night, and then unmark them as they are unlocked in the morning.

This app isn't limited to one map eaither. In further expansions this app could have secondary maps with regard to specific locations on campus. A Computer lab map could highlight where all computer labs are on campus while listing what operating systems are avalible, current lab occupancy, and lab closing times. Or a gym map could mark gym and field locations, as well as what fields are reserved for some group's practice at a given time.

To personalize this app, it could have a schedule map. Each semester it could look up the student's class locations and highlight them on a map to simplify locating their classes. This could also be used for finals and other location dependant activities. The possibilities are endless.

Cost

This app will require a talented programer. This programer will need to ensure that this app can be quickly an easily edited for the additional tasks mentioned above. They will also need to be avalible to update this app as newbuildings are finished and old buildings are renovated.

While sites like Guru.com, a freelancing site that seems to draw talented programers, could provide such a programmer, the University has a much better option. This app could be programmed by IT and computer science students for a capstone project or a competition. Then the process of updating the app can simply be a recurring capstone project or extra credit project as needed. The students walk away with a protfolio app and the University has a free and evolving app to suit the needs of the students and the maintenance crews.

Recommendation

I recommend for all Universities to create such an app. This app can be created at little to no expense to the university since students could construct the code for it. The benefits of this app, even just too engineering and architectural students will be immeasurable. Beyond that, this app could be a gateway to inform the student population of sustainability efforts on campus. It could even serve to motivate the students to take a more active part in improving the sustainability of campus. The potential benefits of such an app far outweigh the initial cost of creation.

Final Recommendations and Conclusions

This thesis used Prince Frederick Hall as an example and benchmark to study and compare alterative systems against. In the end this is the humble opinion of the 5th year architectural engineering student against a University steeped in tradition and a very accomplished Construction Group. The University of Maryland is rightly comfortable with the construction methods and systems currently used. However there is always room to improve.

While the investigation of greywater systems discovered that such a system is impractical, the other investigations revealed more positive results. Further investigation of photovoltaic cell windows may be wisely delayed until solar technology increases the efficiency of the cells. The Infinity System however is a practical system with many advantages that could suit campus construction and absolutely should be investigated further.

The app however should be implemented, if for no greater reason other than to provide students with a map. The University will gain from having an easy way to communicate with students and students will benefit from better understanding the campus they occupy. While the app does not strictly address any particular part of Prince Frederick Hall, it was inspired by the lack of understanding about LEED. Since the University is putting so much effort and time into building LEED buildings and attempting to create a sustainable campus, it is a shame for the students to not understand and support this effort.

Appendix A: References

Sources:

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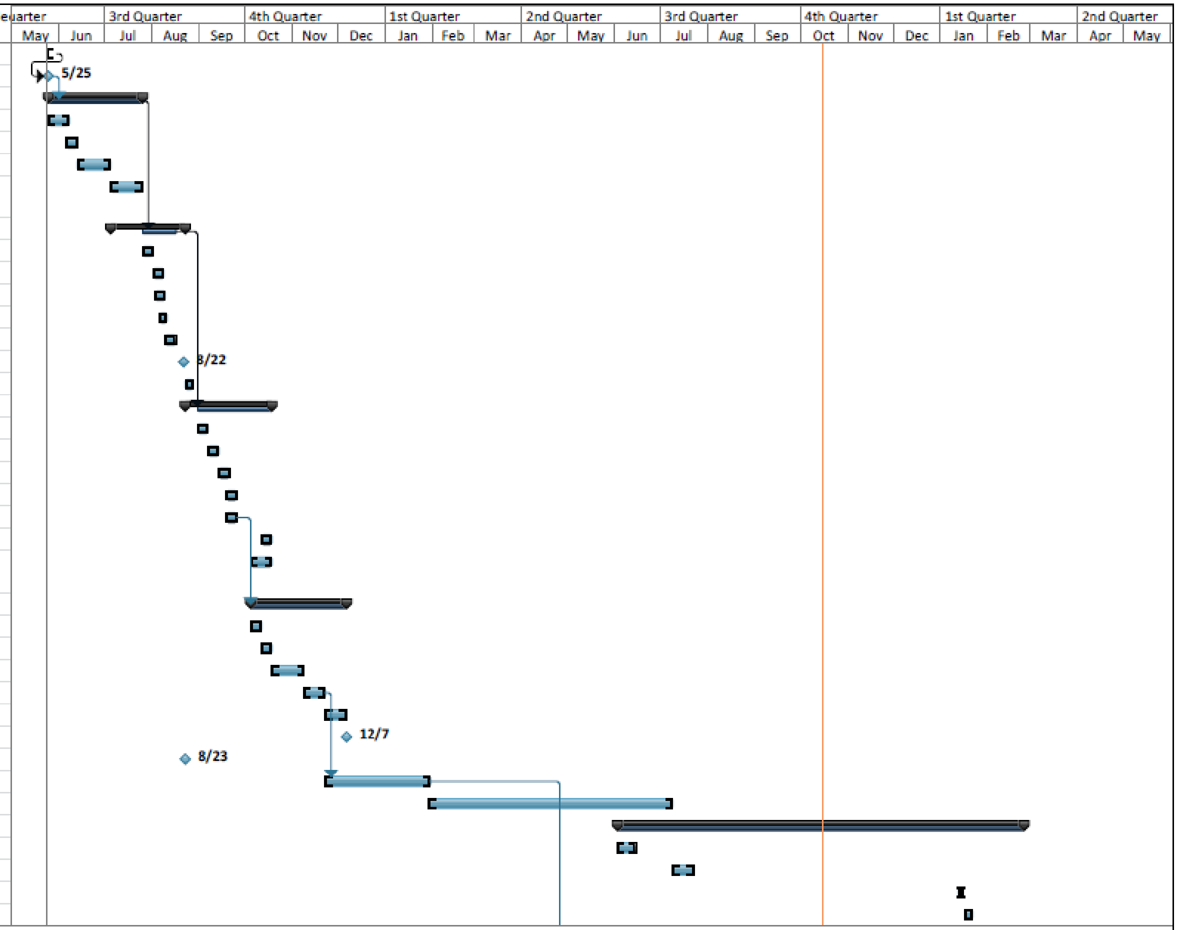
Appendix B: Project Overview

Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	Procurement		Thu 5/24/12		
2	Notice to Proceed	0 days	Fri 5/25/12	Fri 5/25/12	1
3	**Mobilization**	**44 days**	**Fri 5/25/12**	**Wed 7/25/12**	**2**
4	Clark Mobilization	10 days	Fri 5/25/12	Thu 6/7/12	
5	Install Site Fencing	5 days	Wed 6/6/12	Tue 6/12/12	
6	Clearing the Site	16 days	Wed 6/13/12	Wed 7/4/12	
7	Abatement/Demo Building 066	15 days	Thu 7/5/12	Wed 7/25/12	
8	**Sitework**	**35 days**	**Thu 7/5/12**	**Wed 8/22/12**	**3**
9	Grade for Road	5 days	Thu 7/26/12	Wed 8/1/12	
10	Install Road Sub base	5 days	Thu 8/2/12	Wed 8/8/12	
11	Install Curb and Gutter	5 days	Fri 8/3/12	Thu 8/9/12	
12	Install Sidewalks	5 days	Mon 8/6/12	Fri 8/10/12	
13	Fine Grade/ Stabilization	5 days	Fri 8/10/12	Thu 8/16/12	
14	Road Relocation Complete	0 days	Wed 8/22/12	Wed 8/22/12	
15	Install Fencing Part 2	3 days	Thu 8/23/12	Mon 8/27/12	
16	**Excavation**	**41 days**	**Thu 8/23/12**	**Thu 10/18/12**	**8**
17	Survey	5 days	Fri 8/31/12	Thu 9/6/12	
18	Remove/Relocate Sanitary	5 days	Fri 9/7/12	Thu 9/13/12	
19	Drive Piles	5 days	Fri 9/14/12	Thu 9/20/12	
20	Install Fall Protection	5 days	Wed 9/19/12	Tue 9/25/12	
21	Excavate 1st Tier	5 days	Wed 9/19/12	Tue 9/25/12	
22	Excavate 3rd Tier	5 days	Fri 10/12/12	Thu 10/18/12	
23	Prepare Subgrade for GeoPiers	10 days	Fri 10/5/12	Thu 10/18/12	
24	**Foundations**	**45 days**	**Fri 10/5/12**	**Thu 12/6/12**	**21**
25	Moblize GeoPiers	5 days	Fri 10/5/12	Thu 10/11/12	
26	GeoPier Modulus Test	5 days	Fri 10/12/12	Thu 10/18/12	
27	Install West Wing GEoPiers	15 days	Fri 10/19/12	Thu 11/8/12	
28	Install SCUB level GeoPiers	10 days	Fri 11/9/12	Thu 11/22/12	
29	Install East Wing GeoPiers	10 days	Fri 11/23/12	Thu 12/6/12	
30	Phase One Complete	0 days	Fri 12/7/12	Fri 12/7/12	
31	Phase Two Notice to Proceed	0 days	Thu 8/23/12	Thu 8/23/12	
32	SCUB	49 days	Fri 11/23/12	Wed 1/30/13	28
33	Above Grade Structure	114 days	Wed 1/30/13	Mon 7/8/13	
34	**Stair 1**	**191 days**	**Mon 6/3/13**	**Mon 2/24/14**	
35	Install Center Rails	10 days	Mon 6/3/13	Fri 6/14/13	
36	Install Wall Rails	10 days	Tue 7/9/13	Mon 7/22/13	
37	Caulk Stringer	3 days	Mon 1/13/14	Wed 1/15/14	
38	Prime Paint	3 days	Fri 1/17/14	Tue 1/21/14	



Project: TechTwoSchedule
Date: Wed 10/16/13

Task · Split · Milestone · Summary · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Deadline · Progress

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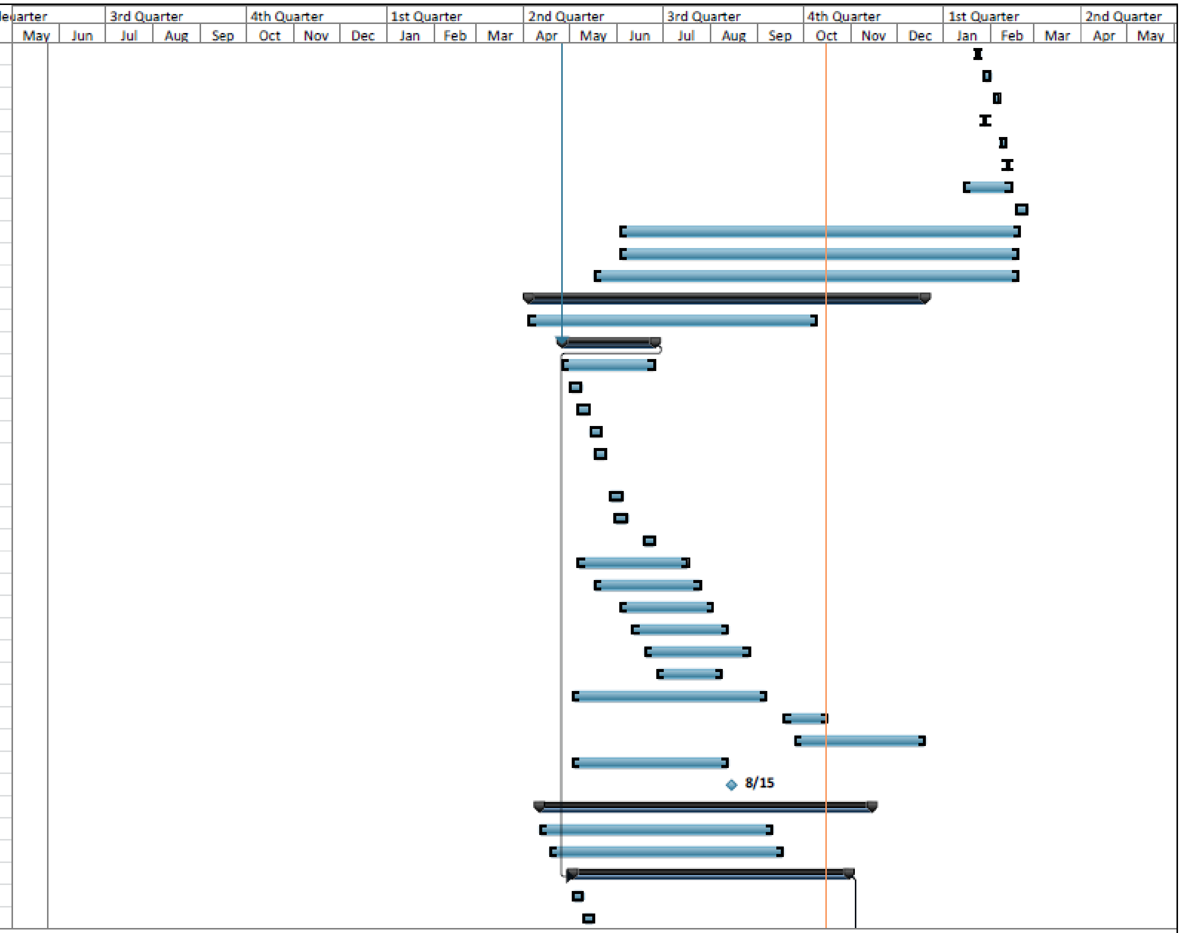
ID	Task Name	Duration	Start	Finish	Predecessors
39	Finish Paint First Coat	3 days	Wed 1/22/14	Fri 1/24/14	
40	Install Lighting Fixtures	5 days	Mon 1/27/14	Fri 1/31/14	
41	Install Fire Alarm Devices	4 days	Mon 2/3/14	Thu 2/6/14	
42	Install Grills	2 days	Mon 1/27/14	Tue 1/28/14	
43	Final Paint	2 days	Fri 2/7/14	Mon 2/10/14	
44	Install Flooring/Treads	2 days	Tue 2/11/14	Wed 2/12/14	
45	Signage	24 days	Tue 1/14/14	Fri 2/14/14	
46	Stair Pressurization Testing	6 days	Mon 2/17/14	Mon 2/24/14	
47	Stair 2	188 days	Mon 6/3/13	Wed 2/19/14	
48	Stair 3&4	187 days	Mon 6/3/13	Tue 2/18/14	
49	Stair 5&6	198 days	Fri 5/17/13	Tue 2/18/14	
50	**Building Envelope**	**186 days**	**Thu 4/4/13**	**Thu 12/19/13**	
51	Ground to Second Floor	135 days	Thu 4/4/13	Wed 10/9/13	
52	**Second Floor**	**43 days**	**Fri 4/26/13**	**Tue 6/25/13**	**32**
53	Exterior Wall Lay Out	43 days	Fri 4/26/13	Tue 6/25/13	
54	Hang Relievign Angles	6 days	Wed 5/1/13	Wed 5/8/13	
55	Exterior Framing	6 days	Mon 5/6/13	Mon 5/13/13	
56	Exterior Sheathing	6 days	Tue 5/14/13	Tue 5/21/13	
57	Set Relievign Angle Flashing	6 days	Fri 5/17/13	Fri 5/24/13	
58	Vapor Barrier/Brick Ties	7 days	Mon 5/27/13	Tue 6/4/13	
59	Brick	7 days	Thu 5/30/13	Fri 6/7/13	
60	Punch Windows	6 days	Tue 6/18/13	Tue 6/25/13	
61	Third Floor	53 days	Mon 5/6/13	Wed 7/17/13	
62	Fourth Floor	50 days	Fri 5/17/13	Thu 7/25/13	
63	Fifth Floor	45 days	Mon 6/3/13	Fri 8/2/13	
64	Sixth Floor	45 days	Tue 6/11/13	Mon 8/12/13	
65	Seventh Floor	49 days	Wed 6/19/13	Mon 8/26/13	
66	Roof Level	31 days	Thu 6/27/13	Thu 8/8/13	
67	Roof Activities	91 days	Fri 5/3/13	Fri 9/6/13	
68	Brick Washdown	21 days	Wed 9/18/13	Wed 10/16/1	
69	Metal Panels	62 days	Wed 9/25/13	Thu 12/19/13	
70	Building MEP	72 days	Fri 5/3/13	Mon 8/12/13	
71	Building Watertight	0 days	Thu 8/15/13	Thu 8/15/13	
72	**Framing and MEP Rough In**	**156 days**	**Thu 4/11/13**	**Thu 11/14/13**	
73	Ground Floor	109 days	Thu 4/11/13	Tue 9/10/13	
74	First Floor	109 days	Thu 4/18/13	Tue 9/17/13	
75	**Second Floor**	**129 days**	**Fri 5/3/13**	**Wed 10/30/1**	**52**
76	Lay Out Interior Walls	5 days	Fri 5/3/13	Thu 5/9/13	
77	Interior CMU	5 days	Fri 5/10/13	Thu 5/16/13	



Project: TechTwoSchedule
Date: Wed 10/16/13

Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Progress

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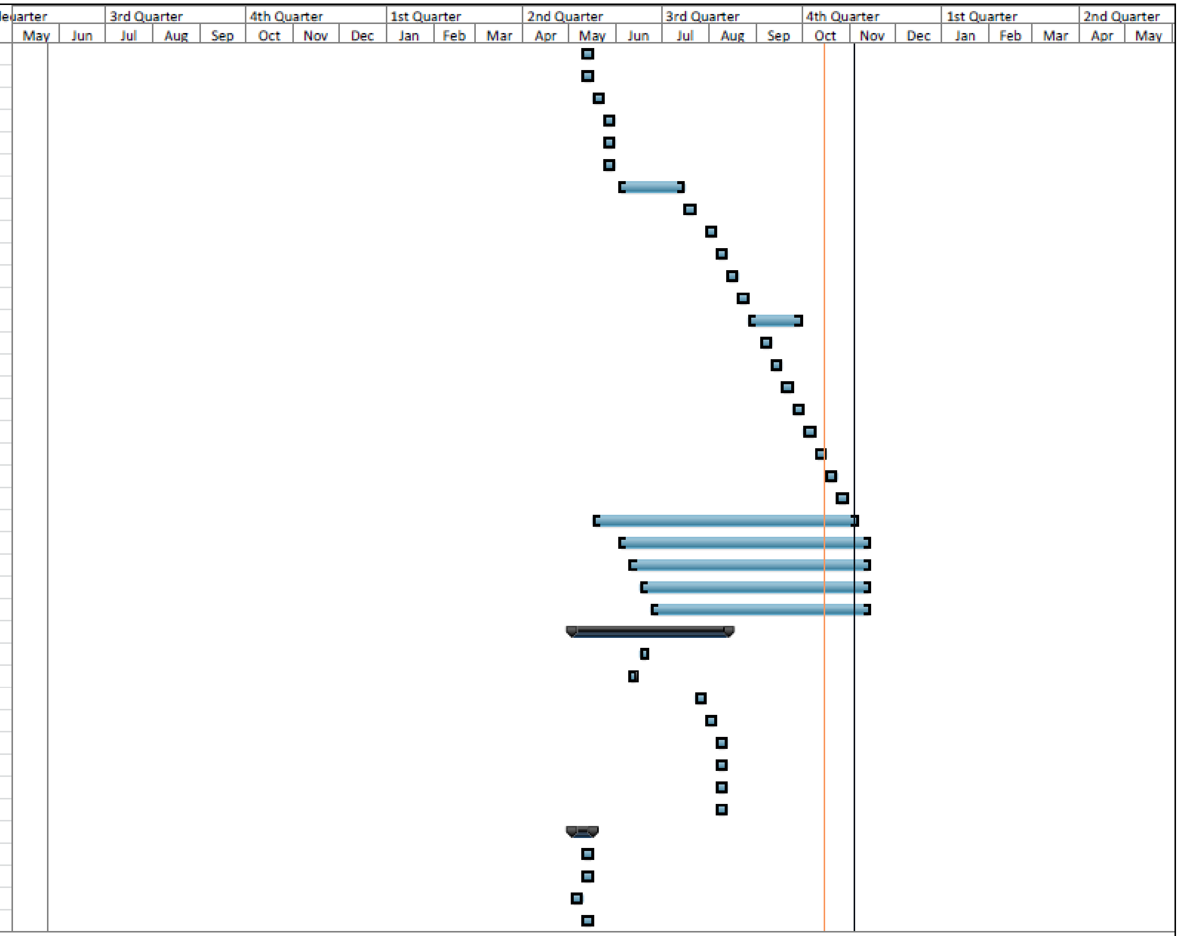
ID	Task Name	Duration	Start	Finish	Predecessors
78	Sprinkler Risers	5 days	Fri 5/10/13	Thu 5/16/13	
79	Plumbing Risers	5 days	Fri 5/10/13	Thu 5/16/13	
80	Mechanical Risers	5 days	Fri 5/17/13	Thu 5/23/13	
81	Duct Risers	5 days	Fri 5/24/13	Thu 5/30/13	
82	Electric Risers	5 days	Fri 5/24/13	Thu 5/30/13	
83	Security/Telecom Risers	5 days	Fri 5/24/13	Thu 5/30/13	
84	Riser Testing	31 days	Mon 6/3/13	Mon 7/15/13	
85	Shaft Walls	5 days	Tue 7/16/13	Mon 7/22/13	
86	Ductwork Rough In	5 days	Tue 7/30/13	Mon 8/5/13	
87	Interior Framing	5 days	Tue 8/6/13	Mon 8/12/13	
88	Blocking	5 days	Tue 8/13/13	Mon 8/19/13	
89	Pre Rock/Set Showers	5 days	Tue 8/20/13	Mon 8/26/13	
90	Plumbing Rough In	25 days	Tue 8/27/13	Mon 9/30/13	
91	Mechanical Rough In	5 days	Wed 9/4/13	Tue 9/10/13	
92	Pipe Insulation	5 days	Wed 9/11/13	Tue 9/17/13	
93	Ceiling Rippers/Framing	5 days	Wed 9/18/13	Tue 9/24/13	
94	Sprinkler Rough In	5 days	Wed 9/25/13	Tue 10/1/13	
95	Electric Rough In	6 days	Wed 10/2/13	Wed 10/9/13	
96	Low Voltage Rough In	5 days	Thu 10/10/13	Wed 10/16/1	
97	Rough in Inspections	5 days	Thu 10/17/13	Wed 10/23/1	
98	Insulation	5 days	Thu 10/24/13	Wed 10/30/1	
99	Third Floor	124 days	Fri 5/17/13	Wed 11/6/13	
100	Fourth Floor	119 days	Mon 6/3/13	Thu 11/14/13	
101	Fifth Floor	114 days	Mon 6/10/13	Thu 11/14/13	
102	Sixth Floor	109 days	Mon 6/17/13	Thu 11/14/13	
103	Seventh Floor	104 days	Mon 6/24/13	Thu 11/14/13	
104	**MEP Equipment**	**73 days**	**Fri 5/3/13**	**Tue 8/13/13**	
105	Ground Floor	5 days	Mon 6/17/13	Fri 6/21/13	
106	First Floor	5 days	Mon 6/10/13	Fri 6/14/13	
107	Second Floor	5 days	Tue 7/23/13	Mon 7/29/13	
108	Third Floor	5 days	Tue 7/30/13	Mon 8/5/13	
109	Fourth Floor	5 days	Tue 8/6/13	Mon 8/12/13	
110	Fifth Floor	5 days	Tue 8/6/13	Mon 8/12/13	
111	Sixth Floor	5 days	Tue 8/6/13	Mon 8/12/13	
112	Seventh Floor	5 days	Tue 8/6/13	Mon 8/12/13	
113	**Roof Activities**	**10 days**	**Fri 5/3/13**	**Thu 5/16/13**	
114	Set Cooling Tower	5 days	Fri 5/10/13	Thu 5/16/13	
115	Set Emegency Generator	5 days	Fri 5/10/13	Thu 5/16/13	
116	Set Fan Curbs/Fans	5 days	Fri 5/3/13	Thu 5/9/13	
117	Set Rooftop Units	5 days	Fri 5/10/13	Thu 5/16/13	



Project: TechTwoSchedule
Date: Wed 10/16/13

Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only
Deadline	Progress		

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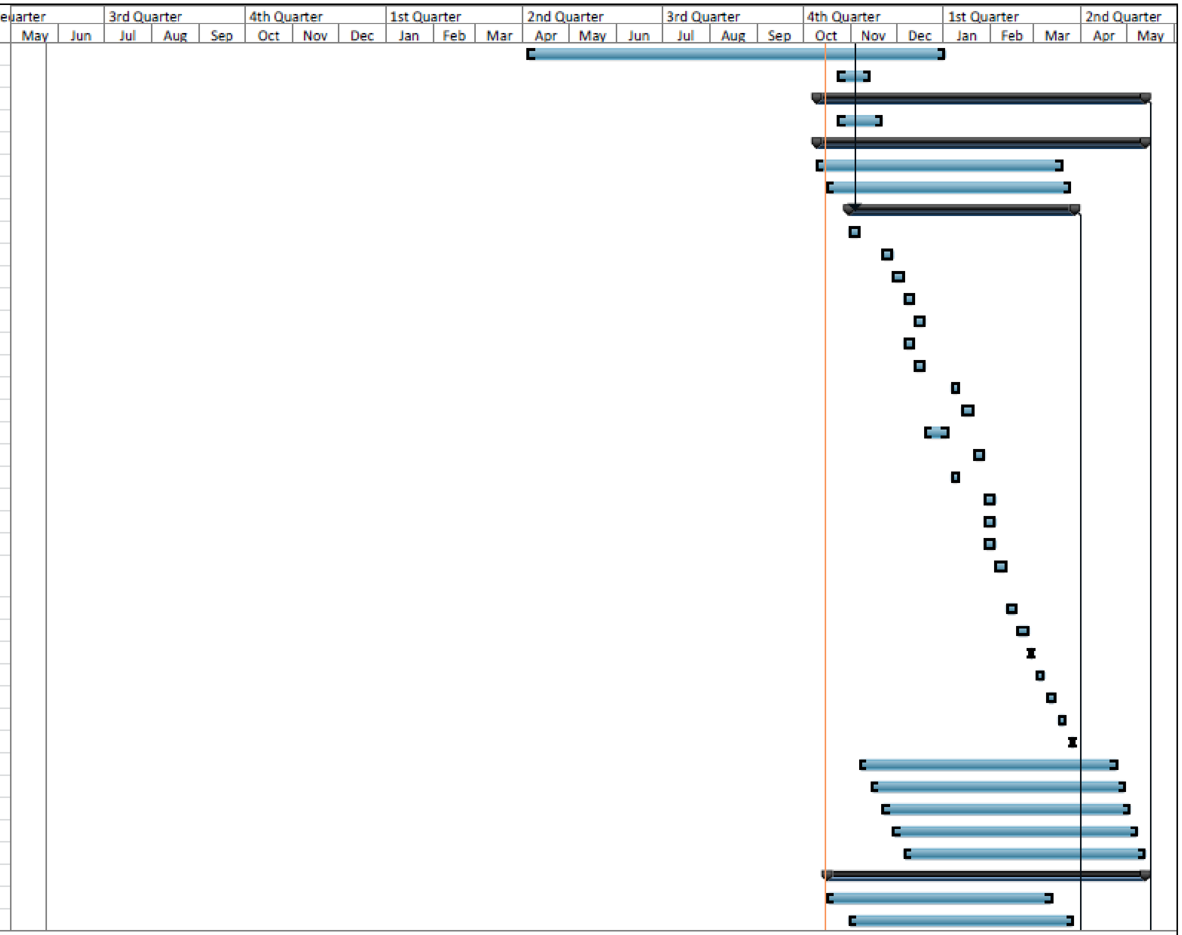
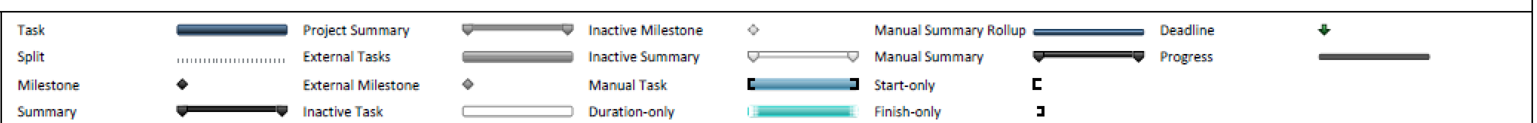
ID	Task Name	Duration	Start	Finish	Predecessors
118	Scub MEP Equipment	195 days	Thu 4/4/13	Wed 1/1/14	
119	SCUB Finishes	15 days	Thu 10/24/13	Wed 11/13/1:	
120	**Finishes**	**153 days**	**Thu 10/10/13**	**Mon 5/12/14**	
121	SCUB Level	21 days	Thu 10/24/13	Thu 11/21/13	
122	**Common Areas**	**153 days**	**Thu 10/10/13**	**Mon 5/12/14**	
123	Ground Floor	115 days	Thu 10/10/13	Wed 3/19/14	
124	First Floor	113 days	Thu 10/17/13	Mon 3/24/14	
125	**Second Floor**	**106 days**	**Thu 10/31/13**	**Thu 3/27/14**	**75**
126	Hang Drywall	5 days	Thu 10/31/13	Wed 11/6/13	
127	Finish Drywall	5 days	Fri 11/22/13	Thu 11/28/13	
128	Prime Paint	5 days	Fri 11/29/13	Thu 12/5/13	
129	Point Up	5 days	Fri 12/6/13	Thu 12/12/13	
130	Finish Paint	5 days	Fri 12/13/13	Thu 12/19/13	
131	Waterproof Baths	5 days	Fri 12/6/13	Thu 12/12/13	
132	Install Bath Tile	5 days	Fri 12/13/13	Thu 12/19/13	
133	ACT Rough In	5 days	Mon 1/6/14	Fri 1/10/14	
134	Overhead Inspections	6 days	Mon 1/13/14	Mon 1/20/14	
135	Install Vanity Tops	11 days	Fri 12/20/13	Fri 1/3/14	
136	Install ACT Tile	5 days	Tue 1/21/14	Mon 1/27/14	
137	Plumbing Fixtures	5 days	Mon 1/6/14	Fri 1/10/14	
138	Electric Trim Out	5 days	Tue 1/28/14	Mon 2/3/14	
139	Mechanical Trim Out	5 days	Tue 1/28/14	Mon 2/3/14	
140	Sprinkler Trim Out	5 days	Tue 1/28/14	Mon 2/3/14	
141	Bath Accessories/ Shelving	5 days	Tue 2/4/14	Mon 2/10/14	
142	Doors/ Hardware	5 days	Tue 2/11/14	Mon 2/17/14	
143	Rough Punch	6 days	Tue 2/18/14	Tue 2/25/14	
144	Rough Clean	3 days	Wed 2/26/14	Fri 2/28/14	
145	Final Paint	5 days	Mon 3/3/14	Fri 3/7/14	
146	Carpet	5 days	Mon 3/10/14	Fri 3/14/14	
147	Final Punch	5 days	Mon 3/17/14	Fri 3/21/14	
148	Final Clean	3 days	Tue 3/25/14	Thu 3/27/14	
149	Third Floor	121 days	Thu 11/7/13	Thu 4/24/14	
150	Fourth Floor	118 days	Fri 11/15/13	Tue 4/29/14	
151	Fifth Floor	116 days	Fri 11/22/13	Fri 5/2/14	
152	Sixth Floor	114 days	Fri 11/29/13	Wed 5/7/14	
153	Seventh Floor	112 days	Fri 12/6/13	Mon 5/12/14	
154	**Living Areas**	**148 days**	**Thu 10/17/13**	**Mon 5/12/14**	
155	First Floor	105 days	Thu 10/17/13	Wed 3/12/14	
156	Second Floor	105 days	Thu 10/31/13	Wed 3/26/14	



Project: TechTwoSchedule
Date: Wed 10/16/13



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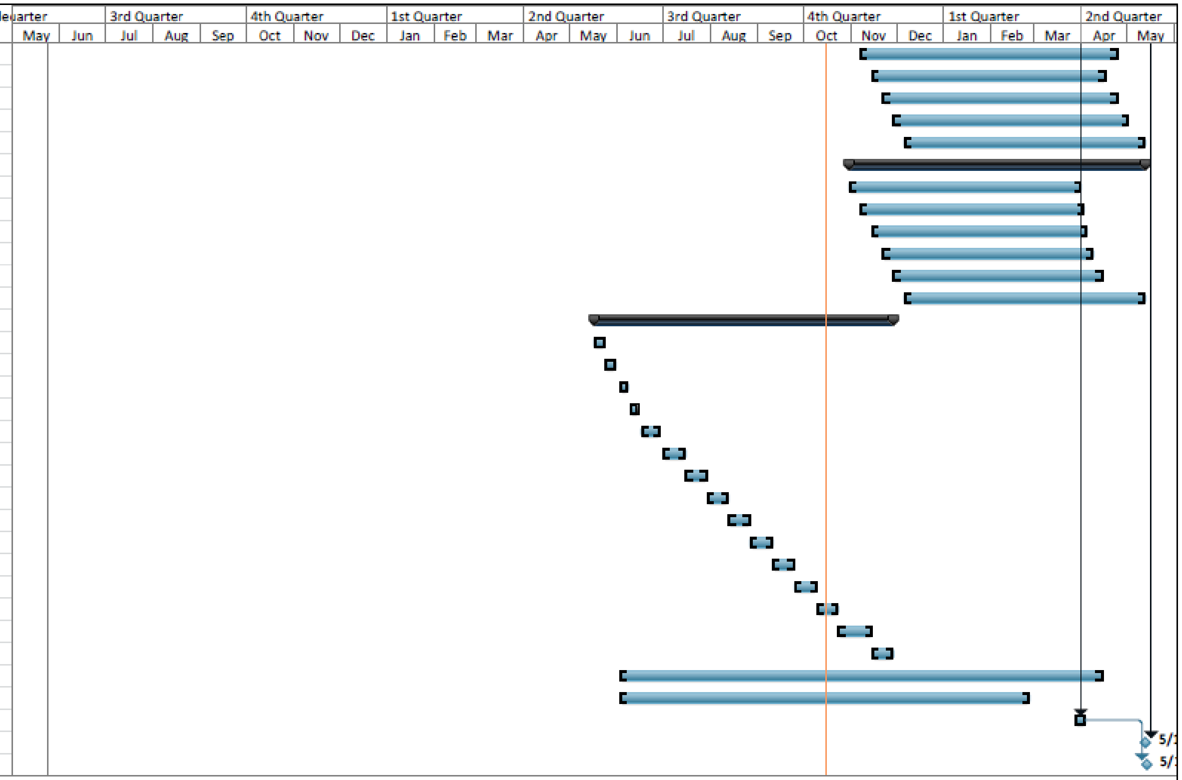
ID	Task Name	Duration	Start	Finish	Predecessors
157	Third Floor	121 days	Thu 11/7/13	Thu 4/24/14	
158	Fourth Floor	109 days	Fri 11/15/13	Wed 4/16/14	
159	Fifth Floor	110 days	Fri 11/22/13	Thu 4/24/14	
160	Sixth Floor	110 days	Fri 11/29/13	Thu 5/1/14	
161	Seventh Floor	112 days	Fri 12/6/13	Mon 5/12/14	
162	**Corridors**	**138 days**	**Thu 10/31/13**	**Mon 5/12/14**	
163	Second Floor	108 days	Thu 10/31/13	Mon 3/31/14	
164	Third Floor	105 days	Thu 11/7/13	Wed 4/2/14	
165	Fourth Floor	101 days	Fri 11/15/13	Fri 4/4/14	
166	Fifth Floor	98 days	Fri 11/22/13	Tue 4/8/14	
167	Sixth Floor	97 days	Fri 11/29/13	Mon 4/14/14	
168	Seventh Floor	112 days	Fri 12/6/13	Mon 5/12/14	
169	**Elevators 4-5**	**140 days**	**Fri 5/17/13**	**Thu 11/28/13**	
170	Hoistway Dried In	5 days	Fri 5/17/13	Thu 5/23/13	
171	Control Room Ready	5 days	Fri 5/24/13	Thu 5/30/13	
172	Power Ready	5 days	Mon 6/3/13	Fri 6/7/13	
173	Mobilise Elevators	5 days	Mon 6/10/13	Fri 6/14/13	
174	Install Rails/Platforms	10 days	Mon 6/17/13	Fri 6/28/13	
175	Install Door Frames	11 days	Mon 7/1/13	Mon 7/15/13	
176	Grout Sills	10 days	Tue 7/16/13	Mon 7/29/13	
177	Close in Elevator Fronts	10 days	Tue 7/30/13	Mon 8/12/13	
178	Install Doors	10 days	Tue 8/13/13	Mon 8/26/13	
179	Hoistway Wiring	11 days	Tue 8/27/13	Tue 9/10/13	
180	Call Buttons/Lanterns	10 days	Wed 9/11/13	Tue 9/24/13	
181	Build Cabs	11 days	Wed 9/25/13	Wed 10/9/13	
182	Adjusting	10 days	Thu 10/10/13	Wed 10/23/1:	
183	Third Party Inspection	16 days	Thu 10/24/13	Thu 11/14/13	
184	State Inspection	10 days	Fri 11/15/13	Thu 11/28/13	
185	Elevators 1-3	226 days	Mon 6/3/13	Mon 4/14/14	
186	Final Sitework	192 days	Mon 6/3/13	Tue 2/25/14	
187	Inspections	5 days	Fri 3/28/14	Thu 4/3/14	125
188	Building Finish	0 days	Tue 5/13/14	Tue 5/13/14	120
189	Occupancy	0 days	Wed 5/14/14	Wed 5/14/14	187



Project: TechTwoSchedule
Date: Wed 10/16/13

Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Progress

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LEED Credits

Prince Frederick Hall

University of Maryland, College Park, MD 20742

LEED for New Construction v2009 Scorecard

June 24, 2013

Prepared by EMO Energy Solutions

Total Score: Yes 63 | ? 8 | No 39 — **Certified:** 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80+ points

(blue) = LEED Online documention is complete.

Sustainable Sites — 26 Points (Yes 21 | ? 1 | No 4)

Yes	?	No		Credit	Description	Points
Y			C	Prereq 1	**Construction Activity Pollution Prevention**	Required
1			D	Credit 1	**Site Selection**	1
5			D	Credit 2	**Development Density & Community Connectivity**	5
		1	D	Credit 3	**Brownfield Redevelopment**	1
6			D	Credit 4.1	**Alternative Transportation:** Public Transportation Access	6
1			D	Credit 4.2	**Alternative Transportation:** Bicycle Storage & Changing Rooms	1
3			D	Credit 4.3	**Alternative Transportation:** Low-Emitting & Fuel-Eff. Vehicles	3
2			D	Credit 4.4	**Alternative Transportation:** Parking Capacity	2
		1	C	Credit 5.1	**Site Development:** Protect or Restore Habitat	1
1			D	Credit 5.2	**Site Development:** Maximize Open Space	1
1			D	Credit 6.1	**Stormwater Design:** Quantity Control	1
		1	D	Credit 6.2	**Stormwater Design:** Quality Control	1
	1		C	Credit 7.1	**Heat Island Effect**, Non-Roof	1
1			D	Credit 7.2	**Heat Island Effect**, Roof	1
		1	D	Credit 8	**Light Pollution Reduction**	1

Water Efficiency — 10 Points (Yes 4 | ? 2 | No 4)

Yes	?	No		Credit	Description	Points
Y			D	Prereq 1	**Water Use Reduction**, 20% Reduction	Required
	2		D	Credit 1.1	**Water Efficient Landscaping:** Reduce by 50%	2
		2	D	Credit 1.2	**Water Efficient Landscaping:** No Potable Use or No Irrigation	2
		2	D	Credit 2	**Innovative Wastewater Technologies**	2
4			D	Credit 3	**Water Use Reduction**	2 to 4
					30% Reduction	2
					35% Reduction	3
					4 — 40% Reduction (43%)	4

Energy & Atmosphere — 35 Points (Yes 13 | ? 2 | No 20)

Yes	?	No		Credit	Description	Points
Y			C	Prereq 1	**Fundamental Commissioning of Energy Systems**	Required
Y				Prereq 2	**Minimum Energy Performance**	Required
Y				Prereq 3	**Fundamental Refrigerant Management**	Required
6		13		Credit 1	**Optimize Energy Performance**	1 to 19
					12% New Buildings or 8% Existing Building Renovations	1
					14% New Buildings or 10% Existing Building Renovations	2
					16% New Buildings or 12% Existing Building Renovations	3
					18% New Buildings or 14% Existing Building Renovations	4
					20% New Buildings or 16% Existing Building Renovations	5
					6 — 22% New Buildings or 18% Existing Building Renovations	6
					24% New Buildings or 20% Existing Building Renovations	7
					26% New Buildings or 22% Existing Building Renovations	8
					28% New Buildings or 24% Existing Building Renovations	9
					30% New Buildings or 26% Existing Building Renovations	10
					32% New Buildings or 28% Existing Building Renovations	11
					34% New Buildings or 30% Existing Building Renovations	12
					36% New Buildings or 32% Existing Building Renovations	13
					38% New Buildings or 34% Existing Building Renovations	14
					40% New Buildings or 36% Existing Building Renovations	15
		7		Credit 2	**On-Site Renewable Energy**	1 to 7
2			C	Credit 3	**Enhanced Commissioning**	2
2				Credit 4	**Enhanced Refrigerant Management**	2
1	2		C	Credit 5	**Measurement & Verification**	3
2			C	Credit 6	**Green Power**	2

Materials & Resources — 14 Points (Yes 4 | ? 2 | No 8)

Yes	?	No		Credit	Description	Points
Y			D	Prereq 1	**Storage & Collection of Recyclables**	Required
		3	C	Credit 1	**Building Reuse, Maintain Existing Walls Floors & Roof**	1 to 3
				Credit 1.1	55% Existing Walls Floors & Roof	1
				Credit 1.2	75% Existing Walls Floors & Roof	2
				Credit 1.3	95% Existing Walls Floors & Roof	3
		1	C	Credit 1.4	**Building Reuse, Maintain 50% Interior Non-Structural Elements**	1
1			C	Credit 2.1	**Construction Waste Management:** Divert 50% from Disposal	1
1			C	Credit 2.2	**Construction Waste Management:** Divert 75% from Disposal	1
		1	C	Credit 3.1	**Materials Reuse:** 5%	1
		1	C	Credit 3.2	**Materials Reuse:** 10%	1
1			C	Credit 4.1	**Recycled Content:** 10% (post-consumer + ½ pre-consumer)	1
	1		C	Credit 4.2	**Recycled Content:** 20% (post-consumer + ½ pre-consumer)	1
1			C	Credit 5.1	**Regional Materials:** 10% Extracted, Processed & Manufactured Regionall	1
	1		C	Credit 5.2	**Regional Materials:** 20% Extracted, Processed & Manufactured Regionall	1
		1	C	Credit 6	**Rapidly Renewable Materials**	1
		1	C	Credit 7	**Certified Wood**	1

Indoor Environmental Quality — 15 Points (Yes 12 | ? 1 | No 2)

Yes	?	No		Credit	Description	Points
Y			D	Prereq 1	**Minimum IAQ Performance**	Required
Y			D	Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
1			D	Credit 1	**Outdoor Air Delivery Monitoring**	1
1			D	Credit 2	**Increased Ventilation**	1
1				Credit 3.1	**Construction IAQ Management Plan:** During Construction	1
	1			Credit 3.2	**Construction IAQ Management Plan:** Before Occupancy	1
1				Credit 4.1	**Low-Emitting Materials:** Adhesives & Sealants	1
1				Credit 4.2	**Low-Emitting Materials:** Paints & Coatings	1
1				Credit 4.3	**Low-Emitting Materials:** Flooring Systems	1
1				Credit 4.4	**Low-Emitting Materials:** Composite Wood & Agrifiber Products	1
1			D	Credit 5	**Indoor Chemical Pollutant & Source Control**	1
1			D	Credit 6.1	**Controllability of Systems:** Lighting	1
		1	D	Credit 6.2	**Controllability of Systems:** Thermal Comfort	1
1			D	Credit 7.1	**Thermal Comfort:** Design	1
1			D	Credit 7.2	**Thermal Comfort:** Verification	1
		1	D	Credit 8.1	**Daylight & Views:** Daylight 75% of Spaces	1
1			D	Credit 8.2	**Daylight & Views:** Views for 90% of Spaces	1

Innovation & Design Process — 6 Points (Yes 6 | ? 0 | No 0)

Yes	?	No		Credit	Description	Points
1			D	Credit 1.1	**Innovation in Design:** SSc5.2 Open Space exemplary performance	1
1			C	Credit 1.2	**Innovation in Design:** Green Cleaning Program	1
1			C	Credit 1.3	**Innovation in Design:** Integrated Pest Management	1
1			C	Credit 1.4	**Innovation in Design:** Transportation Demand Management Plan	1
1			C	Credit 1.5	**Innovation in Design:** 70% green power or 35% on a 4-year contract	1
1			C	Credit 2	**LEED® Accredited Professional**	1

Regional Priority Credits — 4 Points (Yes 3 | ? 0 | No 1)

Available: SSc6.1, WEc2, WEc3 (40%), EAc2 (1%), MRc1.1 (55%), MRc2 (50%)

Yes	?	No		Credit	Description	Points
1				Credit 1.1	**Regional Priority Credit:** MRc2(50%)	1
1				Credit 1.2	**Regional Priority Credit:** SSc6.1	1
1				Credit 1.3	**Regional Priority Credit:** WEc3(40%)	1
		1		Credit 1.4	**Regional Priority Credit:** EAc2 (1%)	1

Appendix C: Infinity Structural System

Assumptions

- Foundations remain Concrete
- Infinity Structural System Begins at 2nd Floor
- Infinity Panel Walls and ISP are cost equivalent to Load Bearing Metal Stud Framing: 05 41 13.305110.
- Epicore Decking is cost comparable to Steel Floor Decking: 05 31 13.505200.

Calculations:

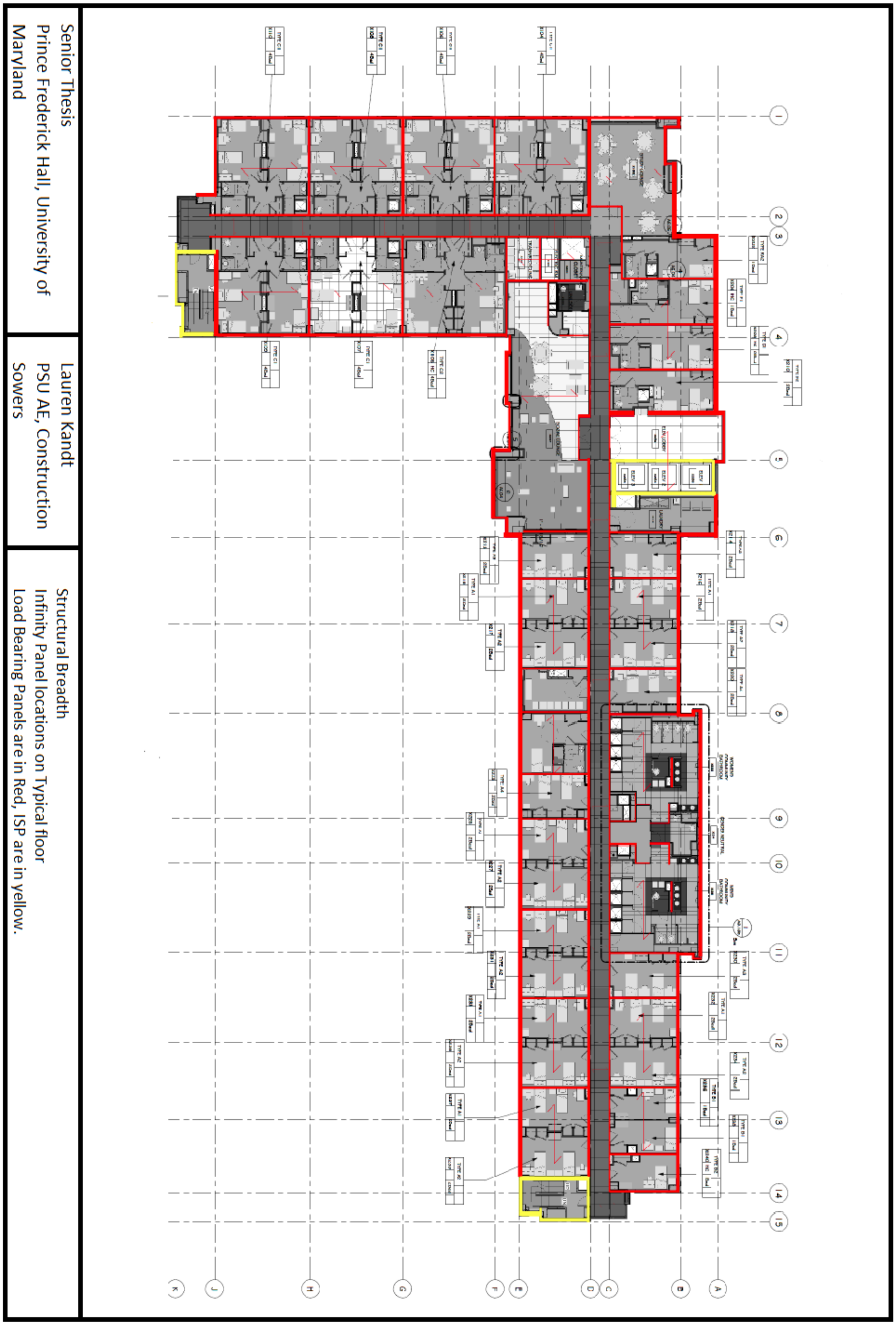
Duration

- (Prince Frederick Days/ Floor) = (Prince Frederick Floor Area)*(Shafer&Grace Days/Floor)/(Shafer&Grace Floor Area)
- Infinity Duration = (Prince Frederick Days/Floor) * 6 Floors
- Duration Difference = Cast-In-Place Duration – Infinity Duration

Other

Duration Estimates					
Project	Floor Area	Days/ Floor		Structural Durations (2-7 floors)	
Shafer and Grace	14000	9		Cast-In-Place	114 days
Prince Frederick Hall	22512	15		Infinity	90 days
				Duration Difference	24 days

Cost Comparison between Concrete Columns/Decking and Infinity Panels/Decking										
Floor 4 only										
	#	unit	Material/Unit	Material Total	Labor/ Unit	Labor Total	Equipment/ Unit	Equipment total	Total plus O&P	Total
Infinity Panels	2507.02	LF	$ 11.30	$ 28,329.33	$ 13.05	$32,716.61	$ -	$ -	$ 32.50	$ 81,478.15
ISP	223.2	LF	$ 11.30	$ 2,522.16	$ 13.05	$ 2,912.76	$ -	$ -	$ 32.50	$ 7,254.00
EPICOR Metal Decking	22512	SF	$ 1.65	$ 37,144.80	$ 0.41	$ 9,229.92	$ 0.03	$ 675.36	$ 2.59	$ 58,306.08
Rebar	6	Ton	$ 1,050.00	$ 6,300.00	$ 540.00	$ 3,240.00	$ -	$ -	$ 2,025.00	$ 12,150.00
Concrete	22512	SF	$ 1.97	$ 44,348.64	$ 0.85	$19,135.20	$ 0.28	$ 6,303.36	$ 3.75	$ 84,420.00
Totals:			Material	$ 118,644.93	Labor	$67,234.49	Equipment	$ 6,978.72	Grand Total	$243,608.23
								Original Cost 4th floor Concrete		$377,000.00
								Difference		$133,391.77


Senior Thesis
Prince Frederick Hall, University of Maryland
Lauren Kandt
PSU AE, Construction
Sowers
Structural Breadth
Infinity Panel locations on Typical floor
Load Bearing Panels are in Red, ISP are in yellow.

Appendix D: Structural Breadth

Assumptions

Regular weight concrete – 150 lb/cuft

Concrete Compressive Strength = 4000 lbs.sqin

EPICORE STEE min yield = 45000 lb/sqin

Reinforcing Rebar Steel minimum yield = 60000 b/sqin

Gauge of MRS deck = 22

Calculations

Design Loads

- Slab Weight = Concrt Weight * (Slab Depth – Deck Depth + Concrete Overrun)= Wc
- Total Load = LL + DL = w
- Ultimate Load = 1.7LL + 1.4DL

Deflection Check

- $E_c = (Wc)^{1.5}(33)*f'c^{.5}$
- I_{eff} =299.3 in^4/ft
- $Defl_{max}=[0084*w*L^4(1728)] / (E_c * I_{eff})$
- $Defl_{lim}$ = L/360

Shear Check

- $d = t - y_o$
- d_1 = t – cover – (bar diameter/2)

Flexural Shear

- $V = (1.15*w*L) / (2 – w*d_1)$
- V_o= V/.85
- $V_u = V_o/ (b*d_1)$
- $V_c = 2*f'c^{.5}$

Flexural Reinforcement

- Positive Steel Area Check

- $w*L^2/ 11 = .9[A_s*F_y*d_1 – (A_s^2 *F_y^2) /(2*b*.85*f'c)]$
- Negative Area Steel Check
- $w*L^2/ 9 = .9[A_s*F_y*d_1 – (A_s^2 *F_y^2) /(2*b*.85*f'c)]$
- Minimum Reinforcement = .3*L/12

Flexural Shear Bond

- $u = w*L/[7.5*1.7(d– (A_s *F_y) /(2*b*.85*f'c)]$

Other

Appendix E: Grey Water

Assumptions:

- Pipes are Copper, L Tubing
- 4” copper for Risers
- Student population has perfect gender split
- Bathroom Fixtures are assumed a 50/50 gender split when unassigned
- Housekeeping and washing machine plumbing will be excluded from greywater system due to chemicals in waste water

Calculations:

Rainfall

- (SF Roof) * (Avg. Annual Rainfall) = Avg Annual Rainwater Collected
- 1ft *1ft * (44in/12in) = 37ft^3
- (37ft^3) * 7.48 = 276.76 Gallons/sf

Risers

- Total Risers = (# risers for Greywater in a set group) * (# of Repeats on Floor)
- (LF Pipe) = (# total Risers) * (Bld. Height)
- Material Total Cost = (Cost/LF) * (LF Pipe)

Water Use Estimates

- (#/Floor 2-7) = (#/ Floor) * 6
- (Students/ Floor 2-7) = (# Students) * 6
- (Gallon/Day/Student) = (Unit/Day/Student)*(Gallon/Unit)
- (Gallon/Day) = (Gallon/Day/Student)*(# Student/ Floor 2-7)
- (Annual Gallons) = (Gallon/Day) * 365
- Rainwater adjusted building total = (Original Total) – (Rainwater Collected)

- Greywater Reuse = (Gallons from toilets & urinals Floor 2-7) +(Gallons from toilets and urinals Floor 1)
- Second Adjusted Total = (Original Total) – (Greywater Reuse)

Other

- Total Students = (# students/Floor 2-7) + (# student / Floor 1)

Graphs

Water Use Estimates								
Per Floors 2-7								
Toilets		# units	# of students	Flush per day/student	Gallons per flush	Gallons/day/student	Gallons per day	Gallons per year
Toilet	Female	12	38	3	1.6	4.8	182.4	66576
	Male	10	38	0.5	1.6	0.8	30.4	11096
Urinal	Male	2	38	2.5	1	2.5	95	34675
Other		# units	# of students	minutes/day/student	avg. gallons/minute	Gallons/day/student	Gallons per day	Gallons per year
Sinks	Female	16	38	5	2.2	11	418	152570
	Male	16	38	5	2.2	11	418	152570
Showers	Female	10	38	10	1.5	15	570	208050
	Male	10	38	5	1.5	7.5	285	104025
Per Floor 1								
Toilets		# units	# of students	Flush per day	Gallons per flush	Gallons/day/student	Gallons per day	Gallons per year
Toilet	Female	7	4	3	1.6	4.8	19.2	7008
	Male	6	4	0.5	1.6	0.8	3.2	1168
Urinal	Male	1	4	2.5	1	2.5	10	3650
Other		# units	# of students	minutes/day/student	avg. gallons/minute	Gallons/day/student	Gallons per day	Gallons per year
Sinks	Female	6	4	5	2.2	11	44	16060
	Male	6	4	5	2.2	11	44	16060
Showers	Female	3	4	10	1.5	15	60	21900
	Male	3	4	5	1.5	7.5	30	10950
							Gallons per day	Gallons per Year
						Building Totals	12203.2	4454168

Students			
	Total	Female	Male
Per Floor (2-7)	76	38	38
Floor (1)	8	4	4
Total Building	388	194	194

Total Fixtures Per Floor (2-7)		
Shower	Womans	4
	Mens	4
	Unassigned	12
Stall	Womans	5
	Mens	3
	Unassigned	14
Sink	Womans	5
	Mens	5
	Unassigned	22
Urinals		2
Total Fixtures Per Floor (1)		
Shower	Unassigned	6
Stall	Womens	4
	Mens	2
	Unassigned	7
Sink	Womens	3
	Mens	2
	Unassigned	7
Urinals		1

Estimated Annual Rainfall Collected			
Gross SF of Roof	Avg. Rainfall (in/sqft)	Avg Rainfall (Gallons/sf)	Avg Rain Collected (Gallons)
1974	44	276.76	546324.24

Initial Results		
	Gallons	
	Per Day	Per Year
Origninal Building Totals	12203.2	4454168
Rainwater Collected		546324
Adjusted Building Total		3907844
Greywater Reuse	1879.2	685908
Adjusted Building Total	10324	3768260

Rough Estimate Risers Material Cost							
	Bld Height (ft)	# Risers Grey	# Repeats	# total Risers	LF Pipe	Cost/LF	Material Total Cost
Communal Bathroom	100	1	2	2	200	99	19800
Individual Bathrooms	100	2	16	32	3200	99	316800

Estimated Greywater Source and Use											
Source		#/floor	#/Floors 2-7	# Students	Students/ Floors 2-7	Unit /Day/Student	Unit	Gallons/Unit	Gallon/Day/Student	Gallon/Day	Gallon/Year
Sink	Female	3	18	22	132	5	Minutes	2.2	11	1452	529980
	Male	3	18	22	132	5	Minutes	2.2	11	1452	529980
Shower	Female	4	24	22	132	10	Minutes	1.5	15	1980	722700
	Male	4	24	22	132	5	Minutes	1.5	7.5	990	361350
									Total Sink Greywater		1059960
									Total Shower Greywater		1084050
									Total Source Greywater		2144010
Use											
Toilets	Female	4	24	22	132	3	Flush	1.6	4.8	633.6	231264
	Male	2	12	22	132	0.5	Flush	1.6	0.8	105.6	38544
Urinals	Male	2	12	22	132	2.5	Flush	1	2.5	330	120450
									Total Used Greywater		390258

Other

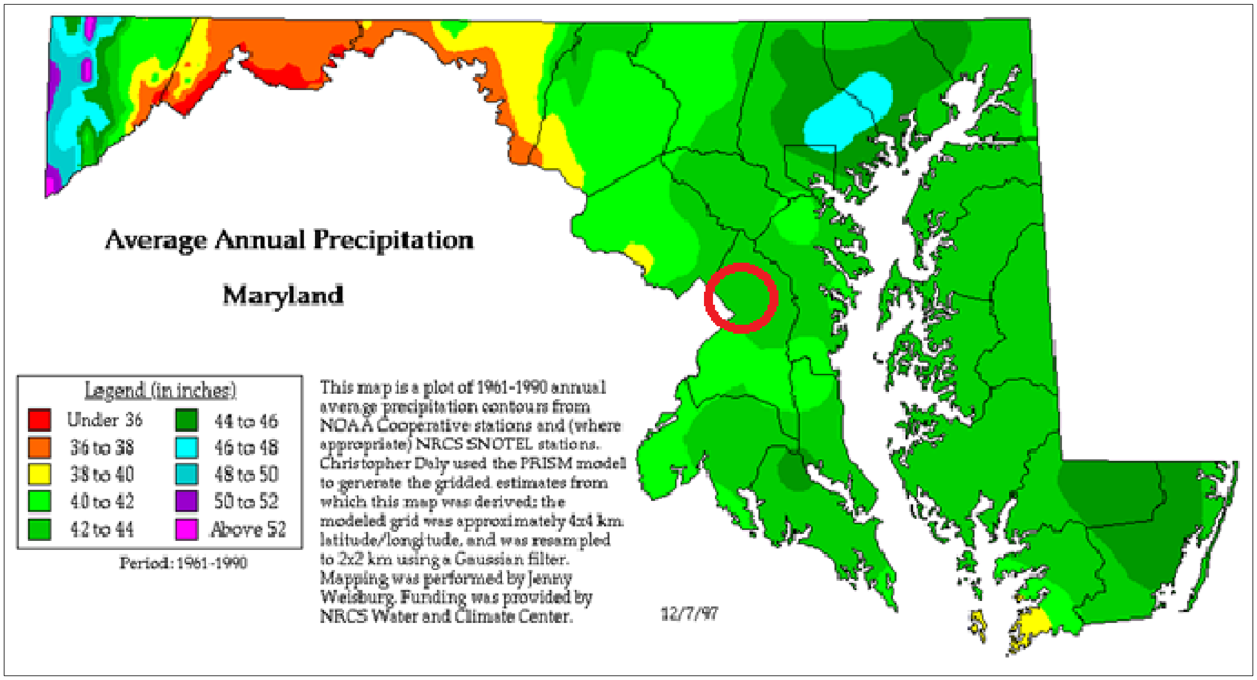
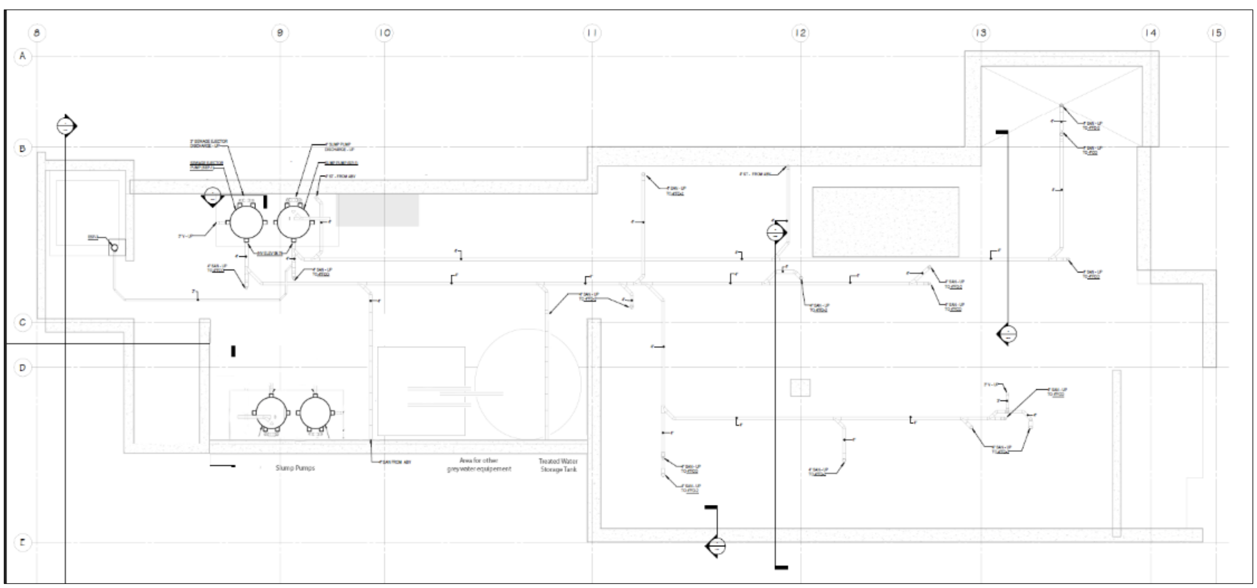
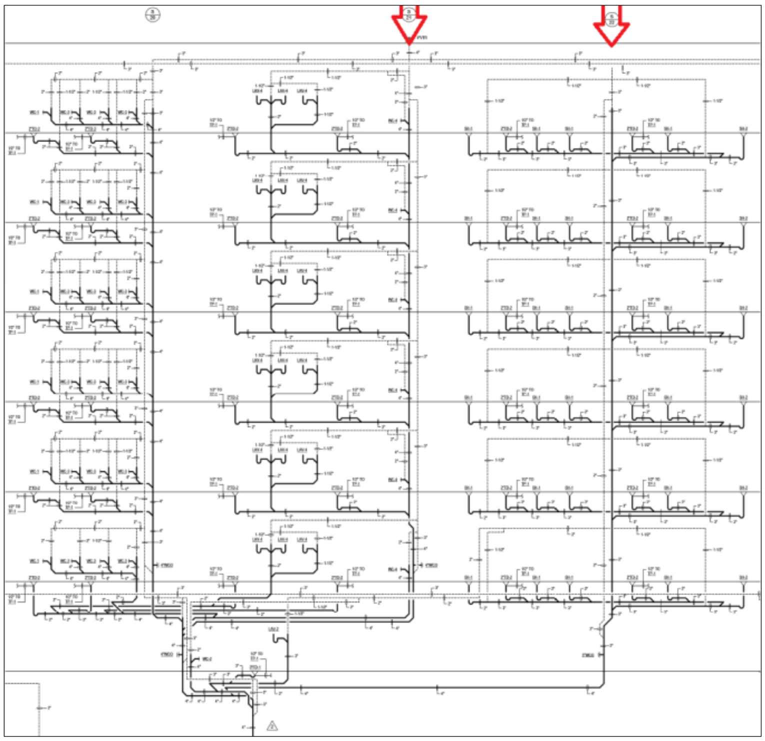
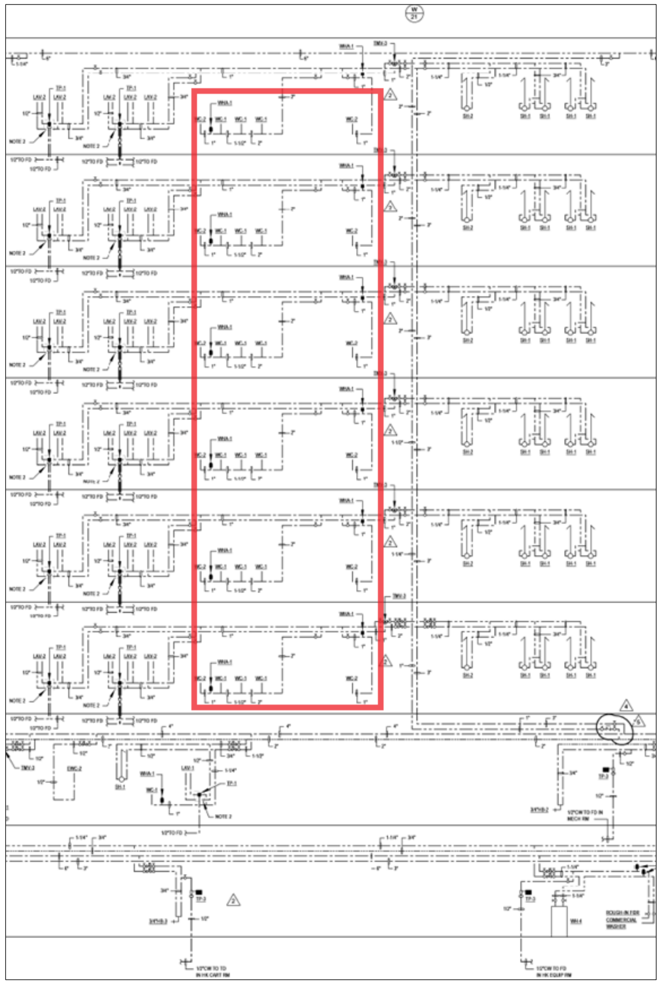


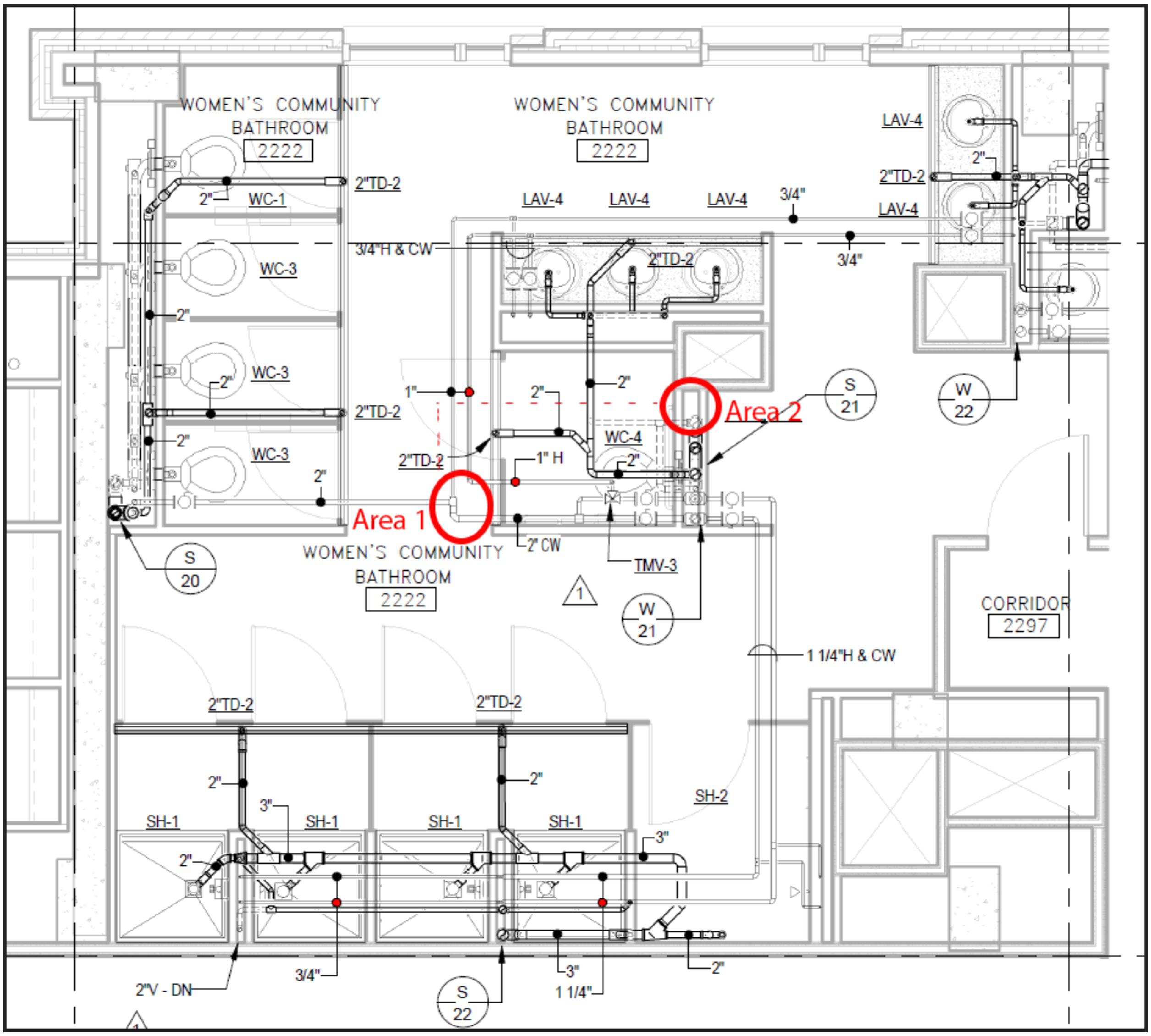
Diagram of potential SCUB slab expansion to create space for greywater system.



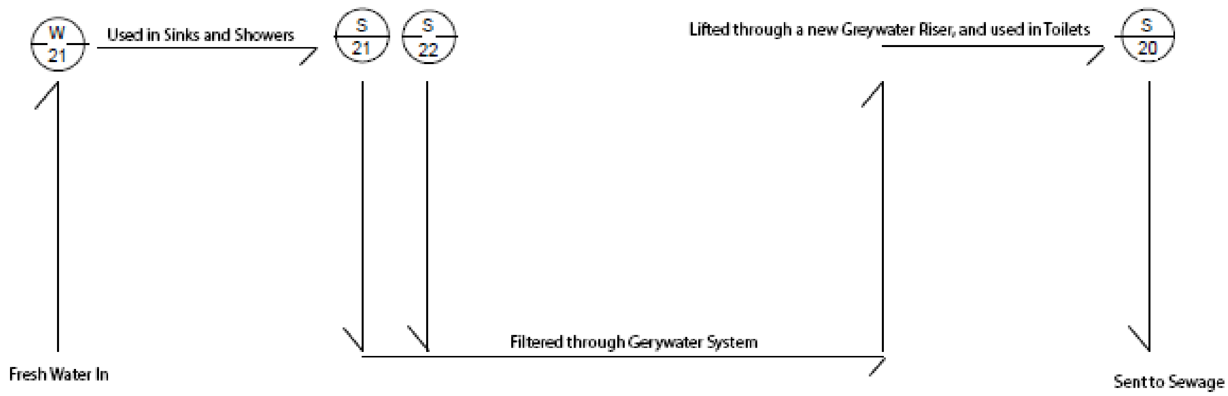
The following are diagrams highlighting risers of note. Created from Plumbing Plans.



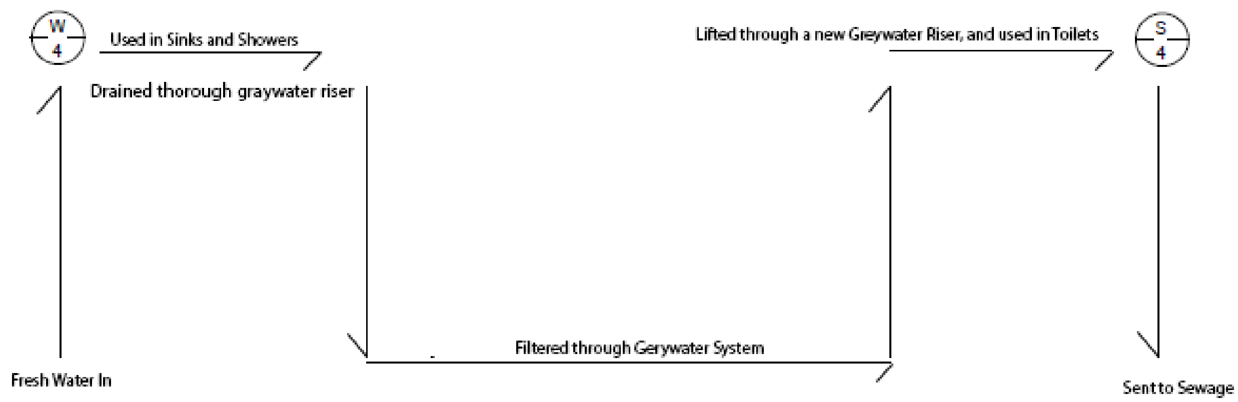



WOMEN'S COMMUNITY BATHROOM 2222
WOMEN'S COMMUNITY BATHROOM 2222
WOMEN'S COMMUNITY BATHROOM 2222
CORRIDOR 2297
Area 1
Area 2
WC-1
WC-3
WC-3
WC-3
WC-4
LAV-4
LAV-4
LAV-4
LAV-4
LAV-4
2"TD-2
3/4"H & CW
1 1/4"H & CW
2" CW
1" H
TMV-3
SH-1
SH-1
SH-1
SH-1
SH-2
2"V - DN
3/4"
3/4"
1 1/4"
3"
2"
1"
S 20
S 21
S 22
W 21
W 22

The following are water path diagrams created to better articulate greywater riser purposes.



Womans Communal Bathroom In Prince Frederick Hall
Greywater Riser Visualization



Individual Bathroom In Prince Frederick Hall
Greywater Riser Visualization

Appendix F: Photovoltaic Cell Window Investigation

Assumptions:

- Common Window is cost comparable with 08 51 13.202000 in RSMeans.
- Curtain Wall is cost comparable with 08 44 13.100050 in RSMeans

Calculations:

Estimated Energy Consumption

- Consumption Total per student = (avg consumption) * (# of Students)
- Consumption Total per SqFt of Office = (avg. consumption per sqft)*(sqft of Floor 1)
- Annual Cost = (Cost per KWH) * (KWH Consumption Total)

Estimated Energy Gain Annual

- KWH Total = (KWH/SF) * (SF)
- Savings = ($/KWH) * (KWH Total)

ROI

- Estimated Material Cost / Estimated Annual Return = Years to ROI

Graphs:

Estimated Energy Consumption					
Unit	Avg. Consumption /Unit (KwH)	# of Unit	Consumption Total (KWH)	$/KWH	Annual Cost
Students	505.74	388	196227.12	0.129	25313.3
SqFt	24	22300	535200	0.129	69040.8
		Building Total	731427.12	0.129	94354.1

Estimated Energy Gain Annual					
	KWH/SF	SF	KWH Total	$/KWH	Savings
Dorm Windows	9.63	5675.88	54658.72	0.13	7050.98
Curtain Wall	9.63	6685.00	64376.55	0.13	8304.57
		Total KWH	119035.27	Total Savings	15355.55

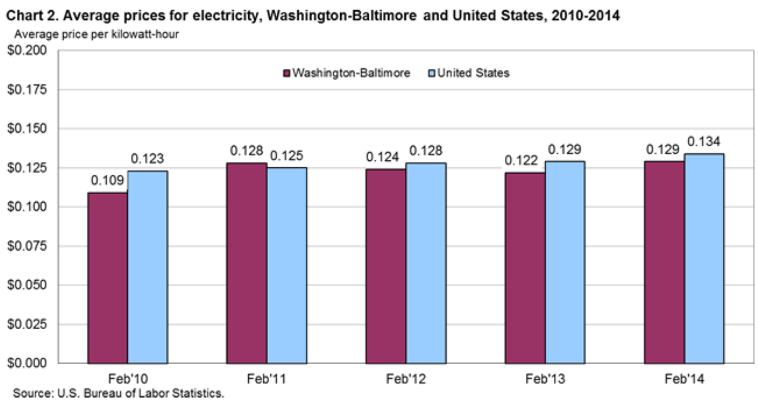
Window Areas					
Original Design					
		Height	Width	ea	Total Area
Curtain	1	87.33	7.33	1	640.13
	2.1	60	6.33	1	379.80
	2.2	25.5	14.66	1	373.83
	2A.1	54	17.16	1	926.64
	2A.2	54	3.25	1	175.50
	3	86.66	7.33	1	635.22
	4	96	6	1	576.00
	5	88.83	13.08	1	1161.90
	5A	88.83	5.33	1	473.46
	6	68.33	19.66	1	1343.37
Dorms	A1	5	6	112	3360.00
	B2	6	4.33	6	155.88
	D1	8	5	54	2160.00
			Total Window Area		12361.72

Energy Gains Annual - New Windows					
	KWH/SF	SF	KWH Total	$/KWH	Savings
Dorm Windows	9.63	6149	59214.87	0.129	7638.72
Curtain Wall	9.63	6685	64376.55	0.129	8304.57
		Total KWH	123591.42	Total Savings	15943.3

North Curtain Wall Area			
	Width	Height	Total sqft
7	9.66	75	724.5
8	12.633	83.33	1052.708
9	14.33	66.5	952.945
9A	2.16	66.5	143.64
9B	2.16	66.5	143.64
		Total	3017.433

Photovoltaic Material Cost Estimate								
	Amount	Unit	Material/Unit	Material Total	Labor/Unit	Labor Total	Total/ Unit	Total
Photovoltaics	172	ea	$ 390.00	$ 67,080.00	$ 53.50	$ 9,202.00	$ 443.50	$ 76,282.00
Curtain Wall Photovoltaics	60	ea	$ 390.00	$ 23,400.00	$ 53.50	$ 3,210.00	$ 443.50	$ 26,610.00
North Windows	114	ea	$ 390.00	$ 44,460.00	$ 98.50	$11,229.00	$ 488.50	$ 55,689.00
North Curtain Walls	3017.433	sqft	$ 50.00	$ 150,871.65	$ 7.55	$22,781.62	$ 57.55	$173,653.27
						Material Total		$332,234.27

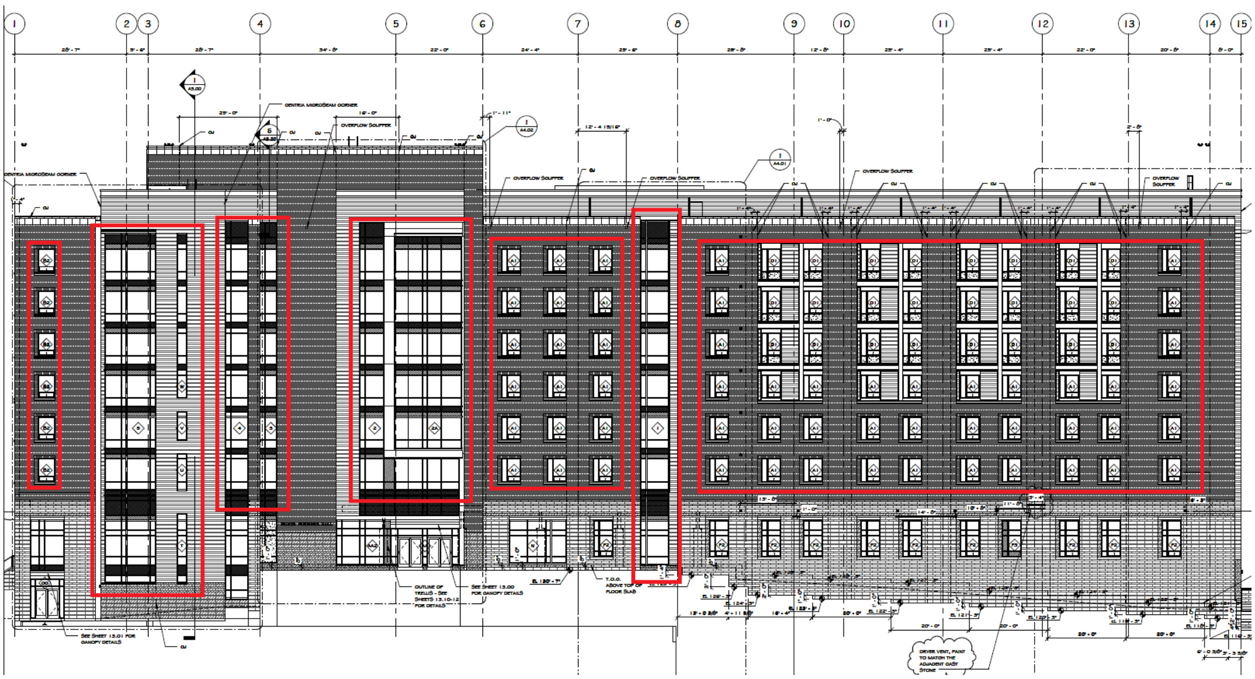
Other



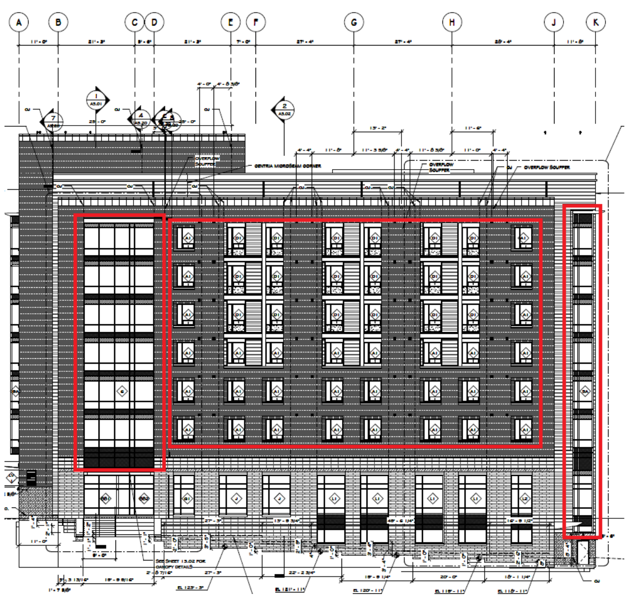
LOCATION	ANNUAL ENERGY YIELD (KWH/FT² (KWH/M²))****
Atlanta	9.63 (97.99)
Chicago	9.50 (96.70)
Denver	11.97 (121.84)
Los Angeles	10.41 (105.93)
New York City	9.51 (96.77)
Phoenix	11.85 (120.61)
San Francisco	10.57 (107.61)
Seattle	8.37 (85.17)

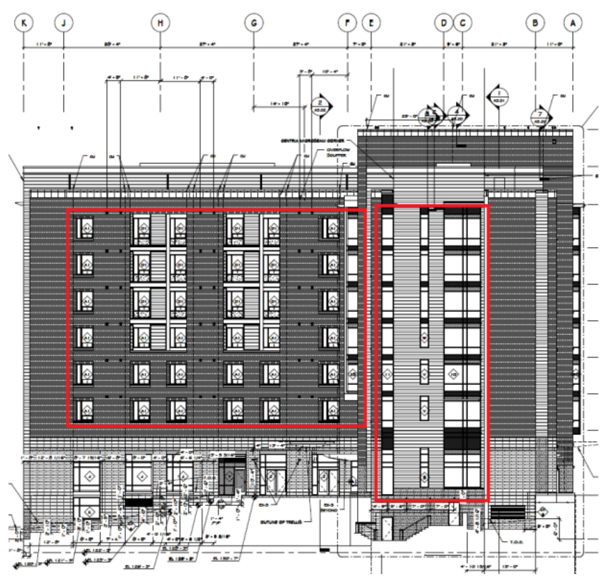
GLAZING SPECIFICATIONS	
Outer Glass**	6mm (1/4") ultra-clear
Inner Glass**	6mm (1/4") low-e coated
U-Value*	0.30
Solar Heat Gain Coefficient (SHGC)***	0.14 (for angles > 25° above normal) 0.41 (for angles < 25° above normal)
Visual Light Transmittance (VT)***	0.00 (for angles > 25° above normal) 0.49 (for angles < 25° above normal)
UV Transmittance (UVT)***	0.00 (for angles > 25° above normal) 0.28 (for angles < 25° above normal)

Elevations Marking Windows appropriate for Photovoltaic Windows



Southern Elevation



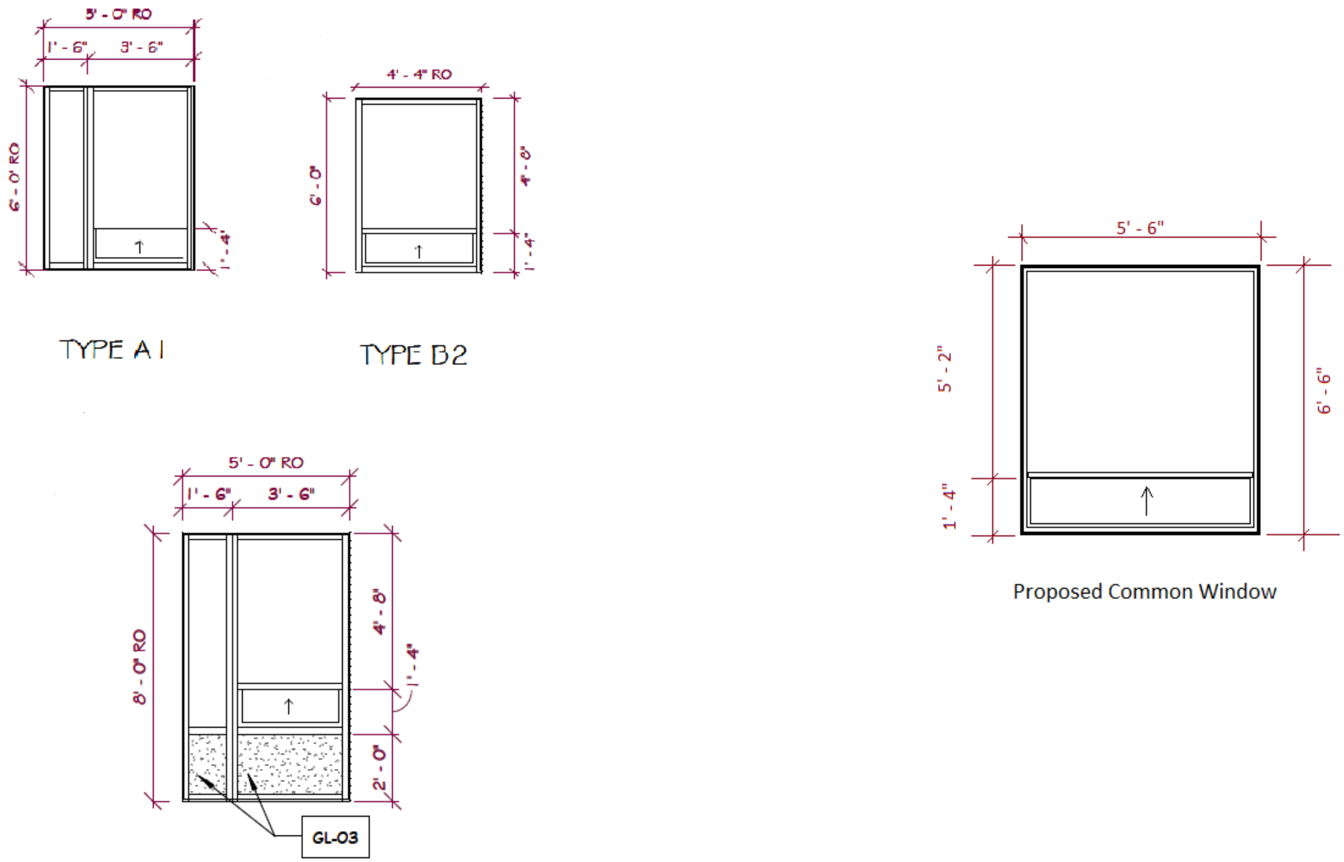


Western Elevation

Eastern Elevation

Appendix G: Architectural Breadth

Plans



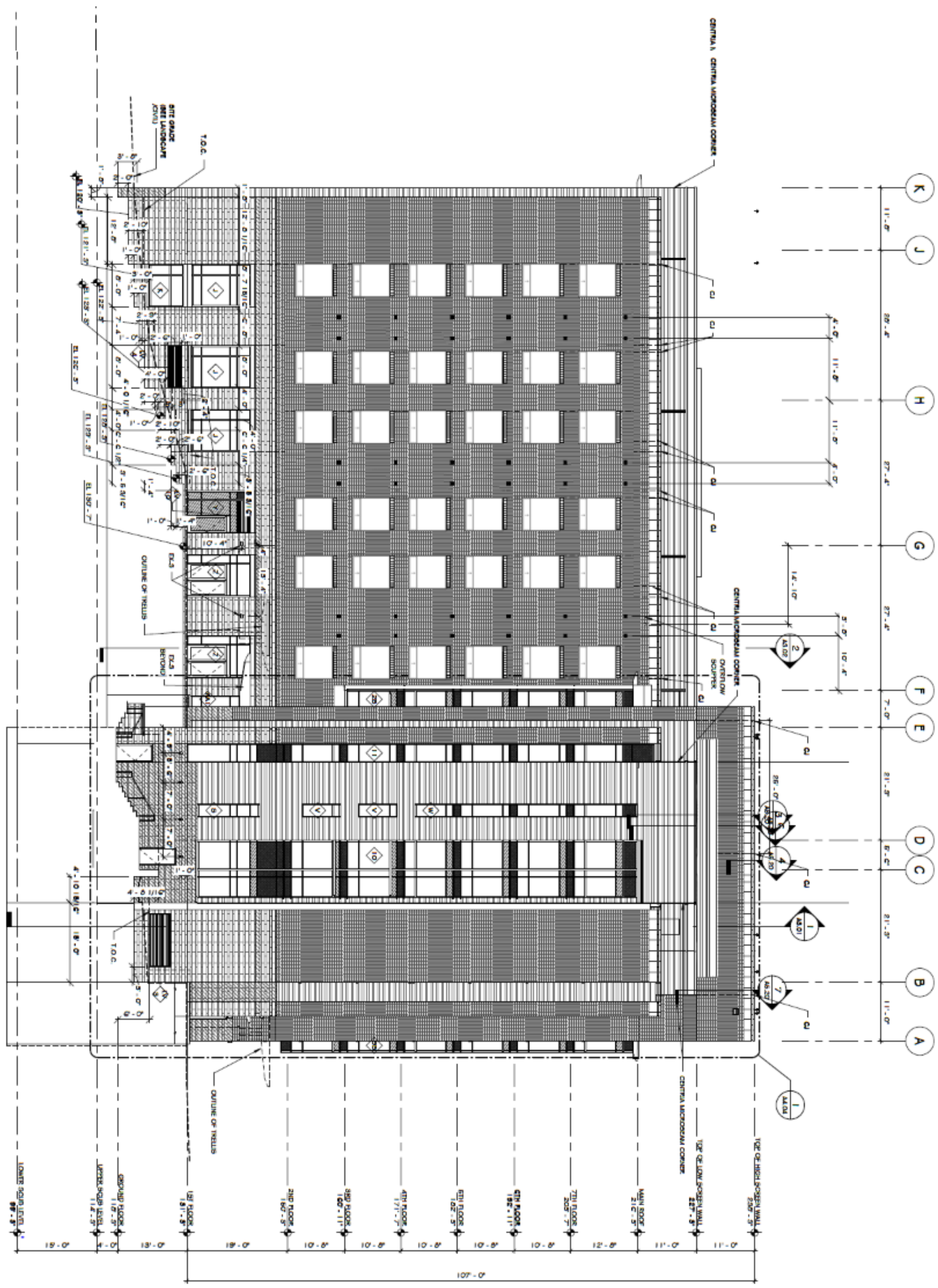
Proposed Common Window

Senior Thesis Prince Frederick Hall, University of Maryland	Lauren Kandt PSU AE, Construction Sowers	Architectural Breadth Window Redesign with Original Window Types from Plans

Senior Thesis
Prince Frederick Hall, University of Maryland

Lauren Kandt
PSU AE, Construction
Sowers

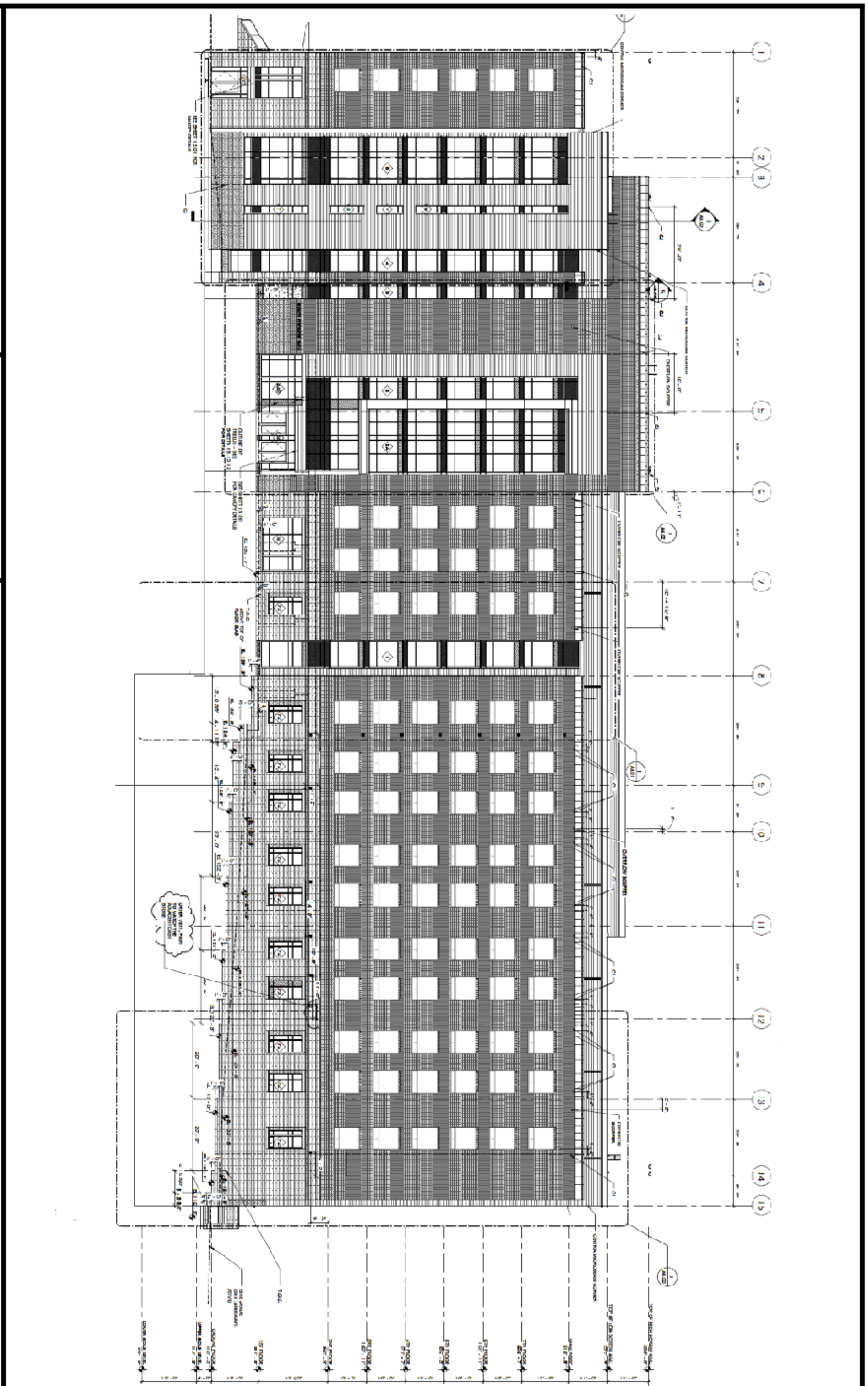
Architectural Breadth
East Elevation with Photovoltaic Windows and extended Louvers on Roof



Senior Thesis
Prince Frederick Hall, University of Maryland

Lauren Kandt
PSU AE, Construction
Sowers

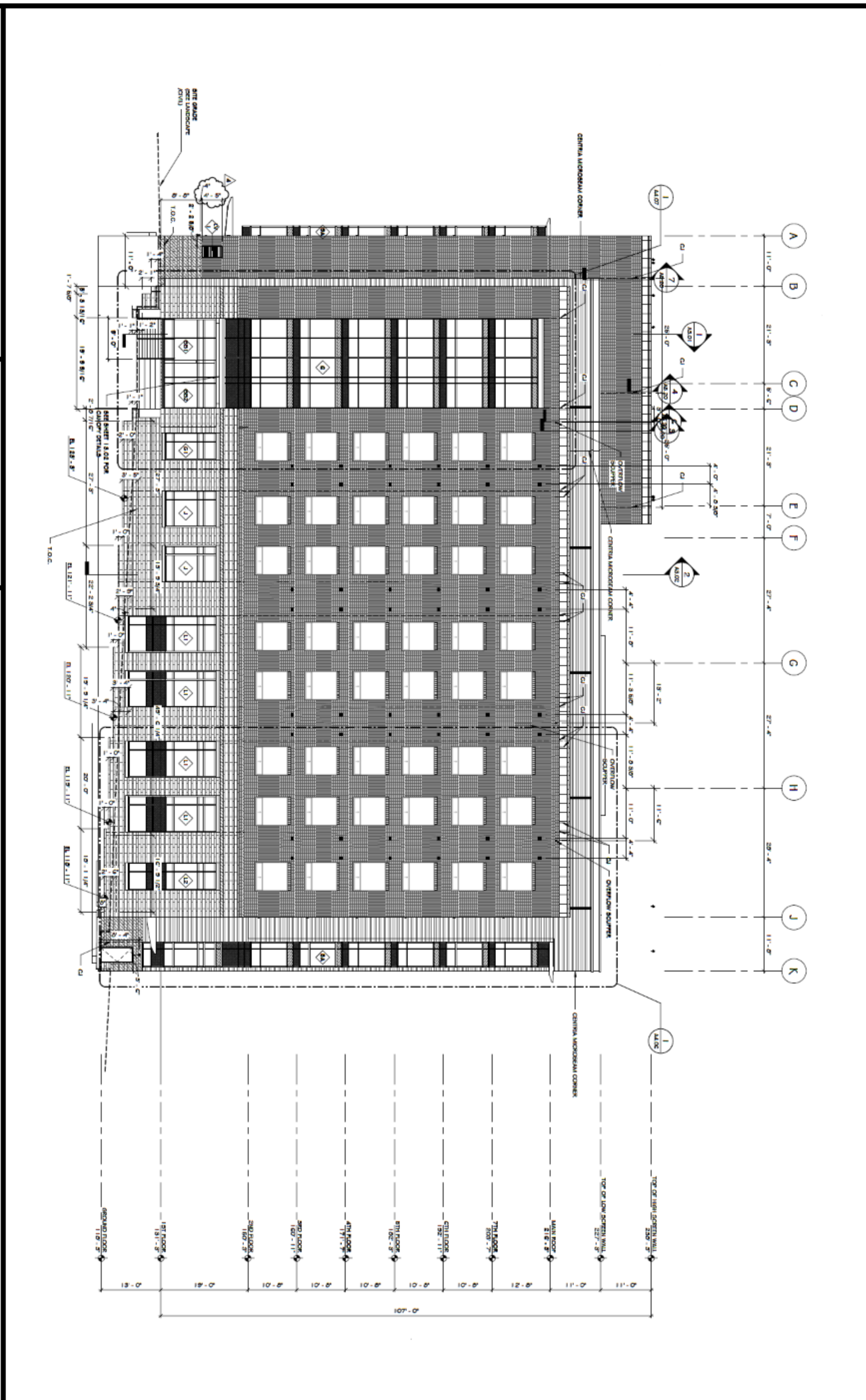
Architectural Breadth
South Elevation with Photovoltaic Windows and Extended Louvers on Roof



Senior Thesis
Prince Frederick Hall, University of Maryland

Lauren Kandt
PSU AE, Construction
Sowers

Architectrual Breadth
West Elevation with Photovoltaic Windows



Graphs

Window Areas					
Original Design					
		Height	Width	ea	Total Area
Curtain	1	87.33	7.33	1	640.13
	2.1	60	6.33	1	379.80
	2.2	25.5	14.66	1	373.83
	2A.1	54	17.16	1	926.64
	2A.2	54	3.25	1	175.50
	3	86.66	7.33	1	635.22
	4	96	6	1	576.00
	5	88.83	13.08	1	1161.90
	5A	88.83	5.33	1	473.46
	6	68.33	19.66	1	1343.37
Dorms	A1	5	6	112	3360.00
	B2	6	4.33	6	155.88
	D1	6	5	54	1620.00
			Total Window Area		11821.72

Window Areas					
New Design					
		Height	Width	ea	Total Area
Curtain	1	87.33	7.33	1	640.13
	2.1	60	6.33	1	379.80
	2.2	25.5	14.66	1	373.83
	2A.1	54	17.16	1	926.64
	2A.2	54	3.25	1	175.50
	3	86.66	7.33	1	635.22
	4	96	6	1	576.00
	5	88.83	13.08	1	1161.90
	5A	88.83	5.33	1	473.46
	6	68.33	19.66	1	1343.37
Dorms	P	6.5	5.5	172	6149.00
			Total Window Area		12834.84

Appendix H: Building Transfer Investigation

Survey:

Targets: RA's, Custodians, Office occupants

Target #s: 40-50 results

Desired data: How much people know about the unique systems within their building.

Q1: What is your job on campus?:

Residential Assistant (floor leader, ect)

Custodian

Office Worker/Desk Worker

Other

Q1.5: How would you describe your interaction with the campus building you spend the most of your time in?

Q2: How would you describe your interaction with the Heating and Cooling systems in a campus building (ie. I don't even know where the thermostat is, thermostat control only, maintenance of the systems, ect) Please be detailed.

Q3: Did you receive any training on the Heating and Cooling systems?

Q4: How would you describe your interactions with the Electrical systems in a campus building (ie. I can flip a switch, I replace lamps when needed, I maintain the breakers, ect) Please be detailed.

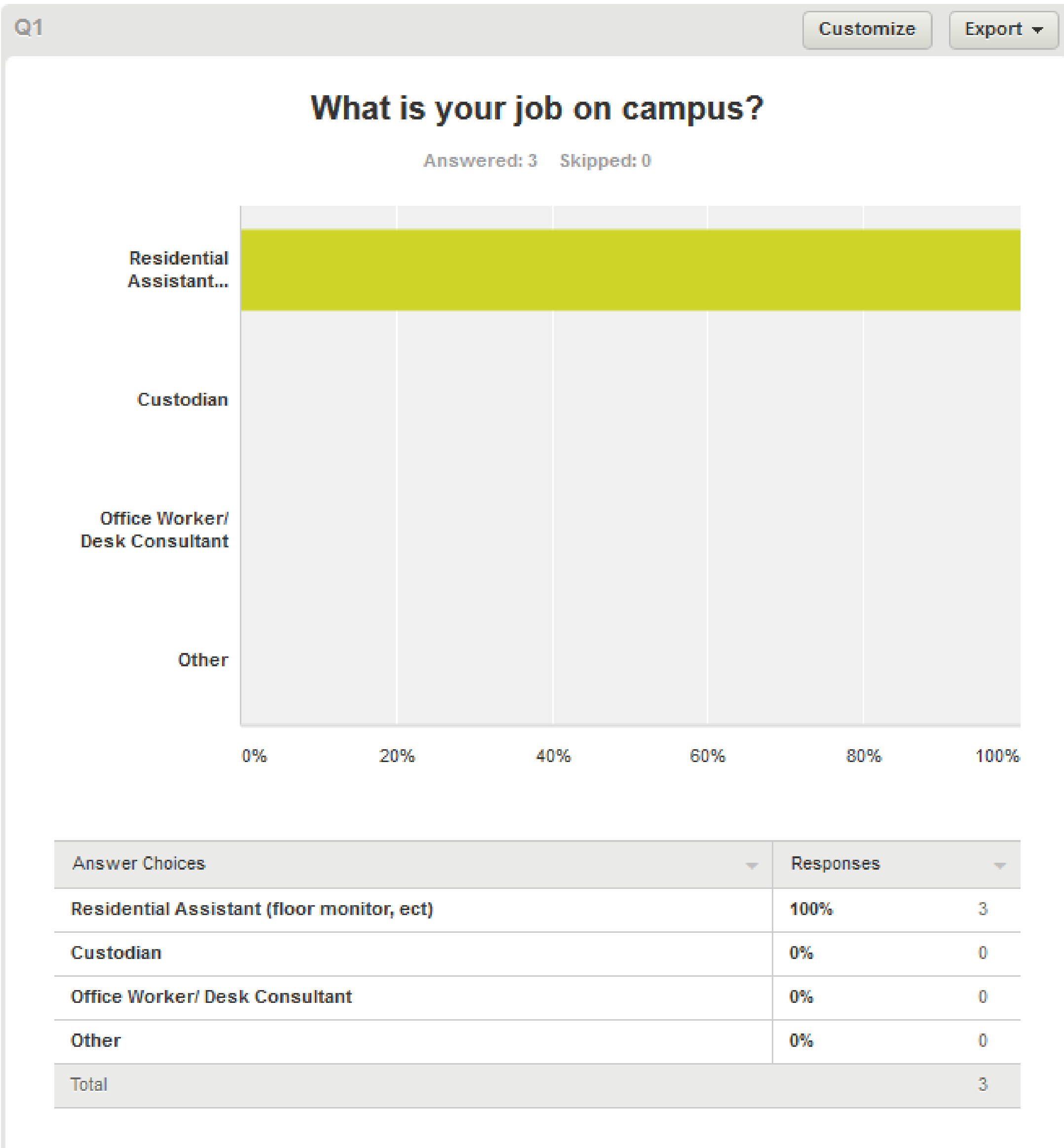
Q5: Did you receive any training on the Electrical systems?

Q6: Do you know if the campus building in question is LEED certified?

Q7: Are you satisfied with what you know about your building and it's systems? If not, please explain what information you would like to know or have easy access too.

Results

Screenshots taken from Survey results on SurveyMonkey.com



Answer Choices	Responses	
Residential Assistant (floor monitor, ect)	100%	3
Custodian	0%	0
Office Worker/ Desk Consultant	0%	0
Other	0%	0
Total		3

Q2

Export

How would you describe your interaction with the campus building you spend the most of your time in?

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

Categorize as... | Filter by Category | Search responses

Showing 3 responses

Sleeping/Eating
3/17/2014 6:12 PM View respondent's answers

I'm not sure what this questions is asking.... My intereaction is good? Really involved? I spend a lot of time in it...?
3/17/2014 12:05 PM View respondent's answers

i live in the building i spend most of my time in
3/17/2014 12:00 PM View respondent's answers

Q3

Export

How would you describe your interaction with the Heating and Cooling systems in a campus building (ie. I don't even know where the thermostat is, thermostat control only, maintenance of the systems, ect) Please be detailed.

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

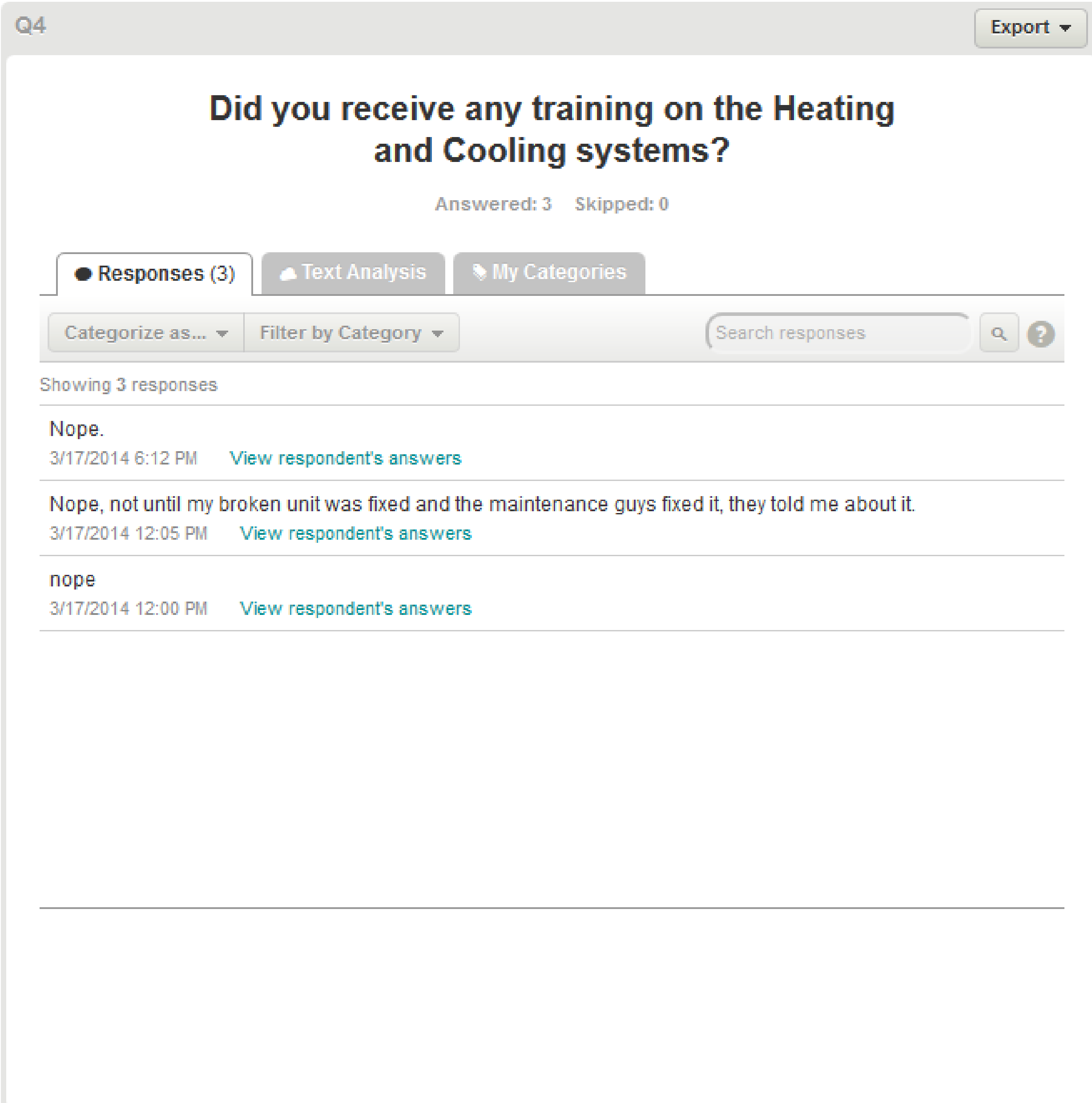
Categorize as... | Filter by Category | Search responses

Showing 3 responses

The thermostat has a ridiculous system of 0-5 and a snowflake in my room. It also produces no heat and clangs loudly. I'm not a fan.
3/17/2014 6:12 PM View respondent's answers

I hate it. My window is my thermostat. Several control rooms across the building manage the temperature. Steam heat is too hot, I have mine turned off.
3/17/2014 12:05 PM View respondent's answers

i dont know where the thermostat is
3/17/2014 12:00 PM View respondent's answers



Q4

Export

Did you receive any training on the Heating and Cooling systems?

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

Categorize as... | Filter by Category | Search responses

Showing 3 responses

Nope.
3/17/2014 6:12 PM View respondent's answers

Nope, not until my broken unit was fixed and the maintenance guys fixed it, they told me about it.
3/17/2014 12:05 PM View respondent's answers

nope
3/17/2014 12:00 PM View respondent's answers

Q5

Export

How would you describe your interactions with the Electrical systems in a campus building (ie. I can flip a switch, I replace lamps when needed, I maintain the breakers, ect) Please be detailed.

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

Categorize as... | Filter by Category | Search responses

Showing 3 responses

I do nothing. If there is any problem, Housing or OPP is asked to fix it. They both do a lovely job.
3/17/2014 6:12 PM View respondent's answers

I can flip a switch.
3/17/2014 12:05 PM View respondent's answers

i only use the electrical outlets in my room
3/17/2014 12:00 PM View respondent's answers

Q6

Export

Did you receive any training on the Electrical systems?

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

Categorize as... | Filter by Category | Search responses

Showing 3 responses

"Don't touch them, call housing"
3/17/2014 6:12 PM View respondent's answers

nope
3/17/2014 12:05 PM View respondent's answers

no
3/17/2014 12:00 PM View respondent's answers

Q7

Export

Do you know if the campus building in question is LEED certified?

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

Categorize as... | Filter by Category | Search responses

Showing 3 responses

No idea matey.
3/17/2014 6:12 PM View respondent's answers

It is most definitely not. LEED certification is silly anyways. People pay all this money to have a "green" building when they can do the same things, and just not pay for the certification.
3/17/2014 12:05 PM View respondent's answers

no, i do not know
3/17/2014 12:00 PM View respondent's answers

Q8

Export

Are you satisfied with what you know about your building and its systems? If not, please explain what information you would like to know or have easy access too.

Answered: 3 Skipped: 0

Responses (3) | Text Analysis | My Categories

Categorize as... | Filter by Category | Search responses

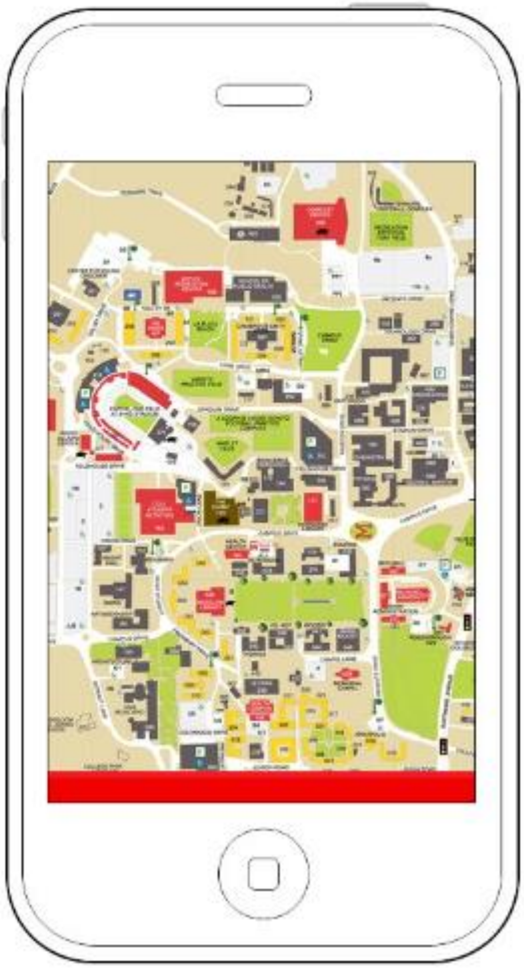
Showing 3 responses

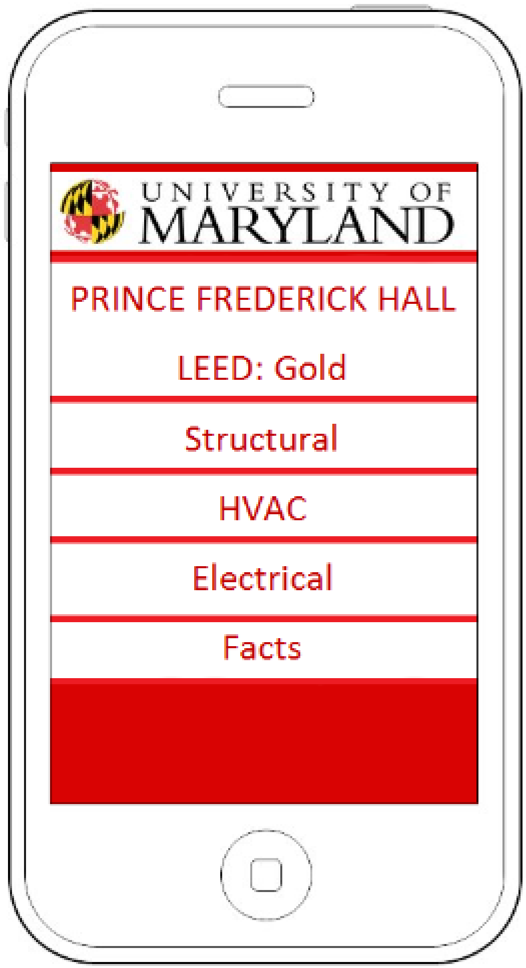
I've had no reason to worry about any of them, so I'd say I'm satisfied.
3/17/2014 6:12 PM View respondent's answers

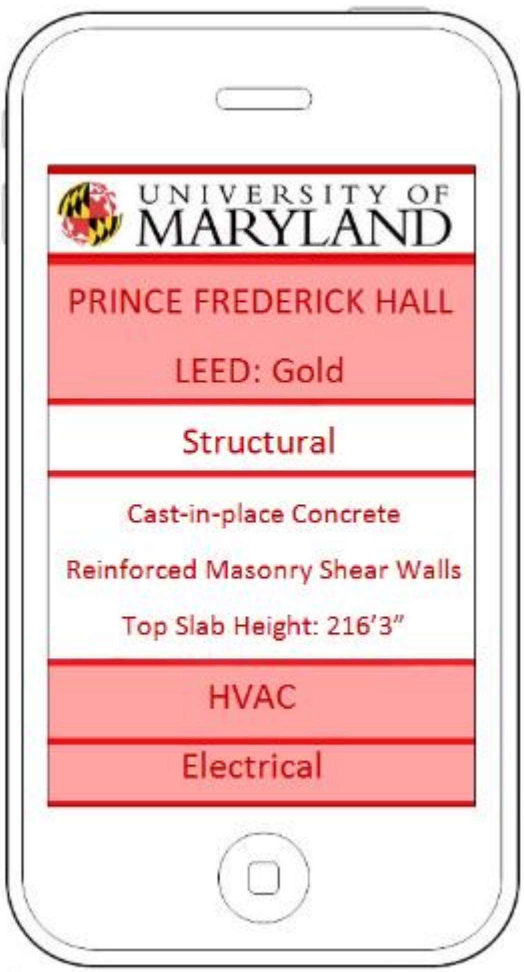
No. I wish I could control the heat. I feel bad letting it all go out the window. I see $$ flying out the window.
3/17/2014 12:05 PM View respondent's answers

yep, pretty satisfied.
3/17/2014 12:00 PM View respondent's answers

App Screenshots




UNIVERSITY OF
MARYLAND
PRINCE FREDERICK HALL
LEED: Gold
Structural
HVAC
Electrical
Facts


UNIVERSITY OF
MARYLAND
PRINCE FREDERICK HALL
LEED: Gold
Structural
Cast-in-place Concrete
Reinforced Masonry Shear Walls
Top Slab Height: 216'3"
HVAC
Electrical

Last Page