Washington Christian Academy

Flagship Building & Gymnasium

AE Senior Thesis
Spring 2008

Casey Mowery

Construction Management Option
The Pennsylvania State University

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CASEY MOWERY

AE CONSTRUCTION MANAGEMENT

WASHINGTON CHRISTIAN ACADEMY

FLAGSHIP SCHOOL AND GYMNASIUM

Owner:
Washington Christian Academy

Architect:
Grimm + Parker Architects

Const. Manager/Design-Builder:
Forrester Construction Company

Civil Engineer:
Rodgers Consulting, Inc.

Structural Engineer:
Columbia Engineering, Inc.

Mechanical & Electrical Engineer:
L.S. Grim Consulting Engineers

Washington Christian Academy
16227 Batchellors Forest Rd
Olney, MD 20832

General Building Data:

- Size: Flagship – 67,594 SF, 3 stories / Gymnasium – 10,655 SF, 1 story
- Function: School for approx. 300 K-12 students & WCA administration offices
- Cost: $20.7 Million including Site, Flagship, & Gymnasium

Construction:

- Project Delivery Method: Design-Build
- Dates of Construction: January 2007 – August 2008

Architecture:

- Exterior: Brick façade with prominent aluminum & glass storefront windows
- Focal Point: Traditional peaked towers with gabled roofs

Structural:

- Foundation: 5" SOG supported by continuous concrete footings & 20"x 20"reinforced concrete piers
- Envelope: Standard cavity wall system & Built-Up roof
- Superstructure: 8" CMU load bearing walls support steel joists, metal deck, & 3"concrete slab floors

Mechanical:

- Room Control: VAV fan powered terminal units with electric heat serve multiple ducts
- Roof: Roof top Air Handling Units serve entire building, typ. 480V, 3 phase

Lighting/Electrical:

- Lighting: Fluorescent lights throughout school accented with indirect wall pendants
- Electrical: Receptacles on roof for servicing mechanical equipment
- Emergency: Self-testing bodine ballasts & circuitry will automatically test emergency lights for 30 seconds every 30 days and 90 minutes per year

2 | Acknowledgements

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Washington Christian Academy

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- Gilbane Building Company
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- Turner Construction Company
- JPI
- Barton Malow Company
- Grunley Construction Company

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- Ryan Sarazen
- Todd Povell

All of my Family & Friends

Especially Mom, Dad, Jill, & Drew

3 | Executive Summary

This senior thesis report examines construction and technical aspects of the Washington Christian Academy. The Washington Christian Academy is a private school serving K-12 students in Olney, MD. This in depth analysis focuses on adding value to the school without substantially increasing costs. In many instances, significant value is added while actually decreasing costs and reducing the schedule. Specifically, this report examines a critical issue that faces the construction industry today, the acoustics in the gymnasium, and the daylight in the classrooms.

A language barrier created by the English and Spanish speaking workers is a critical issue facing the construction industry in and around Washington, D.C., which is mostly an open shop labor market. The number of Spanish speaking laborers is growing at an exponential rate. By surveying industry members information was gathered concerning the status and consequences of the barrier today. To highlight only a few conclusions from the analysis, 95% of the 65 survey participants believe that a language barrier does exist and affects a project's success. The participants were divided over which was more likely to happen: teach English to Spanish speaking people or the inverse. The survey concluded that the largest problems stemming from the barrier are the difficulty in giving basic jobsite instructions and increased safety hazards. To begin solving this problem, there are multiple programs that teach both languages to workers. These programs are being slowly incorporated into the industry through company offered courses and university courses.

The first technical analysis replaces the sheet metal ductwork in the WCA gymnasium with fabric ductwork. This was done to improve the acoustics of the space. There are also many other advantages to using fabric ductwork such as color selection, easy maintenance, light weight, and better air distribution. No structural redesign was necessary for the space. In the end, the fabric duct had a positive but minimal improvement on the acoustics of the space. The cost savings was $9,650, and when compared to the current sheet metal system resulted in a 74% reduction. Most of the money saved was on shipping and installation. The schedule reduction was 21 days, which is an 84% reduction. While the acoustical benefits of the new system alone would not be enough to recommend the change, compounded with the many benefits and the cost and schedule savings the new system is the best solution for the gymnasium.

The second technical analysis examines using daylighting techniques in the WCA Flagship classrooms. The analysis was conducted using a three dimensional model and a lighting design software. After the calculations were run, it was found that the current room design is not acceptable for daylighting practices. If each room were to have four windows rather than two, daylighting could be used and the lamps could be reduced from four to three per luminaire. While exact cost data was difficult to obtain, the reduction of lamps alone would result in a 25% energy cost savings to the owner. The analysis also concluded that switching lamps rather than dimming lamps would benefit the owner with cost savings, and benefit the students with a learning opportunity. This system will raise students' awareness of the uses of daylighting and help them identify situations when electrical lights are not needed.

4 | Project Introduction

The Washington Christian Academy (WCA) Flagship and Gymnasium Buildings are part of a phased construction project located in Olney, MD; Montgomery County. These two initial buildings will serve as the base for a growing religious education campus. The location of the WCA campus is 16227 Batchellors Forest Road.

The owner of the project is a Christian Educational Organization known as the Washington Christian Academy (www.washingonchristian.org). Their intention is to build a Washington Christian Academy campus that will educate students both academically and spiritually. The new Flagship school will provide education for approximately 300 K-12 students and serve as a home to the WCA administration offices. Eventually, the campus will grow to house multiple school buildings for elementary, middle, and high school levels, performing arts spaces, athletic facilities, and outdoor sports fields. A rendered vision for the future campus is shown to the right in Figure 4.1. The Flagship Building is marked with a blue star, and the Gymnasium with a red.

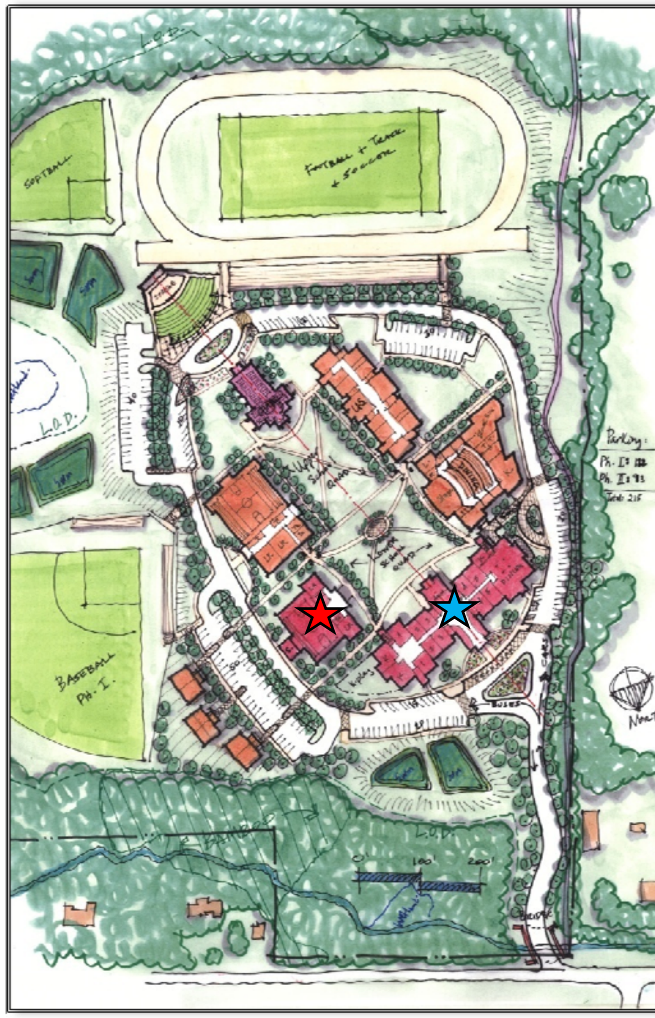


Figure 4.1 Future WCA campus rendering

The size of the Flagship school is approximately 67,600 SF and is 3 stories tall. It houses classrooms, science labs, a cafeteria/auditorium, a foreign language room, a student lounge, and WCA offices. The Gymnasium is approximately 10,700 SF and is 1 story tall. It is a separate building from the Flagship and includes a full basketball court, bleacher seating, locker rooms, and athletic offices.

The Architect on the project is Grimm + Parker Architects (www.grimmandparker.com). This project is classified as a Design-Build project. Forrester Construction Company (www.forresterconstruction.com) is the construction manager/design-builder. The scheduled dates of construction are January 2007 – August 2008. The school will be open and fully functioning for the 2008-2009 school year. The approximated total estimate for the project including site work and construction for both buildings is $20.7 million.

5 | Project Team Overview

5.1 Client Information

The owner of the project is a Christian Educational Organization known as the Washington Christian Academy. Their intention is to build a Washington Christian Academy campus that will educate students both academically and spiritually. The original school was founded in 1960 by families from Presbyterian and Christian churches. It was founded on the principle of Reformed Tradition, which is based on welcoming a diverse student population (racially, socially, and any Christian denomination). In 1996, the school merged with Silver Spring Christian Academy and henceforth was named Washington Christian Academy. The new Flagship school will provide education for approximately 300 K-12 students and serve as a home to the WCA administration offices. The reasons for the move from WCA's current location in Silver Spring, MD to Olney, MD are outlined below in an excerpt taken from the Washington Christian Academy website.

> Building the Promise is rooted in wisdom and good sense. It has been seasoned in prayer and in wide consultation, and it makes sensible provisions for the future of Washington Christian Academy. The proposed location provides many practical advantages: a good location on a major regional road; a setting of natural beauty; room to expand. A permanent home gives our families greater security and stability than rented facilities. We are designing our campus to suit our educational goals. Academics, athletics, music, drama, and extracurricular activities will finally get the space they need.
>
> *http://www.washingtonchristian.org/page05b2.html*

The master plan will take over 10 years to build. Phase I is currently being constructed, which includes the Flagship Building, Gymnasium, a soccer/football field, baseball field, and softball field. The overall campus will accommodate 1,100 students when it is finished and will include separate elementary, middle and high schools, an athletic complex, more athletic fields, a chapel, and performing arts spaces.

<u>Construction Details & Priorities</u>

During construction, the owner is represented by an owner's representative. The school's Headmaster, Vice President, and Chief Financial Officer make most of the decisions concerning the construction of the building, but are represented by one man who attends meetings and deals directly with the construction manager. He serves as the liaison between the WCA decision makers and the field.

The owner is concerned with cost constraints on the project, but ensuring that the job is done well and that the building is of high quality is more important. Vic Bonardi, the Forrester Design-Build Manager, was quoted saying, "In the process of controlling the budget, we never wanted to cheapen any part of the facility that would have to stand the test of time". The owner put some contingency money in the project budget to allow for changes and additions, but would most like to use the money for last minute upgrades that would really make the educational facility first class. At this point, schedule constraints are of the most importance to the Washington Christian Academy. The buildings must be open and

operational for the 2008-2009 school year. As it is scheduled now, Phase I will be completed in early August which does not allow for many more changes or delays. An example of how important the schedule is to the owner is demonstrated by the fact that the owner is spending money to accelerate the project. They are willing to pay overtime in order to recover from the initial project delays.

A close second in priority to the owner is keeping the parties involved happy. Running a smooth project without complaints or high numbers of change orders is important. There is a prosperous working relationship due to the fact that everyone is actively doing the best they can to solve problems quickly and efficiently, and avoid change orders whenever possible. Keeping the neighbors happy is just as important to the Washington Christian Academy. For instance, the WCA spent a bit of extra money to excavate differently near the main road to save some trees that the neighbors wanted to be retained. A few neighbors across Georgia Avenue had concerns that they were not being properly notified of construction dates and durations. These concerns have been addressed and remedied. The WCA intends to keep a positive rapport with its future neighbors in order to gain local support and acceptance in the Olney Community.

5.2 Project Delivery System

Project Delivery Method

The conventional delivery type in Washington, DC and surrounding areas is the standard Design-Bid-Build method. This project, on the contrary, uses the less typical Design-Build approach. The usual trademark characteristics of a Design-Build project are integrated design and construction phases, early retainage of subcontractors, subcontractor input in design, fast moving projects, incomplete design documents, and most notably a single contract between the owner and construction manager. The Washington Christian Academy Flagship Building and Gymnasium only make use of the single contract characteristic of a typical Design-Build delivery. The original contract schedule does not show construction beginning until the final design was complete. This counteracts the concept of a fast-track project and overlapping design/construction phases.

So why did the WCA choose a Design-Build project delivery system, and why choose Forrester Construction Company as the company to hold the contract with? The answer is that the WCA is not an experienced owner. Typically, school boards and presidents are inexperienced in the construction process and hire a third party construction manager to oversee the construction details and logistics. The Washington Christian Academy decided to hire Forrester to assume the role of the construction manager and general contractor. It was then Forrester's job to contract with the architect, engineers, and subcontractors. While the subcontractors were not involved in the design process, Forrester Construction Company was. As a result, the construction consideration during design was still achieved, which is a large benefit of using the Design-Build method. This has the potential to result in fewer change orders and missed scope. Additionally, there is typically less risk for the owner in a Design-Build project delivery. The single prime contract protects the owner from missing scope between multiple

contracts. It is Forrester's job to ensure that the building is completed to the owner's standards and contract agreement terms.

The reason Forrester was chosen as the Design-Builder is because they are a qualified, local, reputable construction company in the metro DC area. Their Design-Build division is growing and completing many successful projects. The project was gained by a negotiated bid. Forrester Construction Company obtained the subcontractors through a competitive bid process. It is required of all subs to have General Liability, Automobile Liability, Workers Compensation, and Excess Umbrella Insurance. Any subcontractor that has a contract amount under $100,000 does not requiring bonding. A contract amount over $100,000 requires a bond for the full contract amount for performance and payment. All forms of insurance must be job specific.

<u>Organizational Structure & Contract Types</u>

Single Prime Contract: The single contract that the owner holds is with the Forrester Construction Company. The primary purpose of a contract is to allocate risk; and this type of system allocates a great deal of risk to Forrester. It is a safe method of contracting for the owner and can be a profitable method of contracting for the Design-Builder. Typically in a GMP contract, the owner recovers the contingency money (and in this case wants to re-invest the extra money for high end finishes or upgrades). This cost reimbursable contract type is frequently used for Design-Build projects because it typically occurs before 100% of the construction documents are complete.

Contracts with Design Companies: Forrester hired and collaborated with Grimm+Parker Architects. The contract type in this situation is a lump sum contract. It becomes the responsibility of Grimm+Parker to obtain and contract engineering consultants. This partially adds to the Design-Build characteristics of the project. The architectural design incorporates the engineers and the construction perspectives because the typical "middle man" is out of the picture.

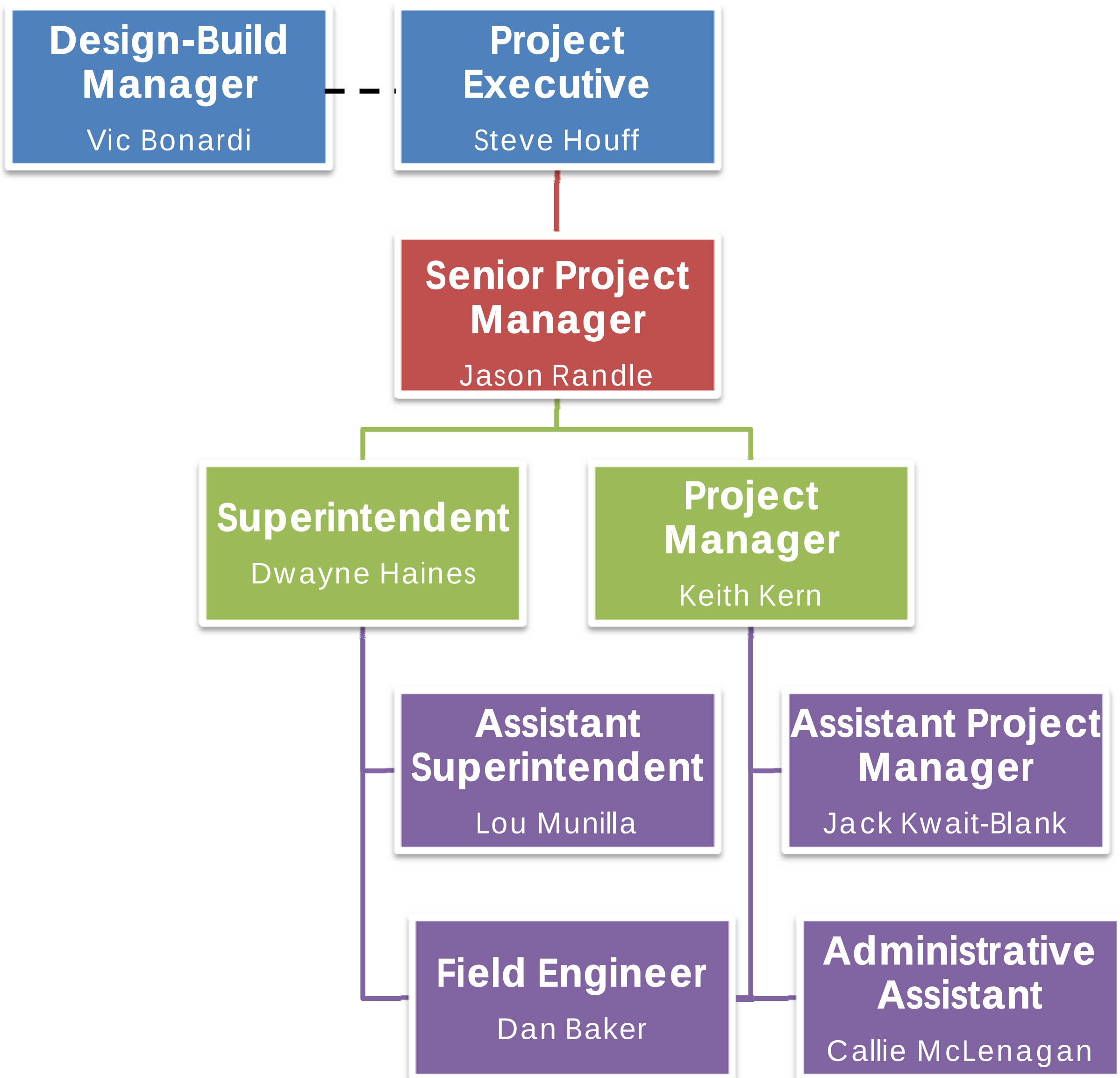
Contracts with Construction Subcontractors: Forrester holds lump sum contracts with each subcontractor on the site. Every CSI division is the responsibility of one or two subcontractors, depending on how the work scope is divided. The subcontractors are chosen based on a variety of selection criteria. This criterion includes but is not limited to previous experience on the type of project, familiarity and relationship with Forrester, current workload and capacity of the subcontractor, and verification of insurance.

These contract types seem appropriate for this type of project delivery system. A typical contract defines scope, compensation, time, schedule constraints, and legal issues. It is logical that an inexperienced owner would only hold one of these contracts with a reputable, trustworthy Design-Builder. This contract allows for the owner's contingency money to be used as they deem necessary, which in this case is for accelerating the project, change orders, and upgrades.

5.3 Project Staffing Plan

Internal Organizational Structure for Washington Christian Academy

Forrester Construction Company



Employees based from the main office in Rockville, MD.

Employees based from the main office in Rockville, MD.

Employees based from the WCA site trailer.

Employees typically based from the WCA site trailer, may travel & assist with other projects from time to time.

Figure 5.1 WCA Project Staffing Organizational Chart

The organizational chart shows the current structure of the Washington Christian Academy team. The Design-Build Manager oversees all of the Design-Build projects in the company, which is why there is a dotted line connecting him to the project. The Project Executive and Senior Project Manager also supervise multiple projects simultaneously. The Superintendent and Project Manager are the most involved upper management on a day-to-day basis. Typically, they are only assigned to one project at a time. These two men work together collectively to solve problems, manage subcontractors, and complete the project successfully. Supporting the Superintendent and Project Manager are the Assistant Superintendent, Assistant Project Manager, Field Engineer, and Administrative Assistant. These employees help to complete tasks, supervise work, and keep everything running smoothly. At Forrester Construction Company, there is a strong emphasis on team work. In fact, the above employees shown in the organizational structure would be referred to as the “WCA Team”. While a certain level of hierarchy exists, the atmosphere is one of equality and respect. Each team member is acknowledged as a vital part of the project’s success.

6 | Existing Conditions Report

6.1 Design Overview

- Architecture
  - The general architecture of the Flagship Building and Gymnasium is classical with a brick façade. Three prominent towers with peaked gable roofs along the Flagship Building serve as focal points of the architecture. These peaks are symbolic of historic tradition, something the WCA prides itself on. Each tower contains a large aluminum and glass storefront window with cast stone lintels. The brick pattern on the towers is made up of assorted bricks that protrude ½" from the face brick. A brick entry archway greets visitors with a cast stone decorative medallion above the door. They gymnasium showcases similar architecture, thus creating a unified campus aesthetic.

- Applicable Codes
  - International Building Code 2003 (IBC)
  - NFPA 101 Life Safety Code 1997

- Zoning and Historical Information
  - Washington Christian Academy History
    - The original school was founded in 1960 by families from Presbyterian and Christian churches. It was founded on the principle of Reformed Tradition, which is based on welcoming a diverse student population (racially, socially, and any Christian denomination). In 1996, the school merged with Silver Spring Christian Academy and henceforth was named Washington Christian Academy. The new Flagship school will serve approximately 300 K-12 students.
  - Zoning
    - The WCA campus will eventually cover a 60 acre site. Of the 60 acre site, approximately 26 acres are reserved for forest retention. This land was bought by the WCA in 2004. The Flagship's construction zoning classification for the building use is E-Educational and A2-Assembly. The Gymnasium's construction classification is A3-Assembly.

- Building Envelope
  - The buildings' envelopes utilize a standard cavity wall system. The Flagship Building uses an 8" CMU load bearing back up wall, and the Gymnasium uses a 12" CMU wall. To the exterior of the CMU walls are 2 inches of rigid insulation and then a 2 inch air gap. Cavity drainage material and through wall flashing are located within the cavity wall near ground level, which allows the moisture to escape. The exterior of the cavity wall system is a brick façade, also referred to as face brick. A standard modular size brick in two colors is used, as well as bands of 8" split face CMU. 8" accent brick patterns project ½" from the face brick on all of the 3-story peaked tower elevations as well as on

the gymnasium exterior walls. Three large arched storefront windows are located on both the Flagship building and the Gymnasium. There is one window on each of the 3 towers of the Flagship, and 3 on the NE face of the Gymnasium. These windows are aluminum and glass, with cast stone lintels.

- Similar roofing systems are used on the two buildings. Both roofs support the mechanical units for the building. The roof system is a Built-Up Roof. The roof is formed by steel roof deck, followed by 3" rigid insulation, 1" cover board, and built-up asphalt roofing. There is a multiple-ply membrane base flashing that extends a minimum of 8" up the parapet wall for moisture protection. The parapet wall is comprised of 100% solid CMU, covered by continuous through wall flashing and a cavity drainage material. Weep holes are located every 16" O.C. Metal gutters and downspouts are used on the perimeter of the roof.

- Both buildings also employ asphalt shingled gabled roofs with a 12:12 pitch. The Gymnasium uses this roof type over the entry canopy. The Flagship building uses this roof on the 3 peaked towers and the entrance to the building. Additionally, a smaller shed-like shingled roof runs along the roof's perimeter of the Flagship building. This aesthetic barrier will add a sense of completeness to the building, as well as hide the roof top mechanical units. The familiar, family-style roof coincides with the architectural appeal of the campus and exemplifies the WCA theme of tradition.

6.2 Building Systems Summary

The following table and written information summarizes the main building systems in the WCA Flagship and Gymnasium Buildings. The information describes the key design and construction aspects of the project.

Table 6.1 Building Systems Summary Table.

Work Scope	Flagship Building		Gymnasium	
	Yes	No	Yes	No
A. Is demolition required?		✓		✓
B. What provides excavation support?	--	--	--	--
C. Is there a structural steel frame?	✓		✓	
D. Is concrete cast-in-place?	✓		✓	
E. Is precast concrete used?		✓		✓
F. Describe the mechanical system.	--	--	--	--
G. Describe the electrical system.	--	--	--	--
H. Is there masonry?	✓		✓	
I. Is there a curtain wall?		✓		✓

As seen in the table, the same design and construction elements are used in the Flagship and Gymnasium Buildings. This is to alleviate an added learning curve, make construction more efficient, and create buildings that look similar.

A. <u>Demolition</u>

The Washington Christian Academy Flagship Building and Gymnasium reside on 60 acres that was once covered in forests. This land will eventually become a resting place for an entire educational and recreational campus. Of the 60 acre site, approximately 26 acres are reserved for forest retention. Retaining a high amount of trees and green space is important to the owner and the community. Therefore, the only demolition that must take place is the necessary clearing of trees and vegetation to make way for the buildings. Extra caution and money were spent to carefully remove only what was necessary, and to retain as much natural vegetation as possible especially along the roadways.

B. <u>Excavation</u>

The excavation for the foundation was simple in nature due to the shallowness of the foundation system. The foundation is comprised of continuous concrete wall footings and a slab on grade. Most of the excavation work had to do with removing the upper 1-2 feet of the top layer of soil and recompacting for bearing strength under the slab on grade. A few man made storm water management ponds were excavated around the site for water management which are not deep enough to require sloped sides. As far as the actual footings, they are under the 5 foot depth requirement that necessitates the use of excavation support, such as sloped or stepped walls. The soils from the onsite cuts are acceptable to use as compacted backfill, as long as they are aerated and dried a bit. The

excavated soils have moisture contents above what is needed for optimum compaction levels. In order to handle the excess water, the man made ponds around the site collect most of the site drainage. They are bordered by silt fences to ensure that they do not overfill or clog with silt and other fine particles. Additionally, there is a pump for dewatering during construction. A stream that runs near the entrance of the site has been temporarily diverted for the construction of an entrance bridge, and will be returned to its original location upon bridge completion. Any remaining ground water is pumped through hoses into one of the storm water management ponds so that the water does not cause erosion and further problems during construction.

C. <u>Structural Systems</u>

Cast-in-place concrete, CMU load bearing block walls, and steel joists comprise the foundation and superstructure of the building. There are also steel tube columns that are supported by cast-in-place concrete piers and footings in the areas of the building where the span from each load bearing wall is too great for the steel joists alone. No precast concrete (unless the concrete masonry units are an exception) is used in either the Flagship Building or Gymnasium.

D. <u>Cast-in-Place Concrete</u>

The cast-in-place concrete foundation is the same for both buildings. The continuous wall footings range in size from 2’-6” to 4’-0” and in thickness from 1’-0” to 1’-4”. They are typically reinforced with #5 or #7 rebar running in both directions along the bottom of the footing. Turned down slabs are employed in the foundation of the Flagship Building. The depth of this part of the foundation is intended to surpass the freeze-thaw line. Also unique to the Flagship Building are concrete footings and piers in the center of the building to support steel tube columns. The cast-in-place pier footings range from 5’ square to 8’-6” square, and support 20”x20” concrete piers with 4-#8 reinforcing bars. The slab on grade (SOG) requires the bearing soil to have a minimum compaction strength of 2500 psf. On top of the compacted soil is 4” of washed gravel and a 6 mil. vapor barrier. The SOG is 5” thick. The cast-in-place concrete slabs for the second and third floors are 3” thick. All slabs in the building are reinforced with 6”x6” W1.4xW1.4 welded wire fabric for reinforcing. The required strength of the concrete is 3000 psi normal weight at 28 days, with the extra stipulation of 4500 psi normal weight if the concrete will be exposed to weather while curing. The preferred method of placing concrete on the site is by a concrete pump. The pump can easily reach the third floor slab, and can reach the entire floor with a minimal amount of truck movement. Keyed construction joints allow for multiple concrete placements.

E. <u>CMU Block & Steel</u>

The Flagship Building uses 8” CMU and the Gymnasium uses 12” CMU block for the load bearing walls. The reinforcing in these walls is spaced every 24” on center. For non-load bearing walls, the only difference is that the reinforcement spaces out to 48” on center. The CMU minimum compression strength is 1900 psi. The steel used in both buildings acts as a load bearing system that spans the distance between load bearing walls. The steel is in the standard forms of beams, joists, and trusses. The ends of the steel beams bear on an average size steel plate of 8”x12”x5/8”. Joists that bear on masonry walls are supported by a steel plate and a bond beam. There are 13 steel tube columns in the

Flagship Building, which allow for large, open architectural spaces. The large spaces would not be possible with CMU load bearing walls alone because the span distance would be too great for the steel joists. The typical column is a HSS 8"x8"x ½". Anchor bolts with a ¾" diameter connect the columns to a steel base plate that sits on top of the cast-in-place concrete pier mentioned previously. The steel is set in place by a mobile crane that will move through three locations for the Flagship Building and one location for the Gymnasium.

F. Mechanical System

Once the building's structure is complete, the mechanical and electrical systems are ready to be put in place. The Flagship Building has an adjoining mechanical and electrical room in the northwest section of the building. There is also a small electrical closet located in the main corridor of every floor. 16 mechanical rooftop units serve the entire building and are typically 480V, 3phase. These units are hidden from a pedestrian line of sight by a shed-like gabled roof that runs along the perimeter of the built up roof. This aesthetic barrier adds a sense of completeness to the building, as well as hides the roof mechanical units. Roof top metal ventilators, bases, and soil stacks are kept watertight by metal flashing and roof sheathing. The kitchen on the main floor of the building requires additional mechanical equipment that would not typically be seen in every building. Compressors and condensing units for the kitchen are located on the roof in addition to 2 exhaust fans. The exhaust fans are rated at 600 and 3250 cfm and are equipped to exhaust very high air temperatures reaching up to 300 degrees Fahrenheit with no damage to the fans.

The supply air is distributed throughout the Flagship Building by VAV fan powered terminal units with electric heat. The size of the units range from 720 to 1350 max cfm. Most of these VAV units serve 4 or 5 air supply diffusers. Typically, one unit is located above each room for maximum occupant temperature control and comfort. The VAV units are connected to each diffuser with a removable flex duct. Larger open spaces, such as the corridors, are equipped with VAV single duct terminal units with electric heat that range in capacity from 300 to 1025 cfm. Typical registers and grilles collect the return air. All of the ductwork is to be insulated sheet metal and sealed with a mastic sealer. Any duct interiors that are visible through a grille or register are to be spray painted mat black to avoid an unfinished metal aesthetic look.

The Gymnasium's mechanical system is similar, only with less ductwork and stronger powered air handling units. There are two roof top units. The first unit has a capacity of 1600 cfm, which serves the lobby, locker rooms, restrooms, and offices. The second unit has a much larger capacity of 6000 cfm and serves the entire gymnasium. Both units are 480V, 3 phase. There is a small mechanical room located in the gym.

G. Electrical System

Electricity is supplied to the Flagship Building through a switchgear located on the other side of Batchellors Forest Road from the school. The 15kV switchgear connects by way of a one-way duct bank to an electrical manhole. This manhole is then connected by a one-way duct bank to a pad mounted 480V Delta Primary – 208Y/120V Secondary 3 phase transformer which is located directly outside the

south end of the Flagship Building. Once inside the building, the main power distribution panel is 480Y/277V 3 phase, 4 wire, 1600A, and 100% rated. All conductors are copper with type THW 75C insulation. The current AV equipment is connected to a junction box embedded in the slab by a 3” diameter conduit. To account for future demand, an extra 3” diameter conduit is attached to a junction box in the ceiling above the AV room for future equipment hookup. Electrical receptacles are mounted on the roof for servicing mechanical equipment.

The lighting in the Flagship Building hallways and classrooms are rectangular fluorescent luminaires. The foyer, also referred to as the Great Hall, has incandescent ceiling and wall mounted fixtures. Indirect wall pendants are used in this space to create an aesthetically pleasing atmosphere.

The Gymnasium gains its electricity from the main Flagship Building electrical room. Two 4” diameter PVC conduits run underground from the electrical room to the Gymnasium. Fluorescent lighting is used in the lobby, offices, and locker rooms. In the gym, HID light fixtures are ceiling mounted for efficiency. There are two main electrical panels for the building, which serve the same areas as the mechanical units.

H. Masonry Facade

Masonry exists in two forms on this project. First, it appears as CMU blocks to provide the main superstructure and interior walls. Secondly, brick serves as the exterior veneer of both buildings. All of the buildings on the WCA campus will be brick in order to create a unified campus aesthetic. The brick exterior exudes a familiar, time-honored architectural feel that exemplifies the WCA traditional theme. A standard modular size brick in two colors is used, as well as bands of 8" split face CMU. 8" accent brick patterns project 1/2" from the face brick on all of the Flagships 3-story peaked tower elevations as well as on the Gymnasium exterior walls. The brick is supported by masonry wall ties anchored into the CMU backup walls. It is the responsibility of the mason to ensure that the brick and mortar are the correct size and color. The schedule allows for a continual work flow from the Gymnasium to the Flagship Building.

I. Building Envelope

While no curtain wall exists on either building, a standard cavity wall system serves as the building envelope. The cavity wall system is located to the exterior of the CMU load bearing walls and is comprised of 2” rigid insulation and 2” air gap. Cavity drainage material and through wall flashing are located within the cavity wall near ground level, which allows the moisture to escape. Six large arched storefront windows are located on the Flagship building and three on the Gymnasium. There is one window on each side of the three towers of the Flagship, and three on the NE face of the Gymnasium. These windows are aluminum and glass, with cast stone lintels.

J. Emergency System

The fire and emergency systems for the two buildings are the same. The fire alarm control panel is located in the first floor main electrical room of the Flagship Building. Annunciator panels are located

next to the front doors of each building. The Great Hall has addressable smoke detectors, and the rest of the building and gym has dual audio/visual smoke detectors. Any HVAC duct producing or serving over 2000 cfm each, or any HVAC serving a common plenum space exceeding 2000 cfm in that plenum, requires a smoke detector. The emergency lighting is unique because it is self-testing. Self-testing bodine ballasts and circuitry will automatically test emergency lights for 30 seconds every 30 days and 90 minutes per year. The sprinkler systems in both buildings are a standard wet sprinkler with cast iron pipe and steel fittings. The sprinkler heads are semi-recessed pendants with a chrome painted finish.

6.3 Local Conditions

The new Washington Christian Academy site is located in a rural area of Montgomery Count, Maryland. It is approximately 30 miles in the slight northwest direction from the center of Washington, DC. The rural area and large site eliminate many of the typical constraints that come along with congested, urban sites. There is designated room to store the excavated soil on site so it can be reused at a later date. As a result, excavating, hauling, and bringing in more soil is a costly process that is eliminated at the WCA site. Another advantage of having a large site is the ability to have a large job site trailer. The WCA team can work together on site everyday and avoid a lot of the misunderstandings and communication delays that occur when teams work in separate buildings.

The soil conditions on site are defined as the following:

- Minimum required bearing pressure is 2500 psf.
- Soils from site may be compacted and reused.
- In place moisture contents are above optimum level for compaction, so excavated soils must be spread out and aerated (for drying purposes) before being reused.
- No rock excavation will be needed.
- Two dry storm water management ponds collect site water and runoff.
- Soils are typically soft to medium density sandy silt and lean clay.

One unique local condition the WCA team faces is a substantial overgrowth of bamboo on the site. Bamboo is natural to this region and is a threat to building structures. Bamboo grows at an alarmingly fast rate and spreads easily. Its strength can break concrete foundations, which is why it must be removed from the site. Removing the bamboo will take a fairly long amount of time due to the fact that it must be chopped down and then each new shoot must be mowed down before it has time to spread again. Eventually, after an unpredictable amount of attempts, the bamboo will lose its energy supply and die.

The two buildings on the WCA site are not attempting LEED certification. However, some attempt to recycle construction materials is still being made. There is a “masonry only” dumpster on site that is used for CMU waste. Tipping fees are less expensive to have “masonry only” dumpsters pulled from the site. While typical dumpster removal charges by weight, the masonry dumpsters are charged a flat fee per dumpster. This creates a win-win situation for the environment and the construction teams.

6.4 Site Plan of Existing Conditions

Site Plan of the Existing Conditions at the WCA Site

16227 Batchellors Forest Road, Olney, MD 20832

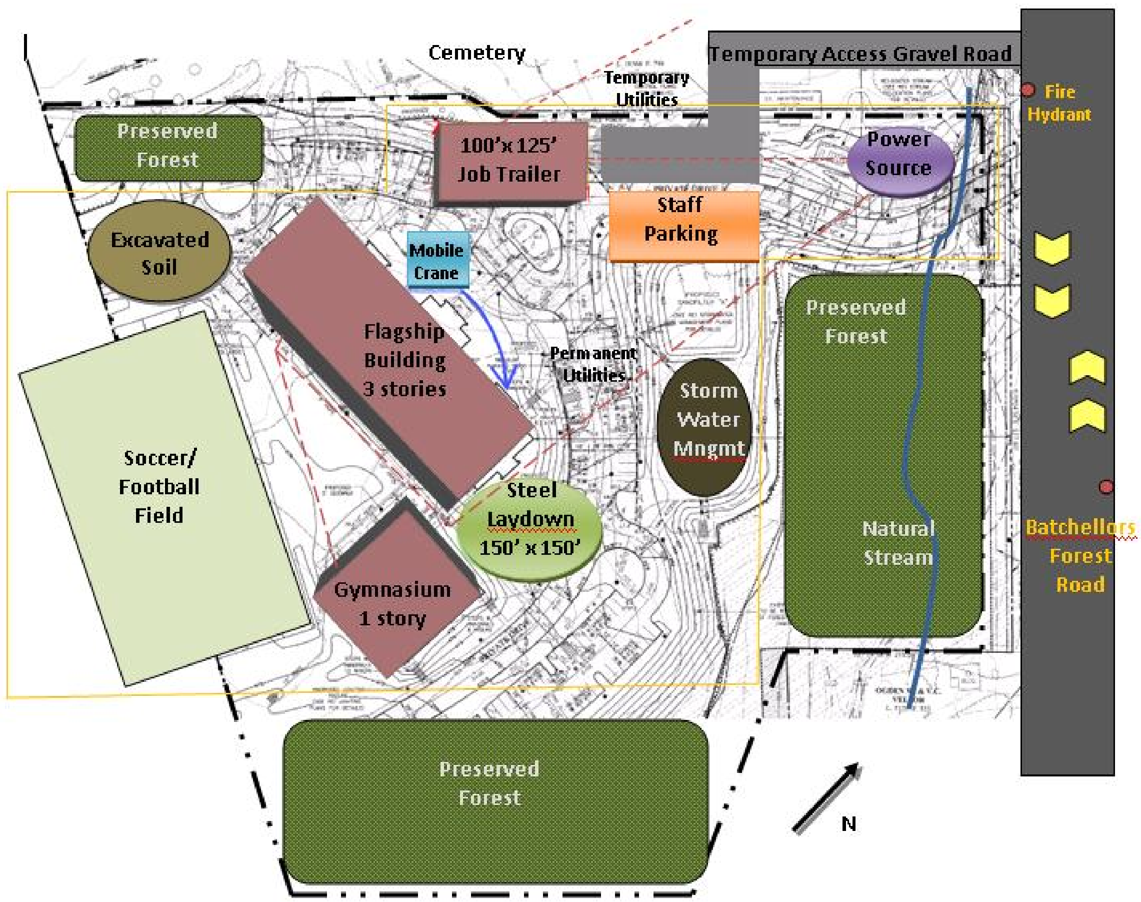


Figure 6.1 WCA Existing Conditions Site Plan

The above site plan represents Phase I of construction. A large site lends itself nicely to much storage area. The site fence (orange line) runs to the interior of the preserved forests. The natural stream was temporarily diverted to build an entrance bride onto the site from Batchellors Forest Road. There is no traffic light to turn into the site; however Batchellors Forest Road is not busy enough to complicate machinery and truck deliveries. The largest obstructions in the temporary site plan are the turns in the temporary access road, which may cause problems with large delivery trucks. The road had to be run around the utility access point, which also powers a maintenance building for the neighboring cemetery. The site is concealed from the street by thick trees, which also helps to dampen sound coming from construction.

6.5 Site Layout Planning

Please see the two Site Layout Planning Drawings (S.1 & S.2) in ***Appendix A.***

Overview

- Address: 16227 Batchellors Forest Road, Olney, Maryland 20832
- County: Montgomery
- Site Size: 60 acres; 26 of the 60 acres are reserved for forest retention

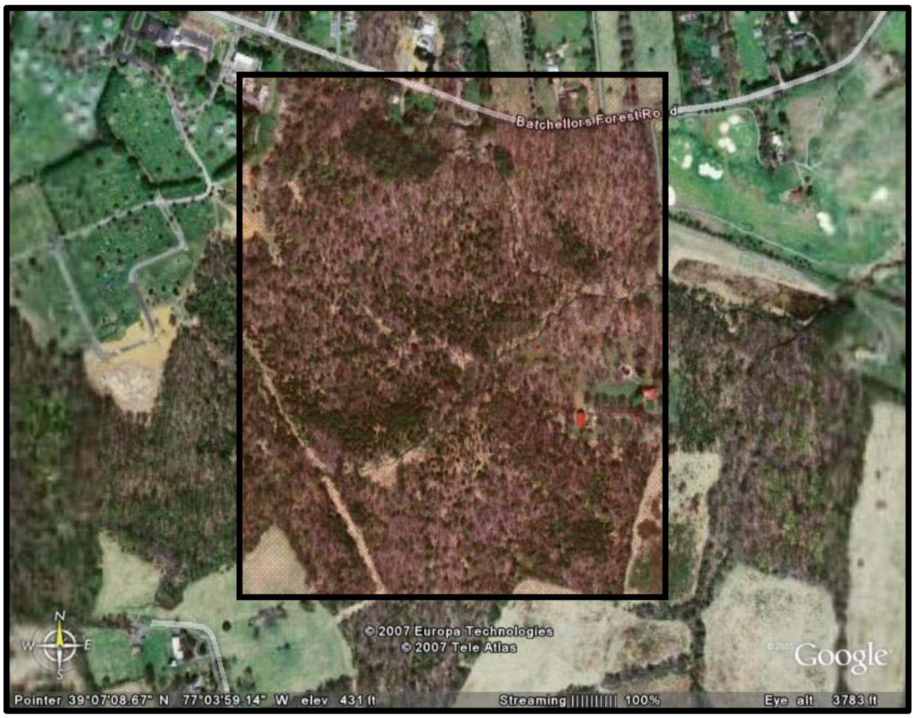


Figure 6.2 *Google Earth* image of WCA site in Olney, MD

The *Google Earth* aerial photograph above shows the vast 60 acre site roughly highlighted in the red box. Only a portion of this site will be developed for the WCA Flagship Building and Gymnasium construction. The rest of the site will be developed over the next decade and will eventually become an entire WCA campus. A full 60 acre site plan can be seen in Appendix A (S.1), with the site perimeter and preserved forests shown. The second site plan (S.2) shows the planning and layout for the superstructure phase of the project.

Site Layout Planning Analysis

- Temporary Facilities:
  - Trailers: The two trailers on site serve as field offices for the general contractor (Forrester Construction) and the owner (Washington Christian Academy). The double-wide trailer is large enough to accommodate the entire WCA project team. This is important to the success and coordination of the project. The trailer is equipped with

electricity and utilities from the nearby temporary transformer and with water from the existing utilities on the neighboring site. The trailers' locations are at the front of the site for easy monitoring of deliveries and visitors.

- Portable Toilets: Four portable toilets are located in a convenient location for the construction workers and management. There are three for men and one for women.
- Construction Fence: The fence runs around the work area for this construction project, not the entire site. A natural barrier is created by the trees. The fence still surrounds the construction areas and prohibits pedestrians and vehicles from access.
- Dumpsters: There are two locations for the dumpsters. One on the north side of the Flagship Building and the other on the south side near the Gymnasium. This is to alleviate long travel distances to discard waste. Additionally, there are two dumpsters in each location because one is for general waste and the other is for masonry only and recycling purposes. The dumpsters are located near the traffic routes for easy trash removal.

- Traffic:
  - Entrance: The only entrance to the site is off of Batchellors Forest Road. There is no traffic light; however traffic on this road is light enough that turning in to the site should not be a problem. The existing paved entrance road outside the site boundary was previously used as a rear entrance for the neighboring cemetery. During construction, it will be used solely for the WCA project.
  - Personal Automobiles: The subcontractors, management, owners, and visitors may continue on the entrance road beyond the trailers to the parking lot created temporarily for the project. After completion, this lot will be demolished. The lot is out of danger from the crane and other construction activities.
  - Deliveries and Equipment: The site is large enough to allow the most efficient traffic pattern; one-way. Material delivery trucks, garbage trucks, and equipment will never have to turn around on the site in order to exit. The circular path is large enough for most vehicles to turn, yet small enough to create efficient route times. There are two routes by the gym in case the crane is working overhead. This alternate route allows trucks to continue moving while the crane is in use.
- Designated Areas:
  - Steel Laydown: This large site lends itself nicely to storage areas. There is plenty of room to have two steel staging areas. These areas were selected to make delivery easy and crane placement efficient. A forklift can easily fit near these two areas to unload the steel delivery trucks.
  - Excavated Soil: The excavated soil is permitted to be reused for backfill and for the athletic fields. Therefore, storing it on site is more cost efficient than having it removed and then brought back.
  - Mock-Up: This area is near the owner's trailer and is relatively far from daily construction activities. Façade mock-ups and other needed scaled mock-ups can be built in a safe zone.
  - Storm Water Management Pond: This is located slightly down grade from the buildings.

- Crane:
  - The crane was selected on three main criterions: mobility, lifting capacity, and placement radius.
  - The following mobile crane was selected:
    LTM 1030-2.1
    - 42 ton max capacity at 10' radius
    - 148' max lifting height
    - 132' max radius (approx. 120' used in site plan)

Figure 6.3 LTM 1030-2.1 Mobile Crane

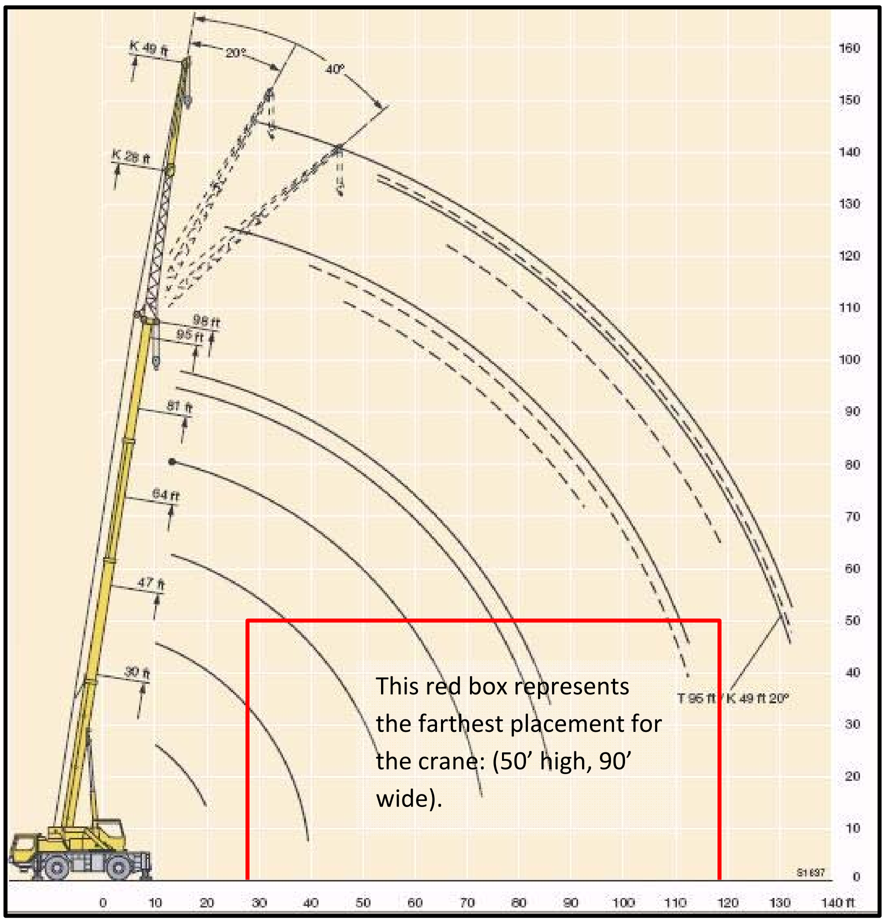


Figure 6.4 Crane reach capabilities diagram from *http://www.liebherr.com/at/en/57534_57537.asp*

The most difficult placement for the crane will be at 50' high and 90' away. The diagram indicates that this mobile crane is more than capable. The heaviest pick will be a 30' W 18x97 (*97 plf x 30' = 2910 lbs → 1.45 tons*). Therefore, the crane capacity is more than adequate. The mobility of the crane will allow for easy transport to and from site. Additionally, the crane will be able to move between the three locations necessary to erect the Flagship Building and Gymnasium.

7 | Project Logistics Details

7.1 Project Schedule Summary

General Schedule Overview

While this project is classified as design-build, the project schedule does not reflect the fast track process that usually coincides with a design-build project. After referencing the detailed project schedule in Appendix B, it is apparent that the design phase was completed before building construction began. It should be noted that small design changes are occasionally made, however the main design was to be finalized before construction began so it could be approved by the Washington Christian Academy Organization. Upon further review of the schedules, a large gap in time exists between October 30, 2006 and January 25, 2007. The reason for the almost 3 month delay was obtaining the necessary permits for construction. During this lapse, the project essentially shut down and valuable time was wasted. To compensate for this delay, many item durations have been shortened and tasks condensed. So in a sense, the project will be moving at a fast track pace even though that was not the initial intention.

The driving force of this project is the schedule. The Flagship School and Gymnasium must be open for the commencement of the 2008-2009 school year. As it is scheduled now, WCA moves in at the end of July 2008, and punchlist items continue through August. While this meets the crucial school year deadline, this leaves no room for delays or complications from now until project completion. The initial delay of permits took away any float or “buffer time” from the contractor. There are key elements in the building process that must happen sequentially. Ensuring that these tasks are completed on time is essential in finishing successfully, as one delay will cause a domino effect. It is the designed structure of the building that dictates this sequential order.

Foundation and Structural Schedule Impacts

The structural foundations are mainly made up of shallow concrete continuous wall footings. The rest of the base structure is a simple slab on grade, bearing on compacted soil. The foundations must be excavated, formed, and placed before the superstructure can begin being constructed. The superstructure of both buildings is CMU load bearing walls with steel joists. These must also be built sequentially, due to the obvious necessity that the CMU walls must bear on the foundation, and the steel must bear on the CMU. Some overlapping occurs in the schedule for the structural construction of the multiple floors. Once the steel trusses are up, and the decking and concrete is placed, the next floor’s load bearing walls may begin. Simultaneously, the lower floors rough-in may begin. Once the roof is complete, the exterior façade and interior finish work may begin.

Proper foresight by the construction manager resulted in building the Gymnasium at the same time as the Flagship Building. This is to keep production and efficiency rates high. Since some items of the Flagship Building will take longer to construct (because it is larger and more complex), the Gymnasium can use trades that are not busy on the Flagship Building. For instance, both foundations will go in at the same time because it is logical to excavate, form, and place concrete at the same time. Naturally,

the Gymnasium foundation will be completed first. While the foundation is still being worked on for the Flagship Building, CMU block can be placed at the Gym. Once finished at the Gym, the mason can move directly over to the Flagship. This creates a parade of trades from the Gymnasium to the Flagship.

Finishing Constraints

The finish work in the Gymnasium is slightly different than an average building. In order to lay the gym flooring, there must be a conditioning period for not less than 7 days prior to the placement of the floor, during the placement of the floor, and 3 days after placement. From this point forward, the ambient temperature must be maintained between 65 and 75 degrees Fahrenheit and have no more than 50 percent relative humidity. All overhead work including mechanical and lighting systems and athletic equipment must be installed prior to the floor placement. Although the gym flooring is a-typical of building finishes and has strict guidelines, it should not cause problems for the overall schedule because the Gymnasium finishes early and it is the Flagship Building that determines when the project is finished.

7.2 Detailed Project Schedule

Please see the Detailed Project Schedule in ***Appendix B.***

Overview

The Washington Christian Academy (WCA) Flagship Building and Gymnasium site was undeveloped prior to breaking ground for the school. Therefore, neither demolition nor school release dates constrained the schedule. In other words, construction was not limited to only the summer months as it most likely would have been on the current WCA site in Silver Spring, MD. The Washington Christian Academy is able to function normally in their current facility while the construction of the new facility is underway. The largest constraint on the project is that the school must be completed and open for the 2008-2009 school year.

This opening date constraint should have been no problem according to the contract schedule. Upon review of the schedule in Appendix B, a large gap in time can be noticed between October 30, 2006 (Building Permit) and January 25, 2007 (NTP, mobilization). The reason for the almost 3 month delay was obtaining the necessary permits for construction. During this lapse, valuable time was wasted. To compensate for this delay, many activity durations have been shortened. The more rigorous schedule will allow the project to still meet the necessary completion date. As it is scheduled now, the tenant will be able to move-in in mid July, 2008. There is very little tolerance for any more substantial project delays.

Sequencing

In general terms, the sequencing of the project is by floor, not by phases or sections. The structural system of the building requires the building to be built from the bottom up, floor by floor. The foundations of both buildings will begin construction at the same time. Tradesmen will work between

the two buildings sequentially, creating less down time and increasing efficiency. An example of the sequence after foundation completion is as follows:

Table 7.1 Sequencing of activities after the foundation.

Time	Activity			
T1	Floor 1 Superstructure	Gym Superstructure		
T2	Floor 2 Superstructure	Floor 1 MEP Rough-In	Gym MEP Rough-In	
T3	Floor 3 Superstructure	Floor 2 MEP Rough-In	Floor 1 Interior	Gym Interior
T4	Roof Superstructure	Floor 3 MEP Rough-In	Floor 2 Interior	Floor 1 Finishes

This sequencing continues until both buildings are complete. This sequence should maximize the productivity of the subcontractors, as well as the use of the crane and concrete pump. Once the crane is on site, it should be used to its maximum capabilities every day in order to avoid losing money on the lack of productivity.

<u>Schedule Assumptions</u>

The following assumptions were made in the creation of the project schedule.

- Activity Durations: Great effort was made to make the activity durations accurate. With limited experience on creating schedules, some of these durations were knowledgeable guesses.
- Floor Sequencing: Activities on each floor occur in the same order as the previous floor.
- Overall Project: The Flagship Building and Gymnasium can be under construction at the same time.
- Inspections: Inspections that need to occur during construction are not listed as activity items. For instance, if the sprinkler system needs to be checked before the ceiling is hung, that inspection time is not included.
- Delays: No weather or any other delay “buffers” were accounted for.
- Move-In: The tenant may move in while punch list items are still being remedied.

7.3 Project Cost Evaluation

Actual Cost

- Total Size: 78,271 SF
    - Flagship: 67,616 SF
    - Gymnasium: 10,655 SF

Table 7.2 Actual Building Construction Costs (CC) and Construction Costs per SF (CC/SF).

Building	Cost per SF (CC/SF)	Size (SF)	Total Cost (CC)
Flagship	$164.03	67,616	**$11,091,050**
Gymnasium	$148.23	10,655	**$1,579,390**
			$12,670,440

This results in a cost of approximately $161.88/SF for the entire project (both buildings).

Project Cost

Table 7.3 Total Project Costs (TC) and Project Costs per SF (TC/SF).

Included	Cost per SF (TC/SF)	Size (SF)	Total Cost (TC)
A	$220.72	78,271	**$17,275,640**
B	$264.99	78,271	**$20,741,480**

A: Includes Actual Building Construction Costs, Permits, and Site work

B: Includes all of *A*, plus Design Costs, Unsuitable Soils Contingency Allowance, Owner's Change Contingency, Testing, and Owner's Rep. Salary

Table 7.4 Major Building Systems Costs.

System	Building	Cost/SF	Size (SF)	Total Cost
Electrical[1]	F	$31.24	67,616	$2,112,322
	G	$9.00	10,655	$95,900
	B	$28.21	78,271	$2,208,222
Fire Protection	F	$2.58	67,616	$174,360
	G	$2.31	10,655	$24,640
	B	$2.54	78,271	$199,000
Mechanical[2]	F	$24.73	67,616	$1,672,188
	G	$18.19	10,655	$193,790
	B	$23.84	78,271	$1,865,978
Structural[3]	F	$37.88	67,616	$2,561,300
	G	$62.39	10,655	$664,765
	B	$41.22	78,271	$3,226,065
TOTAL	B	$95.81	78,271	$7,499,265

F: Flagship Building G: Gymnasium B: Both Buildings (total for project)

[1] Includes Electrical System and Communication System
[2] Includes Plumbing, HVAC Systems, and Mechanical Equipment
[3] Includes Concrete, Masonry, and Structural Steel Only

Square Foot Estimate using *R.S. Means 2007*

The *2007 R.S. Means Square Foot* estimate guide contained entry M.520: Religious Education. Upon review, the largest SF area for this building type was 13,000 SF, 1 story. Even multiplied by 3 to account for the extra stories in the Flagship Building results in 39,000 SF, which is significantly less than the buildings' actual 78,271 SF.

It was decided to use M.580: School, Jr. High, 2-3 story. The reasons for this decision were the following:

- The Flagship Building is a school teaching K-12, Jr. High is in the middle of that range.
- The costs for Elementary schools and High schools were less than the Jr. High, so using the Jr. High for the cost estimate would yield the highest school cost and therefore be the most conservative solution.
- The gymnasium is included in the Jr. High estimate.

Below is the cost breakdown using *R.S Means*:

Cost per square foot of floor area: $121.19
Perimeter Adjustment: $2.51
Story Height Adjustment: <u>$1.22</u>
$124.92/SF

$124.92/SF at 78,271 SF yields a building construction cost of:
$9,777,613

Common Additives account for an approximate additional cost of:
$1,500,000

Location Factor:
Olney, Maryland was not on the list and the WCA is not actually in Washington, D.C. Therefore, the most fair and accurate method available was to use an average.

Average for all listings in Maryland .865
Washington, D.C. .98
Location Factor Average: .92

Time Factor:
Not used because data from 2007

Final Result
R.S. Means M.580: School, Jr. High, 2-3 Story Building Construction Cost:
$132.56/SF x 78,271SF: **$10,375,404**

Parametric Estimate

The following parametric estimate was performed in the *D4 Cost 2002* estimating software. The table represents four similar projects that were chosen to produce SF and Building Construction Cost estimates. The location, time, size, and construction methods were changed from the projects listed below to better match those of the WCA project. After the adjustments, the following cost estimates were reported.

Table 7.5 Parametric Estimate Summary.

Building Name	Description	Cost per SF	Total Building Construction Cost
St. Anne's Episcopal School	Rural, traditional architecture, gym included	$178.48	$13,969,976
Christ the Teacher Catholic School	Rural, gym included, K-8	$108.72	$8,509,695
Pope John XXIII HS	High School Building	$83.41	$5,639,553
	High School Gymnasium	$82.84	$882,608
			$6,522,161
Northwood School District	Rural, K-12, gym included	$53.61	$4,196,163
AVERAGE		$106.03	$8,299,499

Estimate Comparison

Table 7.6 Estimate Comparison Summary.

Estimating Tool	Cost/SF	Cost
Actual Building Construction Cost	$161.88	$12,670,440
Total Project Cost	$264.99	$20,741,480
R.S. Means 2007	$132.56	$10,375,404
D4 2002	$106.03	$8,299,499

For comparisons sake, the total project cost should not be considered because no other estimating tool accounted for sitework, contingencies, design fees, etc. Therefore, the true comparison lies between the Actual Building Construction Cost vs. *R.S Means 2007* and *D4 2002*. The *R.S. Means 2007* comparison is relatively close to the actual cost. This is predictable because practically every part of the WCA buildings was included (correct size, height, school & gymnasium, kitchen, bleachers, etc.). The fact that the guide is from 2007 also helps because SF values are current and more accurate to today's estimates. The *D4 2002* cost estimate is significantly lower. This could be attributed to outdated information, not finding suitable school matches (most were only K-8), and the high quality construction that the WCA owner is seeking.

7.4 General Conditions Estimate

Please see the General Conditions Estimate in ***Appendix C.***

Assumptions

To complete the General Conditions Estimate, the following information was assumed. Most of the information came from the detailed project schedule and basic general conditions estimates from class notes.

- Construction Start: 2/1/07 based off of the 1/25/07 NTP/Mobilization from the project schedule.
- Construction Completion: 7/1/07 based off the substantial completion for the Flagship Building from the project schedule. The reason for the slight change in dates was to create an even number of months on the project. It can be assumed that the project completion date will change as the project continues, however this estimate does not account for that.
- Duration (months): 17 months derived from the dates above.
- Duration (weeks): (52 weeks / 12 months) X 17 month duration = 73.7 weeks
  This is a rough estimate. The leap year is not accounted for, but neither are holidays and other non-working days. Overall, it is a reasonable amount of time for the general conditions estimate.
- Temporary heat will only be needed on the project for 6 months.
- The warranty quantity comes from 10% of the total project cost.
- The Superintendent does not completely finish the project. Once the project is within the final weeks and activities are winding down (finishes, landscaping, punchlist), the Assistant Superintendent takes over and the Superintendent moves on to another project.
- The project time for the Project Executive, Senior Project Manager, Administrative Assistant, and IT Technician were obtained from information from Forrester Construction Company. They are merely estimates and could vary week to week. If problems were to arise on the project, these times would increase.
- Progress photographs, schedules, reports, and meetings are included by the General Contractor with no specific charge.

Analysis

- The General Conditions cost is approximately 9% of the total project cost. This is a reasonable estimate for this size project. The owner and general contractor have a good working relationship. All parties involved are striving to solve problems collectively and efficiently to avoid change orders and delays. Avoiding change orders will save the owner money, and finishing early will save everyone money.

8 | Introduction to Thesis Analyses

The Partnership for Achieving Construction Excellence (PACE) roundtable event was held at Penn State in the fall of 2007. This event inspired the basis for the construction industry research issue. The roundtable motivated me to look more closely at the English-Spanish language barrier in the construction industry, and what problems are created from this barrier. Globalization is prevalent in most markets today, and each industry must create strategies to adapt and compete in the ever changing economy. This inspired the first thesis analysis which addresses the status of the barrier today, surveys industry members, identifies the top consequences from the barrier, and discusses possible solutions.

The Washington Christian Academy owner is concerned with cost constraints on the project, but ensuring that the job is done well and that the building is of high quality is more important. The owner put some contingency money in the project budget to allow for changes and additions, but would most like to use the money for last minute upgrades that would really make the educational facility first class.

Since high quality is a priority to the owner, I began looking into ways to increase the quality of schools. This project is not pursuing any substantial sustainability aspects, even though it has been proven that students perform better in cleaner, sustainable environments. According to the Pennsylvania Governor's Green Government Council, the three main environmental factors that affect students' performance are: better acoustics, utilization of natural light, and improved indoor air quality[4]. Schools that implement these features are healthier, more cost efficient, more sustainable, and the students are more productive.

Research has proven that as a result of bettering the three aspects mentioned above, student test scores increase, attendance rates are higher, and the students and staff are healthier. Additionally, the energy consumption of the building generally decreases which saves the owner money every month from the electrical savings. It was based on these findings that the two of the technical analyses were inspired.

The second thesis analysis is entitled Redesign of Gymnasium Ductwork: Replace Sheet Metal with Fabric Duct. This analysis contains an AE mechanical and acoustical breadth. The analysis addresses the first environmental issue: better acoustics. The mechanical ductwork in the gymnasium is redesigned with fabric duct and the acoustical implications are calculated. Additionally, the advantages of the new system are discussed and construction implications as far as cost and schedule are covered.

The third thesis analysis is entitled Incorporation of Daylighting in Classrooms. This analysis contains an AE lighting and electrical breadth. The analysis addresses the second environmental issue: utilization of natural light. Natural light will only be beneficial to students and reduce energy consumption when the lights are turned off. This analysis focuses on incorporating the concept of daylighting into the

[4] Information obtained from *Green Schools* found at
http://www.gggc.state.pa.us/gggc/cwp/view.asp?a=516&q=157111&gggcNav=|6833|

classrooms. By using daylighting technology, the students will be able to benefit from have increased natural light and the owner will see energy cost savings.

The final environmental factor, improvement of indoor air quality, is not addressed in a technical analysis. There are many viable options for the owner to consider, such as adding advanced filtration systems to the mechanical system or installing CO_2 sensors in the classrooms. Advanced filtration, for example using Ultraviolet Germicidal Irradiation (UVGI), would clean the air much more efficiently and thoroughly than then current filtration system. CO_2 sensors in the classrooms monitor levels of the gas in the air which often causes fatigue and unhealthy conditions for students. Once a certain CO_2 level is reached, the mechanical system triggers the allowance for more outdoor air rather than re-circulated. Either of these solutions would generate a higher quality of indoor air. However, these additions would have to be addressed from a value engineering standpoint because while they would add quality, they would also increase cost. These methods would be adding value to the school, bettering education for the students, and possibly decreasing lifetime cycle costs of the mechanical systems. Due to a lack of time and resources, I cannot fully investigate this issue but I wanted to briefly mention its importance in a school environment.

In summary, I have chosen to investigate three areas of study. The first pertains to the entire construction industry and the latter two pertain specifically to the WCA. The owner would appreciate these improvements because they are focused on producing a high quality environment at a reasonable cost. I expect that all of my technical analyses will result in a better learning environment and cost savings, which creates a happier, healthier environment for the occupants and the owner.

9 | Consequences of the English-Spanish Language Barrier in the Construction Industry

AE Construction Management Critical Industry Research Issue

9.1 Introduction

The Partnership for Achieving Construction Excellence (PACE) roundtable event inspired research of a critical issue facing the construction industry. The PACE event motivated me to look more closely at the English-Spanish language barrier in the construction industry, and what problems are created from this barrier. I have long been a supporter of becoming bilingual, and this skill would be a very beneficial in the construction industry. With schedules as strict as they are today, it is necessary that all involved parties on a project act as a team. Having a language barrier only complicates this process, and ultimately delays the project completion or success.

9.2 Problem Statement

The English-Spanish language barrier between general contractors, subcontractors, and laborers in the Washington, DC and surrounding areas creates problems with efficiency, safety, and a general level of respect. Information is needed to determine which consequences are the most common, and how these consequences can be remedied.

9.3 Goal

The goal of this analysis is to identify the five leading problems the language barrier creates in the industry. The research will focus on the issues presented in the problem statement, and any others that may be prevalent in the industry. Furthermore, it is a goal of this research to determine how industry members currently view the status of the barrier. Viable solutions will be explored in order to remedy these frequent issues.

9.4 Methodology

1. In order to provide a sound basis, step one is to research the history of the language barrier in the Washington, DC construction industry by reading articles and literature focused on this topic.
2. Make a questionnaire for industry members; specifically project managers and superintendants that have been in the industry for at least three years.
3. Survey at least 50 industry members from the eastern United States in order to obtain a statistically appropriate sample size.
4. Compile responses, identify the top five problems related to the language barrier, and graphically represent the data.

5. Research what companies, individuals, and universities are doing to combat against these consequences.
6. Form conclusions and make recommendations on what the industry can do to improve the language differences.

9.5 Tools/Resources

1. Internet and online resources
2. Forrester Construction Company
3. Penn State Architectural Engineering Faculty
4. Microsoft Office and Adobe applications
5. Industry members who serve as survey participants

9.6 Expectations

I expect that the surveys will yield the top five problems relating to the English-Spanish language barrier on the jobsite. I suspect that three of the top five are listed in the problem statement. I expect that the answers on the surveys will vary substantially because many of the answers will be based on personal experience, which varies greatly from person to person. This research will also show ways to break down this barrier and remedy the most frequent problems.

9.7 Research Information on the Language Barrier

The intent of my research is to determine the current status of the language barrier in the industry. In order to do this, I think it is necessary to gain a background of knowledge regarding the current standing of Hispanic workers in the construction industry. According to the U.S. Census Bureau, in 2003 Hispanics made up approximately 18% (1.4 million)[5] of the workforce in the construction industry. One year later, 2004, Hispanics made up approximately 21.4% of the construction workforce (see Figure 9.1). In fact, the construction industry comes second only to agriculture in employing Hispanic workers. This proves that the Hispanic influence in the construction industry is growing, and fast.

[5] According to information found at the US Center for Disease Control
http://www.cdc.gov/eLCOSH/docs/d0100/d000038/pdfs/page%2017.pdf

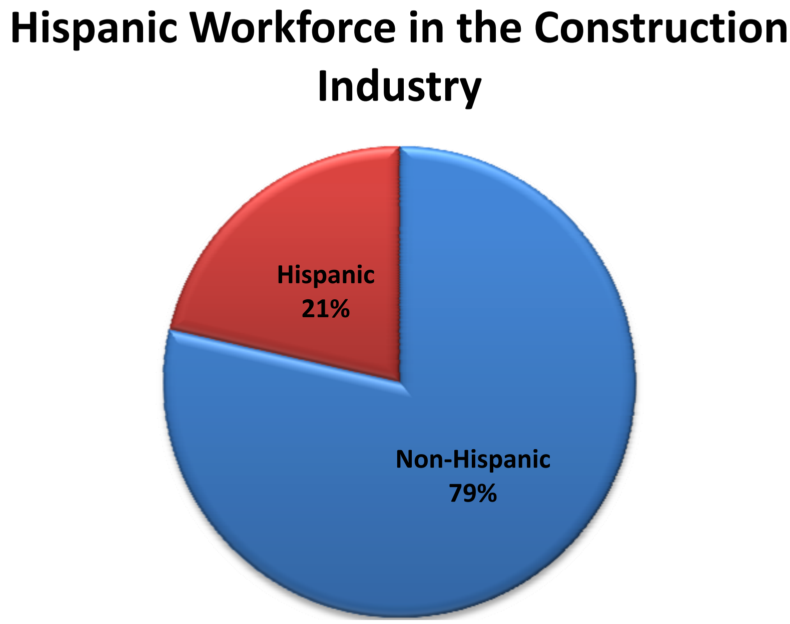


Figure 9.1 Graphical representation of the breakdown of Hispanic and Non-Hispanic workers in the construction industry. Data from http://www.ctre.iastate.edu/pubs/t2summaries/hispanic2.pdf

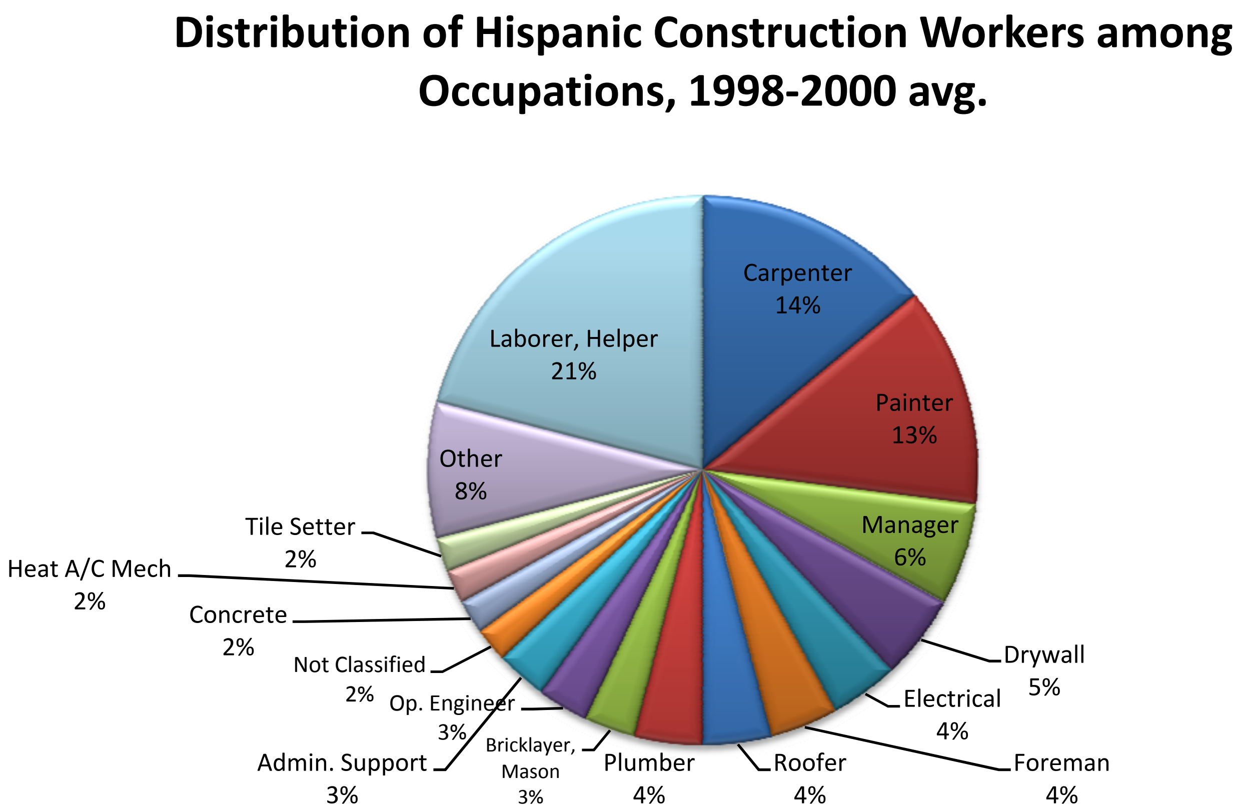


Figure 9.2 Graphical representation of the breakdown of Hispanic construction workers by trade. Data from http://www.cdc.gov/eLCOSH/docs/d0100/d000038/pdfs/page%2017.pdf

Figure 9.1 shows the percentage of construction workers that are Hispanic. In order to be classified as Hispanic, a person has to voluntarily identify themselves as Hispanic. Figure 9.2 displays the breakdown of Hispanic workers by trade. It does not account for Non-Hispanic workers. This chart also proves that Hispanics are much less likely to be managers and more likely to work in the field or perform laborious tasks.

The number of Hispanic workers in the U.S. is growing rapidly. They are most heavily concentrated in the Southern and Western United States, where as much as 86%[6] of Hispanic construction workers work. The Northeast employs about 8% of the Hispanic construction workforce, and the Midwest employs about 6%. Approximately three quarters of Hispanic construction workers are of Mexican origin, with 70% of all Hispanic construction workers born outside the United States. Between 1980 and 2000, construction workers in the U.S. who identified themselves as Hispanic grew 150%[2] (see Figure 9.3).

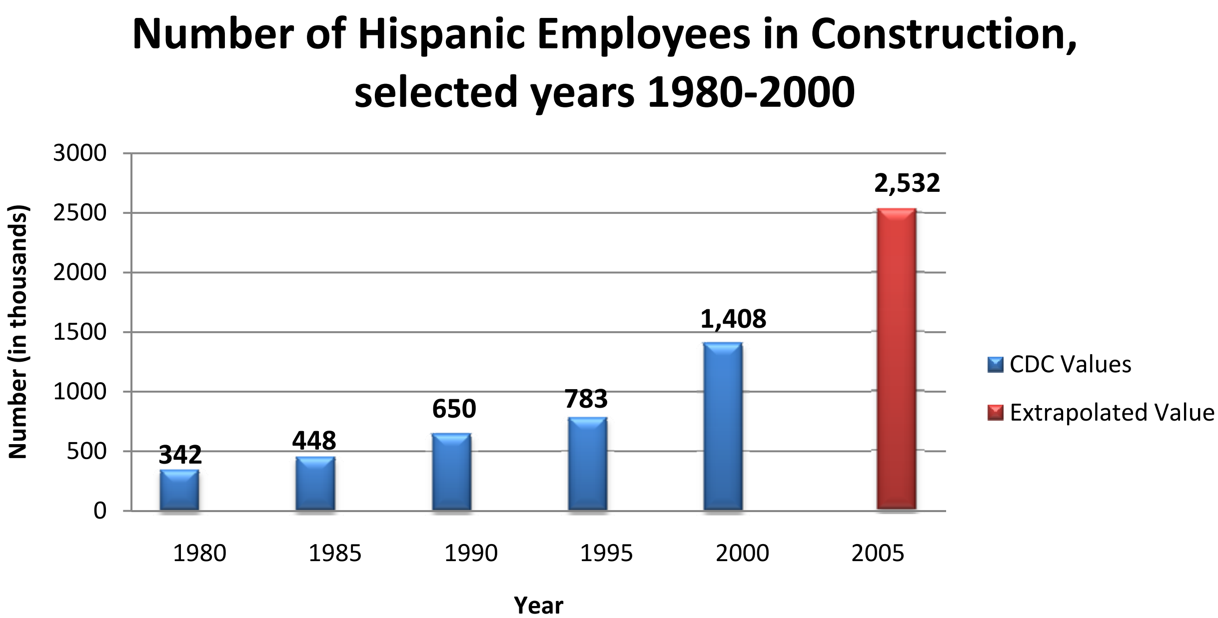


Figure 9.3 Graphical representation of the increase of Hispanic construction workers from 1980-2000. Data from http://www.cdc.gov/eLCOSH/docs/d0100/d000038/sect16.html. *Please note, 2005 data extrapolated and not based on cdc.gov data.*

Figure 9.3 reflects an exponential growth of Hispanic workers in the construction industry. The values for 2005 were extrapolated as follows:

Year 1995 / Year 2000 = 783,300 / 1,408,000 = **55.6%** *or 1.8 times the population growth*

[6] According to information found at the US Center for Disease Control http://www.cdc.gov/eLCOSH/docs/d0100/d000038/sect16.html

Assuming that 2000-2005 grows at the same rate:

1,408,000 / 0.556 = **2,532,000** *or* 1,408,000 X 1.8 = 2,533,000

This estimate is conservative because the chart clearly shows that the growth rate is not constant. Therefore, it can be safely assumed that the current number of Hispanic employees is well above 2.5 million.

But why do all of these statistics matter when considering the English-Spanish language barrier? For a few reasons; the top three being Spanish speaking immigrants, fatalities, and unions. The fact that 70% of the Hispanic workforce was not born in the United States may indicate that 70% of the workforce speaks a native language that is not English. It is estimated that 32% of Hispanic workers speak only Spanish at their homes[7]. This difference in language creates many problems, especially when considering fatality rates. Hispanics have the highest rate of fatal work injuries among all racial/ethnic groups; 4.5/100,000 which considers all occupations (not just construction). Construction accounts for more than any other labor sector (1,126 Hispanic fatalities in 2003)[8]. In 2001, 41% of all construction related deaths in the state of Georgia were people of Hispanic ethnicity.

It is also reported that Hispanic workers are much less likely to join a union than Non-Hispanic construction workers. It may be assumed from this information that the chances for a non-English speaking individual to learn English is increased when in a union due to the rules and regulations of most unions and the apprenticeship practices that new union members endure. The statistical figures provided above for the Northeastern United States say that only 8% of all Hispanic construction workers work in that region. It should be pointed out that the focus of this study is the Washington, DC area which has a much lower union workforce than other Northeastern cities. As such, the quantity of Hispanic workers in the DC area may be quite large when compared to other union-dominated Northeastern cities (NYC, Philadelphia, & Boston).

[7] According to information found at the US Center for Disease Control http://www.cdc.gov/eLCOSH/docs/d0100/d000038/sect16.html

[8] According to information found at the Center for Transportation, Research, and Education at Iowa State University http://www.ctre.iastate.edu/pubs/t2summaries/hispanic2.pdf

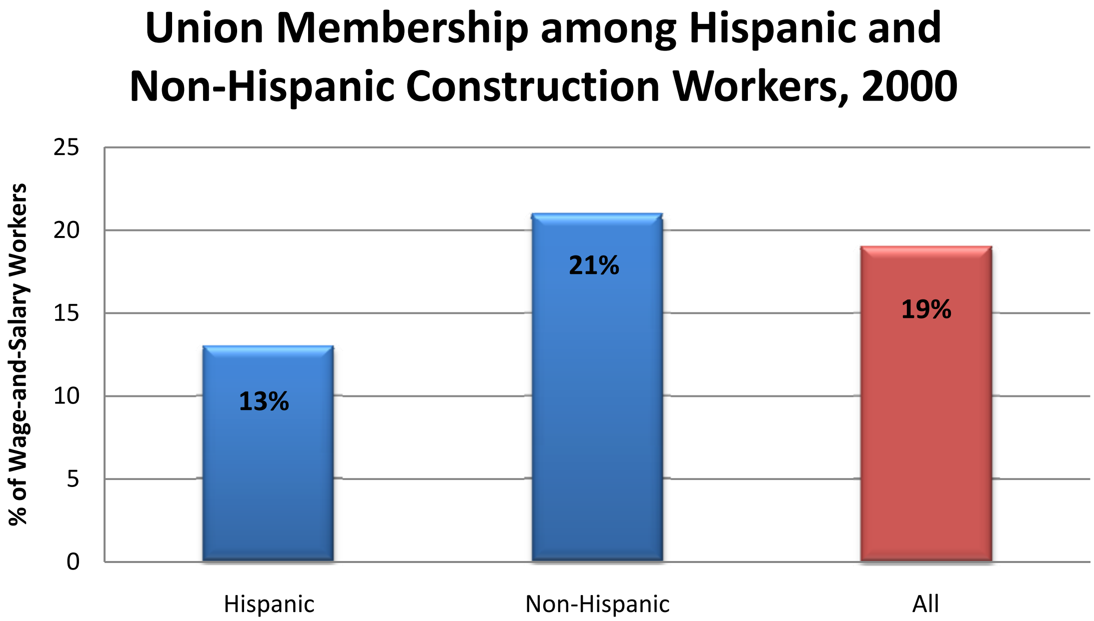


Figure 9.4 Graphical representation of the union membership of Hispanics vs. Non-Hispanics out of the total amount of union construction workers. Data from http://www.cdc.gov/eLCOSH/docs/d0100/d000038/pdfs/page%2017.pdf

Overall, this research has enlightened me to the scope of the Hispanic workforce in the construction industry. There is no denying that there is a valid presence of Spanish speaking workers in the industry. The surveying of industry members will assist in the understanding of how this language difference affects the success of construction projects.

9.8 Industry Survey

After creating a survey entitled "Consequences of the English-Spanish Language Barrier in the Construction Industry", I sent the survey to professionals in the construction industry. The basic requirements for participating in the survey were having at least 3 years of construction experience and currently working somewhere in the Northeastern/Mid-Atlantic U.S. region. It should be noted that the vast majority (approximately 95%) of surveyed professionals were from Washington, DC and surrounding areas. To view a blank version of the survey, please see **Appendix D.**

9.9 Survey Result Summaries & Evaluations

In total, 65 qualified industry members responded to the survey.

Table 9.1 Breakdown of 65 participants by job title.

Job Title	Number of Participants	Percentage of Participants	Average Years Worked in Construction Industry
Superintendent & Asst. Superintendent	16	24.6%	21
PM, Asst. PM, Executive, VP	32	49.2%	15
Field/Project Engineer	12	18.5%	4
Other: estimator, drywall foreman, structural engineer	5	7.7%	10

Project managers, assistant project managers, executives, and vice presidents made up the highest group of professionals that responded to this survey. It is interesting to compare the average years worked in the industry versus some of the answers that each group reported. More on that detail will be discussed in later results.

Table 9.2 Selected survey question results considering all 65 participants.

Q. No.	Question Summary	Answer	Result (people)	Result (percent)
5	Does English-Spanish Language Barrier exist?	Yes	62	**95.4%**
		No	3	**4.6%**
6	Is it getting better or worse?	Better	21	**35.0%**
		Worse	39	**65.0%**
7	Are jobsite signs bi-lingual?	Yes	51	**78.5%**
		No	14	**21.5%**
8	Have you attempted to speak Spanish?	Yes	32	**50.0%**
		No	32	**50.0%**
9	Encounters with Spanish speaking industry members.	Never	2	**3.1%**
		Monthly	1	**1.6%**
		Weekly	6	**9.4%**
		Daily	55	**85.9%**

Table 9.2 presents interesting results from the survey. It should be noted that not all *Results (people)* add up to 65. This is because some participants did not answer every question. In these instances, the *Results (percent)* were calculated by the amount of people who responded to that question rather than 65. Below are some conclusions based on the data above.

- An overwhelming percentage of participants believe that there is currently an English-Spanish language barrier in the construction industry. Therefore, this indicates that my research is based on a realistic problem and that something needs to be done to fix it. Generally, the three

people that responded “no” to question 5 are from union areas where most workers are required to speak English.

- The results representing whether or not the barrier is getting better or worse is not overwhelming. While two-thirds of people believe it is getting worse, there are still a significant amount of people thinking that this problem is going away. This result is expected because this answer would be based completely on experience and everyone’s experiences are very different.

- I was pleased to see the results of question 7. Having bi-lingual jobsite signs is one way to communicate dangers and hazards in both languages. Also, the signs begin to slowly teach each respective language the other language. After reading “hazardous” and “peligroso” on the same sign over and over, workers may be able to remember and utilize the word when speaking.

- Only 50% of participants reported that they have attempted to learn or speak Spanish on a construction site. This could also be seen in a positive light that half of all participants have tried. My personal opinion is that this number is too low, and that when working with individuals different from you it is important to at least attempt to compromise and learn a few phrases or words from their language. They should be doing the same as well.

- Question number 9 results indicate that the strong majority of participants interact with Spanish speaking individuals on a daily basis. This only emphasizes the fact that there is an immediate need for action to begin dissolving this barrier.

The chart and diagrams on the following pages represents the results from survey question 12.

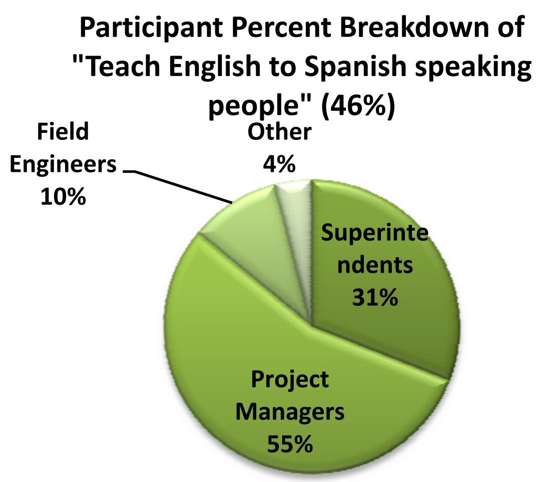
Which do you think is more *likely* to happen?

A. Teach English to Spanish speaking people
B. Teach Spanish to English speaking people

Instinctually, I feel that some participants may have answered the question “which would you prefer to happen?” rather than “which do you feel is more likely to happen?”. In that case, answers would vary greatly depending on how people read or interpreted the question. The misinterpretation turns an already subjective question into a completely personal, biased question which is unfoundedly subjective. However, for research purposes we must assume that people read and understood the question the way it was intended (which is how it was clearly worded). In my opinion, these results are the most intriguing of the entire survey.

Table 9.3 Results on the likelihood of teaching English to Spanish speaking people and vice versa.

	Total (all participants)		Per Participant Category			
Answer	**Results (ppl.)**	**Results (%)**	**Super. (%)**	**PM (%)**	**F/P Eng. (%)**	**Other (%)**
Teach English to Spanish speaking people	29	**46%**	56%	52%	27%	20%
Teach Spanish to English speaking people	34	**54%**	44%	48%	73%	80%



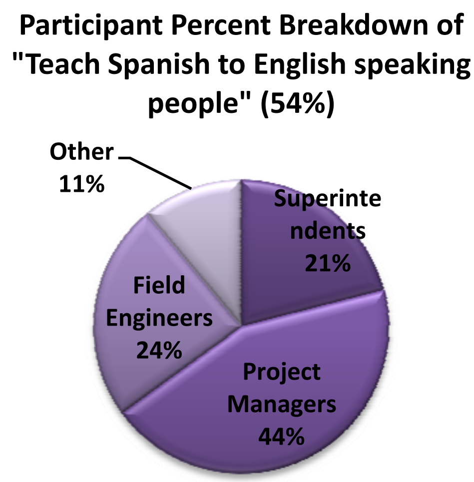


Figure 9.5 Graphical representations of the percent of participants that make up the Total Results

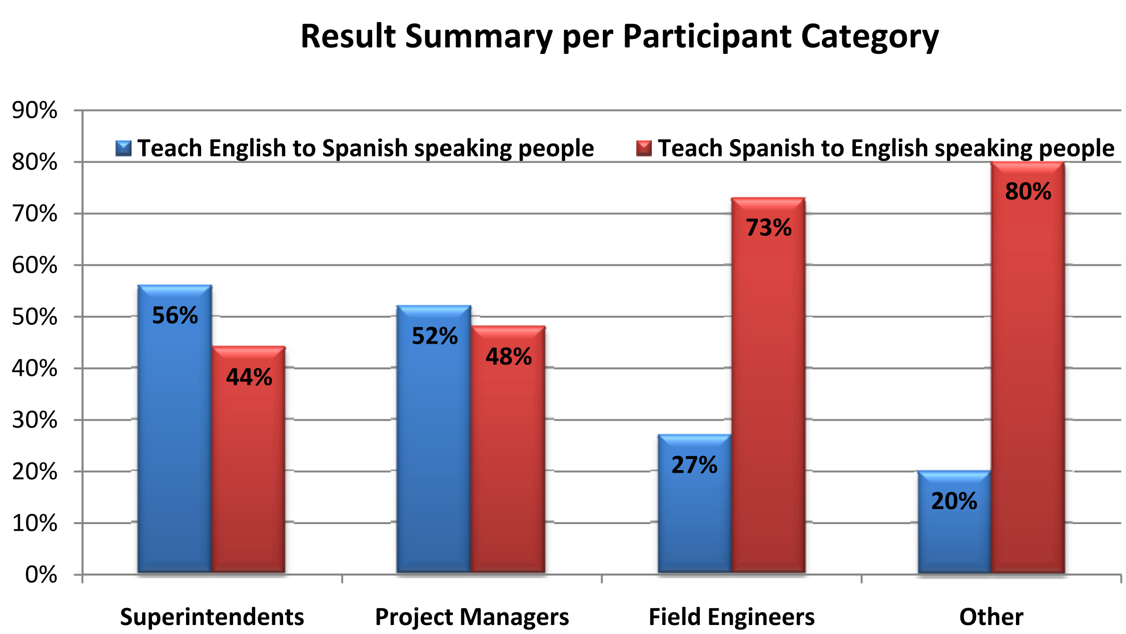


Figure 9.6 Graphical representation of percent breakdown based on participant category

Figure 9.6 is more informative than Figure 9.5. This is because the ratios in Figure 9.5 represent the percent of people who make up the total results. For instance, 16 *Project Managers* out of the total 29 results answered "Teach English to Spanish speaking people". This results in a higher percent than any other participant category, but only because *Project Managers* have more participants.

On the contrary, Figure 9.6 shows relative information per participate category. It is very intriguing to see the breakdown per job position. This chart shows that the *Field Engineers* and *Other* participants were so strongly opinionated that they swayed the outcome of the total in their favor. *Superintendents* and *Project Managers* were more divided in their answers; and neither category's majority was the final total result.

I stated earlier that I thought it was interesting to compare years in the industry with results, and this figure demonstrates why. The strong majority of *Field Engineers* and *Other* participants felt that it is more likely to teach Spanish to English speaking people. The average years in the industry for the two categories are 4 years and 10 years, respectively. It is safe to conclude that generally younger, newer industry members view this issue in a much different light than veteran professionals. This could be for many reasons, including different mentalities from different generations, more vs. less experience with Spanish speaking persons, the more recent education (high school or college) with foreign language studies, the recent growth explosion of the Hispanic workforce, and lastly a generational acceptance of diversity.

The world is becoming a smaller place, and global industry is the wave of the future. The younger generations have been recently educated in the necessity to adapt to globalization and accept diversity. The time is now for everyone to become bilingual, not just in the construction industry. School systems are teaching foreign languages at a much younger age. Advanced foreign nations are leaps and bounds beyond the United States when it comes to bilingual capabilities. It is my opinion that the younger members of the construction workforce have been exposed to this mentality, and therefore responded that it is more likely and assumedly more beneficial to teach Spanish to English speaking individuals.

Below are the summarized explanations from the survey participants.

Teach English to Spanish speaking people:

- Helps Spanish speaking people personally and professionally. Gives workers a competitive advantage and therefore they are more likely to obtain leadership/management roles.
- With only one English speaking foreman who may speak broken English, you are relying on someone who may understand only part of what you say.
- English is part of the American culture.

Teach Spanish to English speaking people:

- Many Spanish speaking workers are uneducated or illiterate, so they are less able to learn.
- English is more difficult to learn because of slang and exceptions.
- It is important and valuable to be bilingual.
- General Contractors and English speaking managers have greater resources to learn Spanish.

9.10 Consequences of the Language Barrier

The survey listed four possible consequences of the English-Spanish Language Barrier and allowed participants to write in up to two more consequences of their choosing (optional). The consequences were then ranked 1-6, with 1 being the most severe or serious consequence and 6 being the least. The results were tallied using a reverse point system, therefore the consequence with the highest point total is considered the most important to survey participants. The results are below.

Table 9.4 Result rankings of the top consequences resulting from the language barrier.

Consequence	Total (all participants)	Super-intendents	Project Managers	Field Engineers	Other
Loss of Productivity/ Efficiency	22.4%	21.9%	22.6%	23.8%	19.5%
Greater Safety Risks	27.3%	29.1%	26.1%	27.5%	27.6%
Difficulty in Giving Instructions (Basic Jobsite Communication)	30.0%	29.8%	30.3%	30.3%	27.6%
Lack of Respect/ Diminished Team Atmosphere	17.9%	18.2%	16.7%	17.4%	25.3%
Other (Write In)	2.4%	1.0%	4.3%	1.0%	0.0%

1st	2nd	3rd	4th	5th	Color Key

This table shows that the categories of survey participants agree with the overall order of the most serious to the least serious consequences of the English-Spanish Language Barrier. The overall ranked order from the most serious consequence to the least is:

1) Difficulty in Giving Instructions (Basic Jobsite Communication)
2) Greater Safety Risks
3) Loss of Productivity/Efficiency
4) Lack of Respect/Diminished Team Atmosphere
5) Other (Write In)

The only variations from this ranking were the members of the *Other* category, who had a tie for the first ranked consequence. In all of the categories, the first and second ranked consequences were extremely close; only an average difference of 2%. This indicates that participants view "Difficulty in Giving Instructions" and "Greater Safety Risks" as the two leading consequences, and that perhaps they go hand in hand. Instructions may include safety instructions or Tool Box Talks, which therefore greatly affects both of those categories.

Below are the #5 Other (Write In) responses.

Similar to #2 {
1) Cultural/Behavioral mores that safety is not important.
2) Lack of safety culture in Spanish speaking supervisors.

Similar to #4 {
3) Prejudice between Spanish speaking and Non-Spanish speaking employees.
4) Tougher to develop casual relationships from which to build long term relationships.

5) Quality of work.
6) Used as an excuse to ignore directions or changes.
7) Foreman promoted based on language skill, not construction experience.

There is not a clear cut top five consequences, but the top four are very distinct. A few of the optional write in responses corresponded to other categories, however none were so similar as to validate a fifth ranked result. In the survey area designated for “Any additional information you would like to share regarding this issue”, many people spoke of discrimination. In my opinion, this corresponds to consequence number 4) Lack of Respect/Diminished Team Atmosphere. However, it was still interesting to read what some industry members had to say on this issue. Below are summaries of a few individual’s comments.

- Discrimination between English speaking workers and Non-English speaking workers is a real and damaging problem. Managers have encountered Anti-English and Anti-Spanish slurs on the job site.
- Discrimination exists even within each language. A Mexican crew would not be very accepting of a Guatemalan member, even though they all speak Spanish (all be it varying forms).
- It seems as though the two parties (English speaking and Spanish speaking) are competing to occupy the site; and generally English speaking workers feel that they are more entitled.

This indicates that the fifth most serious consequence of the English-Spanish Language Barrier on jobsites is discrimination. Below are more summaries from participants regarding their choices for the rankings of the top consequences. There are interesting arguments for many of the categories.

Difficulty in Giving Instructions

- Frustrating to have to find a foreman to give the simplest of instructions.
- Giving instructions influences all of the other categories, especially safety.
- People will nod that they understand instructions, when really they do not.
- Immediate action instructions are nearly impossible to give.

Greater Safety Risks

- Many Spanish workers come from a lacking safety conscious culture.
- Many Spanish workers come from places where they must take large safety risks to get a job (because competition is so high) & they don’t understand English culture of safety = #1 priority.
- Dangerous for all workers because they cannot warn each other of immediate harm.
- Effects EMR of entire company.

Loss of Productivity

- Spanish workers inability to read or understand drawings and specs. greatly hinders productivity. Once they learn, they generally are very productive.
- Time is always compromised to teach or communicate with Spanish speaking workers.
- Demonstrations become more necessary even for simple tasks.
- More supervision is needed.

9.11 Solutions to Breakdown the Language Barrier

Upon researching internet sources and reading survey participant's responses, the following solutions are currently being used in the industry to help alleviate the consequences created by the English-Spanish language barrier.

A) Teach English to Spanish speaking industry members

Research agrees with the survey results; and they say that it is much more likely and easy to teach Spanish to English speaking persons. Therefore, it was difficult to find solutions currently available to teach English as a Second Language (ESL) to Spanish speaking construction workers.

The leading tool on the market today is *Sed de Saber*[9].

Sed de Saber (Thirst for Knowledge) is a tool that uses the interactive LeapFrog (http://www.leapfrog.com/en/shop.html) technology to teach English to Spanish speaking construction workers at their own pace.

> Sed de Saber™ - Construction Edition was developed by a team of subject matter experts including superintendents, remodelers and builders to ensure that it is the most relevant and impactful product available. The seven book series covers job site terminology, tools, equipment and protocol. The entire seventh book focuses on safety and is modeled after the NAHB-OSHA Job Site Safety Handbook. Additionally, Sed de Saber™ - Construction Edition teaches life skills, such as going to the doctor, attending a parent-teacher conference and asking for directions.
>
> -http://www.seddesaberconstruction.com/buynow.aspx

The goals of the program are to create English-speaking jobsites, improve job site safety, improve quality, foster worker loyalty, boost worker recruitment, and reduce turnover. Many of these goals will help combat the consequences outlined in section 9.10 above.

Figure 9.7 shows a typical *Sed de Saber* learning book with the interactive technology. Users can touch the images, words, and phrases and hear them in English and in Spanish. Additionally, there is a microphone that they can speak into and an assessment will be conducted to determine if they are speaking correctly. The book may be reused and shared between coworkers, friends, and family. For 30 minutes a day, a participant could finish the program in about 4.5 months.

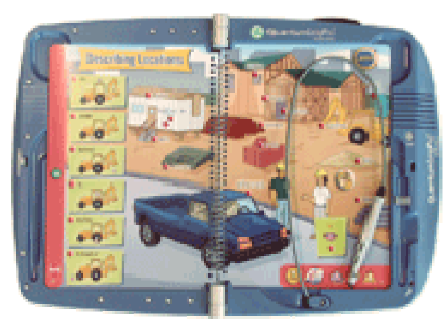


Figure 9.7 *Sed de Saber* interactive learning booklet

[9] All information regarding *Sed de Saber* obtained from http://www.seddesaberconstruction.com and http://www.nbnnews.com/NBN/textonly/2006-07-17/Front+Page/3.html

A second method of combating the language barrier was created by researchers at Georgia Tech. In 2003, researchers at Georgia Tech Research Institute (GTRI) took great strides in helping to make the English-Spanish Language Barrier less of a barrier, and more of a means of education. Safety specialist Juan Rodriguez collaborated on the GTRI project and stated, "Workers who need jobs often won't admit they don't understand the content of safety materials. They're going to nod their heads and say, 'Sure.'" This mentality inspired GTRI to translate OSHA safety information from English to Spanish so that the information is accessible on site to Spanish speaking workers. The safety curriculum they created will help Spanish speaking individuals understand the safety regulations through words and pictures. There are four major parts of the curriculum.

- Computer presentations for formal job orientations.
- Detailed presentations geared to supervisors and trainers who already possess a certain degree of safety expertise.
- Workplace posters and hazard bulletins that use colloquial Spanish and convey safety messages graphically for workers with poor reading skills.
- Pamphlets for foremen and supervisors to use during Toolbox talks.

-http://gtresearchnews.gatech.edu/newsrelease/osha.htm

B) Teach Spanish to English speaking industry members

By no small means, the construction industry is making much larger steps in the way of teaching Spanish to English speaking persons than the reverse. A large majority of survey participants responded that their respective company offers some form of company training sessions or classes intended to teach construction Spanish to employees. These classes are often only one or two sessions long, and focus on teaching basic words, phrases, and commands that are encountered daily on the jobsites. Some companies offer reference manuals and handbooks for employees to take with them to the sight, which many participants felt was helpful.

Other means that participants practiced in order to learn Spanish were:

- Use bilingual coworker as a mentor or teacher.
- Read books on commonly used terms for construction workers.
- Seek out bilingual speakers on site and spend time with them everyday.
- Carry and use a pocket translator.
- Enroll in a Spanish class at a local community college.
- Attempt to speak directly with workers and learn through trial and error.
- High school and college classes.
- Use online learning resources and then speak with workers for practice and guidance in proper usage of certain words.
- Bring a Spanish tutor into the office to work with employees.
- Use Rosetta Stone (http://www.rosettastone.com/) or other popular language teaching tools.

The results of the survey indicated that 50% of the participants are attempting to speak Spanish. In my opinion, I feel that if educational facilities (colleges, universities, and technical programs) teach more foreign language in construction programs, this percentage will grow significantly over the next decade. It was already discussed how younger professionals tend to agree that learning Spanish is more likely to happen. Some universities are leading the cause in helping their students become bilingual; specifically, Iowa State and Virginia Tech.

Iowa State[10]: The Center for Transportation Research and Education at Iowa State University attempted to create Effective Training for American Supervisors with Hispanic Construction Workers. This program focuses on teaching Spanish as a Second Language (SSL). They have developed two courses: the SSL course and the CPCB course.

- SSL: Spanish as Second Language Survival Course
    - Teaches Spanish to American supervisors in four segments: 1) meaning in Spanish, 2) meaning in English, 3) Spanish pronunciation, and 4) a picture of the word.
- CPCB: Concrete Paving Construction Basics
    - Teaches Spanish to American supervisors in any of 12 more specific subtopics that fit their field of work.

While the CPCB course is designed with Civil Engineers in mind, there is no reason that this program could not be implemented in all fields of construction. Iowa State recommends that the courses be taught by bilingual speakers to help students understand the two cultures and the dual meanings of many words or phrases.

Virginia Tech[11]: Virginia Tech is taking monumental strides in teaching students of construction programs Spanish. The Building Construction Department at Virginia Tech has incorporated *InterLingo*[12] into their undergraduate program requirements. *InterLingo* is an online one-on-one tool that has a specific program for the construction profession.

Details of the *InterLingo* Spanish learning tool:

- Course participants use the leading internet video conferencing service from WebEX to connect face-to-face with their personal, native-speaking language instructor from Columbia.
- The Spanish for Construction program uses a dual strategy of group presentations and personal one-on-one review sessions to maximize effectiveness.

[10] CRTE program information found at http://www.ctre.iastate.edu/pubs/t2summaries/hispanic2.pdf
[11] Information for the Building Construction Department at Virginia Tech found at http://www.bc.vt.edu/
[12] InterLingo website contains details of all information found above at http://www.interlingospanish.com/index-1.html

- Course Demands: 3 hours/week for 6 weeks.
- Classes start on an approximate 2 month cycle.
- $500 per participant, reduced group rates available.
- Students given references and resources to use in future.

9.12 Conclusion

After thorough research, surveying, and evaluation, there is no doubt in my mind that industry members believe that a language barrier does exist and that it affects the progress and success of a project. In open shop labor markets, industry members agree that there is a barrier and consequences arise because of that barrier; but beyond those two issues, participant's opinions, rankings, and comments vary greatly based on age, experiences, and biases.

Many English speaking, native born Americans have a mind set that immigrants arriving in this country should learn English. However, I feel it is time for industry members (of practically any industry, not just construction) to realize that what they prefer is irrelevant. In order to be successful in a market, a company needs to focus on doing a good job more costly and effectively than a competitor. According to the CRTE program at Iowa State, they think that "Training American supervisors in Spanish would be quicker, more cost-effective, and easier than training Hispanics in English because supervisors are fewer in number and are better educated." Training English speaking people to speak Spanish seems like the path of least resistance, and it is supported by the fact that so many young professionals agreed in the survey. Then, bilingual supervisors can slowly begin to communicate with the Spanish speaking workforce and possibly continue the learning cycle.

Company offered Spanish classes are a good start, but they are not doing enough to combat this problem. If a company truly intends for their employees to become bilingual (at least enough for a construction site), a one or two hour class with vocabulary words is insufficient. The way to solve this problem is to start in universities and colleges with construction training programs. It is my opinion that a full semester class with a bilingual teacher would be the most effective means in producing students and ultimately a management workforce that could communicate effectively on jobsite with English and Spanish workers. This problem would be lessened with each year, and many of the consequences would stop affecting the success of projects. Virginia Tech is leading the construction education language reform, and I think other schools should follow. Schools need to take a larger role in teaching Spanish because students are already in an active learning environment with the time to learn. Once in the field, it is difficult for companies and professionals to find the ample amount of time needed to actually learn the language.

In summary, the language barrier is no more a barrier than any other obstacle the industry has faced due to globalization. It can be eliminated. A company must develop a strategy to stay competitive in the market, regardless of what the barrier is. Effective communication is the key to success in construction; therefore companies and industry supporters (schools) need to work together to lessen the impacts of this changing industry.

10 | Redesign of Gymnasium Ductwork – Replace Sheet Metal with Fabric Duct

AE Mechanical & Acoustical Breadth

10.1 Introduction

Better acoustics and improved air quality in large, open areas of the school will help to enhance the learning environment for students by providing quieter and more comfortable spaces. The largest open area in the school is the gymnasium. The gymnasium will be used for sports practices, sporting events, and gym classes for all students. Teaching, coaching, learning, and cheering in this large, open environment can become stressful on the ears and also can become quite stuffy when filled to capacity.

10.2 Problem Statement

The current ductwork in the gymnasium is sheet metal with insulation. This creates a noisy environment, which is certainly not cohesive for a learning/coaching environment. It also is costly to install and maintain. Fabric ductwork will be installed in place of the sheet metal ductwork to better the acoustics, possibly reduce costs, and create a more comfortable environment.

10.3 Goal

The analysis will focus on bettering the acoustics in the gymnasium by replacing the typical sheet metal ductwork with a fabric duct system. The benefits of using the new ductwork will be researched, such as the reduction of noise in the gymnasium, cost savings, cleanliness, installation and schedule impacts, and an overall more comfortable learning environment. It is the ultimate goal of this research to determine if changing to fabric duct is worthwhile for the WCA.

10.4 Methodology

1. Perform a quantity takeoff of the current gymnasium ductwork, including size, shape, quantity, and location.
2. Determine the air flow requirements for the space.
3. Estimate the cost, schedule, and installation time of the current system.
4. Research other gymnasiums that have used a fabric ductwork system, in particular the Rec. Hall Expansion Project at Penn State.
5. Research the benefits of using a fabric ductwork system over a typical sheet metal system.
6. Redesign the mechanical ductwork with fabric ductwork, ensuring that the air flow requirements are met for the space.
7. Perform acoustical analysis of the new space with the fabric ductwork.
8. Determine the cost, schedule, and installation time of the new system.

9. Conduct a comparative analysis of the two systems, with the primary focus on acoustics and the secondary focus on cost, schedule, installation, air quality, and availability.
10. Make a recommendation on which system is more suited for the WCA Gymnasium Building.

10.5 Tools/Resources

1. Research fabric ductwork manufacturers' websites
2. Penn State's Office of Physical Plant (OPP)
3. Washington Christian Academy Construction Documents
4. R.S. Means 2007
5. Forrester Construction Company
6. Penn State Architectural Engineering Faculty

10.6 Expectations

After conducting the research and appropriate calculations addressed above, I expect that the fabric ductwork will provide a more acoustically pleasing environment for occupants. Additionally, I expect the new system to be less expensive, more easily installed, and an overall better choice for the WCA Gymnasium.

10.7 Current Mechanical System in Gymnasium

- Roof Top Units:
  - 1,600 cfm (800 cfm outdoor air), serves lobby and offices
  - 6,000 cfm (3,000 cfm outdoor air), serves gymnasium and locker rooms
- Sheet Metal Ductwork
  - Spiral sheet metal, double wall
  - Glass fiber insulation with K-value of 0.29
  - Aluminum jacket 0.025" thick surrounds insulation
  - Painted white
- Quantities
  - 16" diameter: 100 LF
  - 22" diameter: 40 LF
  - 28" diameter: 20 LF
  - Flex Duct: 24 LF
  - Supply: (4) 1,500 cfm diffusers
  - Return: (2) 3,000 cfm grilles
  - 6,000 cfm enters gymnasium
- Schedule for Installation
  - 10 days RTUs
  - 25 days ductwork

10.8 Advantages of Fabric Ductwork

The advantages to using a fabric ductwork system are far reaching. First and foremost, the manufacturer's of fabric ductwork claim that the air is delivered to spaces more quietly than if delivered by metal ductwork. In large spaces that require a lot of airflow, such as the gymnasium, air is delivered without the resonating properties found in metal. Fabric duct provides sound absorption qualities with no additional insulation necessary.

Second, the air supplied to the open area is more uniformly discharged in comparison to a typical sheet metal system with evenly spaced diffusers. Hot and cold spots are practically eliminated because air is supplied all along the fabric ductwork, not in localized spots, which can be seen in Figure 10.. This creates much more comfortable spaces for occupants.

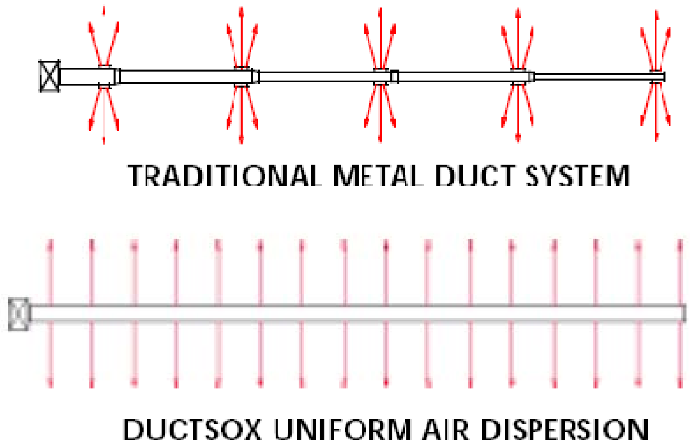


Figure 10.1 *DuctSox* Air distribution comparison

Notice how the traditional system only allows air to be distributed in specific, concentrated areas. This may create drafts and uneven air temperatures throughout a space. The fabric ductwork represented by the *DuctSox* picture, releases air uniformly through designated holes or the porous fabric material.

Table 10.1 Comparative benefits of using fabric ductwork over sheet metal ductwork.

	Fabric Ductwork	Sheet Metal Ductwork
Acoustics	• Better • Reduces resonance	• Worse • Turns create turbulence
Air Distribution	• More uniform	• Concentrated near diffusers
Installation	• 90% faster that Sheet Metal[13]	• Much more intensive (hrs, crew)
Weight	• 1 psf [14]	• 40 psf [14]
Environmental Factors	• Resists scratches, dents common from volleyballs, basketballs, etc.	• Easily scratched or dented during installation, common physical activities
Condensation/Dust	• Porous fabric allows air flow through material • Prevents condensation/dust accumulation on exterior surface	• Metal allows air flow only through specified outlets • Condensation/dust accumulate on exterior surface

[13] According to "Features, Advantages, and Benefits" of Fabric Ductwork found at Ductsox.com
[14] Comparing a 60" fabric duct to a 60" spiral metal duct, 18 ga., single wall

Color	• Optional colored fabric matches walls/ceilings • Silk screening allows for team names, logos on ductwork	• Optional painted exterior surface • Likely to scratch & need touch-ups
Maintenance	• Vacuum or machine washable • Easily removed and re-hung • No lifting machinery needed	• Expensive • Usually requires 3rd party • Lifting machinery needed

10.9 Redesign of the Gymnasium Mechanical Ductwork with Fabric Ductwork

There are many manufacturers of fabric ductwork. Berner International Corporation (www.Berner.com) creates a fabric ductwork system referred to as *Posi-Flow*. There are design steps that the manufacturer recommends, and this section will highlight how the design decisions were made.

Step 1: Determine Application

Application	Fabric Type				Airflow Pattern				Suspension Type Supported		
Indoor Swimming Pools	PV	CP	PE		SF	GF	LD		Snap Clip	Halo Hook	Track
School Classrooms	PV	CP		UP		GF	LD				Track
Gymnasiums	**PV**	**CP**	**PE**		**SF**	**GF**	**LD**		**Snap Clip**	**Halo Hook**	**Track**
Supermarkets	PV	CP	PE	UP	SF	GF	LD	MF	Snap Clip	Halo Hook	Track
Warehouses	PV	CP	PE		SF	GF			Snap Clip	Halo Hook	
Manufacturing Plants	PV	CP	PE		SF	GF			Snap Clip	Halo Hook	
Restaurants	PV	CP		UP		GF	LD	MF	Snap Clip	Halo Hook	Track

Figure 10.2 Application determination chart

Step 2: Select Fabric Type

From Step 1, the suggested fabric types are PV: Polyester Vinyl Coated, CP: Coated Polyester, or PE: Polyethylene. After researching the manufacturer's data on each, the best choice is coated polyester.

CP Series Coated Polyester
"Versatile and aesthetically pleasing. Ideal for schools, sports arenas, supermarkets, swimming pools and retail stores. Water repellent, flame resistant and UV treated. Multiple colors available to complement surroundings."
(http://www.berner.com/commercial_fabric.php5?sec=fabric&top=4&sub=3)

Step 3: Select Color

Colors	
White	
Gray	
Lakeside	
Royal	
Black	

Figure 10.3 Color selection chart

This decision would be made by the owner. The WCA could choose to match the wall color in order to blend in, or choose a brighter color to become an architectural feature of the space. There is also the option of silk screening, which allows school/team names and logos to be printed on the ductwork. Currently, the ductwork is scheduled to be painted white.

Step 4: Determine Size of Ductwork

According to the Berner manufacturing data, the fabric ductwork can be used as a direct replacement of sheet metal. This means size and quantity. Therefore, a total length of 184 LF of fabric ductwork is needed to supply the required 6,000 cfm to the space. The longest straight run is 50 LF; however the ductwork typically comes in lengths of 25 LF. Therefore, eight pieces of fabric duct will be needed.

Step 5: Select Airflow Pattern

From Step 1, the suggested airflow patterns are SF: Super Flow, GF: Gentle Flow, or LD: Linear Diffusers. The best choice for the gymnasium is the super flow, mainly because the ductwork is located approximately 26' above the finished floor and the air has to be able to reach the floor level effectively.

Super Flow: Propel warm ceiling air to cooler floor areas

- Long throw air jets.
- Provide air circulation 30-40' beyond their profile
- Propel warm ceiling air to cooler floor areas
- For heated, cooled or untempered air
- For 10' & above finished floor installation

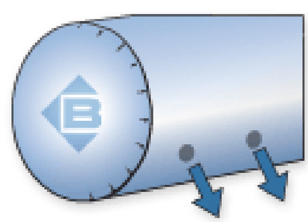


Figure 10.4 Airflow diagram

Step 6: Choose Suspension Type

From Step 1, the suggested types of suspension are Snap Clip, Halo Hook, or Track. The snap clip is recommended for standard installation. It runs on a cord that can easily be strung from the steel joists, therefore no structural redesign will be necessary. The fabric duct is connected to clips, which are simply snapped onto the cord and run across

like a shower curtain. This makes maintenance very easy. The ductwork will be able to slide to the maintenance person and a mobile mechanical lift will not be necessary.

Standard Installation

Used with cable suspension, turn buckles and clamps. Available In:

- Zinc plated
- Black powder coated
- Black plastic
- Stainless steel

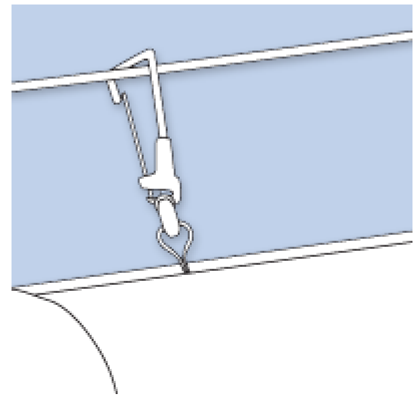


Figure 10.5 Suspension diagram

Step 7: **Choose Filtration System**

It would be up to the owner to decide which filtration method they would like to use. There is already a 2” thick glass fiber air filter for each RTU that has a 65% efficiency. An additional air filter in the fabric ductwork would provide better air quality and help keep airflow through the ductwork steady. This DuctSox filtration system is meant to serve in addition to a prefilter (which is the 2” glass fiber). This zip-in filtration system cleans the air directly before it is dispersed to the breather, and the prefilter keeps the mechanical unit clean. They work together to improve the indoor air quality.

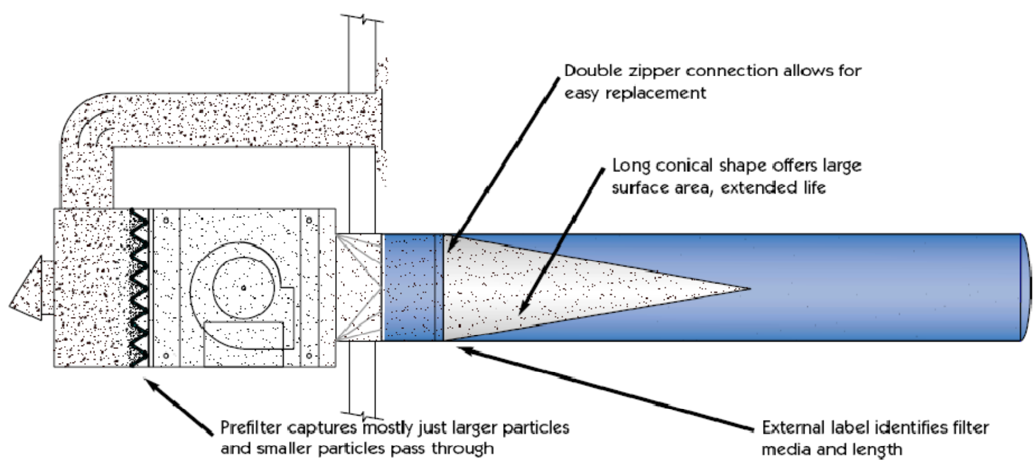


Figure 10.6 Filtration system diagram from *DuctSox.com*

10.10 Acoustical Analysis of the Fabric System

Acoustics is the science that deals with the production, control, transmission, reception, and effects of sound. Mechanical systems create noise and vibrations which may hinder the acoustical quality of a space. The WCA Gymnasium will be used for gym classes, sporting events, performances, speeches, and other various activities. This means that the space needs to be able to acoustically accommodate a conversation between two people and 1,225 screaming spectators.

Fabric ductwork is credited with improving the acoustics of a space. This is due to the fact that sheet metal, which has almost no absorptive quality, is being replaced with polyester fabric, which has a much higher absorptive quality.

Noise Criterion (NC)

Noise criterion was established in the United States for rating indoor noise, noise from air-conditioning equipment etc. According to DuctSox.com, by using fabric ductwork the resulting decibel level is well below or in the lower average of the recommended 20-35 NC rating. An NC rating of 20-30 is considered very quiet to quiet, and an NC rating of 30-35 is moderately noisy. Figure 10.7 shows that the fabric ductwork is continually rated in the very quiet to quiet range.

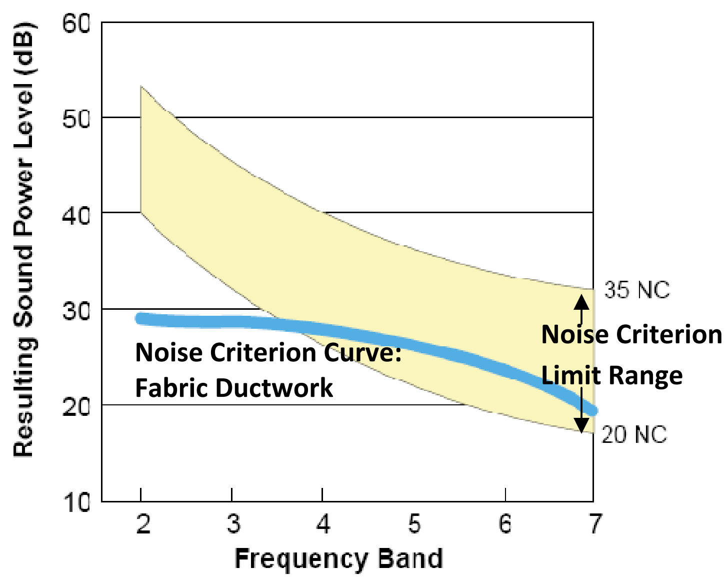


Figure 10.7 NC diagram from *Ductsox.com*

To further examine the noise criteria, a representative NC graph is shown below comparing the typical sheet metal ductwork vs. the proposed fabric ductwork. In this graph, Noise Rating (NR) is simply another term used for Noise Criteria (NC).

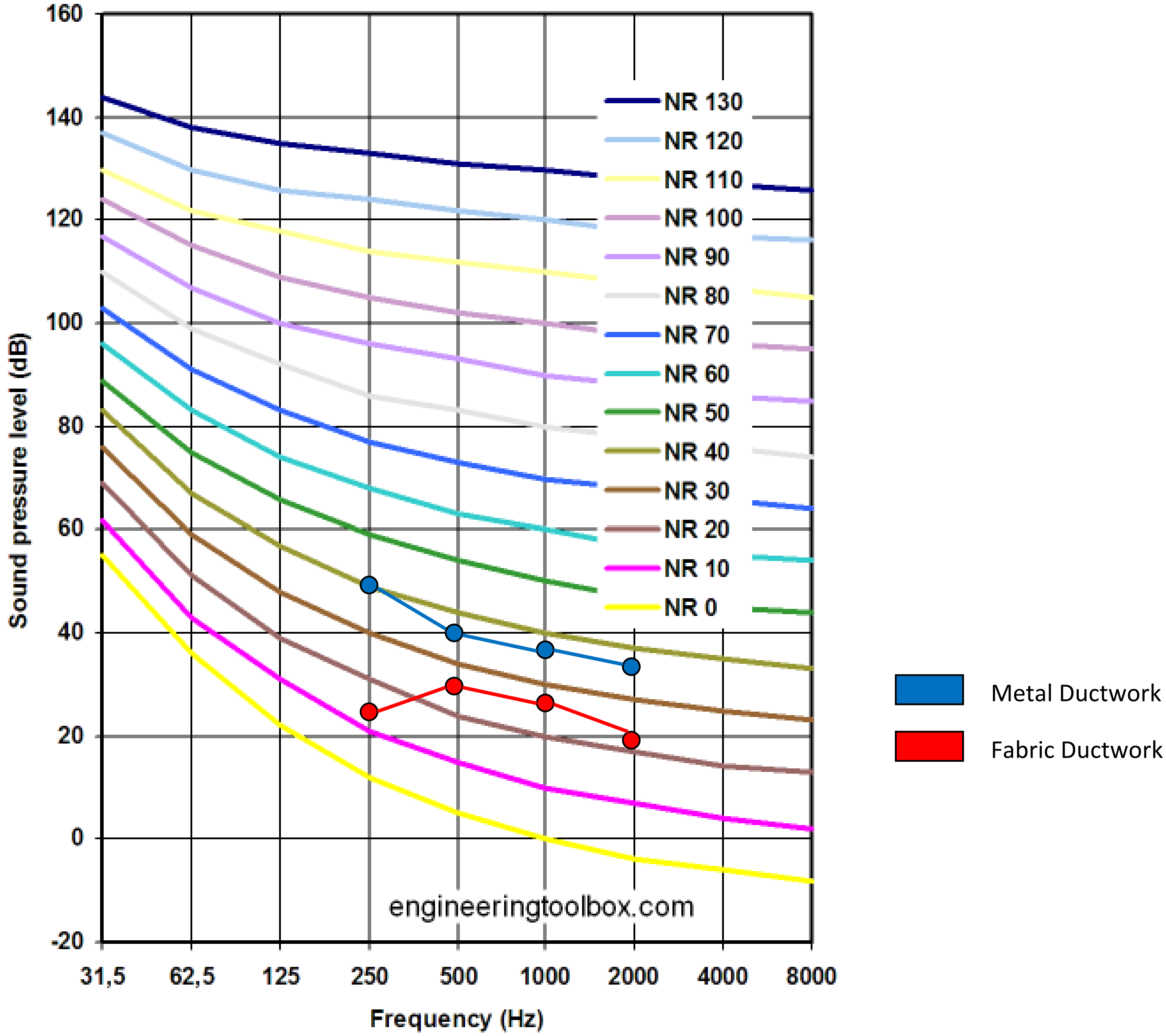


Figure 10.8 Comparative Noise Criteria chart of metal and fabric ductwork

For a gymnasium an NC rating of NC-25 to NC-40 is normal. From this chart, the metal ductwork has an NC rating of NC-40, which is at the highest recommended level. The fabric ductwork has an NC rating of NC-25, which is at the lowest recommended level. A lower noise criteria rating is better, therefore the fabric ductwork is much more efficient in absorbing noise. Additionally, the absence of diffusers in the proposed fabric duct system eliminates any highly concentrated areas of noise.

Reverberation Time

The Reverberation Time in a room is the time it takes before the sound pressure level has decreased by 60 dB after the sound source is terminated. In other words, it is the amount of time a sound bounces around a room until it is absorbed by something. Reverberation Time calculations are important for a space because it is a strong indicator of the acoustical comfort of the space. Different spaces have different reverberation time goals. Too high of a time creates a live space, while too low of a time creates a dead space. Reverberation time for gymnasiums typically range from 1.5 seconds to 2.5 seconds. Below is a summary of the reverberation time calculations for the WCA Gymnasium.

Table 10.2 Comparison reverberation time calculations for metal ductwork vs. fabric ductwork.

Reverberation Time				S	α	α	$a = S\alpha$	$a = S\alpha$	
Material	**Dim. A (ft)**	**Dim. B (ft)**	**Qty.**	**Area (sf)**	**500 Hz**	**1000 Hz**	**500 Hz**	**1000 Hz**	
Metal Ceiling	100	74	1	7400	0	0	0.0	0.0	
Hard Wood Floor	100	74	1	7400	0.3	0.3	2220.0	2220.0	
CMU Block Walls	100	35	2	7000					
	74	35	2	4820					
				11820	0.09	0.09	1063.8	1063.8	
Tectum Panels	10	4	16	640					
	10	12	3	360					
	10	16	2	320					
	4	4	4	64					
				1384	0.85	0.99	1176.4	1370.2	
Glass Windows	12	10	3	360	0.18	0.12	64.8	43.2	
Ductwork	1.33	100	1	836					
	1.83	46	1	529					
	2.33	34	1	498					
Metal				1862	0	0	0.0	0.0	
Fabric				1862	0.2	0.18	372.4	335.2	
			Metal ductwork $\Sigma S\alpha$				4525.0	4697.2	
			Fabric ductwork $\Sigma S\alpha$				4897.4	5032.3	
			Room Volume (ft^3)					259,000	
			Reverberation Time **T= 0.05 V/a**				2.86	2.76	*with metal*
							2.64	2.57	*with fabric*
					Reduction of 0.19-0.22 seconds				

By switching to fabric ductwork, the reverberation time would decrease by an average of 0.21 seconds. This is only a 7% reduction, which is not a significant decrease in time. The material with the largest impact on the acoustics in the space is the tectum acoustical wall panels. It is stated, however, that a Sound Absorption Coefficient (α) difference from 0.1-0.4 results in a noticeable reduction of noise. Between the metal ductwork and the fabric ductwork, the difference of α is 0.2. This is a significant difference between materials. Therefore, it can be concluded that the change of material does reduce noise in the room, but does not have a dramatic effect on the entire room due to the large size of the room and the acoustical wall panels.

Noise Reduction (NR)

The noise reduction is the reduction in reverberant noise level in a space. This reduction would result from changing the sheet metal ductwork to the fabric ductwork. The NR is affected by the size of the room and the amount of absorption within the room.

$$NR = 10\log\frac{a_2}{a_1}$$

$$NR = 10\log\frac{5032.3}{4697.2}$$

$$NR = 1.1\text{ dB}$$

This calculation shows that there would be noise reduction of 1.1 decibels in the gymnasium after the switch. This is not a significant reduction in decibels. This is most likely due the proportion of ductwork to the space. The room has a very large volume and proportionally the ductwork does not take up much of that space.

Noise Reduction Coefficient (NRC)

The efficiency of a sound absorptive material is known as the Noise Reduction Coefficient (NRC). A higher NRC indicates a more absorptive material.

NRC Steel: 0.00-0.05

NRC Fabric: 0.20

The difference between the NRC is 0.15. This proves that there is a significant difference between the absorptive properties of the metal ductwork vs. the fabric ductwork. The fabric ductwork is much more likely to absorb sound in the gymnasium.

10.11 Cost Comparison

Fabric ductwork typically costs 20%-80% less than metal ductwork. This cost analysis will compare material, labor, and shipping costs. Data was obtained from *2007 R.S. Means Building Construction Cost Data*, *2007 R.S. Means Mechanical Cost Data*, and *UPS.com*.

Location Factor:

Olney, Maryland was not on the location list and the WCA is not actually in Washington, D.C. Therefore, the most fair and accurate method available was to use an average.

Average for all listings in Maryland	.865
Washington, D.C.	.98
Location Factor Average:	.92

Time Factor: Not used because data is from 2007

Table 10.3 Cost breakdown of current sheet metal ductwork system.

Mechanical Equipment	Size	Qty.	Material Unit Cost	Labor Unit Cost	Material Total Cost	Labor Total Cost	Total Cost M+L
Double Wall Spiral Duct[15]	16" dia.	100 LF	6.55	15.19[16]	655.0	1,519.0	$2,174
	22" dia.	34 LF	10.80	23.66[16]	367.2	804.4	$1,172
	28" dia.	20 LF	15.48	29.61[16]	309.6	592.2	$902
				Sum	1,331.8	2,915.6	$4,248
Flex Duct[15]	16" dia.	24 LF	5.16	13.13[16]	123.8	315.1	$439
Diffusers[15]	16" dia.	4 ea.	53.00	42.00	212.0	168.0	$380
Flex. Fiberglass Ins.	1 ½"	1525 SF	0.19	1.94	289.8	2958.5	$3248
				TOTAL	$1,958	$6,357	$8,315
				LF = 0.92	$1,800	$5,850	**$7,650**

Table 10.4 Cost breakdown of proposed fabric ductwork system.

Mechanical Equipment	Size	Qty.	Material Total Cost	Labor Total Cost	Total Cost M+L
Fabric Duct	16" dia.	100 LF	768.0	1139.2	$1,907
	22" dia.	34 LF	305.0	603.3	$908
	28" dia.	20 LF	217.0	444.2	$661
		TOTAL	$1,290	$2,185	$3,475
		LF = 0.92	$1,187	$2,010	**$3,200**

Table 10.5 Cost comparison summary.

Ductwork	Material Cost	Labor Cost	Total Cost
Metal	$1,800	$5,850	$7,650
Fabric	$1,190	$2,010	$3,200
Difference	$610 saved	$3,840 saved	**$4,450 saved**

Table 10.5 shows that by switching to the fabric ductwork system, the owner could save $4,450. The total mechanical contract for the gymnasium is approximately $190,000. This yields a savings of approximately 2.5% of the mechanical cost for the gymnasium. The largest savings is on the labor cost; this is because fabric ductwork is more easily and quickly installed. Vast and additional savings would also come from the reduction of shipping costs.

[15] Some of the unit costs had to be interpolated or extrapolated as needed.
[16] As directed by *R.S. Means 2007*, 40% was added to the labor cost because the installation height was between 30'-35'.

Table 10.6 Shipping cost comparison of metal ductwork system and fabric ductwork system.

Ductwork	Weight (lbs.)	Shipping Cost[17]
Metal	7,360	$5,360
Fabric	230	$160
	Difference	**$5,200 saved**

This estimate is conservative. The fabric ductwork could be manufactured in the nearby town of New Castle, PA. The metal ductwork could be manufactured in a much further location. However, to keep comparison's sake conservative, both shipping costs were calculated from New Castle, PA to Olney, MD.

- The total cost of the spiral metal ductwork with shipping is $13,010.
- The total cost of the fabric ductwork with shipping is $3,360.
- By using the fabric ductwork, the owner could save $9,650; a 74% reduction.
- This corresponds to a 5% savings in the gymnasium mechanical contract.

10.12 Schedule Comparison

Installation of the fabric ductwork is remarkably faster than the sheet metal system. This is reflected in the labor costs described in section 10.11. The main reason for this is that the sheet metal ductwork is installed using a scissor lift, piece by piece. The installation height of the ductwork is above 30', which results in additional time and cost. Fabric ductwork, on the contrary, is run along a track or snapped to a cord, and strung across the gymnasium. This is all possible from one location once the track or cord is mounted. The original gymnasium schedule allows 25 days for the installation of mechanical ductwork in the gymnasium. From installation information obtained on Berner.com, a typical crew of three can install up to 50' of fabric ductwork a day. This accounts for installing the suspension system and hanging the ductwork. If this is the case, the fabric ductwork could be installed in 4 days. This results in a significant savings of 21 days from the gymnasium schedule.

[17] Shipping costs retrieved from UPS.com. Costs account for typical ground shipping. Both are from New Castle, PA to Olney, MD.

10.13 Conclusion & Recommendation

Replacing the current sheet metal ductwork with fabric ductwork in the WCA Gymnasium is a prudent decision. The goals and expectations of this breadth study were met and exceeded. The fabric system improves almost every mechanical aspect of the gymnasium, whether great or small. The largest positive impacts are the improvement of the air quality and air distribution, the ease of maintenance, the cost savings, and the schedule reduction. These four areas are significantly improved upon without any additional work. Smaller positive impacts are the betterment of the acoustics and the higher customization level.

Figure 10.9 *DuctSox* Florence, Texas gymnasium with customized fabric ductwork

While these benefits are less dramatic than the previously mentioned; they are improvements none the less. As far as acoustics are concerned, switching to fabric duct results in remarkable improvements to the space. However, the proportional effects to the entire room are minimal. The acoustical improvements would not, by itself, be a reason to switch to the new system. But couple the acoustics with the multitude of other benefits, and it's a win-win situation.

The Washington Christian Academy owner has two primary concerns, budget and quality. In other words, they want to get the absolute best quality school for the budget they have. They are not seeking to cut corners; high quality is worth financing. With the substitution of fabric duct, the owner could achieve the best of both worlds; save money and have a higher quality gymnasium space. The owner would save money, finish earlier, and have a maintenance friendly system while the occupants would be more comfortable from an acoustic and air quality perspective. Switching to the fabric ductwork is a logical, beneficial choice for the WCA Gymnasium.

11 Incorporation of Daylighting in Classrooms

AE Lighting & Electrical Breadth

11.1 Introduction

The second environmental aspect to be discussed in detail that helps students perform better is having a substantial amount of natural light in the classrooms. According to the Northeast Energy Efficiency Partnerships (NEEP), "Good lighting promotes better learning. Today's schools must provide a stimulating environment where children will learn best. High quality light improves students' moods, behavior, concentration, and therefore their learning[18]." There are two large windows in every classroom of the school that may be able to provide an adequate amount of daylight to institute daylighting practices; however this natural light will not result in any energy savings as long as the lights are still turned on. Therefore, adding daylighting photosensors that trigger some of the lights to shut off in the classrooms will allow the natural light to benefit students as well as reduce the electricity consumption.

11.2 Problem Statement

The current lighting used in the classrooms is intended to be on all day, which is costly and reduces the benefits of natural light that enters through the windows. Students' performance improves when an increased amount of natural daylight is used to light the classrooms. Daylighting practices will be implemented in the classrooms. An adequate amount of light will need to penetrate the classrooms in order to utilize daylighting techniques.

11.3 Goal

The goal of this analysis is to determine if daylighting is possible with the current room layout and lighting configuration. If the current design is found to be inadequate for daylighting techniques, a redesign of the room and lighting layout will be done and the daylighting reassessed. This research will also focus on energy savings, and therefore cost savings, and construction impacts. The pros and cons of adding occupancy sensors to the classrooms will be investigated.

11.4 Methodology

1. Research daylighting techniques and the benefits of using these techniques in schools.
2. Meet with AE Lighting/Electrical faculty to obtain advice and guidance.
3. Use computer programs to run daylighting calculations on the current room configuration.
4. Redesign the room configuration and lighting layout.
5. Run daylight calculations and test assumptions with the new room layout.

[18] *Classroom Lighting Know How* found at http://www.designlights.org/downloads/classroom_guide.pdf

6. Compare the results from each lighting test. Determine if daylighting is even possible for the WCA classrooms.
7. Determine how much energy is saved by using the daylighting features, from a financial standpoint.
8. Determine the cost, schedule, and installation time of adding the new sensors.
9. Make a recommendation on whether adding daylighting features to each classroom is a worthwhile investment for the WCA.

11.5 Tools/Resources

1. Research daylighting through articles and information on the internet
2. Washington Christian Academy Construction Documents
3. AGi32 Lighting/Electrical Computer Software
4. AutoCAD 2008 for 3D modeling purposes
5. Penn State Architectural Engineering Faculty
6. 5^{th} year AE lighting students

11.6 Expectations

I expect that the current room configuration is not suitable for incorporating daylighting features. However, I think that after a simple redesign the room will be more equipped for daylighting. I expect that this investment will be beneficial for the owner because it will reduce energy consumption greatly, and that it will be a worthwhile investment for the success of the students and staff.

11.7 Research on Daylighting

Daylighting can be defined as the practice of using windows, skylights, or clerestories to allow penetration of natural light so that there are effective illumination levels in a given space. Energy savings from daylighting is achieved from the reduced use of electrical lighting. Electrical lighting savings occur because daylighting photosensors automatically turn off or dim electrical lights when a certain level of daylight has entered the room and an adequate amount of illuminance is reached. The U.S. Department of Energy had this to say about daylighting.

> In addition to energy savings, daylighting generally improves occupant satisfaction and comfort. Recent studies are implying improvements in productivity and health in daylighted schools and offices. Windows also provide visual relief, a contact with nature, time orientation, the possibility of ventilation, and emergency egress. High daylight potential is found particularly in those spaces that are predominately daytime occupied.
>
> -*Daylighting* found at http://www.eere.energy.gov/buildings/info/design/integratedbuilding/passivedaylighting.html

Studies have found that students with daylighting practices used in their classrooms "perform 20 to 25% better on reading and math tests than students without access to daylight and can progress up to 20% faster than their counterparts in rooms with smaller window areas[19]". These statistics and information from the U.S. Department of Energy make it clear why using daylighting techniques would benefit the students and teachers occupying the WCA Flagship Building classrooms.

Increasing the quality of education is important to the WCA owner. So the above arguments would most likely be enough to convince them that daylighting is a positive improvement to the classrooms. In addition, however, the owner will reap the energy cost savings each month by a reduced electrical load. Daylighting saves energy when the lights are dimmed or shut off, but only when they are dimmed or shut off. Therefore, daylighting controls are needed to spur the lights to dim or shut off.

11.8 Daylighting and Occupancy Sensor Controls

Without turning or dimming the electrical lights, the net energy consumption of the building would increase due to the increased amount of light and heat entering the room. Therefore, daylighting must have controls that trigger lights to shut off. Based on advice from the U.S. Department of Energy, there are two main control systems that should be coupled with daylighting practices; occupancy sensors and light level sensors.

Occupancy Sensors

Occupancy sensors detect when a space is occupied by using infrared technology. Heat or movements from persons in the room signal the lights to stay on. A preset amount of time can be set for the sensor, and once no motion has been detected for that preset amount of time the lights will be automatically shut off. Initially, this seems like a good idea for schools. One large proponent of this system is The Pennsylvania State University. Most of the classrooms on campus employ occupancy sensors, which is a good thing considering how many classrooms there are and the potential to rack up electrical costs due to left on lights.

The reason these are so effective on a college campus is that many times classrooms sit empty and previous occupants may have left the lights on thinking another class is about to enter. After speaking with Dr. Rick Mistrick, a member of the Penn State AE faculty, I have come to agree that this technology is not best suited for a K-12 school environment. Typically, a teacher has his or her own classroom and they would know if someone is coming directly in the room after them. In most cases they are the only teacher using that room. Simply put, when the teacher is in the room they can switch on the lights and when they leave turn them off. This would have the same final result of using the occupancy sensors, but without the cost of installing and maintaining them. A simple laminated sign above the switches reminding teachers to turn off their lights would be as beneficial and much more economical for the WCA than using occupancy sensors.

[19] *Classroom Lighting Know How* found at http://www.designlights.org/downloads/classroom_guide.pdf

Light Level Sensors

Light level sensors will trigger certain lamps to turn off or dim when a preset illuminance level is met within a classroom. Light level sensors have a photoelectric "eye" that measures the illumination[20]. The sensors will also have preset delay timers which prevent the lights from turning off or dimming when there is momentary cloud cover. Fluorescent lamps, like the ones used in the WCA classrooms, are the most common lamps used for daylighting. In the classrooms of the WCA Flagship Building, it would be best to use daylight sensors that switch lights off rather than dim for two reasons; cost savings and educational benefits.

Switching lights off is more financially economical than dimming. If the lamps were to be dimmed, specialized dimming ballasts would have to be used. These cost more than the typical on/off switching ballasts that are already scheduled to be installed in the classrooms. This presents another benefit of switching rather than dimming; the school is already designed for switching so a redesign would not be necessary.

Perhaps the most interesting benefit of using on/off switching daylight photosensors is the educational opportunity it provides for the students. This will appeal to the WCA owner just as much as the cost savings. Children are often taught to turn lights off when leaving a room, but how often are they taught when not to turn on lights in a room? By switching the lights off when there is an adequate amount of daylight in the classroom, it teaches students to be daylight conscious and realize when there is enough natural light to perform a task. When the photosensors reach the pivotal shut off point, the teacher can use the switching lamps as an educational lesson on the value of daylight and energy savings. In a generation that needs to focus on sustainability, using switching and not dimming ballasts with daylighting techniques is a great way to create an interactive learning environment.

[20] *Daylighting* found at http://www.eere.energy.gov/buildings/info/design/integratedbuilding/passivedaylighting.html

11.9 Daylighting Technical Analyses and Calculations

In order to model a typical classroom and perform daylighting analyses two programs were used. AutoCAD 2008 was used to create a basic three dimensional model of a typical WCA classroom. The model was then imported to AGi32, which is a lighting design software. AGi32 has modeling and calculation capabilities; however it was only used for calculations in this analysis. Specifically, the goal of the calculations was to evaluate the illuminance levels from the electrical lights as well as from the natural light and ensure that the proper levels were being met. Additionally, the daylighting factor for the daylight zone should be over 2% in over 75% of the room area in order to obtain a LEED point. Since this project is not aiming for LEED certification, the illuminance levels and daylighting factor will not be required to meet the 2% in 75% of the room requirement, but will be used for reference.

Daylight factor (DF) is a ratio of the daylight illuminance in a zone in a give space due to the light received directly or indirectly from the sky[21]. Wattstopper.com is a valuable resource in defining daylighting terms. Below are terms frequently used in daylighting techniques which will be referred to in each individual analysis.

On/Off Setpoint Levels: The user defined daylight levels that must be reached before the lights are turned on or off.

Deadband: Control margin above the fixed on setpoint or below the fixed off setpoint in which minute variations in light levels will not trigger an on and off response from the electric lights.

On/Off Time Delay: Time-based interval that must elapse after the setpoint has been reached before the controlled lighting will turn on or off. Deadband settings and time delays are used to prevent over switching when there is simply cloud cover or momentary sunlight.

Target Level: User defined daylight level that must be reached before the lights are shut off or turned on.

Daylighting allows the owner or designer to customize many of the settings for the WCA classrooms.

[21] Definition obtained from wattstopper.com (http://www.nxtbook.com/nxtbooks/wattstopper/psg0708/index.php?startpage=262)

Two classrooms between two of the symbolic peaks were used for modeling purposes. The reason for this is because the protruding sections of the building would shield light from the classrooms. Therefore, these peaks had to be modeled so their shadowing effects could be accounted for. The red box in Figure 11.1 highlights an example of the two classrooms between the peaks. This example is repetitive throughout the rest of the building, both North and South elevations. Figure 11.2 is the basic three dimensional model constructed of the two classrooms situated between the protruding building sections.

Figure 11.1 WCA Flagship Building Elevation

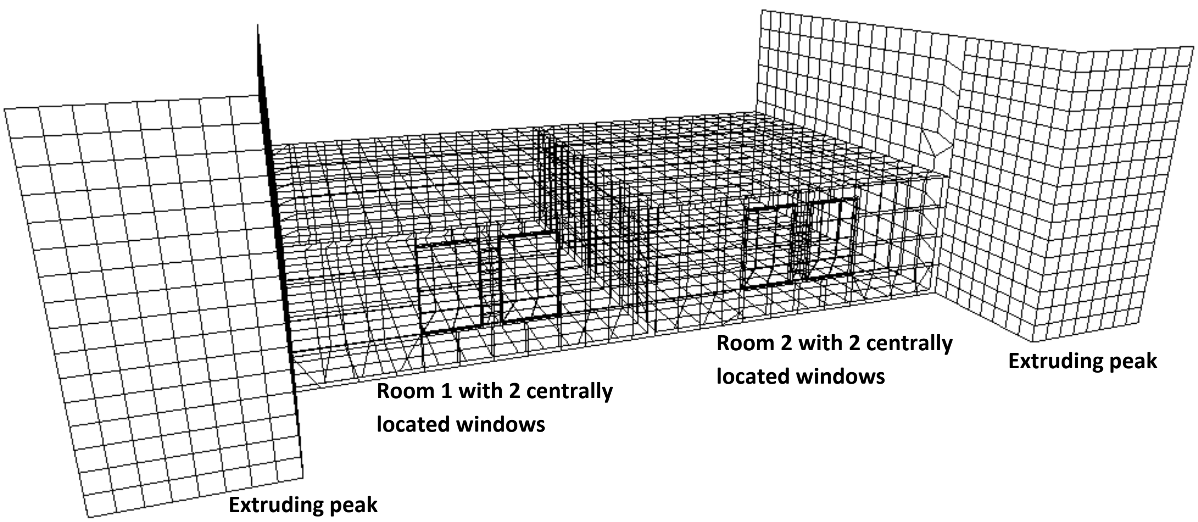


Figure 11.2 3D model of two WCA classrooms situated between peaks as currently designed

Below is a detailed list of the luminaires, lamps, and glass found in each room according the WCA construction documents.

- 2x4 recessed fluorescent light fixtures
- (4) T-8 lamps per fixture
- 4L Ballast

- 1” insulated glass: ¼” clear glass, ½” air space, ¼” clear glass with low-e coating
- Mounting height: 9’-6” above floor

In order to run a model in AGi32 for daylighting calculations, a user must choose a luminaire and make some assumptions about light loss factors and transmittance levels. Listed below are the assumptions made for the AGi32 model.

- Fixtures[22]:
  - XP/XA 2’x4’ Lens Recessed Fluorescent XP/XA432, 4 Lamp, T8 from Lightolier
  - XP/XA 2’x4’ Lens Recessed Fluorescent XP/XA332, 3 Lamp, T8 from Lightolier
- Transmittance:
  - Ceiling: 0.8
  - Walls: 0.5
  - Carpet: 0.2
  - Window: 0.7
- Desk height (work plane) is 2’-6”
- Light Loss Factor (LLF) is 0.70 for conservative measure
- Goal illuminance is 50 foot candles for a classroom +/- 10%
- Sky type is overcast which negates any reason to calculate different months (natural light will always be the same when the sky is overcast. This creates a conservative model.)

[22] Cut sheets for the Lightolier fixture can be found in **Appendix E** and also at www.lightolier.com

A. Daylighting Analysis 1: Current Room Design

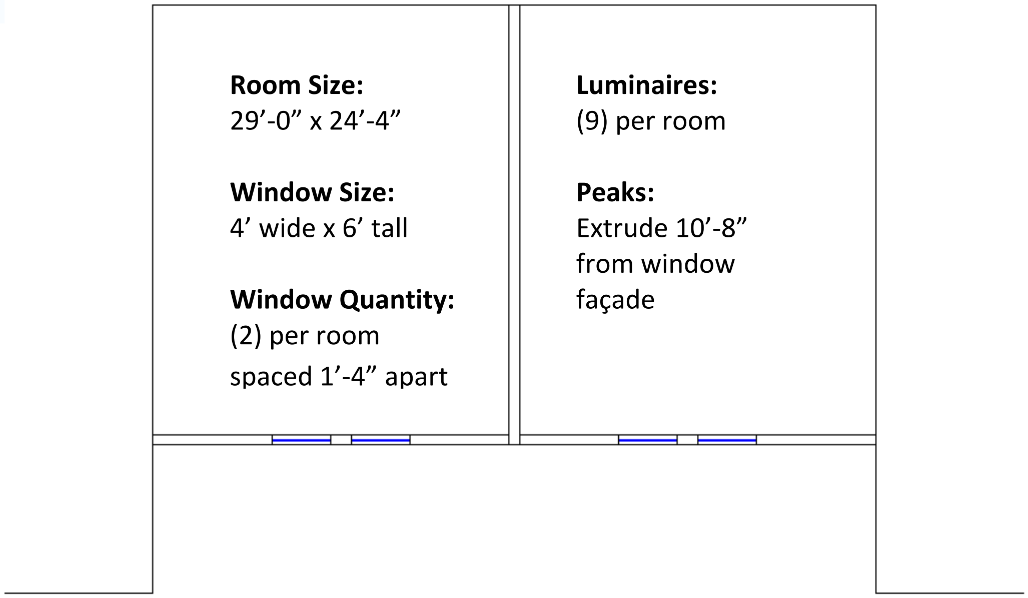


Figure 11.3 Plan view of classrooms with room details

Figure 11.3 is a plan of the two classrooms that were analyzed. Each room has two windows spaced the nominal length of one CMU block for easy installation. Upon running calculations for illuminance and daylight factor in AGi32, the following results were produced.

Out of 6 different trials, the results were:

Table 11.1 AGi32 illuminance result summary with current classroom design.

Category	Trial	Description	No. Lamps	Lum. Orientation	Illuminance (E) Average (fc)	Max (fc)	Min (fc)
I	A	All Lights On (No Daylight)	4	typical	85.6	109.0	57.3
	B	All Lights Off (All Daylight)	4	typical	10.0	52.0	1.0
	C	Both Lights & Daylight	4	typical	95.9	123.0	69.0
	D	2 Rows Lights On, 1 Row Off	4	typical	67.9	95.0	23.0
II	A	All Lights On (No Daylight)	4	rotated 90°	87.2	103.0	66.0
	B	2 Rows Lights On, 1 Row Off	4	rotated 90°	68.9	93.0	23.0

Result Discussion:

- The green and blue rows in Table 11.1 correspond to trials that had the same amount of electric light and outdoor light; the only difference was the luminaires were rotated 90 degrees. The reason that trials II-A & II-B were attempted was to see if more light was gained near the window area by turning the luminaires so more surface area would be facing the windows. As the results prove, turning the luminaires 90 degrees has a negligible effect on the illuminance levels of the classroom. See figures 11.4 and 11.5 below. Please note that dotted luminaires mean they are turned OFF.

Figure 11.4 Illuminance levels with luminaires in typical layout (trial I-D, 2 rows on, 1 row off)

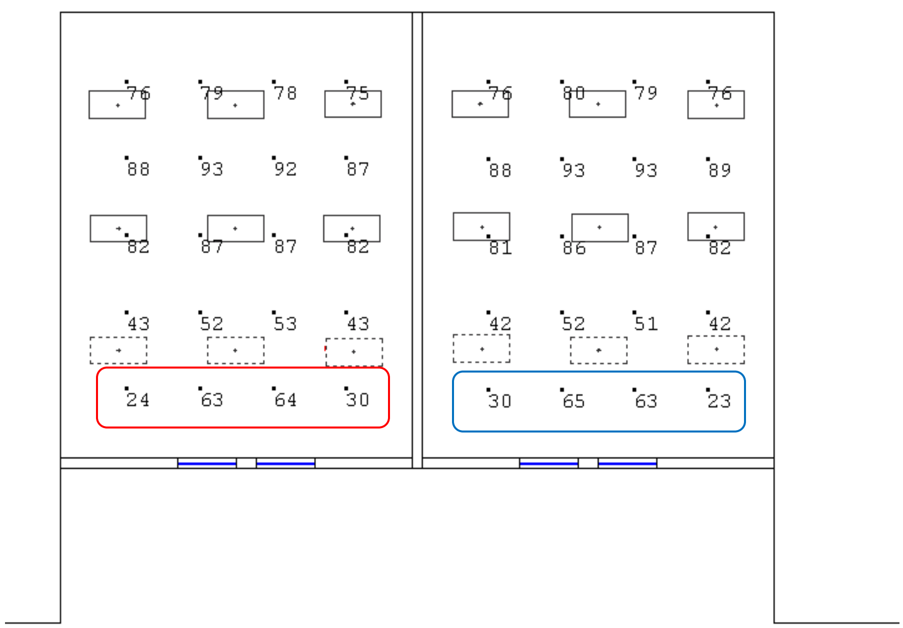


Figure 11.5 Illuminance levels with luminaires rotated 90° (trial II-B, 2 rows on, 1 row off)

- Illuminance from the daylight with the current classroom design is not substantial. Looking at trials I-B & I-C, the average illuminance in all areas of the room was only increased by 10 footcandles due to daylight. The average illuminance in trial I-D signifies that there actually is enough daylight to light the space even when one row of lights is turned off. The important factor in this analysis is not the average though. The deciding factors will be ensuring the illuminance levels near the windows and corners are sufficient and looking at the daylight factor. Figure 11.6 is a rendered image of one classroom looking from the outside-in with two rows of electric lights on and one row off. Figure 11.7 shows the illuminance level in all areas of the room when the luminaire row nearest to the window is turned off.

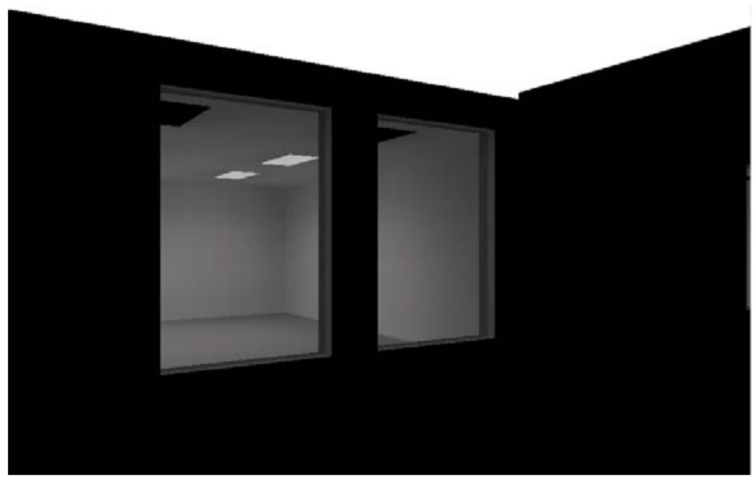


Figure 11.6 Rendered image of classroom with 2 rows on, 1 row

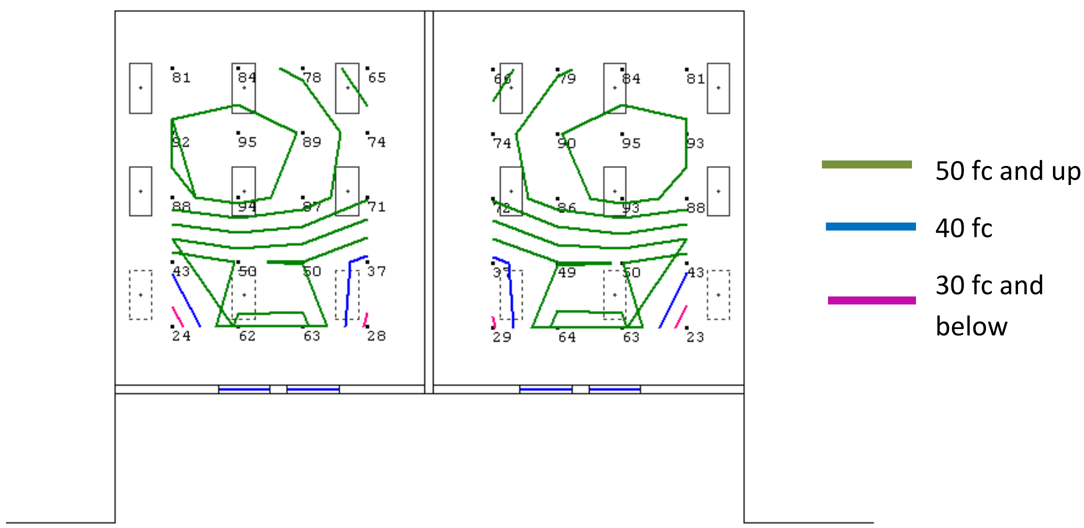


Figure 11.7 Illuminance levels with typical room layout, 2 windows (trial I D, 2 rows on, 1 row off)

Figure 11.7 clearly shows that there is a peak amount of illuminance anywhere the luminaires are turned on (2 rows) and directly in front of the windows. The areas of the room which do not meet the required 50 fc illumination are in the corners of the room, which would have the least amount of light from the windows because the windows are centrally located on the wall. This lighting layout is unacceptable anywhere the blue and pink lines are shown. In some spots the illuminance is as low as 23 footcandles which is too low for a classroom.

Below is the daylight factor in the room. A good goal to reach is 2% DF in over 75% of the room, although it is not required for this particular project.

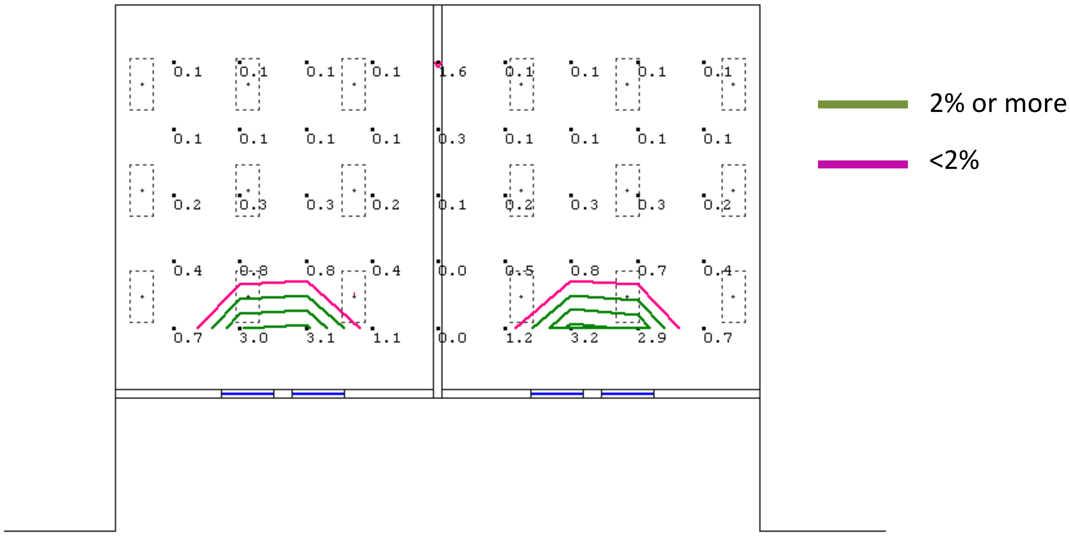


Figure 11.8 Daylight Factor (DF) for typical classroom with 2 windows

Table 11.2 AGi32 daylight factor results for a typical classroom with 2 windows.

Categories	No. Windows	Average	Max	Daylight Factor (DF) Min	% area over 2% DF
I & II	2	0.7	8.3	0.0	10.6

When coupling the results from Table 11.1 and Table 11.2, my conclusion is that the current room layout is not adequate for daylighting practices. While the 4 lamp luminaires provide more than enough light when all 3 rows are turned on, as soon as 1 row is turned off the corners of the room do not sustain enough illuminance for a productive working plane in the classrooms. Furthermore, the daylight factor is below where it should be. There is simply not enough natural light entering the room.

B. Daylighting Analysis 2: New Room Design

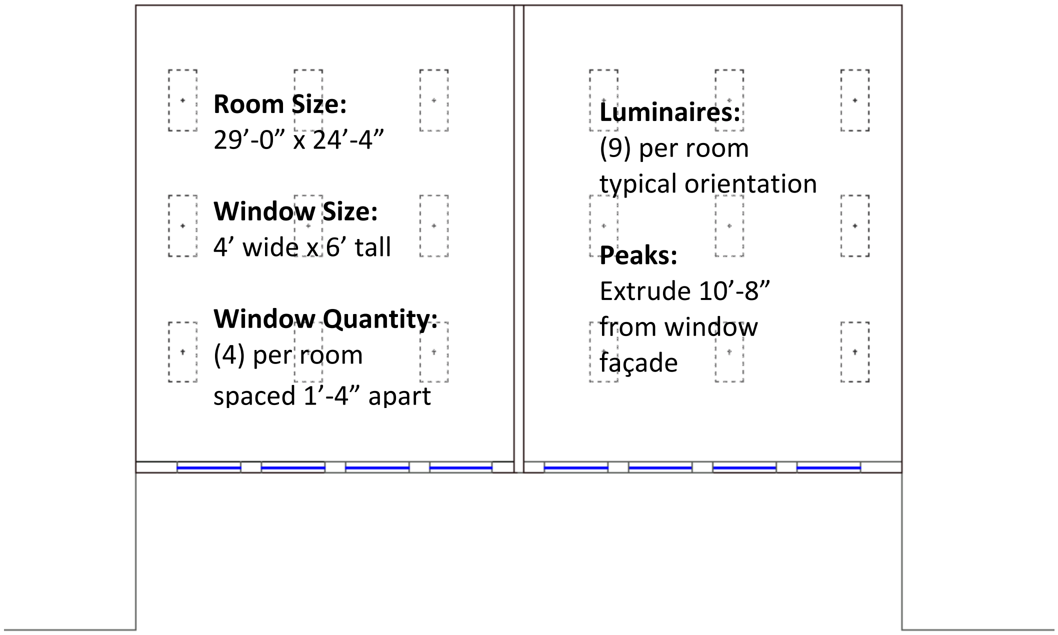


Figure 11.9 Plan view of new designed classrooms with room details

The new room design kept everything constant except the number of windows in each room, which was increased from 2 to 4. By adding more windows, the low illuminance levels in the corners of each room should be eliminated. Also, this design allows more daylight to enter the room and therefore increase the daylight factor. The overall architectural appearance of the building should not change drastically. The focal point of the building is the peaked towers and they do not change at all. The windows will still be separated by a CMU block length and brick façade, which will keep the windows distinct rather than a ribbon window or clerestory. The brick façade will still speak of tradition and integrity.

Upon running calculations for illuminance and daylight factor in AGi32, the following results were produced.

Table 11.3 AGi32 illuminance results summary with new designed classroom.

Category	Trial	Description	No. Lamps	Lum. Orientation	Illuminance (E) Avg (fc)	Max (fc)	Min (fc)
III	A	All Lights Off (All Daylight)	4	typical	39.3	126.0	12.2
	B	2 Rows Lights On, 1 Row Off	4	typical	92.0	134.0	54.7

Result Discussion:

- Trials III-A & III-B suggest that the added windows greatly increase the illuminance levels of the classroom.
- When comparing I-B with III-A (2 windows vs. 4 windows), there is an increase in daylight from an average of 10 fc to 39 fc. This is almost four times the amount of illuminance, which is a surprising result because the window area was doubled and yet the illuminance was quadrupled.

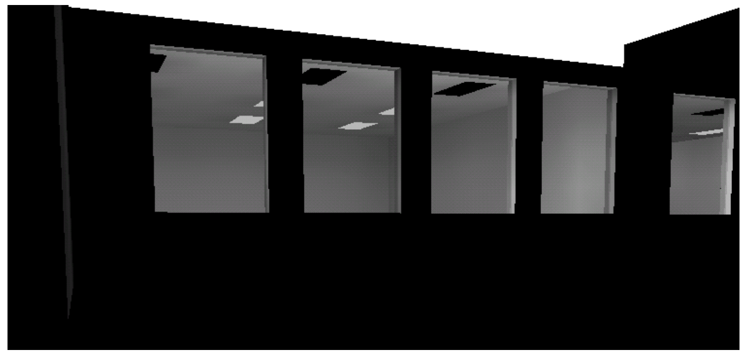


Figure 11.10 Rendered image of classroom with 2 rows on, 1 row off

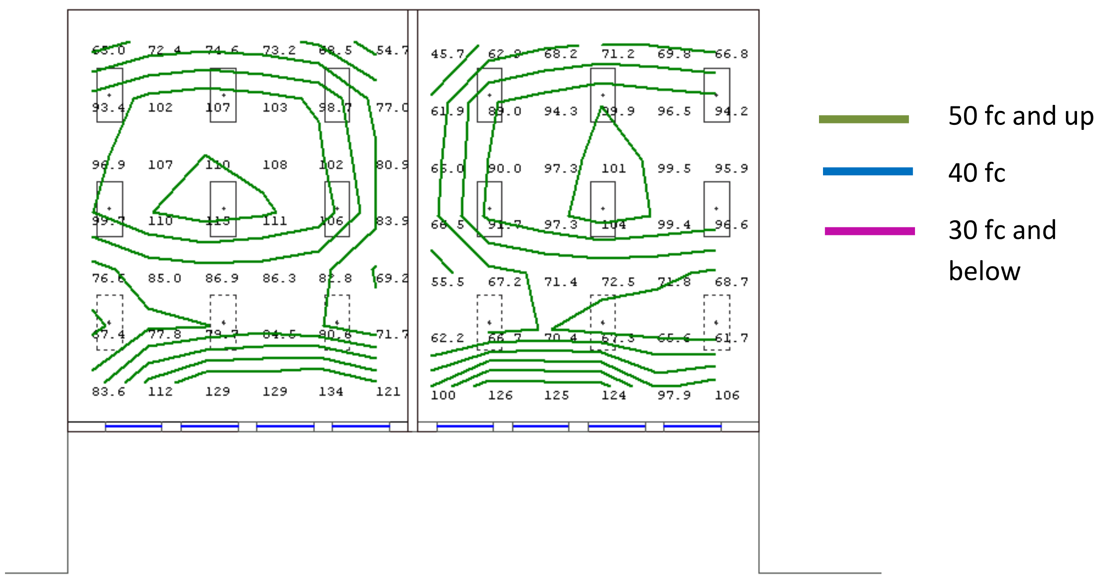


Figure 11.11 Illuminance levels with new room layout, 4 windows (trial III-B, 2 rows on, 1 row off)

With the new room design (4 windows), all areas of the room pass the 50 fc and up requirement when the row of electrical lights nearest the window are turned off. In fact, the average for the entire room is 92 fc. Even the corners of the room which were by far the lowest in Figure 11.7 have increased dramatically. The lower right corner of the right room jumped from 23 fc to 106 fc.

Below is the daylight factor in the room. A good goal to reach is 2% DF in over 75% of the room, although it is not required for this particular project.

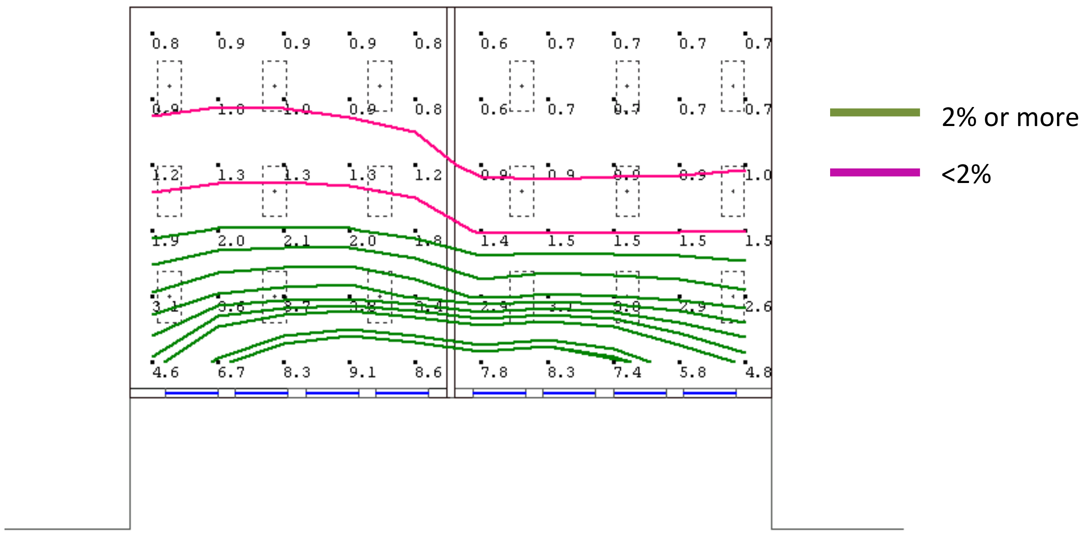


Figure 11.12 Daylight Factor (DF) for new designed classroom with 4 windows

Table 11.4 AGi32 daylight factor results for a new designed classroom with 4 windows.

		Daylight Factor (DF)			
Categories	**No. Windows**	**Average**	**Max**	**Min**	**% area over 2% DF**
III & IV	4	2.6	6.2	0.9	49.7

While this classroom layout has a much higher daylight factor average, it still is not over 75% of the area. Therefore, it would not obtain a LEED credit for natural lighting. In my opinion, however, this room is still a perfect candidate for daylighting. Figure 11.11 proves that there is more than an adequate amount of light in the classroom when 1 row of electric lights is shut off and replaced with natural lighting. In fact, I feel that there is too much lighting and energy is being wasted. This has inspired me to look at using the new designed classroom with 4 windows and using 3 lamps per luminaire rather than 4. The daylight factor would not change because the daylight factor only depends on the window sizes.

C. Daylighting Analysis 3: New Room Design and Lamp Change

This analysis is very similar to *B. Daylighting Analysis 2: New Room Design*. Therefore, the room plan is the same and so are the windows. The only thing that changes is the luminaires have 3 lamps rather than 4. Table 11.5 lists the illuminance results from this trial. Since the illuminance levels in category III were far above the 50 fc requirement, I decided to investigate whether using daylighting and 3 lamps would provide sufficient illuminance to the classroom. Table 11.5 shows that the average illuminance is still plenty high at 79.9 fc.

Table 11.5 AGi32 illuminance results summary with new designed classroom with 3 lamps.

			No.	Lum.	Illuminance (E)		
Category	**Trial**	**Description**	**Lamps**	**Orientation**	**Avg (fc)**	**Max (fc)**	**Min (fc)**
IV	A	All Lights On (No Daylight)	3	typical	59.8	82.6	28.3
	B	Both Lights & Daylight	3	typical	99.0	163.0	46.5
	C	2 Rows Lights On, 1 Row Off	3	typical	79.9	133.0	44.8

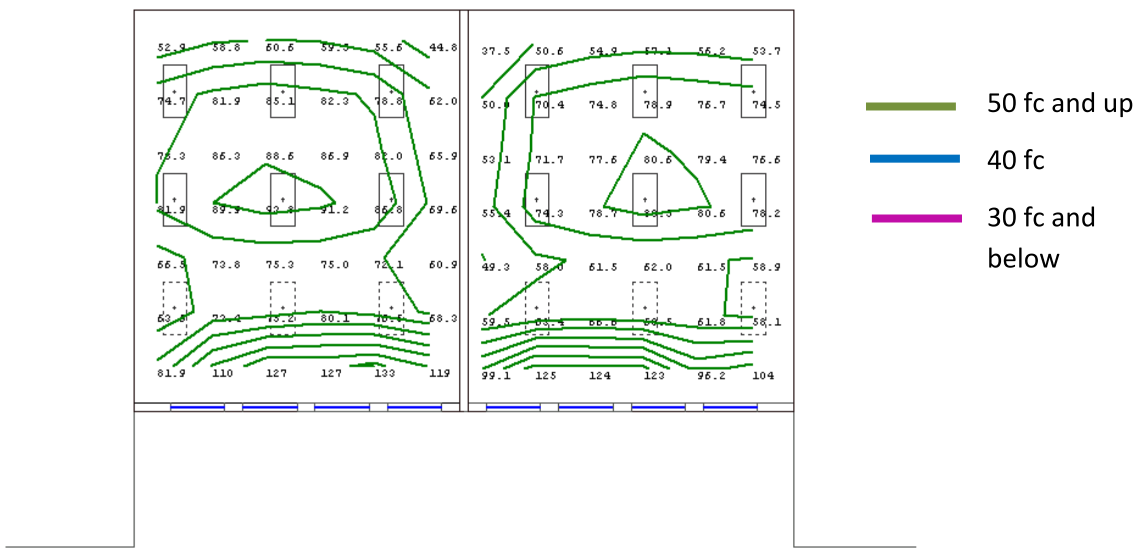


Figure 11.13 Illuminance levels with new room layout, 4 windows, 3 lamps (trial IV-C, 2 rows on, 1 row off)

Figure 11.13 graphically demonstrates that all areas of the room meet the minimum 50 fc requirement for classrooms. As seen in Table 11.5, with one row of lights turned off the minimum illuminance in the room is 44.8 fc, which is right on the +/- 10% illuminance allowance. Additionally, it should be reminded that a 70% light loss factor was used. So if the lights are functioning at a higher rate than 70%, there will be even more light in the classrooms. Please note that the daylight factor for this room layout is in Table 11.4. Changing the number of lamps would not affect the daylight factor in the room; only changing the amount of windows has an effect on the daylight.

11.10 Daylighting Technical Analyses Comparison

Analyses 1, 2, and 3 determined that daylighting is possible in the WCA classrooms, but not with the current room design. With two windows per room, there is simply not enough daylight entering the room to use daylighting techniques. Below is a summary of the results from all three analyses.

Table 11.6 Attempted daylighting hypotheses result summary.

Hypothesis Attempted	Daylighting Capabilities	
	Improve	Not Improve
Rotate Luminaires 90°		✓
Increase to 4 windows/room	✓	
Decrease to 3 lamps/luminaire	✓	

Table 11.7 Analyses summary for use of daylighting techniques.

Analysis	Feature Descriptions	Daylighting Techniques	
		Acceptable	Not Acceptable
1. Current Room Design ***Trials I & II***	2 windows 4 lamps		✓
2. New Room Design ***Trial III***	4 windows 4 lamps	✓	
3. New Room Design & Lamp Change ***Trial IV***	4 windows 3 lamps	✓	

The best option for the WCA classrooms is Analysis 3. With the increase to four windows per classroom, the illuminance level on the desks is plenty high to reach the required 50 fc. Additionally, the reduction of lamps from four down to three saves 25% of cost on lamps for all of the classrooms, and therefore at least a 25% electrical savings. With three lamps the ballasts will be smaller and cheaper. Furthermore, using three lamps gives teachers more flexibility in switching options. There are two switches in every room, which will allow teachers to achieve three different light levels; all on, two lamps on, or one lamp on. This will help with technology presentations in the classrooms.

11.11 Choosing a Daylighting Sensor

The cut sheet for Daylighting Sensor LS-101 can be viewed in ***Appendix E.***

Using Wattstopper.com for product information and installation guidelines of daylighting sensors has lead to using the Light Saver LS-101 Daylighting Controller[23]. Outlined in this section is the decision process in choosing a daylighting sensor.

Wattstopper.com Product Selection Guide 2007-2008.

1) **Standalone or system controls?**
   I chose a standalone system because it controls a single group of lights. In the WCA classrooms, it needs to control the row of lights nearest the window in one, single group. Also, it is simple to install, low in cost, and suitable for relatively small rooms.
2) **Single or multiple control zones?**
   A single control zone was chosen because this is most commonly used with standalone systems and only one zone is being controlled per sensor.
3) **Open or closed loop technology?**
   I decided to go with closed loop technology, although a more qualified lighting designer may choose differently. I chose closed loop because it allows for on/off switching and it measures daylight and electric light levels in the room. In case the lights are functioning below 70% (the light loss factor in which the trials were tested), I felt it was important that the sensor account for the entire light in the room, not just the natural daylight. Also, the closed loop allows for manual override in case the teachers wanted the extra lights on for a specific reason.
4) **Placement?**
   The best place to put a daylighting sensor is on the ceiling. It needs to be near the window and pointed toward an area representative of the work space. Please refer to Figure 11.14 for an example sensor location within a room.

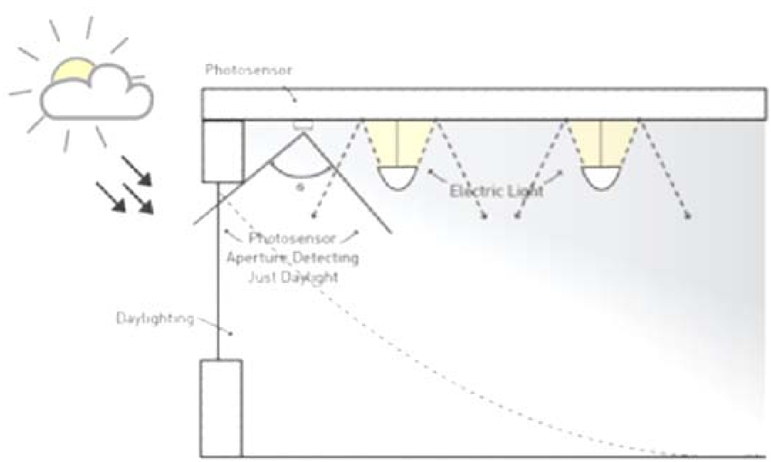


Figure 11.14 Daylighting room graphic from Wattstopper.com

23 Wattstopper.com Product Selection Guide 2007-2008 found at http://www.nxtbook.com/nxtbooks/wattstopper/psg0708/index.php?startpage=262

	On/Off Switching	Dimming
Single Zone	LS-101 (either)	LS-301 (closed loop)
Multi Zone	LCO-203 system (open loop)	LCD-203 system (open loop)

Figure 11.15 Daylighting sensor selection chart

Figure 11.15 suggests using a LS-101. The LS-101 is a Light Saver Daylighting Controller that can sense 1-1400 footcandles. The product overview says,

> The LS-101 Daylighting Controller is a single zone, ON/OFF device which can be installed in an open or closed loop application to turns lights off automatically when sufficient natural daylight is present. It consists of an advanced digital multiband photosensor that measures light similar to the way the human eye perceives it, an on-board microcontroller, and an LCD display. This photosensor is positioned behind a 100Þ cone that cuts off unwanted light, preventing false triggering.
>
> **-**LS-101 Product Overview, more available in **Appendix E**

Below is a diagram featured on Wattstopper.com which shows the elements of a LS-101 controller.

Figure 11.16 LS-101 features diagram from Wattstopper.com

11.12 Cost and Schedule Considerations

<u>Cost</u>

There is no doubt that using daylighting techniques saves energy and therefore reduces the electrical costs for the owner. The question is by how much. Unfortunately, I do not have the resources to examine a dollar figure. It can be assumed that since the lamps are being reduced from 4 lamps to 3 lamps, there is an automatic 25% cost savings. This alone is significant. By shutting off the row of lights nearest the window, there would be a 33% reduction in electrical cost per classroom. It is difficult to estimate how often these lights could be turned off, which makes cost analysis even tougher. However, the test trials of the space were conducted when the sky type was overcast. This conservative estimate gives hope that a large amount of days will be overcast or better, and therefore the daylighting techniques will be able to function. Coupling the lamp reduction with the possibility of turning off one row of lights during most of the day results in substantial savings to the owner and the environment.

The cost of adding the daylighting photosensors to the classrooms would be offset by electrical savings within the first year. Since I chose to switch the lights on and off rather than dim, the ballasts do not have to be changed. Therefore, the only additional cost to the owner is the actual sensors. A sensor could cost approximately $100 to $200 dollars. Taking the average and multiplying by the 24 classrooms yields a cost of $3600. The automatic 25% savings from the lamps should account for this addition. Beyond the first year would be only more savings.

Increased mechanical load to cool the building due to the extra windows is not expected. The window area was doubled, but still only makes up 40% of the exterior wall. The wall is insulated and the windows have a low emissivity glazing which helps heat loss and gain. Additionally, these windows are only being added to the 24 classrooms. None of the windows on the peaks will change, and these peak windows will receive the most direct sunlight and therefore heat gain. Many classrooms with daylighting have ribbon windows or clerestories; and these WCA classrooms are still well below that amount of windows.

<u>Schedule</u>

The photosensors would not cause any delay or extra time in the schedule. They are not a long lead item and are readily available through manufacturers with proper order preparation. However, adding daylighting techniques would not reduce the schedule, either. The most dramatic schedule change would occur in the design phase. To incorporate daylighting into the WCA classrooms, it should have been considered in the initial design phase of the school. Even as far back as schematic because the number of windows needs to be high enough to allow in a substantial amount of light. The architect and lighting designer need to work together in the initial project stages to create a system that works both aesthetically and electrically. Then, the owner would have to approve such an addition. Although with the long term energy cost savings and proven benefits for the occupants, it is difficult to find a reason not to employ daylighting techniques when possible.

11.13 Conclusion & Recommendation

Based on the current WCA classroom design, it would not be advisable to use daylighting techniques. In addition, it would be a waste of money to install occupancy sensors. Rather, I recommend educating teachers about the benefits of turning out the lights and possibly placing laminated or permanent signs above the switches that remind teachers to shut the lights off when leaving the room.

As far as daylighting is considered, there is nothing that can be done now for the WCA classrooms considering construction is so far along. Had this been two years ago, I would recommend that the architect, lighting designer, and owner collaborate to incorporate the necessary amount of windows to achieve daylighting into the initial building design.

The trials conducted with AGi32 concluded that rotating the luminaires 90 degrees had no effect on the lighting in classroom. Positively, though, it also concluded that with four windows per classroom the lamps per luminaire could drop from four to three and daylighting techniques could be used.

Figure 11.17 Classroom with natural light entering
http://www.cstrainingcenter.com/images/classroom6.jpg

Overall, I recommend designing four windows per classroom which provides ample natural light for daylighting and visual comfort for students. It would create a more environmentally friendly and cohesive space for students. Also, I recommend using three lamps per luminaire which reduces energy and gives teachers more switching options during presentations or different activities. I think the LS-101 daylight photosensor should be used in every classroom which would control the row of lights nearest the windows. This sensor would switch the row on and off rather than dim which provides yet another educational benefit to the space and allows teachers to make an example of how turning the lights off is energy efficient and can be done when there is enough light in the room to still perform all necessary tasks.

While the cost of the daylighting system is slightly more expensive than the current system, the benefits of energy cost savings and a better educational environment for students far outweigh the additional money spent. The schedule is not impacted so the WCA would still be able to finish on time and open for the 2008-2009 school year.

12 | Conclusion

As an owner, the Washington Christian Academy is seeking to build a high quality educational facility that promotes healthy and valuable learning for its students. According to the Governor's Green Council, there are three areas of a school that should be improved upon to make them above average in acoustics, lighting, and air quality. The owner is interested in constructing a quality building at a reasonable cost and the analyses discussed in this thesis reflect adding value without dramatically increasing cost.

The critical issue facing the construction industry in and around Washington, D.C., which is mostly an open shop labor market, is a language barrier created by the English and Spanish speaking workers. The number of Spanish speaking laborers is on the rise and growing at an exponential rate. Through surveying industry members a lot of information was gathered concerning the status and consequences of the barrier today. To highlight only a few conclusions from the analysis, 95% of the 65 people who responded believe that a language barrier does exist and affects a project's success. The participants were split almost equally on whether teaching English to Spanish speaking people or the inverse is more likely to happen. One thing is for sure; something needs to happen. The survey concluded that the largest problems stemming from the barrier are the difficulty in giving basic jobsite instructions and increased safety hazards. To begin solving this problem, there are programs that teach both languages to workers. These programs are being slowly incorporated into the industry through company offered courses and university courses.

The first technical analysis replaced the sheet metal ductwork in the WCA Gymnasium with fabric ductwork. This was done to improve the acoustics of the space. There are also many other advantages to using fabric ductwork such as cost and schedule reduction, color selection, easy maintenance, light weight, and better air distribution. No structural redesign was necessary for the space. In the end, the fabric duct had a minimal improvement on the acoustics of the space. The cost savings was $9,650, and when compared to the current sheet metal system resulted in a 74% reduction. Most of the money saved was on shipping and installation. The schedule reduction was an astounding 21 days, which is an 84% reduction. While the acoustical benefits of the new system would not alone be enough to recommend the change, when compounded with the many benefits and cost and schedule savings the new system seems like the best solution for the gymnasium.

The second technical analysis examined using daylighting techniques in the WCA Flagship classrooms. The analysis was conducted using a three dimensional model in a lighting design software. After the calculations were run, it was found that the current room design is not acceptable for daylighting practices. If each room were to have four windows rather than two, daylighting could be used and the lamps could be reduced from four to three per luminaire. While exact cost data was difficult to obtain, the reduction of lamps alone would result in a 25% energy cost savings to the owner. The analysis also concluded that using switching rather than dimming would benefit the owner with cost savings and benefit the students with a learning opportunity. This system will raise students' awareness of the uses of daylighting and help them identify situations when electrical lights are not needed.

Appendix A

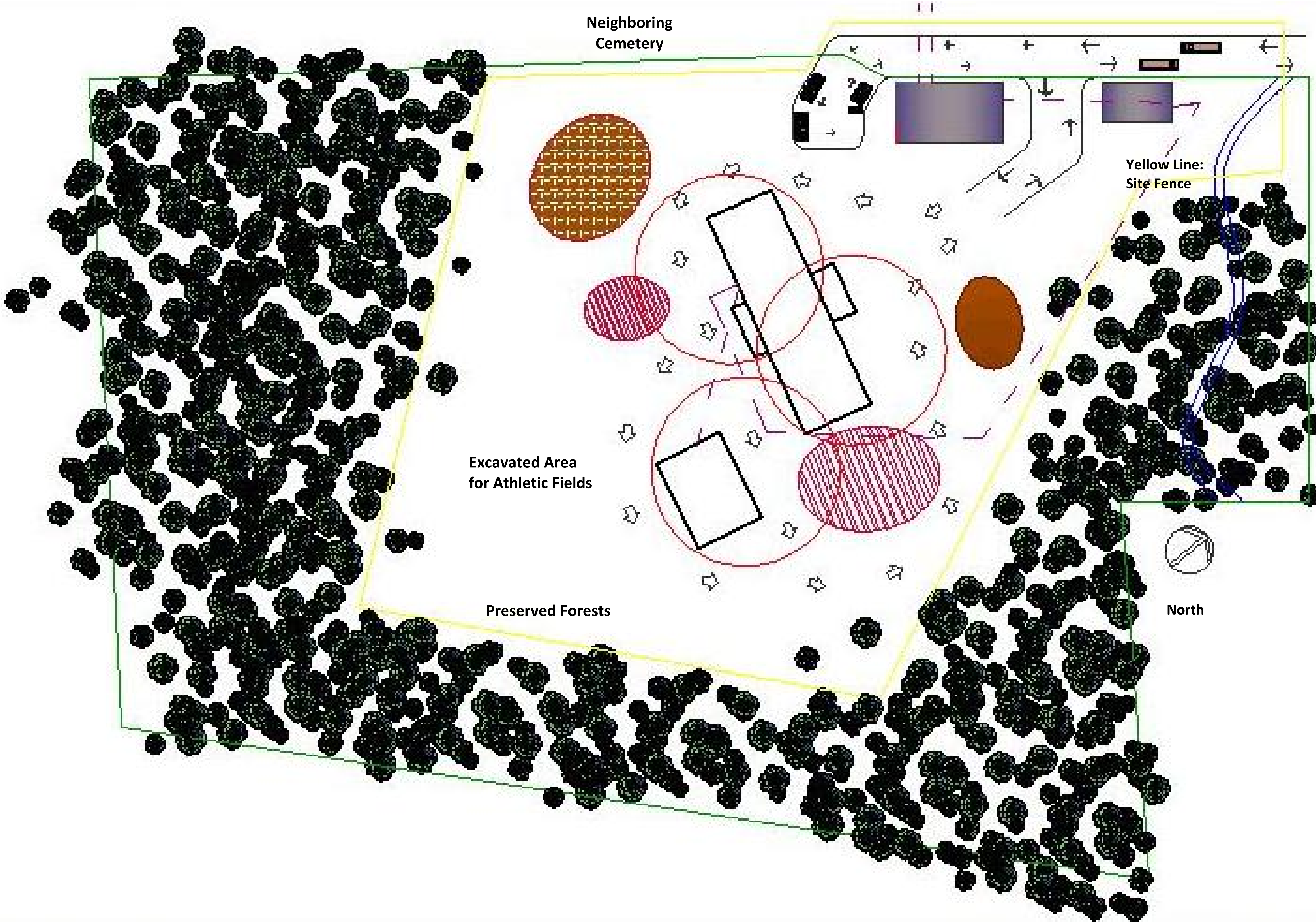
Site Plans

Contents:

Drawing S.1: Full Site

Drawing S.2: Superstructure Flagship & Gymnasium

Please note: These site plans has been created by Casey Mowery. While great effort was made to make the plans realistic and accurate, they are not the actual site plans for the Washington Christian Academy project.



For further Site Layout Planning detail, See S.2: Superstructure Flagship & Gymnasium

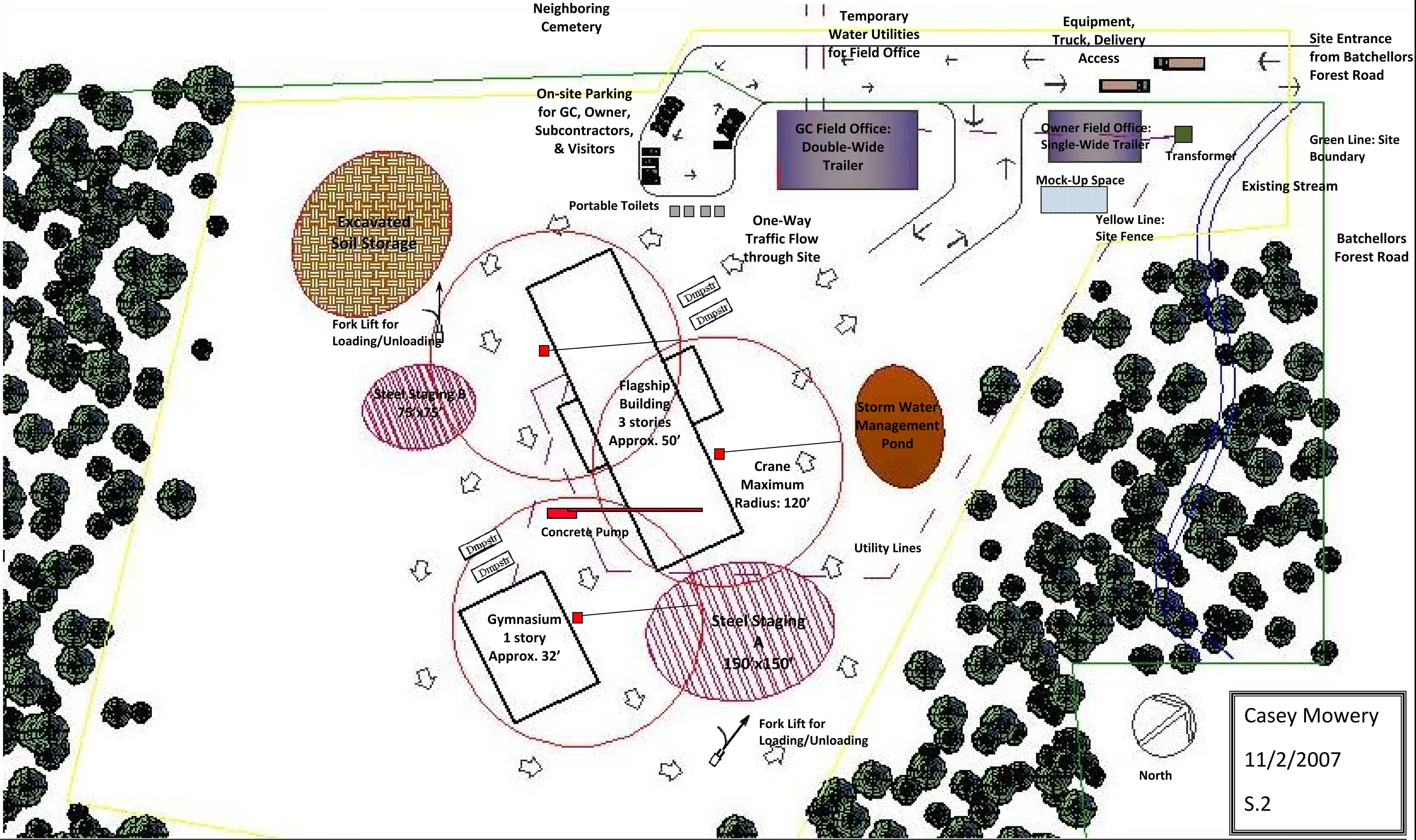
Casey Mowery

11/2/2007

S.1

FULL SITE: SITE LAYOUT PLANNING

Washington Christian Academy



Casey Mowery

11/2/2007

S.2

SUPERSTRUCTURE FLAGSHIP & GYMNASIUM: SITE LAYOUT PLANNING

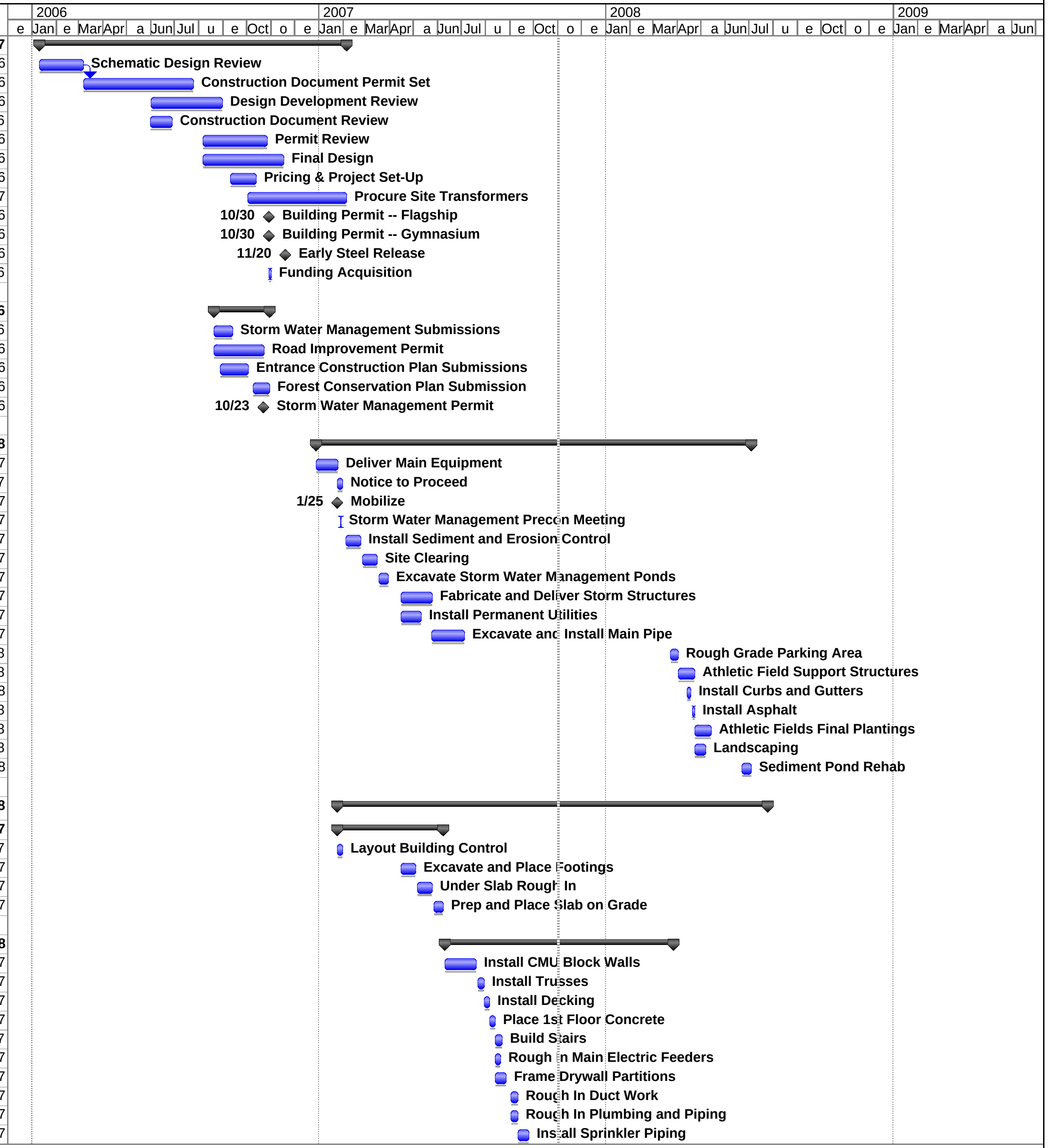
Washington Christian Academy

Appendix B

Detailed Project Schedule

Please note: This schedule has been created by Casey Mowery. While great effort was made to make this schedule realistic and accurate, it is not the actual project schedule for the Washington Christian Academy project.

ID	Task Name	Duration	Start	Finish
1	**Procurement**	**279 days**	**Wed 1/11/06**	**Mon 2/5/07**
2	Schematic Design Review	40 days	Wed 1/11/06	Tue 3/7/06
3	Construction Document Permit Set	100 days	Wed 3/8/06	Tue 7/25/06
4	Design Development Review	65 days	Fri 6/2/06	Thu 8/31/06
5	Construction Document Review	20 days	Thu 6/1/06	Wed 6/28/06
6	Permit Review	60 days	Mon 8/7/06	Fri 10/27/06
7	Final Design	75 days	Mon 8/7/06	Fri 11/17/06
8	Pricing & Project Set-Up	25 days	Mon 9/11/06	Fri 10/13/06
9	Procure Site Transformers	90 days	Tue 10/3/06	Mon 2/5/07
10	Building Permit -- Flagship	0 days	Mon 10/30/06	Mon 10/30/06
11	Building Permit -- Gymnasium	0 days	Mon 10/30/06	Mon 10/30/06
12	Early Steel Release	0 days	Mon 11/20/06	Mon 11/20/06
13	Funding Acquisition	3 days	Mon 10/30/06	Wed 11/1/06
14				
15	**Civil Permits**	**51 days**	**Mon 8/21/06**	**Mon 10/30/06**
16	Storm Water Management Submissions	18 days	Mon 8/21/06	Wed 9/13/06
17	Road Improvement Permit	46 days	Mon 8/21/06	Mon 10/23/06
18	Entrance Construction Plan Submissions	26 days	Tue 8/29/06	Tue 10/3/06
19	Forest Conservation Plan Submission	15 days	Tue 10/10/06	Mon 10/30/06
20	Storm Water Management Permit	0 days	Mon 10/23/06	Mon 10/23/06
21				
22	**Site Work**	**397 days**	**Fri 12/29/06**	**Fri 7/4/08**
23	Deliver Main Equipment	20 days	Fri 12/29/06	Thu 1/25/07
24	Notice to Proceed	5 days	Thu 1/25/07	Wed 1/31/07
25	Mobilize	0 days	Thu 1/25/07	Thu 1/25/07
26	Storm Water Management Precon Meeting	1 day	Mon 1/29/07	Mon 1/29/07
27	Install Sediment and Erosion Control	15 days	Mon 2/5/07	Fri 2/23/07
28	Site Clearing	15 days	Mon 2/26/07	Fri 3/16/07
29	Excavate Storm Water Management Ponds	10 days	Mon 3/19/07	Fri 3/30/07
30	Fabricate and Deliver Storm Structures	30 days	Mon 4/16/07	Fri 5/25/07
31	Install Permanent Utilities	20 days	Mon 4/16/07	Fri 5/11/07
32	Excavate and Install Main Pipe	30 days	Fri 5/25/07	Thu 7/5/07
33	Rough Grade Parking Area	8 days	Mon 3/24/08	Wed 4/2/08
34	Athletic Field Support Structures	15 days	Thu 4/3/08	Wed 4/23/08
35	Install Curbs and Gutters	5 days	Mon 4/14/08	Fri 4/18/08
36	Install Asphalt	3 days	Mon 4/21/08	Wed 4/23/08
37	Athletic Fields Final Plantings	15 days	Thu 4/24/08	Wed 5/14/08
38	Landscaping	10 days	Thu 4/24/08	Wed 5/7/08
39	Sediment Pond Rehab	10 days	Mon 6/23/08	Fri 7/4/08
40				
41	**FLAGSHIP BUILDING**	**393 days**	**Thu 1/25/07**	**Fri 7/25/08**
42	**Foundation**	**97 days**	**Thu 1/25/07**	**Fri 6/8/07**
43	Layout Building Control	5 days	Thu 1/25/07	Wed 1/31/07
44	Excavate and Place Footings	15 days	Mon 4/16/07	Fri 5/4/07
45	Under Slab Rough In	15 days	Mon 5/7/07	Fri 5/25/07
46	Prep and Place Slab on Grade	10 days	Mon 5/28/07	Fri 6/8/07
47				
48	**1st Floor**	**210 days**	**Mon 6/11/07**	**Thu 3/27/08**
49	Install CMU Block Walls	30 days	Mon 6/11/07	Fri 7/20/07
50	Install Trusses	6 days	Mon 7/23/07	Mon 7/30/07
51	Install Decking	5 days	Tue 7/31/07	Mon 8/6/07
52	Place 1st Floor Concrete	5 days	Tue 8/7/07	Mon 8/13/07
53	Build Stairs	7 days	Tue 8/14/07	Wed 8/22/07
54	Rough In Main Electric Feeders	5 days	Tue 8/14/07	Mon 8/20/07
55	Frame Drywall Partitions	10 days	Tue 8/14/07	Mon 8/27/07
56	Rough In Duct Work	7 days	Mon 9/3/07	Tue 9/11/07
57	Rough In Plumbing and Piping	7 days	Mon 9/3/07	Tue 9/11/07
58	Install Sprinkler Piping	10 days	Wed 9/12/07	Tue 9/25/07



Project: WCA 200 Item Schedule
Date: 11/2/2007

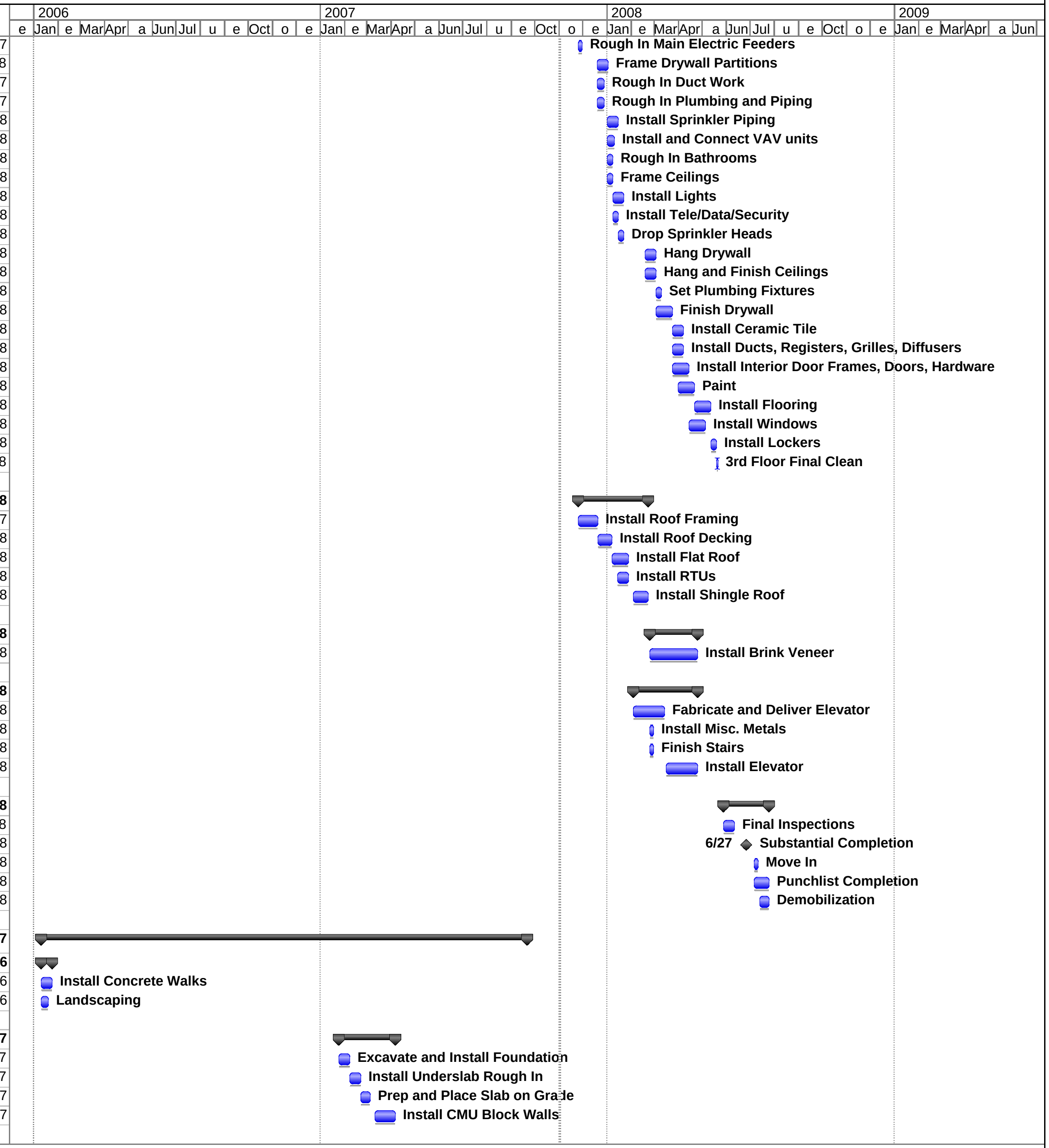
Task	Progress	Summary	External Tasks
Deadline	Split	Milestone	Project Summary
External Milestone			

ID	Task Name	Duration	Start	Finish
59	Install and Connect VAV units	7 days	Wed 9/12/07	Thu 9/20/07
60	Rough In Bathrooms	5 days	Wed 9/12/07	Tue 9/18/07
61	Frame Ceilings	5 days	Wed 9/12/07	Tue 9/18/07
62	Install Lights	10 days	Wed 9/19/07	Tue 10/2/07
63	Install Tele/Data/Security	5 days	Wed 9/19/07	Tue 9/25/07
64	Drop Sprinkler Heads	5 days	Wed 9/26/07	Tue 10/2/07
65	Hang Drywall	10 days	Thu 12/27/07	Wed 1/9/08
66	Hang and Finish Ceilings	10 days	Thu 12/27/07	Wed 1/9/08
67	Kitchen Rough In	15 days	Thu 1/10/08	Wed 1/30/08
68	Set Plumbing Fixtures	5 days	Thu 1/10/08	Wed 1/16/08
69	Finish Drywall	10 days	Thu 1/10/08	Wed 1/23/08
70	Install Ceramic Tile	7 days	Thu 1/24/08	Fri 2/1/08
71	Install Store front	7 days	Thu 1/24/08	Fri 2/1/08
72	Install Ducts, Registers, Grilles, Diffusers	8 days	Thu 1/24/08	Mon 2/4/08
73	Install Interior Door Frames, Doors, Hardware	15 days	Thu 1/24/08	Wed 2/13/08
74	Paint	15 days	Thu 1/24/08	Wed 2/13/08
75	Install Kitchen Equipment	15 days	Wed 1/30/08	Tue 2/19/08
76	Install Flooring	15 days	Thu 2/14/08	Wed 3/5/08
77	Install Windows	15 days	Wed 2/27/08	Tue 3/18/08
78	Install Exterior Door Frames and Doors	15 days	Wed 2/27/08	Tue 3/18/08
79	Install Lockers	5 days	Wed 3/19/08	Tue 3/25/08
80	1st Floor Final Clean	2 days	Wed 3/26/08	Thu 3/27/08
81				
82	**2nd Floor**	**169 days**	**Tue 8/14/07**	**Thu 4/3/08**
83	Install CMU Block Walls	20 days	Tue 8/14/07	Mon 9/10/07
84	Install Trusses	6 days	Tue 9/11/07	Tue 9/18/07
85	Install Decking	5 days	Wed 9/19/07	Tue 9/25/07
86	Place 2nd Floor Concrete	5 days	Wed 9/26/07	Tue 10/2/07
87	Build Stairs	7 days	Wed 10/3/07	Thu 10/11/07
88	Rough In Main Electric Feeders	5 days	Tue 9/11/07	Mon 9/17/07
89	Frame Drywall Partitions	10 days	Mon 11/19/07	Fri 11/30/07
90	Rough In Duct Work	7 days	Mon 11/12/07	Tue 11/20/07
91	Rough In Plumbing and Piping	7 days	Mon 11/12/07	Tue 11/20/07
92	Install Sprinkler Piping	10 days	Mon 11/19/07	Fri 11/30/07
93	Install and Connect VAV units	7 days	Mon 11/19/07	Tue 11/27/07
94	Rough In Bathrooms	5 days	Mon 11/19/07	Fri 11/23/07
95	Frame Ceilings	5 days	Mon 11/19/07	Fri 11/23/07
96	Install Lights	10 days	Mon 11/26/07	Thu 12/6/07
97	Install Tele/Data/Security	5 days	Mon 11/26/07	Fri 11/30/07
98	Drop Sprinkler Heads	5 days	Sat 12/1/07	Thu 12/6/07
99	Hang Drywall	10 days	Thu 12/27/07	Wed 1/9/08
100	Hang and Finish Ceilings	10 days	Wed 1/2/08	Tue 1/15/08
101	Set Plumbing Fixtures	5 days	Wed 1/16/08	Tue 1/22/08
102	Finish Drywall	10 days	Wed 1/16/08	Tue 1/29/08
103	Install Ceramic Tile	7 days	Wed 1/30/08	Thu 2/7/08
104	Install Ducts, Registers, Grilles, Diffusers	8 days	Wed 1/30/08	Fri 2/8/08
105	Install Interior Door Frames, Doors, Hardware	15 days	Wed 1/30/08	Tue 2/19/08
106	Paint	15 days	Wed 2/13/08	Tue 3/4/08
107	Install Flooring	15 days	Wed 3/5/08	Tue 3/25/08
108	Install Windows	15 days	Tue 2/26/08	Mon 3/17/08
109	Install Lockers	5 days	Wed 3/26/08	Tue 4/1/08
110	2nd Floor Final Clean	2 days	Wed 4/2/08	Thu 4/3/08
111				
112	**3rd Floor**	**167 days**	**Wed 10/3/07**	**Wed 5/21/08**
113	Install CMU Block Walls	20 days	Wed 10/3/07	Tue 10/30/07
114	Install Trusses	8 days	Wed 10/31/07	Fri 11/9/07
115	Install Decking	5 days	Mon 11/12/07	Fri 11/16/07
116	Place 3rd Floor Concrete	5 days	Mon 11/19/07	Fri 11/23/07
117	Build Stairs	7 days	Mon 11/26/07	Mon 12/3/07

Project: WCA 200 Item Schedule
Date: 11/2/2007

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

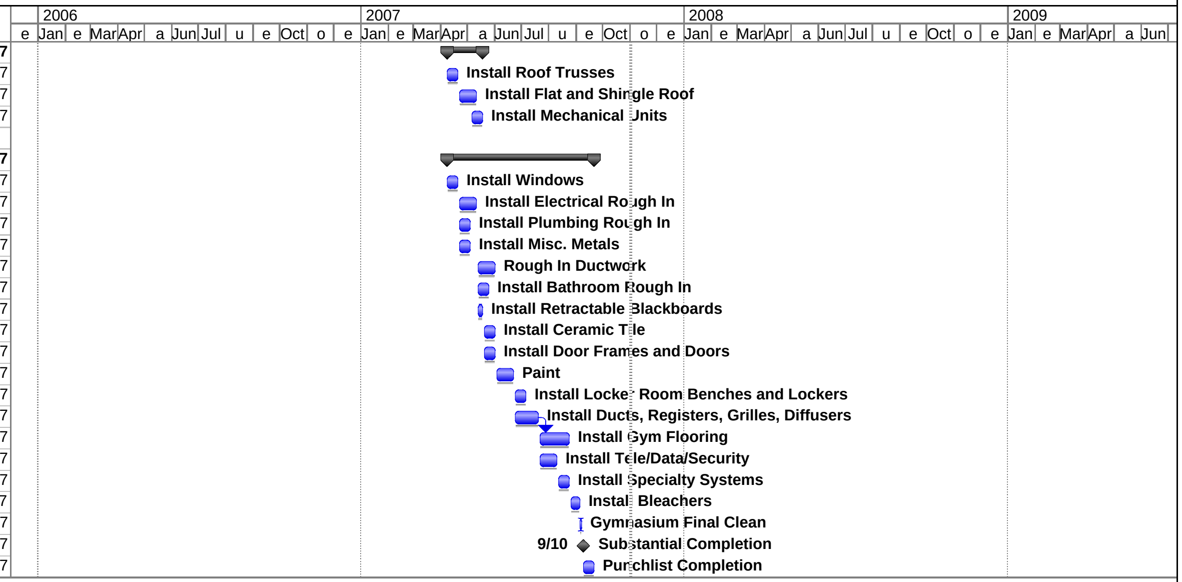
ID	Task Name	Duration	Start	Finish
118	Rough In Main Electric Feeders	5 days	Mon 11/26/07	Fri 11/30/07
119	Frame Drywall Partitions	10 days	Thu 12/20/07	Wed 1/2/08
120	Rough In Duct Work	7 days	Thu 12/20/07	Fri 12/28/07
121	Rough In Plumbing and Piping	7 days	Thu 12/20/07	Fri 12/28/07
122	Install Sprinkler Piping	10 days	Wed 1/2/08	Tue 1/15/08
123	Install and Connect VAV units	7 days	Wed 1/2/08	Thu 1/10/08
124	Rough In Bathrooms	5 days	Wed 1/2/08	Tue 1/8/08
125	Frame Ceilings	5 days	Wed 1/2/08	Tue 1/8/08
126	Install Lights	10 days	Wed 1/9/08	Tue 1/22/08
127	Install Tele/Data/Security	5 days	Wed 1/9/08	Tue 1/15/08
128	Drop Sprinkler Heads	5 days	Wed 1/16/08	Tue 1/22/08
129	Hang Drywall	10 days	Tue 2/19/08	Mon 3/3/08
130	Hang and Finish Ceilings	10 days	Tue 2/19/08	Mon 3/3/08
131	Set Plumbing Fixtures	5 days	Tue 3/4/08	Mon 3/10/08
132	Finish Drywall	15 days	Tue 3/4/08	Mon 3/24/08
133	Install Ceramic Tile	10 days	Tue 3/25/08	Mon 4/7/08
134	Install Ducts, Registers, Grilles, Diffusers	10 days	Tue 3/25/08	Mon 4/7/08
135	Install Interior Door Frames, Doors, Hardware	15 days	Tue 3/25/08	Mon 4/14/08
136	Paint	15 days	Tue 4/1/08	Mon 4/21/08
137	Install Flooring	15 days	Tue 4/22/08	Mon 5/12/08
138	Install Windows	15 days	Tue 4/15/08	Mon 5/5/08
139	Install Lockers	5 days	Tue 5/13/08	Mon 5/19/08
140	3rd Floor Final Clean	2 days	Tue 5/20/08	Wed 5/21/08
141				
142	**Roof**	**66 days**	**Mon 11/26/07**	**Fri 2/22/08**
143	Install Roof Framing	20 days	Mon 11/26/07	Thu 12/20/07
144	Install Roof Decking	12 days	Fri 12/21/07	Mon 1/7/08
145	Install Flat Roof	15 days	Tue 1/8/08	Mon 1/28/08
146	Install RTUs	10 days	Tue 1/15/08	Mon 1/28/08
147	Install Shingle Roof	15 days	Mon 2/4/08	Fri 2/22/08
148				
149	**Exterior**	**45 days**	**Mon 2/25/08**	**Fri 4/25/08**
150	Install Brink Veneer	45 days	Mon 2/25/08	Fri 4/25/08
151				
152	**Finish Work**	**60 days**	**Mon 2/4/08**	**Fri 4/25/08**
153	Fabricate and Deliver Elevator	30 days	Mon 2/4/08	Fri 3/14/08
154	Install Misc. Metals	5 days	Mon 2/25/08	Fri 2/29/08
155	Finish Stairs	5 days	Mon 2/25/08	Fri 2/29/08
156	Install Elevator	30 days	Mon 3/17/08	Fri 4/25/08
157				
158	**Inpsections**	**42 days**	**Thu 5/29/08**	**Fri 7/25/08**
159	Final Inspections	10 days	Thu 5/29/08	Wed 6/11/08
160	Substantial Completion	0 days	Fri 6/27/08	Fri 6/27/08
161	Move In	5 days	Mon 7/7/08	Fri 7/11/08
162	Punchlist Completion	15 days	Mon 7/7/08	Fri 7/25/08
163	Demobilization	10 days	Mon 7/14/08	Fri 7/25/08
164				
165	**GYMNASIUM BUILDING**	**443 days**	**Wed 1/11/06**	**Fri 9/21/07**
166	**Site**	**10 days**	**Wed 1/11/06**	**Tue 1/24/06**
167	Install Concrete Walks	10 days	Wed 1/11/06	Tue 1/24/06
168	Landscaping	7 days	Wed 1/11/06	Thu 1/19/06
169				
170	**Foundation and Structure**	**52 days**	**Thu 1/25/07**	**Fri 4/6/07**
171	Excavate and Install Foundation	10 days	Thu 1/25/07	Wed 2/7/07
172	Install Underslab Rough In	10 days	Thu 2/8/07	Wed 2/21/07
173	Prep and Place Slab on Grade	8 days	Thu 2/22/07	Mon 3/5/07
174	Install CMU Block Walls	20 days	Mon 3/12/07	Fri 4/6/07
175				



Project: WCA 200 Item Schedule
Date: 11/2/2007

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

ID	Task Name	Duration	Start	Finish
176	**Roof**	**30 days**	**Mon 4/9/07**	**Fri 5/18/07**
177	Install Roof Trusses	10 days	Mon 4/9/07	Fri 4/20/07
178	Install Flat and Shingle Roof	15 days	Mon 4/23/07	Fri 5/11/07
179	Install Mechanical Units	10 days	Mon 5/7/07	Fri 5/18/07
180				
181	**Finish Work**	**120 days**	**Mon 4/9/07**	**Fri 9/21/07**
182	Install Windows	10 days	Mon 4/9/07	Fri 4/20/07
183	Install Electrical Rough In	15 days	Mon 4/23/07	Fri 5/11/07
184	Install Plumbing Rough In	10 days	Mon 4/23/07	Fri 5/4/07
185	Install Misc. Metals	10 days	Mon 4/23/07	Fri 5/4/07
186	Rough In Ductwork	15 days	Mon 5/14/07	Fri 6/1/07
187	Install Bathroom Rough In	10 days	Mon 5/14/07	Fri 5/25/07
188	Install Retractable Blackboards	5 days	Mon 5/14/07	Fri 5/18/07
189	Install Ceramic Tile	10 days	Mon 5/21/07	Fri 6/1/07
190	Install Door Frames and Doors	10 days	Mon 5/21/07	Fri 6/1/07
191	Paint	15 days	Mon 6/4/07	Fri 6/22/07
192	Install Locker Room Benches and Lockers	10 days	Mon 6/25/07	Fri 7/6/07
193	Install Ducts, Registers, Grilles, Diffusers	20 days	Mon 6/25/07	Fri 7/20/07
194	Install Gym Flooring	25 days	Mon 7/23/07	Fri 8/24/07
195	Install Tele/Data/Security	15 days	Mon 7/23/07	Fri 8/10/07
196	Install Specialty Systems	10 days	Mon 8/13/07	Fri 8/24/07
197	Install Bleachers	8 days	Mon 8/27/07	Wed 9/5/07
198	Gymnasium Final Clean	2 days	Thu 9/6/07	Fri 9/7/07
199	Substantial Completion	0 days	Mon 9/10/07	Mon 9/10/07
200	Punchlist Completion	10 days	Mon 9/10/07	Fri 9/21/07



Project: WCA 200 Item Schedule
Date: 11/2/2007

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Appendix C

General Conditions Estimate

Please note: This estimate has been prepared by Casey Mowery. While great effort was made to make this estimate realistic and accurate, it is not the actual GCs estimate for the Washington Christian Academy project.

Washington Christian Academy

General Conditions Estimate Summary

A potential General Conditions Estimate prepared by Casey Mowery

Approx. Construction Start Date: 2/1/2007 Approx. Duration (months): 17

Approx. Construction Completion Date: 7/1/2008 Approx. Duration (weeks): 73.7

		Unit Cost	Unit	Multiplier	Unit		Total Cost	
Temp. Facilities, Supplies, & Expenses								
Field Office Trailer	$	275.00	/wk	73.7	wks	$	20,268	
Project Signs	$	1,200.00	/ea	3.0	ea	$	3,600	
Construction Site Fencing	$	19,900.00	ls	1.0	ls	$	19,900	
Computers	$	17.00	/wk	73.7	wks	$	3,759	3 unit(s)
Copy Machines (Lease)	$	60.00	/wk	73.7	wks	$	4,422	1 unit(s)
Fax Machines	$	20.00	/wk	73.7	wks	$	1,474	1 unit(s)
Nextel Communication Devices	$	20.00	/wk	73.7	wks	$	7,370	5 unit(s)
Site Company Truck	$	200.00	/wk	73.7	wks	$	14,740	
IT Services Equipment	$	2,500.00	ls	1.0	ls	$	2,500	
Postage & Shipping	$	5,500.00	ls	1.0	ls	$	5,500	
Field Office Weekly Expenses	$	100.00	/wk	73.7	wks	$	7,370	
Relocation Expenses	$	3,500.00	/ea	1.0	ea	$	3,500	
						$	94,402	
Drawings & Inspections								
Drawings & Specifications	$	17,500.00	ls	1.0	ls	$	17,500	
Surveys, Layouts, & Grades	$	59,670.00	ls	1.0	ls	$	59,670	
Safety Inspections		$240	/mo	17.0	mos	$	4,080	
Tests & Inspections	$	48,800.00	ls	1.0	ls	$	48,800	
						$	130,050	
Project Staffing								
Estimating Group	$	200,000.00	ls	1.0	ls	$	200,000	
Project Executive	$	4,800.00	/wk	6.0	wks	$	28,800	
Senior Project Manager	$	4,300.00	/wk	14.0	wks	$	60,200	
Project Manager	$	3,100.00	/wk	73.7	wks	$	228,470	
Assistant Project Manager	$	2,150.00	/wk	73.7	wks	$	158,455	
Superintendent	$	3,450.00	/wk	68.8	wks	$	237,360	
Assistant Superintendent	$	2,300.00	/wk	73.7	wks	$	169,510	
Field Engineer	$	1,700.00	/wk	73.7	wks	$	125,290	
Administrative Assistant	$	1,300.00	/wk	25.0	wks	$	32,500	
IT Technician	$	2,000.00	/wk	4.0	wks	$	8,000	
						$	1,248,585	

Temporary Utilities							
Telephone Service Connection	$	650.00	ls	1.0	ls	$	650
Tele. Monthly Charges -- Cellular	$	700.00	/mo	17.0	mos	$	11,900
Tele. Monthly Charges -- Ground	$	300.00	/mo	17.0	mos	$	5,100
Electrice Service Connection	$	3,000.00	ls	1.0	ls	$	3,000
Electric Monthly	$	1,200.00	/wk	73.7	wks	$	88,440
Water Monthly	$	125.00	/wk	73.7	wks	$	9,213
Temporary Heat	$	1,000.00	/wk	26.4	wks	$	26,400
Sanitary Facilities	$	90.00	/mo	17.0	mos	$	1,530
Site Drinking Water	$	20.00	/wk	73.7	wks	$	1,474
						$	147,707
Fees, Warranty, & Bonds							
Legal Fees / Contract Review	$	5,000.00	/ea	1.0	ea	$	5,000
Warranty	$	18,000.00	/ea	1.0	ea	$	18,000
GC Payment & Performance Bonds	$	100,000.00	ls	1.0	ls	$	100,000
						$	123,000
Total General Conditions						**$**	**1,743,744**

Appendix D

Language Barrier Survey

Senior Thesis Critical Issue in the Construction Industry Research Survey

Consequences of the English-Spanish Language Barrier in the Construction Industry

This survey was created for the sole purpose of Casey Mowery's senior thesis research. All responses will be kept confidential and any results/conclusions from this survey are for academic research purposes only. Participant name and contact information are optional, and will only be used if Casey needs to contact the individual for more questions/clarifications. If you wish to remain anonymous, please still fill out the survey form for research purposes. Thank you in advance to all participants. Please try to have your responses in by Friday, ***February 22*** *.*

1. Name & Contact Info. Name ____

Email ____

2. May Casey contact you with further questions? Y N

3. Your Position ____

4. Approximately how many years have you been in the construction industry? ___________

5. Do you think there is an English-Spanish language barrier in the construction industry today? Yes No

6. If yes, do you think that this problem is getting better or worse each year? Better Worse

7. In your experience, are the signs around typical jobsites bilingual? Y N

8. Have you attempted to learn or speak Spanish on the jobsite? Y N

8a. If yes, how?

9. On site, how often do you encounter people whose primary language is Spanish?

A. Never B. Monthly C. Weekly D. Daily

10. Please rank the following in order of (1) biggest problem to (6) least problem that you have witnessed as a result of the language barrier (particularly on site).

________ Loss of Productivity/Efficiency

________ Greater Safety Risks

________ Difficulty in Giving Instructions (Basic Jobsite Communication)

________ Lack of Respect / Diminished Team Atmosphere

optional ________ Other ____

optional ________ Other ____

11. In your opinion, why did you rank #1 as the biggest problem related to the English-Spanish Language Barrier?

12. Which do you think would be more likely to happen?

Teach English to Spanish speaking individuals or Teach Spanish to English speaking individuals

Any additional information you would like to provide or share regarding the English-Spanish Language Barrier in the construction industry:

Thank you for participating in this survey. Confidential results will be made available in April through Casey Mowery's Penn State Architectural Engineering Senior Thesis E-Portfolio found at http://www.engr.psu.edu/ae/thesis/portfolios/2008/cam459/. Please contact Casey with any inquiries or information at cam459@psu.edu.

Please complete the survey and send as:

1. email attachment to **cam459@psu.edu**
2. posted mail to 134 W. Fairmount Ave, Apt. 2, State College, PA 16801

Blank versions of this survey can be found at: http://www.engr.psu.edu/ae/thesis/portfolios/2008/cam459/research.htm

Appendix E

Lighting Resources

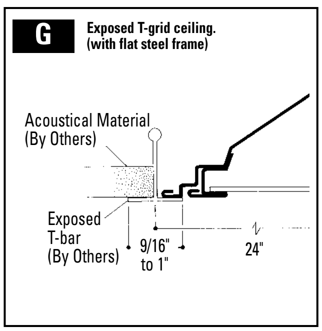
Contents:

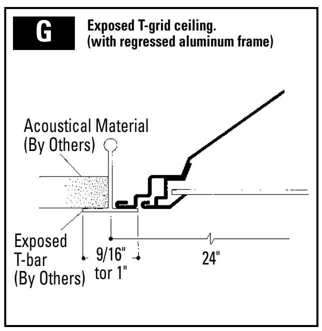
Static, Flat Steel or Regressed Aluminum Lens Frame, 4 Lamp, T8

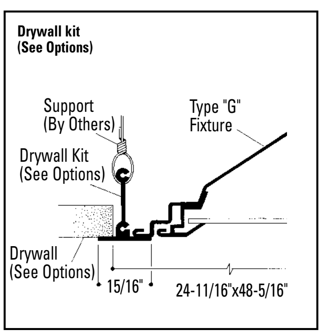
Features

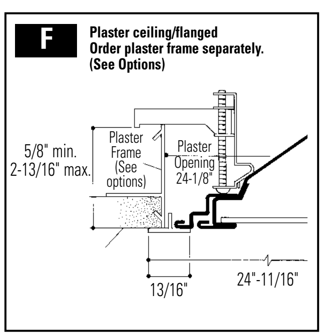
- Efficiency 83.0%.
- Shallow 3" deep housing.
- Ribbed housing for strength and stability.
- Ends of housing formed inward for safe handling.
- Built-in earthquake clips.
- Hemmed-over side rails for safe handling.
- Ends have screw dimples for installation to T-bar (no fixture or ceiling distortion).
- Flat steel or regressed aluminum lens frame with mitered corners.
- Edges of steel door frame hemmed-over for safe handling.
- No light leak.
- Internal "T" hinges – easy installation and maintenance.
- Rooster head spring latches.
- Meets code 30 requirements in New England.

Mounting Methods

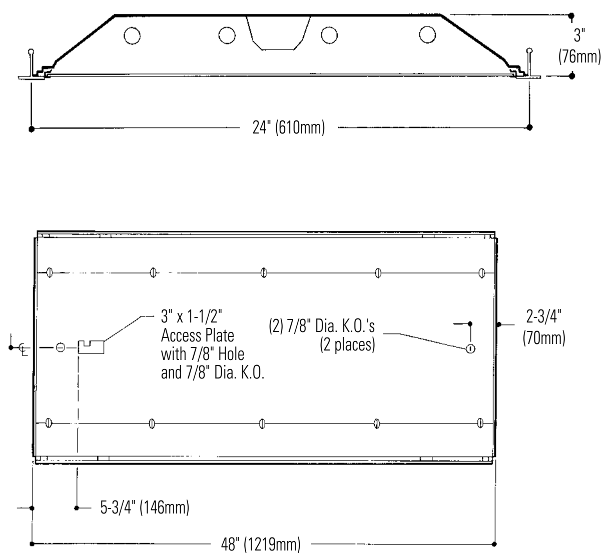








Dimensions



Job Information	Type:
Job Name:	
Cat. No.:	
Lamp(s):	
Volts/Ballast:	

Lightolier a Genlyte Thomas Company www.lightolier.com
Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710

LIGHTOLIER®

Photometry

Model No. XP2GVA43212004

GTI TESTING LABORATORY

45 Industrial Way
Wilmington, MA 01887
(978) 657-7600

REPORT NO.: G22910 DATE: 7/2/02
CATALOG NO.: XP2GVA43212004
LAMP(S): 4 F32T8, EACH RATED 2850 LUMENS.
LUMINAIRE: 2X4 G TROFFER W/ VA LENS
TRIAD B432I120RH-A

CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
0	3551	3551	3551	3551	3551	
5	3559	3554	3546	3535	3527	338
15	3433	3441	3475	3497	3505	981
25	3158	3195	3299	3381	3410	1517
35	2735	2801	2963	3101	3154	1844
45	2140	2210	2364	2507	2568	1815
55	1426	1496	1630	1678	1718	1428
65	819	844	835	888	945	863
75	487	463	371	428	472	468
85	204	205	178	176	190	201
90	29	35	38	40	39	

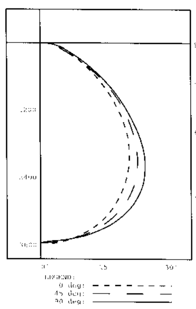
ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 30	2836	25.0	30.0
0- 40	4679	41.0	50.0
0- 60	7923	70.0	84.0
0- 90	9454	83.0	100.0
90-180	0	0.0	0.0
0-180	9454	83.0	100.0

TOTAL LUMINAIRE EFFICIENCY = 83.0%
CIE TYPE - DIRECT
PLANE : 0-DEG 90-DEG
SPACING CRITERIA : 1.2 1.4
SHIELDING ANGLES : 90 90
PLANE : 0-DEG 90-DEG
LUMINOUS LENGTH :46.000 21.000

LUMINANCE DATA IN CANDELA/SQ M

ANGLE IN DEG	AVERAGE 0-DEG	AVERAGE 45-DEG	AVERAGE 90-DEG
45	4854.	5362.	5825.
55	3988.	4558.	4804.
65	3108.	3169.	3587.
75	3018.	2299.	2925.
85	3754.	3276.	3497.



THIS REPORT IS BASED ON PUBLISHED INDUSTRY PROCEDURES • FIELD PERFORMANCE MAY VARY FROM LABORATORY PERFORMANCE.

LER = FL - 74.3 IW - 112 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $3.23

coefficients of utilization — zonal cavity method (effective floor cavity reflectance 0.20)

RF	20			20			20		
RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
room cavity ratio 1	91	87	84	82	79	77	78	76	74
2	83	76	71	72	68	64	69	66	63
3	76	68	61	64	59	55	62	57	54
4	70	60	53	57	51	47	55	50	46
5	64	54	47	51	45	41	50	45	40
6	60	49	42	47	41	36	45	40	36
7	55	44	37	42	36	32	41	36	32
8	52	41	34	39	33	29	38	32	28
9	48	37	31	36	30	26	35	30	26
10	45	34	28	33	27	23	32	27	23

visual comfort probability (rated lumens per lamp 2850.)

room size W	room size L	luminaries lengthwise: ceiling height 8.5	10.0	13.0	16.0	luminaries crosswise: ceiling height 8.5	10.0	13.0	16.0
20	20	54	59	67	76	53	57	63	72
20	30	46	51	57	64	47	50	54	61
20	40	41	45	51	57	43	46	49	53
20	60	37	41	45	51	39	42	45	49
30	20	56	60	65	73	55	59	63	71
30	30	47	51	55	62	48	51	54	59
30	40	42	45	49	54	43	46	49	52
30	60	37	41	43	48	39	42	44	47
30	80	35	38	40	44	37	40	41	44
40	20	58	62	67	72	57	61	65	71
40	30	49	53	56	61	49	53	55	59
40	40	43	46	50	53	45	47	49	52
40	60	38	41	43	47	40	43	44	47
40	80	35	38	39	43	38	40	41	44
40	100	34	36	37	40	37	39	39	42
60	30	50	54	57	62	50	54	56	60
60	40	44	48	50	54	45	48	50	53
60	60	39	42	43	47	41	43	44	47
60	80	35	38	39	43	38	40	41	44
60	100	34	36	37	40	36	38	39	41
100	40	47	50	53	57	48	51	52	55
100	60	42	44	46	49	43	45	46	49
100	80	38	40	41	44	40	42	43	45
100	100	36	37	38	41	38	40	40	41

Ordering Information

Explanation of Catalog Number. Example: XP2GVA232120SOGLR

[ ] [2] [ ] [VA] [4] [32] [ ] [ ] [ ]

XP = Recessed Fluorescent with Flat Steel Lens Frame
XA = Recessed Fluorescent with Regressed Aluminum Lens Frame

Fixture Width

Ceiling Type:
G = Grid (lay-in) T-bar
F = Flanged (overlap) Z spline and plaster frame

Lens Shielding Type:
VA = Virgin Acrylic (standard) see options and consult factory

Lamp Quantity: (By others)
4 = 4-Lamp

Lamp Fixture Length:
32=T8, 4' Length

Voltage:
120 or 277

Ballast:

	<20THD	<10THD
2-2 Lamp Elec. (T8)	**SO***	**HI***
1-4 Lamp Elec. (T8)	**O4***	**H4***
LOL Dimming (T8)	**PS**	

*Instant Start Standard
Other dimming options. Consult factory.

Options:
Add appropriate suffix to catalog no, ie: (GLR)

Options/Accessories

Special Lens: Substitute VI for **.125"** nominal pattern. For other lenses, consult factory.
Access Plates: Top wiring access plate is shipped with fixture as standard. When access plates are required in advance for wiring convenience, specify separately. Order Catalog number: **ACPX CSP**.
Electrical Wiring Options: Consult factory.
Fusing: Internal fast-blow fusing. Suffix: **GLR**.
Internal slow-blow fusing. Suffix: **GMF**.
Radio Interference Filter: 120 or 277 volt, 50 or 60 Hz. One per fixture: Suffix: **R**. One per ballast: Suffix: **B**.
Drywall Kit: Order Catalog Number: **FK92x4** (Request Folio OA30-10).

Specifications

Performance: In an installation of 4 lamps 32 W luminaires in a room cavity of 1, with reflectance of 80% ceiling, 50% walls, 20% floor, the C.U. shall not be less than .87. To control veiling reflections, luminaire output in the 30°-90° zone shall be not less than 70%.
Materials: Chassis parts are die-formed code gauge cold rolled steel.
Housing is embossed for added strength and rigidity with all edges turned over for safe handling. **Lens frames**—(**XP**) flat full-size steel frame, (**XA**) regressed full-size aluminum frame.
Finish: Chassis exterior—white baked polyester enamel. **Cavity**—white baked polyester enamel minimum 86% reflectance. Phosphate undercoating.

Specifications (continued)

Lens: Extruded virgin acrylic 3/16" square based female cones, running 45° to the panel edge. .095" nominal thickness (similar to pattern 12).
Electrical: Thermally protected class "P" ballast C.B.M. approved, non PCB. If K.O. is within 3" of ballast, use wire suitable for at least 90°.
Labels: I.B.E.W./UL and ULc Listed.

Job Information	**Type:**

Lightolier a Genlyte Thomas Company www.lightolier.com
Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710
We reserve the right to change details of design, materials and finish.

LIGHTOLIER®

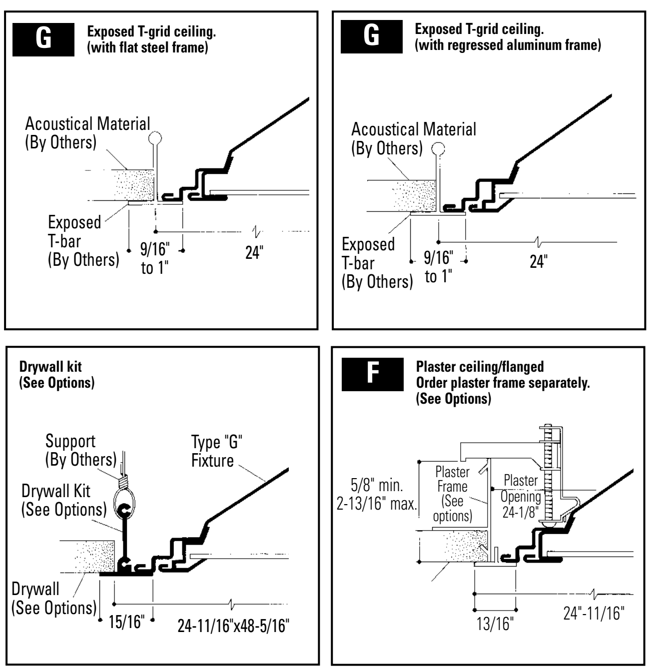
XP/XA 2' x 4' Lens Recessed Fluorescent XP/XA332

Static, Flat Steel or Regressed Aluminum Lens Frame, 3 Lamp, T8

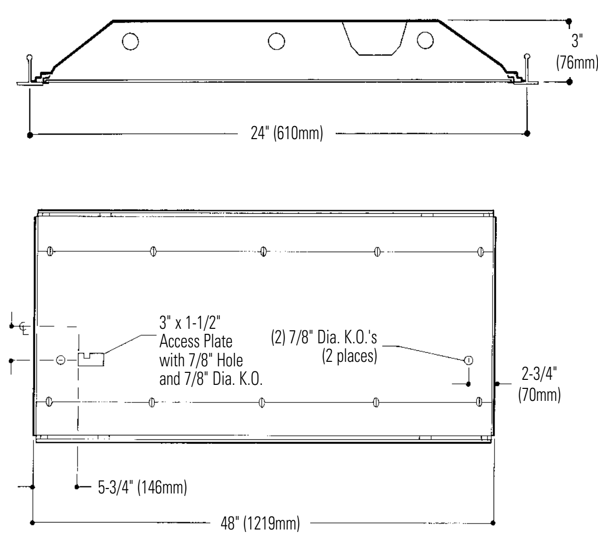
Features

- Efficiency 85.0%.
- Shallow 3" deep housing.
- Ribbed housing for strength and stability.
- Ends of housing formed inward for safe handling.
- Built-in earthquake clips.
- Hemmed-over side rails for safe handling.
- Ends have screw dimples for installation to T-bar (no fixture or ceiling distortion).
- Flat steel or regressed aluminum lens frame with mitered corners.
- Edges of steel door frame hemmed-over for safe handling.
- No light leak.
- Internal "T" hinges – easy installation and maintenance.
- Rooster head spring latches.
- Meets code 30 requirements in New England.

Mounting Methods



Dimensions



Job Information	**Type:**
Job Name:	
Cat. No.:	
Lamp(s):	
Volts/Ballast:	

Lightolier a Genlyte Thomas Company www.lightolier.com
Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710

Photometry

Model No. XP2GVA33212003

GTL TESTING LABORATORY

45 Industrial Way
Wilmington, MA 01887
(978) 657-7600

REPORT NO.: G22921 DATE: 7/2/02
CATALOG NO.: XP2GVA33212003
LAMP(S): 3 F32T8, EACH RATED 2850 LUMENS.
LUMINAIRE: 2X4 G TROFFER W/ VA LENS
ADVANCE REL-3P32-SC

CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
0	2708	2708	2708	2708	2708	
5	2709	2703	2703	2691	2694	257
15	2618	2623	2645	2666	2677	748
25	2402	2438	2518	2588	2616	1160
35	2078	2135	2269	2384	2429	1412
45	1630	1689	1818	1931	1985	1394
55	1093	1153	1263	1304	1339	1101
65	634	646	643	684	741	668
75	377	361	291	329	362	363
85	145	151	133	140	149	150
90	25	24	23	26	26	

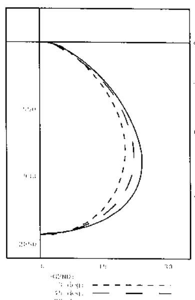
ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 30	2165	25.0	30.0
0- 40	3577	42.0	49.0
0- 60	6072	71.0	84.0
0- 90	7253	85.0	100.0
90-180	0	0.0	0.0
0-180	7253	85.0	100.0

TOTAL LUMINAIRE EFFICIENCY = 85.0%
CIE TYPE - DIRECT
PLANE : 0-DEG 90-DEG
SPACING CRITERIA : 1.2 1.4
SHIELDING ANGLES : 90 90
PLANE : 0-DEG 90-DEG
LUMINOUS LENGTH :46.000 21.000

LUMINANCE DATA IN CANDELA/SQ M

ANGLE IN DEG	AVERAGE 0-DEG	AVERAGE 45-DEG	AVERAGE 90-DEG
45	3697.	4124.	4503.
55	3057.	3532.	3744.
65	2406.	2440.	2812.
75	2336.	1803.	2243.
85	2669.	2448.	2742.



THIS REPORT IS BASED ON PUBLISHED INDUSTRY PROCEDURES • FIELD PERFORMANCE MAY VARY FROM LABORATORY PERFORMANCE.

LER = FL - 75.2 IW - 85 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $3.19

coefficients of utilization — zonal cavity method (effective floor cavity reflectance 0.20)

RF	20			20			20		
RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
room cavity ratio 1	93	89	85	83	81	78	80	78	76
2	85	78	73	74	69	66	71	67	64
3	78	69	63	65	60	56	63	59	55
4	71	62	54	58	53	48	56	51	47
5	66	55	48	53	46	42	51	46	41
6	61	50	43	48	41	37	46	41	36
7	56	45	38	43	37	33	42	37	32
8	53	41	34	40	34	29	39	33	29
9	49	38	31	37	31	26	35	30	26
10	46	35	28	34	28	24	33	28	24

visual comfort probability (rated lumens per lamp 2850.)

room size		luminaries lengthwise: ceiling height				luminaries crosswise: ceiling height			
W	L	8.5	10.0	13.0	16.0	8.5	10.0	13.0	16.0
20	20	60	65	73	81	59	63	69	78
20	30	52	57	63	71	53	56	60	67
20	40	48	52	58	63	50	52	56	60
20	60	44	48	52	58	46	49	52	56
30	20	62	66	72	79	61	65	69	76
30	30	53	58	62	68	54	57	60	65
30	40	48	52	56	61	50	53	55	58
30	60	44	47	50	55	46	49	50	54
30	80	42	45	46	51	44	46	48	51
40	20	64	68	72	78	63	66	70	76
40	30	55	59	63	67	56	59	61	65
40	40	49	53	56	60	51	54	56	58
40	60	45	48	50	54	46	49	51	53
40	80	42	45	46	50	44	46	48	50
40	100	41	43	44	47	43	45	46	48
60	30	56	60	64	68	57	60	62	66
60	40	50	54	57	60	52	55	56	59
60	60	45	48	50	54	47	50	51	54
60	80	42	45	46	49	44	46	47	50
60	100	41	43	43	46	43	44	45	48
100	40	54	57	59	63	54	57	59	62
100	60	48	51	52	56	49	52	53	56
100	80	45	47	47	51	46	48	49	52
100	100	43	44	44	47	44	46	46	48

Ordering Information

Explanation of Catalog Number. Example: XP2GVA33212003GLR

[ ]	2	[ ]	VA	3	32	[ ]	[ ]	[ ]
XP = Recessed Fluorescent with Flat Steel Lens Frame **XA** = Recessed Fluorescent with Regressed Aluminum Lens Frame	**Fixture Width**	**Ceiling Type:** **G** = Grid (lay-in) T-bar **F** = Flanged (overlap) Z spline and plaster frame	**Lens Shielding Type:** **VA** = Virgin Acrylic (standard) see options and consult factory	**Lamp Quantity:** (By others) **3** = 3-Lamp	**Lamp Fixture Length:** **32**=T8, 4' Length	**Voltage:** 120 or 277	**Ballast:** (see below)	**Options:** Add appropriate suffix to catalog no, ie: (GLR)

Ballast:

	<20THD	<10THD
1 & 2 Lamp Elec. (T8)	**SO***	**HI***
1-3 Lamp Elec. (T8)	**O3***	**H3***
LOL Dimming (T8)	**PS**	

*Instant Start Standard
Other dimming options. Consult factory.

Options/Accessories

Special Lens: Substitute VI for **.125"** nominal pattern. For other lenses, consult factory.

Access Plates: Top wiring access plate is shipped with fixture as standard. When access plates are required in advance for wiring convenience, specify separately. Order Catalog number: **ACPX CSP**.

Electrical Wiring Options: Consult factory.

Fusing: Internal fast-blow fusing. Suffix: **GLR**.
Internal slow-blow fusing. Suffix: **GMF**.

Radio Interference Filter: 120 or 277 volt, 50 or 60 Hz. One per fixture: Suffix: **R**. One per ballast: Suffix: **B**.

Drywall Kit: Order Catalog Number: **FK92x4** (Request Folio OA30-10).

Specifications

Performance: In an installation of 3 lamps 32 W luminaires in a room cavity of 1, with reflectance of 80% ceiling, 50% walls, 20% floor, the C.U. shall not be less than .89. To control veiling reflections, luminaire output in the 30°-90° zone shall be not less than 70%.

Materials: Chassis parts are die-formed code gauge cold rolled steel. **Housing** is embossed for added strength and rigidity with all edges turned over for safe handling. **Lens frames**—(**XP**) flat full-size steel frame, (**XA**) regressed full-size aluminum frame.

Finish: Chassis exterior—white baked polyester enamel. **Cavity**—white baked polyester enamel minimum 86% reflectance. Phosphate undercoating.

Specifications (continued)

Lens: Extruded virgin acrylic 3/16" square based female cones, running 45° to the panel edge. .095" nominal thickness (similar to pattern 12).

Electrical: Thermally protected class "P" ballast C.B.M. approved, non PCB. If K.O. is within 3" of ballast, use wire suitable for at least 90°.

Labels: I.B.E.W./UL and ULc Listed.

Job Information	**Type:**

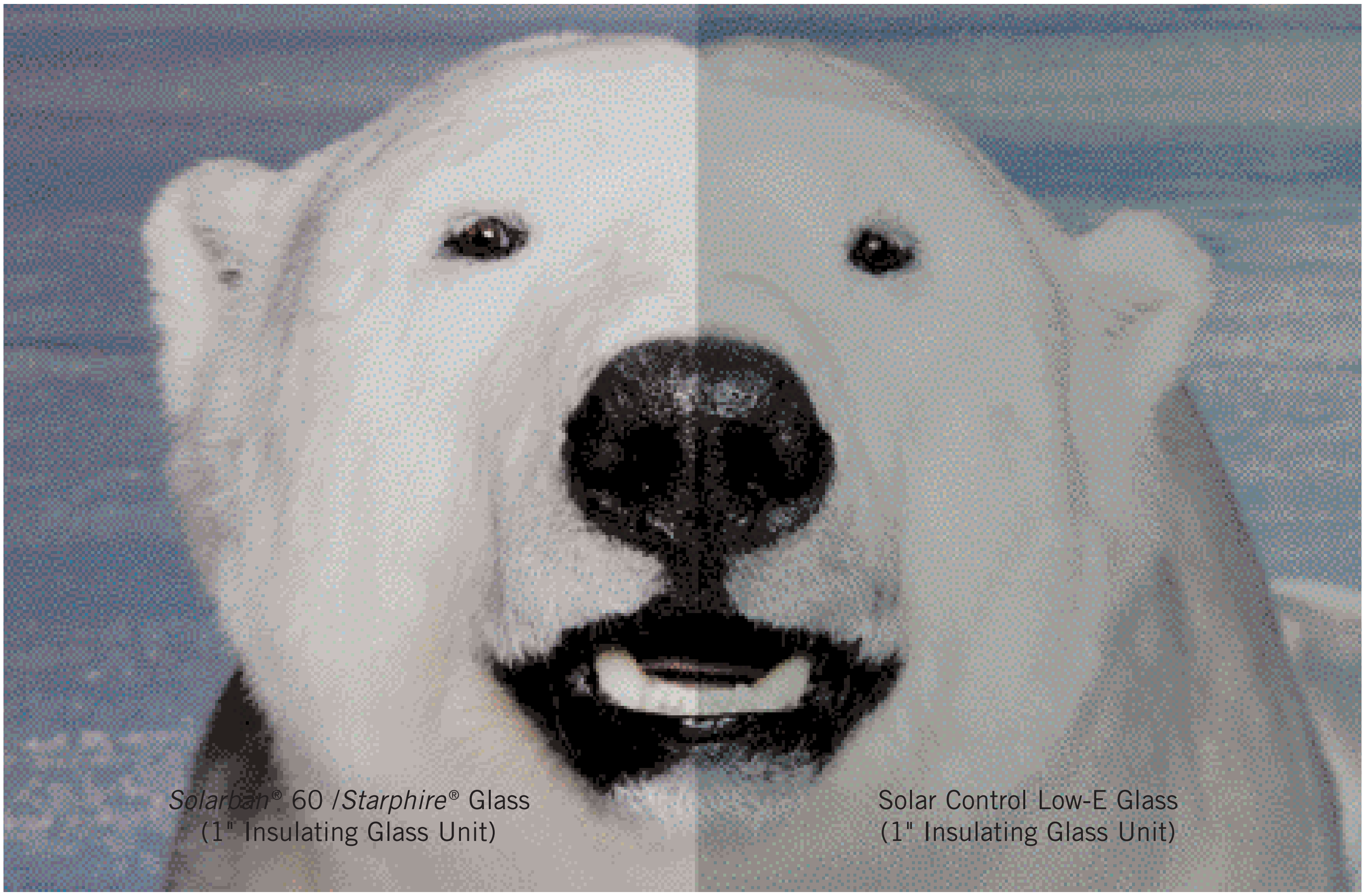
Lightolier a Genlyte Thomas Company www.lightolier.com
Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710

We reserve the right to change details of design, materials and finish.

LIGHTOLIER®

Solarban® 60 Coating on *Starphire*® Ultra-Clear Glass

Glass • Coatings • Paint



True Color Clarity and Solar Control in One Brilliant, Affordable Package

What happens when you combine two of the most popular architectural glass products? The answer is ***Solarban*** 60 ***Starphire***, a new standard product from PPG that offers the unequalled transparency of ***Starphire*** glass together with the proven solar control of the ***Solarban*** 60 Solar Control Low-E coating in one competitively priced package.

Superior Energy Performance

Solarban 60 ***Starphire*** glass allows ultra-clear glass to be used for vision glass, skylights, atriums, storefronts and entryways *without sacrificing energy performance*. This new product, used in an insulating glass unit, provides high visible light transmittance (73%) while offering superior solar control (0.41 SHGC).

Clearer than Clear

Used in a one-inch insulating glass unit with a ***Starphire*** glass inboard lite as well, ***Solarban*** 60 ***Starphire*** glass is visibly clearer and has a higher light transmittance than a conventional clear/clear Low-E coated insulating unit. ***Solarban*** 60 ***Starphire*** glass can also be used in laminated glass applications and is ideal for safety, security and noise-reducing glazings. The unique clarity of ***Solarban*** 60 ***Starphire*** glass, when laminated with multiple layers of ***Starphire Ultra-Clear*** glass, can dramatically reduce the greenish visual effect common with laminated clear glass.

SOLARBAN 60
SOLAR CONTROL LOW-E GLASS

Starphire®
Ultra-Clear Glass
By PPG

Solarban® 60 *Starphire*® Ultra-Clear Glass

Competitive Pricing

Thanks to recent manufacturing advances, ***Solarban*** 60 ***Starphire*** is affordable, too. PPG manufacturing cost advances have moved ***Starphire*** out of its niche as a premium-priced specialty product and made it price-competitive with other frequently specified architectural glasses. With its energy-saving characteristics and competitive pricing, ***Solarban*** 60 ***Starphire*** glass has become an affordable and practical choice for virtually any standard architectural glass application, from street-level storefronts to soaring office building facades.

Fabrication and Availability

Solarban 60 ***Starphire*** glass can be laminated, tempered or heat strengthened and is readily available as a standard product. Like other high-performance PPG architectural glasses, ***Solarban*** 60 ***Starphire*** is available through 28 locations of the PPG Certified Fabricator Network. PPG Certified Fabricators can meet tight construction deadlines and can accelerate the delivery of replacement glass during and after construction.

Additional Resources

Solarban 60 ***Starphire*** glass is just one of the *EcoLogical Building Solutions* from PPG. For more information, or to obtain samples of ***Solarban*** 60 ***Starphire*** glass, call 1-888-PPG-IDEA, or visit www.ppgglazing.com.

PPG *IdeaScapes*.™ Integrated products, people and services to inspire your design and color vision.

Solarban® 60 *Starphire*® Glass Performance Comparison with *Solarban*® 60 on Clear Glass

Insulating Vision Unit Performance Comparisons 1-inch (25mm) units with 1/2-inch (13mm) airspace and two 1/4-inch (6mm) lites; as shown below												
Glass Type	Transmittance			Reflectance		U-Value (Imperial)		K-Value (Metric)		Shading Coeffi-cient	Solar Heat Gain Coeffi-cient	Light to Solar Gain (LSG)
	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time	Winter Night-time	Summer Day-time			
***SOLARBAN*® 60 Solar Control Low-E Coating**												
SOLARBAN 60 (2) *STARPHIRE/STARPHIRE*	18	73	38	12	40	0.29	0.28	1.64	1.57	0.47	0.41	1.78
SOLARBAN 60 (2) Clear/Clear	19	70	33	11	30	0.29	0.28	1.65	1.55	0.44	0.38	1.84

Performance data simulated using LBL Window 5.2. For detailed information on the methodologies used to calculate the aesthetic and performance values in this table, please visit www.ppgglazing.com or request our Architectural Glass Catalog.

Solarban® 60 *Starphire*® Laminated Glass Performance

SOLARBAN® 60 (2) *STARPHIRE*® + interlayer + *STARPHIRE*® – thicknesses as shown below												
Configuration		Transmittance			Reflectance		U-Value (Imperial)		K-Value (Metric)		Shading Coeffi-cient	Solar Heat Gain Coeffi-cient	Light to Solar Gain (LSG)
Inches	mm	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time	Winter Night-time	Summer Day-time			
0.030 Lamination between 2-lites												
***SOLARBAN*® 60 (2) *STARPHIRE*®**												
1/8	3	0	76	39	9	42	1.00	0.90	5.67	5.12	0.51	0.44	1.72
0.060 Lamination between 2-lites												
***SOLARBAN*® 60 (2) *STARPHIRE*®**												
1/8	3	0	76	39	9	42	0.98	0.89	5.55	5.03	0.51	0.44	1.72
***SOLARBAN*® 60 (2) *STARPHIRE*®**												
1/4	6	0	76	38	9	41	0.95	0.86	5.41	4.90	0.51	0.44	1.72
0.090 Lamination between 2-lites												
***SOLARBAN*® 60 (2) *STARPHIRE*®**												
1/4	6	0	76	38	9	41	0.93	0.85	5.30	4.81	0.51	0.44	1.72

Performance data simulated using LBL Optics 5 and Window 5.2. For detailed information on the methodologies used to calculate the aesthetic and performance values in this table, please visit www.ppgglazing.com or request our Architectural Glass Catalog.

Printed in U.S.A.
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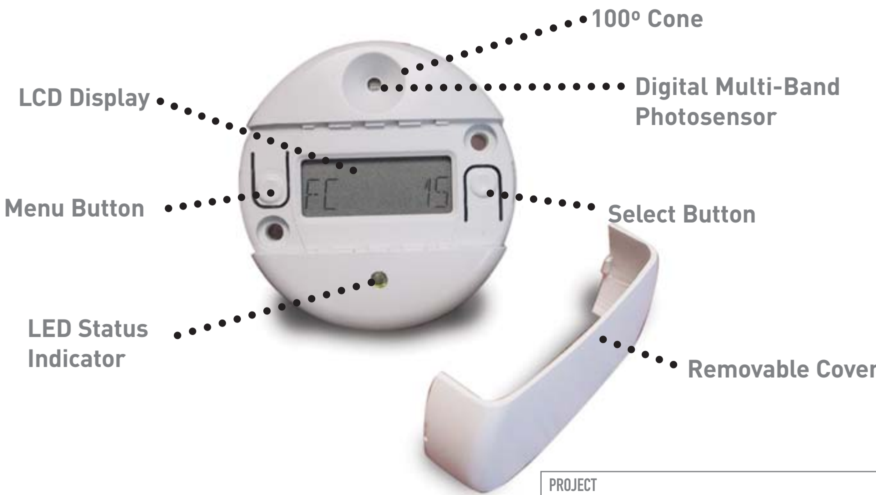
LightSaver® LS-101 Daylighting Controller



PROJECT

LOCATION/TYPE

Product Overview

Description

The LS-101 Daylighting Controller is a single zone, ON/OFF device which can be installed in an open or closed loop application to turns lights off automatically when sufficient natural daylight is present. It consists of an advanced digital multi-band photosensor that measures light similar to the way the human eye perceives it, an on-board microcontroller, and an LCD display. This photosensor is positioned behind a 100Þ cone that cuts off unwanted light, preventing false triggering.

Operation

The LS-101 is a self-contained 24 VDC device with an extended range of 1-1400 fc that only requires a low voltage power pack to operate. By adjusting the setpoints, it will turn lighting systems off when the ambient light levels exceed the OFF setpoint, and will turn lighting systems back on when natural light levels have fallen far enough to warrant it. Because of its factory presets, many set-up applications require little or no adjustment of the settings. The LS-101 is expandable with a low voltage wall switch to enable manual override or with a occupancy sensor to enable its 'Hold On While Occupied' feature.

On, Off & Deadband Settings

The LS-101 features adjustable settings for ON setpoint, OFF setpoint and time delay, should adjustment be required. Adjusting the ON setpoint will automatically calculate your OFF setpoint to a predetermined deadband setting. The deadband can be adjusted to a value of 25%, 50%, 75% or 100% above the ON setpoint. When the sensed light level drops below the ON setpoint for 20 seconds, the output signal will switch on. And when the sensed light level exceeds the OFF setpoint for the length of the time delay, the output signal will switch OFF. The time delay can be adjusted to 3, 10, 20 or 30 minutes.

Applications

The LS-101 Daylighting Controller can be used to control any type of lighting: incandescent, fluorescent, compact fluorescent (CFL) and HID . The sensors work in peripheral offices, skylit areas, cafeterias, warehouses and any other indoor areas with natural light access.

Features

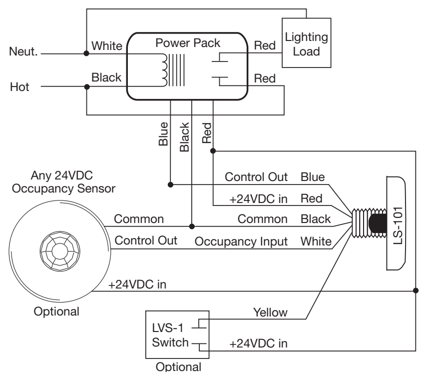
- Easy-to-read LCD Display prompts installer through set-up and accurately reflects the current control mode and light level.
- Four user-adjustable parameters: ON Setpoint, OFF Setpoint, OFF Setpoint Time Delay, and 'Hold On While Occupied' Mode (if wired with an occupancy sensor)
- Test Mode overrides the programmed Time Delay to allow installer to check if settings are correct.
- Control load status verification allows testing and confirmation that the wiring is correct by pressing the select button
- Manual Override for one hour (if wired with a low voltage, push-button wall switch)
- Meets Section 119's requirement for daylighting in California's Title 24 Lighting Code.
- LED status indicator identifies if the LS-101 is in Override or Test Mode, or if the device has switched the lights on or off.
- Two mounting options for either top-lit or side-lit applications
- Low voltage leads are color coded to match wire colors on the power pack.
- Shape and design developed to prevent mis-alignments.
- Can be programmed in most daylight conditions

Specifications

- Digital Multi-Band Photosensor Range: 1-1400 foot candles
- ON Setpoint Range: 1-850 foot candles
- Status Indicator: Multi-function green LED
- Power Requirements: 12/24 VDC; 7 mA typical
- Output Signal: 24VDC; maximum 120 mA
- Location: Suitable for dry interior locations
- Environment: 32 to 120ºF, less than 90% rh
- Dimensions: 2.4” diameter x 0.7” deep (61mm x 17mm)
- Five-year warranty
- UL listed

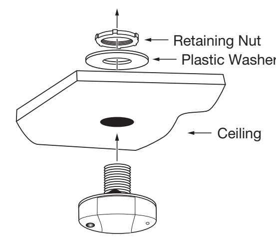
Wiring & Installation Location

Wiring Diagram

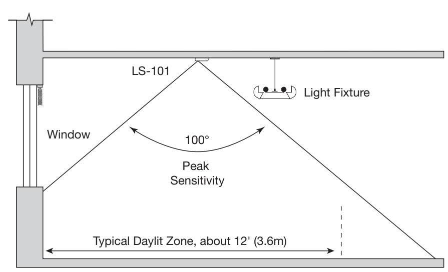


For other wiring diagrams, please visit the CAD Resource Center at www.wattstopper.com

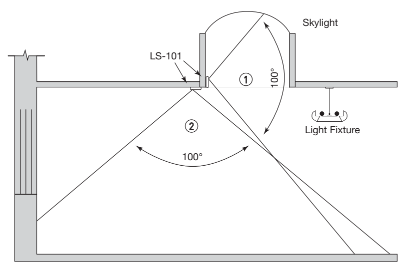
Mounting Installation



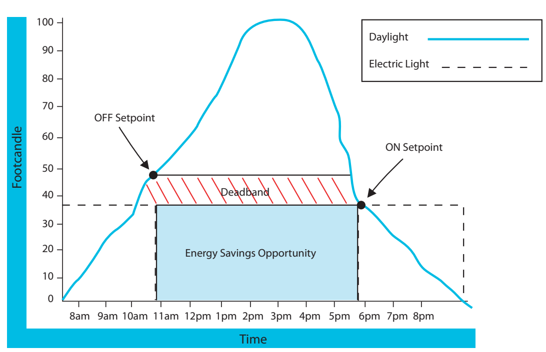
Side Lighting Application



Top Lighting Application



Deadband Level Chart

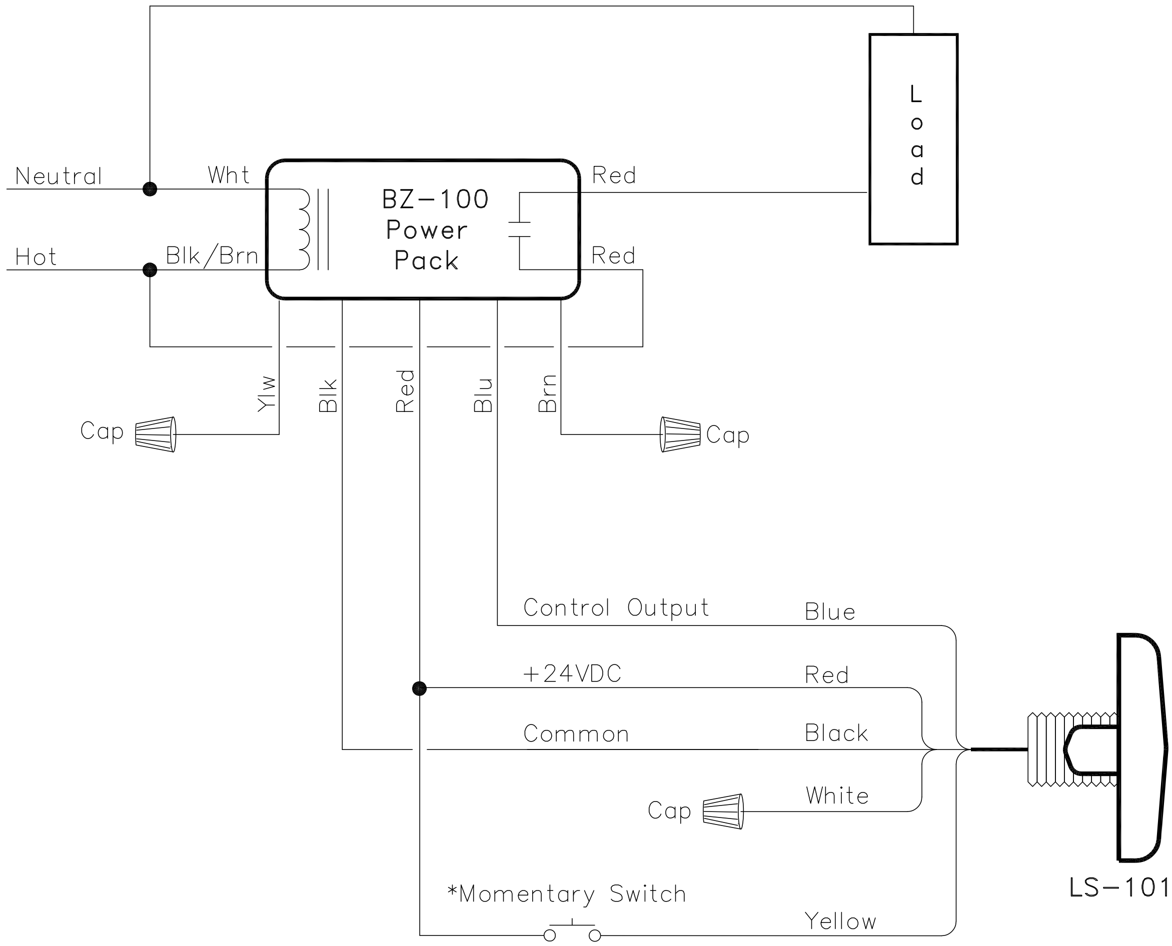


If the LS-101’s photosensor lighting level drops below the ON setpoint, the lights will remain on. If the sensor’s lighting level rises above the OFF setpoint, the LS-101 will automatically turn the lights off. If the sensor’s lighting level remains in the predetermined deadband range (25%, 50%, 75% or 100%) the lighting will be passive until the sensor’s level reaches the high or low setpoints.

Ordering Information

Catalog No.	Voltage	Current	Photosensor Range	Deadband Adjustment Range
☐ LS-101	12-24 VDC	7 mA Typical	1-1400 foot candles	25%, 50%, 75% & 100% above the ON setpoint

Pub. No. 24702



Note
See the product data sheet to determine the maximum number of Sensors per power pack.

Operation:
* Switch lets you turn Load Off for 1 Hour

LS-101 turns power pack ON/OFF based on light level. The momentary switch will override the LS-101 ON/OFF.

Watt Stopper/Legrand 800-879-8585			
Title: Typical LS-101 Wiring Diagram With one hour timed off override			
Scale: None	Drawing#: 58-004	Date: 12/10/07	Rev. 1

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