# Loyola Intercollegiate Athletic Complex
# Baltimore, MD

## Final Report

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Mr. Faust

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Construction Management

# RIDLEY ATHLETIC COMPLEX

BALTIMORE, MD

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## PROJECT TEAM

- Owner: Loyola College In Maryland
- Architect: Sasaki Associates
- Construction Manager: Whiting Turner
- Structural Engineer: Whitney-Bailey & Associates
- MEP/FP Engineer: Gipe Associates
- Geotechnical Engineer: Haley & Aldrich

## PROJECT INFORMATION

- Size: 41,520 Square Feet
- Date of Construction: December 2006-February 2009
- Cost: $53, 872, 347
- Project Delivery Method: Guaranteed Maximum Price (GMP)
- Stories: 4 stories (Includes Press Boxes and Presidential Suite)

## ARCHITECTURE

The stadium is composed of a four-story complex with upper and lower grandstands, which can hold up to 5, 966 people. The complex also contains a home game field and two practice fields. There are two main stairwells, one on the north end of the building and one in the middle of the building. The exterior is composed of stone veneer, glazed aluminum curtain wall systems, EIFFs, and concrete walls.

## MEP SYSTEMS

- Electric Distributed through building at 277/480 V
- (1) backup 400kW generator with 2 Automatic Transfer Switches, (1) 400 Amps and (1) 800 Amps
- (7) ERVs totaling 24,850 CFM
- (66) Water Source Heat Pumps Provide the Heat To The Building
- Linear fluorescent luminaries with direct distribution is utilized the most throughout the building

## STRUCTURAL

- Lower grandstands consist of 4000 psi cast-in-place concrete with a typical column being 18”x18”
- Upper grandstands are supported by the columns, spread footings, and concrete shear walls of the building.
- Columns range from W10x49 to W12x120
- 3 1/4” lightweight concrete slabs on 3”x 20 gauge composite metal decking

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## Executive Summary

The 41, 520 square foot project is located off Cold Spring Lane just north of Baltimore, MD and is owned by Loyola University in Maryland. It is a multi-venue facility providing field space for a diverse range of outdoor athletics including lacrosse, soccer, rugby, and track and field. The athletes will have a brand new stadium which will provide the training facilities to compete at the Division 1 level.

The following report contains an overview of the project including the buildings systems, construction schedule, estimated cost, and three analyses of the Loyola IAC that could have been implemented during construction or as an opportunity for improvement. These areas will be researched and analyzed in this report.

The first analysis looked making the Loyola IAC a LEED Certified building. A project checklist was created to demonstrate that this goal was indeed achievable. It was determined that the schedule was not drastically affected and the costs were difficult to determine because they vary from project to project and it depends on the design. With the current design, LEED would not be very costly.

The second analysis looked changing out the hand laid brick with a precast concrete wall system. This will allow for schedule acceleration but turns out being very costly. This change will also affect the structural and mechanical systems of the building. The structural system ended up needing to resize the exterior beam. The mechanical system was not drastically affected.

The last analysis will research Building Information Modeling (BIM) in hopes of understanding possible impacts it may have had on the Loyola Intercollegiate Athletic Complex (IAC). The use of BIM to improve the overall construction methods of projects throughout the world is becoming extremely popular. The growth of BIM in the market has established it as a critical issue of research for this study. Different software will be researched to determine which will benefit the project the best.

# 1.0 Introduction

The Loyola Intercollegiate Athletic Complex is the construction of a new, multi-venue facility that will be replacing the Diane Geppi-Aikens Field, which is currently located on campus. It is located off Cold Spring Lane just north of Baltimore, MD. The project is being built on a 71-acre site approximately two miles from campus.

The owner of the new Athletic Complex is Loyola University in Maryland. Their intent is to have a larger facility for the expanding University and to be able to compete with other Division 1 lacrosse programs. The facility will also provide field space for a diverse range of outdoor athletics including soccer, rugby, and track and field.

The overall size of the stadium is 41,520 square feet and features upper and lower grandstands, which can seat up to 6000 spectators. The stadium has supporting locker room spaces, athletic training/equipment spaces, athletic offices, and a press box with broadcast capabilities. It also consists of a home synthetic turf game field, a synthetic turf practice field, and a grass field with a track around it.

The architect for the Athletic Complex was Sasaki Associates. The project delivery was a Guaranteed Maximum Price (GMP) with the Construction Manager being Whiting-Turner Contracting Company. The project was completed February 26, 2010 and the total project cost was $53,872,347.

# 2.0 Project Team Overview

## 2.1 Client Information

The Loyola IAC is owned by Loyola University in Maryland. Loyola is a Catholic university based on high standards upon which St. Ignatius built the Jesuit. Loyola is building the IAC for three main reasons: to get nationally televised, be able to compete with other Division 1 lacrosse programs, and for a larger facility for the expanding university. The tight space that the Diane Geppi-Aikens field sits on makes it difficult for parking and seating for spectators. Also, the university is expanding and the old field cannot handle multiple sports without scheduling conflicts. The new Athletic Complex is allowing Loyola to have more parking and more than one sporting event going on at once. The new complex is also allowing for a better traffic flow in and out the complex. Loyola occupied the complex March 2010.

## 2.2 Project Delivery System and Contracts

As shown in Appendix A, there are three key players in the delivery of the project. Loyola University in Maryland is the owner of the building. Whiting-Turner (WT) acts as the CM at risk and holds a GMP contract with the owner. WT has lump sum contracts will all of its subcontractors. Sasaki is the architect on the project and was chosen based on their experience with athletic complexes and their past performance with Loyola. Sasaki holds cost + fee contracts with the MEP, structural, geotechnical, and the environmental engineers.

## 2.3 Project Team Organization

The organizational structure, as shown in Appendix B, establishes all the personnel that the CM has staffed on the project. All the staff personnel are onsite. The project manager, assistant project manager, superintendent, and one of the project engineers will see the project from start to finish. The other project staff will spend the time it takes their phase to be completed and then will go to another job.

# 3.0 Existing Conditions

## 3.1 Architectural Description

The Complex consists of an upper and lower grandstand and has four floors. The building has many different exterior systems. On the North side of the building there is CMU Veneer on stud backup along the lower grandstands and there is cement board stucco veneer on stud backup, which is also known as Exterior Insulation Finishing System (EIFS), on the outside of stair 2.

On the West side of the building there are four different exterior wall assemblies being utilized. The press box entry is EIFS. The first floor has CMU veneer on CMU backup and floors 2 and 3 have CMU veneer on stud backup. On the fourth floor, there is a mechanical screen, which is perforated metal.

The South side of the building, stair 3, has metallic finished cement board stucco on a stud backup as the exterior. The East side of the building has the aluminum upper and lower grandstands, colored metal panels on stud backup, and aluminum framed entrances and storefronts in the press boxes.

There are two different types of roof systems in the building. The main roofing system is a single ply membrane on metal deck. The roof slopes at a minimum ¼” per 12” toward the drain, which is located in the center of the roof system. Wide flange beams support the deck. The other roof system is similar but is a single ply membrane on concrete deck. This is used on the concourse level above the concessions and restrooms.

## 3.2 Zoning and Codes

**Zoning:**
Residential Planned Development per City of Baltimore Ordnance 02-348, Council Bill 01-0549
Underlying District: M-1-1, Light Industrial Zone

**Table 1 – Zoning Requirements**

| Zoning Requirements | |
|---|---|
| Residential Planned Development: | Required: |
| Minimum Lot Area | N/A |
| Minimum Front/ Rear Setback | 30’ |
| Minimum Side Yard | 10’ |
| Maximum Height of Buildings | 80’ |

| | |
|---|---|
| Maximum Floor Area Ratio | 1.0 |

**Applicable Codes:**

Building Code-2006 Baltimore City Building Code (2006 International Building Code with Amendments)

Plumbing Code- 2006 National Standard plumbing code/2007 supplement (NSPC)

Fire Code- All Applicable National Fire Protection Association Standards

Mechanical Code- International Mechanical Code (IMC), Latest Adopted Edition

### 3.3 Building Systems Summary

**Table 2 – Building Systems Summary**

| Work Scope Questions | Loyola IAC | |
|---|---|---|
| | Yes | No |
| Is Demolition Required? | | **X** |
| Is there a Structural Steel Frame? | **X** | |
| Is there Cast in Place Concrete? | **X** | |
| Is Precast Concrete used? | | **X** |
| Describe Mechanical System | **n/a** | **n/a** |
| Describe Electrical System | **n/a** | **n/a** |
| Is Masonry used? | **X** | |
| Is there a Curtain Wall? | **X** | |
| What supports the Excavation? | **n/a** | **n/a** |

### 3.4 Structural Steel Frame

The structural system is made up of wide flange columns, beams, and hollow steel sections. Columns and beams range from W8x48 to W18x175. The hollow steel sections are used for miscellaneous steel framing. For lateral support, 3 1/4" lightweight concrete slabs on 3"x20 gauge composite metal decking were used.

**Figure 1 - Crawler Cranes**

The structural steel was erected with two different cranes. A 90 ton crawler crane was used to erect the larger wide flange beams and the North end of the building. For the smaller beams and the South end of the building, a 70 ton crawler crane was used.

### 3.5 Cast in Place Concrete

All the concrete on the project will be cast in place concrete. 3000 psi reinforced concrete was used for all footings, grade beams, walls and piers. For the slab on grade and slab on metal deck, 3500 psi concrete with welded wire fabric was used. The lower grandstands consist of 4000 psi reinforced concrete. All concrete is placed by a concrete pump truck.

### 3.6 Mechanical System

The mechanical system being used at the IAC consists of (7) ERVs, (66) water source heat pumps, central heat pump system, and (1) cooling tower. The ERVs have a total output of 24, 850 CFM and provide the building with the proper circulation. There are 11 different types of water source heat pumps each having a different output, which ranges anywhere from 350 CFM to 2000 CFM. The heat pumps are the main source of heat for the building. The water source heat pumps get their heat from the central heat pump system, which has a system volume of 20,000 gallons and maintains a constant temperature at 90°. The cooling tower provides the cooling to the building and is 860 GPM.

### 3.7 Electrical System

The building runs on 480Y/277 delivering 3000 Amps, 3 phase, 4 wire electrical system and is connected to Baltimore Gas and Electric (BGE). A 400 kW diesel generator provides emergency power to certain parts of the system through two automatic transfer switches (A.T.S). One A.T.S. is 400 amps and the other is 800 amps. The luminaries throughout the main areas of the building are fluorescent luminaries. However, there are also different types of lighting throughout the building.

### 3.8 Masonry

There are three different types of masonry used to give the building its architectural features. Concourse level toilet rooms/ concessions and the two story building beneath the concourse are ground faced CMU. Limited areas of Butler stone veneer are used to accent the west entry. A cast masonry unit veneer known as “Renaissance Stone”, is used for the lobby tower and the north stair tower of the stadium.

### 3.9 Curtain Wall Systems

Figure 2 - Aluminum Storefront

Fenestration includes glazed aluminum curtain wall system, glazed aluminum storefront framing and entrance doors, and aluminum windows. Glazing generally is clear, 1” insulated, low-E type glass units. The stadium press box is a prefabricated metal panel system over stud backup and storefront glazing system with in-fill vertical sliding (single hung) windows on the field elevation.

### 3.10 Excavation Support

Figure 3 - VRSS-2

The mass excavation is permanently supported by five Vegetation Reinforcing Steep Slopes (VRSS). The heights range from 60 feet to 110 feet tall. The system features geo-membranes to reinforce the soil structures and fill materials plus erosion control blankets, seeding & sodding, landscaped vegetation and bioengineering.

### 3.11 Local Conditions

The project is located just outside of Baltimore, MD. The large site allows for many freedoms when it comes to contractor parking, available lay-down areas, dumpster space, and other storage spaces. The subsurface explorations conducted at the site revealed natural soils weathered from bedrock, uncontrolled soil/ rock fill, and MSW landfill. The subsurface explorations identified several ground water conditions. Ground water levels were close to the bedrock surface and perched ground water was encountered in the landfill areas.

### 3.12 Site Plan of Existing Conditions

*Please see Appendix C for Existing Conditions Site Plan*

### 3.13 Site Location

The location for the Intercollegiate Athletic Complex is just outside of Baltimore, Maryland. The site is 72 acres in size and is very open which will allow for adequate lay down area, storage, parking, and other things that a small site cannot take advantage of. The following figures, Figure 4 and Figure 5, show aerial photographs of the existing site.

**Figure 4 - Existing Site**

**Figure 5 - Site/ Adjacent Bldg. Outlines**

### 3.14 Adjacent Structures

The project is next to the Kennedy Krieger Institute (indicated in teal in Figure 5) and the Emerald Estates Retirement Community (indicated in red in Figure 5). Also, the entrance of the site is the baltimore City police station, which is outlined in blue in figure two. Emerald Estates Retirement Community is approximately 50 feet tall. The Kennedy Kriger Institute stands approximately 40 feet tall. The police station is approximately 25 feet in elevation.

### 3.15 Temporary Utilities

The site had no existing utilities so everything had to be brought on site. The electricity came from Emerald Estates Retirement Community. The telephone and data lines were tapped into the same service Emerald Estates and Kennedy Kreiger used.

### 3.16 Site Logistics Plan

The site logistic plan created, as shown in Appendix D, are a combination of a final site layout and a site logistics plan. This is useful to show the relationship of each item relative to the final landscaping and site plan.

### 3.17 Common Items

Since the site is a large site, the temporary facilities, storage areas, and traffic patterns do not need to be moved throughout the duration of construction. Items that are common to all logistics plans are: Temporary offices, site fencing, parking, dumpsters, storage are, fire hydrant, entries, and temporary power.

### 3.18 Phase 3 Logistics Plan

During phase 3, steel was erected using two cranes. One crane was on the East side of the building and one was on the West side of the building as shown on the logistics plan. The larger of the two cranes was on the West side of the building because of the heights and lengths that the crane had to reach. The smaller of the two cranes was on the East side of the building because it could reach the lower beams and the steel for the upper grandstands. The utilization of the truck cranes allows for access to all parts of the erection sequence.

# 4.0 Detailed Project Schedule, Sequencing, and Budget Information

## 4.1 Project Schedule Overview

The Loyola Intercollegiate Athletic Complex detailed project schedule, refer to Appendix E, is a detailed schedule that breaks the 3 phases of the project down into several different sequences. These sequences cover the critical construction process of each phase, which in turn makes the construction of the project go smoothly. Some of the main sequences are outlined below and other sequences can be found in more detail in Technical Assignment 1.

## 4.2 Building/ Lower Grandstand Foundations Schedule Impacts

Figure 6 - Foundation Sequence

The construction crews started with the building foundations first and then began pouring the foundation for the lower grandstands. The sequencing for the building and the lower grandstands starts on the North side of the building and works its way to the south end, as shown in figure 6.

## 4.3 Steel Sequencing

Figure 7 - Steel Sequence

The steel sequencing consisted of the six sequences. The sequences were based on the floor level and north end or south end of the building. All steel started in the north end of the building and worked its way to the south end. The amount of space allowed the project team to use a 70 and 90 ton crane.

### 4.4 Enclosure

Figure 8 - Enclosure

Again, during this stage the enclosure begin on the North end and worked its way to the south end. First, the metal stud backup was installed. After the metal backup was installed, the sheathing, air barrier, and cement board was put into place. Then the stucco finish was applied or the ground faced CMU was laid. Next, the installation of the glass/ glazing will occur. The installation of the roofing was the last step of the enclosure process but was being installed the same time as the facade. Standard scaffolding was utilized to install the building facade, as shown in figure 8.

### 4.5 Schedule Assumptions

The schedule includes all sequences for each phase but not all of the tasks. Therefore, I just stated which sequence it was similar to in the schedule. Activity durations were carefully determined; however, with limited experience in developing schedules, some durations were educated, knowledge based assumptions from the information provided by the project team. Also, being bound by activity limits, many activities were combined and may distort the actual duration of each detailed line item.

## 4.6 Project Cost Evaluation

### 4.6.1 Cost Summary

Table 3 – Project Costs

| Loyola IAC: Costs | | | |
|---|---|---|---|
| | **Cost** | **Total SF** | **Cost/SF** |
| **Construction Cost** | $20,237,252 | 41,520 | $487.41 |
| **Building Cost** | $28,189,112 | 41,520 | $678.93 |
| **Total Project Cost** | $53,872,347 | 41,520 | $1297.50 |

*Construction Cost excludes site work and permits.

*Building Cost includes site work and permits.

### 4.6.2 Building Systems Cost

Table 4 – Building Systems Cost

| Loyola IAC: Building System Costs | | | |
|---|---|---|---|
| **Building System** | **Cost** | **Total SF** | **Cost/SF** |
| Structural | $6,005,389 | 41,520 | $144.64 |
| HVAC/ Plumbing | $3,602,794 | 41,520 | $86.77 |
| Fire Protection | $207,750 | 41,520 | $5.00 |
| Electrical | $1,522,280 | 41,520 | $36.66 |
| Conveying System | $137,300 | 41,520 | $3.31 |
| Fixed Grandstands | $1,110,165 | 41,520 | $26.74 |
| Gas Collection System | $900,074 | 41,520 | $21.68 |

### 4.6.3 D4 Cost Estimate

**Table 5 – D4 Cost Estimate**

| **Historical Data Projects** | | | |
|---|---|---|---|
| **Project Name** | **Size(SF)** | **# of Floors** | **Cost** |
| YMCA Recreational Center | 83,377 | 4 | $13,495,528 |
| Kemper Arena | 75,750 | 3 | $15,937,000 |

The complete summary of the D4 cost estimate can be found in Appendix F. These projects were selected based on the number of floors and occupant use. The D4 cost estimate ran closer to the construction cost and was 39.1% lower than the total project costs, which was $21,085,271 or $507.83/SF.

### 4.6.4 RS Means

The complete summary of the RS means square foot estimate can be found in Appendix G. In RS means, there was no athletic complex or stadium for building type. So I chose a gymnasium to closely mimic the seating arrangements and the building type. Since RS means did not have face brick with metal stud back-up I assumed it to be face brick with concrete block back-up.

### 4.6.5 Cost Comparison

**Table 6 – Cost Comparison**

| **Cost Comparison** | |
|---|---|
| Method | Total Construction Costs |
| D4 Cost Software | $21,085,271 |
| RS Means Data | $22,699,500 |
| Actual Costs | $28,189,112 |

An analysis of all three costs shows D4 Cost estimate and RS means to be lower than the actual building costs.

There are several factors that I believe contributed to the differences among the estimates:

- The split between steel and cast in place concrete. Cast in place concrete took a lot of extra time.
- D4 cost estimate and RS means did not have an exact match for the building type. These estimates did not account for the stadium seating or the building type.
- The amount of site work that had to be done was not taken into account.

### 4.6.6 General Conditions Estimate

The general conditions estimate, refer to Appendix H, provides costs for the general items covered by the construction manager for the project. In order to estimate the General Conditions cost for the IAC, a standard GCs items list was used to comprehend what type of items are typically included in this cost. RS Means was then used to determine the unit, duration and unit cost of each line item. This estimate is for Phase 1 & 2 of the project only. The general conditions for Phase 3 of the project are 7% of the total cost for phase 3, which comes out to be $2,236,989.

**Table 7 – General Conditions**

| **General Conditions Estimate Summary** | |
|---|---|
| Description | Total Costs |
| Project Staffing | $1,257,036 |
| Temporary Utilities | $83,325 |
| Field Office, Equipment, & Expenses | $120,900 |
| **Total General Conditions Estimate** | **$1,701,741** |

As Table 7 and Appendix H show, the majority of the estimate is made up of the project staffing costs.

# 5.0 LEED Analysis

## 5.1 Problem Statement

The Loyola Intercollegiate Athletic Complex is not seeking any LEED rating from the United States Green Build Council (USGBC). Currently, there are multiple areas that would award LEED points based on the LEED Version 3.0 Rating System. Not only are there areas that are already LEED, but also this project has the potential to achieve multiple points in other areas with little or no effort.

## 5.2 Goal

Demonstrate that LEED could have been achieved on this project and the costs are minimal to achieve LEED.

I will also do the following to achieve the above goal:

- calculate the upfront costs of setting up the LEED program onsite
- the manpower it will take to set up the program
- if this will have an impact on the schedule
- analyze the possible current credits available that accommodate LEED points

## 5.3 Methodology

The LEED analysis was handled in a three step process the first was to retrieve the information from the industry professionals. Information was attained through email interviews and face-to-face interviews. Emails were sent to the director of facilities and director of operations from Loyola University in Maryland. I conducted face-to-face interviews with construction managers from Whiting-Turner and Rafael Vinoly Architects (RVA). The common questions that I asked are on the following pages. The next step was to analyze the Intercollegiate Athletic Complex myself to find current and potential LEED points. The last step was to compile the data that I had received from the interviews and make the LEED worksheet that demonstrates LEED could have been achieved.

## 5.4 Interview Questions

### 5.4.1 Owner

1. Does Loyola have a perceived value to make the upcoming buildings LEED?
2. Does Loyola have a master plan for the construction on campus?

3. If so, does the master plan contain any information regarding LEED and could you send me the master plan?
4. Has Loyola looked into the costs of incorporating LEED and if so did they come up with a ballpark number?
5. Has Loyola constructed LEED projects on campus before? If so, how did the project run and were there any problems in the construction process?
6. What are your thoughts of constructing LEED buildings on campus?

### 5.4.2 Construction Manager (Millennium Science Complex (MSC) and Loyola IAC)

7. How much manpower does it take to setup the LEED program and also to manage it on a day to day basis?
8. Will LEED affect the schedule?
9. What are possible LEED credits to research for a lacrosse stadium?
10. Do you believe there is a perceived value for attaining LEED for projects? If so, explain.
11. How many LEED projects have you worked on before and what was your role in the LEED process there?
12. Which area was the hardest to attain points in for LEED certification? What made this section more difficult to attain points?
13. What were the easiest points to attain points and why?

### 5.4.3 RVA (Architect on MSC)

14. What role do you play in the LEED process?
15. If costs are associated, what are the costs of LEED for the Architect?
16. Does LEED affect any of the steps in the construction process? If so, what steps does LEED affect?
17. How many LEED projects have you worked on before and what was your role in the LEED process there?
18. Which area was the hardest to attain points in for LEED certification? What made this section more difficult to attain points?
19. What were the easiest points to attain points and why?
20. Does LEED require more manpower on a project?

## 5.5 Interview Results

### 5.5.1 Owner

The director of facilities, Les Pely, at Loyola said “they have thought about LEED buildings but have not looked too deeply because of the costs involved.” Les also mentioned that Baltimore City has enacted LEED as part of their building requirements and Loyola where therefore include it in future construction. He thinks LEED is a good for the environment and will help clear up some of the pollution in the Baltimore area.

Helen Schneider, which is the Associate Vice President at Loyola, said "the cost of certification for LEED is too expensive so therefore Loyola has not pursued LEED." She said that Loyola has multiple green buildings that could probably certify the most recent construction projects but just have not pursued the certification. Loyola has a master plan for construction on campus and will follow the city's requirement. With the minimum being LEED silver, Helen stated "I'm sure we will consider higher levels of certification."

### 5.5.2 Project Manager

On the Millennium Science Complex (MSC), Whiting-Turner uses a Project Manager and one intern to setup and manage the LEED information for the whole project. I interviewed Chris Dolan from Whiting-Turner. In the construction manager's questionnaire, the question was asked if LEED would affect the schedule at all. The answer was that LEED can affect the schedule if the material specified has a long lead time and is not readily available. To prevent this, the suggestion from Chris was too "prepare and procure all of LEED items ahead of time. When asked about the perceived value of attaining LEED, Chris responded, "There is a perceived value and that is that the facility is more environmentally friendly and energy efficient."

### 5.5.3 Superintendent

The following results are based off the interview with Jason Frith, a superintendent, LEED AP for Whiting Turner in Baltimore. He is on his first LEED project currently. For his particular project, they have a 3rd party LEED consultant and the Architect handling most of the submission requirements to United States Green Building Council (USGBC). On a day-to-day basis, it requires extra time from the project engineer to review and obtain the additional LEED attachments for submittals that must be reviewed before submitting. Also, on the superintendent's side, waste has to be tracked for extra credits. Some larger projects may dedicate a Project Engineer to track LEED. He stated, "I believe they might be having a Project Engineer track LEED for the Towson Phase II dorms." LEED affects the schedule, but not drastically. Additional time has to be allocated in the schedule for the commissioning requirements for LEED at the tail end of the schedule. Jason said, "Most of the LEED requirements are achieved through design, not construction." From the superintendents perspective, certain credits that pertain to the building systems (i.e. electrical, HVAC, and MEP) are more difficult to achieve. He gave an example of the Towson Dorms Phase II project. They are using a four pipe split system for HVAC vs. a PTAC (through wall air conditioning units like in a hotel). This caused the cost of Div 15 to almost double the cost of the dorms HVAC budget. This change was implemented to get credits in efficiency and controllability of the system. Jason said, "the trade off is that it is supposed to reduce operating cost to the owner because it will be more efficient." Lastly, the easiest credits, in his opinion, to achieve are waste diversion, using recycled content for materials like drywall, concrete, steel, metal studs and low emitting materials.

### 5.5.4 RVA

The architect plays a vital role in the LEED process. RVA handles all the design LEED credits, which is where most of the LEED points come from. The costs for the architect are similar to that of the construction manager, where with LEED comes extra paperwork. The extra paperwork causes more time and maybe even more architects. The extra LEED attachments to each submittal cause more time to be consumed reviewing submittals. More costs can also be associated with certain materials. For example, Gypsum Wall board can be bought at any builder supply center, but if you need a certain high recycle content, you may have to place an order ahead of time, which could be more expensive. Some of the hardest points to attain come with the electrical, HVAC, and MEP systems of the building. There is more commissioning involved, which makes it a lot harder to coordinate with testing agents and to meet the required results. The easiest points for the MSC to achieve will be the 5 points for development density and community connectivity and the 6 points for Alternative Transportation- Public Transportation Access. From an architect's standpoint, LEED requires more manpower due to the amount of paperwork involved and the design of LEED materials and systems.

## 5.6 Solution

Loyola IAC chose not to strive for LEED certification of any type, with the research done for this analysis the goal was to determine the LEED points that were feasible for the lacrosse stadium and the cost and schedule impacts it would have on the project. After receiving feedback from the surveys, interviews, and the information obtained through research of the United States Green Building Councils (USGBC) website, a spreadsheet was made to show more simply the areas that would be relatively easy for Loyola to attain along with those that may be possible to attain with a little more effort. A filled out sample for the Loyola IAC of the "Registered Project Checklist" from the USGBC website is shown in Appendix I. This table is simply a summary of the findings of my research applied to Loyola IAC, this chart in no way reflects that Loyola IAC would be guaranteed the points marked as yes.

As the LEED checklist indicates, LEED certification should be possible and maybe even LEED silver could be achieved, which would meet Baltimore City's requirement. All of this would depend upon the level of commitment by all parties. With the potential of achieving each point being determined by the responses of industry professionals, some of the maybes were placed as such because the professionals responded that a significant cost was associated with the point or were unsure. The Loyola IAC could have become a LEED certified project but the building was constructed utilizing traditional construction techniques.

### 5.7 Conclusion/ Recommendations

After analyzing all the data that has been attained, I would suggest that Loyola Intercollegiate Athletic Complex become a LEED certified building. As shown on the Project Checklist, points can easily be attained in Development Density and Community Connectivity, Alternative Transportation – Public Transportation Access, and in water efficiency. Right there alone, is almost half of the points needed to obtain LEED certification. As stated by Jason Frith, the schedule is not drastically affected and costs vary from project to project and depending on the Architect/ Engineers design. Finally, this analysis shows the potential that the Loyola IAC had to become LEED Certified and possible even LEED Silver.

# 6.0 Precast Concrete Wall System Implementation

## 6.1 Problem Statement

The hand laid brick takes a considerable amount of time to construct, takes up room with the scaffolding, and leaves room for error between trades. Currently, the exterior façade that is hand laid brick is mainly located on the first two floors of the stadium and the stair towers. The exterior studs, insulation, and sheathing are completed by a separate contractor and as separate activities that includes more time, labor, and coordination.

## 6.2 Goal

The goal of this research is to shorten the schedule and look into the costs of the precast, determine if the structural system can handle the loads of the precast, and analyze the mechanical properties of the precast to determine if the MEP equipment can be resized to cut costs.

## 6.3 Methodology

The precast analysis was broken down into three distinct phases. The first was the research phase for the type of system that I wanted to use. Also during this phase, I got the Tekla model from Hope Furrer, which provided me with the original design loads and the mechanical properties for the current wall system from Gipe Associates. The second phase consisted of comparing the current wall system to the new system and to determine how effective, from a cost and schedule standpoint, the precast system is from the hand laid brick system. The last phase consisted of my two breadths. For the structural breadth, I did hand calculations to determine if the original design could withstand the added loads. For the mechanical breadth, the new R and U values were calculated and compared against the hand laid brick.

## 6.4 System Selection Criteria

Loyola IAC is a lacrosse stadium with almost 28,000 square feet of split face masonry. Therefore, it is extremely important to match the brick façade on the existing structure. Cost and weight of the system, erection time, and lead time are also important. The High Concrete precast concrete wall system was investigated and compared against the existing façade.

Figure 9 – Old Wall System

Figure 10 – Prefabricated Wall System Color

Table 9 - Concrete Precast vs. Brick

| Criteria | Concrete Precast | Brick |
|---|---|---|
| Ability to match existing façade? | As shown in figure 2, a variety of brick finishes can be matched through the use of Thin brick inlays to the system. | Existed brick is hand laid split face brick, so matching the existing color is easy. |
| Cost of system? | $45.64/SF, which includes material, crane costs, and installation costs. | $17.22, which includes split face CMU and labor. |
| Weight of System? | 70 lbs/ SF | 40 lbs/ SF |
| Erection Time? | 21 days | 49 days |
| Lead Time? | 30 days | 45 days |

## 6.5 Wall System Constructability

The following pictures were taken by Chris Dolan from Whiting-Turner and show the process of how the precast wall system is put together after you choose the type and color of the split face CMU.

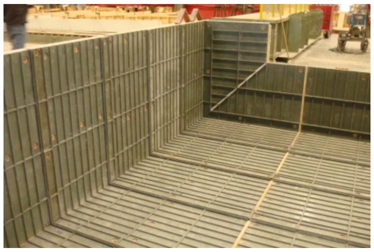


Figure 11 – Precast Mold

The first step of the process is too set up the mold for the split face to be placed in.

Figure 12 – Split Face Being Placed

The next step is to insert the split face CMU into the mold.

Figure 13 – Rebar

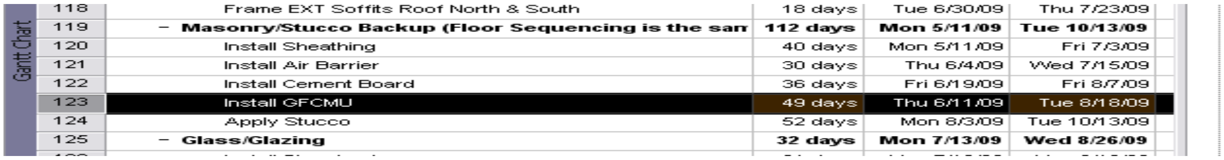
The rebar is placed after the split face CMU is inserted into the mold.

Figure 14 – Insulation Being Installed in the Mold

The last step is to pour the concrete into the mold, place the insulation, and let the concrete cure.

### 6.6 Schedule Analysis

One factor for selecting the precast system was its speed for erection. The current hand laid brick façade lies on the critical path and takes 49 days to construct. Below in figure 15 and 16, there is an excerpt from the CPM schedule showing the current duration of the masonry and the substantial completion of the project.



| | | | | |
|---|---|---|---|---|
| 118 | Frame EXT Soffits Roof North & South | 18 days | Tue 6/30/09 | Thu 7/23/09 |
| 119 | **– Masonry/Stucco Backup (Floor Sequencing is the san** | **112 days** | **Mon 5/11/09** | **Tue 10/13/09** |
| 120 | Install Sheathing | 40 days | Mon 5/11/09 | Fri 7/3/09 |
| 121 | Install Air Barrier | 30 days | Thu 6/4/09 | Wed 7/15/09 |
| 122 | Install Cement Board | 36 days | Fri 6/19/09 | Fri 8/7/09 |
| 123 | Install GFCMU | 49 days | Thu 6/11/09 | Tue 8/18/09 |
| 124 | Apply Stucco | 52 days | Mon 8/3/09 | Tue 10/13/09 |
| 125 | **– Glass/Glazing** | **32 days** | **Mon 7/13/09** | **Wed 8/26/09** |

Figure 15 – SFCMU Duration

| | | | | | |
|---|---|---|---|---|---|
| 172 | Sitework & EXT Work | 5 days | Thu 11/5/09 | Wed 11/11/09 | |
| 173 | Final Inspections | 10 days | Tue 12/8/09 | Mon 12/21/09 | |
| 174 | Final Commissioning | 10 days | Tue 12/8/09 | Mon 12/21/09 | |
| 175 | Substantial Completion | 0 days | Tue 12/22/09 | Tue 12/22/09 | 1 |
| 176 | Final Building Clean | 8 days | Thu 12/24/09 | Mon 1/4/10 | |
| 177 | Final Punchlist | 20 days | Thu 12/24/09 | Wed 1/20/10 | |
| 178 | Owner Training | 5 days | Tue 1/5/10 | Mon 1/11/10 | |
| 179 | Occupancy | 0 days | Tue 3/2/10 | Tue 3/2/10 | |

Figure 16 – Original Substantial Completion Date

Shortening the duration of the critical path activities will generally shorten the overall duration of the project, as long as other activities do not get pushed into the critical path. Shown above in table 9, shows a side by side comparison of the durations it would take to complete the façade construction. Changing the hand laid brick to precast can shorten the building envelope construction by almost 43% of the original duration.

The duration of the precast system is based off the Millennium Science Complex project. It was calculated that 1316 square feet/ day could be erected on average, see Appendix J. Using the gross building envelope area of 27, 713 SF, calculated from the hand takeoff shown in Appendix J, it will take 28 days to erect the prefabricated wall system.

| | | | | | |
|---|---|---|---|---|---|
| 171 | − Phase 3-Final Completion | 63 days | Thu 11/5/09 | Tue 2/2/10 | |
| 172 | Sitework & EXT Work | 5 days | Thu 11/5/09 | Wed 11/11/09 | |
| 173 | Final Inspections | 10 days | Tue 12/8/09 | Mon 12/21/09 | |
| 174 | Final Commissioning | 10 days | Mon 11/9/09 | Fri 11/20/09 | |
| 175 | Substantial Completion | 0 days | Mon 11/23/09 | Mon 11/23/09 | 1 |
| 176 | Final Building Clean | 8 days | Tue 11/24/09 | Thu 12/3/09 | |
| 177 | Final Punchlist | 20 days | Fri 12/4/09 | Thu 12/31/09 | 1 |
| 178 | Owner Training | 5 days | Mon 1/4/10 | Fri 1/8/10 | |
| 179 | Occupancy | 0 days | Tue 2/2/10 | Tue 2/2/10 | |

**Figure 17 – New Substantial Completion Date**

Comparing Figure 16 to Figure 17 illustrates how much time can be saved. The completion date for the project moves from December 22, 2009 to November 23, 2009. This is a 4 week savings on the entire project. This allows the owner to occupy and begin using the state of the art facility a month early.

### 6.7 Cost Analysis

Changing out the façade system affects not only the schedule but the financial aspect as well. The overall cost of the prefabricated system was analyzed along with the savings of the system. The initial costs of the system are compared against the original cost of the masonry façade in the table below, Table 2. The cost of the precast system is based off the Millennium Science Complex and costs received from High Concrete, see Appendix J.

**Table 10 - Cost Comparison**

| System Type | Cost/SF | Total Cost |
|---|---|---|
| Prefabricated System | $45.64 | $1,264,821 |
| Hand Laid Brick | $17.22 (From Contract) | $477,250 |
| $ Difference | | $787,571 |
| % Difference of Building Facade | | 165.7 % |
| % Difference of Total Project Cost | | 1.4 % |

The cost of the prefabricated system is more expensive to produce and install when compared to hand laid brick. The dollar value per SF used above was an average between the MSC and the dollar amount that High Concrete provided. A 165.7 % increase in the cost of a façade system is a large increase, but this is only a 1.4 % increase in the total project cost. The costs above do not look into the savings in the general conditions and the metal studs. Table 11 below outlines the savings from general conditions and the credit for the metal studs.

**Table 11 - General Conditions & Metal Studs**

| **General Conditions/ Metal Stud Credit** | |
|---|---|
| General Conditions per Month | $58, 912 |
| Total Months Saved | 1 |
| Metal Studs Credit (from contract) | $40, 765 |
| Total Saved | $99,677 |

All the costs and savings must be considered to determine the final impact of switching to the prefabricated façade. Table 12 below looks at all the costs and savings associated with the new prefabricated façade system that has been outlined above.

**Table 12 - Summary**

| **Summary** | |
|---|---|
| Total Added Cost of system | $787,571 |
| Total of Credits and General Conditions | $99, 677 |
| Total Cost | $687,894 |
| Total % Difference of Building Facade | 144 % |
| Total % Difference of Total Project Cost | 1.27 % |

## 6.8 Structural Breadth

### 6.8.1 Introduction

With the loads of the precast system resting on the existing structural system, it has the potential to greatly affect the structural system. If the existing structure cannot hold the precast, the structural system will have to be redesigned, which will result in added cost to the project costs. Hand calculations will be used to determine if the current structure will support the new façade.

### 6.8.2 Connection Details

First, in order to determine how the load will affect the structure, it must be determined how the gravity load will be transferred to the superstructure. This is done by a means of a bearing stud or connection that project from the back of the panel, which bears directly on the supporting structure. See figure 18 for an example of the typical connection used with the precast concrete system provided by High Concrete.

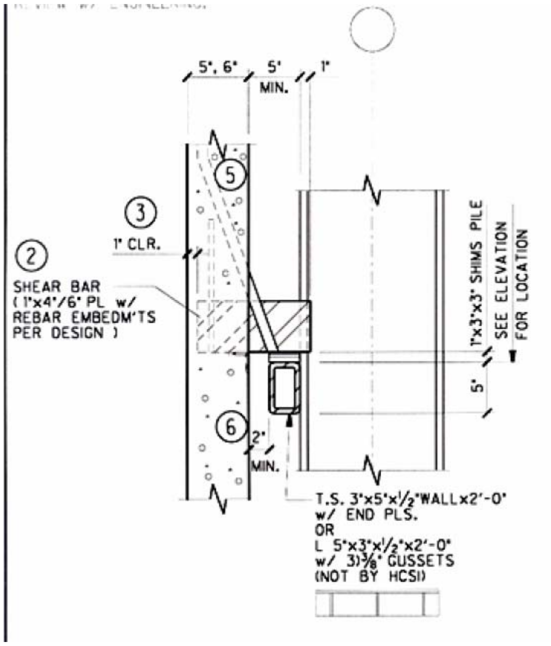


Figure 18 – Typical Panel to Column Connection Detail

This detail shows how the load will transfer directly into the columns and down to the foundation.

### 6.8.3 Hand Calculations

Given parameters and assumptions (See Appendix K for complete calculations):

- From Contract Documents, Live Load design weight: 100 PSF for typical floors, 100 PSF for upper Grandstands, and 80 PSF for press box and press box roof
- From ASCE 7-05 Table 4-2: Live Load Element Factor, $K_{LL}$ = 2 for edge beams and 4 for Exterior Columns
- From contract documents, allow 61 PSF for dead load
- All live loads do not account for the amount of people in the stadium during home games

### 6.8.4 Exterior Beam Calculation

The typical exterior edge beam for the Loyola IAC must support the loads from its tributary floor areas the exterior brick façade. The current beam size of W16x26 is typical for the edge beams and has a maximum LRFD moment capacity of 166 kip-ft.

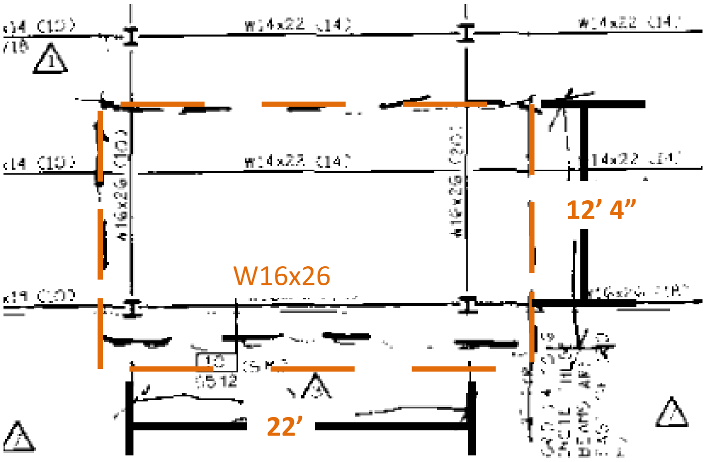


**Figure 19 – Exterior Beam Tributary Area**

Using the LRFD method, the beam will be designed to:

$$\phi M_n > M_u$$

The reduced live load based on the tributary area equals 89 PSF. The total dead load used for the calculations was 61 PSF. Using the equation for load combination 2 from ASCE, the total design load is:

$$1.2D + 1.6L = 1.2\,(61) + 1.6\,(89) = 215.6\ psf$$

Based on the calculations in Appendix K, the design load translates into

$M_u = 19.49\ kips * 7'4'' = 142.86$ kip ft for the live loads and structure self-weight. This does not include the weight of the façade, which based on the calculations in Appendix K, adds an additional 40.66 kip ft. The final equality for the LRFD design:

For W16x26: $M_{Total} = 183.52 > \phi M_n = 166\ kip\ ft\ \therefore Not\ ok$

Based on the above, it is clear the beam is undersized, indicating that gravity loads are controlling the design of the typical exterior beam. This also means that this beam will have to be resized in order for the precast system to be applied.

For W16x31: $M_{Total} = 183.52 < \phi M_n = 203\ kip\ ft\ \therefore ok$

### 6.8.5 Column Calculation 1 & 2

The new added loads of the precast wall system will be analyzed to assess the impact on the columns of the structure. The analysis will occur along column H3.

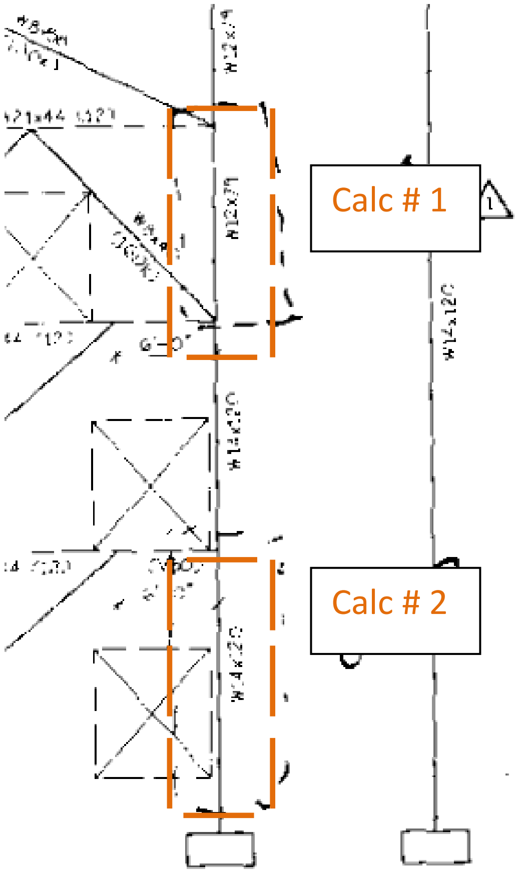


**Figure 20 – Column Sections**

As shown in figure 20 to the left, two areas will be analyzed with the new loading conditions. Level 1 and level 3 are being analyzed because this is where most of the loads are carried for each column. The same parameters and assumptions will be followed that are established at the beginning of this subsection.

Using the LRFD method, this column will be designed to:

$$\phi_c P_n > P_u$$

The reduced live load based on the tributary area equals 92.3 psf. Using the equation for load combination 2 from ASCE, the total design load is:

$1.2D + 1.6L = 1.2\,(61) + 1.6\,(92.3) = 220.88\ psf$

Based on the calculations put forth in Appendix K, this design load translates into $P_u = 241.2$ kips, which includes the axial load of the façade.

The final equality for the LRFD design:

For W12x79: $\phi_c P_n = 836\ kips > 241.2\ kips = P_u\ \therefore ok$

Similar calculations were conducted to analyze the second highlighted area from figure 20. The detailed calculations can be found in the appendix. The final equality for the LRFD for the second set of calculations:

For W14x120: $\phi_c P_n = 1370\ kips > 475.1\ kips = P_u \ \therefore ok$

Based on the above calculations, the current column design will be able to support the change in the façade system. Therefore, even with the additional dead loads from the heavier system, no redesign must occur in order to facilitate the change. The reason for the overdesign of the original structural system is due to the amount of people that will be using the stadium during the home games, which was not taken into account during the design checks for the prefabricated façade.

## 6.9 Mechanical Breadth

### 6.9.1 Introduction

The U-Value is a coefficient of heat transfer that indicates the amount of heat that will move through a material. The lower the U-Value means a greater ability to resist heat movement. U-Values are expressed in BTU/ (hr*SF*°F).

This analysis will calculate both the existing façade U-Value and the proposed precast façade U-Value. The parallel material calculation method was used to calculate the U-Value. This method requires the gathering of R-Values for the materials that comprise the wall section. These R-Values came from the 2001 ASHRAE Handbook. The formula used to calculate the U-Value is $U = 1/R_{total}$. Using the equation for heat transfer, $h = A * U * \Delta T$, the affects of the new façade can then be compared to the existing system. The windows are not going to change, so they are going to be omitted for the heat transfer calculation. Lastly, these results will be looked at to see if the buildings HVAC equipment can be resized.

### 6.9.2 Hand Calculations

**Table 13 - Original Split Face Façade**

| Layer | R-Value ((hr x ft$^2$ x °F)/BTU) |
|---|---|
| Exterior Air Film | .17 |
| 4" Face Brick | .8 |
| 1.5" Air Space | .93 |
| 2" Rigid Insulation | 10 |
| 5/8" Gypsum Board | .56 |
| Framing Cavity | 9 |
| ½" Gypsum Board | .45 |
| Interior Air Film | .68 |
| Total | 22.59 |
| U-Value | .044 |

**Table 14 - Prefabricated Split Face Façade**

| Table 2: Estimated Heat Loss Comparison | R-Value ((hr x ft$^2$ x °F)/BTU) |
|---|---|
| Exterior Air Film | .17 |
| 12” Concrete | .96 |
| 2” Batt Insulation | 12 |
| Interior Air Film | .68 |
| 5/8” Gypsum Board | .56 |
| Framing Cavity | 9 |
| ½” Gypsum Board | .45 |
| Total | 23.82 |
| U-Value | .042 |

**Table 15 - Summer Temperatures in Baltimore**

| Summer Temperatures | °F |
|---|---|
| $T_o$ | 93 (99.6%) |
| $T_i$ | 71 |
| ΔT | 22 |

**Table 16 - Winter Temperatures in Baltimore**

| Summer Temperatures | °F |
|---|---|
| $T_o$ | 11 (99.6%) |
| $T_i$ | 71 |
| ΔT | 60 |

**Table 17 - Estimated Heat Gain Comparison**

| Estimated Heat Gain (Summer) | U-Value (BTU/ hr*SF*°F) | Area (SF) | ΔT (°F) | Heat Loss (BTU/hr) |
|---|---|---|---|---|
| Prefabricated Split Face System | .042 | 10,296 | 22 | 9513.5 |
| Original Spit Face Façade | .044 | 10,296 | 22 | 9966.5 |
| | | | **Difference** | 453 |
| | | | **Reduction In Heat Gain** | 4.5% |

**Table 18 – Estimated Heat Loss Comparison**

| Estimated Heat Loss (Winter) | U-Value (BTU/ hr*SF*°F) | Area (SF) | ΔT (°F) | Heat Loss (BTU/hr) |
|---|---|---|---|---|
| Prefabricated Split Face System | .042 | 10,296 | 60 | 25945.9 |
| Original Spit Face Façade | .044 | 10,296 | 60 | 27181.4 |
| | | | **Difference** | 1235.5 |
| | | | **Reduction In Heat Loss** | 4.5% |

This thermal analysis shows an overall reduction in both the heat gain in the summer and the heat loss in the winter by 4.5 %. The R-Values of the two wall systems are very close, which embraced the fact that there would only be a small change in the overall systems rated design. Since there was such a small change, no redesign of the HVAC equipment is necessary.

### 6.10 Conclusions and Recommendations

Changing out the façade of a building impacts many aspects of a project. In this specific case study, the construction duration was shortened by 4 weeks, resulting in savings on overhead and allowing the occupancy of the building to occur a month earlier. Structural systems and mechanical systems can also be impacted by a new façade. In this case study, no significant gains were attained from these systems. The new façade adversely affected the exterior beam causing resizing of the beam, which would be an added cost.

I would not recommend the switch from hand laid brick to a precast façade system. The positives of the reduced schedule and the slight mechanical benefits are encouraging but the initial costs are too high to make this a good investment.

# 7.0 BIM Analysis

## 7.1 Introduction

The construction industry has numerous amounts of technology at its disposal in Building Information Modeling. This technology has great potential for improving the construction process if used properly. The complex buildings of today and the future along with the standards we've become custom to can benefit with the use of this technology in multiple ways ranging from MEP models with clash detection to 4D animated models. This technology is great but still today is not being utilized to its potential.

## 7.2 Problem Statement

Building Information Modeling (BIM) was only used on the MEP section of the Loyola IAC. If BIM was used on the project, it could help in project coordination with the steel erection and also with the construction of the VRSS slopes. The construction manager would be able to assist in site layout as well as sequencing.

## 7.3 Goal

The goal of this research is to identify different programs that could be used in the BIM process, create a 4D model in synchro based off the Architect's 3D model, determine what is expected of the contributing parties, create a Virtual Design and Construction (VDC) execution plan and analyze some basic upfront cost impacts it has on a project.

## 7.4 Methodology

The BIM Implementation analysis was broken down into four phases. The first phase consisted of receiving the models from the project team. It also included researching some 4D software, which consisted of NavisWorks and Synchro, which in the end synchro was used. The next phase was comprised of interviews with the project team at Millennium Science Complex. The third phase was constructing the 4D synchro model. The final and last phase was writing up the VDC execution and implementing BIM into the subcontractor's contract.

## 7.5 Virtual Design and Construction (VDC) Execution Plan

The VDC execution plan is a plan that outlines the procedures for BIM for a specific project and how BIM is going to be implemented. There are multiple sections to a VDC execution plan.

They include: Mission Statement, General Modeling Responsibilities, Contractual Language, Costs and Scheduling Restraints, information exchange among the team, software and hardware that will be used throughout the project's lifecycle, model progression schedule, who is the model manager, and any additional items for consideration. This plan is meant to be used as a checklist for items of concern and most importantly to begin getting all parties involved as early as possible to determine the best approach for the project. A project specific VDC execution plan was created for the Loyola IAC based off the VDC execution plan for the Millennium Science complex and can be found in Appendix L. When looking at the different sections for the VDC execution plan there are many things to consider.

The mission statement should be made prior to the beginning of a project. The project mission statement should be based on three questions: Why is VDC being considered, how will it benefit the project, and what are the desired results. A few things to consider: the entire project does not have to be modeled (i.e. it can be modeled to a problem) and it is important to clearly define specific goals and objectives (the objectives should be measurable).

General modeling responsibilities should be clearly outlined for every party. Responsibilities should be made for the Architect & Design Consultants, Owner, Construction Manager, and Subcontractor. Not only should the responsibilities be outlined, but defining who is going to create the information models and how this information will be exchanged among the team is also important. It should be outlined in the subcontractors scopes of work what software is required of each subcontractor and their responsibilities and role in the BIM process.

When defining the software and hardware that will be used throughout the project's lifecycle, it is important to take into account how the different programs interact in a collaborative environment, what programs can easily transfer files from one to the other, and is there a type of workaround that can be used to help with the weaknesses.

When discussing the model progression schedule, meetings should be scheduled to review the model in both the design and construction phases with the modelers. Prioritize the schedule of information and modeling requirements for decision making and work processes. For example, when considering model progression for HVAC duct runs:

- **Conceptual** – no need to model ducts,
- **Approximate Geometry** – 2D layout or basic design model of 3D duct with approximate X, Y, Z locations – By Design Team
- **Precise geometry** – Design and Fabrication model of 3D duct with precise engineered dimension - by Design Team and/or Subcontractor

- **Fabrication** – Fabrication model of a 3D duct with precise engineered dimensions and fabrications details – by Subcontractor
- **100% Coordinated** – A 3D representation of the installed duct – By Fabrication Model

The most vital role of this whole process is to determine who will act as the model manager. The model manager ensures smooth workflow of the collaboration process. The model manager gathers the design and fabrication models and combines them into a composite model. Then, runs clash detection, records, and organizes any issues found in the main model. Lastly, create a coordination sign-off procedure. Depending on the agreements made with the project team, traditional roles and responsibilities need to be respected and no party should assume additional risk as a result of this new tool.

### 7.6 3D Modeling Process

When creating a 3D model for a project, a lot of group coordination between all trades is needed. The base model is normally made by the architect. This model creates a very unique tool for architects, owners, and contractors, which allows them to review possible conflicts and construction issues early on in the design phase. The Architect has the ability to add objects as needed to achieve the project goals. Design consultants can be hired to create certain pieces of the model. For example, on the Millennium Science Complex the structural model was produced by High Concrete. Subcontractors create their own models for their own trade. The model can be designed in AutoCADD or Autodesk Revit. Lastly, the construction manager normally will act as the model coordinator or they will hire someone else to manage the model.

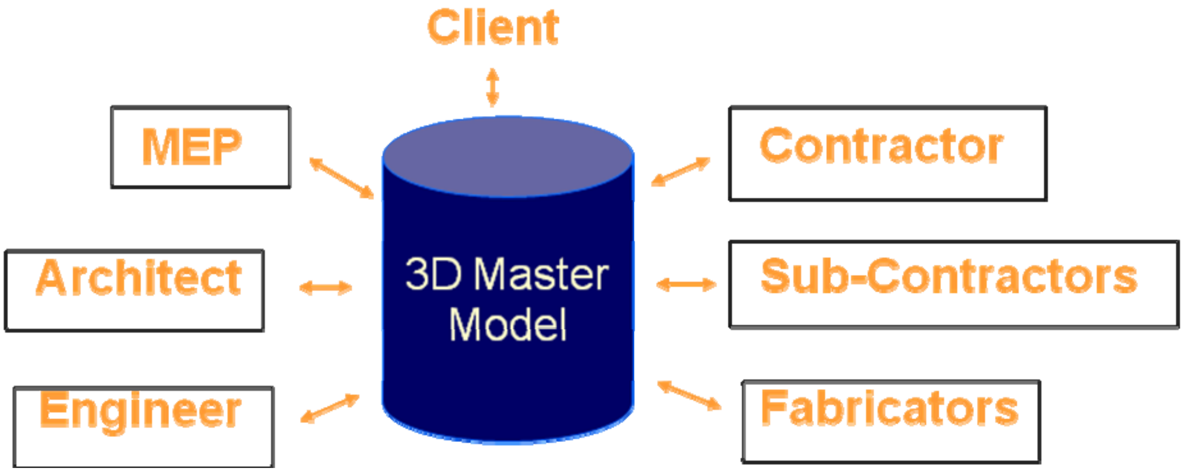


**Figure 21 – 3D Modeling Process**

## 7.7 4D Modeling Process

The 4D modeling process starts with the 2D drawings to the construction of the 3D model. The 3D model can be in CADD or Revit as stated above. While the Architect and designers are constructing the model, the construction manager is creating the schedule. Once the schedule and model is completed, the model and schedule are then imported to the 4D software (Navisworks Timeliner, Synchro, Innovaya Simulation, and VICO Office). Lastly, the tasks in the schedule are linked to the CADD objects, as shown below in figure 22.

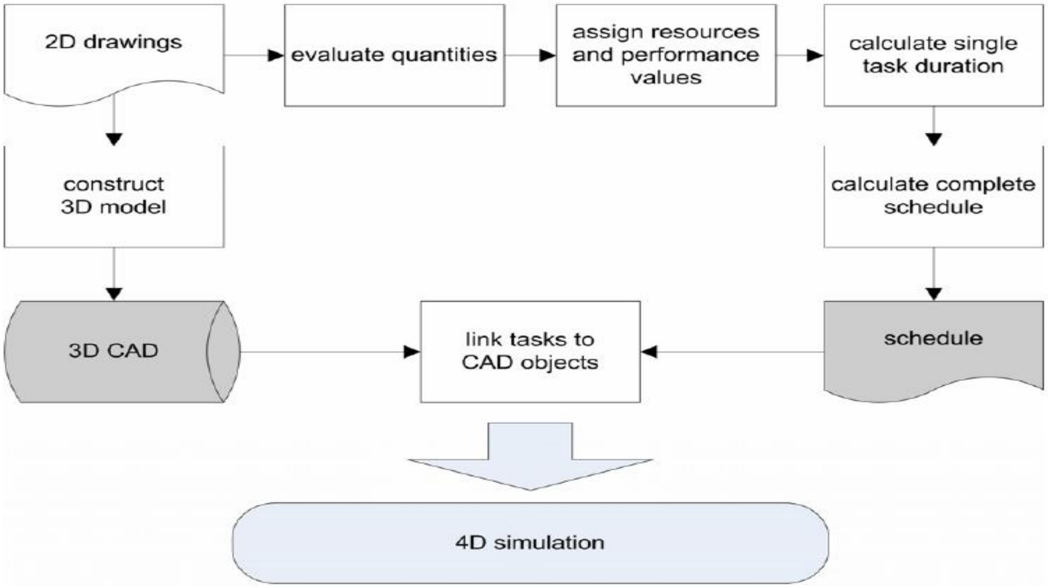


**Figure 22 – 4D Modeling Process**

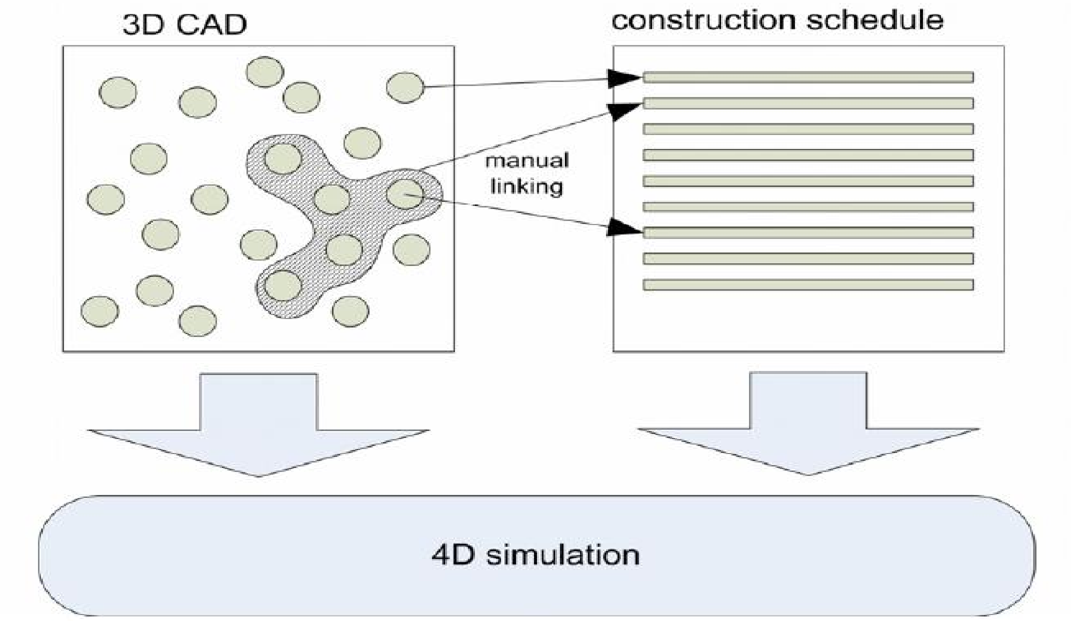


**Figure 23 – 4D Communication Process**

### 7.8 Synchro

For the 4D model of the Loyola IAC, I used Synchro. The project schedule and 3D model were obtained through interviews with the project team. After the model and schedule were received, they were imported into Synchro. To assign tasks to the objects, highlight the task then select the objects for the task. After that, right click and assign the objects to the selected tasks. When assigning tasks to the objects, some problems arose. When the model was created by Sasaki, instead of breaking the walls down into sections, the walls were one continuous wall. Since the model was locked by Sasaki, it could not be edited before it was imported into Synchro. So after the model was imported, the objects that needed to be cut had to be exported. At this time, the objects are now editable.

After all the objects are linked, synchro has an animation creator embedded in it to make a video of the project being constructed. First, the camera views had to be setup. The camera views help you look at the whole project from more than one view. Next, the animation timeframe has to be determined. The animation timeframe is often just the duration of the project for the whole project or it can be the duration of a certain task for individual tasks (i.e. concrete pour). Lastly, the video of the project being constructed is ready to be exported to a video file.

### 7.9 Benefits

There are many benefits that come along with BIM. BIM improves the project communication between trades before the trades even start performing their work. Since coordination is being completed before the start of work, this allows time to visualize the construction sequence, which allows for many design conflicts to be resolved before change orders or RFIs are made. Lastly, owners, engineers, architects, and contractors have a shared understanding of the project (i.e. milestones, responsibilities, project status, and construction plans).

### 7.10 Costs

With the new technology, comes multiple different costs associated with it. A BIM room is recommended for coordination meetings. The BIM room cost was estimated to be $3295, as shown in Appendix M. Since Whiting-Turner was the construction manager, the software costs will be relatively low because they already have Autodesk Revit and AutoCADD. The total estimated software cost for the Synchro license is $10,000, see Appendix M. The total estimation for BIM came out to be $44, 453, as shown in Appendix M.

### 7.11 Conclusions and Recommendations

A Visual Design and Construction plan is very useful when applying BIM to a project. Using a VDC execution plan will allow your project to flow smoothly by outlining the responsibilities of everyone involved in the BIM process. The 3D modeling process is a key step to creating the overall 4D model. When creating the 3D model, the architect and designer should make the model as detailed as possible. Making the model detailed makes it easier to assign tasks to objects in Synchro.

Based on the benefits and above costs, I recommend that BIM be utilized throughout the project. BIM offers the great potential for learning and a better execution of the construction process.

# 8.0 Conclusion

As an owner, the Loyola Intercollegiate Athletic Complex is constantly looking for ways to enhance the construction of their project. Enhancement comes in many ways such as cost savings, schedule enhancement, and the use of technology to enhance constructability and logistics as shown throughout this report. The constant management of project success depends heavily on these factors too. This report provided alternates for the owner to help Loyola University achieve their goals.

As reported in the first analysis, the ability for this project to become LEED certified is very achievable. The analysis looked to industry professionals for potential LEED credit ideas and also their opinion regarding LEED. Through research of credits a project checklist was created to demonstrate possible credits that were easily achievable.

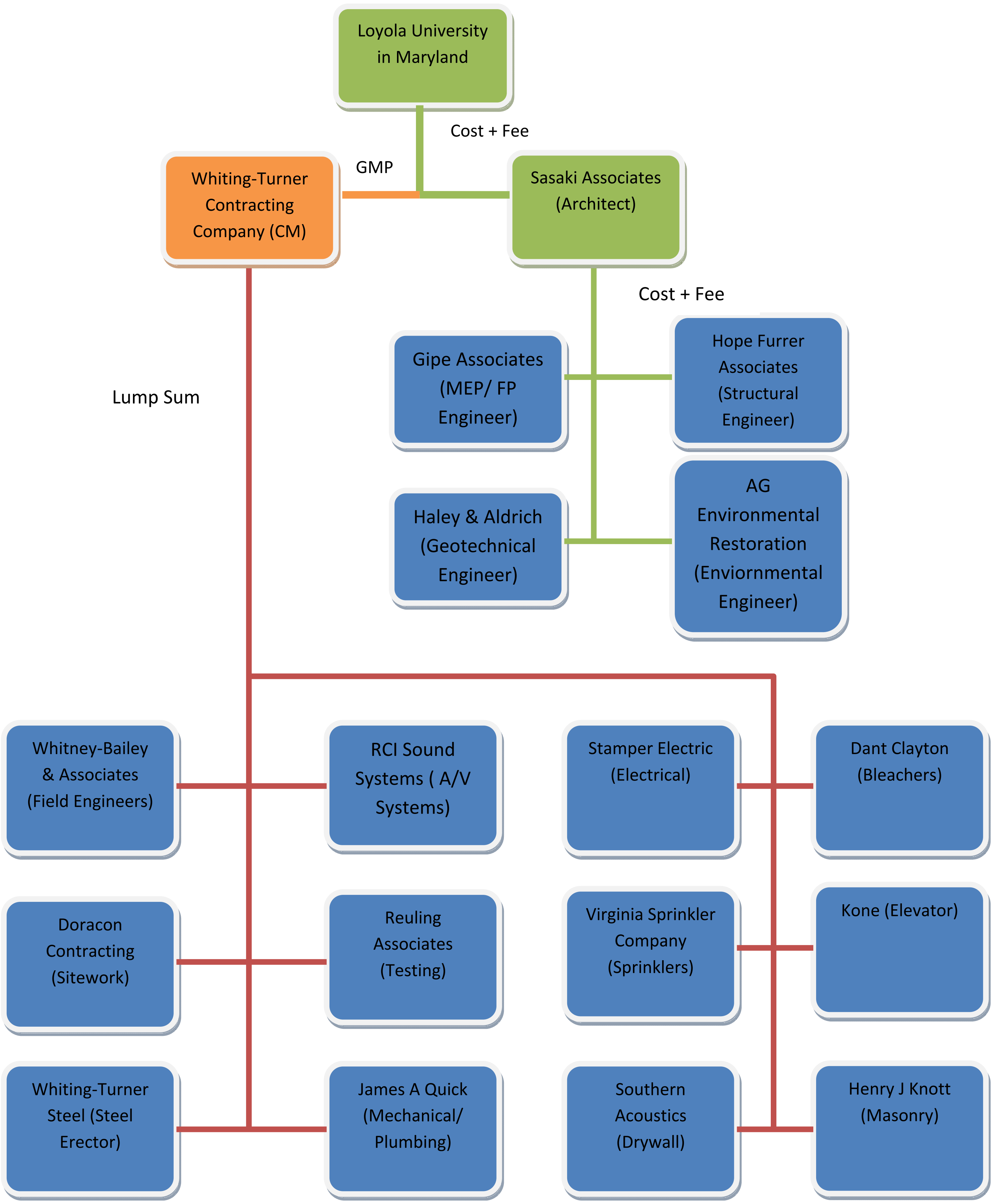
The second analysis looked into replacing the hand laid split face CMU with a precast façade system. To highlight a few conclusions from this analysis, 4 weeks would be cut off the schedule, cost of the façade would be increased by 144%, the exterior beam had to be resized, and lastly there was very little impact to the mechanical system. Overall, the prefabricated system did not turn out to be a good fit for the owner.

The third and final analysis looked at BIM implementation into the project. A Virtual Design and Construction Execution Plan was made to help outline the procedures for BIM and the project team. The 3D and 4D modeling processes were described to give a good idea of what was involved in BIM. Lastly, a synchro model was made to show how the building would be constructed.

Ultimately, the report provided one critical analysis that was able to help the constructability of the Loyola IAC and one analysis that would raise the perceived value of the stadium and meet the Baltimore City requirements. With the results in this report, the owner can consider the results for enhancement to the project.

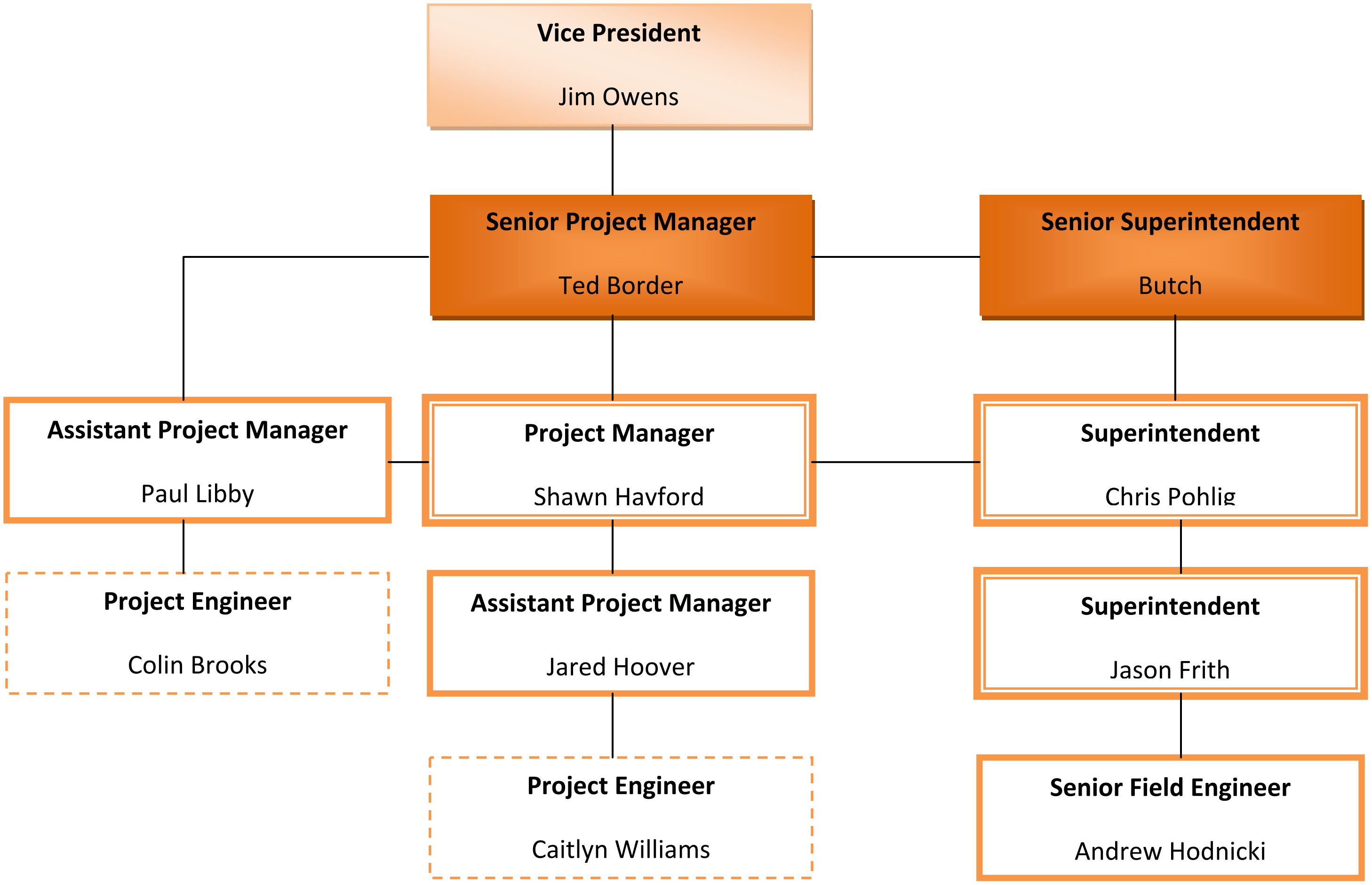
# Appendix A

# Project Delivery System


Loyola University in Maryland
Cost + Fee
GMP
Whiting-Turner Contracting Company (CM)
Sasaki Associates (Architect)
Cost + Fee
Lump Sum
Gipe Associates (MEP/ FP Engineer)
Hope Furrer Associates (Structural Engineer)
Haley & Aldrich (Geotechnical Engineer)
AG Environmental Restoration (Enviornmental Engineer)
Whitney-Bailey & Associates (Field Engineers)
RCI Sound Systems ( A/V Systems)
Stamper Electric (Electrical)
Dant Clayton (Bleachers)
Doracon Contracting (Sitework)
Reuling Associates (Testing)
Virginia Sprinkler Company (Sprinklers)
Kone (Elevator)
Whiting-Turner Steel (Steel Erector)
James A Quick (Mechanical/ Plumbing)
Southern Acoustics (Drywall)
Henry J Knott (Masonry)

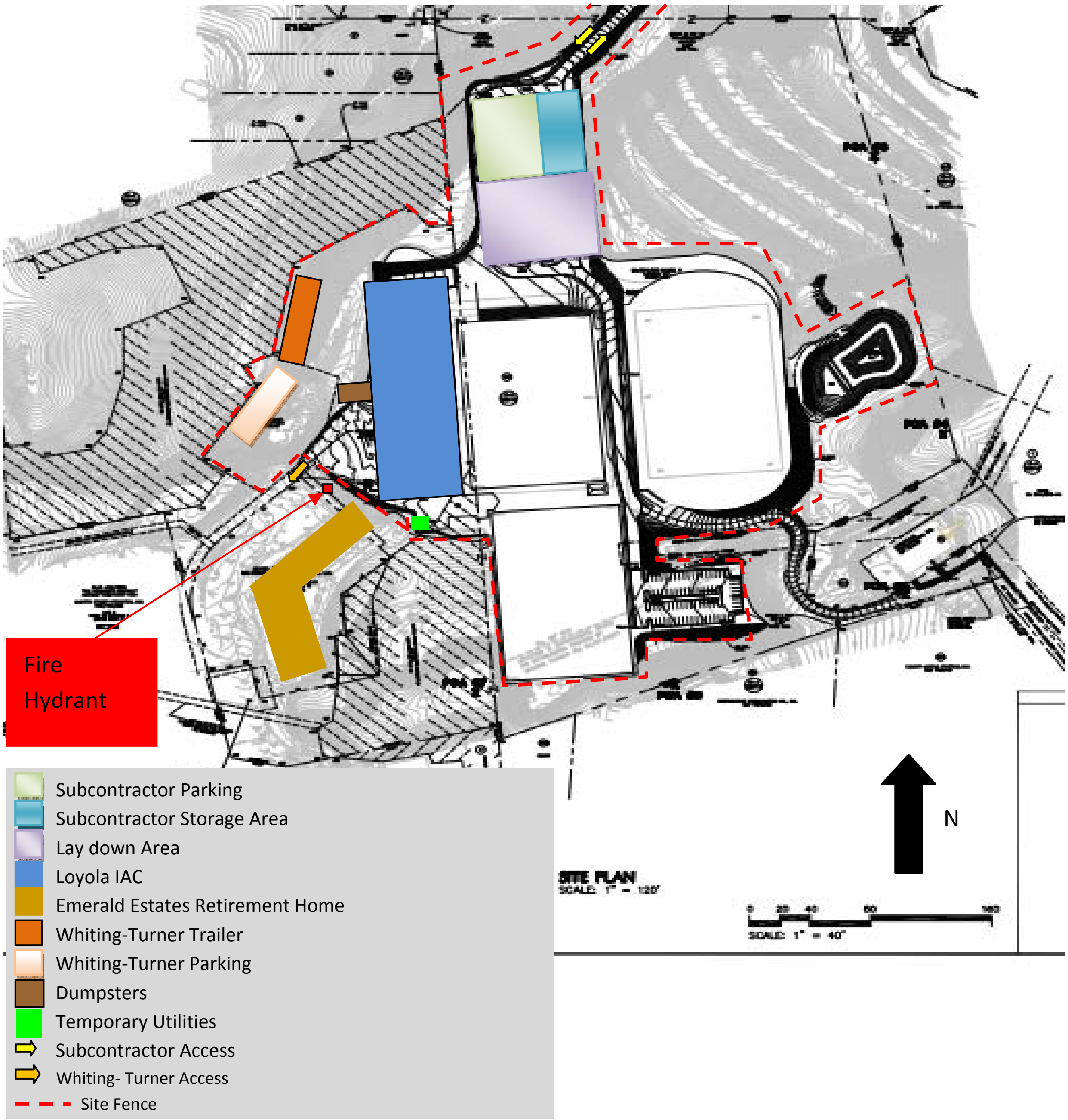
# Appendix B

# Project Team Organization


Vice President
Jim Owens
Senior Project Manager
Ted Border
Senior Superintendent
Butch
Assistant Project Manager
Paul Libby
Project Manager
Shawn Havford
Superintendent
Chris Pohlig
Project Engineer
Colin Brooks
Assistant Project Manager
Jared Hoover
Superintendent
Jason Frith
Project Engineer
Caitlyn Williams
Senior Field Engineer
Andrew Hodnicki

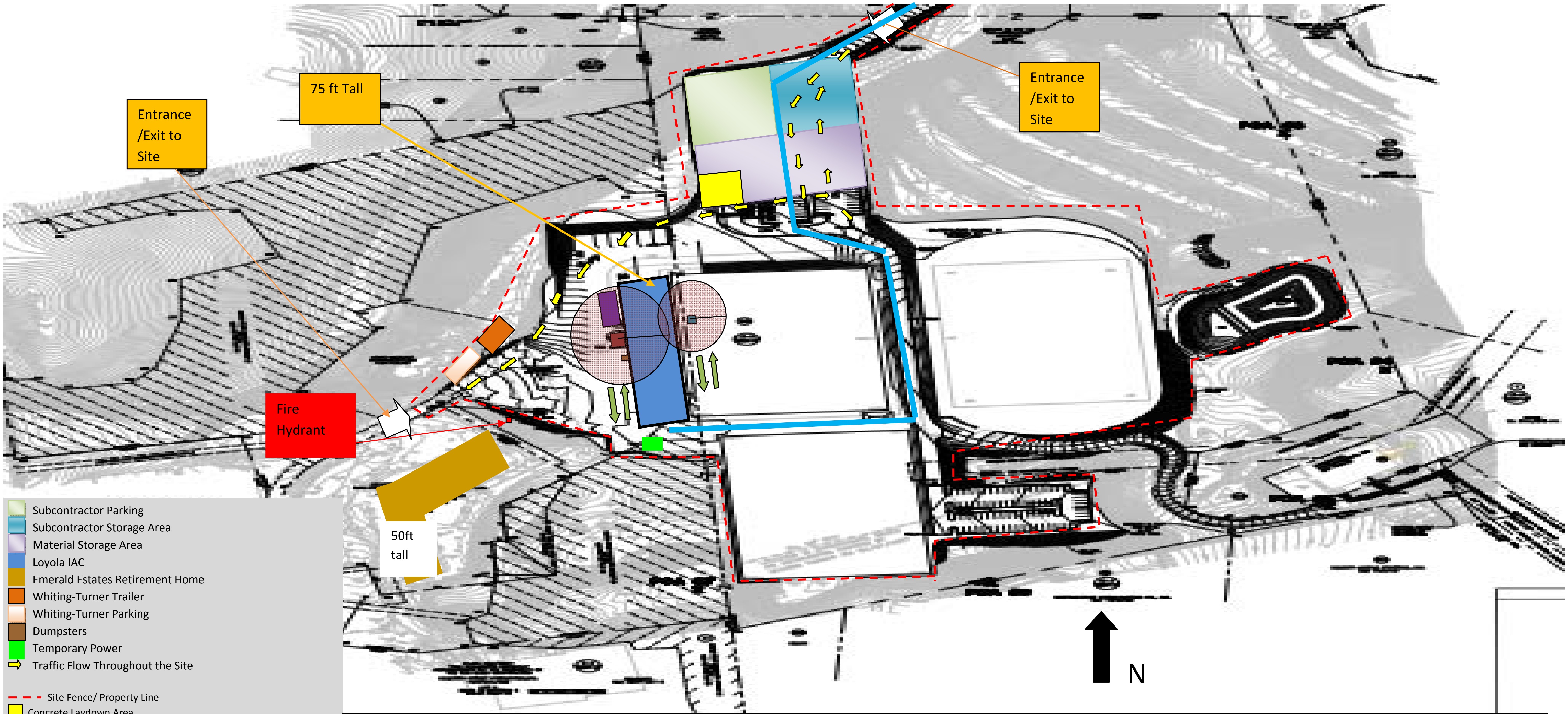
# Appendix C

# Site Plan of Existing Conditions


Fire Hydrant
N
SITE PLAN
SCALE: 1" = 120'
0 20 40 80 160
SCALE: 1" = 40'
🟩 Subcontractor Parking
🟦 Subcontractor Storage Area
🟪 Lay down Area
🟦 Loyola IAC
🟨 Emerald Estates Retirement Home
🟧 Whiting-Turner Trailer
🟧 Whiting-Turner Parking
🟫 Dumpsters
🟩 Temporary Utilities
⇨ Subcontractor Access
⇨ Whiting- Turner Access
- - - Site Fence

# Appendix D

# Site Logistics Plan



- 🟩 Subcontractor Parking
- 🟦 Subcontractor Storage Area
- 🟪 Material Storage Area
- 🟦 Loyola IAC
- 🟫 Emerald Estates Retirement Home
- 🟧 Whiting-Turner Trailer
- ▨ Whiting-Turner Parking
- 🟫 Dumpsters
- 🟩 Temporary Power
- ⇨ Traffic Flow Throughout the Site

- - - Site Fence/ Property Line
- 🟨 Concrete Laydown Area
- 🟪 Steel Shakedown Area
- 🟥 90 Ton Truck Crane
- 🟦 70 Ton Truck Crane
- ⇨ Arrows Indicating the Cranes can move back and forth
- ▬ New Utility Trench

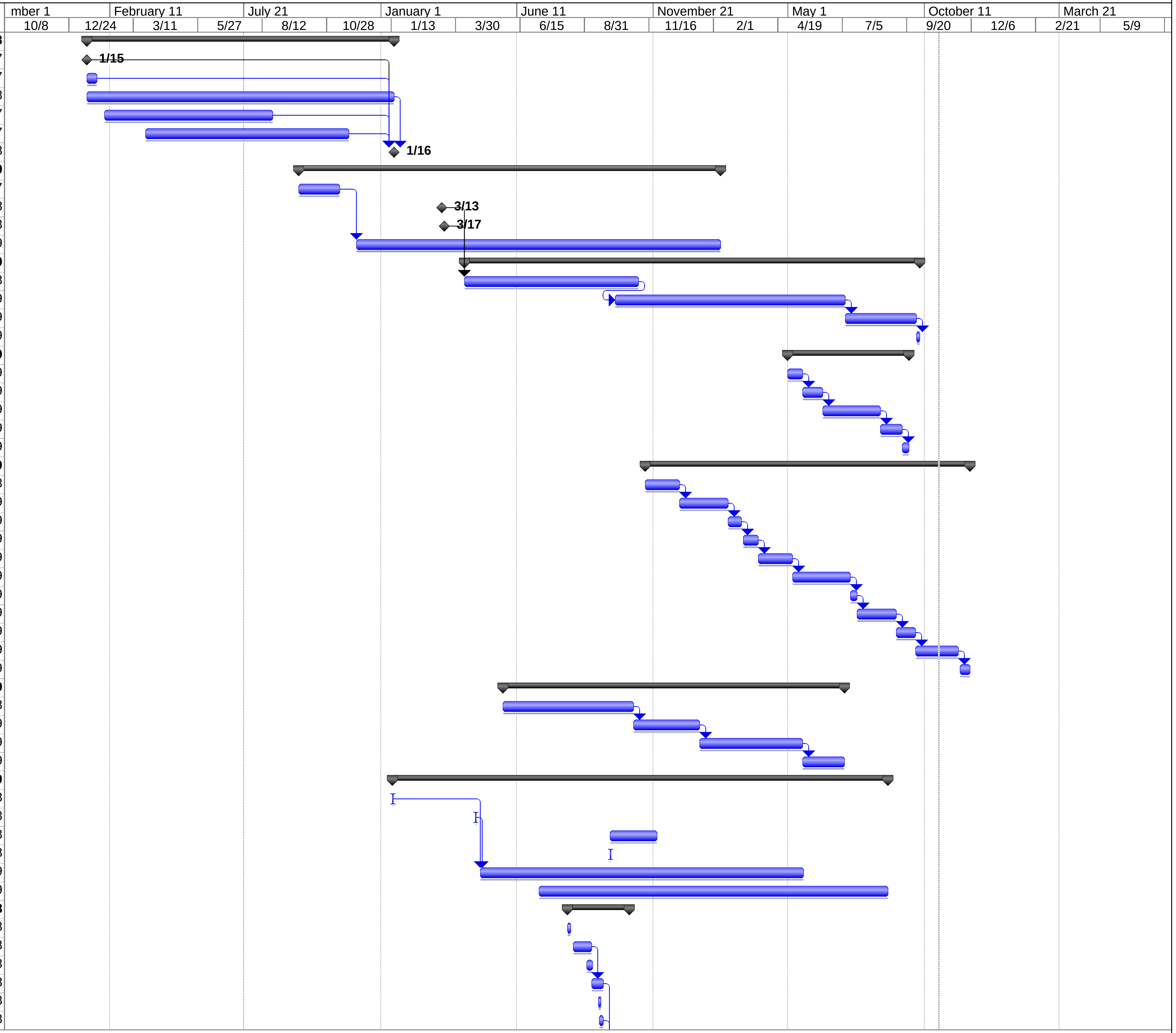
| Steven Rogers<br>October 27, 2009 | Loyola Intercollegiate Athletic Complex | Phase 3 of<br>Construction |
|---|---|---|

# Appendix E

# Detailed Project Schedule

# Loyola IAC Detailed Project Schedule

| ID | Task Name | Duration | Early Start | Early Finish |
|---|---|---|---|---|
| 1 | **Phase 1** | **263 days** | **Mon 1/15/07** | **Wed 1/16/08** |
| 2 | Notice to Proceed | 0 days | Mon 1/15/07 | Mon 1/15/07 |
| 3 | Mobilize Onsite | 10 days | Mon 1/15/07 | Fri 1/26/07 |
| 4 | Mass Excavation Cut/Fill | 263 days | Mon 1/15/07 | Wed 1/16/08 |
| 5 | DDC Ground Improvements | 145 days | Mon 2/5/07 | Fri 8/24/07 |
| 6 | VRSS Slopes | 175 days | Mon 3/26/07 | Fri 11/23/07 |
| 7 | Complete Earthwork | 0 days | Wed 1/16/08 | Wed 1/16/08 |
| 8 | **Phase 2-General Admin To Start Construction** | **360 days** | **Tue 9/25/07** | **Mon 2/9/09** |
| 9 | Drawings Completed & Submitted | 35 days | Tue 9/25/07 | Mon 11/12/07 |
| 10 | Received Permit | 1 day | Thu 3/13/08 | Thu 3/13/08 |
| 11 | Begin Construction | 0 days | Mon 3/17/08 | Mon 3/17/08 |
| 12 | Procurement | 311 days | Mon 12/3/07 | Mon 2/9/09 |
| 13 | **Phase 2 Utility Trench** | **388 days** | **Thu 4/10/08** | **Mon 10/5/09** |
| 14 | Excavate for Utilities | 148 days | Thu 4/10/08 | Mon 11/3/08 |
| 15 | Install Utilities | 197 days | Tue 10/7/08 | Wed 7/8/09 |
| 16 | Backfill Utilities | 61 days | Thu 7/9/09 | Thu 10/1/09 |
| 17 | Utility Trench Punchout | 2 days | Fri 10/2/09 | Mon 10/5/09 |
| 18 | **Phase 2-Practice Field And Track** | **103 days** | **Fri 5/1/09** | **Tue 9/22/09** |
| 19 | Grade To Elevation | 12 days | Fri 5/1/09 | Mon 5/18/09 |
| 20 | Excavate Drainage and Fence | 18 days | Tue 5/19/09 | Thu 6/11/09 |
| 21 | Pole Base/ Concrete Pour for Sports Lights/Set Lights | 49 days | Fri 6/12/09 | Wed 8/19/09 |
| 22 | Drill Foundation Footings/Install Chain Link Fence | 18 days | Thu 8/20/09 | Mon 9/14/09 |
| 23 | Install Natural Grass Seed For Practice Feild | 6 days | Tue 9/15/09 | Tue 9/22/09 |
| 24 | **Phase 2-Game Field and South Field** | **278 days** | **Wed 11/12/08** | **Fri 12/4/09** |
| 25 | Grade to Elevation | 29 days | Wed 11/12/08 | Mon 12/22/08 |
| 26 | Excavate/Drill/Pour Footings for Sports Lights | 42 days | Tue 12/23/08 | Wed 2/18/09 |
| 27 | Set Scoreboards/Wire Tie-In | 12 days | Thu 2/19/09 | Fri 3/6/09 |
| 28 | Add Baskets to VRSS-4 for the South Field | 14 days | Mon 3/9/09 | Thu 3/26/09 |
| 29 | Form/ Pour Perimeter Curb | 29 days | Fri 3/27/09 | Wed 5/6/09 |
| 30 | Install Turf Drainage Pipe/Drainage Stone | 49 days | Thu 5/7/09 | Tue 7/14/09 |
| 31 | Testing the Turf for Drainage and Compaction (Just Turf and | 6 days | Wed 7/15/09 | Wed 7/22/09 |
| 32 | Install Turf/Logos | 33 days | Thu 7/23/09 | Mon 9/7/09 |
| 33 | Infill Turf | 17 days | Tue 9/8/09 | Wed 9/30/09 |
| 34 | Pour Footings for Fence/ Set Fench | 37 days | Thu 10/1/09 | Fri 11/20/09 |
| 35 | Punchout | 10 days | Mon 11/23/09 | Fri 12/4/09 |
| 36 | **Phase 2-Stormwater Management Ponds** | **292 days** | **Mon 5/26/08** | **Tue 7/7/09** |
| 37 | Clear, Grub, and Excavate Existing | 112 days | Mon 5/26/08 | Tue 10/28/08 |
| 38 | Rough Grade | 57 days | Wed 10/29/08 | Thu 1/15/09 |
| 39 | Pour Forebay Pad | 87 days | Fri 1/16/09 | Mon 5/18/09 |
| 40 | Install Fence | 36 days | Tue 5/19/09 | Tue 7/7/09 |
| 41 | **Phase 3 Design** | **424 days** | **Tue 1/15/08** | **Fri 8/28/09** |
| 42 | Schematic Drawings | 1 day | Tue 1/15/08 | Tue 1/15/08 |
| 43 | Main Frame Structural Package | 1 day | Wed 4/23/08 | Wed 4/23/08 |
| 44 | Architectural/MEP 100% Drawings | 40 days | Wed 10/1/08 | Tue 11/25/08 |
| 45 | Sitework 100% Drawings | 1 day | Wed 10/1/08 | Wed 10/1/08 |
| 46 | Permits | 276 days | Tue 4/29/08 | Tue 5/19/09 |
| 47 | Procurement | 299 days | Tue 7/8/08 | Fri 8/28/09 |
| 48 | **Phase 3-Building Foundations** | **54 days** | **Mon 8/11/08** | **Thu 10/23/08** |
| 49 | Grade Builidng Pad | 4 days | Mon 8/11/08 | Thu 8/14/08 |
| 50 | Excav/FRP Footings/Piers (1-9/H & /G-E) | 16 days | Mon 8/18/08 | Mon 9/8/08 |
| 51 | FRP Foundation Walls/Columns | 5 days | Wed 9/3/08 | Tue 9/9/08 |
| 52 | Excav/FRP Footings/Piers (1-9/E & 9-18/E) | 10 days | Tue 9/9/08 | Mon 9/22/08 |
| 53 | Excav/FRP Foundations for Stair #2 | 3 days | Wed 9/17/08 | Fri 9/19/08 |
| 54 | FRP Columns/Peirs Col.J | 3 days | Thu 9/18/08 | Mon 9/22/08 |



Project: Detailed Project Schedule.mp
Date: Wed 10/28/09

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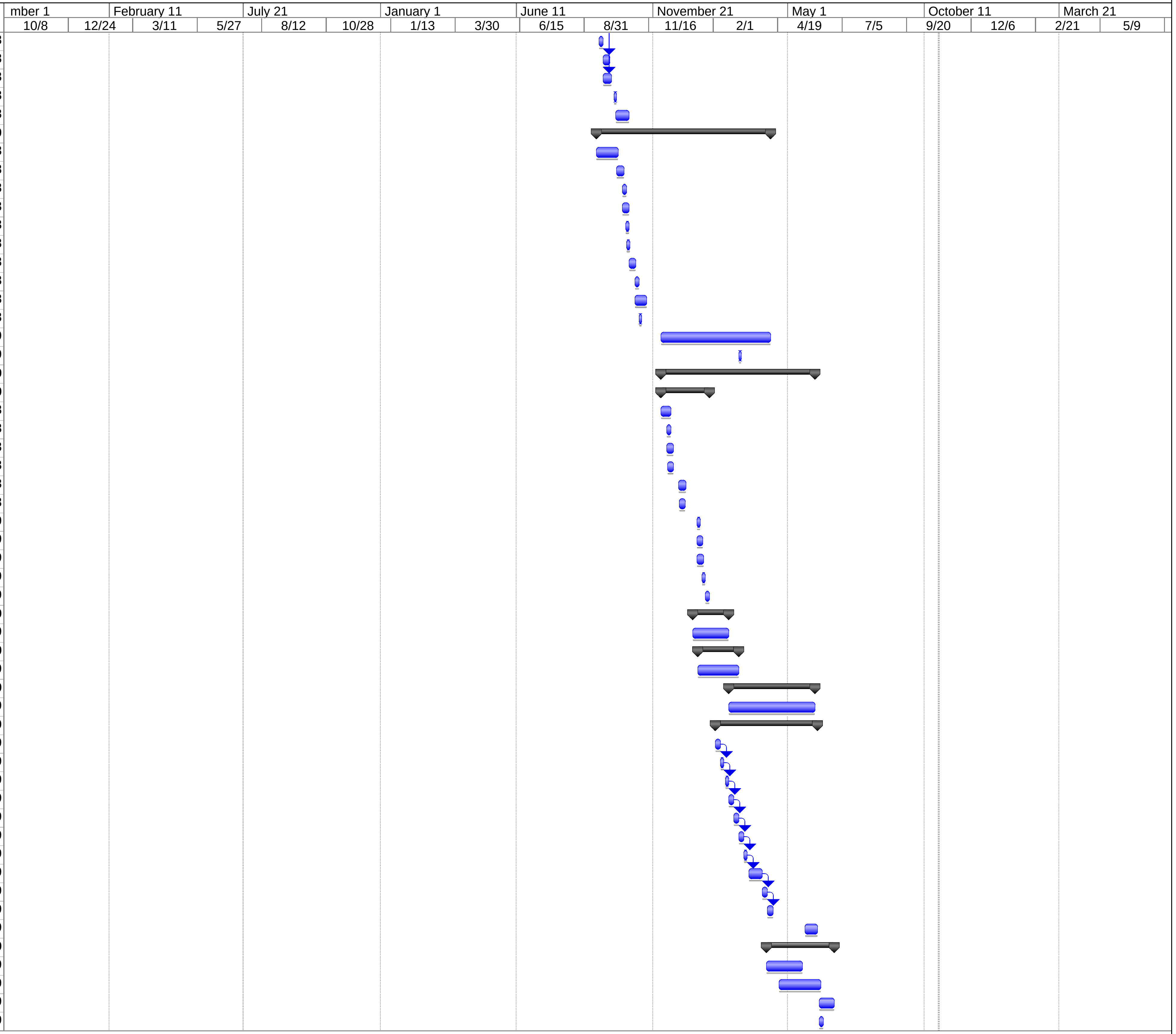
|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Progress | ▬ | Summary | ▬ | External Tasks | ▬ | Deadline | ⇩ |
| Split | ┈ | Milestone | ◆ | Project Summary | ▬ | External Milestone | ◆ | | |

Steven Rogers

# Loyola IAC Detailed Project Schedule

| ID | Task Name | Duration | Early Start | Early Finish |
|---|---|---|---|---|
| 55 | FRP Foundation Walls/Columns | 3 days | Thu 9/18/08 | Mon 9/22/08 |
| 56 | Excav/FRP Footings/Piers (18/E-H & 9-18H) | 6 days | Tue 9/23/08 | Tue 9/30/08 |
| 57 | FRP Foundation Walls/Columns | 8 days | Tue 9/23/08 | Thu 10/2/08 |
| 58 | Excav/FRP Footings/Col. Elevator Pit | 3 days | Mon 10/6/08 | Wed 10/8/08 |
| 59 | FRP Foundation Walls Stair #2 | 12 days | Wed 10/8/08 | Thu 10/23/08 |
| **60** | **Phase 3-Lower Grandstand Foundations** | **150 days** | **Mon 9/15/08** | **Fri 4/10/09** |
| 61 | Excav/FRP Footings/ Columns | 20 days | Mon 9/15/08 | Fri 10/10/08 |
| 62 | FRP Foundation End Walls/Columns | 7 days | Thu 10/9/08 | Fri 10/17/08 |
| 63 | Erect Scaffolding Col 1-9 | 3 days | Thu 10/16/08 | Mon 10/20/08 |
| 64 | FRP Foundation End Walls Col. 18/A-G | 6 days | Thu 10/16/08 | Thu 10/23/08 |
| 65 | Erect Scaffolding col. 9-18 | 4 days | Mon 10/20/08 | Thu 10/23/08 |
| 66 | Pour Spandrel Beams Col. 1-9 | 4 days | Tue 10/21/08 | Fri 10/24/08 |
| 67 | Pour Raker Beams Col. 1-9 | 6 days | Fri 10/24/08 | Fri 10/31/08 |
| 68 | Pour Spandrel Beams Col. 9-18 | 3 days | Fri 10/31/08 | Tue 11/4/08 |
| 69 | Pour Main Deck Riser 1 | 10 days | Fri 10/31/08 | Thu 11/13/08 |
| 70 | Pour Raker Beams Col. 9-18 | 3 days | Wed 11/5/08 | Fri 11/7/08 |
| 71 | Pour Main Deck Riser 2-9 | 95 days | Mon 12/1/08 | Fri 4/10/09 |
| 72 | Pour Stairs Beyond 1-9 | 3 days | Wed 3/4/09 | Fri 3/6/09 |
| **73** | **Phase 3-Superstructure Steel Sequence 1-6** | **132 days** | **Mon 12/1/08** | **Tue 6/2/09** |
| **74** | **Seq #1** | **42 days** | **Mon 12/1/08** | **Tue 1/27/09** |
| 75 | Erect Steel 2nd and 3rd Concourse North Side | 10 days | Mon 12/1/08 | Fri 12/12/08 |
| 76 | Bolt up 2nd | 5 days | Mon 12/8/08 | Fri 12/12/08 |
| 77 | Misc Detailing 2nd | 6 days | Mon 12/8/08 | Mon 12/15/08 |
| 78 | Bolt up 3rd | 5 days | Tue 12/9/08 | Mon 12/15/08 |
| 79 | Metal Deck 2nd | 7 days | Mon 12/22/08 | Tue 12/30/08 |
| 80 | Welding 2nd | 5 days | Tue 12/23/08 | Mon 12/29/08 |
| 81 | Welding 3rd | 4 days | Tue 1/13/09 | Fri 1/16/09 |
| 82 | Misc. Detailing 3rd | 5 days | Tue 1/13/09 | Mon 1/19/09 |
| 83 | Metal Deck 3rd | 6 days | Tue 1/13/09 | Tue 1/20/09 |
| 84 | Shear Studs 2nd | 4 days | Mon 1/19/09 | Thu 1/22/09 |
| 85 | Shear Studs 3rd | 3 days | Fri 1/23/09 | Tue 1/27/09 |
| **86** | **Seq #2** | **31 days** | **Thu 1/8/09** | **Thu 2/19/09** |
| 87 | Similiar Seq but for 4th floor and Upper North Side | 31 days | Thu 1/8/09 | Thu 2/19/09 |
| **88** | **Seq #3** | **35 days** | **Wed 1/14/09** | **Tue 3/3/09** |
| 89 | Similar Seq but for Pressbox & Roof North Side | 35 days | Wed 1/14/09 | Tue 3/3/09 |
| **90** | **Seq #4-6** | **73 days** | **Fri 2/20/09** | **Tue 6/2/09** |
| 91 | Similar to Seq's 1-3 but for the South Side | 73 days | Fri 2/20/09 | Tue 6/2/09 |
| **92** | **Phase 3-Structural Slabs** | **88 days** | **Wed 2/4/09** | **Fri 6/5/09** |
| 93 | Pour 2nd Floor North | 4 days | Wed 2/4/09 | Mon 2/9/09 |
| 94 | Pour 3rd Floor North | 4 days | Tue 2/10/09 | Fri 2/13/09 |
| 95 | Pour 4th Floor North | 4 days | Mon 2/16/09 | Thu 2/19/09 |
| 96 | Pour Press Box Floor North | 4 days | Fri 2/20/09 | Wed 2/25/09 |
| 97 | Pour 2nd Floor South | 4 days | Thu 2/26/09 | Tue 3/3/09 |
| 98 | Pour 3rd Floor South | 4 days | Wed 3/4/09 | Mon 3/9/09 |
| 99 | Pour 4th Floor South | 4 days | Tue 3/10/09 | Fri 3/13/09 |
| 100 | Pour SOG North and South | 12 days | Mon 3/16/09 | Tue 3/31/09 |
| 101 | Pour Stairs | 4 days | Wed 4/1/09 | Mon 4/6/09 |
| 102 | Pour Topping Slabs | 5 days | Tue 4/7/09 | Mon 4/13/09 |
| 103 | Install WP/Drainage Board | 11 days | Fri 5/22/09 | Fri 6/5/09 |
| **104** | **Phase 3- Metal Bleachers** | **59 days** | **Mon 4/6/09** | **Thu 6/25/09** |
| 105 | Lower Grandstands | 31 days | Mon 4/6/09 | Mon 5/18/09 |
| 106 | Upper Grandstands | 36 days | Tue 4/21/09 | Tue 6/9/09 |
| 107 | Upper Grandstand Railings | 14 days | Mon 6/8/09 | Thu 6/25/09 |
| 108 | Punchlist | 5 days | Mon 6/8/09 | Fri 6/12/09 |



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Date: Wed 10/28/09

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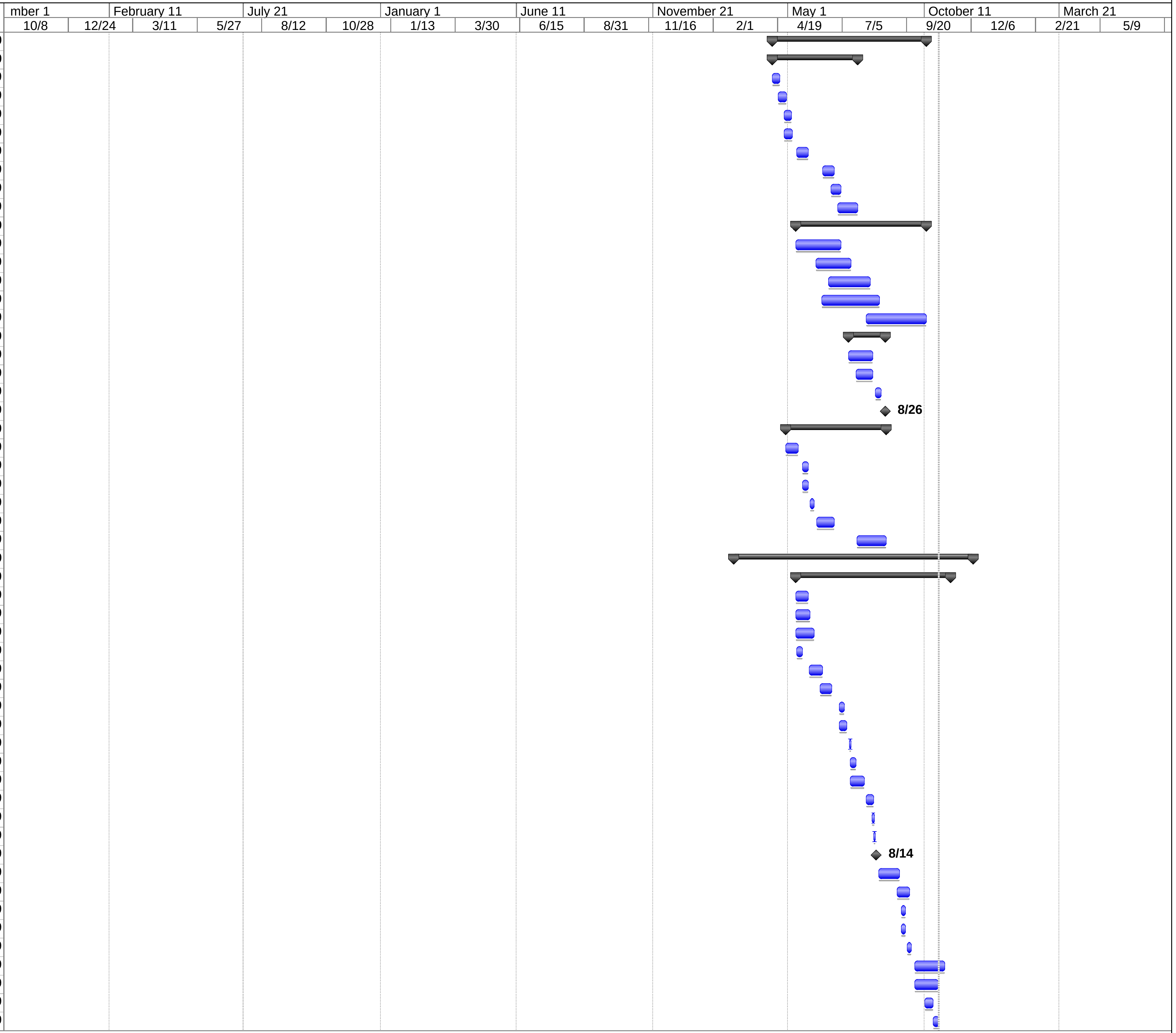
|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Progress | ▬ | Summary | ▬ | External Tasks | ▬ | Deadline | ⇩ |
| Split | ┈ | Milestone | ◆ | Project Summary | ▬ | External Milestone | ◆ | | |

Steven Rogers

## Loyola IAC Detailed Project Schedule

| ID | Task Name | Duration | Early Start | Early Finish |
|---|---|---|---|---|
| 109 | **Phase 3-Exterior Skin** | **132 days** | **Mon 4/13/09** | **Tue 10/13/09** |
| 110 | **Metal Stud Backup** | **74 days** | **Mon 4/13/09** | **Thu 7/23/09** |
| 111 | Install EXT. Metal Stud 2nd Floor North | 7 days | Mon 4/13/09 | Tue 4/21/09 |
| 112 | Install EXT. Metal Stud 3rd Floor North | 8 days | Mon 4/20/09 | Wed 4/29/09 |
| 113 | Install EXT. Metal Stud 2nd Floor South | 7 days | Mon 4/27/09 | Tue 5/5/09 |
| 114 | Install EXT. Metal Stud 3rd Floor South | 8 days | Mon 4/27/09 | Wed 5/6/09 |
| 115 | Install EXT. Metal Stud 1st Floor North & South | 10 days | Tue 5/12/09 | Mon 5/25/09 |
| 116 | Install EXT. Metal Stud 5th Floor | 10 days | Fri 6/12/09 | Thu 6/25/09 |
| 117 | Install EXT. Metal Stud 4th & 5th Floor | 10 days | Mon 6/22/09 | Fri 7/3/09 |
| 118 | Frame EXT Soffits Roof North & South | 18 days | Tue 6/30/09 | Thu 7/23/09 |
| 119 | **Masonry/Stucco Backup (Floor Sequencing is the same a** | **112 days** | **Mon 5/11/09** | **Tue 10/13/09** |
| 120 | Install Sheathing | 40 days | Mon 5/11/09 | Fri 7/3/09 |
| 121 | Install Air Barrier | 30 days | Thu 6/4/09 | Wed 7/15/09 |
| 122 | Install Cement Board | 36 days | Fri 6/19/09 | Fri 8/7/09 |
| 123 | Install GFCMU | 49 days | Thu 6/11/09 | Tue 8/18/09 |
| 124 | Apply Stucco | 52 days | Mon 8/3/09 | Tue 10/13/09 |
| 125 | **Glass/Glazing** | **32 days** | **Mon 7/13/09** | **Wed 8/26/09** |
| 126 | Install Storefront | 21 days | Mon 7/13/09 | Mon 8/10/09 |
| 127 | Install Punch Windows | 14 days | Wed 7/22/09 | Mon 8/10/09 |
| 128 | Install Curtain Wall | 5 days | Fri 8/14/09 | Thu 8/20/09 |
| 129 | Pressbox Water Tight | 0 days | Wed 8/26/09 | Wed 8/26/09 |
| 130 | **Roofing** | **86 days** | **Wed 4/29/09** | **Wed 8/26/09** |
| 131 | Install Roof Drains | 11 days | Wed 4/29/09 | Wed 5/13/09 |
| 132 | Metal Framing | 5 days | Tue 5/19/09 | Mon 5/25/09 |
| 133 | Install Roof Curbs | 5 days | Tue 5/19/09 | Mon 5/25/09 |
| 134 | Plywood Blocking | 3 days | Thu 5/28/09 | Mon 6/1/09 |
| 135 | Metal Panels | 15 days | Fri 6/5/09 | Thu 6/25/09 |
| 136 | Install Roofing | 25 days | Thu 7/23/09 | Wed 8/26/09 |
| 137 | **Phase 3-Interiors** | **204 days** | **Thu 2/26/09** | **Tue 12/8/09** |
| 138 | **LV1 North** | **133 days** | **Mon 5/11/09** | **Wed 11/11/09** |
| 139 | Install Ductwork | 11 days | Mon 5/11/09 | Mon 5/25/09 |
| 140 | Electrical Conduit R/I | 13 days | Mon 5/11/09 | Wed 5/27/09 |
| 141 | Install Plumbing | 16 days | Mon 5/11/09 | Mon 6/1/09 |
| 142 | Interior Wall Framing | 5 days | Tue 5/12/09 | Mon 5/18/09 |
| 143 | Pull Wire (tele/data/audio visual/ security | 12 days | Wed 5/27/09 | Thu 6/11/09 |
| 144 | Pull Wire (fire alarm/ light & power) | 10 days | Tue 6/9/09 | Mon 6/22/09 |
| 145 | Insulate Plumbing Pipe | 4 days | Thu 7/2/09 | Tue 7/7/09 |
| 146 | Install Fire Protection | 7 days | Thu 7/2/09 | Fri 7/10/09 |
| 147 | Hydrotest Fire Protection | 2 days | Tue 7/14/09 | Wed 7/15/09 |
| 148 | Insulate Ductwork | 5 days | Wed 7/15/09 | Tue 7/21/09 |
| 149 | Install HVAC | 13 days | Wed 7/15/09 | Fri 7/31/09 |
| 150 | Frame Ceilings/ Bulkheads | 7 days | Mon 8/3/09 | Tue 8/11/09 |
| 151 | Electrical R/I @ Ceilings | 3 days | Mon 8/10/09 | Wed 8/12/09 |
| 152 | Install Insulation/Plywood/ Drywall | 2 days | Wed 8/12/09 | Thu 8/13/09 |
| 153 | Ceiling Close-In Inspection | 2 days | Thu 8/13/09 | Fri 8/14/09 |
| 154 | Hang, Finish, and Paint Drywall Walls | 19 days | Tue 8/18/09 | Fri 9/11/09 |
| 155 | Install Ceiling Grid/Tile | 11 days | Wed 9/9/09 | Wed 9/23/09 |
| 156 | Install Sprinkler Heads | 5 days | Mon 9/14/09 | Fri 9/18/09 |
| 157 | HVAC G/R/D's | 5 days | Mon 9/14/09 | Fri 9/18/09 |
| 158 | Install Light Fixtures | 5 days | Mon 9/21/09 | Fri 9/25/09 |
| 159 | Install Flooring | 26 days | Wed 9/30/09 | Wed 11/4/09 |
| 160 | Final Paint | 20 days | Wed 9/30/09 | Tue 10/27/09 |
| 161 | Install Tiolet Partitions | 8 days | Mon 10/12/09 | Wed 10/21/09 |
| 162 | Install Doors & Hardware | 5 days | Thu 10/22/09 | Wed 10/28/09 |



Project: Detailed Project Schedule.mp
Date: Wed 10/28/09

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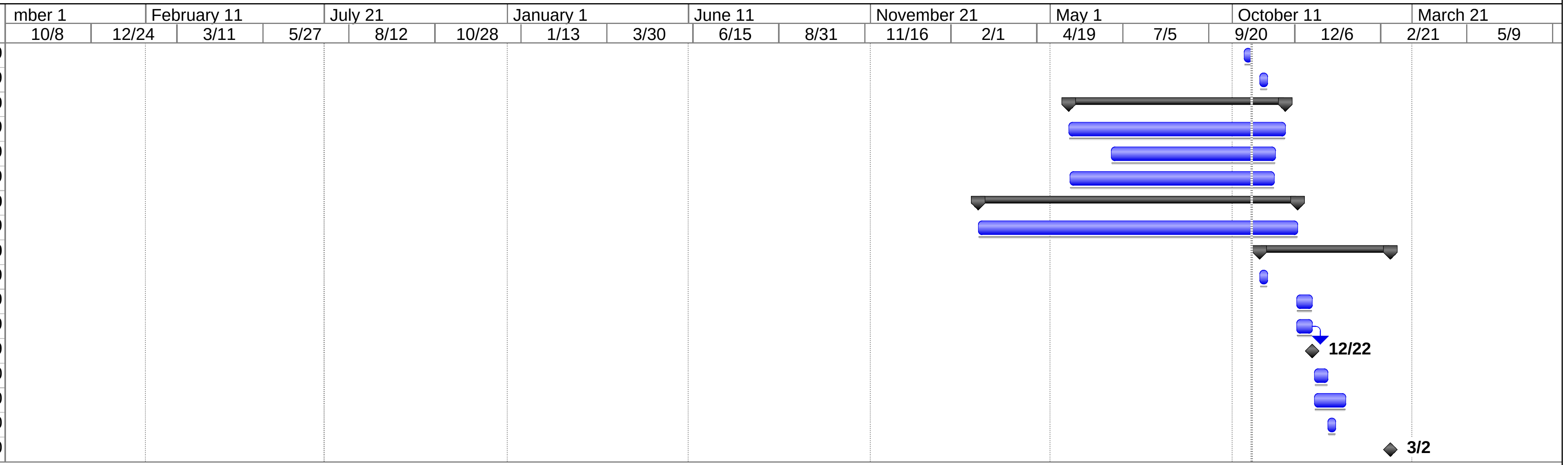
|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Progress | ▬ | Summary | ▬ | External Tasks | ▬ | Deadline | ⇩ |
| Split | ┄ | Milestone | ◆ | Project Summary | ▬ | External Milestone | ◆ | | |

Steven Rogers

Loyola IAC Detailed Project Schedule

| ID | Task Name | Duration | Early Start | Early Finish |
|---|---|---|---|---|
| 163 | Final Trimout | 5 days | Thu 10/22/09 | Wed 10/28/09 |
| 164 | Punchlists | 5 days | Thu 11/5/09 | Wed 11/11/09 |
| 165 | **LV1 South** | **140 days** | **Mon 5/18/09** | **Fri 11/27/09** |
| 166 | Similar Seq. as LV1 North | 140 days | Mon 5/18/09 | Fri 11/27/09 |
| 167 | Main Electrical Room | 105 days | Thu 6/25/09 | Wed 11/18/09 |
| 168 | Main Mechanical Room | 131 days | Tue 5/19/09 | Tue 11/17/09 |
| 169 | **LV2 North & South, LV3 North & South, LV4 North & Sou** | **204 days** | **Thu 2/26/09** | **Tue 12/8/09** |
| 170 | Similar Seq. as LV1 North | 204 days | Thu 2/26/09 | Tue 12/8/09 |
| 171 | **Phase 3-Final Completion** | **83 days** | **Thu 11/5/09** | **Tue 3/2/10** |
| 172 | Sitework & EXT Work | 5 days | Thu 11/5/09 | Wed 11/11/09 |
| 173 | Final Inspections | 10 days | Tue 12/8/09 | Mon 12/21/09 |
| 174 | Final Commissioning | 10 days | Tue 12/8/09 | Mon 12/21/09 |
| 175 | Substantial Completion | 0 days | Tue 12/22/09 | Tue 12/22/09 |
| 176 | Final Building Clean | 8 days | Thu 12/24/09 | Mon 1/4/10 |
| 177 | Final Punchlist | 20 days | Thu 12/24/09 | Wed 1/20/10 |
| 178 | Owner Training | 5 days | Tue 1/5/10 | Mon 1/11/10 |
| 179 | Occupancy | 0 days | Tue 3/2/10 | Tue 3/2/10 |



Project: Detailed Project Schedule.mp
Date: Wed 10/28/09

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Progress | ▬ | Summary | ▬ | External Tasks | ▬ | Deadline | ⇩ |
| Split | ┈ | Milestone | ◆ | Project Summary | ▬ | External Milestone | ◇ | | |

Steven Rogers

# Appendix F

# D4 Cost Estimate

# Statement of Probable Cost

Loyola IAC - Jan 2007 - MD - Baltimore

| | | | |
|---|---|---|---|
| Prepared By: | **Steven Rogers**<br>**AE Senior Thesis: Class of 2010**<br>**232 E. Fairmount Ave.**<br>**State College, PA 16801**<br>**724-953-3014 Fax:** | Prepared For: | **Faculty Consultant: Dr. Riley**<br>**AE Faculty**<br>**104 Engineering Unit A**<br>**University Park, PA 16802**<br>**814-865-6394 Fax:** |
| Building Sq. Size: | **41520** | Site Sq. Size: | **72** |
| Bid Date: | | Building use: | |
| No. of floors: | **4** | Foundation: | **CAS** |
| No. of buildings: | **1** | Exterior Walls: | **CMU** |
| Project Height: | **65.4** | Interior Walls: | **GYP** |
| 1st Floor Height: | | Roof Type: | **EPD** |
| 1st Floor Size: | | Floor Type: | **CON** |
| | | Project Type: | **NEW** |

| Division | | Percent | Sq. Cost | Amount |
|---|---|---|---|---|
| **00** | **Bidding Requirements** | **0.00** | **0.00** | **0** |
| **01** | **General Requirements** | **10.06** | **51.08** | **2,120,831** |
| | General Requirements | 10.06 | 51.08 | 2,120,831 |
| **02** | **Site Work** | **0.00** | **0.00** | **0** |
| **03** | **Concrete** | **12.41** | **63.01** | **2,616,354** |
| | Concrete | 12.41 | 63.01 | 2,616,354 |
| **04** | **Masonry** | **2.26** | **11.49** | **477,250** |
| | Masonry | 2.26 | 11.49 | 477,250 |
| **05** | **Metals** | **21.08** | **107.06** | **4,445,042** |
| | Structural Steel | 16.07 | 81.62 | 3,389,035 |
| | Miscellaneous Steel | 5.01 | 25.43 | 1,056,007 |
| **06** | **Wood & Plastics** | **1.57** | **7.96** | **330,475** |
| | Finish Carpentry | 1.25 | 6.36 | 263,875 |
| | Wood Lockers | 0.32 | 1.60 | 66,600 |
| **07** | **Thermal & Moisture Protection** | **6.00** | **30.45** | **1,264,122** |
| | Waterproofing | 0.64 | 3.23 | 134,100 |
| | Stucco System | 2.37 | 12.06 | 500,716 |
| | Fireproofing | 0.84 | 4.26 | 177,000 |
| | Expansion Joint System | 0.59 | 3.01 | 125,056 |
| | Caulking | 0.24 | 1.23 | 50,900 |
| | Roofing | 1.31 | 6.66 | 276,350 |
| **08** | **Doors & Windows** | **5.16** | **26.21** | **1,088,084** |
| | Glass and Glazing | 1.99 | 10.12 | 420,184 |
| | Sliding Glass Doors | 0.62 | 3.16 | 131,408 |
| | Doors and Hardware | 1.53 | 7.76 | 322,300 |
| | Misc. | 1.02 | 5.16 | 214,192 |
| **09** | **Finishes** | **9.67** | **49.11** | **2,039,210** |
| | Drywall | 5.87 | 29.82 | 1,237,970 |
| | Flooring | 2.55 | 12.97 | 538,540 |
| | Paint | 1.25 | 6.33 | 262,700 |
| **10** | **Specialties** | **0.54** | **2.72** | **113,130** |
| | Visual Display Surfaces | 0.06 | 0.29 | 12,000 |
| | Metal Lockers | 0.06 | 0.33 | 13,575 |
| | Misc. | 0.42 | 2.11 | 87,555 |
| **11** | **Equipment** | **0.04** | **0.22** | **9,309** |
| | Locker Room Clocks | 0.03 | 0.16 | 6,500 |
| | Ceiling Mounted Projector w/ Controls | 0.01 | 0.07 | 2,809 |
| **12** | **Furnishings** | **0.01** | **0.03** | **1,175** |
| | Sun Shades | 0.01 | 0.03 | 1,175 |

| | | | | |
|---|---|---|---|---|
| **13** | **Special Construction** | **5.27** | **26.74** | **1,110,165** |
| | Fixed Grandstands | 5.27 | 26.74 | 1,110,165 |
| **14** | **Conveying Systems** | **0.65** | **3.31** | **137,300** |
| | Elevator | 0.65 | 3.31 | 137,300 |
| **15** | **Mechanical** | **18.07** | **91.78** | **3,810,544** |
| | Fire Protection | 0.99 | 5.00 | 207,750 |
| | Plumbing & HVAC | 17.09 | 86.77 | 3,602,794 |
| **16** | **Electrical** | **7.22** | **36.66** | **1,522,280** |
| | Electrical | 7.22 | 36.66 | 1,522,280 |
| **Total Building Costs** | | **100.00** | **507.83** | **21,085,271** |
| **Total Non-Building Costs** | | **100.00** | **0.00** | **0** |
| **Total Project Costs** | | **--** | **--** | **21,085,271** |

# Appendix G

# RS Means Square Foot Estimate

# Square Foot Cost Estimate Report

| | |
|---|---|
| Estimate Name: | **Untitled** |

| | |
|---|---|
| Building Type: | **Gymnasium with Face Brick with Concrete Block Back-up / Rigid Steel Frame** |
| Location: | National Average |
| Stories Count (L.F.): | **4.00** |
| Stories Height | **79.50** |
| Floor Area (S.F.): | **41,520.00** |
| LaborType | **Union** |
| Basement Included: | No |
| Data Release: | **Year 2009** |
| Cost Per Square Foot | **$546.71** |
| Total Building Cost | **$22,699,500** |

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.
**Parameters are not within the ranges recommended byRSMeans.**

| | | % of Total | Cost Per SF | Cost |
|---|---|---|---|---|
| **A Substructure** | | **1.1%** | **4.37** | **$181,500** |
| **A1010** | **Standard Foundations** | | **1.37** | **$57,000** |
| | Strip footing, concrete, reinforced, load 11.1 KLF, soil bearing capacity 6 KSF, 12" deep x 24" wide | | | |
| | spread footings, 3000 PSI concrete, load 50K, soil bearing capacity 3 KSF, 4' - 6" square x 12" deep | | | |
| | spread footings, 3000 PSI concrete, load 50K, soil bearing capacity 6 KSF, 3' - 0" square x 12" deep | | | |
| **A1030** | **Slab on Grade** | | **1.18** | **$49,000** |
| | Slab on grade, 4" thick, non industrial, reinforced | | | |
| **A2010** | **Basement Excavation** | | **0.05** | **$2,000** |
| | Excavate and fill, 30,000 SF, 4' deep, sand, gravel, or common earth, on site storage | | | |
| **A2020** | **Basement Walls** | | **1.77** | **$73,500** |
| | Foundation wall, CIP, 4' wall height, direct chute, .099 CY/LF, 4.8 PLF, 8" thick | | | |
| **B Shell** | | **67.6%** | **276.16** | **$11,466,000** |
| **B1020** | **Roof Construction** | | **16.17** | **$671,500** |
| | Steel frame for 1 story buildings, 60 - 100' span | | | |
| | Steel deck, 3" deep, 16 ga, single 20' span, 6.0 PSF, 40 PSF superimposed load | | | |
| **B2010** | **Exterior Walls** | | **223.62** | **$9,284,500** |
| | Brick wall, composite double wythe, standard face/CMU back-up, 8" thick, perlite core fill | | | |
| **B2020** | **Exterior Windows** | | **34.63** | **$1,438,000** |
| | Windows, aluminum, awning, standard glass, 3'-1" x 3'-2" | | | |
| **B2030** | **Exterior Doors** | | **0.52** | **$21,500** |
| | Door, aluminum & glass, sliding patio, tempered glass, economy, 6'-0" x 7'-0" opening | | | |
| | Door, wood, overhead, panels, heavy duty, manual operation, 10'-0" x 10'-0" opening | | | |
| | Door, steel 24 gauge, overhead, sectional, manual operation, 10'-0" x 10'-0" opening | | | |
| **B3010** | **Roof Coverings** | | **1.22** | **$50,500** |
| | Drip edge, aluminum .016" thick, 5" girth, mill finish | | | |
| | Roofing, single ply membrane, EPDM, 60 mils, fully adhered | | | |
| | Insulation, rigid, roof deck, polyisocyanurate, 2#/CF, 3.5" thick, R25 | | | |
| **C Interiors** | | **9.3%** | **38.02** | **$1,578,500** |

|  |  | % of Total | Cost Per SF | Cost |
|---|---|---|---|---|
| **C1010** | **Partitions** |  | **1.69** | **$70,000** |
|  | Concrere block (CMU) partition, light weight, hollow, 6" thick, no finish |  |  |  |
| **C1020** | **Interior Doors** |  | **1.75** | **$72,500** |
|  | Door, single leaf, kd steel frame, hollow metal, commercial quality, flush, 3'-0" x 7'-0" x 1-3/8" |  |  |  |
| **C1030** | **Fittings** |  | **0.22** | **$9,000** |
|  | Toilet partitions, cubicles, ceiling hung, stainless steel |  |  |  |
| **C3010** | **Wall Finishes** |  | **19.20** | **$797,000** |
|  | 2 coats paint on masonry with block filler |  |  |  |
|  | Painting, masonry or concrete, latex, brushwork, primer & 2 coats |  |  |  |
|  | Ceramic tile, thin set, 4-1/4" x 4-1/4" |  |  |  |
| **C3020** | **Floor Finishes** |  | **14.22** | **$590,500** |
|  | Tile, ceramic natural clay |  |  |  |
|  | Maple strip, sanded and finished, maximum |  |  |  |
|  | Add for sleepers on concrete, treated, 24" OC, 1"x2" |  |  |  |
| **C3030** | **Ceiling Finishes** |  | **0.95** | **$39,500** |
|  | Acoustic ceilings, 3/4"mineral fiber, 12" x 12" tile, concealed 2" bar & channel grid, suspended support |  |  |  |
| **D Services** |  | **7.8%** | **32.00** | **$1,328,500** |
| **D2010** | **Plumbing Fixtures** |  | **5.52** | **$229,000** |
|  | Water closet, vitreous china, bowl only with flush valve, wall hung |  |  |  |
|  | Urinal, vitreous china, wall hung |  |  |  |
|  | Lavatory w/trim, wall hung, PE on CI, 19" x 17" |  |  |  |
|  | Service sink w/trim, PE on CI, corner floor, wall hung w/rim guard, 24" x 20" |  |  |  |
|  | Shower, stall, baked enamel, terrazzo receptor, 36" square |  |  |  |
|  | Water cooler, electric, wall hung, dual height, 14.3 GPH |  |  |  |
| **D2020** | **Domestic Water Distribution** |  | **2.38** | **$99,000** |
|  | Electric water heater, commercial, 100< F rise, 500 gal, 240 KW 984 GPH |  |  |  |
| **D3050** | **Terminal & Package Units** |  | **10.34** | **$429,500** |
|  | Rooftop, single zone, air conditioner, banks or libraries, 10,000 SF, 41.67 ton |  |  |  |
| **D4010** | **Sprinklers** |  | **2.77** | **$115,000** |
|  | Wet pipe sprinkler systems, steel, light hazard, 1 floor, 10,000 SF |  |  |  |
| **D5010** | **Electrical Service/Distribution** |  | **0.48** | **$20,000** |
|  | Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 400 A |  |  |  |
|  | Feeder installation 600 V, including RGS conduit and XHHW wire, 400 A |  |  |  |
|  | Switchgear installation, incl switchboard, panels & circuit breaker, 400 A |  |  |  |
| **D5020** | **Lighting and Branch Wiring** |  | **8.49** | **$352,500** |
|  | Receptacles incl plate, box, conduit, wire, 8 per 1000 SF, .9 watts per SF |  |  |  |
|  | Wall switches, 1.0 per 1000 SF |  |  |  |
|  | Miscellaneous power, 1 watt |  |  |  |
|  | Central air conditioning power, 4 watts |  |  |  |
|  | Fluorescent fixtures recess mounted in ceiling, 2 watt per SF, 40 FC, 10 fixtures @40 watt per 1000 SF |  |  |  |
| **D5030** | **Communications and Security** |  | **1.82** | **$75,500** |
|  | Communication and alarm systems, includes outlets, boxes, conduit and wire, sound systems, 12 outlets |  |  |  |
|  | Communication and alarm systems, fire detection, non-addressable, 25 detectors, includes outlets, boxes, conduit a |  |  |  |
| **D5090** | **Other Electrical Systems** |  | **0.19** | **$8,000** |
|  | Generator sets, w/battery, charger, muffler and transfer switch, gas/gasoline operated, 3 phase, 4 wire, 277/480 V, 7 |  |  |  |
| **E Equipment & Furnishings** |  | **14.2%** | **58.21** | **$2,417,000** |
| **E1090** | **Other Equipment** |  | **58.21** | **$2,417,000** |
|  | 10 - Sound system, amplifier, 250 W |  |  |  |
|  | 200 - Lockers, steel, baked enamel, single tier, maximum |  |  |  |
|  | 2 - School equipment, scoreboards, basketball, one side, maximum |  |  |  |

|  | % of Total | Cost Per SF | Cost |
|---|---|---|---|
| 6900 - Bleachers, telescoping, school equipment, manual, 21 to 30 tier, maximum |  |  |  |
| Architectural equipment, school equipment bleachers-telescoping, manual operation, 15 tier, economy (per seat) |  |  |  |
| Architectural equipment, school equipment, weight lifting gym, universal, deluxe |  |  |  |
| Architectural equipment, sauna, prefabricated, including heater and controls, 7' high, 6' x 4' |  |  |  |
| **F Special Construction** | **0.0%** | **0.00** | **$0** |
| **G Building Sitework** | **0.0%** | **0.00** | **$0** |
| **Sub Total** | **100%** | **$408.75** | **$16,971,500** |
| **Contractor's Overhead & Profit** | **25.0%** | **$102.19** | **$4,243,000** |
| **Architectural Fees** | **7.0%** | **$35.77** | **$1,485,000** |
| **User Fees** | **0.0%** | **$0.00** | **$0** |
| **Total Building Cost** |  | **$546.71** | **$22,699,500** |

# Appendix H

# General Conditions Estimate

# GENERAL CONDITIONS

## Loyola College - Athletic Complex

| CODE | DESCRIPTION | DURATION | UNIT COST | Budget TOTAL | General Conditions |
|---|---|---|---|---|---|
| 100000 | Mobilization | 2 Ea | $ 3,500.00 | $ 7,000 | |
| 100002 | Move Trailer In/Out | 6 Ea | $ 500.00 | $ 3,000 | |
| 100007 | Misc. Charges-Yard | 12 Mos | $ 500.00 | $ 6,000 | |
| 110001 | Small Tools & Equipment | 12 Mos | $ 750.00 | $ 9,000 | |
| 110002 | Miscellaneous Supplies | 12 Mos | $ 750.00 | $ 9,000 | |
| 110005 | Computer Equipment | 12 Mos | $ 300.00 | $ 3,600 | |
| 110007 | Office Equipment | 12 Mos | $ 650.00 | $ 7,800 | |
| 110009 | Computer Supplies | 1 ls | $ 3,500.00 | $ 3,500 | |
| 120001 | Drawings & Specs. | 12 Mos | $ 450.00 | $ 5,400 | |
| 120006 | Shop Drawings & Samples | 12 Mos | $ 350.00 | $ 4,200 | |
| 120008 | As-Built Drawings | 1 ls | $ 15,000.00 | $ 15,000 | |
| 120013 | Pest Control | 12 Mos | $ 450.00 | $ 5,400 | |
| 122000 | Postage | 12 Mos | $ 250.00 | $ 3,000 | |
| 123100 | Equipment Rental | 12 Mos | $ 500.00 | $ 6,000 | |
| 123150 | Trailer Rental | 12 Mos | $ 1,200.00 | $ 14,400 | |
| 123500 | PC Rental | 12 Mos | $ 2,500.00 | $ 30,000 | |
| 123600 | PC support | 12 Mos | $ 250.00 | $ 3,000 | |
| 130003 | Superintendent 4 | 12 Mos | $ 16,521.00 | $ 198,252 | |
| 130003 | Superintendent 2 | 12 Mos | $ 10,500.00 | $ 126,000 | |
| 130004 | Superintendent 1 | 8 Mos | $ 9,620.00 | $ 76,960 | |
| 130006 | QC Coordinator | 12 Mos | $ 9,620.00 | $ 115,440 | |
| 130008 | Secretary | 12 Mos | $ 5,600.00 | $ 67,200 | |
| 130009 | Guard Service | 12 Mos | $ 7,000.00 | $ 84,000 | |
| 130013 | Sr PM | 12 Mos | $ 16,207.00 | $ 194,484 | |
| 130016 | Labor Charges - Yard | 12 LS | $ 250.00 | $ 3,000 | |
| 130024 | PM | 12 Mos | $ 10,835.00 | $ 130,020 | |
| 130024 | PM | 8 Mos | $ 10,835.00 | $ 86,680 | |
| 130025 | PE | 12 Mos | $ 9,620.00 | $ 115,440 | |
| 130025 | PE | 8 Mos | $ 9,620.00 | $ 76,960 | |
| 130026 | Intern | 12 Mos | $ 5,800.00 | $ 69,600 | |
| 140001 | Access Road/Traf. Mt. | 1 ls | $ 12,500.00 | $ 12,500 | |
| 140002 | Safety & Barricades | 12 Mos | $ 400.00 | $ 4,800 | |
| 140004 | Temp. Ladders/Stairs | 1 ls | $ 5,500.00 | $ 5,500 | |
| 140007 | Weather/Dust Protect | 1 ls | $ 6,500.00 | $ 6,500 | |
| 140008 | Project Signs | 1 Ls | $ 6,500.00 | $ 6,500 | |
| 140009 | Construction Fence | 12 Mos | $ 750.00 | $ 9,000 | |
| 140010 | Mucking & Pumping | 12 Mos | $ 650.00 | $ 7,800 | |
| 140011 | Maintenance Of Traffic | 1 ls | $ 3,500.00 | $ 3,500 | |
| 150001 | Progress Photos | 24 Mos | $ 200.00 | $ 4,800 | |
| 150002 | Completion Photos | 1 Ls | $ 5,000.00 | $ 5,000 | |
| 150003 | Schedules & Reports | 1 ls | $ 12,500.00 | $ 12,500 | |
| 150008 | NEXTELS | 12 Mos | $ 90.00 | $ 1,080 | |
| 150010 | C.M. Reimbursable | 1 Ls | $ 3,500.00 | $ 3,500 | |
| 160006 | Telephone Charges | 27 Mos | $ 175.00 | $ 4,725 | |
| 160007 | Temporary Electric Service | 1 ls | $ 20,000.00 | $ 20,000 | |
| 160008 | Temporary Electric Charges | 1 s | $ 40,000.00 | $ 40,000 | |
| 160009 | Temporary Water | 12 Mos | $ 150.00 | $ 1,800 | |

| CODE | DESCRIPTION | DURATION | UNIT COST | Budget TOTAL | General Conditions |
|---|---|---|---|---|---|
| 160011 | Sanitary Facilities | 12 Mos | $ 600.00 | $ 7,200 | |
| 160021 | Temporary Lighting | 12 Mos | $ 350.00 | $ 4,200 | |
| 160023 | Security/Alarm System | 12 Mos | $ 450.00 | $ 5,400 | |
| 170001 | Daily Clean Up (Laborer FT) | 12 mos | $ 3,700.00 | $ 44,400 | |
| 170004 | Snow Removal | 1 ls | | $ 7,500 | |
| 180000 | Travel & Subsistence | 12 Mos | $ 350.00 | $ 4,200 | |
| | Total | | $ | 1,701,741 | |

# Appendix I

# Registered Project Checklist

# LEED 2009 for New Construction and Major Renovation

Project Checklist

Loyola Intercollegiate Athletic Complex
4/1/2010

| | | | | | |
|---|---|---|---|---|---|
| 17 | 0 | 9 | **Sustainable Sites** | Possible Points: | **26** |
| Y | N | ? | | | |
| **Y** | | | Prereq 1 | Construction Activity Pollution Prevention | |
| **1** | | | Credit 1 | Site Selection | 1 |
| **5** | | | Credit 2 | Development Density and Community Connectivity | 5 |
| **1** | | | Credit 3 | Brownfield Redevelopment | 1 |
| **6** | | | Credit 4.1 | Alternative Transportation—Public Transportation Access | 6 |
| **1** | | | Credit 4.2 | Alternative Transportation—Bicycle Storage and Changing Rooms | 1 |
| | | **3** | Credit 4.3 | Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles | 3 |
| | | **2** | Credit 4.4 | Alternative Transportation—Parking Capacity | 2 |
| **1** | | | Credit 5.1 | Site Development—Protect or Restore Habitat | 1 |
| **1** | | | Credit 5.2 | Site Development—Maximize Open Space | 1 |
| **1** | | | Credit 6.1 | Stormwater Design—Quantity Control | 1 |
| | | **1** | Credit 6.2 | Stormwater Design—Quality Control | 1 |
| | | **1** | Credit 7.1 | Heat Island Effect—Non-roof | 1 |
| | | **1** | Credit 7.2 | Heat Island Effect—Roof | 1 |
| | | **1** | Credit 8 | Light Pollution Reduction | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | 0 | 4 | **Water Efficiency** | Possible Points: | **10** |
| **Y** | | | Prereq 1 | Water Use Reduction—20% Reduction | |
| **2** | | **2** | Credit 1 | Water Efficient Landscaping | 2 to 4 |
| | | | | ☒ Reduce by 50% | 2 |
| | | | | ☐ No Potable Water Use or Irrigation | 4 |
| **2** | | | Credit 2 | Innovative Wastewater Technologies | 2 |
| **2** | | **2** | Credit 3 | Water Use Reduction | 2 to 4 |
| | | | | ☒ Reduce by 30% | 2 |
| | | | | ☐ Reduce by 35% | 3 |
| | | | | ☐ Reduce by 40% | 4 |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| **4** | **0** | **31** | **Energy and Atmosphere** | Possible Points: | **35** |
| **Y** |  |  | Prereq 1 | Fundamental Commissioning of Building Energy Systems |  |
| **Y** |  |  | Prereq 2 | Minimum Energy Performance |  |
| **Y** |  |  | Prereq 3 | Fundamental Refrigerant Management |  |
|  |  | **19** | Credit 1 | Optimize Energy Performance | 1 to 19 |
|  |  |  |  | ☐ Improve by 12% for New Buildings or 8% for Existing Building Renovations | 1 |
|  |  |  |  | ☐ Improve by 14% for New Buildings or 10% for Existing Building Renovations | 2 |
|  |  |  |  | ☐ Improve by 16% for New Buildings or 12% for Existing Building Renovations | 3 |
|  |  |  |  | ☐ Improve by 18% for New Buildings or 14% for Existing Building Renovations | 4 |
|  |  |  |  | ☐ Improve by 20% for New Buildings or 16% for Existing Building Renovations | 5 |
|  |  |  |  | ☐ Improve by 22% for New Buildings or 18% for Existing Building Renovations | 6 |
|  |  |  |  | ☐ Improve by 24% for New Buildings or 20% for Existing Building Renovations | 7 |
|  |  |  |  | ☐ Improve by 26% for New Buildings or 22% for Existing Building Renovations | 8 |
|  |  |  |  | ☐ Improve by 28% for New Buildings or 24% for Existing Building Renovations | 9 |
|  |  |  |  | ☐ Improve by 30% for New Buildings or 26% for Existing Building Renovations | 10 |
|  |  |  |  | ☐ Improve by 32% for New Buildings or 28% for Existing Building Renovations | 11 |
|  |  |  |  | ☐ Improve by 34% for New Buildings or 30% for Existing Building Renovations | 12 |
|  |  |  |  | ☐ Improve by 36% for New Buildings or 32% for Existing Building Renovations | 13 |
|  |  |  |  | ☐ Improve by 38% for New Buildings or 34% for Existing Building Renovations | 14 |
|  |  |  |  | ☐ Improve by 40% for New Buildings or 36% for Existing Building Renovations | 15 |
|  |  |  |  | ☐ Improve by 42% for New Buildings or 38% for Existing Building Renovations | 16 |
|  |  |  |  | ☐ Improve by 44% for New Buildings or 40% for Existing Building Renovations | 17 |
|  |  |  |  | ☐ Improve by 46% for New Buildings or 42% for Existing Building Renovations | 18 |
|  |  |  |  | ☐ Improve by 48%+ for New Buildings or 44%+ for Existing Building Renovations | 19 |
|  |  | **7** | Credit 2 | On-Site Renewable Energy | 1 to 7 |
|  |  |  |  | ☐ 1% Renewable Energy | 1 |
|  |  |  |  | ☐ 3% Renewable Energy | 2 |
|  |  |  |  | ☐ 5% Renewable Energy | 3 |
|  |  |  |  | ☐ 7% Renewable Energy | 4 |
|  |  |  |  | ☐ 9% Renewable Energy | 5 |
|  |  |  |  | ☐ 11% Renewable Energy | 6 |
|  |  |  |  | ☐ 13% Renewable Energy | 7 |
| **2** |  |  | Credit 3 | Enhanced Commissioning | 2 |
| **2** |  |  | Credit 4 | Enhanced Refrigerant Management | 2 |
|  |  | **3** | Credit 5 | Measurement and Verification | 3 |
|  |  | **2** | Credit 6 | Green Power | 2 |

| | | | | | |
|---|---|---|---|---|---|
| 9 | 0 | 5 | | **Materials and Resources** | Possible Points: **14** |
| Y | | | Prereq 1 | Storage and Collection of Recyclables | |
| | | 3 | Credit 1.1 | Building Reuse—Maintain Existing Walls, Floors, and Roof | 1 to 3 |
| | | | | ☐ Reuse 55% | 1 |
| | | | | ☐ Reuse 75% | 2 |
| | | | | ☐ Reuse 95% | 3 |
| | | 1 | Credit 1.2 | Building Reuse—Maintain 50% of Interior Non-Structural Elements | 1 |
| 2 | | | Credit 2 | Construction Waste Management | 1 to 2 |
| | | | | ☐ 50% Recycled or Salvaged | 1 |
| | | | | ☒ 75% Recycled or Salvaged | 2 |
| 2 | | | Credit 3 | Materials Reuse | 1 to 2 |
| | | | | ☐ Reuse 5% | 1 |
| | | | | ☒ Reuse 10% | 2 |
| 2 | | | Credit 4 | Recycled Content | 1 to 2 |
| | | | | ☐ 10% of Content | 1 |
| | | | | ☒ 20% of Content | 2 |
| 2 | | | Credit 5 | Regional Materials | 1 to 2 |
| | | | | ☐ 10% of Materials | 1 |
| | | | | ☒ 20% of Materials | 2 |
| 1 | | | Credit 6 | Rapidly Renewable Materials | 1 |
| | | 1 | Credit 7 | Certified Wood | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 12 | 0 | 3 | | **Indoor Environmental Quality** | Possible Points: **15** |
| Y | | | Prereq 1 | Minimum Indoor Air Quality Performance | |
| Y | | | Prereq 2 | Environmental Tobacco Smoke (ETS) Control | |
| 1 | | | Credit 1 | Outdoor Air Delivery Monitoring | 1 |
| 1 | | | Credit 2 | Increased Ventilation | 1 |
| 1 | | | Credit 3.1 | Construction IAQ Management Plan—During Construction | 1 |
| 1 | | | Credit 3.2 | Construction IAQ Management Plan—Before Occupancy | 1 |
| 1 | | | Credit 4.1 | Low-Emitting Materials—Adhesives and Sealants | 1 |
| 1 | | | Credit 4.2 | Low-Emitting Materials—Paints and Coatings | 1 |
| 1 | | | Credit 4.3 | Low-Emitting Materials—Flooring Systems | 1 |
| 1 | | | Credit 4.4 | Low-Emitting Materials—Composite Wood and Agrifiber Products | 1 |
| | | 1 | Credit 5 | Indoor Chemical and Pollutant Source Control | 1 |
| 1 | | | Credit 6.1 | Controllability of Systems—Lighting | 1 |
| 1 | | | Credit 6.2 | Controllability of Systems—Thermal Comfort | 1 |
| 1 | | | Credit 7.1 | Thermal Comfort—Design | 1 |
| 1 | | | Credit 7.2 | Thermal Comfort—Verification | 1 |
| | | 1 | Credit 8.1 | Daylight and Views—Daylight | 1 |
| | | 1 | Credit 8.2 | Daylight and Views—Views | 1 |

| | | | | | |
|---|---|---|---|---|---|
| **1** | **5** | **0** | **Innovation and Design Process** | | Possible Points: **6** |
| | **1** | | Credit 1.1 | Innovation in Design: Specific Title | 1 |
| | **1** | | Credit 1.2 | Innovation in Design: Specific Title | 1 |
| | **1** | | Credit 1.3 | Innovation in Design: Specific Title | 1 |
| | **1** | | Credit 1.4 | Innovation in Design: Specific Title | 1 |
| | **1** | | Credit 1.5 | Innovation in Design: Specific Title | 1 |
| **1** | | | Credit 2 | LEED Accredited Professional | 1 |
| **0** | **4** | **0** | **Regional Priority Credits** | | Possible Points: **4** |
| | **1** | | Credit 1.1 | Regional Priority: Specific Credit | 1 |
| | **1** | | Credit 1.2 | Regional Priority: Specific Credit | 1 |
| | **1** | | Credit 1.3 | Regional Priority: Specific Credit | 1 |
| | **1** | | Credit 1.4 | Regional Priority: Specific Credit | 1 |
| 49 | 9 | 52 | **Total** | | Possible Points: **110** |

**Certified 40 to 49 points** **Silver 50 to 59 points** **Gold 60 to 79 points** **Platinum 80 to 110**

# Appendix J

# Precast Cost and Schedule Analysis

| | MSC | Loyola IAC (Original) | Loyola IAC (Prefabricated Wall) |
|---|---|---|---|
| **Total SF of Precast** | 105,285 | 27,713 | 27,713 |
| **Total Package Cost** | $5,715,000 | $477,250 | $1,264,821.32 |
| **Total Lead Time (days)** | 115 | 45 | 30 |
| **Total Erection Time (days)** | 80 | 49 | 21 |
| **SF/day (Erection)** | 1316.1 | 565.6 | |
| **SF/day (Lead Time)** | 915.5 | 615.8 | |
| **$/SF** | $45.64 | $17.22 | |

*MSC $/SF is averaged between the MSC cost of $54.28 and the High Concrete Price of $37

# Appendix K

# Precast Façade System – Structural Calculations

Exterior Beam:

Live Load Reduction:

$$LL_r = LL\ (.25 + \left(\frac{15}{\sqrt{k_{LL} \times A_t}}\right))$$

$$LL_r = 100\ (.25 + \left(\frac{15}{\sqrt{2 * 271}}\right))$$

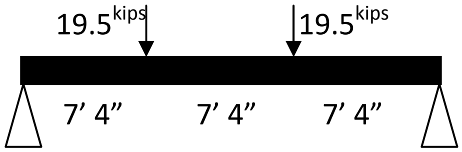
$$LL_r = 100\ (.89) \qquad (.89 > .4\ \therefore ok)$$

$$\boldsymbol{LL_r = 89\ psf}$$

Beam Shear and Moment Calculations:

$$1.2D + 1.6L = 1.2\ (61) + \ 1.6\ (89) = 215.6\ psf$$

$$215.6 * (7.33' * 12.33') = 19.5\ kips$$



Support Reactions = 19.5 kips by symmetry. $\therefore V_{max} = 19.5\ kip$

$M_u = V_{max} * Spacing\ (for\ simply\ supported\ beams\ \&\ point\ loads)$

$M_u = 19.49\ kips * 7'4" = \boldsymbol{142.86\ kip\ ft}$

Load due to Exterior Brick Façade:

Brick Weight: 40 psf Story Height: 14'

Distributed Load = DL Safety Factor * Brick Weight * Story height

$$= 1.2 * 40 * 14' = \ .672\ klf$$

For simply supported beam with distributed load:

$$M_{max} = \left(\frac{dist.load * \ Beam\ length^2}{8}\right)$$

$$M_{max} = \left(\frac{.672 * \ 22^2}{8}\right)$$

$$= \boldsymbol{40.66\ kip\ ft}$$

$$M_{Total} = 142.86 + 40.66 = \boldsymbol{183.52\ kip\ ft}$$

For W16x26: $\boldsymbol{M_{Total}} > \phi \boldsymbol{M_n} = \boldsymbol{166\ kip\ ft}\ \therefore \boldsymbol{Not\ ok}$

For W16x31: $\boldsymbol{M_{Total}} < \phi \boldsymbol{M_n} = \boldsymbol{203\ kip\ ft}\ \therefore \boldsymbol{ok}$

*Resize this beam to W16x31, similar to beam between column lines 4 and 5.

Exterior Column:

$KL = 1 * 14 = 14\ (column\ sizing\ from\ AISC\ manual)$

Live Load Reduction for Calculation 1:

$$LL_r = LL\ (.25 + \left(\frac{15}{\sqrt{k_{LL} \times A_t}}\right))$$

$$LL_r = 180\ (.25 + \left(\frac{15}{\sqrt{4 \times 271 \times 3}}\right))$$

$$LL_r = 180 * .51\ \ (.51 > .4\ \therefore ok$$

$$LL_r = \mathbf{92.3\ psf}$$

Axial Loading Calculations for W12x79:

$$1.2D + 1.6L = 1.2\ (61) +\ 1.6\ (92.3) = 220.88\ psf$$

$$Axial\ Load = Tributary\ Area * Load$$

$$Axial\ Load = \left(271 \frac{sf}{floor} * 3\ floors\right) *\ 220.88\ psf$$

$$= \mathbf{179.6\ kips}\ (excluding\ the\ facade)$$

$$Axial\ Load_{facade} = \left(293.3 \frac{sf}{floor} * 3 floors\right) * 70 psf$$

$$= \mathbf{61.6\ kips}$$

$$Total\ Axial\ Load =\ P_u = \mathbf{241.2\ kips}$$

$$\boldsymbol{\phi_c P_n} = \mathbf{836\ kips}\ > 241.2\ kips = \boldsymbol{P_u}\ \ \therefore \mathbf{ok}$$

Live Load Reduction for Calculation 2:

$$LL_r = LL\ (.25 + \left(\frac{15}{\sqrt{k_{LL} \times A_t}}\right))$$

$$LL_r = 280\ (.25 + \left(\frac{15}{\sqrt{4 \times 271 \times 5}}\right))$$

$$LL_r = 280 * .45\ \ (.45 > .4\ \therefore ok$$

$$LL_r = \mathbf{126\ psf}$$

Axial Loading Calculations for W14x120:

$$1.2D + 1.6L = 1.2\ (61) +\ 1.6\ (126) = 274.8\ psf$$

$$Axial\ Load = Tributary\ Area * Load$$

$$Axial\ Load = \left(271 \frac{sf}{floor} * 5\ floors\right) *\ 274.8\ psf$$

$$= \mathbf{372.4\ kips}\ (excluding\ the\ facade)$$

$$Axial\ Load_{facade} = \left(293.3 \frac{sf}{floor} * 5 floors\right) * 70 psf$$

$$= \mathbf{102.7\ kips}$$

$$Total\ Axial\ Load =\ P_u =\ \mathbf{kips}$$

$$\boldsymbol{\phi_c P_n} = \mathbf{1370\ kips}\ > \mathbf{475.1\ kips} = \boldsymbol{P_u}\ \ \therefore \mathbf{ok}$$

# Appendix L

# Visual Design and Construction Execution Plan

# Loyola Intercollegiate Athletic Complex

## VIRTUAL DESIGN AND CONSTRUCTION (VDC)
## Project EXECUTION PLAN

## *I. VDC Overview*

1) **Project VDC Mission Statement.**
   Use VDC technology to utilize 3D models for structural and MEP coordination, including the Vegetation Reinforcing Steep Slopes (VRSS) and 4D automated scheduling.

2) **Reasons VDC is being considered, and how will it benefit the project**
   a) The complex curves in the VRSS walls make it really difficult to determine the offsets with each row and provide a great opportunity to use new methods of planning techniques and methods.
   b) The structural steel of the upper grandstands coupled with the MEP system provides a great opportunity to make use of new coordination and building planning techniques and methods.

3) **The desired results**
   a) Utilize construction documents produced from the model.
   b) Advance the model in order to produce model based shop drawing submittals for the trades listed below.
      i) Structural Steel
      ii) Miscellaneous Steel
      iii) CIP Concrete
      iv) Under-slab Plumbing
      v) Mechanical – HVAC
      vi) Mechanical – Plumbing
      vii) Fire Protection (Sprinkler System)
      viii) Electrical
   c) Use clash detection to minimize MEP clashes.
   d) Visualize the project ***systems & components*** in 3D
   e) Perform 3D Constructability reviews for complex areas such as the curves in the VRSS walls.
   f) Minimize field changes. Reduce RFI's after coordination submittals are complete.
   g) Increase prefabrication of materials from model to increase ease of installation in field and productivity.
   h) Increase ease of Operation & Maintenance by collaborating with facilities management on access areas required for equipment.
   i) Investigate what trades can utilize electronic layout (Trimble/ Total Station).
   j) Provide an As-Built model to the Owner for their use.
   k) Use Automated Scheduling (4D) to investigate and communicate schedule to project team.

**4) Stakeholders VDC capabilities, modeling responsibilities, and collaborative roles as it relates to the project. (Owners, architects, design consultants, subcontractors, suppliers / fabricators and facility maintenance).**

a) Architect:
   *i)* Creates base design models for CD Production.
   ii) Architect has ability to add objects and/or change models for downstream use if needed to achieve project goals.

b) Design Consultants:
   i) Creates Structural Model complete.
   ii) Creates partial Mechanical/ Electrical model.

c) Owner:
   i) Provides programming and design input.
   ii) Provides facility maintenance requirements input during coordination.
   iii) Interested in using model for facilities maintenance, but needs to define expectations.

d) Whiting-Turner:
   i) Acts as Model Coordinator.
   ii) Performs 3D clash detection for MEP and as needed for other trades.
   iii) Manages 3D coordination sessions.
   iv) Adds 4D (scheduling) information to model for structure and envelope components of project.

e) Subcontractors:
   i) Create fabrication models for own trade and MEP coordination.  See trades listed in 3.b. above.
   ii) Assist in clash detection resolution.

**5) Special Contractual Language or Documents between parties.**

PD Agreement (Integrated Product Delivery)

VDC / BIM Addendums (Virtual Design & Construction; Building Information Model)

Confidentiality Agreements

Modeling Scopes of Work

6) **Cost and Scheduling Restraints**(Keep in mind learning curve of project team)

   a) It is not technically approved, but this is where the budgeted cost for BIM would go.

## *II. Collaboration/Coordination Guidelines*

1. **Creating the information models and how information will be exchanged among the team.**

   Create a modeling matrix.

   Identify the processes that will be used to exchange the models, i.e. an FTP site, jobsite sever, etc.  Establish who will setup and maintain site.

   Identify key modeling standards such as common reference points, floor elevations, type of 3D objects that are acceptable (no wireframe objects, only solids), color differentiations between trades and "clean model" requirements (no extraneous line work).

   Define how the model will be divided to ease the constraints of large files sizes.  This can be done horizontally (each floor level as a separate file) as well as vertically (multiple zones within the overall floor plan).

2. **Model Communication of Information and Collaboration Process**

   a. <u>VRSS Wall Sequence</u>:  The Contractor Sequence shall run in the same order of the actual construction and typical 2-D submittal process.  The design engineer, Haley & Aldrich, will develop the 2-D shop drawings as the baseline for the walls.  Whiting-Turner in turn, will input this into Revit to develop the baseline for the site model.  As the construction progresses, Whiting-Turner will update the model bi-weekly and coordinate with the subcontractor on a day to day basis.  This will allow Whiting- Turner to compare information and discuss changes with the subcontractor and engineer.

   b. <u>Structural Steel Sequence:</u> The Contractor Sequence shall run in the same order of precedence as the actual construction and typical 2-D submittal review process. The Steel Contractor will develop the initial 3-D Steel Shop Drawing Model as the baseline similar to a 2-D anchor bolt layout shop drawing for concrete embed locations. Once the steel contractor develops the baseline 3-D model, WT can forward this baseline model in .IFC to the MEP contractors.

c. Mechanical/ Electrical/ Plumbing: The MEP Contractors will participate in all weekly computer generated coordination drawing meeting to identify and resolve all interfaces between trades. It is expected that detailers attend all meetings and be prepared to make revisions/ updates at the meeting with their lap top computers connected to the project network. Between meetings, the detailers are required to work on detailing and resolving identified clashes. The meetings are held in a dedicated room with dimmed lighting and the model is viewed on a wide screen via two projectors showing two images at once. All attendees are provided access to the model at the meetings via cabling switches, and network connections provided by W-T.

## 3. Software and Hardware to Exchange Information

a. Whiting-Turner:
    i. *2009 & 2010 Revit Architecture:* 3-D Model Design & Drafting
    ii. *Synchro:* 4-D Model/Schedule Integration
    iii. *Navisworks:* 3-D Viewing & Clash Detection
    iv. *AutoCAD 2009:* 3-D .DWG Designing, Drafting, Field Survey Quality Control
    v. *DWG TruView:* 3-D .DWG Viewer
    vi. *Topcon TopSurv:* Topcon Survey Data Collection & CAD Transfer Software
    vii. CIS/2 to IFC File Converter
    viii. *Google Sketch-Up:* Synchro Generic Models

b. VRSS Walls:
    i. *2009 & 2010 Revit Architecture:* 3-D Model Design & Drafting
    ii. *Synchro:* 4-D Model/Schedule Integration
    iii. *AutoCAD 2009:* 3-D .DWG Designing, Drafting, Field Survey Quality Control
    iv. *DWG TruView:* 3-D .DWG Viewer
    v. *Google Sketch*-UP: Synchro Generic Models
    vi. *Navisworks:* 3-D Viewing & Clash Detection

c. Structural Steel:
    i. SDS2 – 3D Steel Design
    ii. CIS/2 to IFC File Converter
    iii. Teckla

d. Miscellaneous Steel: Revit Architecture 2010 – 3D Misc. Metals Design Software

e. MEP Contractors:

    i. Utilize 3D DWG Files for sharing. (reference Exhibit C)
    ii. Utilize Navisworks for Coordination. (reference Exhibit C)
    iii. For Software used reference Exhibit B – Modeling Matrix

f. File Interpolation: As described above, WT will produce a shop drawing model with all of the various trades overlaid and coordinated prior to fabrication and construction. WT uses Revit as the basis for opening and overlaying all of the subcontractor models. Therefore, WT requires that contractors submit their models in a 3-D .DWG or .IFC file. Revit will allow WT to import this information and manipulate as required for review and/or overlay. WT also will export .IFC files from Revit into 3-D .DWG files and manipulate accordingly.

## 4. Model progression schedule.

Prioritize the schedule of information and modeling requirements for decision making and work processes (Value Stream Mapping). Tie the modeling efforts to the procurement and construction schedules.

*Define when the design model should start.*
*Define when the fabrication model should start.*
*Define when 3D coordination should start*
*Define when a 100% coordinated model needs to be completed.*

*For example, when considering model progression for HVAC duct runs:*

**Conceptual** – no need to model ducts,

**Approximate Geometry** – 2D layout or basic design model of 3D duct with approximate X, Y, Z locations – By Design Team

**Precise geometry** – Design and Fabrication model of 3D duct with precise engineered dimension - by Design Team and/or Subcontractor

**Fabrication** – Fabrication model of a 3D duct with precise engineered dimensions and fabrications details – by Subcontractor

**100% Coordinated** – A 3D representation of the installed duct – By Fabrication Model

## 5. Model manager(s).

*a.* The Architect manages the model until it is ***provided to Whiting-Turner.***

b. The model manager, Whiting-Turner, shall gather (transferring and archiving from FTP site or server) the design and fabrication models and combine them into a composite model. The model manager then, runs clash detection, records, and organizes any issues found in the composite model that need to be discussed during the 3D coordination meetings. The W-T model managers are as listed below.

    i. Structure/ Envelope: Jarod Hoover/ BIM Group
    ii. MEP: Jarod Hoover/ BIM Group

c. In general, any ***modifications*** resulting from the coordination process between the ***Construction Manager*** and subcontractors, and quality control of the model as it relates to the contract documents shall remain the responsibility of the ***subcontractors utilizing*** the models.

d. <u>Rules of Engagement for Coordination/Collaboration</u>:
    i. Nothing gets deleted once distributed to team members
    ii. Nobody changes/alters another's model (electronic file)
    iii. Everyone sees everything
    iv. Items that are not modeled will be installed after items that where modeled.

> *For example, a sprinkler subcontractor chooses to model mains/branches only, therefore drops will be installed after the other subcontractors have installed the items they modeled.*

**6. System Model Coordination Sign-Off Procedure for Subcontractors**

Depending on the agreements made with the project team, traditional roles and responsibilities need to be respected and no party should assume additional risk as a result of this new tool.

> *For Example, still provide 2D drawings created from the system models for sign off. Design team responsible to update their models based on our coordination process.*

### *III. Additional Items for Consideration*

1. **Synchro – 4D Modeling:** WT will implement the 4-D Synchro Software on this project with success. Synchro is a 4-D program that connects the 3-D models with the Project Schedule and creates a time lapse of the proposed construction. This allows WT and the design team to review the constructability, sequencing, and design constraints prior to fabrication and installation.

a. <u>3D Modeling:</u> BIM Group Representative, the BIM Coordinator/ Model Manager, coordinated all of the 3-D Model Geometry and converted to .DWF format prior to import. Once imported, they had to dissect certain large objects such as foundation walls and slabs into the areas of the building to match the schedule. Synchro also was simple to update when the design model changed. You can just delete the outdated geometry and import ONLY the new objects without having to re-import the entire model. Google Sketch-Up can be used to model objects such as cranes and rigs to simulate site logistics.

b. <u>Schedule:</u> WT will import the Primavera P3 schedule into Synchro. Once imported, WT broke the generic schedule items down into detailed sequences depending on the requirement of the review. For example, the footings were broken down by the north and south ends of the building.

# Appendix M

# BIM Set-up Costs

| Item | Cost | Qty | Total |
|---|---|---|---|
| **Hardware** | | | |
| 42" Monitors | $799 | 2 | $1,598 |
| Additional CPU from IT Dept | $13,200 | 2 | $26,400 |
| Monitor Mounts | $80 | 2 | $160 |
| Wireless Keyboard and Mouse | $65 | 1 | $65 |
| 16 port Ethernet Switch | $85 | 1 | $85 |
| Various Cables, Surge Protectors, etc. | $200 | 1 | $200 |
| Survey Equipment | $2,000 | 1 | $2,000 |
| | | | |
| **Software** | | | |
| Synchro Licenses | $10,000 | 1 | $10,000 |
| Bluebeam | $150 | 6 | $900 |
| | | | |
| **Coordination Meeting Room** | | | |
| Projection Screen | $150 | 1 | $150 |
| Projector Mounts (ceiling) | $45 | 1 | $45 |
| Lighting | $570 | 1 | $570 |
| Lighting/Electrical work | $1,000 | 1 | $1,000 |
| Projectors | $640 | 2 | $1,280 |
| Network Hard Drive for Coordination | $250 | 1 | $250 |
| **Total** | | | **$44,453** |
| | | | |

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