2013

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Construction Management Option
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[SENIOR THESIS FINAL REPORT]

North Hall – American University
Washington, D.C.

NORTH HALL

AMERICAN UNIVERSITY

WASHINGTON, D.C.

Project Overview

- **Occupancy Type:** A-3 and R-2
- **Size**: 122,200 Square Feet
- **Number of Stories**: 8 Stories + Penthouse
- **Construction Date**: May 15, 2012 to August 9, 2013
- **Overall Project Cost**: $29,000,000
- **Project Delivery**: Negotiated Guaranteed Maximum Price (GMP)

Project Team

- **Owner**: American University
- **Architect**: Little Diversified Architectural Consulting
- **Construction Manager**: Grunley Construction Company
- **Geotechnical Engineer**: Schnabel Engineering Consultants, Inc.
- **Landscape Architect**: Mahan Rykiel Associates, Inc.
- **Civil Engineer**: Wiles Mensch
- **Structural Engineers**: ReStl Designers Inc. & Tadjer Cohen Edelson Assoc., Inc
- **Mechanical Engineer & Electrical Engineer**: Vanderweil
- **Plumbing Engineer & Fire Protection Engineer**: AKF

Structural System

- Reinforced Cast-In-Place Concrete
- Post Tensioned Slabs on 3rd Floors and Above
- Supported by Caissons and Grade Beams
- Precast Panels Façade

Mechanical

- Each Suite Contains a Fan Coil Unit (FCU) Allowing for Temperature Control in Each Suite
- 3 Air Handling Units Supply the Ground Floor
- Connected to Campus Steam & Chilled Water Loop

Electrical/ Lighting

- Main Distribution: 277/480 V, 3 Phase, 4 Wire, 2000A
- Emergency Diesel Generator : 180 kW/125 kVA Producing 277/480 V. 3 Phase, 4 Wire Service
- 2,869 Lighting Fixtures : Majority of Fixtures are Fluorescent

GRUNLEY
Building on Tradition

BRANDON TEZAK, LEED GREEN ASSOCIATE | CONSTRUCTION MANAGEMENT

http://www.engr.psu.edu/ae/thesis/portfolios/2013/bmt5078/index.html

Executive Summary

After American University's 2011 Campus Plan was approved the by District of Columbia Zoning Commission on March 8, 2012 Grunley Construction Company was awarded the construction contract on April 23, 2012 for American University's newest dormitory, North Hall. North Hall is an eight story, tracked for LEED Gold upon completion, dormitory building that is located on American University's Main Campus in downtown Washington, D.C. The 122,200 square foot building will house 358 undergraduate students in 94 suite style dorm rooms consisting of six bed, four bed and, RA units (1 bed). Grunley bid North Hall with a Guaranteed Maximum Price (GMP) of just under $ 29 Million. North Hall is scheduled to house students for the start of the Fall 2013 semester.

Analysis 1: Modularization of Bathrooms

North Hall has both an extremely tight and congested site and well as a very tight schedule. Modularization will more some of the work to an offsite facility and will allow the bathroom units to be constructed before they would be needed onsite and with a less expensive labor force. Modularization allows for 13.2 weeks in schedule savings as well as a cost increase of $92,315.52.

Analysis 2: GPS Tracking of Precast Panels

The installation of the precast panels is confined to a small window in the schedule and the site entrance for deliveries is extremely congested. With a GPS tag tracking system the precast panel can be tracked from the time they leave the factory until they are installed. The tracking will not stop at installation, the same GPS tags will be used to track the testing required for the façade panels. The cost of the tacking system will be roughly $112,785. The schedule did not see any savings.

Analysis 3: Solar Panel Upgrade, Electrical Breadth

North Hall will have two arrays of solar panels when construction is complete. The current design only has the capability to heat domestic hot water. By upgrading the solar panels to a hybrid/cogeneration solar panel system the capability to generate electricity will be added. Upgrading the solar panel system, Analysis 3, is recommended to be implemented on North Hall. The solar panel system will be upgrade from the current solar hot water panel system to a hybrid (cogeneration) system that will have both solar hot water and electrical generation. With the upgrade of the panel system approximately $18,600 a year could be saved in utility costs.

Analysis 4: Traditional Reinforced Cast in Place Floor Slabs, Structural Breadth

Currently floors 3 through 7 are post-tensioned floor slabs. This post-tensioning adds extra cost that can be value engineered to a traditional reinforced cast-in-place concrete slab. Removing the post tensioned cable will cause the slabs to be thickened from 7 inches to 10 inches. The reinforcing will also need to be increased. These required increases in the material need cause the cost to increase by $33,729.40 per slab and $168,647 for all five slabs. The schedule was not shortened by eliminating the post-tensioning due to the increase amount of reinforcement that needs to be placed.

Acknowledgements

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American University

AE Classmates

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Project Overview

Introduction

Figure 1: North Hall South Façade
Photo Taken By: Brandon Tezak

North Hall is going to be American University's newest dormitory building upon its completion in early August 2013. Starting in the Fall 2013 semester North Hall will be the home to 358 undergraduate students living in the 94 suite style rooms spread out through the 8 story, 122,200 square foot building. North Hall is laid out in an elongated "L" shape. The south façade is show in Figure 1. Precast panels will make up a majority of North Hall's façade with small sections of a curtain wall system mixed in.

The first floor is home to both the mechanical and electrical rooms. There is also a fitness center as well as two dance studios located on the ground floor that will serve students in the building. All the suite rooms are located on floors 2 through 8. There are three different layouts for the suites, three bedrooms (two students per bedroom), two bedrooms, and a one bedroom (resident assistant). Each suite has a bathroom and shower located within the suite. The two and three bedroom units have a living room area as well.

North Hall will be located directly adjacent to three existing dormitory building and directly behind the President's Office Building (POB) all of which will be fully occupied through the construction process. These surround buildings create a very small and tight sight for North Hall. Careful planning and coordination has been critical by the project team from Grunley Construction. The structure of North Hall is entirely cast-in-place concrete. Additionally, floors 3 through 8 are post-tensioned slabs.

Client Information

American University is a private university that is located in the heart of Washington, D.C. There are approximately 6,000 undergraduate and 4,000 graduate students enrolled at American. American University is a liberal arts research university.

American University recently had their 2011 Campus Plan approved by District of Columbia Zoning Commission on March 8, 2012. This Campus Plan calls for new on-campus housing for undergraduate students, academic, athletic, recreation, dining and, activity facilities to be built by 2020 (Campus Plan, 2012). North Hall is the first the new on-campus housing being built as part of the 2011 Campus Plan. The president of American University, Dr. Cornelius Kerwin, was instrumental in this new plan. He wants to get as many students onto the campus as they can fit.

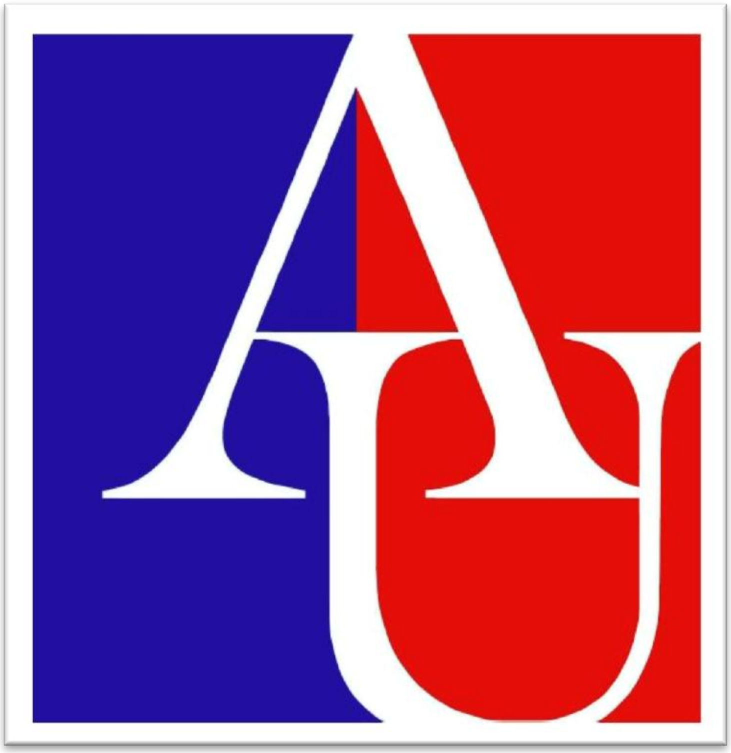


Figure 2: American University Logo
Source: www.american.edu

The cost of the building is a concern for American University since they are a private school and do not get any government funding. The school was originally funded by the United Methodist Church. American seemed to care about the cost of the building when the Guaranteed Maximum Price was negotiated with Grunley Construction as they try tried to get the lowest price with the best value. However American was quick to spend nearly $100,000 to make a place for the president of the university and his two support staff to park. The President's Office Building (POB) is located right next to North Hall, which will sit in the place of the parking lot that was used for the POB. There is a large parking garage right across Massachusetts Avenue from the POB. Why couldn't those three spots be located across the street in the parking garage? This would have saved American University approximately $100,000, making it appear that they are not completely cost focused.

American's quality expectations are simply the level of quality that is specified in the specifications for North Hall. Grunley's project team is responsible for quality control on items that do not specify a third party inspection. American University has hired their own third party inspection firm to complete the quality checks on items that are specified to need a third party.

The schedule is top priority for American University. The rooms in North Hall have already been assigned to for the Fall 2013 Semester so the completion date of August 9, 2013 must be met. These rooms are being offered to any student who lived in one of the three neighboring dorms during construction of North Hall as a gesture of thanks for dealing with a possible inconvenience caused to the students by the ongoing construction by American. This was evident this past summer when clearing the site of trees. In Washington, D.C. a special permit is required to cut down any tree that is over 55 inches in diameter. Strittmatter, the site work subcontractor, removed two trees that American University needed a permit before they each be cut down. American did not know about the permit that was required or they choose not to get it since the job potentially could have been stopped for a few weeks while the tree permit was obtained. Within a day of the trees being cut down a neighbor called the District Department of the Environment (DDOE) to report the cutting down of the two trees. Fortunately DDOE only fined the job approximately $30,000 and did not shut the job down allowing construction to proceed uninterrupted. This was important since it had the potential to negatively impact the schedule possibly making the end date unreachable.

Safety is also very important to American University. With three dorms adjacent to the site there is a lot of student traffic around the site. The site fence was placed in a way that students could still access all of the entrances and exits to the building so they would not be wondering onto the site looking for a way into their dorm. There are numerous signs posted at every gate in the fence that states it is a construction site and authorized personnel are the only ones allowed in. The only gate that is open during construction is right in front of the office trailers which allow Grunley's project team to stop anybody who shouldn't be in the fence before they get to the area where there is lots of activity taking place. Grunley has a site safety plan that was a proved by American University before the project started.

One of American University's major concerns is the noise level during construction. There are two reasons for this. One of them is there are hundreds of students living right next to the site in the three adjacent dorm buildings. Due to this work hours are limited to 7AM to 7 PM to minimize disrupt of the students sleep and or studying in their rooms. American also required Grunley Construction to inform the American University representative a few days in advance of any loud activity that will be taking place so the nearby President's Office Building (POB) staff so that they are prepared for any loud noises during the day. This was critical during the site excavation when a large retaining wall and footing was demolished. There was a constant noise of roughly 100dB from the Hoeram and Concrete Pulverizer that were used in the demolition.

Project Delivery

Grunley Construction is relative new to the Higher Education Construction market. Grunley's primary market for the past several years was GSA jobs throughout the Washington, D.C. area. Grunley was selected to preform preconstruction services for American University. Some of duties that Grunley preformed for American included surveying existing utilities, schematic design review, develop a BIM model, value engineering and, identify long lead-time material and equipment. Grunley was then awarded the construction services part of North Hall.

North Hall is being delivered with a Guaranteed Maximum Price (GMP) contract. This type of contract required an open book style of accounting for Grunley. They must submit back up for the requisition that they submit each month to be paid. This gives American University the schedule of values for the project so they know exactly what they are paying for each month.

The contract was negotiated to a price of $28,729,368. This price includes a 2% contingency, general liability insurance, builder's risk insurance, preconstruction services and the CM Fee. The CM Fee includes the cost of all the general conditions. With all these removed the direct cost of the construction is $27,046,788.

The subcontractors are required to get bonding as well. Grunley holds or will hold lump sum contracts with each of the subcontractors. Grunley also has a working relationship with the architect, Little Diversified Architectural Consulting but there is no contract between Grunley and Little. The project organizational chart can be seen on the following page in Figure 3. Contracts are shown with solid lines and a working relationship is shown with a dashed line. The structural engineer is a joint venture between ReStl Designers, Inc. and Tadjer Cohen Edelson Associates, Inc.

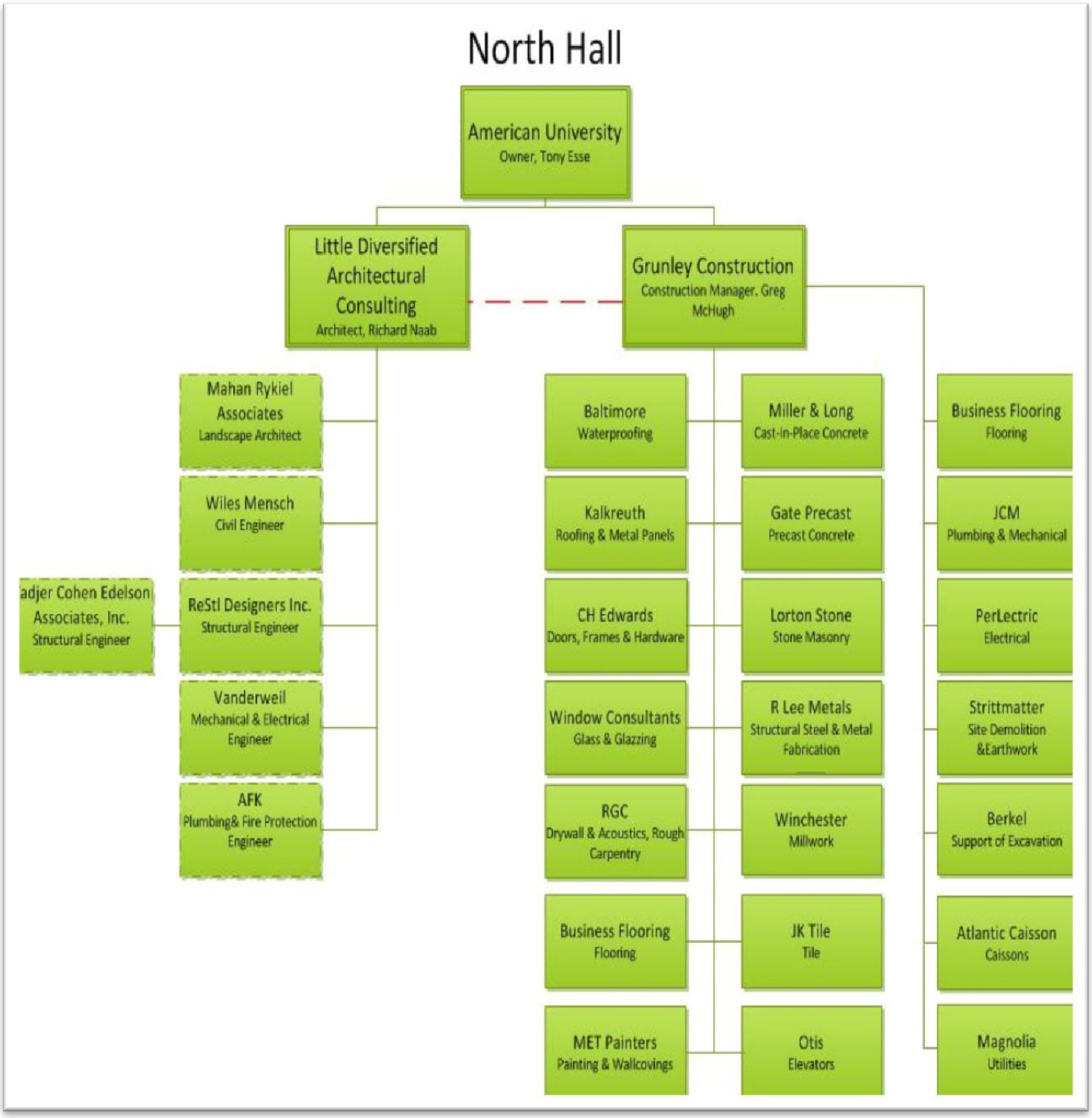


Figure 3: North Hall Organizational Chart
Chart Developed By: Brandon Tezak

Staffing Plan

Grunley Construction has project team consisting of a Project Executive, a Project Manager, an Assistant Project Manager/Project Engineer, a Jr. Project Engineer (Intern), a Senior Superintendent and, a Superintendent. All but the Project Executive are located on site with the Project Executive being located at the main office and overseeing multiple projects. Refer to Figure 4 for the Staffing Chart for North Hall.

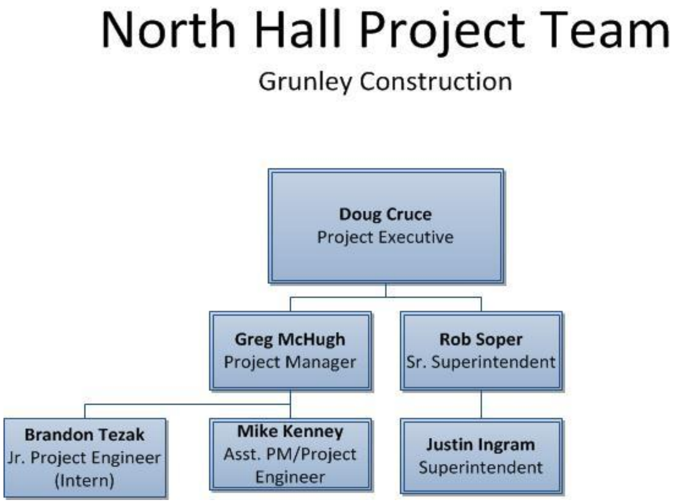


Figure 4: Grunley Construction Project Team
Chart Developed By: Brandon Tezak

Design and Construction Overview

Building Systems

The checklist shown below in Table 1 provides a summary of the major building systems for North Hall. A more detailed explanation each system follows the major building systems table.

Table 1: North Hall Building Systems Checklist

Building Systems Checklist		
Work Scope	Yes	No
Demolition Required	X	
Structural Steel Frame	X	
Cast in Place Concrete	X	
Precast Concrete	X	
Mechanical System	X	
Electric System	X	
Masonry	X	
Curtin Wall	X	
Support of Excavation	X	
LEED Gold Certification	X	

Demolition

North Hall required only some minor demolition of two retaining walls and a parking lot. One of the retaining walls was only 6 feet tall at its highest point and sloping to a height of 6 inches at its lowest point. This wall was approximately 30 linear feet in length. The other retaining wall was much bigger this wall was 20 feet tall and 80 linear feet in long. This wall can be seen in Figure 5 during the demolition process. There was parking lot that needed demolished to before the site could be excavated to subgrade. There was approximately 6,100 square feet of asphalt parking lot that had to be removed.

Figure 5: Large Retaining Wall Demolition
Photo Taken By: Brandon Tezak

Structural Steel Frame

The building's structure is not a steel frame. The structure is predominately cast-in-place concrete. However, there is a small area that uses structural steel framing to support the roof in the Penthouse area. There are only 24 pieces of structural steel used in the penthouse area. The tower crane will be used to fly these pieces in to place. See the next section for more information on the tower crane.

Cast in Place Concrete

The structure of the building is entirely made up of reinforced concrete except for the penthouse area. Sixty-six concrete caissons ranging in diameter from 30 inches to 48 inches support North Hall. These caissons are located under either a grade beam or a concrete column. The slab on grade and second floor slab are both reinforced cast in place concrete. Post tensioned reinforced concrete will be used for floors three through eight as well as the eighth floor roof slab.

The caissons were poured right out of the back of the concrete truck. The rest of the building will be poured using a concrete bucked and the tower crane. The tower crane that is being used for North Hall is a Peiner SK575. The jib height for the tower crane is 155 feet 2 inches and the reach of the crane is 196 feet 10 inches. The Peiner SK575 is sported by four 36 inch caissons and a reinforced concrete pad that is 5 feet thick. The crane was erected in early August of 2012 and will be used until approximately the end of December 2012.

Miller & Long, the concrete subcontractor, is using a metal form system to form up the concrete walls, slabs, and columns so that they will be able to reuse the forms throughout the duration of the construction of North Hall

Precast Concrete

North Hall will utilize a precast panel system for the building façade. These precast panels will sit on the second floor slab and stack on top of each other. The panels will be attached to each floor slab with imbeds in the edge of the floor slabs. The entire exterior of the building except for the lounge areas and the stair towers at the end of the central hallways of the building will have precast panels.

Gate Precast is providing the precast panels. The panels are being cast in Oxford, North Carolina. They will be shipped to from North Carolina to Washington, D.C and then will be erected with the Peiner SK575 tower crane.

Mechanical System

The main mechanical room is located on the Western side of the first floor. There are two air handing units located within the mechanical room that serve the ground floor areas. The electrical room has its own dedicated air handing unit. The mechanical system is fed by both chilled water and steam from a campus loop similar to Penn State's steam loop.

Each suite has a Fan Coil Unit (FCU) that will also be supplied with steam and chilled water. These fan coil units will provide the heating and cooling needed for each suite. The FCU's will be located in each suite's mechanical room. This will provide the residents of each suite to control their heating or cooling. Each floor has a lounge that also will have its own FCU.

The building will be protected from fires with a wet pipe sprinkler system. There will be a dry sprinkler system in the electrical room and loading dock areas. This is to protect the electrical equipment from water unless it is necessary and to avoid having a pipe burst in the loading dock area.

Electrical System

North Hall will get its electrical supply from a nearby campus electrical vault. The vault will supply the switchgear with 277/480 V, 3 phase, 4 wire, 2,000 Amp service. A backup emergency 180 KW/125 kVA diesel generator will supply the emergency power with 277/480V, 3 phase, 4 wire. The lighting of North Hall will be primarily fluorescent lighting. LED's are going to be used for emergency exit signs.

Masonry

A field stone veneer is going to be used on the Southwestern corner of North Hall. The stone veneer will be applied to the concrete wall on the first floor. The stone will be part of the precast panels on the second floor and above. This will eliminated the need for scaffolding since the stone will be cast into the panels and then placed with the tower crane.

Curtain Wall

North Hall will have three areas that have an aluminum curtain wall system, the exterior side of the lounge areas, the Southeast stair tower, and a section of the Northeast wall that is at the end of the main hallway. The curtain wall system is supported by the floor slabs, an imbed is in the edge of the slabs and attaches to the curtain wall frame.

Support of Excavation

A portion of North Hall's first floor will be underground. To avoid having to over excavate as well as the small site would not allow for it, soldier beams and lagging with tiebacks were used to hold back the earth. The project required 46 soldier beams with 11 tiebacks. The support of excavation can be seen in Figure 6. The support of excavation is four feet from the exterior face of the first floor wall.

Figure 6: North Hall Soldier Beams, Lagging and Tiebacks
Photo Taken By: Brandon Tezak

When the building is complete, the top four feet will be cut off and the rest will be abandoned and buried.

LEED Gold Certification

Upon completion North Hall will track to obtain LEED Gold Certification under the LEED 2009 for New Construction and Major Renovations System. Grunley is in charge of making sure certain credits' requirements are met during the construction process. These specific credits include Materials and Resources Credits such as 75% of construction waste is recycled or salvaged, 20% recycled content, and 20% of materials are regional. In addition, Grunley is responsible for Indoor Environmental Quality credit for having an indoor air quality (IAQ) management plan during construction and Innovation and Design credit for exemplary performance in either regional recycle or construction waste management.

Project Cost Evaluation

Project Parameters

Table 2: North Hall Project Parameters

Project Parameters	
Parameter	**Total**
Square Footage	122,000
Number of Floors	8 + Penthouse
Footprint (SF)	15,400

Construction Costs & Total Project Costs

All cost information was for North Hall was provided by Grunley Construction Company. The construction cost shown below in Table 3 does not include the costs of land, site work, permitting, or Grunley's Fee. The square foot cost was calculated by using the square footage listed in Table 2. The total project costs include all costs for the project including all that was not included in construction costs except for the cost of land since American University already owned the land prior to construction.

Table 3: North Hall Actual Project Costs

Actual Project Costs	
Parameter	**Total**
Construction Costs (CC)	$ 26,042,366
CC/SF	$ 213.11
Total Project Costs (TC)	$ 28,953,457
TC/CC	$ 236.94

Building System Costs

The major building systems construction costs are listed below in Table 4. These costs are the costs provided in each subcontractors bid that was submitted to Grunley Construction during the bid process.

Table 4: North Hall Major Building Systems Actual Costs

Major Building Systems Actual Costs		
System	**Construction Cost (CC)**	**CC/SF**
Electrical	$ 2,403,875	$ 19.67
Fire Protection	$ 385,500	$ 3.15
Mechanical/Plumbing	$ 6,800,000	$ 55.65
Precast Panels	$ 2,386,300	$ 19.53
Structural Concrete	$ 4,029,750	$ 32.97

Cost Comparison

RS means does not include site work contingencies, etc., therefore when comparing the RS Means value to the actual cost the construction cost not the total project cost should be used. Table 5 compares the Construction Costs to the RS Means total.

Table 5: North Hall Actual Construction Costs VS RS Means Costs

	Total Construction Cost	CC/SF
Actual Construction	$ 26,042,366	$ 213.11
RS Means	$ 21,430,000	$ 175.37

The RS Means costs are much lower than the Actual Construction Costs are for a variety of reasons. RS Means makes many assumptions about what is in the building so it is hard to get a completely accurate cost from using strictly RS Means cost data. North Hall has some features that are not found in RS Means. For example very little of the Mechanical System's components were listed in RS Means CostWorks database. In addition, RS Means only assumes one crew will be working on the particular system when in reality that might not be the case and there could be multiple crews working which would increase the labor on the job.

Local Conditions

The construction industry in Washington, D.C. has been somewhat unaffected by the recent recession in the economy unlike the rest of the country has been. This is mainly due to the large amount of government construction that takes place. Congress has not only kept the construction industry going it also controls the height of buildings in the District of Columbia with the Height of Building Act of 1910. Buildings are limited to 130 feet in height (Craig). This limiting of the building height makes reinforced concrete buildings the preferred type of construction in Washington D.C. When reinforced concrete is used instead of the traditional steel framed building one more floor can be achieved.

American University is located in the Northwest quadrant of Washington, D.C. near Embassy Row. As the case in all of Washington, D.C. space is very valuable, thus parking is expensive. The site of North Hall has no onsite parking due to the extremely tight site. American University allotted Grunley 45 spaces in a surface lot about a block and half away from the site free of the normal $16 a day rate. These 45 spaces are shared with another Grunley project at American University, Nebraska Hall Expansion. It is first come first serve for the parking spaces and during the peak of construction activity there will not be enough spaces for every worker. There is a Metro stop about a mile away from the site so workers are encouraged to use the Metro or carpool to avoid paying for parking.

Grunley Construction has it written into each of the subcontracts that each subcontractor is responsible for hauling all of their own waste from the site. The tipping fee for the dumpsters that are being used on site is $500. The dumpsters contents are sorted by the dumpster company and the proper items are recycled and tracked for LEED credit.

Schnabel Engineering Consultants Inc. is the Geotechnical Engineer for North Hall. They found 6 to 7 inches of topsoil on the site in places there was not an existing parking lot. Between 2.5 to 5 feet below ground sandy lean clay, sandy silt, silty sand and sandy fat clay, containing gravel, silt mica, clay pockets, roots and quartz fragments where encountered. From a depth of 8.5 to 13.5 feet Schnabel found brown and light gray sandy lean clay, sandy silt, and sand fat clay with varying amounts of quartz fragments, clay seams, silt seams, roots, gravel and, mica. At a depth of 24.5 to 44 feet below the surface residual soils consisting of varying shades of brown and gray silty sand, clayey sand, sandy silt, and varying amounts of elastic silt seams, quartz fragments, mica, roots and, clay layers/pockets. Also in some of the borings, Schnabel found disintegrated rock at depths ranging from 35 to 49 feet below the surface. Schnabel used eight test borings spread throughout the building footprint. Groundwater was encountered in half of the borings at 8.5 to 9 feet below ground. The other borings did not hit any ground water. However, there was no ground water problem when the site was excavated to the required depth.

Site Plans

Please See Appendix D for the full All Site Plans.

Existing Conditions

North Hall is being built on what used to be a parking lot directly behind the President's Office Building. The parking lot was also right next to both Leonard Hall and McDowell Hall, which are both dorms. The site sits on a hill that overlooks Massachusetts Avenue NW the on the side opposite of the two dorm buildings. The Wesley Theological Seminary borders the other side of the site. The site of North Hall is the parking lot on the right side of Figure 7.

Figure 7: North Hall Site
Source: Google Maps

The campus road that runs between the site and Leonard and McDowell Halls has been closed down during the construction of North Hall. All construction traffic will enter and exit the site through the same gate. The gate is on the campus road that is closed which runs diagonally across Figure 3. The Grunley office trailers were placed right inside the gate to North Hall. This location was picked due to the fact that it the trailers were completely out of the way of construction for the duration of the project.

Phase 1: Foundation

Demolition of the parking lot along with two retaining walls and excavation to the subgrade elevation was required to prepare the site for the caissons to start. Due to the small site, American University's restrictions on what campus roads could be used by construction vehicles and, the traffic of downtown Washington, D.C. made planning the excavation very important. The same road is used as the entrance and exit of the site. Unfortunately the road is too narrow for two dump trucks to be able to pass each going opposite directions at the same time, essentially turning the main entrance into a one way street. This became an issue during the excavation of North Hall when multiple dump trucks would return to the site all at once and block the roadway while waiting to be filled and not allowing the full truck out. To avoid this one of the site work subcontractor's laborers was stationed at the gate of the site to control the flow of trucks into and out of the site.

Figure 8: Material Storage/ Staging Area
Photo Taken By: Brandon Tezak

The same issue was a problem for the caisson subcontractor when their concrete trucks would arrive and leave only not on the scale of the site work subcontractor. North Hall's foot print is in the shape of the letter "L". The part of the site that was not occupied with the footprint was utilized for material storage and staging. This area shown in Figure 8 was used to store the caisson's rebar cages so that the crawler crane and the two drill rigs had full access to the site during the installation of the caissons.

Phase 2: Superstructure

Before the structure of North Hall started the tower crane was erected. The Piener SK575 tower crane can reach the entire site. A concrete bucket will be used to place the concrete for the entire building as well as for erecting the precast panel façade. A material hoist will be installed along the side of North Hall that runs along the road that services the site. This will allow trucks to be unloaded in the road and the material placed on the hoist to be delivered to the appropriate floor.

The flow of traffic in and out of the site is critical to this phase. As the building moves out of the ground the area where smaller trucks were able to turn around will disappear meaning that the trucks will need to back out of the site if the truck had pulled directly in to the site or back in to the site so that the truck will be able to pull out when the material is unloaded.

Phase 3: Finishes

The final phase of construction at North Hall will be the finishes. The tower crane will have been disabled by this time of construction meaning that materials will be delivered to the correct floor by the material hoist or by hand delivery. As this phase moves on the material hoist will be removed to allow the Curtin Wall system to be installed in the lounges on each floor. As in the previous phases traffic control of the delivery trucks into and out of the site is still critical since there is still only one entrance and exit.

Detailed Project Schedule

See Appendix B for the Detailed Project Schedule.

North Hall is being driven by its schedule due to the need for the building being ready to move students in for the start of the Fall 2013 semester. Grunley Construction Company has been pushing the schedule from the start of the project trying to get ahead whenever possible.

Sequencing

The structure of North Hall will be built from the ground up. North Hall's precast panel façade will be start being erected as the structure nears completion. The precast will follow the same sequence as the building's structure. All the rough in of the mechanical, electrical and plumbing systems as well as the wall framing will also start on the ground floor and rise floor by floor to the top of the building.

The finishes will not follow the same sequence of floors that the earlier trades followed. The finishes will start at the penthouse level and work down the building floor by floor finally working out of the building as the construction wraps up.

Construction Phasing

Most of the phases of North Hall's construction are relatively independent of each other in terms of one phase does not require the pervious phase be completely finished. A major delay to one of the activities that fall on the critical path could delay the next phase. A prime example of this is the structure of the building to be completed on time. Any delay could have a negative effect on the downstream activities. Table 6 below shows the major construction phases for North Hall.

Table 6: North Hall Construction Phasing

North Hall Phasing			
Phase Name	**Duration**	**Start**	**Finish**
Site Work	259 Days	5/15/12	5/14/13
Building Structure	89 Days	7/2/12	11/2/12
Enclosure	93 Days	9/6/12	1/16/13
Rough-In	190 Days	9/6/12	5/31/13
Finishes	165 Days	12/19/12	8/9/13

General Conditions Estimate

See Appendix C for the General Conditions Estimate. Note: RS Means Costworks Database was used for all cost data.

Figure 9: Site Office Trailers, Photo Taken by Brandon Tezak

North Hall's General Conditions can be broken down into two distinct categories, Site Expenses and the Project Team Staffing costs. The General Conditions Costs are relatively low for a few reasons. Grunley is expanding into a new market sector, Higher Education Construction, and to get their foot in the door they needed to be as competitive as possible and keep their costs down. Due to the very small site, Grunley decided to use a very small office trailer compared to the typical construction office trailer. Grunley's office trailer is an 8' by 40' sea container, which converted to an office. All of the onsite project staff is located in the trailer. A smaller trailer is also located on site as an office space of the American University Representative, which also serves as a meeting space for the project. Both trailers can be seen on the right side of Figure 9. The General Conditions was estimated at $1,093,102.55.

The actual budgeted General Conditions costs are much higher than the estimated costs. Grunley was able to save a substantial amount of money on some items. One example of this was that instead of having to run a Comcast Cable line to the trailers to get internet and phone access to the trailers, Grunley was able to tie into the campus wide wireless internet network that American University has. This is just one of many example of saving Grunley has made.

Figures 10 and 11 on the next page show the breakdown between the actual cost and estimated costs of North Hall's General Conditions.

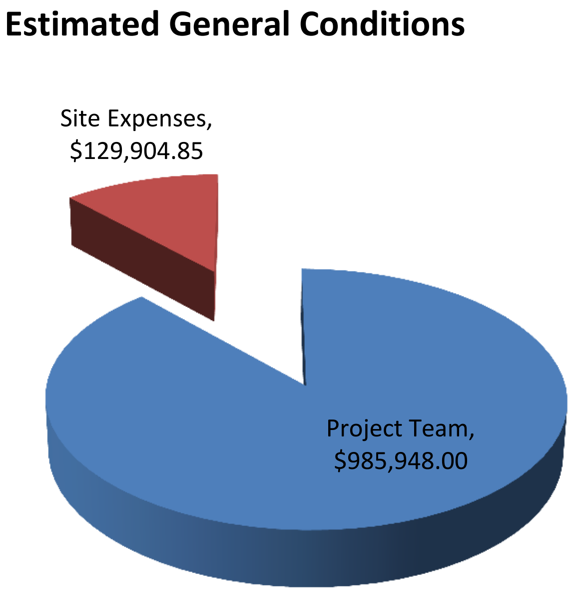


Figure 10: Estimated North Hall General Conditions Costs

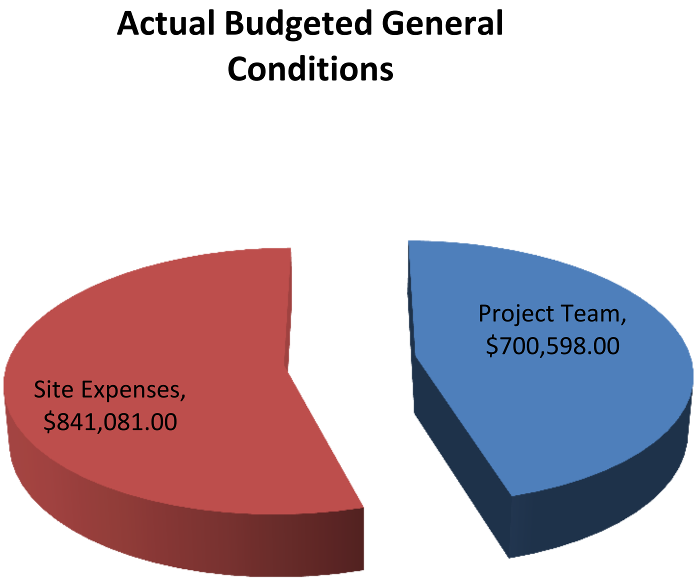


Figure 11: Actual Budgeted North Hall General Conditions

LEED Evaluation

Please See LEED 2009 for New Construction and Major Renovations Scorecard in Appendix D.

North Hall is tracking to achieve LEED Gold Certification under the LEED 2009 for New Construction and Major Renovation upon completion. In order for North Hall to achieve the LEED Gold Rating, at least 60 of the possible 110 credits must be earned in addition to the required prerequisites. Upon completion, North Hall will join the School of International Service, as American University's only other LEED certified building, which is also Gold Certified.

American University, the Design Team and, Grunley are all working together to complete the requirements for the LEED Gold rating for North Hall. Currently the team has identified 42 credits that are definitely being pursued as well as 34 credits that are being investigated to see if it will be feasible to obtain them. The project will need to get 18 of the 34 credits to reach the threshold for LEED Gold Certification. Figure 12 breaks down how many credits are being pursued, are possibly being pursued or not being pursued in the six LEED categories; Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources , Indoor Environmental Quality, Innovation and Design Process and, Regional Priority.

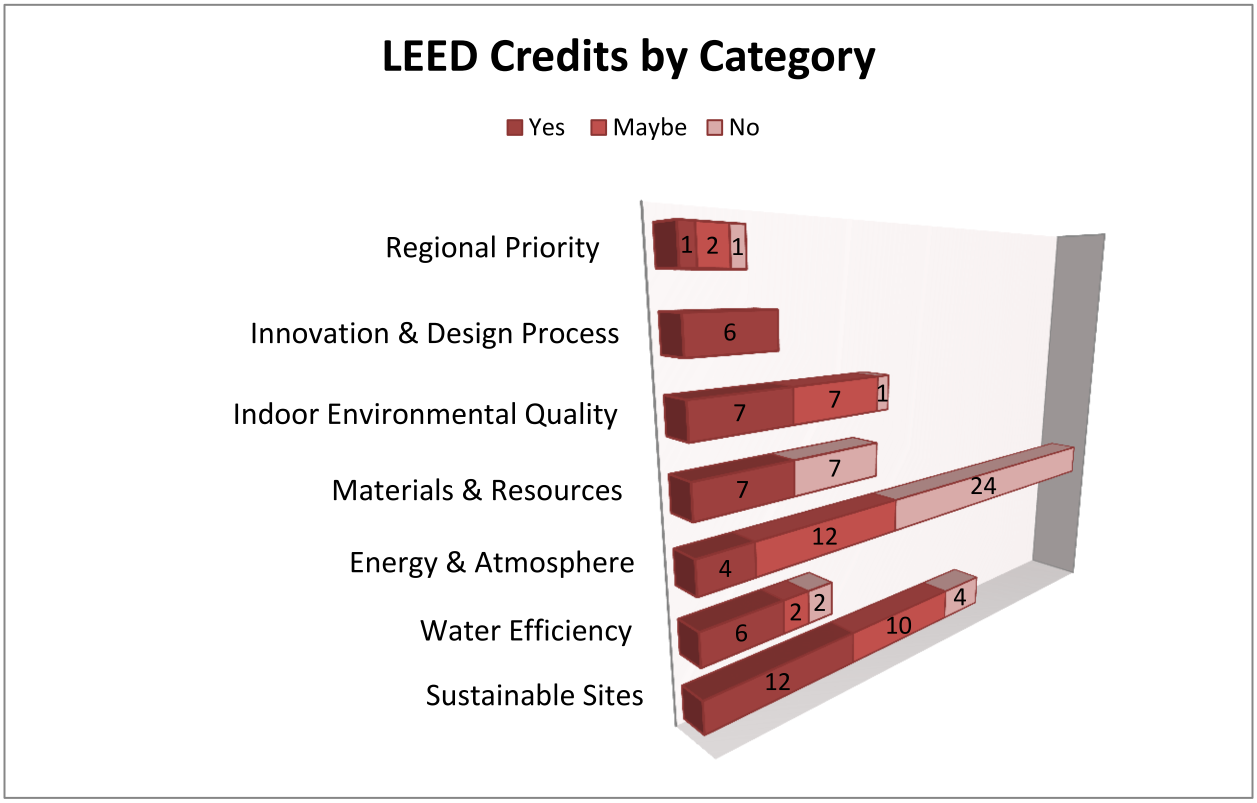


Figure 12: LEED Credits by Category

Sustainable Sites

Under the Sustainable Sites category the project team is aiming to get at least 12 credits and possibly get another 10 credits if they are deemed feasible. North Hall will benefit from its location near public transportation systems such as Washington, D.C.'s Metro and Bus systems as well as it urban location with 10 services within a half mile of the site. The proximity of the site to all these amenities will earn 9 credits for Alternative Transportation. With a light colored roof one credit for the Heat Island Effect-Roof. The 10 credits that are possibly going to be achieved include Site Selection, Development Density and Community Connectivity, Heat Island Effect- Non-roof as well as, Light Pollution Reduction.

Water Efficiency

North Hall is aiming to gain eight of the possible ten points available for Water Efficiency. North Hall will earn four credits by meeting the requirements of Water Efficient Landscaping – No Potable Water Use for Irrigation. North Hall will utilize a storm water re-use system to eliminate the need for potable water for irrigation purposes. Additionally, four credits will be earned with Water Use Reduction – Reduce by 40 %. This will be accomplished by using low flush fixtures.

Energy and Atmosphere

The one LEED category that North Hall is not earning nearly as many credits as it could possibly earn is the Energy and Atmosphere. With the information provided North Hall was on set to earn one out of a possible 19 points for Optimizing Energy Performance by improving the performance by 12%. This calculation was done before the energy model was complete. If the performance was improved by 48%, North Hall would receive 18 more credits which would easily propel North Hall to a LEED Platinum Rating. The mechanical engineer on North Hall, Vanderweil, has specified that North Hall will have Enhanced Refrigerant Management, earning two credits. Other possible credits include two credits for Enhanced Commissioning, three credits for Measuring and Verification, and two credits for Green Power.

Materials and Resources

Grunley Construction will be the driving force behind achieving credits in the Material and Resources category. They will be requiring the subcontractors to recycle their materials as well as use recycled materials in the construction. North Hall will should receive tow credits for each of the following; Construction Waste Management – 75% Recycled or Salvaged, Recycled Content – 20% of Content and, Regional Materials – 20 % of Materials. In addition, North Hall may also receive one credit for using Certified Wood.

Indoor Environmental Quality

The indoor quality will be monitored during the construction process. By doing this North Hall will receive a credit for Construction Indoor Air Quality (IAQ) Management Plan – During Construction. Materials that emit volatile organic compounds are bad of a good indoor environment. Consequently, LEED rewards a project for using low emitting materials. North Hal l will receive a credit each for using low emitting materials in the following; Adhesives and Sealants, Paints and Coatings, Flooring Systems, and Composite Wood and Agrifiber Products. Each room within North Hall is designed to have a thermostatic controlled damper which will earn a credit for Controllability of Systems – Thermal Comfort. North Hall will also receive a credit for Thermal Comfort – Design since the HVAC system and building envelope was designed to meet the requirements of ASHRAE 55 2004. Other credits that North Hall could possibly receive include Outdoor Air Delivery Monitoring, Construction Indoor Air Quality Management Plan – Before Occupancy, Indoor Chemical and Pollutant Source Control, Controllability of Systems – Lighting, Thermal Comfort- Verification, Daylight and Views – Daylight, and Daylight and Views – Views.

Innovation and Design Process

North Hall is aiming to earn all six of the possible credits in the Innovation and Design Process category. The project will earn five credits for Innovation in Design for the following: Materials and Resources Exemplary Performance, Educational Outreach, Green Cleaning, Low Mercury Lamping and, Intergraded Pest Management. The project team also contains at least one LEED Accredited Professional, which earns one credit.

Regional Priority

The project is tacking to earn one credit in the Regional Priority category. North Hall will earn a credit for Innovative Waste Water Technologies. The specifics of this technology are still in the works by the design team.

If the project team is able to fulfill all of the requirement for the credits that have been designated “yes” or “maybe” North Hall will earn 76 credits. If only four more credits would be pursued from the list of credits that are not currently being pursued, North Hall could receive a LEED Platinum Rating. North Hall would then become American University’s first LEED Platinum building. However, it is more likely that closer to only the 60 credits will be pursed to keep the costs down for the project.

Building Information Modeling Use Evaluation

See Appendix E for the North Hall BIM Execution Plan Guide.

All processes, methods, and charts discussed or used are courtesy of Computer Integrated Construction at The Pennsylvania State University.

Using the BIM uses outlined in the *BIM Project Execution Plan Guide*, developed by The Computer Intergraded Construction (CIC) Research Group at The Pennsylvania State University, five additional uses of 3D coordination that the project team is already using. These six uses of BIM were ranked on a three tier scale of High, Medium or Low importance to the project. These ranking will help the project team to decide to pursue these particular uses of Building Information Modeling.

The BIM uses receiving the highest ranking included 3D Coordination, Site Utilization Planning, and Design Reviews. The project team is already using 3D Coordination to reduce field conflicts. As the structure of North Hall is being constructed all sleeves in the slabs were coordinated to assure the correct location as well as that none were missed since, core drilling the concrete slabs is not an option due the post-tensioned cables within the slab. 3D coordination will also be used in erecting the precast façade as can be seen in Figure 6, as well as coordination of the MEP trades. North Hall has an extremely small and tight site. Using BIM for Site Utilization Planning would benefit all parties involved in the project. North Hall's only entrance and exit is located right next to three large dorm buildings. Due to the large amount of both construction traffic and regular campus traffic using the space on site to its ultimate capacity will make the entire area safer and reduce the congestion on the road into and out of the site. Design Review using BIM would also be a great benefit to the project. Having the subcontractors input on the design that they will ultimately be building in the field will minimize the potential problems with a design of a system by the Architect and Engineering Design Teams. Seeing these designs on a computer screen will also help increase the productivity of subcontractors since they will have a model to reference how the system they are building should look and work before they actually put any work physically into place.

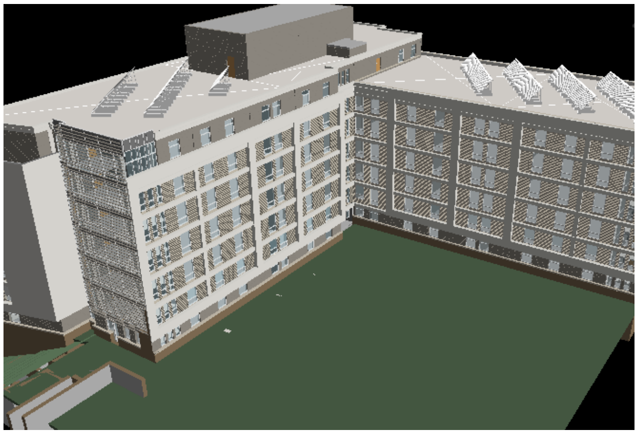


Figure 13: Precast Facade Coordination, Model Courtesy of Grunley Construction Company

LEED Documentation and Record Modeling both received the medium ranking of importance. North Hall is track to receive LEED Gold Certification upon completion. Using BIM to track materials and their properties all in one place would help make managing the LEED documentation of the project. Documenting these materials recycled content, regional location and, effect on indoor air quality would be simplified. Taking the 3D coordination to the next level would make producing a record model of North Hall a logical step. This would be beneficial to American University to go along with the As-Built

Drawings giving them a complete representation would have they have in their new building. All of the equipment information could be added to the model.

With a record model with all the equipment information imputed Maintenance Scheduling would be the final potential use of BIM for North Hall. This particular use of BIM received a low importance ranking since it will only have benefit to American University and its maintenance staff. American would have to have the infrastructure to support a maintenance scheduling component as well as have the personnel that understand how this system operates.

Analysis 1: Modularization of Bathrooms

Problem Identification

Any way in which the construction of North Hall can be accelerated can be beneficial to the schedule and meeting the completion date for North Hall. North Hall has a very important completion date since the building must be ready for students to move in for the start of the Fall 2013 semester. Modularization of the bathrooms in the suites is a way that the schedule can be accelerated. The bathrooms are typical from suite to suite making the repetitiveness of them ideal for modularization. North Hall contains 94 of the typical bathroom units. With the implementation of modularization on this part of North Hall both time and money can be saved.

Research Goal

The purpose of this analysis is to evaluate the benefits of incorporating modularization in to the bathrooms in each suite.

Methodology

- Identify constraints
- Identify bathroom activities durations
- Identify site logistics related to modules
- Identify module construction activity durations
- Develop cost comparison between current method and modularized method
- Develop schedule comparison between stick built method and modularized method
- Develop logistics plan for module installation
- Analyze constructability issues related to integration of modular units to rest of building
- Analyze cost and schedule comparisons
- Draw conclusions if modularization is feasible for North Hall

Resources and Tools

- Industry Professionals
- Related Literature and Case Studies
- Grunley Construction Project Team
- AE 570: Production Management in Construction, Modularization Information
- AE Department Faculty

Background Information

North Hall is a perfect candidate for modular construction due to its repetitive floor plan and makeup. Modular Construction was used in 42% of Higher Education construction projects in 2010 (Bernstein 2011). For the full benefit of modularization to be realized the building must be designed with modular construction in mind. Since this was not the case with North Hall small portions of the building, such as, the bathroom/ shower of each suite using the modularized construction approach will help decrease the project schedule and budget if properly implemented. The bathroom areas are typical for the four and six bedrooms suites. The bathroom in the one bedroom RA suite is will not be built using modular construction due to the variation form the four and six bedroom version as well as the suites at the end of each corridor and the corner suite.. Each bathroom area will be broken into three modules as can be seen in Figure 14.

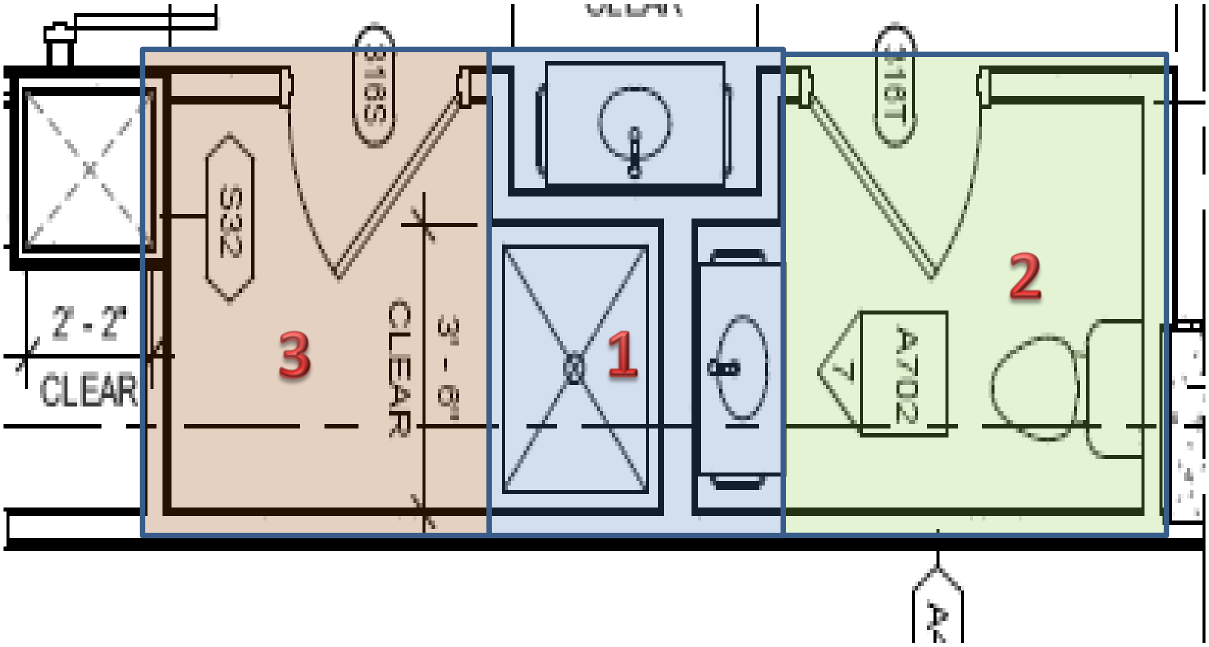


Figure 14: Bathroom Suite Modules

Module Constraints

The modules will need to be able to fit on the material hoist and then moved down the stud-framed hallways of each floor. Modules must be small enough to fit on the back of a truck for transportation from the production facility to site. The framed hallway will be 8 feet wide before the modules are installed into each suite. Also a key constraint is to make the modules as easy and manageable to handle so that limited equipment will be needed for installation.

The modules are designed to meet all of these size constraints. Module 1 will be the smallest module of the three with dimensions of 6 feet by 5 feet. Module 2 is the largest at 6 feet by 7 feet. Module 3 is 6 feet by 6 feet.

Site Logistics

Site logistics are relatively simple for the modules. There is no onsite storage for the modules due to the location of the material hoist and extremely small site. When the delivery truck arrives at the site, it will back into the site and up to the material hoist as can be seen in Figure 15. The modules will be unloaded from the truck to the material hoist and moved to the appropriate floor. Then the modules will be moved the approximate location where they will be connected and installed at a later time. By placing the modules at their approximate final location, the double handling of the modules will be eliminated ultimately making the process much more efficient.

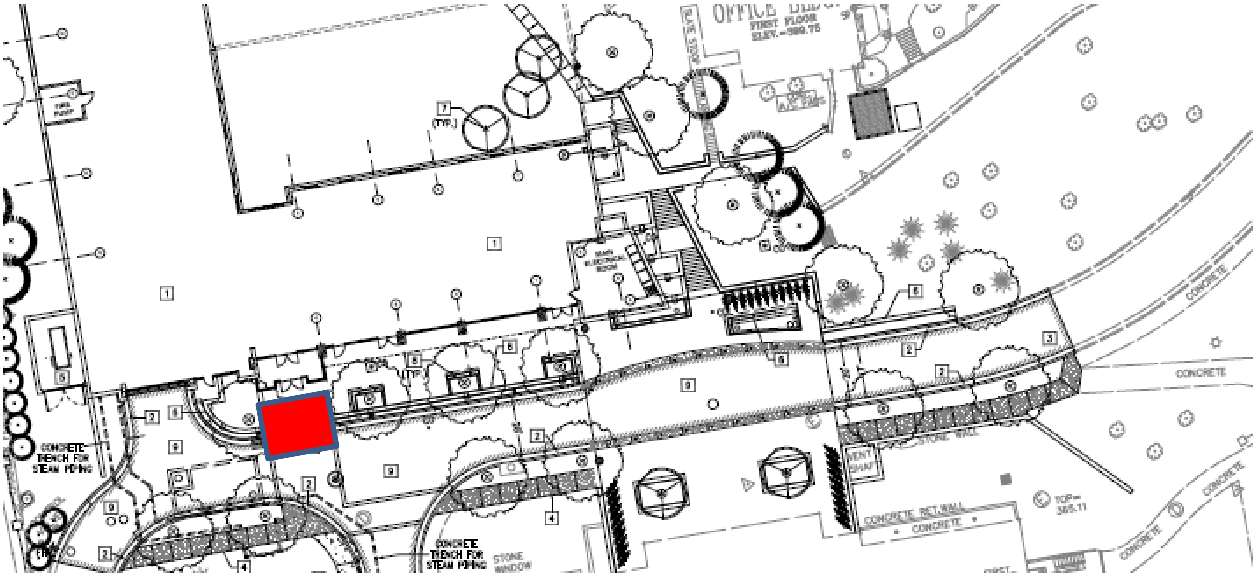


Figure 15: Material Hoist (Red Box) Location

Constructability Issues

It is important to realize the challenges of integrating the suite bathroom modules in the rest of the stick built construction on each floor. The bathroom modules will need to be installed in a in order from the suite farthest from the material hoist to the one closest to the material hoist. One the modules are placed in their location, the 8 feet wide hallways will become only 5 feet wide make the 6 foot wide module unable to fit through.

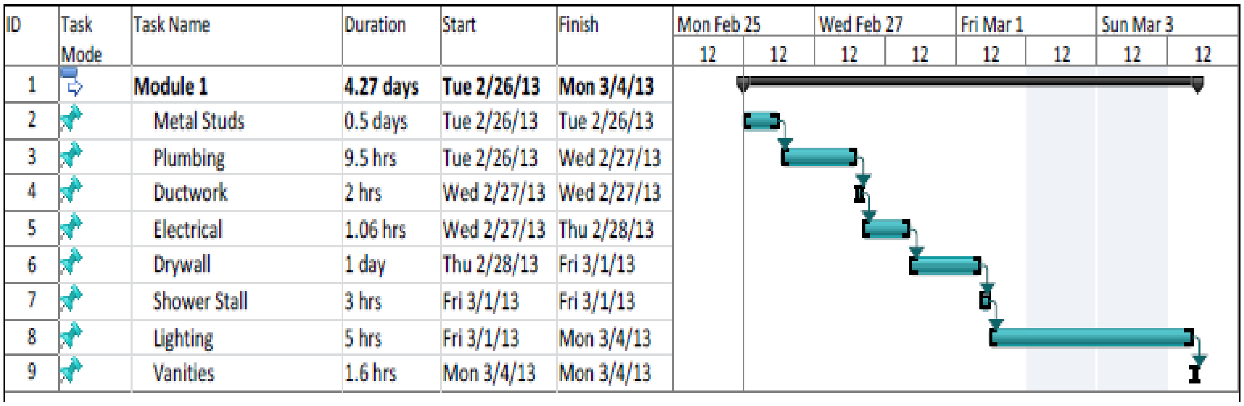
Another important issue that needs to be accounted for is the interface where the modules connect into the rest of the walls. Planning to allow proper access in and around the modules so the installation crew can make any connections and adjustment that need to be made. These connections and adjustments need to be completed without damaging the work that has already been completed, causing potential rework and negating the time savings.

The tolerances and dimensions are critical so that the modular will fit as they were designed to. The piping must be in the correct location so that connections can be easily made to slab penetrations for vertical risers and, floor drains

Module Construction Schedules

Each module will be constructed concurrently since each module is completely independent of the other modules. The schedule is broken down to activities such as, Metal Studs, Plumbing, Ductwork, Electrical, Door Frames, Drywall, Fixtures and Lighting. The schedules are all based on a 8 hour work day as well as only working Monday through Friday.

Module 1 has the longest duration as can be seen in Figure 16. Even though module 1 is the smallest, it contains the most components. The shower and both vanities are included in this module.

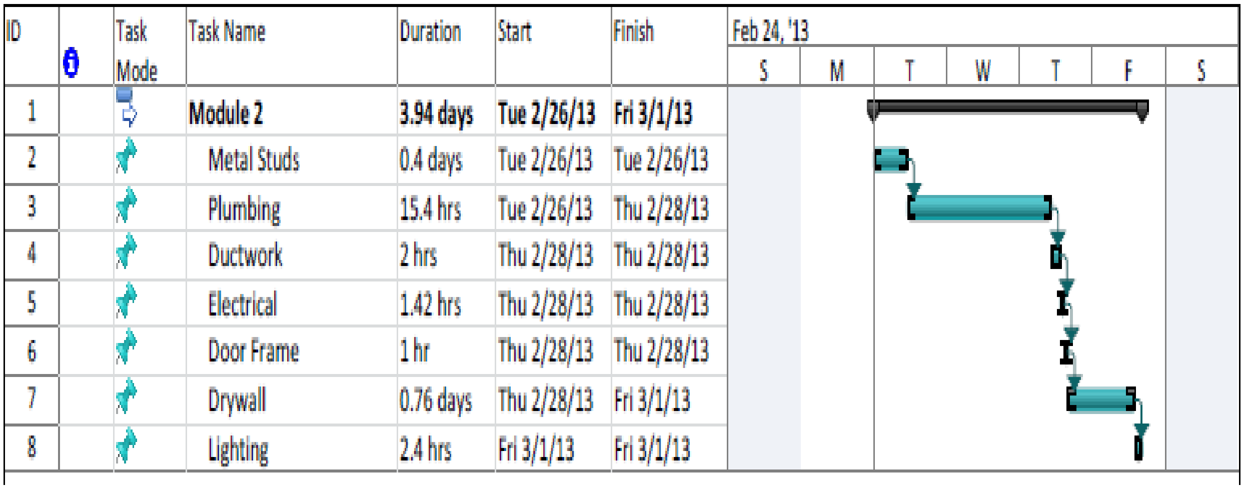


ID	Task Mode	Task Name	Duration	Start	Finish
1		**Module 1**	**4.27 days**	**Tue 2/26/13**	**Mon 3/4/13**
2		Metal Studs	0.5 days	Tue 2/26/13	Tue 2/26/13
3		Plumbing	9.5 hrs	Tue 2/26/13	Wed 2/27/13
4		Ductwork	2 hrs	Wed 2/27/13	Wed 2/27/13
5		Electrical	1.06 hrs	Wed 2/27/13	Thu 2/28/13
6		Drywall	1 day	Thu 2/28/13	Fri 3/1/13
7		Shower Stall	3 hrs	Fri 3/1/13	Fri 3/1/13
8		Lighting	5 hrs	Fri 3/1/13	Mon 3/4/13
9		Vanities	1.6 hrs	Mon 3/4/13	Mon 3/4/13

Figure 16: Module 1 Schedule

Module 1 will take 4.27 days to fully construct. The durations for each activity were calculated using RS Means Online database durations. Since the module is only 6 feet by 5 feet only one activity will be going on at a time to avoid the different trades from getting in each other's way.

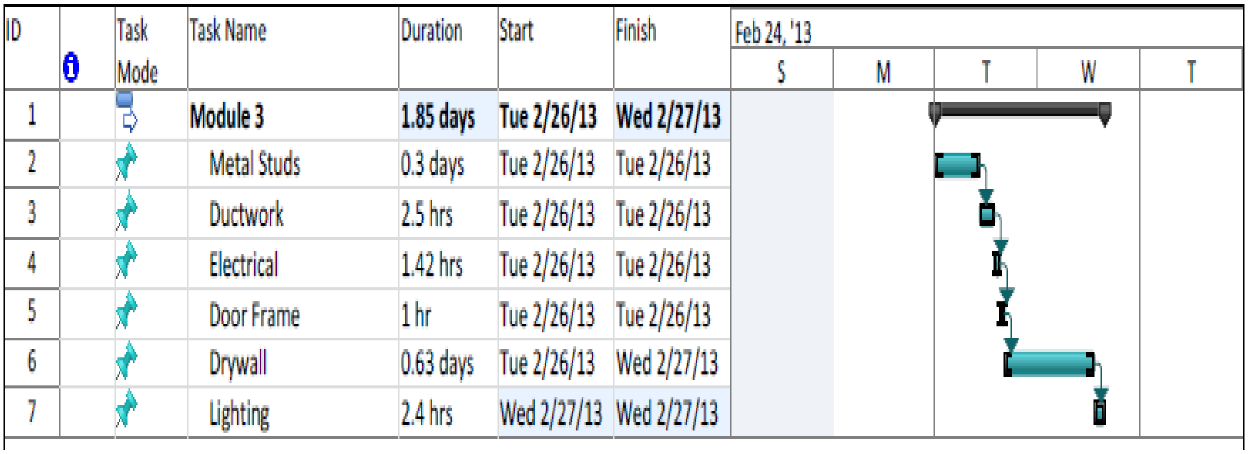
Module 2 is largest module but is will take about a quarter of a day less than module 1. Module 2 contains the hot and cold-water chase piping as well as the toilet. The schedule of module 2 can be found in Figure 17. In 3.94 days module 2 will be complete.



ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
1			**Module 2**	**3.94 days**	**Tue 2/26/13**	**Fri 3/1/13**
2			Metal Studs	0.4 days	Tue 2/26/13	Tue 2/26/13
3			Plumbing	15.4 hrs	Tue 2/26/13	Thu 2/28/13
4			Ductwork	2 hrs	Thu 2/28/13	Thu 2/28/13
5			Electrical	1.42 hrs	Thu 2/28/13	Thu 2/28/13
6			Door Frame	1 hr	Thu 2/28/13	Thu 2/28/13
7			Drywall	0.76 days	Thu 2/28/13	Fri 3/1/13
8			Lighting	2.4 hrs	Fri 3/1/13	Fri 3/1/13

Figure 17: Module 2 Schedule

Module 3 is the most simple of the three modules. This is the case since there is no plumbing required in the module since the shower is located in module 1. This module is the room the rest of the shower room. Due to the simplicity of this module is will only take 1.85 days to construct as can be seen in Figure 18.



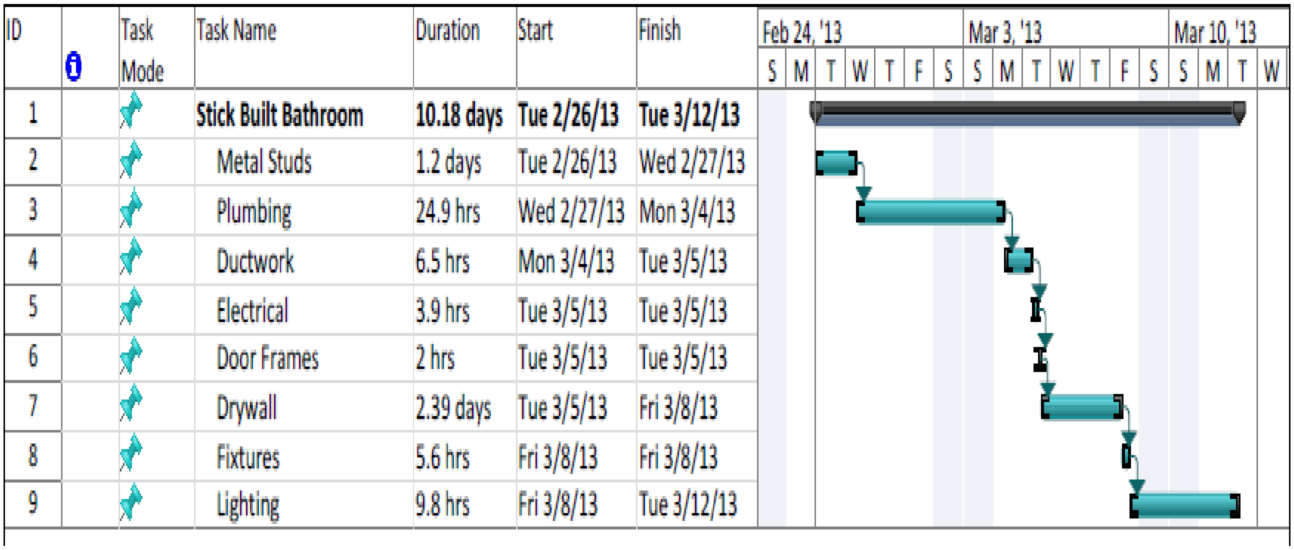
ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
1			**Module 3**	**1.85 days**	**Tue 2/26/13**	**Wed 2/27/13**
2			Metal Studs	0.3 days	Tue 2/26/13	Tue 2/26/13
3			Ductwork	2.5 hrs	Tue 2/26/13	Tue 2/26/13
4			Electrical	1.42 hrs	Tue 2/26/13	Tue 2/26/13
5			Door Frame	1 hr	Tue 2/26/13	Tue 2/26/13
6			Drywall	0.63 days	Tue 2/26/13	Wed 2/27/13
7			Lighting	2.4 hrs	Wed 2/27/13	Wed 2/27/13

Figure 18: Module 3 Schedule

Since all three of the modules will be built concurrently thus the modules will be complete and ready for shipment to the site after 4.27 days of construction. This is cutting significant time from the time required for is the bathroom was to be completely built in place on site.

Stick Built Schedule

The suite bathrooms for North Hall will built using a traditional stick built method. The schedule shown in Figure 19 was developed using the RS Means Online database activity durations since a detailed schedule of the bathroom construction was unavailable.



ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
1			**Stick Built Bathroom**	**10.18 days**	**Tue 2/26/13**	**Tue 3/12/13**
2			Metal Studs	1.2 days	Tue 2/26/13	Wed 2/27/13
3			Plumbing	24.9 hrs	Wed 2/27/13	Mon 3/4/13
4			Ductwork	6.5 hrs	Mon 3/4/13	Tue 3/5/13
5			Electrical	3.9 hrs	Tue 3/5/13	Tue 3/5/13
6			Door Frames	2 hrs	Tue 3/5/13	Tue 3/5/13
7			Drywall	2.39 days	Tue 3/5/13	Fri 3/8/13
8			Fixtures	5.6 hrs	Fri 3/8/13	Fri 3/8/13
9			Lighting	9.8 hrs	Fri 3/8/13	Tue 3/12/13

Figure 19: Stick Built Bathroom Schedule

A bathroom built using the stick built method will be completed in 10.18 work days. The schedule in Figure 19 shows the construction of the bathroom in one continuous cycle from start to finish of the bathroom. In actuality the bathrooms will not be built before or after the rest of the floor. The construction of each trade's work will be integrated in to the construction of each floor. For the analysis to be performed the assumption that the bathroom will be built start to finish in one continuous process was made.

Schedule Comparison

The module construction will be completed at an offsite warehouse facility located within the District of Columbia. By having the production facility only 7.6 miles (25 minute drive) away will eliminate long shipping durations. All the modules required to construct a single bathroom unit will be shipped together on the same truck thus eliminating the chances of modules getting mixed up on site. Once they are delivered to site the modules will be immediately moved to the correct floor and location within North Hall. From the time the module leave the warehouse until they are in place waiting for the connections and adjustments by the field crew will be approximately a half of a day. There is some extra time built into this particular duration to account for the restriction of large vehicles in the District of Columbia during rush hour as well as the unpredictability of traffic in the area.

Once the modules are in place it will take a day and a half for all the connections and final adjustment to be made for the bathrooms. As more modules are installed this duration should theoretically decrease due to the benefits from the learning curve that the installation crew will experience. Table 7 outlines the total duration of construction for a single suite as well as for all the suites receiving the modularized bathrooms. Please note that the full building durations assumes each bathroom will start once the previous bathroom has been under construction for 2 days. Also that the modularized units will be shipped in groups of six suites (18 modules) and it takes two days to set, connect and adjust the six groups of modules.

Table 7 Suite Bathroom Schedule Comparison

	Single Suite		**Full Building (64 suites)**	
	Modularized	Stick Built	Modularized	Stick Built
Duration (days)	6.27	10.18	70.31	136.18
Savings (days)	3.91		65.87	

Almost four full working days can be saved from just a single suite bathroom and over 67.87 days when the schedule savings is extrapolated for the entire building.

Module Cost

Construction of the modules will take place a warehouse in Washington, D.C. The warehouse is about 9,000 square feet which will allow for six of the sets of modules to be built at the same time as well as plenty of room to stage materials and store the modules until the modules are needed on site. The warehouse will be used for 3 months at a cost of $17,280. Also the shipping cost for each set of three modules was assumed to be $150 per shipment for a total cost of $9,600.

The labor will be cheaper by using a factory setting at the production warehouse. To approximate the labor rate that will be paid to the less skilled workers at the warehouse. Table 8 lists the labor rates according to the Bureau of Labor Statics for the required trades in the Washington D.C. metro area. The rates were then averaged with the given rate for a laborer to approximate the labor rate for the modules.

Table 8: Labor Rates by Trade

Trade	Rate	Adjusted Rate
Carpenter	$21.54	$18.49
Electrician	S26 66	$21.05
Plumber	$25.69	$20.56
Laborer	$15.43	N/A

Rates are from United Department of Labor Bureau of Labor Statistics

The estimate of the module cost is broken down by the three different versions of the modules. Module 1 is the most expensive which is expected since it is also is the most intricate of the three modules. Table 9 breaks down the cost by module. A more detailed estimate can be found in Appendix F.

Table 9: Cost by Module

	Single Suite	Full Building (64 Suites)
Module 1	$6,617.83	$423,541.12
Module 2	$5,637.25	$360,784
Module 3	$2,577.38	$164,952.32
Shipping	$150	$9,600
Warehouse	$270	$17,280
TOTAL	$15,252.46	$976,157.44

Stick Built Cost

North Hall is using the stick built method in the construction of each floor including the suite bathrooms. This method does not require the warehouse and shipping cost that the modularized construction needed. Modularized construction at the warehouse was able to utilize a cheaper less skilled labor force however this is not the case in onsite constriction. Please see Table 7 for the labor rate of each trade involved in the construction. These more expensive labor rates will cause the labor cost to change compared to the modules. Table 10 provides the stick built costs.

Table 10: Stick Built Suite Bathroom Cost

	Material	Labor	Equipment	Total
Single Suite	$8,309.20	$5,500.83	$-	$13,810.03
Full Building (64 Suites)	$531,780.80	$352,053.12	$-	$883,841.92

Please see Appendix G for detailed of the bathroom.

Cost Comparisons

The stick built cost is approximately 9.5% less expensive compared to the modular construction as can been seen in Table 11. From strictly a cost perspective it doesn't make sense to use modular construction but when other components of the construction added to the equation their costs must also be considered such as general conditions savings from time cut out of the project schedule.

Table 11: Modular vs. Stick Built Costs

	Single Suite	Full Building (64 Suites)
Modular	$15,525.46	$976,157.44
Stick Built	$13,810.03	$883,841.92
Difference	$1,715.43	$92,315.52

Conclusions

Implementing modular construction for the bathroom suites in North Hall will allow for the project schedule to be accelerated more than is already is. Finishing the project on time is paramount for Grunley Construction. The potential savings of about 66 working days using modular construction make sense from a schedule standpoint.

The time gained from modular construction can be used to offset delays encountered during the early stages of the construction of North Hall. The foundation systems (caissons) were about two weeks behind schedule. Due to the small site, no other work could be performed while the caissons were being worked on. The precast façade installation was also approximate two weeks behind schedule as well. Fortunately, other work was able to be done during the precast panel installation. In addition, there was few days in the fall that were lost due to serve weather such as Hurricane Sandy.

For modularization to be implemented, the cost of the bathrooms will increase by $92,315.52. This increase can save the project money in the end by helping the project be finished on time. North Hall needs to be completed and turned over to American University so that student can move into North Hall for the Fall 2013 semester.

If Grunley Construction is able to find was to save about $92,000 in the project then they should absolutely use the modular construction for the bathrooms of the suites. If they are unable to find a way to save the money elsewhere they must justify to American University why $92,315.52 should be spent to get the project completed earlier than originally anticipated.

Analysis 2: GPS Material Tracking - Precast Panels

Problem Identification

Deliveries to site can be extremely problematic because of the single lane access to the site as well as the extremely tight site. Once a truck pulls onto site it is next to impossible for another truck to get in or out of the gate essentially shutting down the access road to until the truck is unloaded and leaves. North Hall would benefit greatly from a material tracking system.

North Hall's façade is primarily made up of precast panels and the schedule to erect these panels is extremely tight. The precast subcontractor must have erect all of the over 400 panels in eight weeks. Implementing Global Positioning System tracking system to track the precast panels from the production facility in North Carolina to site in downtown Washington, D.C. and then when they are placed in their correct location. This tag would also be used to track the test done on the panels once they are installed. The GPS tag will allow the project team to better coordinate deliveries to site and track the material when it is onsite. Grunley is currently using a similar technology, RFID tags on the workers' hard hats to track certified business enterprise (CBE) requirements in the contract.

Research Goal

The goal of this analysis is to analyze the benefits of using a GPS tracking system for the precast panel façade for material tracking and site logistics.

Methodology

- Obtain precast façade schedule and details
- Identify erection sequence
- Identify required testing
- Identify potential GPS software programs
- Evaluate information to be included on GPS tags
- Determine best method for implementation
- Analyze cost impacts
- Analyze schedule impacts

Resources and Tools

- Industry Professionals
- Related Literature
- Grunley Construction Project Team
- AE Department Faculty

Background Information

North Hall's façade is made up of almost entirely of an architectural precast concrete panel system. The precast panels are being manufactured by Gate Precast from Oxford, North Carolina and then will be shipped to site in Washington D.C. for installation. Erecting the panels on schedule is key to getting the tower crane offsite. The tower crane that was used by Miller and Long for the concrete structure will also be used by Gate Precast installation subcontractor. As mentioned earlier in this report North Hall's site entrance is extremely tight and congested. The road is so narrow that large construction vehicles, such as the trucks that will be delivering the precast panels. A system to manage and track the panel delivery and installation such as a GPS tracking would be beneficial to Grunley Construction's project team.

This GPS system would not only be used to track the delivery and installation of the precast panels but also for the required testing of the panels once they are installed. This will provide the project team a place to store all the data from these important activities.

Figure 20: RFID Hard Hat Sticker, Photo Taken By Brandon Tezak

Figure 21: RFID Tag Reader, Photo Taken By Brandon Tezak

Currently Grunley is using an RFID tracking system for the onsite workers. This tracking is done as part of the Certified Business Enterprise (CBE) requirement that Grunley Construction has with the owner, American University. Each of the workers receives a sticker shown in Figure 20 that has an RFID tag embedded in it that goes on their hardhats. Grunley they then faxes the tag number and the workers home location to the third party data collection company, Automated Daily Reporting (ARD) Network out of Reston, Virginia. When they arrive at site for the day, they walk under a RFID tag reader as seen in Figure20, that read the tag and the data is then sent to ARD Network where the report is generated and then sent to the project team.

Precast Erection and Sequence

The tower crane will pick the precast panels directly from the delivery truck and then lift the panel into place. Gate Precast's contract included an aggressive eight week schedule so that they would have full use of the tower crane. Miller and Lang agreed to leave their tower crane up for eight weeks after they finished the concrete structure. To meet the eight-week schedule they must average 10.25 panels per day if they are not working on Saturdays. If they would work on Saturdays, 8.54 panels per day need to be erected.

The precast panel erection was planned to start on the West elevation as shown in Figure 22 and then work around the building in a counter clockwise fashion. The panels are designed to stack on top of each other and connected to each floor slab by an embed placed in the floor slabs. The panels will rest on the second floor slab.

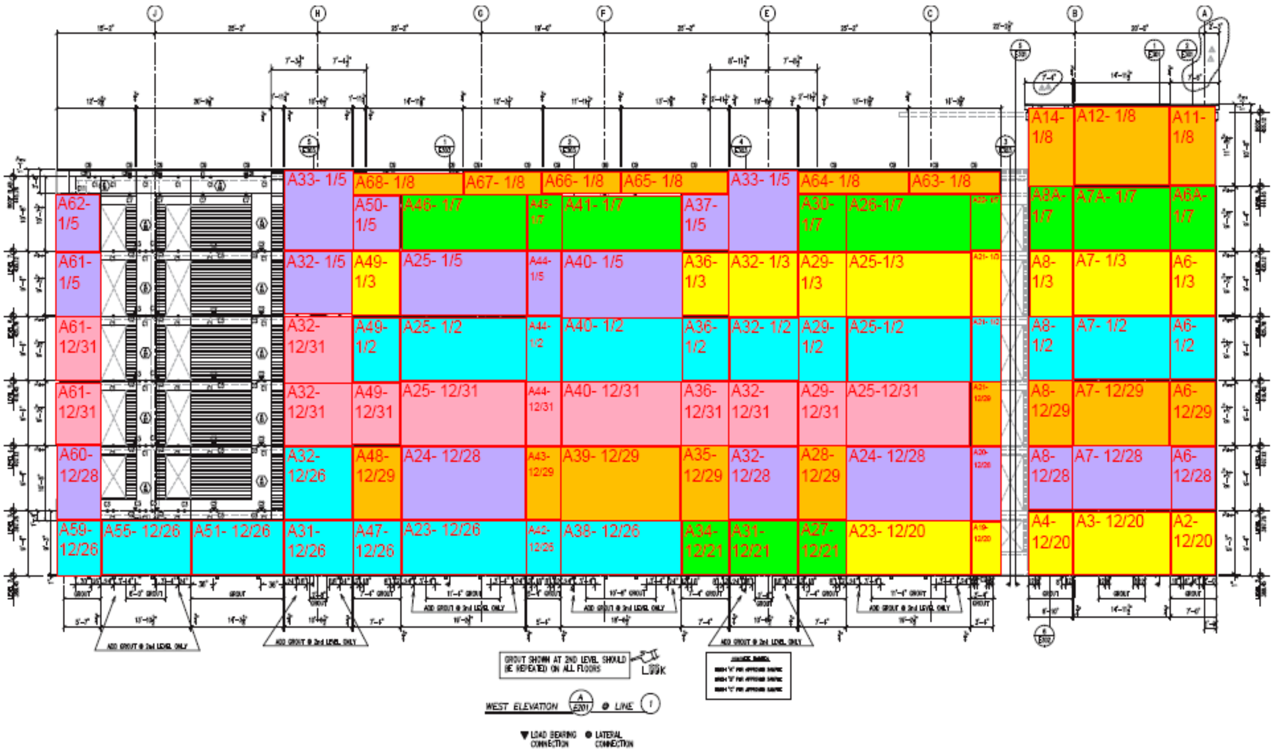


Figure 22: West Elevation Precast Panel Installation Tracking, Image Courtesy of Grunley Construction Company

Unfortunately, the planned schedule and sequence was hindered by a few factors such as logistical mismanagement and weather issues. Since the panels were being manufactured in Oxford, North Carolina, which is approximately 3 hours and 45 minutes or 220 miles, South of Washington D.C. and truck were sent every day with panels. On day where snow was forecasted for the Washington D.C. metro area fewer trucks than was needed. The forecast for snow was wrong and they only received rain. On days like this, the installation crew would run out of panels.

It is unsafe of be operating a crane let alone a tower crane in high winds. There were a few days that winds prohibited the erection of the precast panels. Once again the schedule was delayed which has caused some costly changes to happen.

The most significant problem was that the 8 weeks of the tower crane was up and the crane was needed on Miller and Long's next job therefore Gate Precast now needed to find another means of installing the precast panels. The remedy for this was to bring in a mobile crane and erect from the road in the site. This caused even more congestion since part of the road was taken up by the crane. Once it was determined that the original schedule and sequence was not going to be obtainable, the panels on the backside of the building that would not be easily reached by the mobile crane were erected. Gate Precast resorted to erecting which ever panel they could to keep the project moving forward.

Precast Testing

The specification for the Precast Architectural Concrete on North Hall call for some field quality control testing. A third party testing agency was hired by American University to perform the required test and inspections as well as create and prepare the test reports for both the Architect, Little Diversified, and the contractor, Grunley Construction.

The embed that attach to the floor slabs to the precast panel are welded together. These field welds were inspected visually by the testing agency. Along with the visual inspections of the welds, nondestructive testing can be used that conforms to the standards outlined in ASTM E 165 or ASTM E 709. If any if these welds fail the testing, they must be repaired so that the connection will pass the inspection. In addition, the high strength bolted connections were tested.

GPS Software Programs

There are a number of GPS tacking programs available on the market today. Many of the systems are similar to ones that are used by trucking and transportation companies to track their vehicles such as the one used by many students at The Pennsylvania State University's main campus to track the location of the CATA buses. The great thing about a system like this is that these systems are all web based GPS tracking systems. The tracking system can then be viewed on any computer or mobile device such as a smart phone or tablet.

Figure 23: Tracking Tag, Photo Source: www.intelliwavetechnologies.com

Intelliwave Technologies has a GPS tracking system designed specifically for tracking materials in the construction industry. The system is known as *SiteSense*. *SiteSense* will allow for the North Hall Project team to track the precast panels from the production facility to site at American University in real time. GPS tags would be attached to the panel Gate Precast's production facility in Oxford, North Carolina. These GPS tags are very rugged and will have no problem taking any abuse they may face during the production, transportation or installation, as the tags are design and tested to meet military specifications. In addition, the tags have a battery life of up to seven years. These tags as shown in Figure 23 have barcodes on they that can be read with a special handheld computer from Intelliwave Technologies. Documents can be attached to the identification on the GPS tags for the management of quality control. The customizable software system can be set up to notify the users of an impending delivery of material (Technologies, 2013). The fact that documents such as the third party testing agency reports on the welds and connections of the precast panels to the embed in the concrete floor slabs can be directly linked to the identification number located on the individual tags will greatly help the project team.

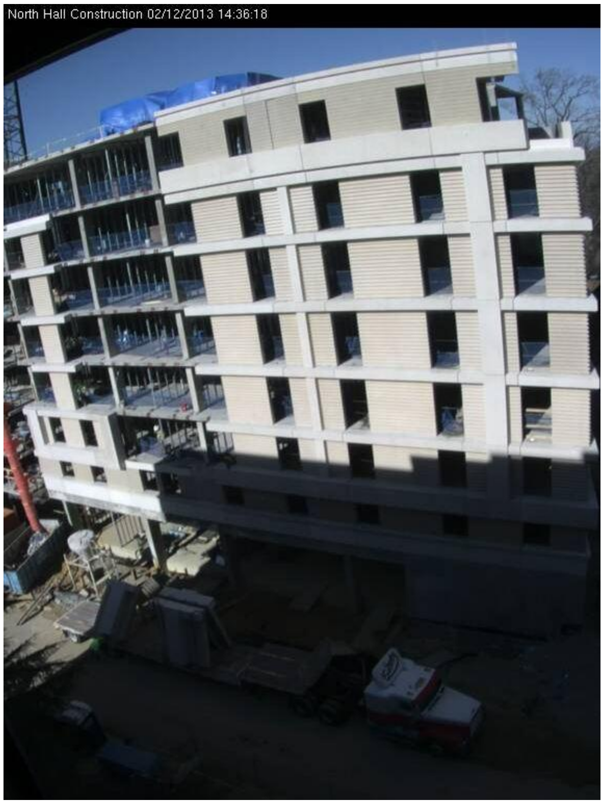


Figure 24: Precast Panel Delivery, Photo Courtesy of Grunley Construction Company

The most important feature of the *SiteSense* tracking system is that the project team can track each panel's location in real time. This is important since the site entrance as discussed previously is only big enough for one truck to enter and park on the road to be unloaded at one as scan be seen in Figure 24 during the installation of the precast panels. Since there is a lot of other work going on during this phase of construction such as the framing and rough in work on each floor there will be other construction vehicles in and out of the site. The project team and can be alerted to when a delivery truck carrying the precast panels is nearby so that the road can be clear of other vehicles to allow the truck unobstructed access of the site. This will help eliminate any delays by the delivery trucks not being able to get into the site.

Another system that has potential to be used for tracking the precast panels it produced by GPS Insight. GPS Insight's system is similar to Inteliwave Technologies' system in the web based software aspect. The major difference is that GPS Insight is more gears toward tracking a fleet of vehicles however they do make a GPS tracking product that is designed for tracking materials and assets, the FT-1000 as shown in Figure 25. This unit would be mounted directly to the precast panel. The FT-1000 is battery operated. The unit is designed to be able to work anywhere such as inside of buildings due to its strong signal strength. Also included in the FT-1000 is a #D accelerometer to track the speed the unit is moving at. The FT-1000 is small and very light weight, measuring at 2.5" x 1" x .625" and weighing on .8 ounces (FT-1000, 2012).

Figure 25: FT-1000 GPS Tracking Unit, Photo Source: www.gpsinsight.com

North Hall will benefit most from the Inteliwave Technologies' *SiteSense* GPS tracking system. *SiteSense's* design and features are more tailored to the needs of North Hall's precast panels more so than the GPS tacking system developed by GPS Insight. Another key consideration when comparing the two systems is the battery life since there will be not be an easy way to charge the GPS unit once it is mounted on to the precast panel at Gate Precast's production facility. Additionally *SiteSense* allows for the attachment of documents which will allow the GPS tags to be used to track and manage the testing reporting on the welds and bolted connections for each precast panel. This will allow the project team to be able to access the testing reports as they are walking through the building

Information on GPS Tags

Documents are able to be attached via the web based software that *SiteSense* uses. The GPS unit will have unique identification that will be used to identify which panel will go where in the erection sequence. The project team will be able to check that the correct panels are enroute to the site when they will be needed. Also, the testing of the connections from the embeds to the precast panel will be attached in the web based software program.

Cost Impacts

Adding the GPS tracking to the precast panels will cost some money upfront but the money spent will help ensure that more money will not have to be spent if the schedule is blown. If the eight week schedule is not kept a new crane will need to be used. The tower crane is only available for the erection of the precast panels for the eight weeks after Miller and Long is finished with the concrete structure. After those eight weeks the tower crane will be removed.

The actual GPS units are cost approximately $350 each. There are 409 precast panels on North Hall. This will be a cost of $143,150 if each panel would have its own GPS tracking unit. As a way to save some money in the tracking system some of the GPS units could be removed and then reused once the panels are installed, tested and approved and then sent back to the production facility for reuse. If the first 100 precast panel's GPS units (about two weeks of erection) are reused on the last 100 panels on 309 units would be needed saving about $40,000. If only 309 unit would be used it would cost $108,150. There is charge of about $15 per month for the service per device. Assuming that all the devices would be activated for the entire duration of the installation they will be active for 2 months. The service charge for having 409 GPS units is $6,135 and if only 309 GPS units are used the cost is $4,635.

A mobile 70 Ton crane was used when the precast erection ran over the original scheduled 8 weeks. Due to some hard work by both the precast contractor and Grunley's project team, the mobile crane was only needed for a week. The average rental rate for a 70 ton crane can range anywhere from $9,450 to $15,750 a month with an average cost of $12,600 (Crane, 2013). This means that the cost to rent the crane for a week will be approximately $3,150.

The overall cost with the GPS tracking system (309 GPS units) and the crane rental will cost a total of $115,935. All the cost are outline in Table 12.

Table 12: GPS Tracking Costs

Description	Cost
GPS Tracking Units (309)	$108,150
GPS Tracking Service Fee	$4,635
Crane Rental	$3,150
Total	$115,935

Since the precast only ran over the scheduled time by a week the crane rental is not that big of a deal in the big picture since the installation was well over two weeks behind at one point before the project team was able to bring the expected costs with a longer crane rental time to only a needing the crane for a week.

Schedule Impacts

Implementing the GPS tracking system will be beneficial to the schedule for the installation of the precast panel façade. The system will help the project team and the subcontractor, Gate Precast, meet the aggressive 8 week schedule. If the 8 week schedule is kept on track the entire installation will be completed with the Piener SK575 tower crane that was used for the construction of the concrete structure by Miller and Long. After the 8 weeks the tower crane will be removed and a mobile roadside crane will have to be used. This will cause much logistical problems on site due to the tight site.

Adding the GPS tracking units to the precast panels will give the project team a tool to keep the schedule going as planned. This will eliminate the delays that were experienced by the project when not enough panels were shipped from the plant in North Carolina to the site in Washington D.C. The project team will be able to see which panels are currently being shipped. If there was a problem with the number of panels or the particular panels that were being shipped they will have approximately three and a half hours to get the problem sorted out or get more panels on the way. This will make the shipments much more efficient.

The weather is the one cause for delays that there is no way to fix and or control. It is dangerous to be operating the tower crane in high winds let alone lifting very heavy precast panels in these conditions. There is no amount of save time what is worth somebody getting injured or killed by an accident. Safety is also key since there are two occupied dorms that are within the reach of the tower crane.

GPS tracking will give the project team an added tool to keep the schedule moving along without any delays that are in their control such as, having enough material or the site entrance no being blocked.

Conclusion

The GPS tracking system would be ideal for a project that is a larger in scale than North Hall. Since money is an issue for the owner, the GPS system will not be cost effective for North Hall. The project team was able to bring the finish of the precast panels only a week after the date that was expected without using the GPS tracking system.

Since the precast was only a week late the new crane rental cost only $3,150 more it does not justify spending $112,785 on the GPS tracking system. The project team is confident that they will be able to make up this week that they went over throughout the rest of the project. Although the GPS tracking system would good to help keep the installation on track the cost implications out way the benefits making the GPS tracking system not a good idea for implementation on North Hall.

Analysis 3: Solar Panel Upgrade, Electrical Breadth

Problem Identification

North Hall will have two set of solar panel arrays on its roof when the building is complete. The original design of the solar panel array only uses a system that heats domestic hot water. Hybrid Solar Panels have capability to not only heat water but also generate electricity. North Hall is located on a site in which the sun is unobstructed from any neighboring building or trees. The solar energy that will hit the roof and solar panels every can be captured a used to meet the part of the electrical load for North Hall. With an upgrade to the original design, American University has the potential to not only save on their electrical costs over time but also be an example of an environmental steward in Washington, D.C.

Research Goal

The goal of this analysis is to analyze the advantages and disadvantages related to upgrading the solar panels to a hybrid solar panel. Also analyze which of the building's electrical system's load should be supplemented by the new solar panel design.

Methodology

- Investigate hybrid solar panels
- Determine feasibility of proposed upgrade
- Determine cost impacts
- Determine schedule impacts
- Analyze electrical system
- Evaluate where generated electrical energy can best be used
- Analyze effects of upgrade on existing electrical system

Resources and Tools

- AE Electrical Students
- AE Faculty
- Product Specifications
- Project Team
- Related Literature
- Case Studies

Background Information

North Hall was originally designed to include two sets of flat plate solar panels on its roof. Due to some budget problems by American University the solar panels have been delayed. American University plans to install the solar panel system in three to five years after construction is complete. However the design was of the system was to use a solar hot water system. A solar hot water system is used to supplement the heating of domestic hot water. North Hall will eventually have two grouping of these solar hot water panels on the seventh and eighth floor roofs as can be seen in Figure 26.

Figure 26: Hall Solar Panels, Model Courtesy of Grunley Construction Company

The solar hot water panels typically only capture about 10% to 20% of the possible energy they see from the sun. The original design used Cinco Solar Incorporated's, of Spring Branch, Texas, Thermomax CS-40 evacuated tube solar collector. The Thermomax CS-40 uses the heat that is absorbed and then transfers the heat to the water in the system as seen in Figure 27. Each of the CS-40 units are capable of producing approximately 40,000 BTU per day and while heating 5 gallons per minute (Thermomax).

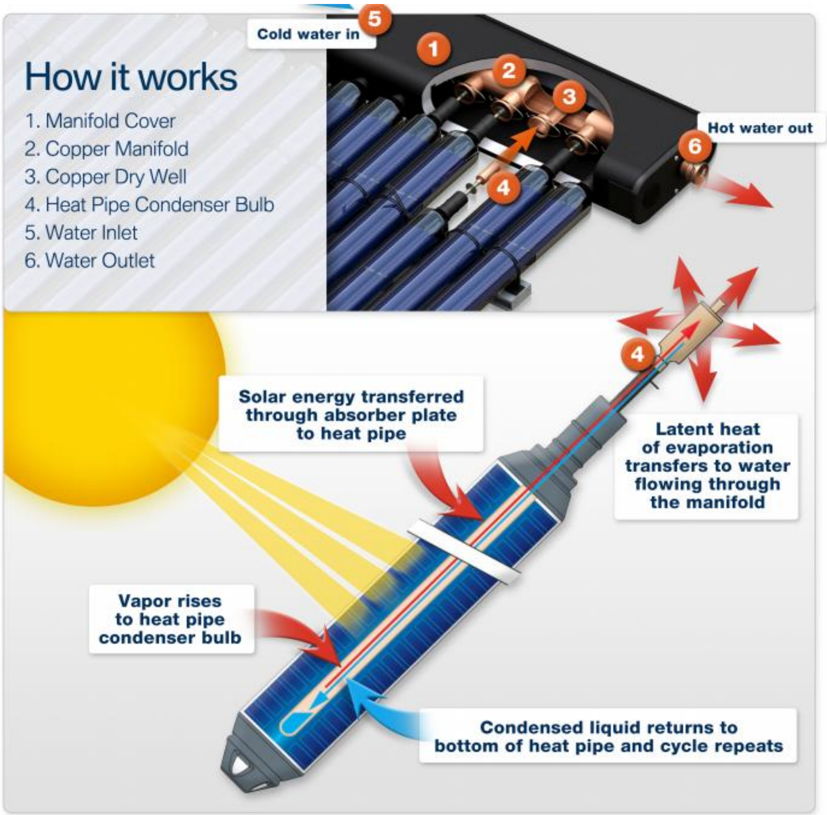


Figure 27: CS-40 Schematic Diagram, Photo Taken from www.cincosolar.com

The CS-40 only has the ability to use the energy that it captures from the sun for heating water. Some of the energy that is being unused by the CS-40 with an upgrade to the panel the ability to capture some of the unused energy for the generation of electricity such as a hybrid solar panel.

Hybrid Solar Panel

A hybrid solar panel has the ability to both heat water and generate electricity. Typically one of the two applications is attainable since the excess heat creates a problem when the panel is used for generating electricity. Solar cells decrease in efficiency when the temperatures rise. This is due to the increase of the conductivity of the semiconductor and the balancing that occurs in the material to the charge. Thus the magnitude of the electric field is reduced causing a lower voltage across the solar cell (den Haan, 2009). This decrease in efficiency is out lined in Figure 28, a graph developed by manufacturer, Cogenra Solar.

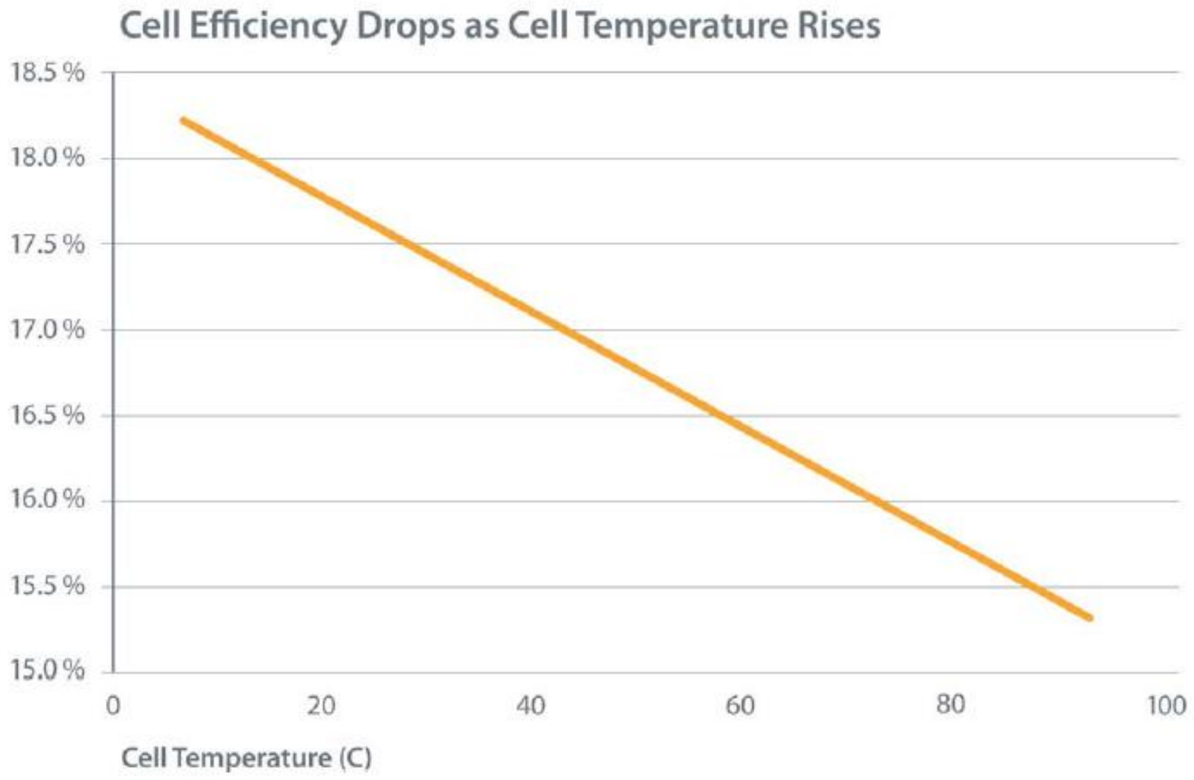


Figure 28: PV Cell Efficiency vs Temperature (typical 15-17% efficiency cell), Source: Cogenra Solar

This is the opposite of what a solar hot water panel is designed to do. As mentioned before the solar hot water panel captures the heat and then transfers the heat from the fluid in the solar collector to the water line.

According to den Haan, typical solar cell will drop its efficiency approximately .5% for every 1.8°F that the temperature rises above 77°F (den Haan, 2009). The average high temperature in Washington D.C. is above the 77°F for four months of the summer; June 84°F, July 89°F, August 87°F, and September 80°F.

]

The actual solar cell will be much hotter than the air temperature will be. For a hybrid solar panel system to be successful this efficiency problem must be accounted for and resolved.

Cogenra Solar, from California, has developed a solar panel that can generate both hot water and electricity while improving the overall efficiency of the panel. The manufacture claims that the panel, shown in Figure 29, captures up to 75% of the energy that it receives form the sun. Unlike the CS-40 this panel system will track the sun to optimize the output of the panel.

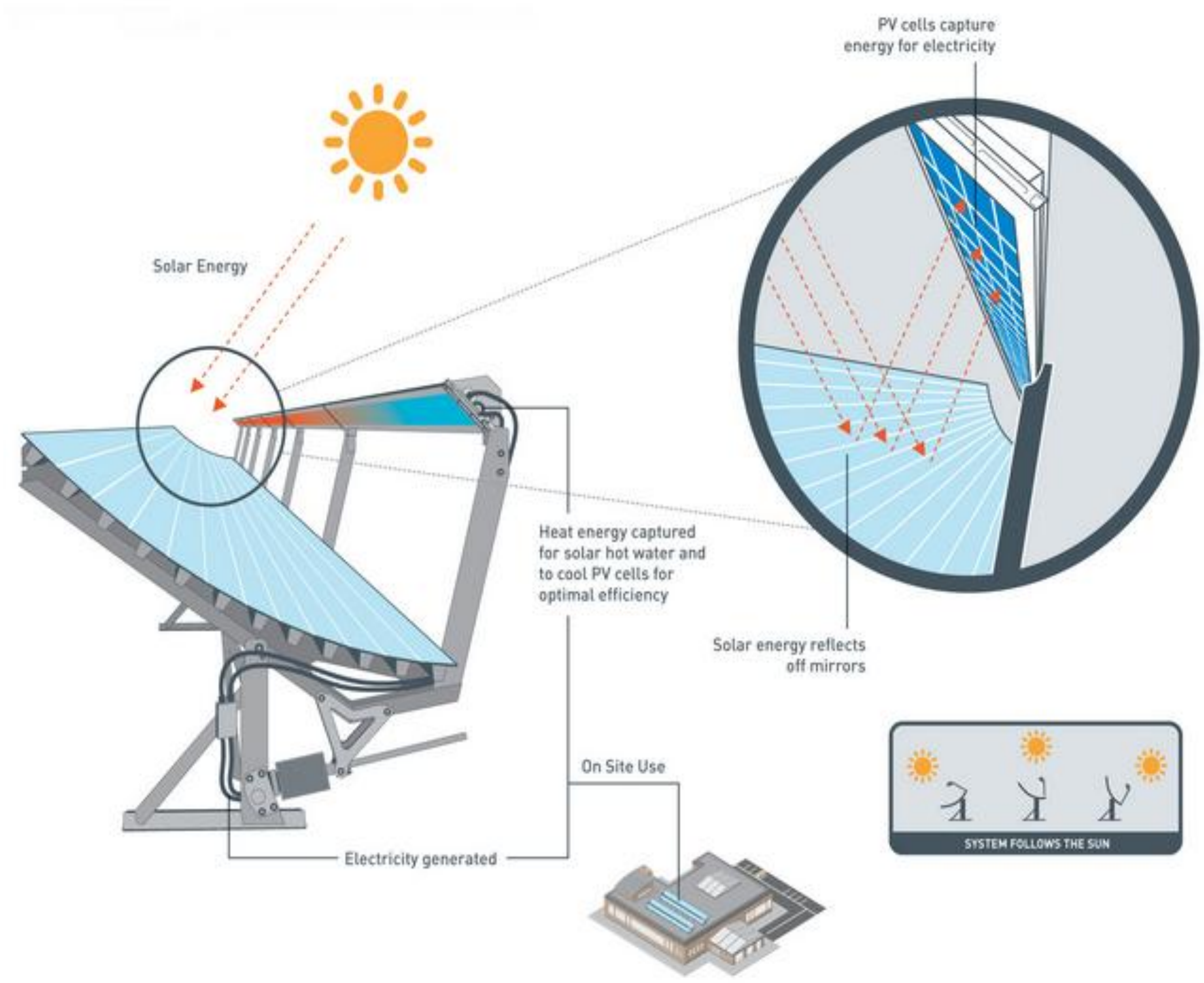


Figure 29: Cogenra Solar's Cogeneration Panel, Source: www.cogenra.com

This product minimizes the problem with the electrical generation panel from overheating by reflecting the solar energy with the large concave reflector. The special silicone PV cells are mounted above and facing down to the reflector. These silicone PV cell are able to convert approximately 15% of the solar energy into electricity (Solar Cogeneration). The silicone cells are almost as effective in absorbing the solar energy as the traditional black coating of solar cells. The silicone is what allows the cells to capture both electricity and heat. These cells are as able to capture 65% of the solar energy as thermal energy that is used to generate hot water (How Solar, 2012). The reflector system is made up of small, custom curved glass mirrors that are used to focus the solar energy up to 10x to the silicone PV cells. A special piping system in the arm that contains the high efficiency silicone cells is coated in a black to optimize the absorption of heat. A mixture of distilled water and antifreeze removes the heat from the cells and turns the heat into useable hot water for the building (Burger, 2012).

Cogenra Solar's cogeneration panels have been primary used on the West Coast since the company is just only 4 years old. Clover Stornetta Farms, La Posada, Kendall- Jackson Winery, General Hydroponics, Inc., Sonoma Wine Company, Facebook, Southern California Gas Company, the United States Military, and Maui Brewing Company are a few of Cogenra Solar's clients that have installed the new solar panels since late 2010.

The Sonoma Wine Company, needed a way to limits its energy expenses for electricity and natural gas used to heat the water needed in for the production of its wine. Cogenra designed a system to meet the need of the owner. The design used 15 *SunBase* modules which are shown in Figure 30.

Figure 30: Sonoma Wine Company's Cogenra Solar Panels, Source: http://guntherportfolio.com/2010/11/in-search-of-cogenra-solar/

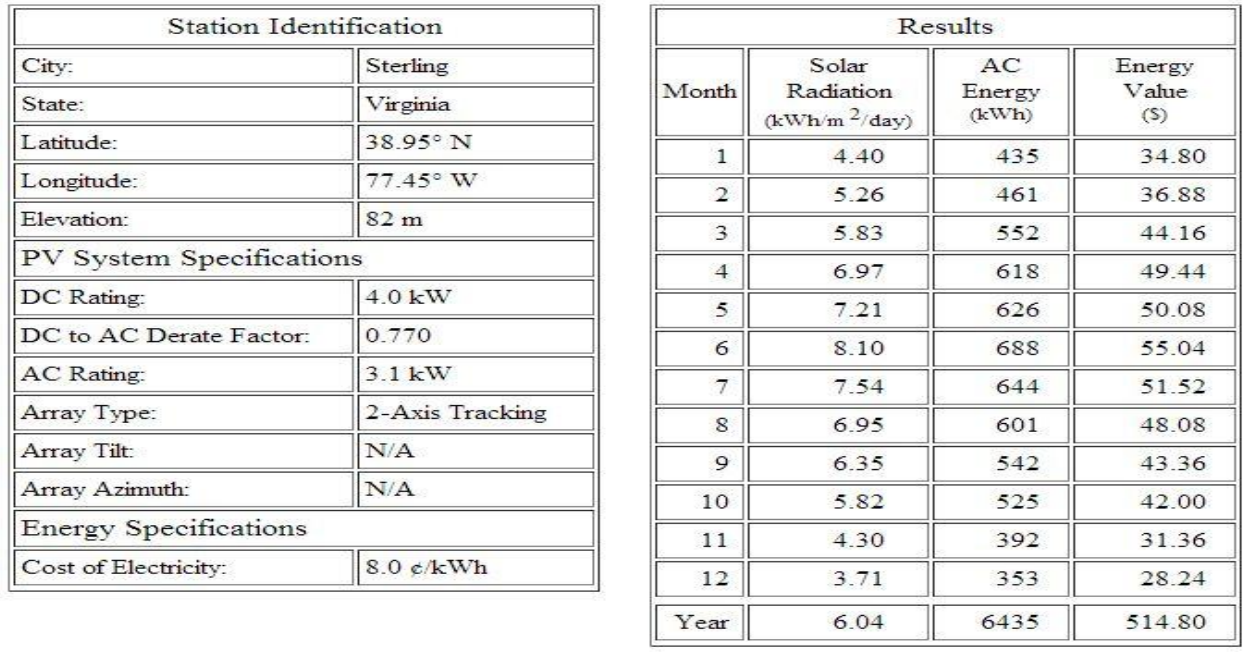
The 15 modules generate 272 total kilowatts of electric and thermal output. This eliminated up to 64,000 kilo-watt hours and 12,500 therms of natural gas each year. The hot water generated from this system is heated to 165°F for the barrel wash system which washes over 800 barrels per shift entirely on the hot water generated from the panels (Sonoma, 2010). This size of these area the panels at the Sonoma Wine Company facility occupy is about the size of the roof area that North Hall has available for the solar panels. North Hall's system will roughly be the same size.

Another one of Cogenra's clients was La Posada, a retirement community located in Green Valley, Arizona. This senior community is one of the largest in Arizona with over 700 residents in the 477 independent living apartments, 85 assisted living apartments, 29 memory care suites and 58 skilled nursing care suites. Due to the large demand for energy on the campus La Posada wanted a way to cut the expenses for the over 15,000 gallons of hot water used daily on campus. After studying the electricity and hot water need of La Posada, Cogenra designed a system of 84 of their *SunPack* modules split between the fitness center and laundry facility buildings. The fitness facility has 24 modules and 60 at the laundry facility. These modules have total output of 211 kilowatts, 36 kilowatts for electricity and 175 kilowatts of thermal capacity. La Posada has eliminated the need for 41,858 kilowatt-hours and 11,057 therms of natural gas per year. This is approximately 70% of the total energy need for the fitness and laundry buildings (La Posada, 2012). Cogenra's products have been very successful in cutting the energy needs of the buildings that they have been installed on. North Hall should be no different than these buildings.

Electrical Impacts

North Hall will receive a system of Cogenra Solar's *SunBase* panels. The system will be almost identical to the 15 modules that were installed at the Sonoma Wine Company. The only major difference is that the panels were installed on the ground at the Sonoma Wine Company and they will be installed on the roofs of North Hall.

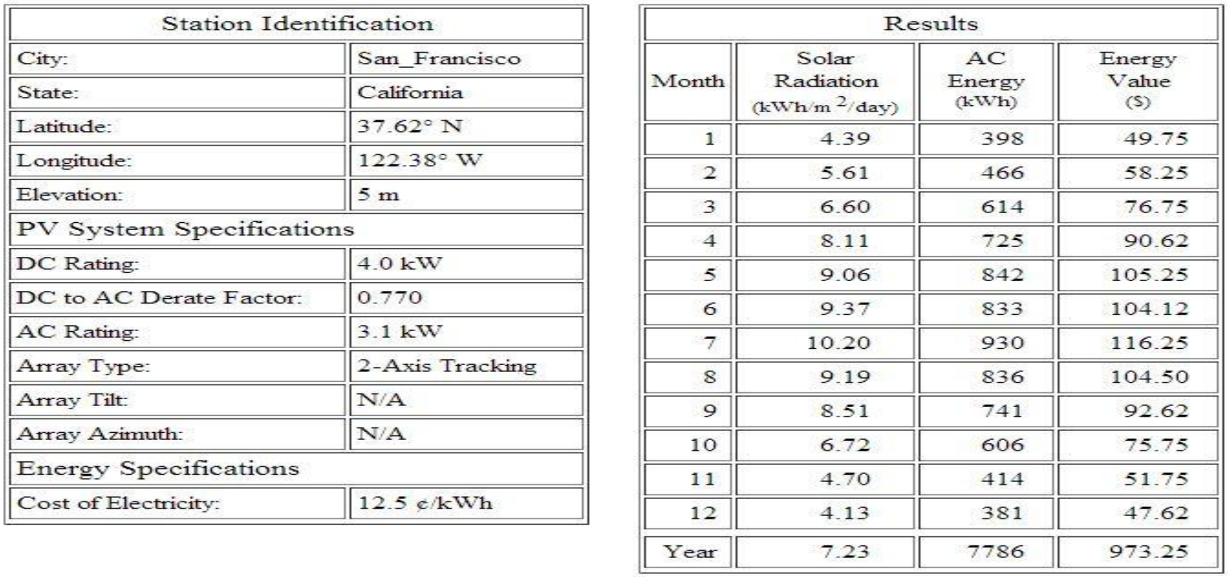
The estimated output of the panels was determined by using the data provided in the Cogenra Solar's case study on the project for the Sonoma Wine Company and translating that to the conditions at North Hall. This had to be done since the manufacture was unable to provide output data for their panels. Using PVWatts, and online tool used to calculate estimated solar radiation that a particular area receives each day. The nearest data station to North Hall is Sterling, Virginia and to the Sonoma Wine Company is San Francisco, California. The estimated solar radiation data can be found in Figure 31 for North Hall (Sterling, VA) and Figure 32 for the Sonoma Wine Company (San Francisco, CA).



Station Identification	
City:	Sterling
State:	Virginia
Latitude:	38.95° N
Longitude:	77.45° W
Elevation:	82 m
PV System Specifications	
DC Rating:	4.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.1 kW
Array Type:	2-Axis Tracking
Array Tilt:	N/A
Array Azimuth:	N/A
Energy Specifications	
Cost of Electricity:	8.0 ¢/kWh

Results			
Month	Solar Radiation (kWh/m ^{2}/day)	AC Energy (kWh)	Energy Value ($)
1	4.40	435	34.80
2	5.26	461	36.88
3	5.83	552	44.16
4	6.97	618	49.44
5	7.21	626	50.08
6	8.10	688	55.04
7	7.54	644	51.52
8	6.95	601	48.08
9	6.35	542	43.36
10	5.82	525	42.00
11	4.30	392	31.36
12	3.71	353	28.24
Year	6.04	6435	514.80

Figure 31: PVWatts Data for North Hall,
Source: http://rredc.nrel.gov/solar/calculators/pvwatts/version1/US/Virginia/Sterling.html



Station Identification	
City:	San_Francisco
State:	California
Latitude:	37.62° N
Longitude:	122.38° W
Elevation:	5 m
PV System Specifications	
DC Rating:	4.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.1 kW
Array Type:	2-Axis Tracking
Array Tilt:	N/A
Array Azimuth:	N/A
Energy Specifications	
Cost of Electricity:	12.5 ¢/kWh

Results			
Month	Solar Radiation (kWh/m ^{2}/day)	AC Energy (kWh)	Energy Value ($)
1	4.39	398	49.75
2	5.61	466	58.25
3	6.60	614	76.75
4	8.11	725	90.62
5	9.06	842	105.25
6	9.37	833	104.12
7	10.20	930	116.25
8	9.19	836	104.50
9	8.51	741	92.62
10	6.72	606	75.75
11	4.70	414	51.75
12	4.13	381	47.62
Year	7.23	7786	973.25

Figure 32: Figure 31: PVWatts Data for Sonoma Wine Company, Source:http://rredc.nrel.gov/solar/calculators/pvwatts/version1/US/California/San_Francisco.html

By using the average solar radiation that each location receives the number from California the outputs from the Sonoma Wine Company panels can be modified to the differing condition that are found on the East Coast of the United States at North Hall in Washington D.C. The Sonoma Wine Company panels have a total output of 272 kilowatts and have displaced 64,000 kilowatts of electricity and 12,500 therms of natural gas a year. Using the solar radiation data from PVWatts to modify the output to approximate what the panels should produce at North Hall are shown in Table 13.

Table 13: North Hall and Sonoma Wine Company Panel Outputs

	North Hall	Sonoma Wine Company
Solar Radiation (kWh/m^2/day)	6.04	7.23
Total Output (kW)	227	272
Displacement-Electricity (kWh/year)	53,411	64,000
Displacement-Natural Gas (Therms/year)	10,431	12,500

Please note that all values for North Hall are approximations.

The original design for the solar panels have no electrical generation component. All the 227 kilowatts that would be generated will be bonus for North Hall. None of the power was accounted for in the electrical design. The 227 kilowatts will give North Hall power to power the lighting in the fitness center on the ground floor. There are six different types of lighting fixture for a total of 273 fixtures. Table 14 lists each of the fixtures and their wattages.

Table 14: North Hall Fitness Center Lighting

Fixture Description	Quantity	Input Watts	Total Watts
K2- 6" Recessed Shower Downlight	3	36	108
L-2'x2' Recessed Indirect/ Direct	8	19	152
L2-2'x2' Recessed Indirect/ Direct	10	30	300
M- Pendent 3" Diameter Decorative	12	50	600
P2- 6" Recessed CLF	132	36	4,752
T-1'x4' Recessed Fluorescent	108	32	3,456
Total	273		8,498

Under the ideal conditions the solar panel system should put out about 53,411 kilowatt-hours a year. This means that if the fitness center is open each and every day of the year and that the fitness center light will be on for 16 hours each day that there will be about 9,145 watts per day to use. This means that if all the light were used for 16 hours day and for 365 days a year that the solar panel will be able to power the lights and most likely have some extra capacity.

Cost Impacts

The manufacture was unable to provide a cost for the panels or the installation. Since these panels are relatively new and there are very few manufactures that produce this hybrid cogeneration panel system. However the savings on utility costs can be estimated.

The average cost of a kilowatt-hour of electricity is in the Washington D.C. area is $.122 and the average cost of a therm of natural gas is $1.112 in February 2013 (Average, 2013). The estimated displacement of the panel system is 53,411 kilowatt-hours and 10,432 therms of natural gas a year. This would result in savings of approximately $6,516 on electrical costs and 11,600 on natural gas costs. About $18,116 can be saved a year in utility cost

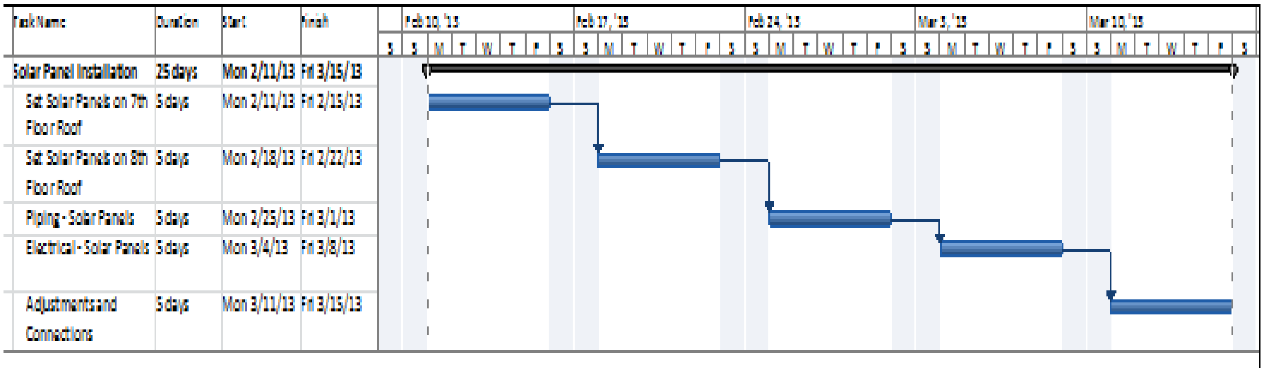
A system that is similar to the original system is estimated to cost $124,952 according to RS Mean data. Assuming that the new cogeneration system will be more expensive than the original system due to the increased complexity. The addition of the sun tacking and the electrical equipment will increase the overall cost. If the new system were to cost $200,000, the system would pay for itself in just over 11 years. The typical lifespan of Cogenra Solar's cogeneration panels is expected to be about 25 years.

Schedule Impacts

Fortunately the solar panel installation is not a critical activity for the North Hall schedule. The installation of the panels will be going on while the rough-in and finish construction is going on inside

North Hall. The only impact that the solar panel system has on the critical path is the embeds for mounting the structure that the solar panels will be mounted on as well as the roof slab penetrations.

The installation of the panels will take approximately 7 weeks. The schedule for the installation of the solar panel system is shown in Figure 33.



Task Name	Duration	Start	Finish
Solar Panel Installation	25 days	Mon 2/11/13	Fri 3/15/13
Set Solar Panels on 7th Floor Roof	5 days	Mon 2/11/13	Fri 2/15/13
Set Solar Panels on 8th Floor Roof	5 days	Mon 2/18/13	Fri 2/22/13
Piping - Solar Panels	5 days	Mon 2/25/13	Fri 3/1/13
Electrical - Solar Panels	5 days	Mon 3/4/13	Fri 3/8/13
Adjustments and Connections	5 days	Mon 3/11/13	Fri 3/15/13

Figure 33: Solar Panel Schedule

The solar panel upgrade will not add any additional time to the project schedule. There will not be any other work that is taking place on the roof while then panel installation is happening.

Conclusion

North Hall would greatly benefit from the hybrid solar panel system. The upgrade from the system that will be installed within the 2 to 3 years, a solar hot water panel system, to a cogeneration panel system will help North Hall reduce its carbon footprint. The cogeneration panel will able to produce both solar hot water as the current design will and add the electrical generation to the equation.

The new panel system is estimated to be able to displace 53,411 kilowatt-hours and 10,432 therms of natural gas a year. This will provide the owner, American University, the opportunity to save about $18,000 a year on utility costs. Assuming that the panel system will cost around $200,000 the panel system would pay for itself in just over 11 years.

The schedule will not be negatively impacted by the panel installation since it will be occurring in an area that will have very little activity, the roof. The panels do not fall on the critical path and there will be a rough in work going on in the lower floors of the building at the same time. The installation will take approximately 7 weeks to complete.

The upgrade of the solar panel system is a good idea for North Hall. There will be an upfront cost for the panel system but this will pay for itself over time. Since the price of energy is so volatile and is expected to increase in the coming years the panels have the potential to save even more money than they are projected to currently. North Hall also has the ability to be a leader in using renewable sources of energy.

Analysis 4: Traditional Reinforced Cast in Place Floor Slabs, Structural Breadth

Problem Identification

All of the floor slabs expect the ground floor and second floor are all post-tensioned. This post-tensioning requires some extra time to tension all the cables, test them, burn off the excess length and then come back and grout the end compared to traditional reinforced concrete. In addition, the tension cables add some additional costs that traditional reinforced concrete does not require.

Research Goal

The goal of this analysis is to determine the structural, cost and scheduling impacts of changing floor slabs 3 to 8 to traditional reinforced concrete from the current design of post-tensioned reinforced concrete.

Methodology

- Determine post tension costs
- Determine post tensioning activity durations
- Determine cost impacts
- Determine schedule impacts
- Determine reinforcing in slabs 3 to 7
- Determine slab thickness for floors 3 to 7
- Analyze cost and schedule impacts of redesign

Resources and Tools

- AE Structural Students
- AE Faculty
- Industry Professionals
- Project Team
- Case Studies

Background Information

Floors three through seven are all identical to each other. Each floor slab is a post-tensioned slab. The typical layout of each floor is shown in Figure 34. Using post-tensioned concrete slab has some advantages in reducing material. A typical post tensioned slab uses anywhere from one third to on fourth less concrete than a more traditional reinforced concrete slab. In addition to the smaller amount of concrete needed by post-tensioned slabs allow for more open spaces with fewer columns (Havel, 2009). With all benefits there are pitfalls. Post-tensioned slabs have some that must be carefully considered.

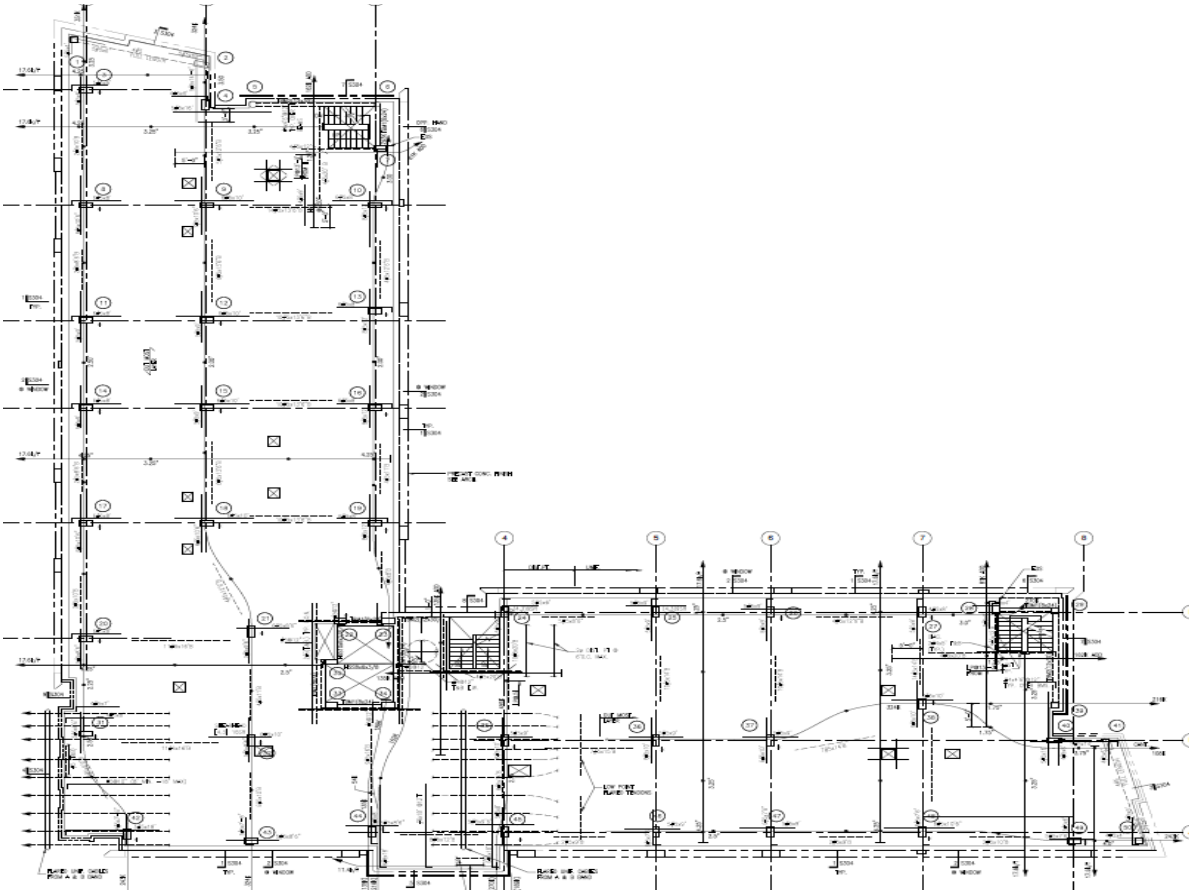


Figure 34: North Hall Typical Post-Tensioned Slab

A few of these issue deal with the effects that a fire can have on the post-tensioned slab. Since the tendons are made of tempered steel they typically will fail when temperatures of 800°F are reached and will weaken at lower temperatures. Also since the slab has less concrete it in turn will have less mass giving the slab a lower fire resistance (Havel, 2009).

There are many other problems that post-tensioning can cause if special care is not taken. The tendons must be placed in the location that the engineer designed them to go. If the tendons end up in a place they were not designed to go they can cause a large uplift force to be experienced by the slab. This uplift force will cause a tensile stress at the bottom of the slab. In most instances there is little to no reinforcement in this area of the slab. The large uplift force will result the edge of the slab lifting up

(Allred, 2006). As long as the tendons are careful placed in the correct location during the placement of the reinforcing the uplift problem can be minimized.

If the post tensioned slab is not restrained by a lateral system the slab is likely to move. Typically for every 100 feet a post-tensioned slab that is unrestrained the slab will move approximately one inch. However when the movement is restricted cracks will form. Post-tensioned slabs have less reinforcing than a more traditional slab does. The reinforcing helps keep cracks to a minimum and most importantly keeps them from become large. With the reduced reinforcement the post-tensioned slabs are very susceptible to large and noticeable cracks. To minimize this downside special slip details are used. Usually felt, building paper or plastic is used to eliminate the bond from the slab to the walls (Allred, 2006). North Hall only has concrete walls that support the second floor and the post tensioned slabs do not start until the third floor. This was not an issue for North Hall according to the project team from Grunley Construction.

Proper vibration of the concrete during placement is important whether the slab is post-tensioned or a traditional reinforced slab especially around slab penetrations. When the tendons are stressed they each have approximately 33,000 pounds of loading. This extreme force can cause a blowout if the concrete is not properly consolidated. Around slab penetrations the force can cause the opening in the slab to be crushed. Steel pipes can be used to structurally support the penetration. When the tendons are placed extreme curves in the tendon should be avoided to reduce the chance of a blowout (Allred, 2006). North Hall had a problem with a blowout occurring while the tendons on one of the upper floors were being stressed. Fortunately nobody was injured when the blowout occurred at on the slab openings.

The post-tensioned slabs in North Hall can be changed to a more traditional reinforced concrete slab. Making this change can provide the building with some added safety in the event of a fire as well as some problems that the post-tensioning can cause during construction.

Post-Tensioned Slab Cost

There are five slabs that are identical in makeup. They are all post-tensioned slabs. Each of these floors are 14,708 square feet. Table 15 outlines the cost per floor for floors three through seven. The typical floor contains 318 cubic yards of concrete and 4 tons of reinforcing steel. There is over 2,000 pounds of tendons that will be stressed for the post-tensioning.

Table 15: North Hall Post-Tensioned Slab Cost by Floor

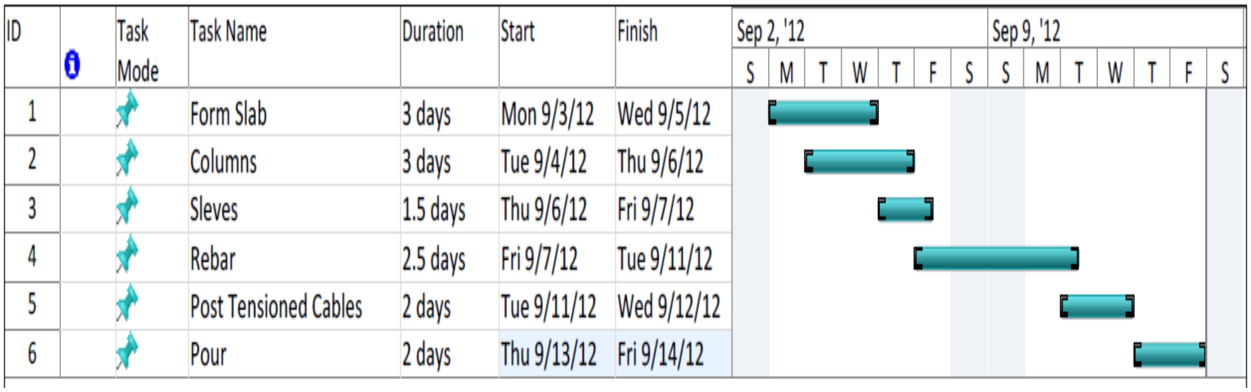
Floor	Cost
Three	$136,179.65
Four	$136,179.65
Five	$136,179.65
Six	$136,179.65
Seven	$136,179.65
Total	$680,898.25

Please see Appendix H for a detailed estimate of the typical slab.

The typical post tensioned slab is estimated to cost $136,179.65. When that cost is applied to the typical post tensioned slabs (floors 3 through 7) the cost is $680,898.25.

Post-Tensioned Slab Schedule

The slab construction is a critical activity for North Hall. Any delay during the construction of the concrete structure will have an effect on the project schedule since the structure lies on the critical path. Also since the tower crane is used for the construction of the structure any delay will keep the tower crane on site longer which will obviously cost more. The schedule for a typical a floor is shown in Figure 35.



ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
1		📌	Form Slab	3 days	Mon 9/3/12	Wed 9/5/12
2		📌	Columns	3 days	Tue 9/4/12	Thu 9/6/12
3		📌	Sleves	1.5 days	Thu 9/6/12	Fri 9/7/12
4		📌	Rebar	2.5 days	Fri 9/7/12	Tue 9/11/12
5		📌	Post Tensioned Cables	2 days	Tue 9/11/12	Wed 9/12/12
6		📌	Pour	2 days	Thu 9/13/12	Fri 9/14/12

Figure 35: Typical Post-Tensioned Slab Schedule

The schedule shown in Figure 35 is the one that was used during the construction with each floor taking 2 weeks or 10 working days. The plywood formwork was constructed first which provided a working platform for the workers in 3 days. From the "new" platform the workers construct the columns by placing the rebar cages and then building the formwork around it before the columns were poured. The column construction took 3 days to complete. Once the slab formwork was completed the sleeves for slab penetrations were placed. Next the reinforcing steel was placed by the rodmen. The rodmen then placed the post-tensioning tendons so they could be woven in and out of the rebar. All the activities up to this point have a duration of 8 working days. The final 2 days were used to pour and finish the slab. The process this then repeated on each floor. The stressing of the tendons shown in Figure 36 are done once

Figure 6: Post-Tensioned Tendon Stressing, Photo Taken by Brandon Tezak

the concrete reaches the specified strength. This activity was not included on the schedule in Figure 35 since it is done once the construction is onto the next floor.

New Slab Thickness

The designed post-tensioned slab has a thickness of 7 inches. When the post-tensioned tendons are removed from the design of the slab the thickness of the slab will change. Post-tensioning allows for a thinner slab than is required for a traditional reinforced concrete slab. The second floor slab is a traditional reinforced concrete slab that uses a drop panel systems around all the columns. This slab is 8 inches thick and at the drop panels the thickness is 11".

The design of the new slabs will not have a drop panel system. The whole slab will be one uniform thickness to keep the design as simple as possible. This simple design will also eliminate the need for a more intricate form work that the drop panels will need.

American Concrete Institute (ACI) codes govern the design of the slab. Chapter 9 of ACI 318, Strength and Serviceability Requirements outlines the thickness requirements for slabs. Table 9.5 (c)- Minimum Thickness of Slabs Without Interior Beams gives the equation for a slab without drop panels and without edge beams. This equation is used when *f'y*= 60,000 psi steel is used.

$$h = \frac{l_n}{30} \quad \text{……………………………………………………Equation (1)}$$

Where *h* is the thickness of the slab and l_n is the length of clear span in the long direction, from face to face of the columns. The clears span on the typical floor layout is 25 feet. When 25 feet is plugged in to Equation 1 *h* is equal to .833 feet which is 10 inches.

The graph shown in Figure 37 can also be used to determine the required thickness for the slab.

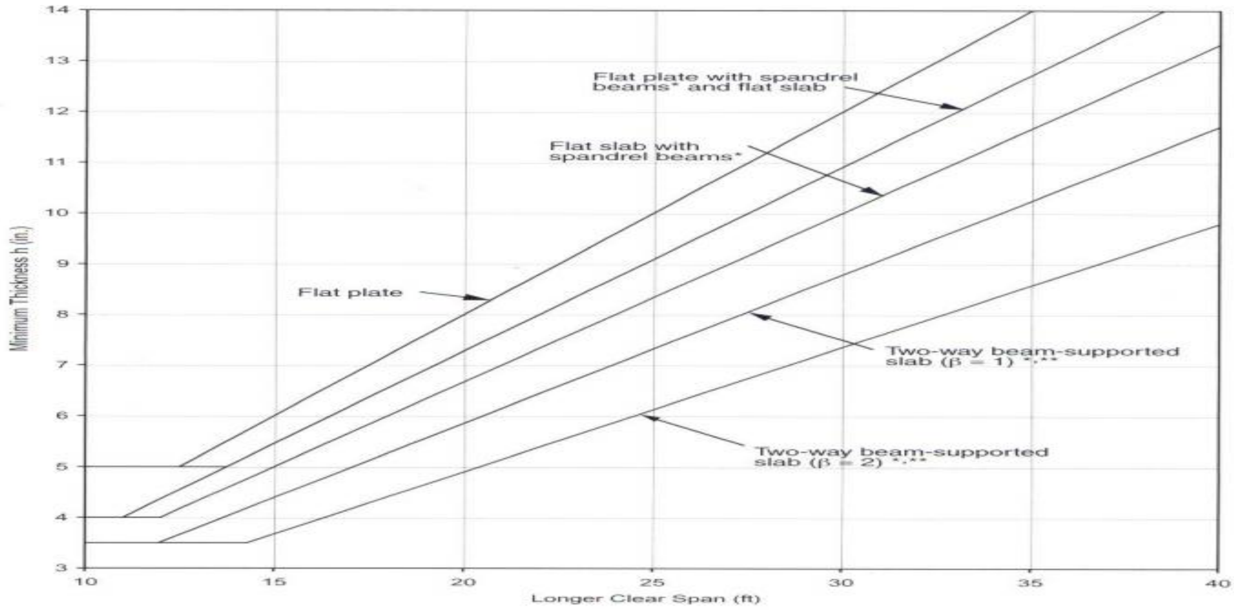


Figure 37: Minimum Slab Thickness for Two-Way Slab System, Source: http://www.inti.gob.ar/cirsoc/pdf/estructuras_hormigon/ACI_318_05.pdf

Using the line for flat plate slabs, which is the upper most line of the five lines shown on the graph, a clear span of 25 feet is gives a slab thickness of 10 inches.

Thickening the slabs from the original 7 inches to the new 10 inches will impact the floor to floor heights in the building from the second floor to the top floor the floor to floor height is 9 feet 4 inches. If the overall height of the building was not to change this would result in the floor to floor height shirking by 3 inches to 9 feet 1 inch. This small change in the floor to floor height will not have a large impact since the ceiling in all the suites are the painted exposed underside of the slab. Also there is minimal overhead mechanical, electrical or plumbing that runs in the ceiling plenum, a majority of this is kept in the chases attached to each suite's mechanical room.

New Slab Reinforcing

The reinforcing that was designed for the post-tensioned slab cannot simply be used for the newly designed slab that has no post-tensioned tendons in it. The flat slab tables that are published by the Concrete Reinforcing Steel Institute (CRSI) were used to size the reinforcing that will be need for the new 10 inch slab. The flat slab system table can be found in Appendix I. The span of 25 feet was used well as a factored superimposed load of 184 pounds per square foot were used. The superimposed load was calculated using Equation 2 where *L* is the live load and *D* is the dead load. Equation 2 is taken from ACI.

$$Factored\ Superimposed\ Load\ = 1.6L + 1.2\ D \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation (2)}$$

The live load is assumed to be 100 pounds per square foot and the estimated dead load is listed at 20 pounds per square in the structural drawings for North Hall.

The CRSI table is broken down by column strips and middle strips. Different sizes and quantities of reinforcing are required in each the column strip and the middle strip. A floor plan of the slab can be found in Appendix J. The columns are colored red. Each strip is numbered with the numbers relating to the table that is also in Appendix J. This table lists the reinforcing that is specified in the CRI table.

Cost Comparison

The new slab will have more concrete since the thickness has increased from 7 inches to 10 inches. The post-tensioned slab has 318 cubic yards of concrete. The addition the 3 inches of concrete increase the concrete required for the new slab by 136 cubic yards to 454 cubic yards of concrete. The reinforcing also increases significantly from 4 tons in the post-tensioned slab to 16.26 ton for the traditional slab. There is no post-tensioned cables in the new slab. The formwork will still be the same for both slabs. The detailed estimate can be found in Appendix J. Table 16 compares the cost of the post-tensioned slab to the new traditional reinforced concrete slab.

Table 16: North Hall Post-Tensioned Slab vs Traditional Slab

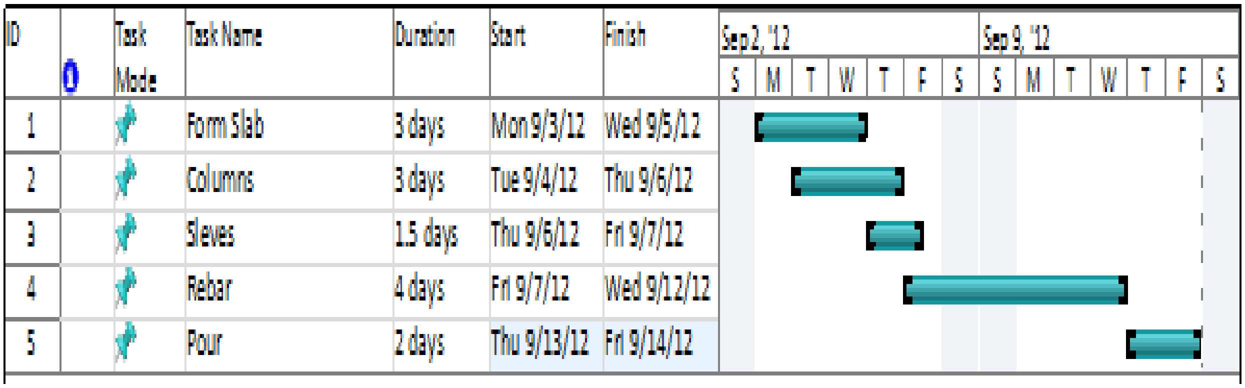
	Post-Tensioned Slab	New Traditional Slab
Thickness	7”	10”
Concrete (CY)	318	454
Concrete Cost	$44,990.64	$64,231.92
Reinforcing (tons)	4	16.26
Reinforcing Cost	$5,590.16	$22,724
Post-Tension Tendons (lb.)	2,151	0
Post-Tension Tendons Cost	$2,645.73	$0
Total Cost	$136,179.65	$169,909.04

The post-tensioned slab much cheaper than the traditional reinforced concrete slab. The traditional slab is $33,729.40 more expensive due to the increase reinforcement as well as the addition of more concrete.

When the cost per floor is applied to all five of the post-tensioned slabs the difference in cost becomes even more apparent. The cost for the five post-tensioned slabs is $680,898. If the more traditional reinforced concrete slab is used for the five typical floors the cost is $849,545. This is a large difference of $168,647 for the change of removing the post-tensioning when only $2,645 is removed from the original design.

Schedule Comparison

The schedule for the new 10 inch traditional reinforced slab is shown in Figure 38. The new slab’s schedule is very similar to the schedule for the post-tensioned slab which is shown in Figure 35.



ID		Task Mode	Task Name	Duration	Start	Finish
1			Form Slab	3 days	Mon 9/3/12	Wed 9/5/12
2			Columns	3 days	Tue 9/4/12	Thu 9/6/12
3			Sleves	1.5 days	Thu 9/6/12	Fri 9/7/12
4			Rebar	4 days	Fri 9/7/12	Wed 9/12/12
5			Pour	2 days	Thu 9/13/12	Fri 9/14/12

Figure 738: New Traditional Slab Schedule

The major difference between the two schedules is the number of activities. The post-tensioned slab has six activities and the traditional slab has only five activities. The post-tensioned cables is activity that does not appear on both. Also since there is close to four times more in the amount weight of rebar in the new slab, the duration was upped to four days. The overall duration for the floor slab has not changed. Both the post-tensioned slab and the traditional reinforced concrete slab should be completed in two weeks. No time will be saved from the schedule with these changes to the slab design.

Conclusion

Post-tensioned slabs have some inherent problems that if the proper care and planning is done will not be an issue. Removing the post-tensioned tendons in the slabs will have some negative effects to the original design such as reducing the floor to floor height from 9 feet 4 inches to 9 feet 1 inch. This change in height is due to the required thickness of the slab changing from 7 inch to 10 inches.

The removal of the post tensioned cable was thought to be able to possibly shorten the schedule for each of the post-tensioned slabs. Due to the significant increase in reinforcing required for the new slab, the time saved by not installing the tendons was offset by the additional time need to place the reinforcing. The additional reinforcing as well as the 3 inches of additional concrete increase the cost from $136,179.65 for the post-tensioned slab by $33,729.40 to $169,909.04 for the newly designed traditionally reinforced concrete slab.

Making the change from a post-tensioned slab does not make sense in the case of North Hall. This is the case for North Hall since there will be no schedule savings and a large increase in the slab cost by $168,647 for all five of the slabs that would be affected.

Conclusion and Recommendations

The analyses where all successful in terms of developing a better understanding for the systems or concepts that were studied and analyzed. Two of the four analyses are recommended to be implemented if North Hall would be built again. The other two analyses although were good ideas on how to improve the project were determined not work for North Hall. Please see the below recommendation for each analysis.

Analysis 1

It is recommended for Analysis 1, modularization of the suite bathroom units, to be used on North Hall. The modularization will have both cost and schedule savings for the project. About 66 working days or 13.2 weeks of work can be saved from the schedule. This savings can be used to speed up the rest of the fit-out of each of the 7 floors that contain the suites. This is important due to the fast paced aggressive schedule for the project. A cheaper labor force can be used for the offsite construction of the modules allowing for some saving in the labor costs. Approximately $92,315.52 will be added to the project cost from the construction of the modules.

Analysis 2

Analysis 2, the implementation of a GPS material tracking system on the precast façade panels, is not recommended for North Hall. The GPS tacking system would be used to track the precast panels from the production facility in North Carolina to the site in Washington D.C. The cost of the tacking system is $112,785. The actual installation of the panels only missed the completion date by one week which required a new crane for the last week since the tower crane had to be removed. This is good considering the installation was as many as two and half weeks behind at one point due to weather and logistical/sequence mismanagement. Due to the large cost of the tracking system and the tight budget on the project North Hall will not benefit enough to justify the expense of the tracking system.

Analysis 3

Upgrading the solar panel system, Analysis 3, is recommended to be implemented on North Hall. The solar panel system will be upgrade from the current solar hot water panel system to a hybrid (cogeneration) system that will have both solar hot water and electrical generation. While there will be expense for upgrading the panel system but this will be offset with the dollars that are saved on utility bills. Approximately $18,600 a year could be saved from the panels. Although the upfront costs for the panels they will pay for themselves in about 11 years making this a good idea for American University since this building will be used for well over that time period.

Analysis 4

Analysis 4 dealt with removing the post-tensioned cables from the floor slabs on floors 3 through 7 by using a traditional reinforced concrete slab. All five of these floors have identical layouts housing the suite style rooms. Removing the post tensioned cable will cause the slabs to be thickened from 7 inches to 10 inches. The reinforcing will also need to be increased. These required increases in the material need cause the cost to increase by $33,729.40 per slab and $168,647 for all five slabs. The schedule was not shortened by eliminating the post-tensioning due to the increase amount of reinforcement that needs to be placed. Since there is only an increase in the cost from removing the post tensioned cables it is not recommended that the slabs be changed from the current design.

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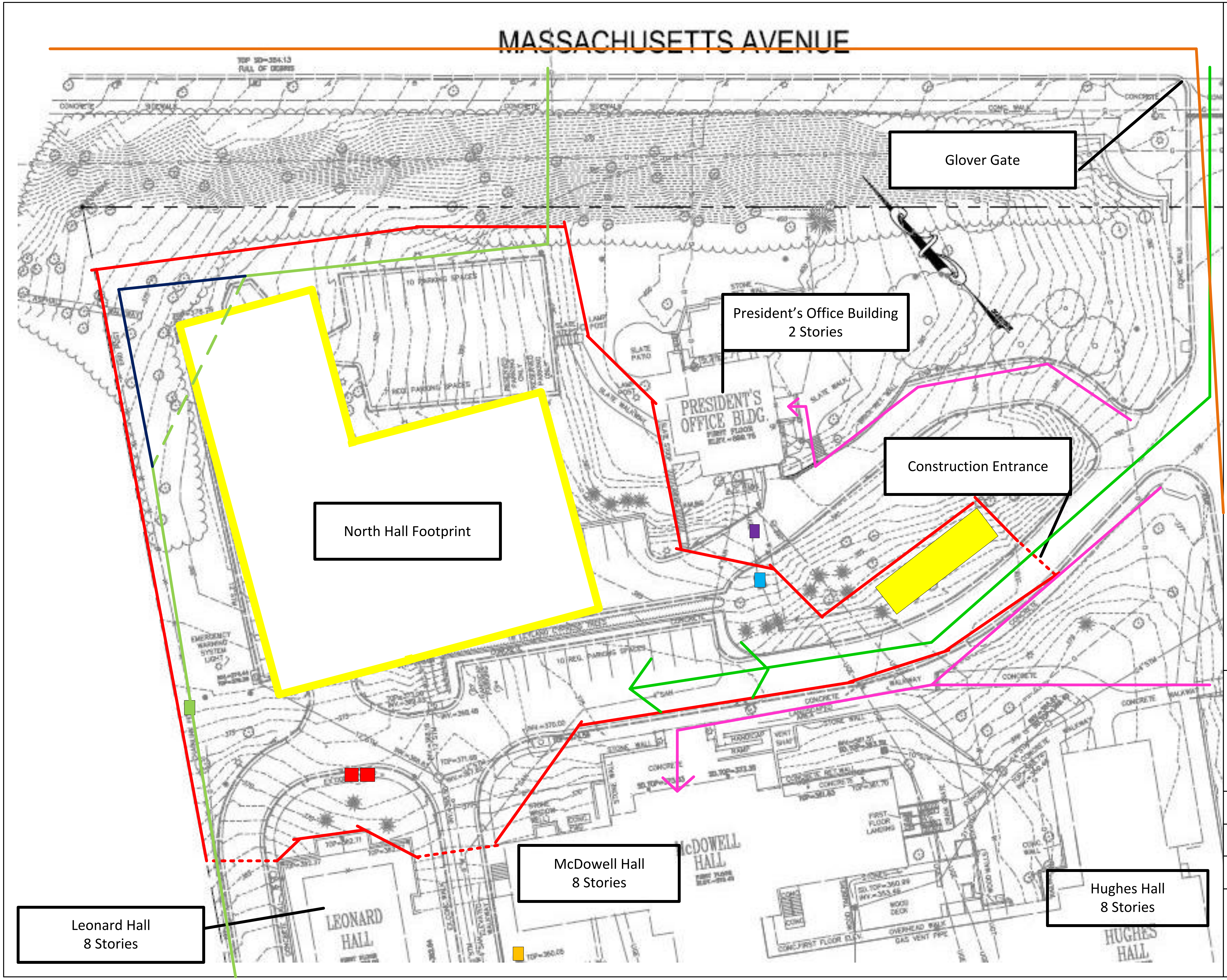
Appendix A: Site Plans



Legend

Site Fence —
Fence Gate - - -
Temporary Electric Tie In 🟦
Natural Gas Tie In 🟩
Sanitary Sewer Tie In 🟧
Telephone Tie In 🟪
Pedestrian Traffic —
Construction Vehicle Traffic —
Vehicle Traffic —
Existing Gas Line —
Abandoned Gas Line - -
Relocated Gas Line —
Office Trailer 🟨
Toilet 🟥

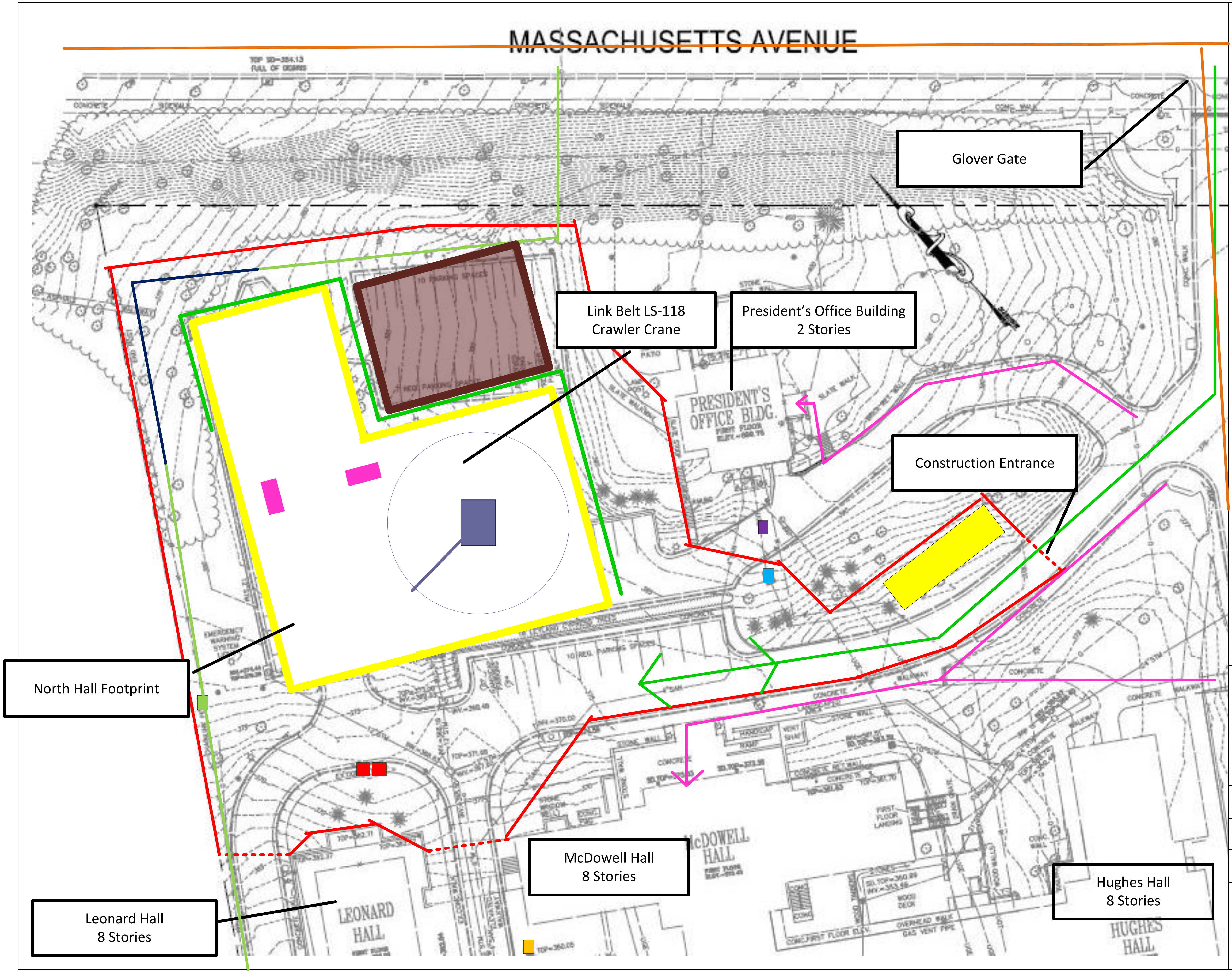
North Hall
American University
4400 Mass. Ave., NW
Washington, D.C.

Scale: NTS

Date: 9.21.2012

Brandon Tezak

Existing Conditions
Site Plan



Legend

Site Fence ━
Fence Gate ┅
Temporary Electric Tie In 🟦
Natural Gas Tie In 🟩
Sanitary Sewer Tie In 🟧
Telephone Tie In 🟪
Pedestrian Traffic ━
Construction Vehicle Traffic ━
Vehicle Traffic ━
Existing Gas Line ━
Relocated Gas Line ━
Office Trailer 🟨
Toilet 🟥
Support of Excavation ━
Material Storage 🟫
Watson Drill Rig ▬

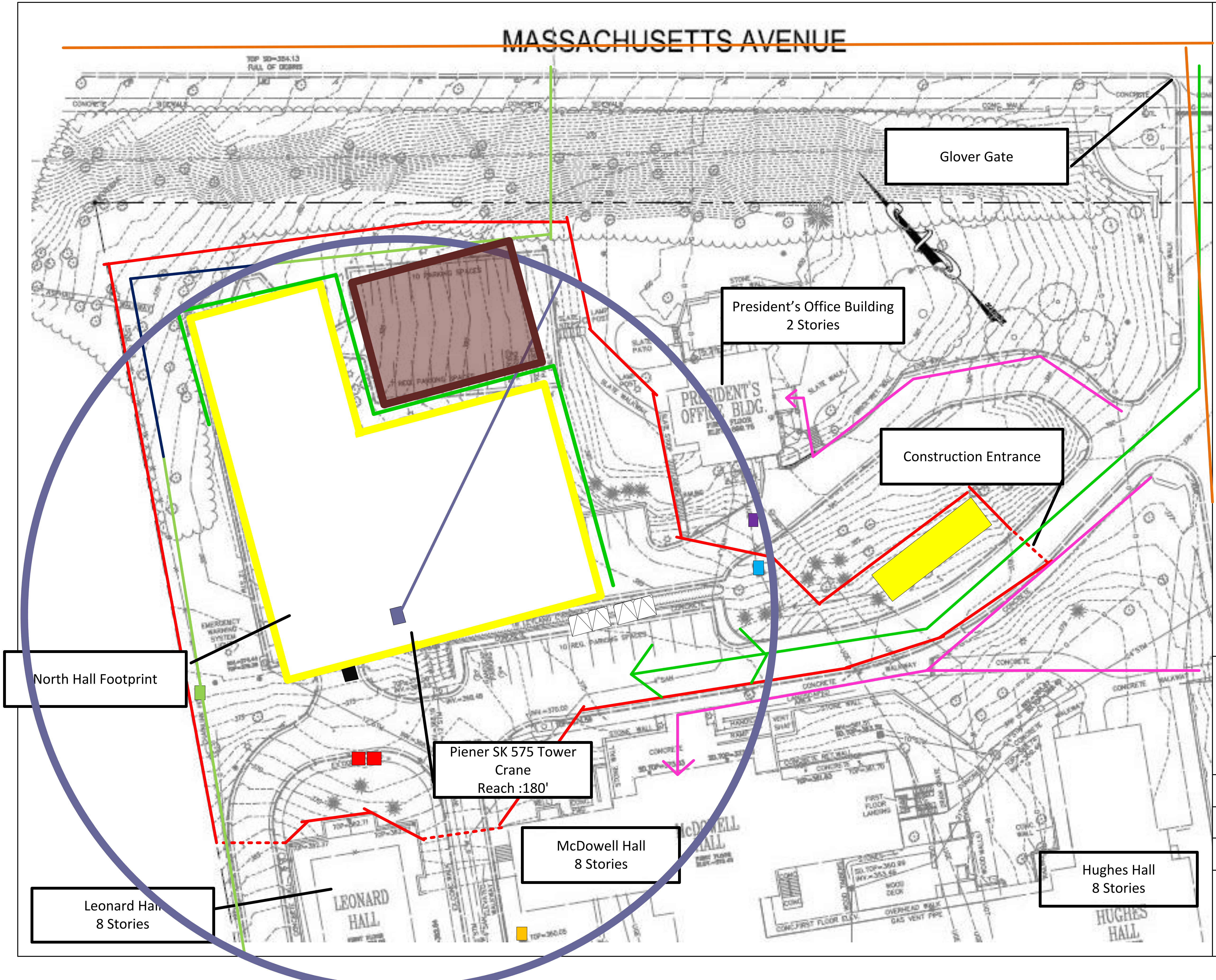
North Hall
American University
4400 Mass. Ave., NW
Washington, D.C.

Scale: NTS

Date: 9.21.2012

Brandon Tezak

Phase 1 : Foundation
Site Plan



Legend

- Site Fence ━━
- Fence Gate ┅┅
- Temporary Electric Tie In 🟦
- Natural Gas Tie In 🟩
- Sanitary Sewer Tie In 🟧
- Telephone Tie In 🟪
- Pedestrian Traffic ━━
- Construction Vehicle Traffic ━━
- Vehicle Traffic ━━
- Existing Gas Line ━━
- Relocated Gas Line ━━
- Office Trailer 🟨
- Toilet 🟥
- Support of Excavation ━━
- Material Storage 🟫
- Hoist ⬛

North Hall
American University
4400 Mass. Ave., NW
Washington, D.C.

Scale: NTS

Date: 9.21.2012

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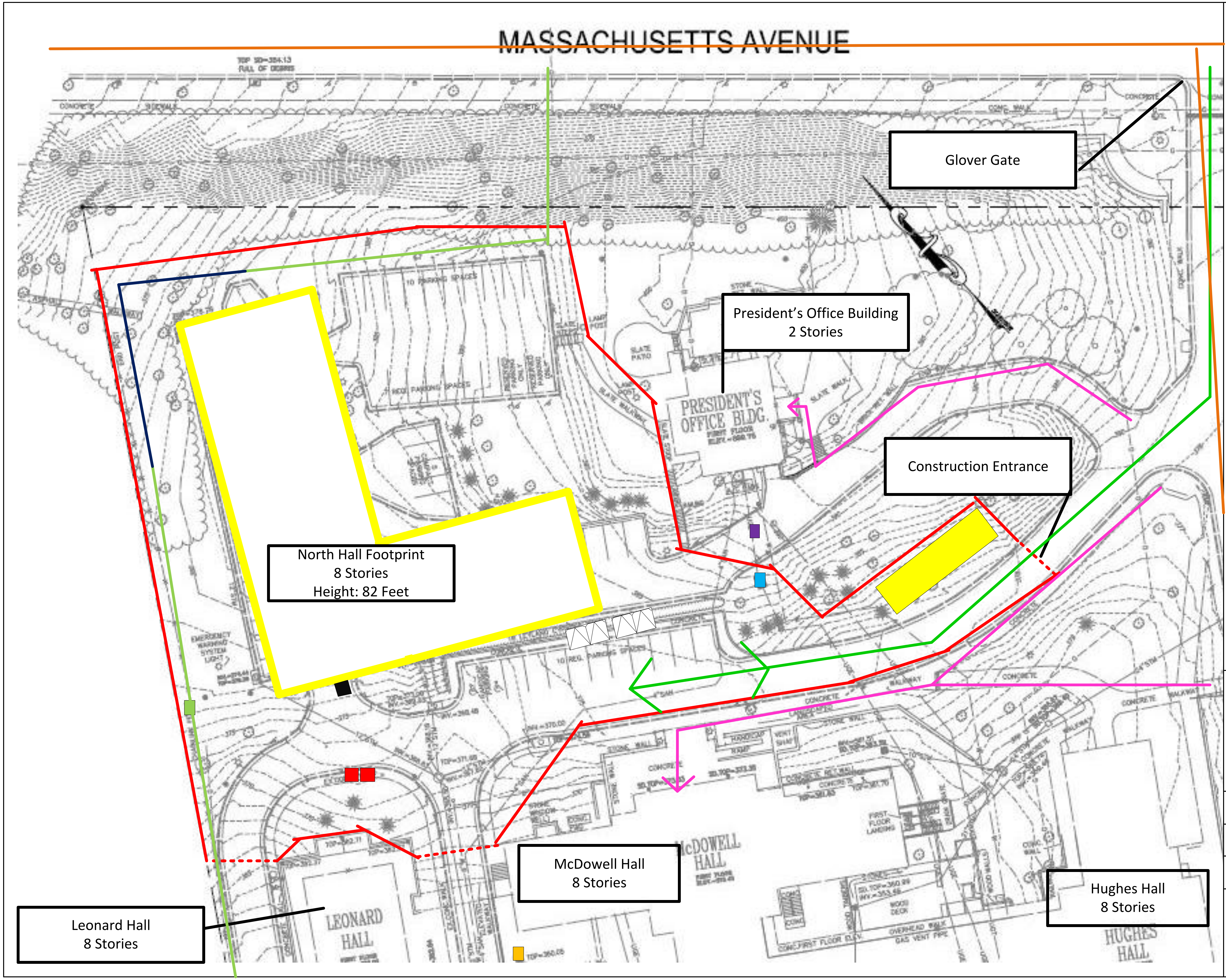
Phase 2 : Superstructure
Site Plan



Legend

Site Fence ——
Fence Gate - - - -
Temporary Electric Tie In 🟦
Natural Gas Tie In 🟩
Sanitary Sewer Tie In 🟧
Telephone Tie In 🟪
Pedestrian Traffic ——
Construction Vehicle Traffic ——
Vehicle Traffic ——
Existing Gas Line ——
Relocated Gas Line ——
Office Trailer 🟨
Toilet 🟥
Hoist ⬛

North Hall
American University
4400 Mass. Ave., NW
Washington, D.C.

Scale: NTS

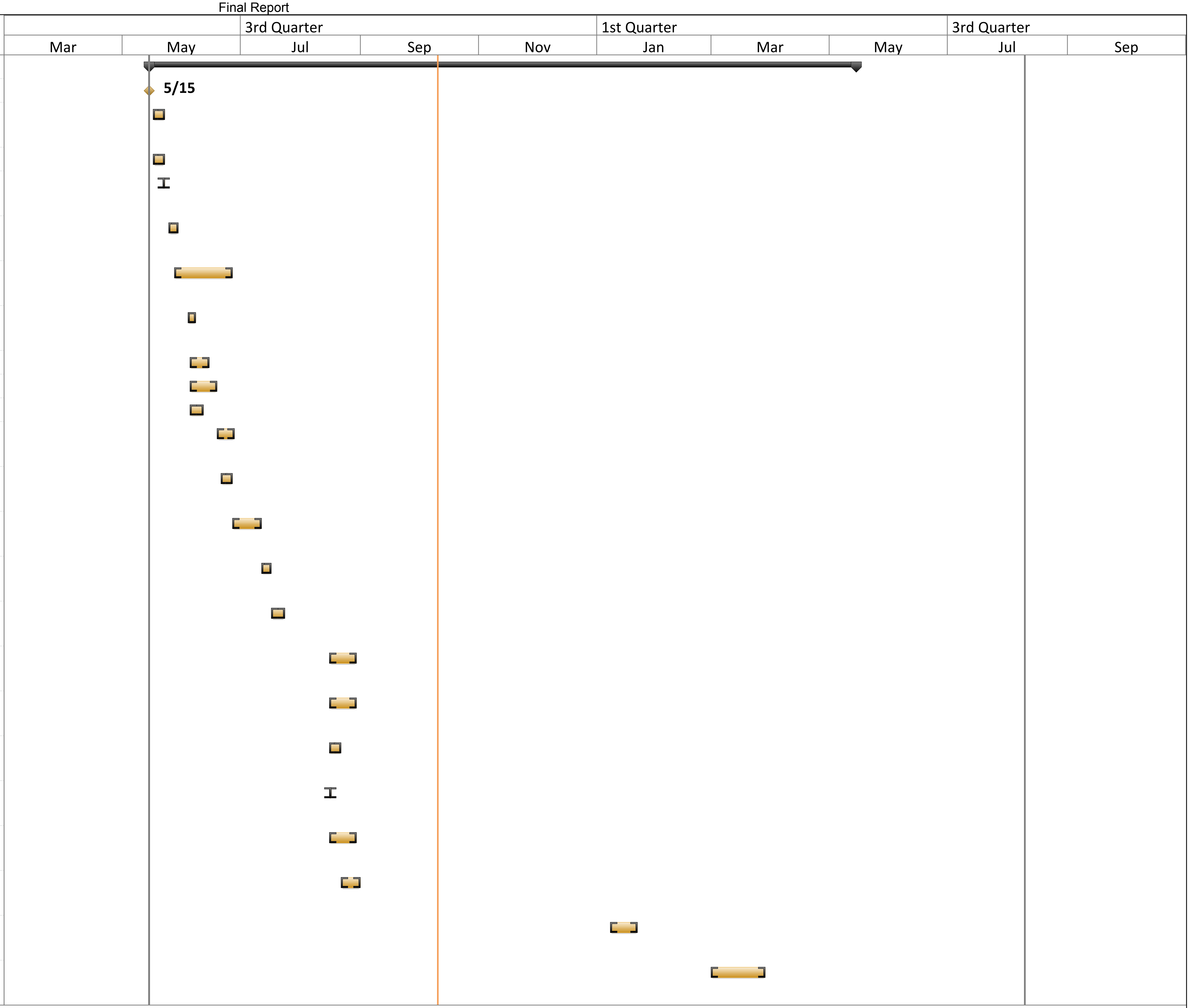
Date: 9.21.2012

Brandon Tezak

Phase 3 : Finishes
Site Plan

Appendix B: Detailed Schedule

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Site Work**	**259 days**	**Tue 5/15/12**	**Tue 5/14/13**
2		Moblize to Site	0 days	Tue 5/15/12	Tue 5/15/12
3		Sediment/ Erosion Control	4 days	Thu 5/17/12	Tue 5/22/12
4		Site Clearing	4 days	Thu 5/17/12	Tue 5/22/12
5		Construction Enterance Washrack	1 day	Tue 5/22/12	Tue 5/22/12
6		Site to Grade for Sheeting and Shoring	3 days	Fri 5/25/12	Tue 5/29/12
7		Sheeting and Shoring	22 days	Mon 5/28/12	Tue 6/26/12
8		Relocate Gas Main in NW Corner	4 days	Mon 6/4/12	Thu 6/7/12
9		Demo Retaining Walls	8 days	Tue 6/5/12	Thu 6/14/12
10		Install Sewer Main	10 days	Tue 6/5/12	Mon 6/18/12
11		Electrical Manhole	5 days	Tue 6/5/12	Mon 6/11/12
12		Install Water Main in SW Corner	7 days	Tue 6/19/12	Wed 6/27/12
13		Positive Drainage System	4 days	Thu 6/21/12	Tue 6/26/12
14		Excavation To Foundation Grade	11 days	Wed 6/27/12	Wed 7/11/12
15		Sheeting and Shoring for Cistern	3 days	Thu 7/12/12	Mon 7/16/12
16		Excavate and Install Cistern	5 days	Tue 7/17/12	Mon 7/23/12
17		Telecom Ductback to Building	10 days	Thu 8/16/12	Wed 8/29/12
18		Electrical Ductbank from MH to Building	10 days	Thu 8/16/12	Wed 8/29/12
19		Sewer Main to Building	4 days	Thu 8/16/12	Tue 8/21/12
20		Water Mains to Building	1 day	Thu 8/16/12	Thu 8/16/12
21		Chilled Water from MH to Building	10 days	Thu 8/16/12	Wed 8/29/12
22		Steam Line from Courtyard to Building	8 days	Wed 8/22/12	Fri 8/31/12
23		Install Site Lighting Conduit	10 days	Tue 1/8/13	Mon 1/21/13
24		Mansonry Veneer on Foundation	20 days	Fri 3/1/13	Thu 3/28/13



Project: Project Schedule
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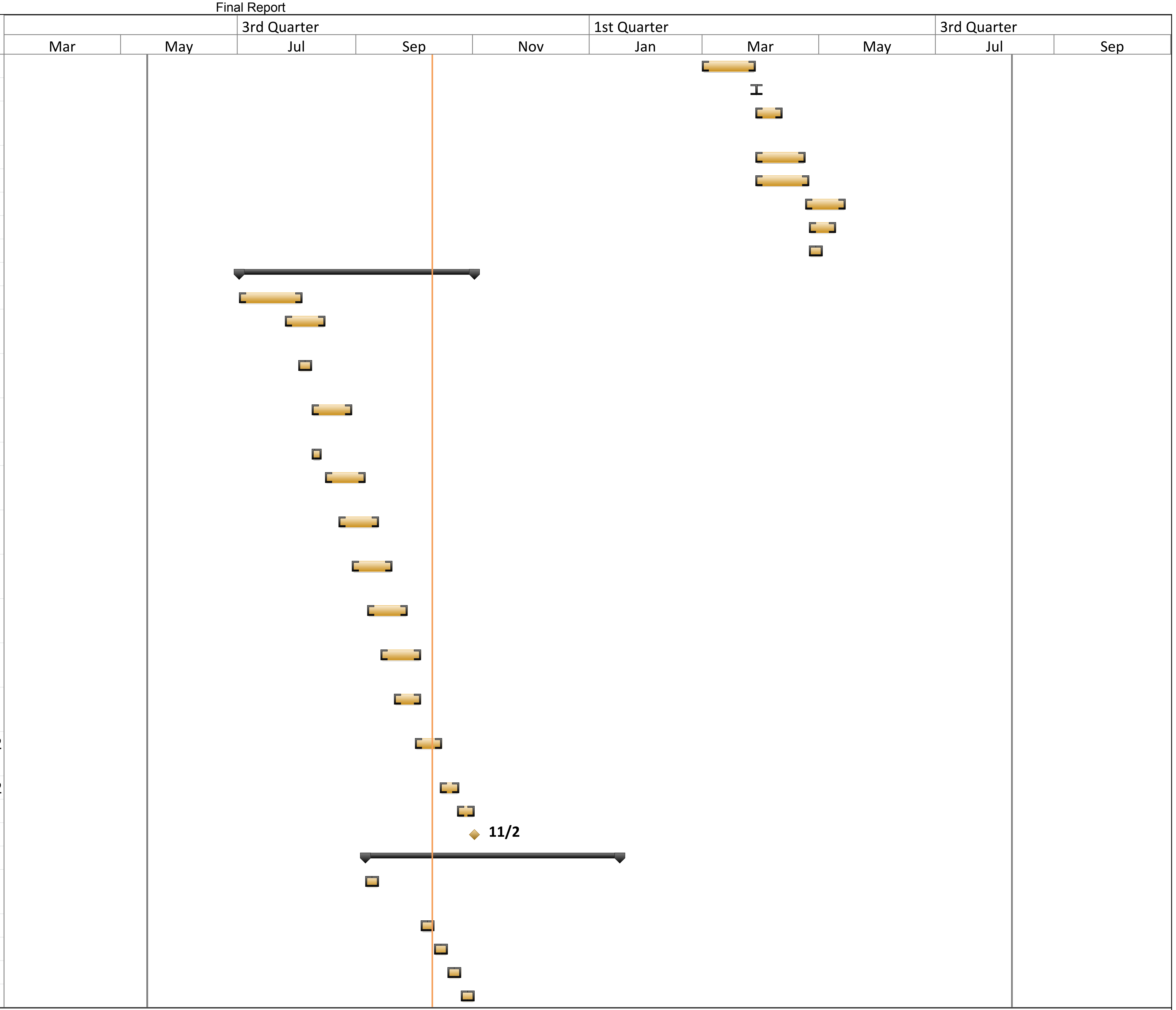
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	↓
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▭	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

ID	Task Mode	Task Name	Duration	Start	Finish
25		Site Concrete	20 days	Fri 3/1/13	Thu 3/28/13
26		Gas Line to Building	1 day	Fri 3/29/13	Fri 3/29/13
27		Exterior Site Handrails	10 days	Fri 3/29/13	Thu 4/11/13
28		Landscaping	18 days	Fri 3/29/13	Tue 4/23/13
29		Pavers	20 days	Fri 3/29/13	Thu 4/25/13
30		Site Stone Masonry	15 days	Wed 4/24/13	Tue 5/14/13
31		Site Lighting Finishes	10 days	Fri 4/26/13	Thu 5/9/13
32		Asphalt Paving	5 days	Fri 4/26/13	Thu 5/2/13
33		**Building Structure**	**89 days**	**Mon 7/2/12**	**Fri 11/2/12**
34		Caissons	25 days	Mon 7/2/12	Fri 8/3/12
35		Footings and Grade Beams	15 days	Thu 7/26/12	Wed 8/15/12
36		Tower Crane Foundation	5 days	Thu 8/2/12	Wed 8/8/12
37		Founation Walls and 1st Floor Columns	15 days	Thu 8/9/12	Wed 8/29/12
38		Install Tower Crane	3 days	Thu 8/9/12	Mon 8/13/12
39		2nd Floor Slab and Columns	15 days	Thu 8/16/12	Wed 9/5/12
40		3rd Floor Slab and Columns	15 days	Thu 8/23/12	Wed 9/12/12
41		4th Floor Slab and Columns	15 days	Thu 8/30/12	Wed 9/19/12
42		5th Floor Slab and Columns	15 days	Fri 9/7/12	Thu 9/27/12
43		6th Floor Slab and Columns	15 days	Fri 9/14/12	Thu 10/4/12
44		7th Floor Slab and Columns	10 days	Fri 9/21/12	Thu 10/4/12
45		8th Floor Slab and Columns	10 days	Tue 10/2/12	Mon 10/15/12
46		Roof Slab	8 days	Mon 10/15/12	Wed 10/24/12
47		Penthouse	7 days	Wed 10/24/12	Thu 11/1/12
48		Structure Complete	0 days	Fri 11/2/12	Fri 11/2/12
49		**Enclosure**	**93 days**	**Thu 9/6/12**	**Wed 1/16/13**
50		South Elevation 2nd Floor Precast Panels	5 days	Thu 9/6/12	Wed 9/12/12
51		Precast 1st Floor	5 days	Fri 10/5/12	Thu 10/11/12
52		Precast 2nd Floor	5 days	Fri 10/12/12	Thu 10/18/12
53		Precast 3rd Floor	5 days	Fri 10/19/12	Thu 10/25/12
54		Precast 4th Floor	5 days	Fri 10/26/12	Thu 11/1/12



Project: Project Schedule
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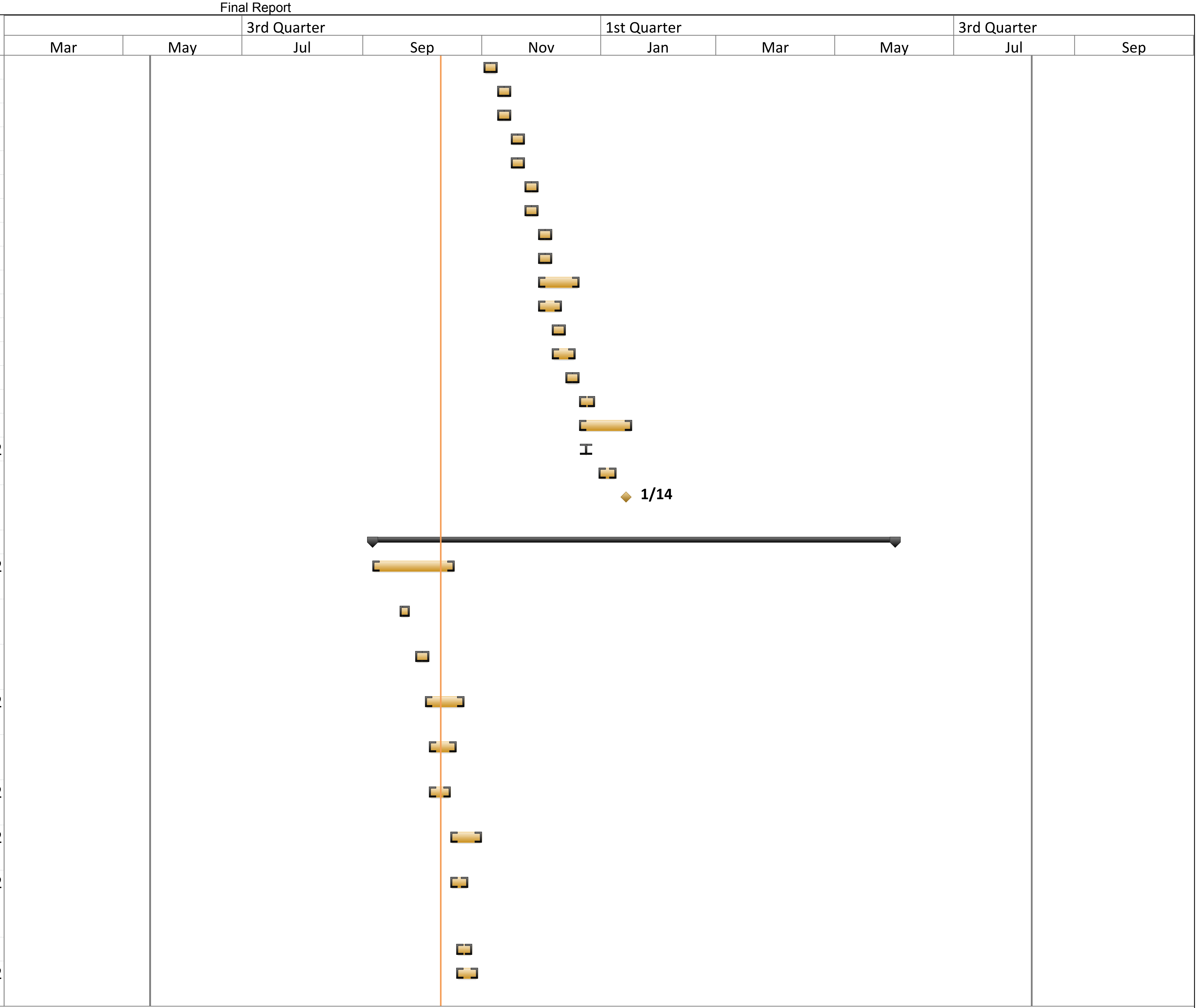
Task		Project Summary		Inactive Milestone	◇	Manual Summary Rollup		Deadline	↓
Split		External Tasks		Inactive Summary		Manual Summary		Critical	
Milestone	◆	External Milestone	◆	Manual Task		Start-only	[	Critical Split	
Summary		Inactive Task		Duration-only		Finish-only	]	Progress	

ID	Task Mode	Task Name	Duration	Start	Finish
55		Precast 5th Floor	5 days	Fri 11/2/12	Thu 11/8/12
56		Precast 6th Floor	5 days	Fri 11/9/12	Thu 11/15/12
57		Windows 1st Floor	5 days	Fri 11/9/12	Thu 11/15/12
58		Precast 7th Floor	5 days	Fri 11/16/12	Thu 11/22/12
59		Windows 2nd Floor	5 days	Fri 11/16/12	Thu 11/22/12
60		Precast 8th Floor	5 days	Fri 11/23/12	Thu 11/29/12
61		Windows 3rd Floor	5 days	Fri 11/23/12	Thu 11/29/12
62		Precast Penthouse	5 days	Fri 11/30/12	Thu 12/6/12
63		Windows 4th Floor	5 days	Fri 11/30/12	Thu 12/6/12
64		Curtin Wall	15 days	Fri 11/30/12	Thu 12/20/12
65		Lower Roof	8 days	Fri 11/30/12	Tue 12/11/12
66		Windows 5th Floor	5 days	Fri 12/7/12	Thu 12/13/12
67		Upper Roof	8 days	Fri 12/7/12	Tue 12/18/12
68		Windows 6th Floor	5 days	Fri 12/14/12	Thu 12/20/12
69		Windows 7th Floor	5 days	Fri 12/21/12	Fri 12/28/12
70		Sunshade System	17 days	Fri 12/21/12	Wed 1/16/13
71		Penthouse Roof	1 day	Mon 12/24/12	Mon 12/24/12
72		Windows 8th Floor	6 days	Mon 12/31/12	Tue 1/8/13
73		Building Envelope Complete	0 days	Mon 1/14/13	Mon 1/14/13
74		**Rough- In**	**190 days**	**Thu 9/6/12**	**Fri 5/31/13**
75		Interior Handrails for Stairs	30 days	Thu 9/6/12	Wed 10/17/12
76		Frame 1st Floor Electric Rm Walls	3 days	Thu 9/20/12	Mon 9/24/12
77		Layout and Install Track to Ceiling 1st Floor	5 days	Fri 9/28/12	Thu 10/4/12
78		HVAC Pipe Rough-In 1st Floor	14 days	Wed 10/3/12	Mon 10/22/12
79		Install VAVs/Fan Coils and Ducts 1st Floor	10 days	Fri 10/5/12	Thu 10/18/12
80		Layout and Install Track to Ceiling 2nd Floor	7 days	Fri 10/5/12	Mon 10/15/12
81		HVAC Pipe Rough-In 2nd Floor	12 days	Tue 10/16/12	Wed 10/31/12
82		Layout and Install Track to Ceiling 3rd Floor	7 days	Tue 10/16/12	Wed 10/24/12
83		1st Floor AHU	6 days	Fri 10/19/12	Fri 10/26/12
84		Install VAVs/Fan Coils and Ducts 2nd Floor	7 days	Fri 10/19/12	Mon 10/29/12



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

ID	Task Mode	Task Name	Duration	Start	Finish
85	📌	Frame 1st Floor Walls	7 days	Fri 10/19/12	Mon 10/29/12
86	📌	HVAC Pipe Rough-In 3rd Floor	12 days	Thu 10/25/12	Fri 11/9/12
87	📌	Layout and Install Track to Ceiling 4th Floor	7 days	Thu 10/25/12	Fri 11/2/12
88	📌	Install VAVs/Fan Coils and Ducts 3rd Floor	7 days	Tue 10/30/12	Wed 11/7/12
89	📌	Frame 2nd Floor Walls	7 days	Tue 10/30/12	Wed 11/7/12
90	📌	Install Electrical and FA conduit and Panels 1st Floor	7 days	Tue 10/30/12	Wed 11/7/12
91	📌	Fire Protection Rough-In 1st Floor	7 days	Tue 10/30/12	Wed 11/7/12
92	📌	Plumbing Rough-In 1st Floor	7 days	Tue 10/30/12	Wed 11/7/12
93	📌	Install ERU	12 days	Fri 11/2/12	Mon 11/19/12
94	📌	HVAC Pipe Rough-In Penthouse	16 days	Fri 11/2/12	Fri 11/23/12
95	📌	HVAC Pipe Rough-In 4th Floor	12 days	Mon 11/5/12	Tue 11/20/12
96	📌	Layout and Install Track to Ceiling 5th Floor	7 days	Mon 11/5/12	Tue 11/13/12
97	📌	Install VAVs/Fan Coils and Ducts 4th Floor	7 days	Thu 11/8/12	Fri 11/16/12
98	📌	Frame 3rd Floor Walls	7 days	Thu 11/8/12	Fri 11/16/12
99	📌	Install Electrical and FA conduit and Panels 2nd Floor	7 days	Thu 11/8/12	Fri 11/16/12
100	📌	Branch Circuit Rough-In 2nd Floor	7 days	Thu 11/8/12	Fri 11/16/12
101	📌	Fire Protection Rough-In 2nd Floor	7 days	Thu 11/8/12	Fri 11/16/12
102	📌	Plumbing Rough-In 2nd Floor	7 days	Thu 11/8/12	Fri 11/16/12
103	📌	Elevator Machine Equipment In Room	4 days	Tue 11/13/12	Fri 11/16/12
104	📌	HVAC Pipe Rough-In 5th Floor	12 days	Wed 11/14/12	Thu 11/29/12

Project: Project Schedule
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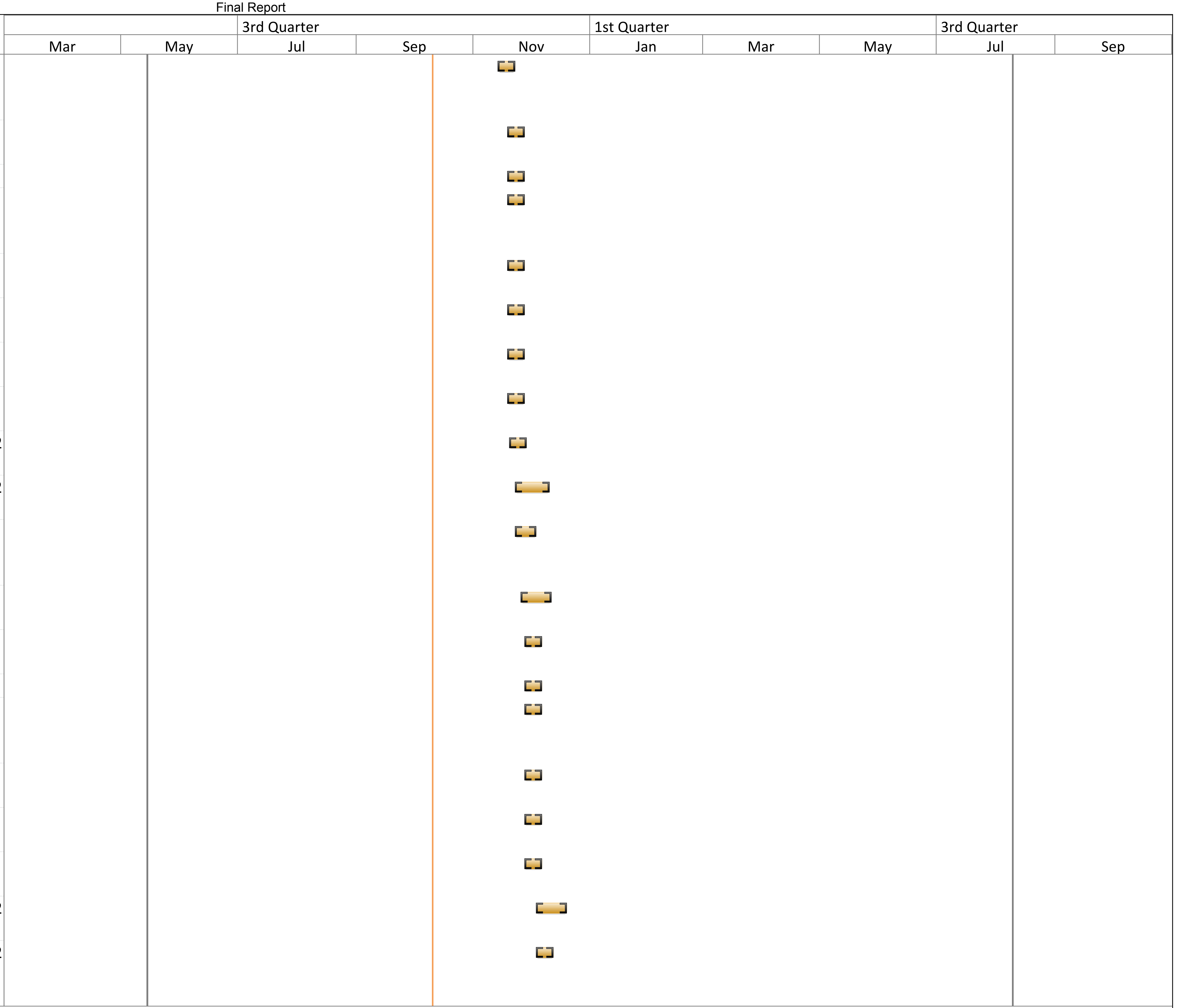
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	🟥
Milestone	◆	External Milestone	◆	Manual Task	▭	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

ID	Task Mode	Task Name	Duration	Start	Finish
105		Layout and Install Track to Ceiling 6th Floor	7 days	Wed 11/14/12	Thu 11/22/12
106		Install VAVs/Fan Coils and Ducts 5th Floor	7 days	Mon 11/19/12	Tue 11/27/12
107		Frame 4th Floor Walls	7 days	Mon 11/19/12	Tue 11/27/12
108		Install Electrical and FA conduit and Panels 3rd Floor	7 days	Mon 11/19/12	Tue 11/27/12
109		Branch Circuit Rough-In 1st Floor	7 days	Mon 11/19/12	Tue 11/27/12
110		Branch Circuit Rough-In 3rd Floor	7 days	Mon 11/19/12	Tue 11/27/12
111		Fire Protection Rough-In 3rd Floor	7 days	Mon 11/19/12	Tue 11/27/12
112		Plumbing Rough-In 3rd Floor	7 days	Mon 11/19/12	Tue 11/27/12
113		Install Ductwork Penthouse	7 days	Tue 11/20/12	Wed 11/28/12
114		HVAC Pipe Rough-In 6th Floor	12 days	Fri 11/23/12	Mon 12/10/12
115		Layout and Install Track to Ceiling 7th Floor	7 days	Fri 11/23/12	Mon 12/3/12
116		Set and Pipe Heat Exchangers	12 days	Mon 11/26/12	Tue 12/11/12
117		Install VAVs/Fan Coils and Ducts 6th Floor	7 days	Wed 11/28/12	Thu 12/6/12
118		Frame 5th Floor Walls	7 days	Wed 11/28/12	Thu 12/6/12
119		Install Electrical and FA conduit and Panels 4th Floor	7 days	Wed 11/28/12	Thu 12/6/12
120		Branch Circuit Rough-In 4th Floor	7 days	Wed 11/28/12	Thu 12/6/12
121		Fire Protection Rough-In 4th Floor	7 days	Wed 11/28/12	Thu 12/6/12
122		Plumbing Rough-In 4th Floor	7 days	Wed 11/28/12	Thu 12/6/12
123		HVAC Pipe Rough-In 7th Floor	12 days	Tue 12/4/12	Wed 12/19/12
124		Layout and Install Track to Ceiling 8th Floor	7 days	Tue 12/4/12	Wed 12/12/12



Project: Project Schedule
Date: Thu 10/11/12

Task
Split
Milestone ◆
Summary

Project Summary
External Tasks
External Milestone ◆
Inactive Task

Inactive Milestone ◇
Inactive Summary
Manual Task
Duration-only

Manual Summary Rollup
Manual Summary
Start-only [
Finish-only]

Deadline ⬇
Critical
Critical Split
Progress

ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
125		📌	Install VAVs/Fan Coils and Ducts 7th Floor	7 days	Fri 12/7/12	Mon 12/17/12
126		📌	Frame 6th Floor Walls	7 days	Fri 12/7/12	Mon 12/17/12
127		📌	Install Electrical and FA conduit and Panels 5th Floor	7 days	Fri 12/7/12	Mon 12/17/12
128		📌	Branch Circuit Rough-In 5th Floor	7 days	Fri 12/7/12	Mon 12/17/12
129		📌	Fire Protection Rough-In 5th Floor	5 days	Fri 12/7/12	Thu 12/13/12
130		📌	Plumbing Rough-In 5th Floor	7 days	Fri 12/7/12	Mon 12/17/12
131		📌	Set and Pipe Chilled Water Pumps	12 days	Wed 12/12/12	Fri 12/28/12
132		📌	Pipe Steam Station	12 days	Wed 12/12/12	Fri 12/28/12
133		📌	HVAC Pipe Rough-In 8th Floor	12 days	Thu 12/13/12	Mon 12/31/12
134		📌	Install VAVs/Fan Coils and Ducts 8th Floor	7 days	Tue 12/18/12	Thu 12/27/12
135		📌	Frame 7th Floor Walls	7 days	Tue 12/18/12	Thu 12/27/12
136		📌	Install Electrical and FA conduit and Panels 6th Floor	7 days	Tue 12/18/12	Thu 12/27/12
137		📌	Branch Circuit Rough-In 6th Floor	7 days	Tue 12/18/12	Thu 12/27/12
138		📌	Fire Protection Rough-In 6th Floor	7 days	Tue 12/18/12	Thu 12/27/12
139		📌	Plumbing Rough-In 6th Floor	7 days	Tue 12/18/12	Thu 12/27/12
140		📌	Frame and Drywall Elevator Shaft	9 days	Mon 12/24/12	Mon 1/7/13
141		📌	Set Electrical Equipment	7 days	Mon 12/24/12	Thu 1/3/13
142		📌	Frame 8th Floor Walls	7 days	Fri 12/28/12	Tue 1/8/13
143		📌	Install Electrical and FA conduit and Panels 7th Floor	7 days	Fri 12/28/12	Tue 1/8/13
144		📌	Branch Circuit Rough-In 7th Floor	7 days	Fri 12/28/12	Tue 1/8/13
145		📌	Fire Protection Rough-In 7th Floor	7 days	Fri 12/28/12	Tue 1/8/13

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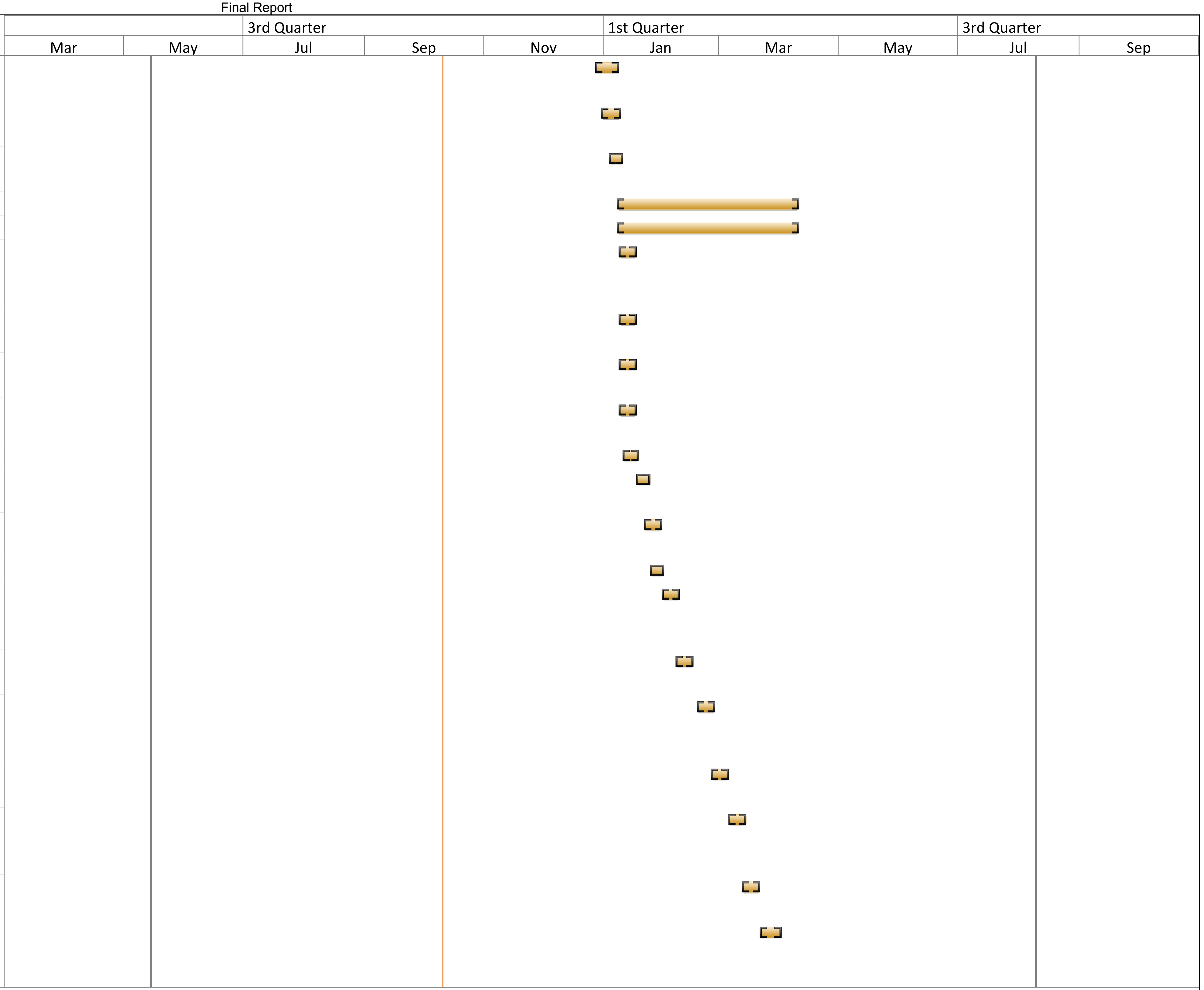
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⬇
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
146		📌	Plumbing Rough-In 7th Floor	7 days	Fri 12/28/12	Tue 1/8/13
147		📌	Pipe Solar Panel System	7 days	Mon 12/31/12	Wed 1/9/13
148		📌	Conduit to Electrical Gear	5 days	Fri 1/4/13	Thu 1/10/13
149		📌	Construct Elevator 1	67 days	Tue 1/8/13	Wed 4/10/13
150		📌	Construct Elevator 2	67 days	Tue 1/8/13	Wed 4/10/13
151		📌	Install Electrical and FA conduit and Panels 8th Floor	7 days	Wed 1/9/13	Thu 1/17/13
152		📌	Branch Circuit Rough-In 8th Floor	7 days	Wed 1/9/13	Thu 1/17/13
153		📌	Fire Protection Rough-In 8th Floor	7 days	Wed 1/9/13	Thu 1/17/13
154		📌	Plumbing Rough-In 8th Floor	7 days	Wed 1/9/13	Thu 1/17/13
155		📌	Pull Electrical Feeders	6 days	Fri 1/11/13	Fri 1/18/13
156		📌	Fire Protection Rough-In Penthouse	5 days	Fri 1/18/13	Thu 1/24/13
157		📌	Frame Drywall Ceilings 8th Floor	7 days	Tue 1/22/13	Wed 1/30/13
158		📌	Install Fire Pump	5 days	Fri 1/25/13	Thu 1/31/13
159		📌	Above Ceiling Electrical Rough-In 8th Floor	7 days	Thu 1/31/13	Fri 2/8/13
160		📌	Frame Drywall Ceilings 7th Floor	7 days	Thu 2/7/13	Fri 2/15/13
161		📌	Above Ceiling Electrical Rough-In 7th Floor	7 days	Mon 2/18/13	Tue 2/26/13
162		📌	Frame Drywall Ceilings 6th Floor	7 days	Mon 2/25/13	Tue 3/5/13
163		📌	Above Ceiling Electrical Rough-In 6th Floor	7 days	Wed 3/6/13	Thu 3/14/13
164		📌	Frame Drywall Ceilings 5th Floor	7 days	Wed 3/13/13	Thu 3/21/13
165		📌	Above Ceiling Electrical Rough-In 5th Floor	7 days	Fri 3/22/13	Mon 4/1/13



Project: Project Schedule
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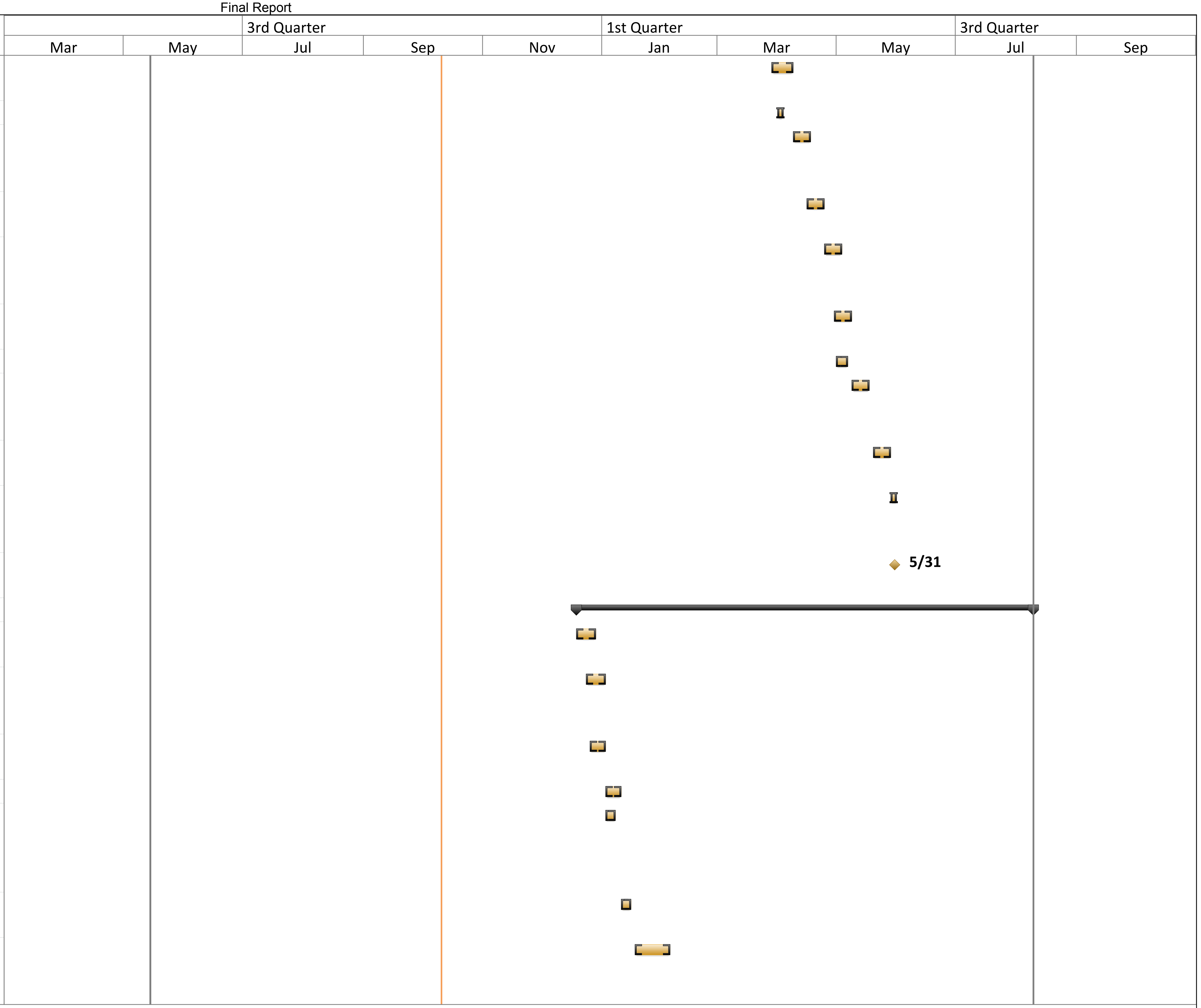
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⬇
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

ID	ℹ Task Mode	Task Name	Duration	Start	Finish
166	📌	Frame Drywall Ceilings 4th Floor	7 days	Fri 3/29/13	Mon 4/8/13
167	📌	Set Gas Meter	3 days	Mon 4/1/13	Wed 4/3/13
168	📌	Above Ceiling Electrical Rough-In 4th Floor	7 days	Tue 4/9/13	Wed 4/17/13
169	📌	Frame Drywall Ceilings 3rd Floor	7 days	Tue 4/16/13	Wed 4/24/13
170	📌	Above Ceiling Electrical Rough-In 3rd Floor	7 days	Thu 4/25/13	Fri 5/3/13
171	📌	Frame Drywall Ceilings 2nd Floor	7 days	Tue 4/30/13	Wed 5/8/13
172	📌	Elevator Pit Ladders	4 days	Wed 5/1/13	Mon 5/6/13
173	📌	Above Ceiling Electrical Rough-In 2nd Floor	7 days	Thu 5/9/13	Fri 5/17/13
174	📌	Frame Drywall Ceilings 1st Floor	7 days	Mon 5/20/13	Tue 5/28/13
175	📌	Above Ceiling Electrical Rough-In 1st Floor	3 days	Wed 5/29/13	Fri 5/31/13
176	📌	Building Fit Out Complete	0 days	Fri 5/31/13	Fri 5/31/13
177	⇨	**Finishes**	**165 days**	**Wed 12/19/12**	**Fri 8/9/13**
178	📌	Set Solar Panels on Roof With Crane	7 days	Wed 12/19/12	Fri 12/28/12
179	📌	Hang and Finish Drywall First Floor Electrical Room	6 days	Mon 12/24/12	Wed 1/2/13
180	📌	Hang and Finish Drywall Penthouse	5 days	Wed 12/26/12	Wed 1/2/13
181	📌	Paint Penthouse	6 days	Thu 1/3/13	Thu 1/10/13
182	📌	Door Frame and Temp. Door/Hardware Electrical Room	3 days	Thu 1/3/13	Mon 1/7/13
183	📌	Door , Frame and Hardware Penthouse	3 days	Fri 1/11/13	Tue 1/15/13
184	📌	Hang and Finish Drywall Walls 8th Floor	12 days	Fri 1/18/13	Mon 2/4/13



Project: Project Schedule
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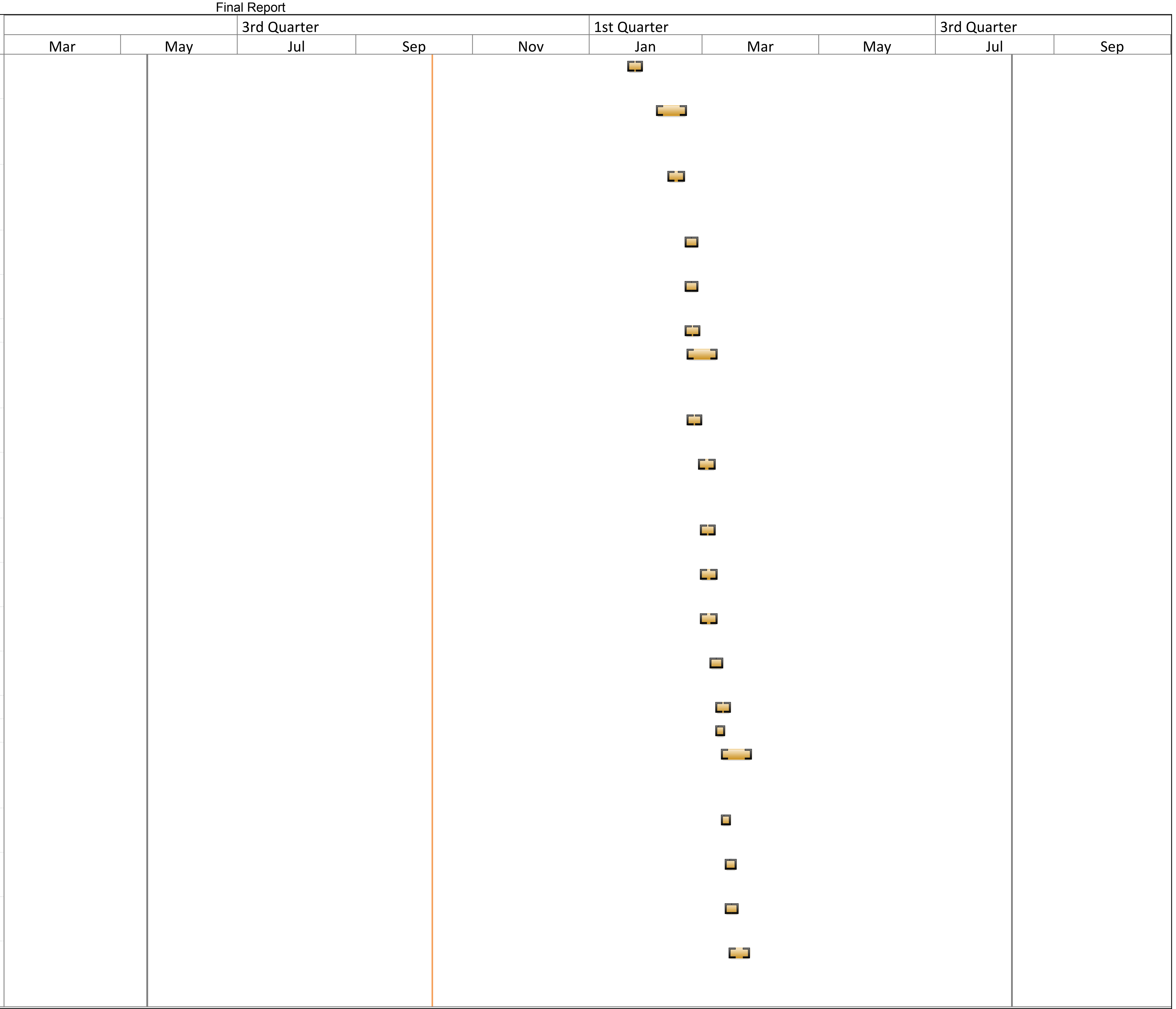
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▭	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

ID	Task Mode	Task Name	Duration	Start	Finish
185	📌	Electrical Gear Testing and Energized	6 days	Mon 1/21/13	Mon 1/28/13
186	📌	Hang and Finish Drywall Walls 7th Floor	12 days	Tue 2/5/13	Wed 2/20/13
187	📌	Hang and Finish Drywall Ceilings 8th Floor	7 days	Mon 2/11/13	Tue 2/19/13
188	📌	ACT Ceilings and Lighting 8th Floor	5 days	Wed 2/20/13	Tue 2/26/13
189	📌	Spray Textured Ceilings 8th Floor	5 days	Wed 2/20/13	Tue 2/26/13
190	📌	Paint 8th Floor	6 days	Wed 2/20/13	Wed 2/27/13
191	📌	Hang and Finish Drywall Walls 6th Floor	12 days	Thu 2/21/13	Fri 3/8/13
192	📌	ACT Ceilings and Lighting 7th Floor	6 days	Thu 2/21/13	Thu 2/28/13
193	📌	Hang and Finish Drywall Ceilings 7th Floor	7 days	Wed 2/27/13	Thu 3/7/13
194	📌	Vanities and Millwork 8th Floor	6 days	Thu 2/28/13	Thu 3/7/13
195	📌	Door, Frame and Hardware 8th Floor	7 days	Thu 2/28/13	Fri 3/8/13
196	📌	Electrical Finishes 8th Floor	7 days	Thu 2/28/13	Fri 3/8/13
197	📌	Spray Textured Ceilings 7th Floor	5 days	Tue 3/5/13	Mon 3/11/13
198	📌	Paint 7th Floor	6 days	Fri 3/8/13	Fri 3/15/13
199	📌	Flooring 8th Floor	3 days	Fri 3/8/13	Tue 3/12/13
200	📌	Hang and Finish Drywall Walls 5th Floor	12 days	Mon 3/11/13	Tue 3/26/13
201	📌	ACT Ceilings and Lighting 6th Floor	5 days	Mon 3/11/13	Fri 3/15/13
202	📌	Install Appliances 8th Floor	4 days	Wed 3/13/13	Mon 3/18/13
203	📌	Plumbing Finishes 8th Floor	5 days	Wed 3/13/13	Tue 3/19/13
204	📌	Hang and Finish Drywall Ceilings 6th Floor	7 days	Fri 3/15/13	Mon 3/25/13



Project: Project Schedule
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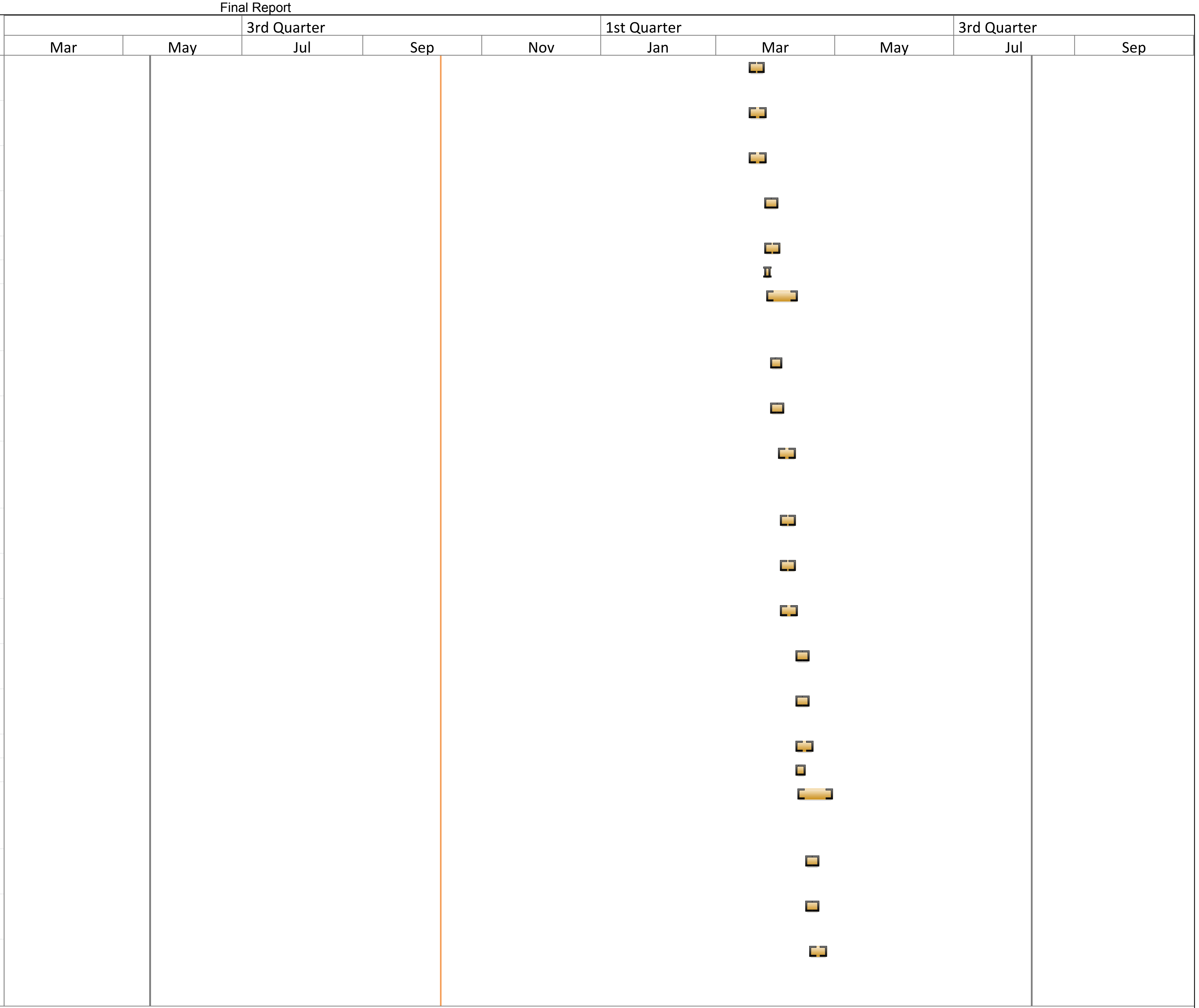
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

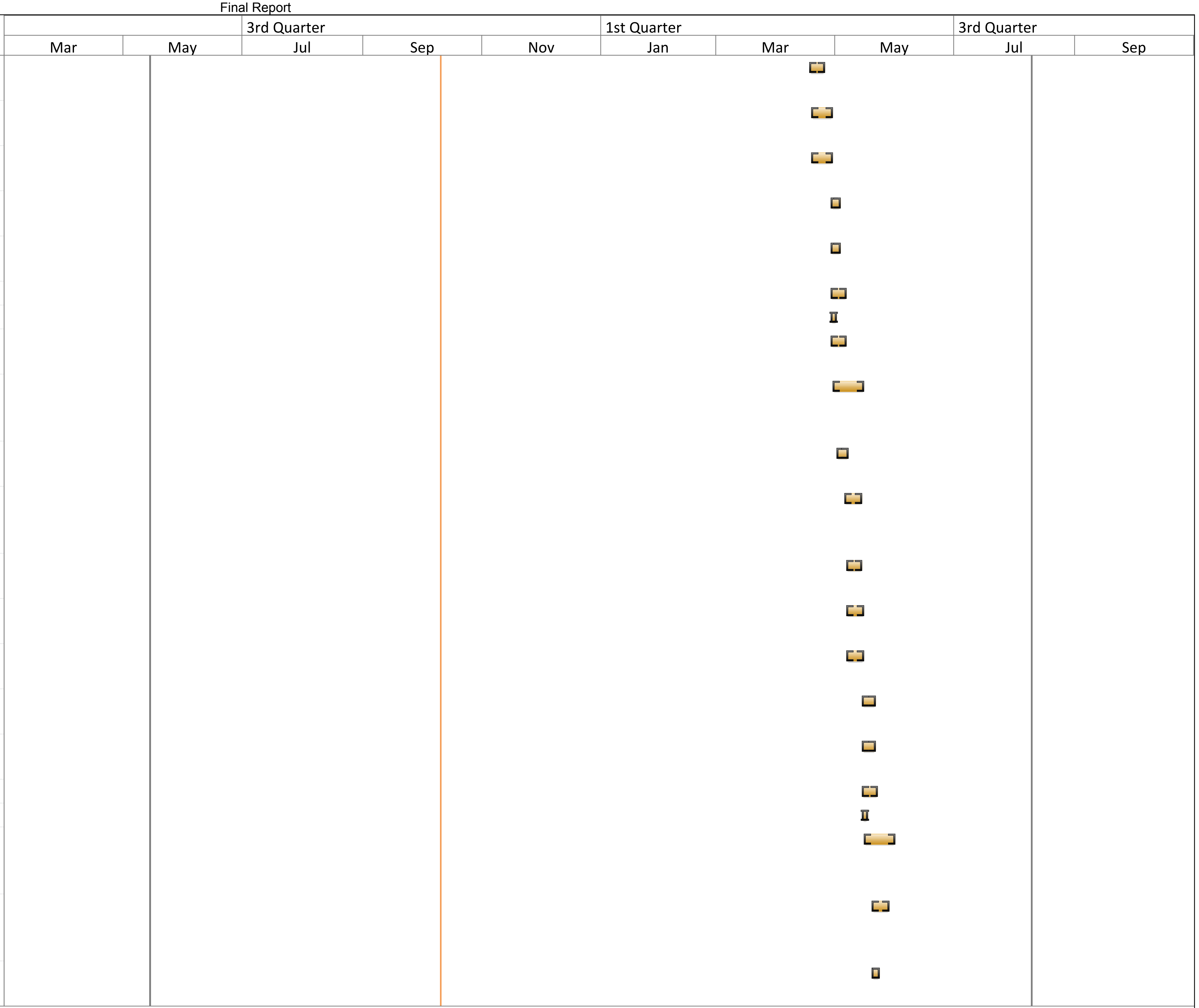
ID	Task Mode	Task Name	Duration	Start	Finish
205	📌	Vanities and Millwork 7th Floor	6 days	Mon 3/18/13	Mon 3/25/13
206	📌	Door, Frame and Hardware 7th Floor	7 days	Mon 3/18/13	Tue 3/26/13
207	📌	Electrical Finishes 7th Floor	7 days	Mon 3/18/13	Tue 3/26/13
208	📌	Spray Textured Ceiling 6th Floor	5 days	Tue 3/26/13	Mon 4/1/13
209	📌	Paint 6th Floor	6 days	Tue 3/26/13	Tue 4/2/13
210	📌	Flooring 7th Floor	3 days	Tue 3/26/13	Thu 3/28/13
211	📌	Hang and Finish Drywall Walls 4th Floor	12 days	Wed 3/27/13	Thu 4/11/13
212	📌	Install Appliances 7th Floor	4 days	Fri 3/29/13	Wed 4/3/13
213	📌	Plumbing Finishes 7th Floor	5 days	Fri 3/29/13	Thu 4/4/13
214	📌	Hang and Finish Drywall Ceilings 5th Floor	7 days	Tue 4/2/13	Wed 4/10/13
215	📌	Vanities and Millwork 6th Floor	6 days	Wed 4/3/13	Wed 4/10/13
216	📌	Door, Frame and Hardware 6th Floor	6 days	Wed 4/3/13	Wed 4/10/13
217	📌	Electrical Finishes 6th Floor	7 days	Wed 4/3/13	Thu 4/11/13
218	📌	ACT Ceilings and Lighting 5th Floor	5 days	Thu 4/11/13	Wed 4/17/13
219	📌	Spray Textured Ceiling 5th Floor	5 days	Thu 4/11/13	Wed 4/17/13
220	📌	Paint 5th Floor	7 days	Thu 4/11/13	Fri 4/19/13
221	📌	Flooring 6th Floor	3 days	Thu 4/11/13	Mon 4/15/13
222	📌	Hang and Finish Drywall Walls 3rd Floor	12 days	Fri 4/12/13	Mon 4/29/13
223	📌	Install Appliances 6th Floor	5 days	Tue 4/16/13	Mon 4/22/13
224	📌	Plumbing Finishes 6th Floor	5 days	Tue 4/16/13	Mon 4/22/13
225	📌	Hang and Finish Drywall Ceilings 4th Floor	7 days	Thu 4/18/13	Fri 4/26/13



Project: Project Schedule
Date: Thu 10/11/12

Task		Project Summary		Inactive Milestone	◇	Manual Summary Rollup		Deadline	⇩
Split		External Tasks		Inactive Summary		Manual Summary		Critical	
Milestone	◆	External Milestone	◆	Manual Task		Start-only	[	Critical Split	
Summary		Inactive Task		Duration-only		Finish-only	]	Progress	

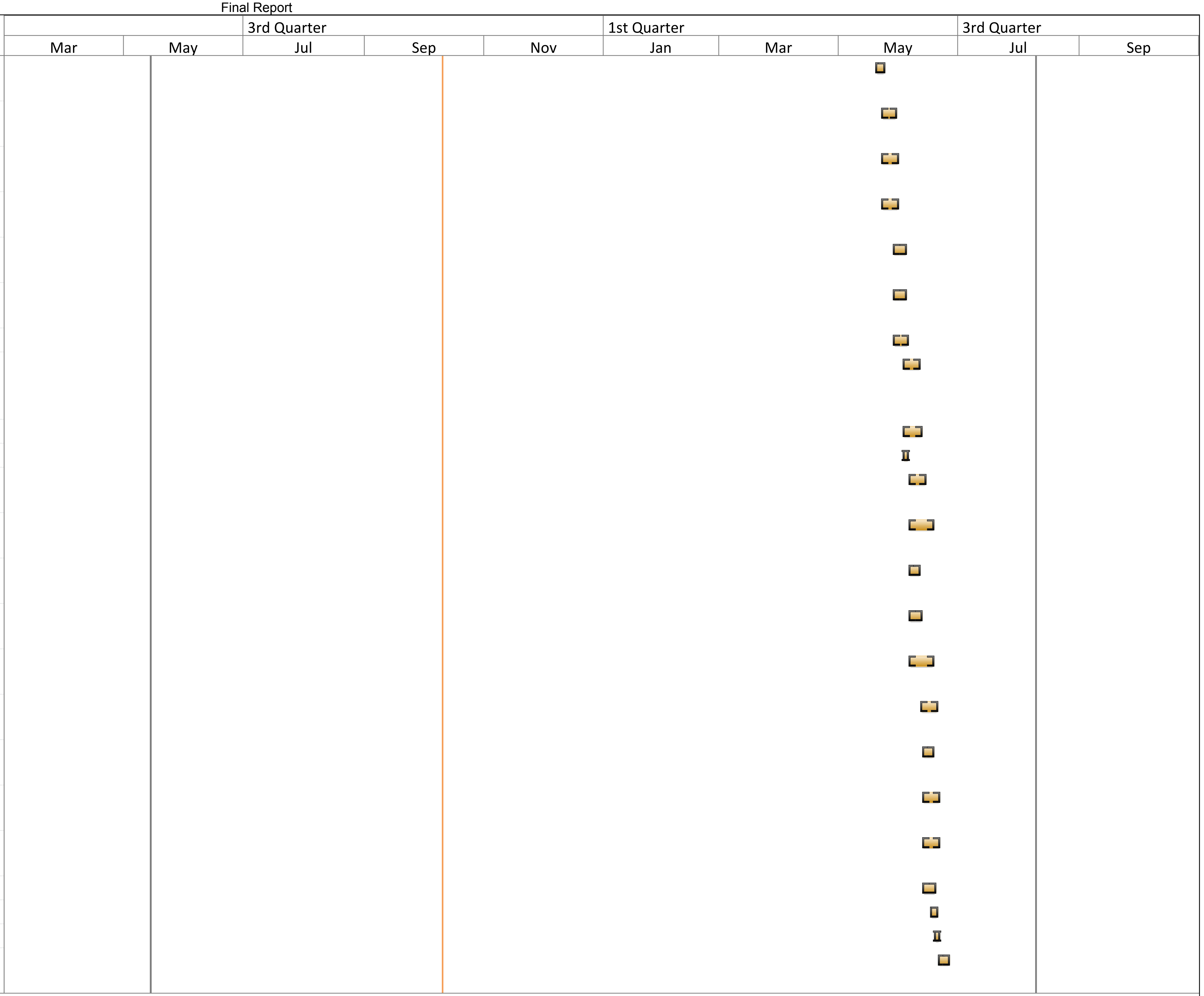
ID	Task Mode	Task Name	Duration	Start	Finish
226	📌	Vanities and Millwork 5th Floor	6 days	Thu 4/18/13	Thu 4/25/13
227	📌	Door, Frame and Hardware 5th Floor	7 days	Fri 4/19/13	Mon 4/29/13
228	📌	Electrical Finishes 5th Floor	7 days	Fri 4/19/13	Mon 4/29/13
229	📌	ACT Ceilings and Lighting 4th Floor	5 days	Mon 4/29/13	Fri 5/3/13
230	📌	Spray Textured Ceilings 4th Floor	5 days	Mon 4/29/13	Fri 5/3/13
231	📌	Paint 4th Floor	6 days	Mon 4/29/13	Mon 5/6/13
232	📌	Flooring 5th Floor	3 days	Mon 4/29/13	Wed 5/1/13
233	📌	Plumbing Finishes 5th Floor	6 days	Mon 4/29/13	Mon 5/6/13
234	📌	Hang and Finish Drywall Walls 2nd Floor	12 days	Tue 4/30/13	Wed 5/15/13
235	📌	Install Appliances 5th Floor	4 days	Thu 5/2/13	Tue 5/7/13
236	📌	Hand and Finish Drywall Ceilings 3rd Floor	7 days	Mon 5/6/13	Tue 5/14/13
237	📌	Vanities and Millwork 4th Floor	6 days	Tue 5/7/13	Tue 5/14/13
238	📌	Door, Frame and Hardware 4th Floor	7 days	Tue 5/7/13	Wed 5/15/13
239	📌	Electrical Finishes 4th Floor	7 days	Tue 5/7/13	Wed 5/15/13
240	📌	ACT Ceilings and Lighting 3rd Floor	5 days	Wed 5/15/13	Tue 5/21/13
241	📌	Spray Textured Ceiling 3rd Floor	5 days	Wed 5/15/13	Tue 5/21/13
242	📌	Paint 3rd Floor	6 days	Wed 5/15/13	Wed 5/22/13
243	📌	Flooring 4th Floor	3 days	Wed 5/15/13	Fri 5/17/13
244	📌	Hang and Finish Drywall Walls 1st Floor	12 days	Thu 5/16/13	Fri 5/31/13
245	📌	Hang and Finish Drywall Ceilings 2nd Floor	7 days	Mon 5/20/13	Tue 5/28/13
246	📌	Install Appliances 4th Floor	4 days	Mon 5/20/13	Thu 5/23/13



Project: Project Schedule
Date: Thu 10/11/12

Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⬇
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	🟥
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

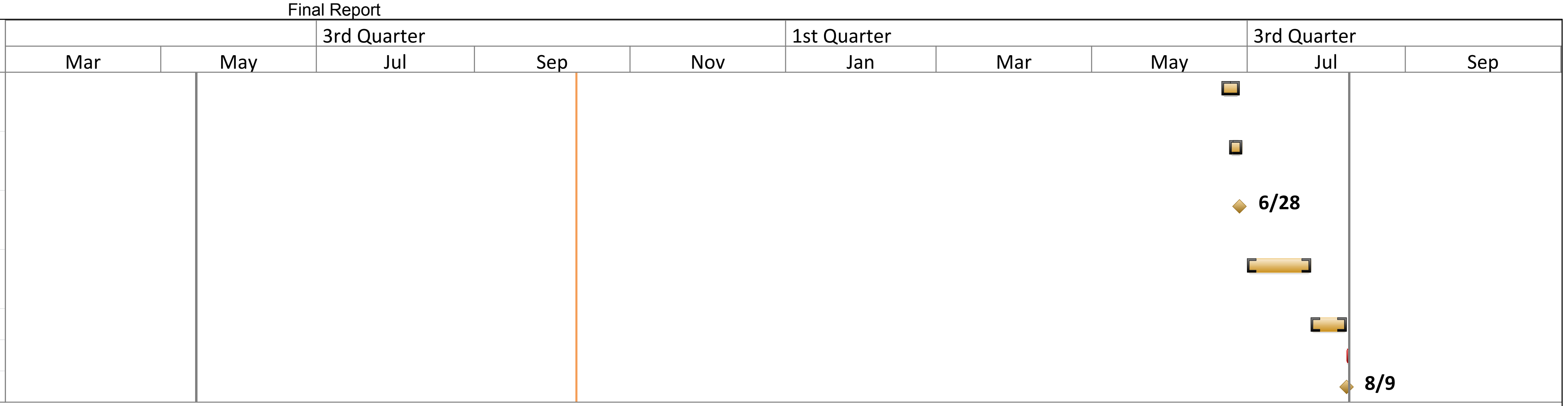
ID	Task Mode	Task Name	Duration	Start	Finish
247	📌	Plumbing Finishes 4th Floor	5 days	Mon 5/20/13	Fri 5/24/13
248	📌	Vanities and Millwork 3rd Floor	6 days	Thu 5/23/13	Thu 5/30/13
249	📌	Door, Frame and Hardware 3rd Floor	7 days	Thu 5/23/13	Fri 5/31/13
250	📌	Electrical Finishes 3rd Floor	7 days	Thu 5/23/13	Fri 5/31/13
251	📌	ACT Ceilings and Lighting 2nd Floor	5 days	Wed 5/29/13	Tue 6/4/13
252	📌	Spray Textured Ceilings 1st Floor	5 days	Wed 5/29/13	Tue 6/4/13
253	📌	Paint 2nd Floor	6 days	Wed 5/29/13	Wed 6/5/13
254	📌	Hang and Finish Drywall Ceilings 1st Floor	7 days	Mon 6/3/13	Tue 6/11/13
255	📌	Paint 1st Floor	8 days	Mon 6/3/13	Wed 6/12/13
256	📌	Flooring 3rd Floor	3 days	Mon 6/3/13	Wed 6/5/13
257	📌	Vanities and Millwork 2nd Floor	7 days	Thu 6/6/13	Fri 6/14/13
258	📌	Door, Frame and Hardware 2nd Floor	9 days	Thu 6/6/13	Tue 6/18/13
259	📌	Install Appliances 3rd Floor	4 days	Thu 6/6/13	Tue 6/11/13
260	📌	Plumbing Finishes 3rd Floor	5 days	Thu 6/6/13	Wed 6/12/13
261	📌	Electrical Finishes 2nd Floor	9 days	Thu 6/6/13	Tue 6/18/13
262	📌	ACT Ceilings and Lighting 1st Floor	7 days	Wed 6/12/13	Thu 6/20/13
263	📌	Vanities and Millwork 1st Floor	4 days	Thu 6/13/13	Tue 6/18/13
264	📌	Door, Frame and Hardware 1st Floor	7 days	Thu 6/13/13	Fri 6/21/13
265	📌	Electrical Finishes 1st Floor	7 days	Thu 6/13/13	Fri 6/21/13
266	📌	Mail Box	5 days	Thu 6/13/13	Wed 6/19/13
267	📌	Flooring 2nd Floor	4 days	Mon 6/17/13	Thu 6/20/13
268	📌	Flooring 1st Floor	3 days	Wed 6/19/13	Fri 6/21/13
269	📌	Install Appliances 2nd Floor	4 days	Fri 6/21/13	Wed 6/26/13



Project: Project Schedule
Date: Thu 10/11/12

Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

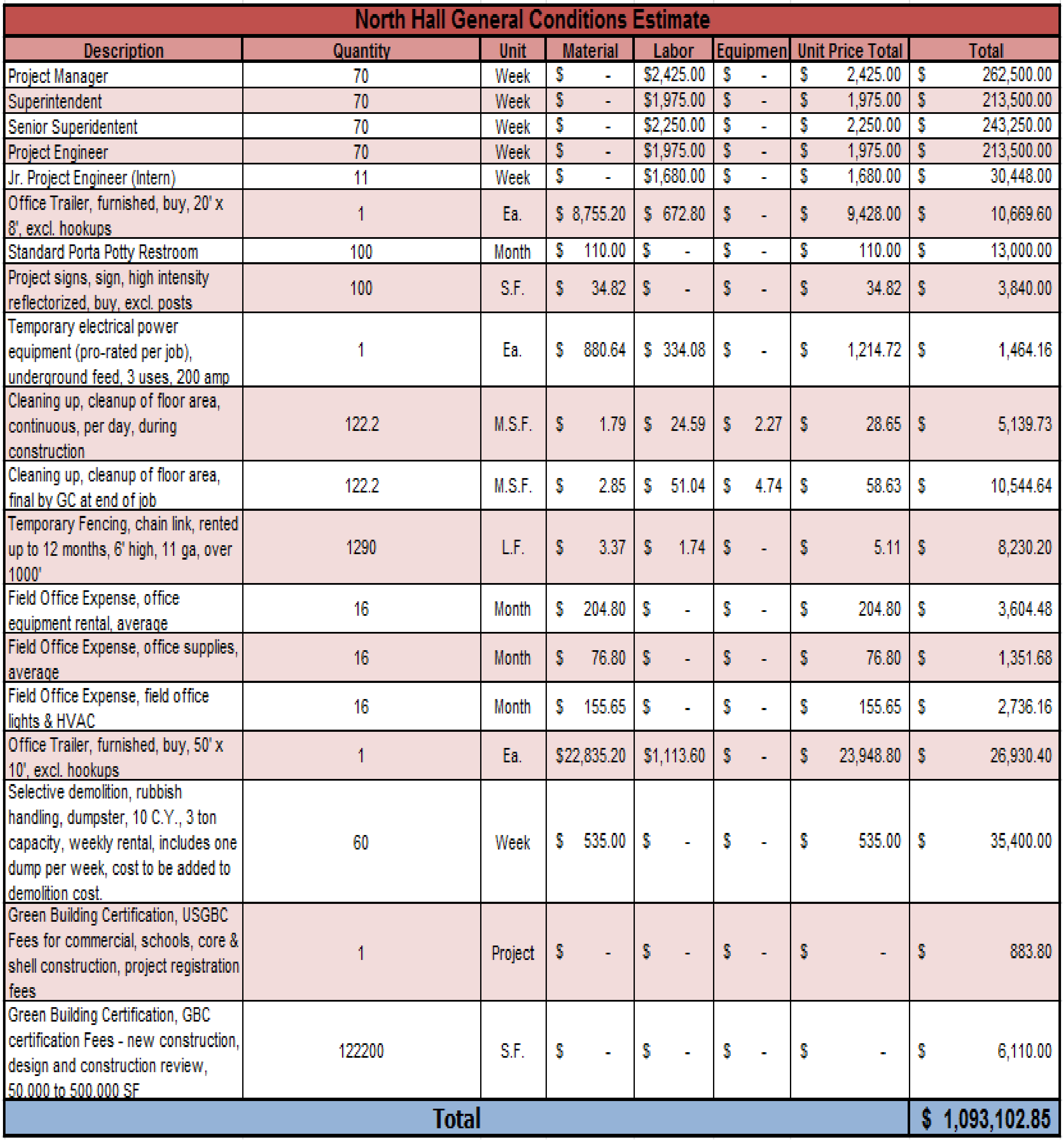
ID	Task Mode	Task Name	Duration	Start	Finish
270	📌	Plumbing Finishes 2nd Floor	5 days	Fri 6/21/13	Thu 6/27/13
271	📌	Plumbing Finishes 1st Floor	5 days	Mon 6/24/13	Fri 6/28/13
272	📌	Substantial Completion	0 days	Fri 6/28/13	Fri 6/28/13
273	📌	Commissioning and Start Up	18 days	Mon 7/1/13	Thu 7/25/13
274	📌	Punchlist	10 days	Fri 7/26/13	Thu 8/8/13
275	📌	Demoblization	1 day	Fri 8/9/13	Fri 8/9/13
276	📌	Final Completion	0 days	Fri 8/9/13	Fri 8/9/13



Project: Project Schedule
Date: Thu 10/11/12

Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Critical	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[	Critical Split	┈
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	▬

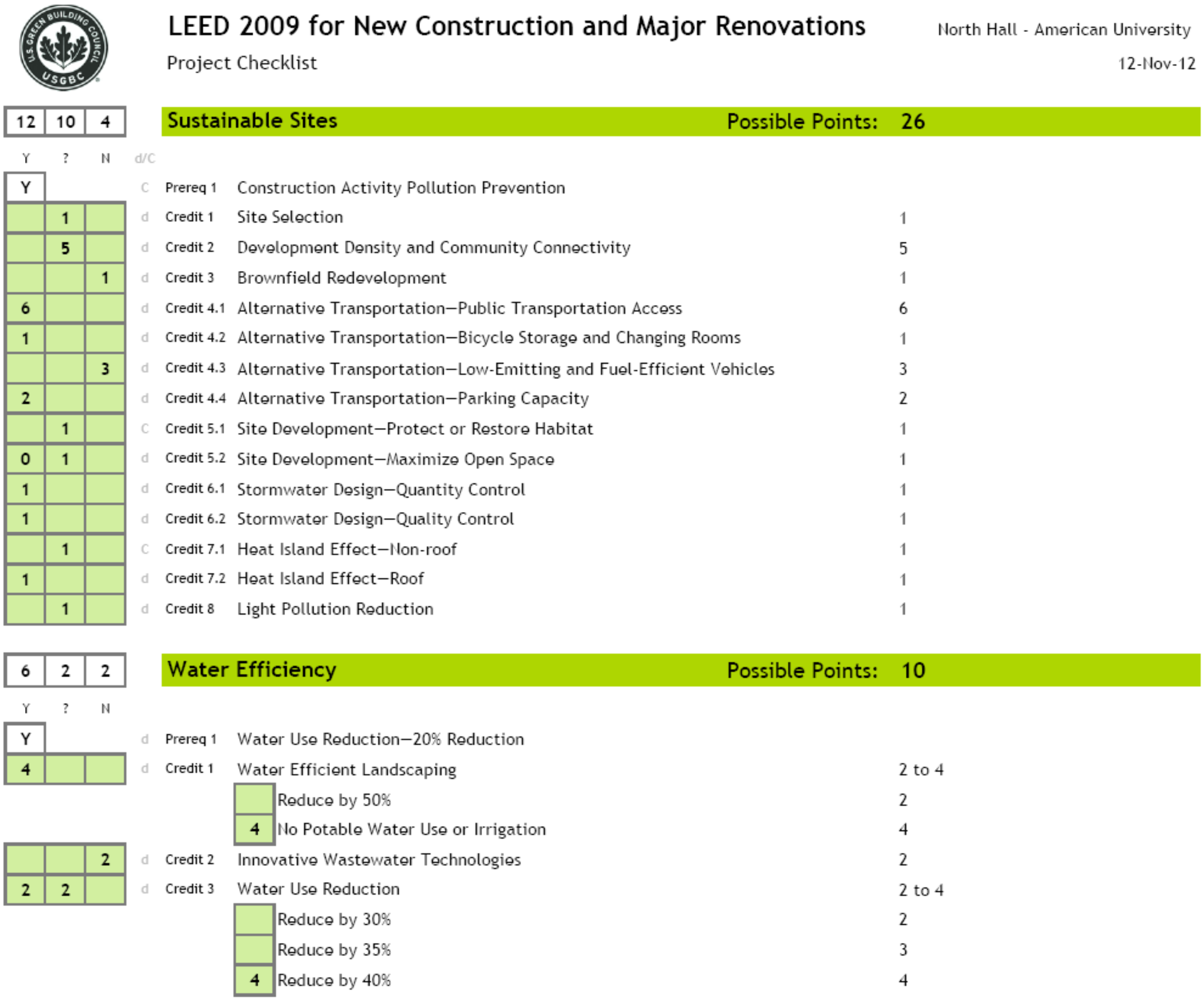
Appendix C: General Conditions Estimate



North Hall General Conditions Estimate

Description	Quantity	Unit	Material	Labor	Equipmen	Unit Price Total	Total
Project Manager	70	Week	$ -	$2,425.00	$ -	$ 2,425.00	$ 262,500.00
Superintendent	70	Week	$ -	$1,975.00	$ -	$ 1,975.00	$ 213,500.00
Senior Superidentent	70	Week	$ -	$2,250.00	$ -	$ 2,250.00	$ 243,250.00
Project Engineer	70	Week	$ -	$1,975.00	$ -	$ 1,975.00	$ 213,500.00
Jr. Project Engineer (Intern)	11	Week	$ -	$1,680.00	$ -	$ 1,680.00	$ 30,448.00
Office Trailer, furnished, buy, 20' x 8', excl. hookups	1	Ea.	$ 8,755.20	$ 672.80	$ -	$ 9,428.00	$ 10,669.60
Standard Porta Potty Restroom	100	Month	$ 110.00	$ -	$ -	$ 110.00	$ 13,000.00
Project signs, sign, high intensity reflectorized, buy, excl. posts	100	S.F.	$ 34.82	$ -	$ -	$ 34.82	$ 3,840.00
Temporary electrical power equipment (pro-rated per job), underground feed, 3 uses, 200 amp	1	Ea.	$ 880.64	$ 334.08	$ -	$ 1,214.72	$ 1,464.16
Cleaning up, cleanup of floor area, continuous, per day, during construction	122.2	M.S.F.	$ 1.79	$ 24.59	$ 2.27	$ 28.65	$ 5,139.73
Cleaning up, cleanup of floor area, final by GC at end of job	122.2	M.S.F.	$ 2.85	$ 51.04	$ 4.74	$ 58.63	$ 10,544.64
Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, over 1000'	1290	L.F.	$ 3.37	$ 1.74	$ -	$ 5.11	$ 8,230.20
Field Office Expense, office equipment rental, average	16	Month	$ 204.80	$ -	$ -	$ 204.80	$ 3,604.48
Field Office Expense, office supplies, average	16	Month	$ 76.80	$ -	$ -	$ 76.80	$ 1,351.68
Field Office Expense, field office lights & HVAC	16	Month	$ 155.65	$ -	$ -	$ 155.65	$ 2,736.16
Office Trailer, furnished, buy, 50' x 10', excl. hookups	1	Ea.	$22,835.20	$1,113.60	$ -	$ 23,948.80	$ 26,930.40
Selective demolition, rubbish handling, dumpster, 10 C.Y., 3 ton capacity, weekly rental, includes one dump per week, cost to be added to demolition cost.	60	Week	$ 535.00	$ -	$ -	$ 535.00	$ 35,400.00
Green Building Certification, USGBC Fees for commercial, schools, core & shell construction, project registration fees	1	Project	$ -	$ -	$ -	$ -	$ 883.80
Green Building Certification, GBC certification Fees - new construction, design and construction review, 50,000 to 500,000 SF	122200	S.F.	$ -	$ -	$ -	$ -	$ 6,110.00
Total							**$ 1,093,102.85**

Appendix D: LEED Scorecard



LEED 2009 for New Construction and Major Renovations

Project Checklist

North Hall - American University

12-Nov-12

12	10	4			Sustainable Sites	Possible Points: 26
Y	?	N	d/C			
Y			C	Prereq 1	Construction Activity Pollution Prevention	
	1		d	Credit 1	Site Selection	1
	5		d	Credit 2	Development Density and Community Connectivity	5
		1	d	Credit 3	Brownfield Redevelopment	1
6			d	Credit 4.1	Alternative Transportation—Public Transportation Access	6
1			d	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
		3	d	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
2			d	Credit 4.4	Alternative Transportation—Parking Capacity	2
	1		C	Credit 5.1	Site Development—Protect or Restore Habitat	1
0	1		d	Credit 5.2	Site Development—Maximize Open Space	1
1			d	Credit 6.1	Stormwater Design—Quantity Control	1
1			d	Credit 6.2	Stormwater Design—Quality Control	1
	1		C	Credit 7.1	Heat Island Effect—Non-roof	1
1			d	Credit 7.2	Heat Island Effect—Roof	1
	1		d	Credit 8	Light Pollution Reduction	1

6	2	2			Water Efficiency	Possible Points: 10
Y	?	N				
Y			d	Prereq 1	Water Use Reduction—20% Reduction	
4			d	Credit 1	Water Efficient Landscaping	2 to 4
					Reduce by 50%	2
				4	No Potable Water Use or Irrigation	4
		2	d	Credit 2	Innovative Wastewater Technologies	2
2	2		d	Credit 3	Water Use Reduction	2 to 4
					Reduce by 30%	2
					Reduce by 35%	3
				4	Reduce by 40%	4

4	12	19				**Energy and Atmosphere**	**Possible Points: 35**
Y	?	N					
Y			C	Prereq 1		Fundamental Commissioning of Building Energy Systems	
Y			d	Prereq 2		Minimum Energy Performance	
Y			d	Prereq 3		Fundamental Refrigerant Management	
1	4	14	d	Credit 1		Optimize Energy Performance	1 to 19
					1	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
1	1	5	d	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		C	Credit 3		Enhanced Commissioning	2
2			d	Credit 4		Enhanced Refrigerant Management	2
	3		C	Credit 5		Measurement and Verification	3
	2		C	Credit 6		Green Power	2

Materials and Resources

Possible Points: 14

6	1	7					
Y	?	N					
Y			d	Prereq 1		Storage and Collection of Recyclables	
		3	C	Credit 1.1		Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
						Reuse 55%	1
						Reuse 75%	2
						Reuse 95%	3
		1	C	Credit 1.2		Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
2			C	Credit 2		Construction Waste Management	1 to 2
						50% Recycled or Salvaged	1
					2	75% Recycled or Salvaged	2
		2	C	Credit 3		Materials Reuse	1 to 2
						Reuse 5%	1
						Reuse 10%	2
2			C	Credit 4		Recycled Content	1 to 2
						10% of Content	1
					2	20% of Content	2
2			C	Credit 5		Regional Materials	1 to 2
						10% of Materials	1
					2	20% of Materials	2
		1	C	Credit 6		Rapidly Renewable Materials	1
	1		C	Credit 7		Certified Wood	1

Indoor Environmental Quality

Possible Points: 15

7	7	1				
Y	?	N				
Y			d	Prereq 1	Minimum Indoor Air Quality Performance	
Y			d	Prereq 2	Environmental Tobacco Smoke (ETS) Control	
	1		d	Credit 1	Outdoor Air Delivery Monitoring	1
		1	d	Credit 2	Increased Ventilation	1
1			C	Credit 3.1	Construction IAQ Management Plan—During Construction	1
	1		C	Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
1			C	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
1			C	Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
1			C	Credit 4.3	Low-Emitting Materials—Flooring Systems	1
1			C	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
	1		d	Credit 5	Indoor Chemical and Pollutant Source Control	1
	1		d	Credit 6.1	Controllability of Systems—Lighting	1
1			d	Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			d	Credit 7.1	Thermal Comfort—Design	1
	1		d	Credit 7.2	Thermal Comfort—Verification	1
	1		d	Credit 8.1	Daylight and Views—Daylight	1
	1		d	Credit 8.2	Daylight and Views—Views	1

Innovation and Design Process

Possible Points: 6

6	0	0				
Y	?	N				
1			d/C	Credit 1.1	Innovation in Design: Specific Title	1
1			d/C	Credit 1.2	Innovation in Design: Specific Title	1
1			d/C	Credit 1.3	Innovation in Design: Specific Title	1
1			d/C	Credit 1.4	Innovation in Design: Specific Title	1
1			d/C	Credit 1.5	Innovation in Design: Specific Title	1
1			d/C	Credit 2	LEED Accredited Professional	1

1	2	1		**Regional Priority Credits**		Possible Points: 4
Y	?	N				
	1		d/C	Credit 1.1	Regional Priority: Specific Credit	1
1			d/C	Credit 1.2	Regional Priority: Specific Credit	1
	1		d/C	Credit 1.3	Regional Priority: Specific Credit	1
		1	d/C	Credit 1.4	Regional Priority: Specific Credit	1
42	34	34		**Total**		Possible Points: 110

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

Appendix E: BIM Execution Planning

BIM PROJECT EXECUTION PLAN
VERSION 2.0

FOR

[North Hall – American University]

DEVELOPED BY

[Brandon Tezak]

[Grunley Construction Company]

This template is a tool that is provided to assist in the development of a BIM project execution plan as required per contract. The template plan was created from the buildingSMART alliance™ (bSa) Project "BIM Project Execution Planning" as developed by The Computer Integrated Construction (CIC) Research Group of The Pennsylvania State University. The bSa project is sponsored by The Charles Pankow Foundation (http://www.pankowfoundation.org), Construction Industry Institute (CII) (http://www.construction-institute.org), Penn State Office of Physical Plant (OPP) (http://www.opp.psu.edu), and The Partnership for Achieving Construction Excellence (PACE) (http://www.engr.psu.edu/pace). The BIM Project Execution Planning Guide can be downloaded at http://www.engr.psu.edu/BIM/PxP.

SECTION A: BIM PROJECT EXECUTION PLAN OVERVIEW

To successfully implement Building Information Modeling (BIM) on a project, the project team has developed this detailed BIM Project Execution Plan. The BIM Project Execution Plan defines uses for BIM on the project (e.g. design authoring, cost estimating, and design coordination), along with a detailed design of the process for executing BIM throughout the project lifecycle.

SECTION B: PROJECT INFORMATION

1. **PROJECT OWNER: AMERICAN UNIVERSITY**
2. **PROJECT NAME: NORTH HALL**
3. **PROJECT LOCATION AND ADDRESS: 4400 MASS. AVE. NW, WASHINGTON, D.C.**
4. **CONTRACT TYPE / DELIVERY METHOD: GUARANTEED MAXIMUM PRICE**
5. **BRIEF PROJECT DESCRIPTION:** AMERICAN UNIVERSITY STARTED EXPANDING THEIR MAIN CAMPUS IN DOWNTOWN WASHINGTON D.C. AFTER THEIR 2011 CAMPUS PLAN WAS APPROVED BY THE LOCAL ZONING BOARD. THE FIRST STEP OF AMERICAN'S PLAN IS THE CONSTRUCTION OF A NEW 122,200 SQUARE FOOT, 8 STORY SUITE STYLE DORMITORY BUILDING, NORTH HALL. THE NEW DORM WILL BE LOCATED IN THE NORTHERN PART OF AMERICAN'S CAMPUS. NORTH HALL WILL BE READY FOR STUDENTS TO OCCUPY THE ROOMS FOR THE FALL 2013 SEMESTER.
6. Additional Project Information: THE BIM EXECUTION PROCESS FOR THIS PROJECT DETAILS THE STRENGTHS AND WEAKNESSES OF BIM IMPLEMENTATION IN THE VARYING STAGES OF NORTH HALL.
7. **PROJECT NUMBERS:**

PROJECT INFORMATION	NUMBER
Project Number:	G12.268

8. **PROJECT SCHEDULE / PHASES / MILESTONES:**

PROJECT PHASE / MILESTONE	ESTIMATED START DATE	ESTIMATED COMPLETION DATE	PROJECT STAKEHOLDERS INVOLVED
PRELIMINARY PLANNING	March 2011	May 2011	Owner, Architect, GC
DESIGN DOCUMENTS	May 2011	March 2012	Owner, Architect, GC
CONSTRUCTION DOCUMENTS	May 2012	Ongoing	Owner, Architect, GC, Subcontractors
CONSTRUCTION	May 15, 2012	August 9,2013	Owner, Architect, GC, Subcontractors
OCCPANCY	August 9,2003	Ongoing	Owner, Occupants

SECTION C: KEY PROJECT CONTACTS

ROLE	ORGANIZATION	CONTACT NAME
Owner	American University	Tony Esse
Project Manager	Grunley Construction	Greg McHugh
BIM Manager	Grunley Construction	Jon Skippers
Architect	Little Diversified	Richard Naab
Structural Concrete Subcontractor	Miller and Long DC	Chris Grant
Mechanical/ Plumbing Subcontractor	JCM	Tom Tran
Electrical Subcontractor	PerLectric	Tom Forman
Precast Subcontractor	Gate Precast	Tim Shaver

SECTION D: PROJECT GOALS / BIM USES

1. MAJOR BIM GOALS / OBJECTIVES:

State Major BIM Goals and Objectives

PRIORITY (HIGH/ MED/ LOW)	GOAL DESCRIPTION	POTENTIAL BIM USES
3	Reduce Field Conflicts	3D Coordination, Subcontractor Design Review
3	Reduce Site Logistics Issues	Site Utilization Planning
2	Operation and Maintenance	Record Model, Maintenance Scheduling,
2	Sustainability	LEED Documentation

2. BIM USE ANALYSIS WORKSHEET: SEE NEXT PAGE

BIM USE ANALYSIS
Version 2.0

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)					YES / NO / MAYBE
				Resources	Competency	Experience			
Maintenance Scheduling	LOW	American	MED	2	2	3	Software to Manage process and link in model compontents		**MAYBE**
Record Modeling	MED	Grunley	MED	3	3	3	3D Model Manipulation, Training		**YES**
		Little	MED	2	2	2			
		American	MED	2	2	2			
Site Utilization Planning	HIGH	Grunley	HIGH	3	3	3	3D Model Manipulation, Scheduling Software		**YES**
		Subcontractors	MED	1	2	1			
		American	MED	2	2	2			
3D Coordination	HIGH	Grunley	HIGH	3	3	3	3D Model Manipulation, Clash Detection Software, Training		**YES**
		Subcontractors	HIGH	1	3	2			
Design Reviews	HIGH	Grunley	MED	3	3	3	3D Model Manipulation, Constructability Understanding		**YES**
		Subcontractors	HIGH	1	3	2			
		A/E Team	MED	2	2	1			
LEED Documentation	MED	Grunley	MED	3	3	3	LEED AP on Project Team	LEED Gold Requirement, Reputation	**YES**
		Liitle	MED	2	2	3		Reputation	
		American	MED	2	2	3		Reputation	

3. BIM Uses:

X	PLAN	X	DESIGN	X	CONSTRUCT	X	OPERATE
	PROGRAMMING		DESIGN AUTHORING	X	SITE UTILIZATION PLANNING	X	BUILDING MAINTENANCE SCHEDULING
	SITE ANALYSIS	x	DESIGN REVIEWS		CONSTRUCTION SYSTEM DESIGN		BUILDING SYSTEM ANALYSIS
		X	3D COORDINATION	X	3D COORDINATION		ASSET MANAGEMENT
			STRUCTURAL ANALYSIS		DIGITAL FABRICATION		SPACE MANAGEMENT / TRACKING
			LIGHTING ANALYSIS		3D CONTROL AND PLANNING		DISASTER PLANNING
			ENERGY ANALYSIS	X	RECORD MODELING	X	RECORD MODELING
			MECHANICAL ANALYSIS				
			OTHER ENG. ANALYSIS				
			SUSTAINABLITY (LEED) EVALUATION				
			CODE VALIDATION				
	PHASE PLANNING (4D MODELING)		PHASE PLANNING (4D MODELING)		PHASE PLANNING (4D MODELING)		PHASE PLANNING (4D MODELING)
	COST ESTIMATION		COST ESTIMATION		COST ESTIMATION		COST ESTIMATION
	EXISTING CONDITIONS MODELING		EXISTING CONDITIONS MODELING		EXISTING CONDITIONS MODELING		EXISTING CONDITIONS MODELING

SECTION F: BIM PROCESS DESIGN

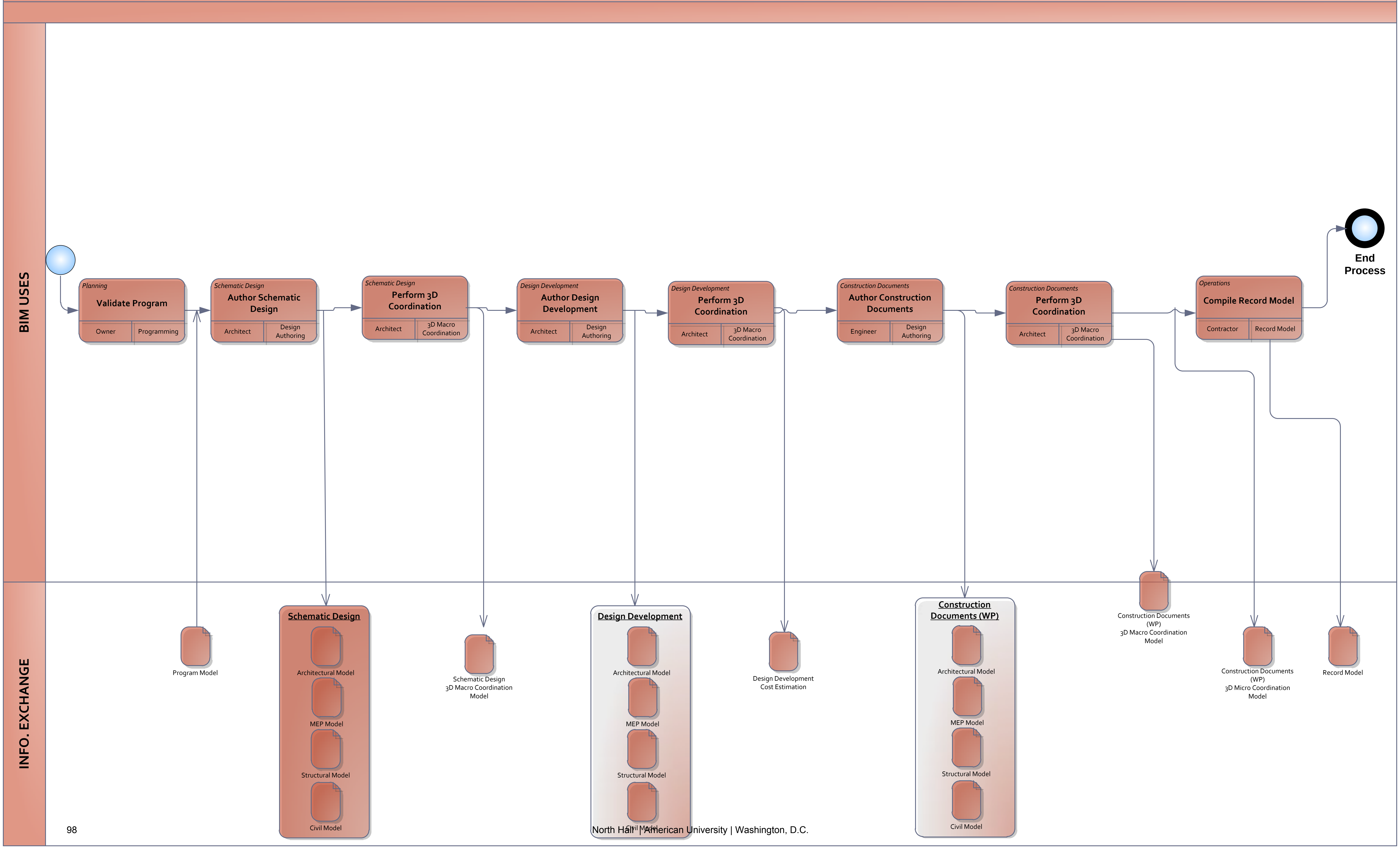
1. Level One Process Overview Map: Please See Pages Following Pages.

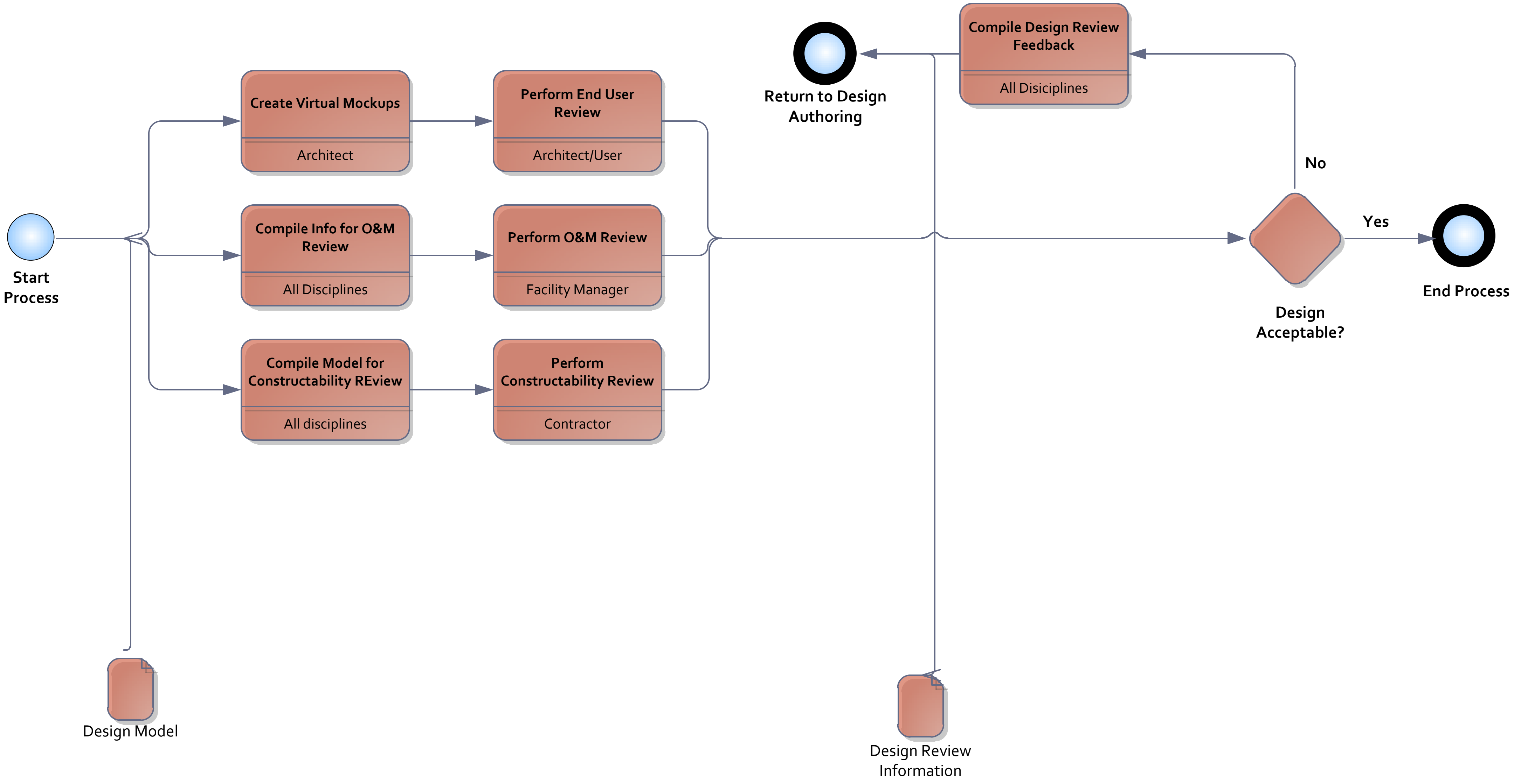
Level 1: BIM Execution Planning Process

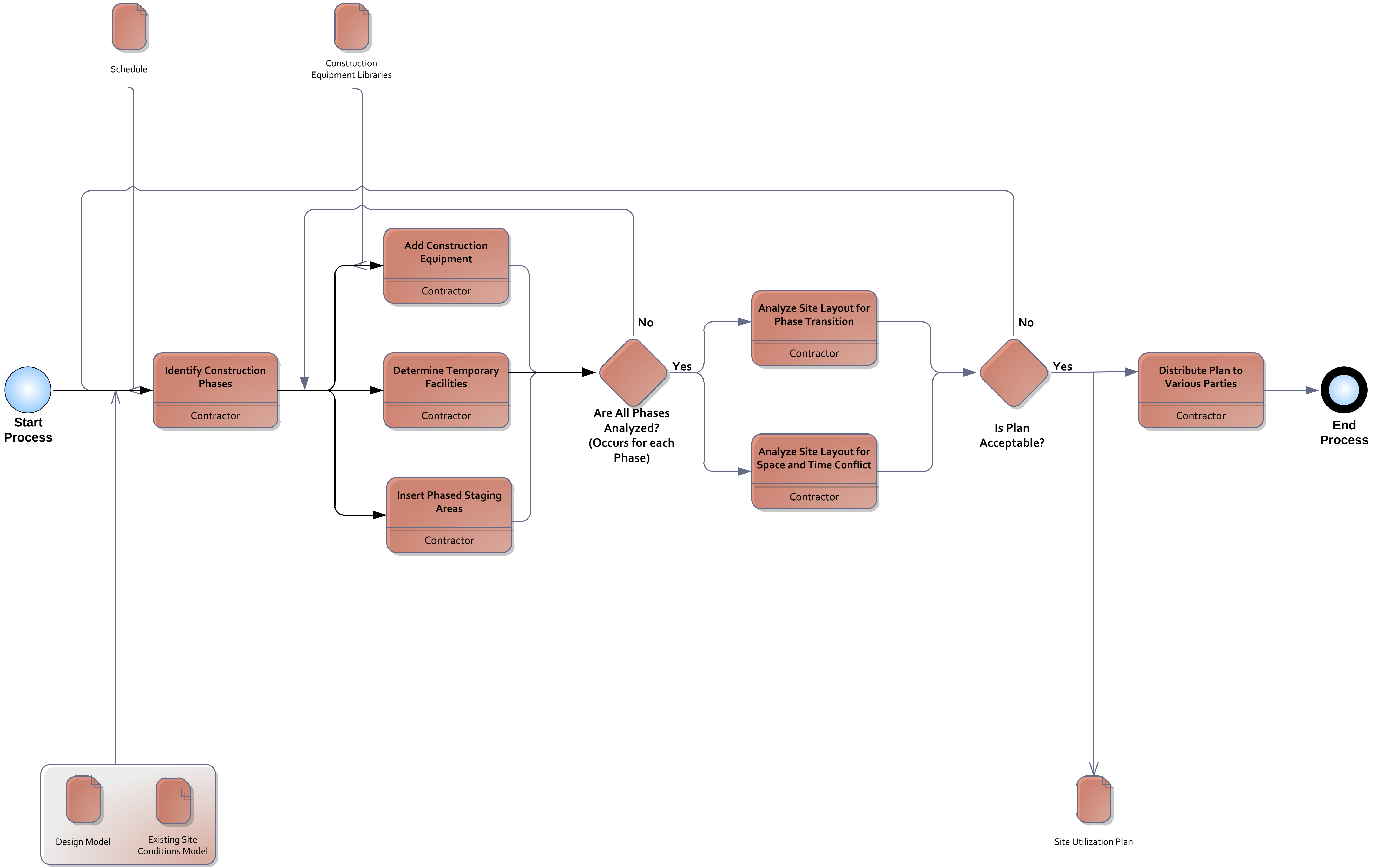
Project Title

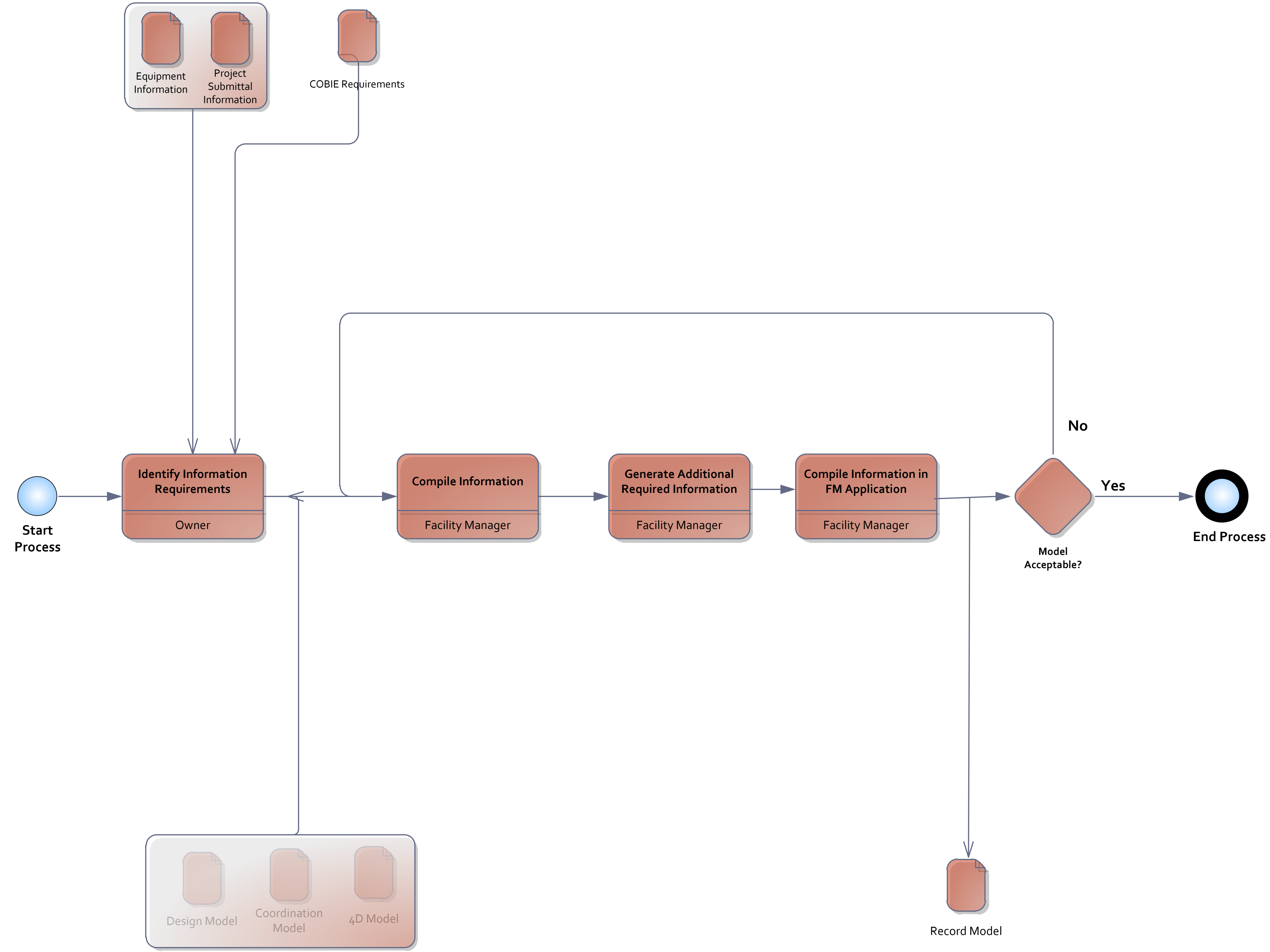
April 3, 2013 | Final Report

Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team.
http://www.engr/psu.edu/ae/cic/bimex




Start Process
Create Virtual Mockups
Architect
Perform End User Review
Architect/User
Compile Info for O&M Review
All Disciplines
Perform O&M Review
Facility Manager
Compile Model for Constructability REview
All disciplines
Perform Constructability Review
Contractor
Return to Design Authoring
Compile Design Review Feedback
All Disiciplines
No
Yes
Design Acceptable?
End Process
Design Model
Design Review Information

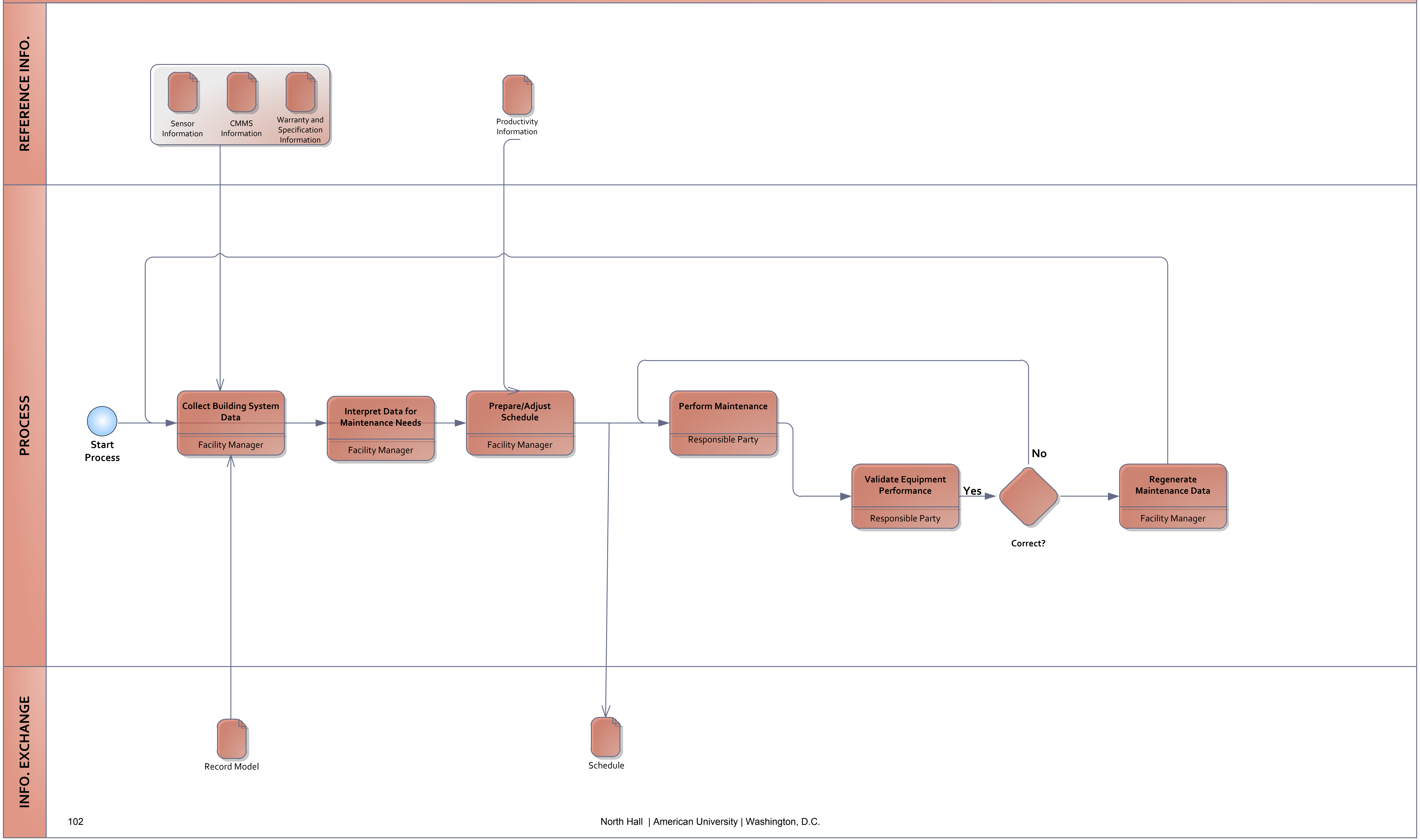

Schedule
Construction Equipment Libraries
Start Process
Identify Construction Phases
Contractor
Add Construction Equipment
Contractor
Determine Temporary Facilities
Contractor
Insert Phased Staging Areas
Contractor
No
Yes
Are All Phases Analyzed? (Occurs for each Phase)
Analyze Site Layout for Phase Transition
Contractor
Analyze Site Layout for Space and Time Conflict
Contractor
No
Yes
Is Plan Acceptable?
Distribute Plan to Various Parties
Contractor
End Process
Design Model
Existing Site Conditions Model
Site Utilization Plan


Equipment Information
Project Submittal Information
COBIE Requirements
Start Process
Identify Information Requirements
Owner
Compile Information
Facility Manager
Generate Additional Required Information
Facility Manager
Compile Information in FM Application
Facility Manager
No
Yes
Model Acceptable?
End Process
Design Model
Coordination Model
4D Model
Record Model

Level 2: Maintenance Scheduling

Project Title

Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team.
http://www.engr/psu.edu/ae/cic/bimex



Appendix F: Module Estimates

Module 1

Data Release : Year 2

Unit Cost Estimate

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
1	123661170070	Vanity Tops, center bowl, 22" x 37"	1 Carp	10	0.8	Ea.	$ 435.00	$ 27.34	$ -	$ 462.34	$ 435.00	$ 27.34	$ -	$ 462.34
1	123661170060	Vanity Tops,center bowl, 22" x 31"	1 Carp	10	0.8	Ea.	$ 375.00	$ 27.34	$ -	$ 402.34	$ 375.00	$ 27.34	$ -	$ 402.34
304	092116331000	Partition Wall, interior, standard, taped both sides,1/2" gypsum drywall	2 Carp	350	0.05	S.F.	$ 0.98	$ 1.25	$ -	$ 2.23	$ 297.92	$ 380.00	$ -	$ 677.92
18	054113103110	Metal Stud Framing	1 Carp	7	1.14	C.L.F.	$ 52.11	$ 42.11	$ -	$ 94.22	$ 937.98	$ 757.98	$ -	$ 1,695.96
1	224123203100	Shower, stall,36" x 36" square	Q1	5.5	2.91	Ea.	$ 555.00	$ 98.79	$ -	$ 653.79	$ 555.00	$ 98.79	$ -	$ 653.79
2	262726202482	Duplex receptacle, ground fault interrupting, 20 amp	1 Elec	27	0.3	Ea.	$ 39.03	$ 12.93	$ -	$ 51.96	$ 78.06	$ 25.86	$ -	$ 103.92
1	260590102120	Switch devices, resi, single pole	1 Elec	14.3	0.56	Ea.	$ 29.64	$ 24.38	$ -	$ 54.02	$ 29.64	$ 24.38	$ -	$ 54.02
4	265113502310	Fluorescent fixture, E	1 Elec	8	1	Ea.	$ 67.68	$ 43.46	$ -	$ 111.14	$ 270.72	$ 173.84	$ -	$ 444.56
1	265113502150	Fluorescent fixture, J, K1	1 Elec	8	1	Ea.	$ 34.09	$ 43.46	$ -	$ 77.55	$ 34.09	$ 43.46	$ -	$ 77.55
10	233113130100	Metal Ductwork	Q10	75	0.32	Lb.	$ 3.58	$ 10.50	$ -	$ 14.08	$ 35.80	$ 105.00	$ -	$ 140.80
18	221113231140	Pipe, copper, tubing, solder, 1/2" diameter	1 Plum	78	0.1	L.F.	$ 5.40	$ 3.86	$ -	$ 9.26	$ 97.20	$ 69.48	$ -	$ 166.68
6	221113231200	Pipe, copper, tubing, solder, 1" diameter	1 Plum	66	0.12	L.F.	$ 12.85	$ 4.57	$ -	$ 17.42	$ 77.10	$ 27.42	$ -	$ 104.52
19	221113231240	Pipe, copper, tubing, solder, 1-1/2" diameter	1 Plum	50	0.16	L.F.	$ 21.00	$ 6.01	$ -	$ 27.01	$ 399.00	$ 114.19	$ -	$ 513.19
7	221316204100	Pipe, cast iron soil,1-1/2" diameter	Q1	71	0.23	L.F.	$ 8.45	$ 7.64	$ -	$ 16.09	$ 59.15	$ 53.48	$ -	$ 112.63
33	221316204160	Pipe, cast iron soil, 4" diameter,	Q1	58	0.28	L.F.	$ 15.70	$ 9.37	$ -	$ 25.07	$ 518.10	$ 309.21	$ -	$ 827.31
Total											**$4349.39**	**$2268.44**	**$.00**	**$6617.83**

Module 2

Data Release : Year 2(

Unit Cost Estimate

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
1	224113401050	Water closet, tank type, floor mounted, one piece	Q1	5.3	1	Ea.	$ 855.00	$ 102.52	$ -	$ 957.52	$ 855.00	$ 102.52	$ -	$ 957.52
266	092116331000	Partition Wall, interior, standard, taped both sides,1/2" gypsum drywall	2 Carp	350	0.05	S.F.	$ 0.98	$ 1.25	$ -	$ 2.23	$ 260.68	$ 332.50	$ -	$ 593.18
20	054113103110	Metal Stud Framing	1 Carp	7	15.4h	C.L.F.	$ 52.11	$ 42.11	$ -	$ 94.22	$ 1,042.20	$ 842.20	$ -	$ 1,884.40
1	262726202482	Duplex receptacle, ground fault interrupting, 20 amp	1 Elec	27	0.3	Ea.	$ 39.03	$ 12.93	$ -	$ 51.96	$ 39.03	$ 12.93	$ -	$ 51.96
2	260590102120	Switch devices, resi, single pole	1 Elec	14.3	0.56	Ea.	$ 29.64	$ 24.38	$ -	$ 54.02	$ 59.28	$ 48.76	$ -	$ 108.04
1	265113500200	Fluorescent fixture, interior, acrylic lens, grid recess ceiling mounted, 2-40 W, 1' W x 4' L, incl lamps, mounting hardware and connections	1 Elec	5.7	1.4	Ea.	$ 53.35	$ 61.48	$ -	$ 114.83	$ 53.35	$ 61.48	$ -	$ 114.83
1	265113502150	Fluorescent fixture, J, K1	1 Elec	8	1	Ea.	$ 34.09	$ 43.46	$ -	$ 77.55	$ 34.09	$ 43.46	$ -	$ 77.55
9	233113130100	Metal Ductwork	Q10	75	0.32	Lb.	$ 3.58	$ 10.50	$ -	$ 14.08	$ 32.22	$ 94.50	$ -	$ 126.72
8	221113231140	Pipe, copper, tubing, solder, 1/2" diameter	1 Plum	78	0.1	L.F.	$ 5.40	$ 3.86	$ -	$ 9.26	$ 43.20	$ 30.88	$ -	$ 74.08
14	221113231180	Pipe, copper, tubing, solder, 3/4" diameter	1 Plum	74	0.11	L.F.	$ 9.55	$ 4.07	$ -	$ 13.62	$ 133.70	$ 56.98	$ -	$ 190.68
19	221113231240	Pipe, copper, tubing, solder, 1-1/2" diameter, type K, includes coupling & clevis hanger assembly 10' O.C.	1 Plum	50	0.16	L.F.	$ 21.00	$ 6.01	$ -	$ 27.01	$ 399.00	$ 114.19	$ -	$ 513.19
24	221316202120	Pipe, cast iron soil, 2" diameter	Q1	63	0.25	L.F.	$ 8.50	$ 8.62	$ -	$ 17.12	$ 204.00	$ 206.88	$ -	$ 410.88
14	221316202160	Pipe, cast iron soil, 4" diameter	Q1	55	0.29	L.F.	$ 15.45	$ 9.83	$ -	$ 25.28	$ 216.30	$ 137.62	$ -	$ 353.92
1	081213130100	Frames, steel,hollow metal, single, 7'-0" h x 3'-0" w	2 Carp	16	1	Ea.	$ 149.63	$ 30.67	$ -	$ 180.30	$ 149.63	$ 30.67	$ -	$ 180.30
Total											**$3521.68**	**$2115.57**	**$.00**	**$5637.25**

Module 3

Data Release : Year 2(Unit Cost Estimate

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
220	092116331000	Partition Wall, interior, standard, taped both sides, 1/2" gypsum drywall	2 Carp	350	0.05	S.F.	$ 0.98	$ 1.25	$ -	$ 2.23	$ 215.60	$ 275.00	$ -	$ 490.60
15	054113103110	Metal Stud Framing	1 Carp	7	1.14	C.L.F.	$ 52.11	$ 42.11	$ -	$ 94.22	$ 781.65	$ 631.65	$ -	$ 1,413.30
1	262726202482	Duplex receptacle, ground fault interrupting, 20 amp	1 Elec	27	0.3	Ea.	$ 39.03	$ 12.93	$ -	$ 51.96	$ 39.03	$ 12.93	$ -	$ 51.96
2	260590102120	Switch devices, resi, single pole	1 Elec	14.3	0.56	Ea.	$ 29.64	$ 24.38	$ -	$ 54.02	$ 59.28	$ 48.76	$ -	$ 108.04
1	265113500200	Fluorescent fixture, P1	1 Elec	5.7	1.4	Ea.	$ 53.35	$ 61.48	$ -	$ 114.83	$ 53.35	$ 61.48	$ -	$ 114.83
1	265113502150	Fluorescent fixture, J, K1	1 Elec	8	1	Ea.	$ 34.09	$ 43.46	$ -	$ 77.55	$ 34.09	$ 43.46	$ -	$ 77.55
1	081213130100	Frames, steel, hollow metal,single, 7'-0" h x 3'-0" w	2 Carp	16	1	Ea.	$ 149.63	$ 30.67	$ -	$ 180.30	$ 149.63	$ 30.67	$ -	$ 180.30
10	233113130100	Metal Ductwork	Q10	75	0.32	Lb.	$ 3.58	$ 10.50	$ -	$ 14.08	$ 35.80	$ 105.00	$ -	$ 140.80
Total											$ 1,368.43	$ 1,208.95	$ -	$ 2,577.38

Appendix G: Stick Built Estimate

Stick Built Estimate

Data Release : Year 2

Unit Cost Estimate

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
1	123661170070	Vanity Tops, center bowl, 22" x 37"	1 Carp	10	0.8	Ea.	$ 435.00	$ 27.34	$ -	$ 462.34	$ 435.00	$ 27.34	$ -	$ 462.34
1	123661170060	Vanity Tops, center bowl, 22" x 31"	1 Carp	10	0.8	Ea.	$ 375.00	$ 27.34	$ -	$ 402.34	$ 375.00	$ 27.34	$ -	$ 402.34
828	092116331000	Partition Wall, interior, standard, taped both sides, 1/2" gypsum drywall	2 Carp	350	0.05	S.F.	$ 0.98	$ 1.25	$ -	$ 2.23	$ 811.44	$ 1,035.00	$ -	$ 1,846.44
53	054113103110	Metal Stud Framing	1 Carp	7	1.14	C.L.F.	$ 52.11	$ 42.11	$ -	$ 94.22	$ 2,761.83	$ 2,231.83	$ -	$ 4,993.66
1	224123203100	Shower, stall, fi 36" x 36" square	Q1	5.5	2.91	Ea.	$ 555.00	$ 98.79	$ -	$ 653.79	$ 555.00	$ 98.79	$ -	$ 653.79
4	262726202482	Duplex receptacle, ground fault interrupting, 20 amp	1 Elec	27	0.3	Ea.	$ 39.03	$ 12.93	$ -	$ 51.96	$ 156.12	$ 51.72	$ -	$ 207.84
5	260590102120	Switch devices, resi, single pole	1 Elec	14.3	0.56	Ea.	$ 29.64	$ 24.38	$ -	$ 54.02	$ 148.20	$ 121.90	$ -	$ 270.10
2	081213130100	Frames, steel,hollow metal, single, 7'-0" h x 3'-0" w	2 Carp	16	1	Ea.	$ 149.63	$ 30.67	$ -	$ 180.30	$ 299.26	$ 61.34	$ -	$ 360.60
2	265113500200	Fluorescent fixture, P1	1 Elec	5.7	1.4	Ea.	$ 53.35	$ 61.48	$ -	$ 114.83	$ 106.70	$ 122.96	$ -	$ 229.66
5	265113502310	Fluorescent fixture, E	1 Elec	8	1	Ea.	$ 67.68	$ 43.46	$ -	$ 111.14	$ 338.40	$ 217.30	$ -	$ 555.70
2	265113502150	Fluorescent fixture, J,K1	1 Elec	8	1	Ea.	$ 34.09	$ 43.46	$ -	$ 77.55	$ 68.18	$ 86.92	$ -	$ 155.10
29	233113130100	Metal Ductwork	Q10	75	0.32	Lb.	$ 3.58	$ 10.50	$ -	$ 14.08	$ 103.82	$ 304.50	$ -	$ 408.32
26	221113231140	Pipe, copper, tubing, solder, 1/2" diameter	1 Plum	78	0.1	L.F.	$ 5.40	$ 3.86	$ -	$ 9.26	$ 140.40	$ 100.36	$ -	$ 240.76
14	221113231180	Pipe, copper, tubing, solder, 3/4" diameter	1 Plum	74	0.11	L.F.	$ 9.55	$ 4.07	$ -	$ 13.62	$ 133.70	$ 56.98	$ -	$ 190.68
6	221113231200	Pipe, copper, tubing, solder, 1" diameter	1 Plum	66	0.12	L.F.	$ 12.85	$ 4.57	$ -	$ 17.42	$ 77.10	$ 27.42	$ -	$ 104.52
38	221113231240	Pipe, copper, tubing, solder, 1-1/2" diameter, type K, includes coupling & clevis hanger assembly 10' O.C.	1 Plum	50	0.16	L.F.	$ 21.00	$ 6.01	$ -	$ 27.01	$ 798.00	$ 228.38	$ -	$ 1,026.38

7	221316204100	Pipe, cast iron soil, 1-1/2" diameter	Q1	71	0.23	L.F.	$ 8.45	$ 7.64	$ -	$ 16.09	$ 59.15	$ 53.48	$ -	$ 112.63
24	221316202120	Pipe, cast iron soil, 2" diameter	Q1	63	0.25	L.F.	$ 8.50	$ 8.62	$ -	$ 17.12	$ 204.00	$ 206.88	$ -	$ 410.88
47	221316204160	Pipe, cast iron soil, 4" diameter	Q1	58	0.28	L.F.	$ 15.70	$ 9.37	$ -	$ 25.07	$ 737.90	$ 440.39	$ -	$ 1,178.29
Total											$ 8,309.20	$ 5,500.83	$ -	$ 13,810.03

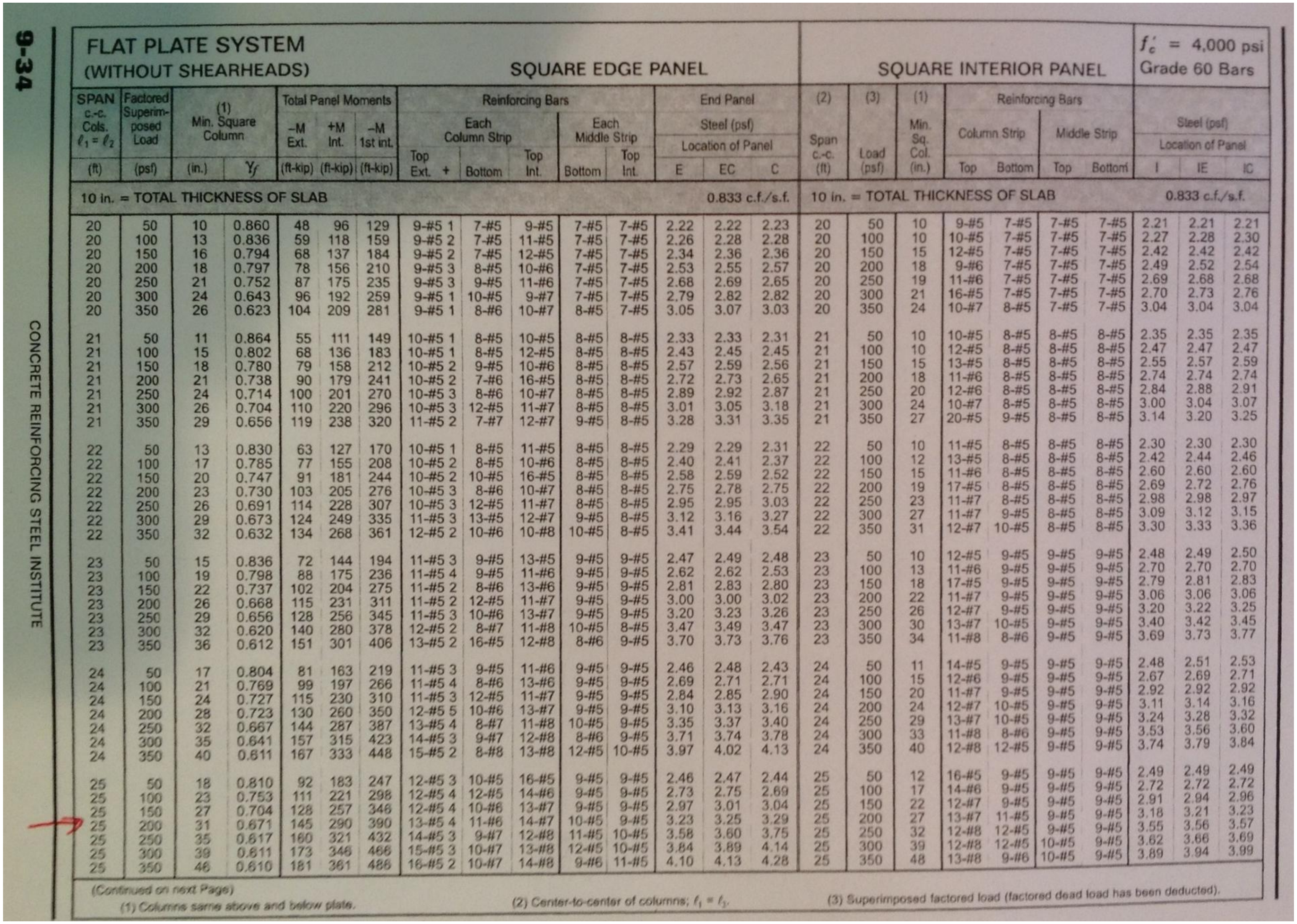
Appendix H: Post-Tensioned Slab Estimate

Post Tensioned Slab

Data Release : Year 20 Unit Cost Estimate

Quantity	Line Number	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
4	032110600400	Reinforcing Steel, in place, elevated slabs, #4 to #7, A615, grade 60,	4 Rodm	2.9	11.03	Ton	$ 1,034.25	$ 363.29	$ -	$ 1,397.54	$ 4,137.00	$ 1,453.16	$ -	$ 5,590.16
14708	031113351000	C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 1 use, includes shoring, erecting, bracing, stripping and cleaning	C2	470	0.1	S.F.	$ 3.10	$ 2.54	$ -	$ 5.64	$ 45,594.80	$ 37,358.32	$ -	$ 82,953.12
318	033105350400	Structural concrete, ready mix, regular weight, 5000 psi, includes local aggregate, sand, Portland cement and water, delivered		0	0	C.Y.	$ 141.48	$ -	$ -	$ 141.48	$ 44,990.64	$ -	$ -	$ 44,990.64
2151	032305501650	Prestressing steel, ungrouted strand, 200' span, 300 kip, post-tensioned in field	C4	1700	0.02	Lb.	$ 0.62	$ 0.59	$ 0.02	$ 1.23	$ 1,333.62	$ 1,269.09	$ 43.02	$ 2,645.73
Total											**$96056.06**	**$40080.57**	**$43.02**	**$136179.65**

Appendix I: CRSI Flat Plate System Table



9-34

FLAT PLATE SYSTEM
(WITHOUT SHEARHEADS)

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANEL

SPAN c.-c. Cols. $\ell_1 = \ell_2$	Factored Superimposed Load	(1) Min. Square Column		Total Panel Moments			Reinforcing Bars						End Panel		
				−M Ext.	+M Int.	−M 1st int.	Each Column Strip				Each Middle Strip		Steel (psf) Location of Panel		
							Top Ext.	+	Bottom	Top Int.	Bottom	Top Int.	E	EC	C
(ft)	(psf)	(in.)	γ_f	(ft-kip)	(ft-kip)	(ft-kip)									
10 in. = TOTAL THICKNESS OF SLAB															0.833 c.f./s.f.
20	50	10	0.860	48	96	129	9-#5	1	7-#5	9-#5	7-#5	7-#5	2.22	2.22	2.23
20	100	13	0.836	59	118	159	9-#5	2	7-#5	11-#5	7-#5	7-#5	2.26	2.28	2.28
20	150	16	0.794	68	137	184	9-#5	2	7-#5	12-#5	7-#5	7-#5	2.34	2.36	2.36
20	200	18	0.797	78	156	210	9-#5	3	8-#5	10-#6	7-#5	7-#5	2.53	2.55	2.57
20	250	21	0.752	87	175	235	9-#5	3	9-#5	11-#6	7-#5	7-#5	2.68	2.69	2.65
20	300	24	0.643	96	192	259	9-#5	1	10-#5	9-#7	7-#5	7-#5	2.79	2.82	2.82
20	350	26	0.623	104	209	281	9-#5	1	8-#6	10-#7	8-#5	7-#5	3.05	3.07	3.03
21	50	11	0.864	55	111	149	10-#5	1	8-#5	10-#5	8-#5	8-#5	2.33	2.33	2.31
21	100	15	0.802	68	136	183	10-#5	1	8-#5	12-#5	8-#5	8-#5	2.43	2.45	2.45
21	150	18	0.780	79	158	212	10-#5	2	9-#5	10-#6	8-#5	8-#5	2.57	2.59	2.56
21	200	21	0.738	90	179	241	10-#5	2	7-#6	16-#5	8-#5	8-#5	2.72	2.73	2.65
21	250	24	0.714	100	201	270	10-#5	3	8-#6	10-#7	8-#5	8-#5	2.89	2.92	2.87
21	300	26	0.704	110	220	296	10-#5	3	12-#5	11-#7	8-#5	8-#5	3.01	3.05	3.18
21	350	29	0.656	119	238	320	11-#5	2	7-#7	12-#7	9-#5	8-#5	3.28	3.31	3.35
22	50	13	0.830	63	127	170	10-#5	1	8-#5	11-#5	8-#5	8-#5	2.29	2.29	2.31
22	100	17	0.785	77	155	208	10-#5	2	8-#5	10-#6	8-#5	8-#5	2.40	2.41	2.37
22	150	20	0.747	91	181	244	10-#5	2	10-#5	16-#5	8-#5	8-#5	2.58	2.59	2.52
22	200	23	0.730	103	205	276	10-#5	3	8-#6	10-#7	8-#5	8-#5	2.75	2.78	2.75
22	250	26	0.691	114	228	307	10-#5	3	12-#5	11-#7	8-#5	8-#5	2.95	2.95	3.03
22	300	29	0.673	124	249	335	11-#5	3	13-#5	12-#7	9-#5	8-#5	3.12	3.16	3.27
22	350	32	0.632	134	268	361	12-#5	2	10-#6	10-#8	10-#5	8-#5	3.41	3.44	3.54
23	50	15	0.836	72	144	194	11-#5	3	9-#5	13-#5	9-#5	9-#5	2.47	2.49	2.48
23	100	19	0.798	88	175	236	11-#5	4	9-#5	11-#6	9-#5	9-#5	2.62	2.62	2.53
23	150	22	0.737	102	204	275	11-#5	2	8-#6	13-#6	9-#5	9-#5	2.81	2.83	2.80
23	200	26	0.668	115	231	311	11-#5	2	12-#5	11-#7	9-#5	9-#5	3.00	3.00	3.02
23	250	29	0.656	128	256	345	11-#5	3	10-#6	13-#7	9-#5	9-#5	3.20	3.23	3.26
23	300	32	0.620	140	280	378	12-#5	2	8-#7	11-#8	10-#5	8-#5	3.47	3.49	3.47
23	350	36	0.612	151	301	406	13-#5	2	16-#5	12-#8	8-#6	9-#5	3.70	3.73	3.76
24	50	17	0.804	81	163	219	11-#5	3	9-#5	11-#6	9-#5	9-#5	2.46	2.48	2.43
24	100	21	0.769	99	197	266	11-#5	4	8-#6	13-#6	9-#5	9-#5	2.69	2.71	2.71
24	150	24	0.727	115	230	310	11-#5	3	12-#5	11-#7	9-#5	9-#5	2.84	2.85	2.90
24	200	28	0.723	130	260	350	12-#5	5	10-#6	13-#7	9-#5	9-#5	3.10	3.13	3.16
24	250	32	0.667	144	287	387	13-#5	4	8-#7	11-#8	10-#5	9-#5	3.35	3.37	3.40
24	300	35	0.641	157	315	423	14-#5	3	9-#7	12-#8	8-#6	9-#5	3.71	3.74	3.78
24	350	40	0.611	167	333	448	15-#5	2	8-#8	13-#8	12-#5	10-#5	3.97	4.02	4.13
25	50	18	0.810	92	183	247	12-#5	3	10-#5	16-#5	9-#5	9-#5	2.46	2.47	2.44
25	100	23	0.753	111	221	298	12-#5	4	12-#5	14-#6	9-#5	9-#5	2.73	2.75	2.69
25	150	27	0.704	128	257	346	12-#5	4	10-#6	13-#7	9-#5	9-#5	2.97	3.01	3.04
25	200	31	0.671	145	290	390	13-#5	4	11-#6	14-#7	10-#5	9-#5	3.23	3.25	3.29
25	250	35	0.617	160	321	432	14-#5	3	9-#7	12-#8	11-#5	10-#5	3.58	3.60	3.75
25	300	39	0.611	173	346	466	15-#5	3	10-#7	13-#8	12-#5	10-#5	3.84	3.89	4.14
25	350	46	0.610	181	361	486	16-#5	2	10-#7	14-#8	9-#6	11-#5	4.10	4.13	4.28

SQUARE INTERIOR PANEL

(2) Span c.-c.	(3) Load	(1) Min. Sq. Col.	Reinforcing Bars				Steel (psf) Location of Panel		
			Column Strip		Middle Strip				
(ft)	(psf)	(in.)	Top	Bottom	Top	Bottom	I	IE	IC
10 in. = TOTAL THICKNESS OF SLAB									0.833 c.f./s.f.
20	50	10	9-#5	7-#5	7-#5	7-#5	2.21	2.21	2.21
20	100	10	10-#5	7-#5	7-#5	7-#5	2.27	2.28	2.30
20	150	15	12-#5	7-#5	7-#5	7-#5	2.42	2.42	2.42
20	200	18	9-#6	7-#5	7-#5	7-#5	2.49	2.52	2.54
20	250	19	11-#6	7-#5	7-#5	7-#5	2.69	2.68	2.68
20	300	21	16-#5	7-#5	7-#5	7-#5	2.70	2.73	2.76
20	350	24	10-#7	8-#5	7-#5	7-#5	3.04	3.04	3.04
21	50	10	10-#5	8-#5	8-#5	8-#5	2.35	2.35	2.35
21	100	10	12-#5	8-#5	8-#5	8-#5	2.47	2.47	2.47
21	150	15	13-#5	8-#5	8-#5	8-#5	2.55	2.57	2.59
21	200	18	11-#6	8-#5	8-#5	8-#5	2.74	2.74	2.74
21	250	20	12-#6	8-#5	8-#5	8-#5	2.84	2.88	2.91
21	300	24	10-#7	8-#5	8-#5	8-#5	3.00	3.04	3.07
21	350	27	20-#5	9-#5	8-#5	8-#5	3.14	3.20	3.25
22	50	10	11-#5	8-#5	8-#5	8-#5	2.30	2.30	2.30
22	100	12	13-#5	8-#5	8-#5	8-#5	2.42	2.44	2.46
22	150	15	11-#6	8-#5	8-#5	8-#5	2.60	2.60	2.60
22	200	19	17-#5	8-#5	8-#5	8-#5	2.69	2.72	2.76
22	250	23	11-#7	8-#5	8-#5	8-#5	2.98	2.98	2.97
22	300	27	11-#7	9-#5	8-#5	8-#5	3.09	3.12	3.15
22	350	31	12-#7	10-#5	8-#5	8-#5	3.30	3.33	3.36
23	50	10	12-#5	9-#5	9-#5	9-#5	2.48	2.49	2.50
23	100	13	11-#6	9-#5	9-#5	9-#5	2.70	2.70	2.70
23	150	18	17-#5	9-#5	9-#5	9-#5	2.79	2.81	2.83
23	200	22	11-#7	9-#5	9-#5	9-#5	3.06	3.06	3.06
23	250	26	12-#7	9-#5	9-#5	9-#5	3.20	3.22	3.25
23	300	30	13-#7	10-#5	9-#5	9-#5	3.40	3.42	3.45
23	350	34	11-#8	8-#6	9-#5	9-#5	3.69	3.73	3.77
24	50	11	14-#5	9-#5	9-#5	9-#5	2.48	2.51	2.53
24	100	15	12-#6	9-#5	9-#5	9-#5	2.67	2.69	2.71
24	150	20	11-#7	9-#5	9-#5	9-#5	2.92	2.92	2.92
24	200	24	12-#7	10-#5	9-#5	9-#5	3.11	3.14	3.16
24	250	29	13-#7	10-#5	9-#5	9-#5	3.24	3.28	3.32
24	300	33	11-#8	8-#6	9-#5	9-#5	3.53	3.56	3.60
24	350	40	12-#8	12-#5	9-#5	9-#5	3.74	3.79	3.84
25	50	12	16-#5	9-#5	9-#5	9-#5	2.49	2.49	2.49
25	100	17	14-#6	9-#5	9-#5	9-#5	2.72	2.72	2.72
25	150	22	12-#7	9-#5	9-#5	9-#5	2.91	2.94	2.96
25	200	27	13-#7	11-#5	9-#5	9-#5	3.18	3.21	3.23
25	250	32	12-#8	12-#5	9-#5	9-#5	3.55	3.56	3.57
25	300	39	12-#8	12-#5	10-#5	9-#5	3.62	3.66	3.69
25	350	48	13-#8	9-#6	10-#5	9-#5	3.89	3.94	3.99

(Continued on next Page)

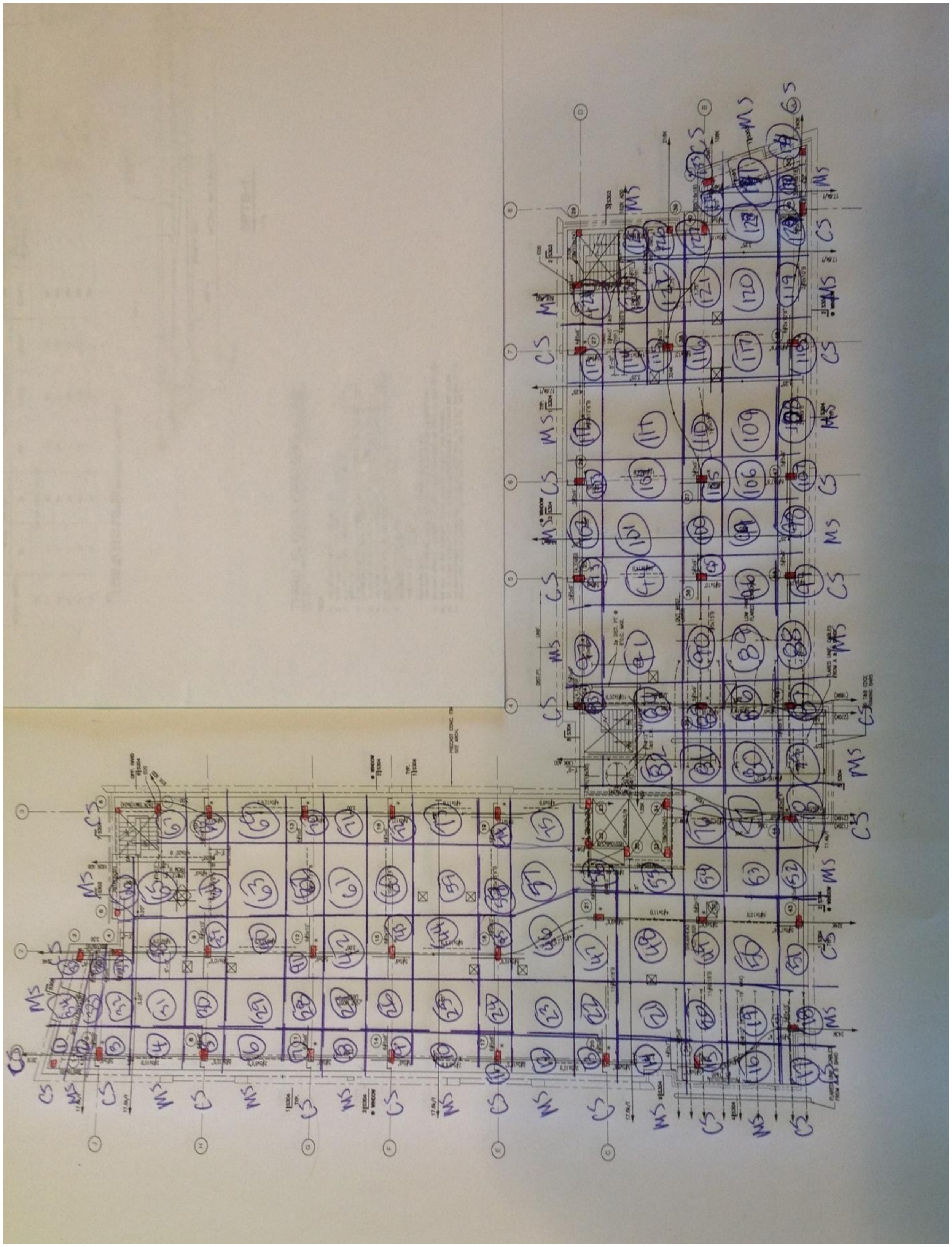
(1) Columns same above and below plate.

(2) Center-to-center of columns; $\ell_1 = \ell_2$.

(3) Superimposed factored load (factored dead load has been deducted).

CONCRETE REINFORCING STEEL INSTITUTE

Appendix J: Slab Column/Middle Strip Floor Plan and Reinforcing

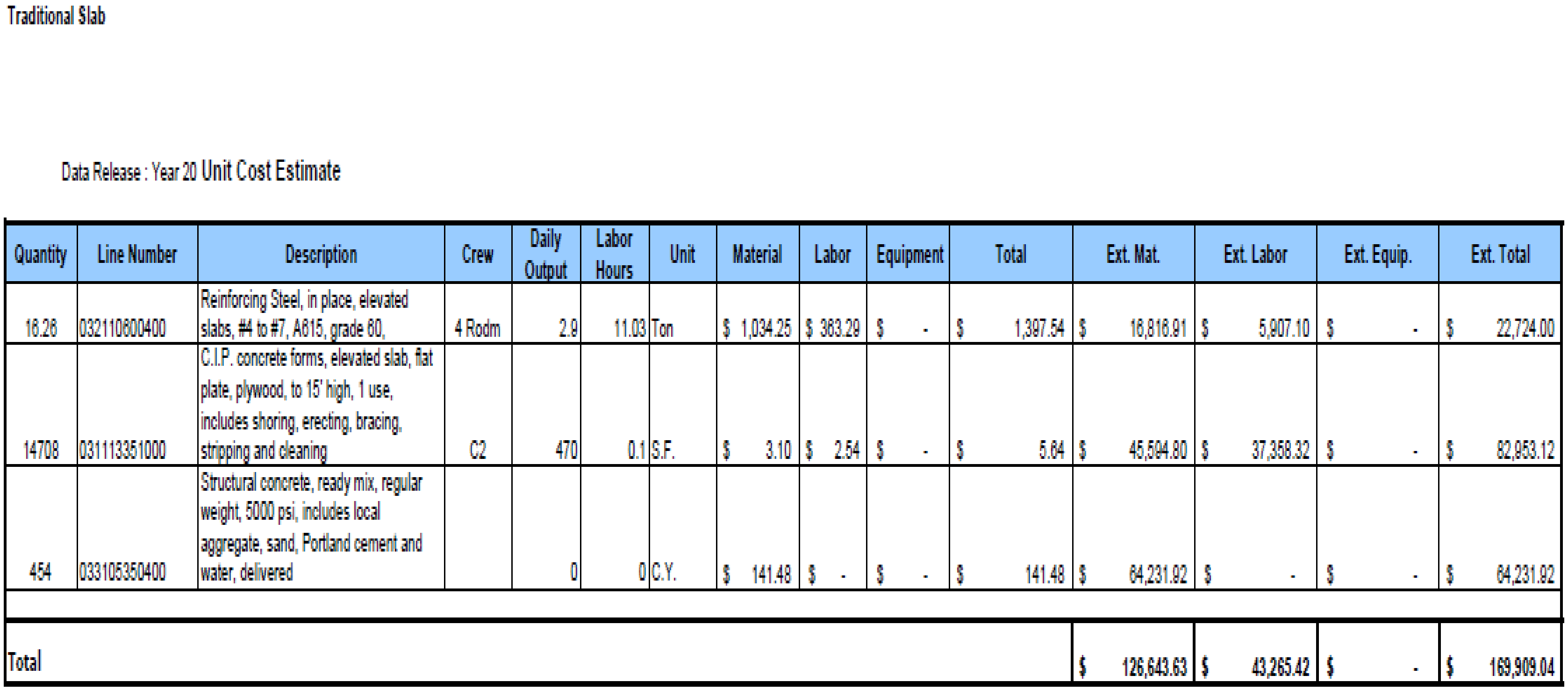

CS
MS

Block No.	East-West			North-South		
	Length (ft)	Top Bars	Bottom Bars	Length (ft)	Top Bars	Bottom Bars
1	6	7-#5		2.5	7-#5	
2	6		11-#6	3		5-#6
3	6	13 - #5		8.5	7-#5	
4	6		11-#6	12		5-#6
5	6	13 - #5		12	7-#5	
6	6		11-#6	12		5-#6
7	6	13 - #5		12	7-#5	
8	6		11-#6	12		5-#6
9	6	13 - #5		12	7-#5	
10	6		11-#6	12		5-#6
11	6	13 - #5		12	7-#5	
12	6		11-#6	12		5-#6
13	6	13 - #5		12	7-#5	
14	6		11-#6	12		5-#6
15	6	13 - #5		12	7-#5	
16	6		11-#6	12		5-#6
17	6	8- # 5		6	7-#5	
18	9		6-#6	6		10-#6
19	9	9-#5		12	9-#5	
20	9		11-#5	12		11-#5
21	9	9-#5		12	9-#5	
22	9		11-#5	12		11-#5
23	9	9-#5		12	9-#5	
24	9		11-#5	12		11-#5
25	9	9-#5		12	9-#5	
26	9		11-#5	12		11-#5
27	9	9-#5		12	9-#5	
28	9		11-#5	12		11-#5
29	9	9-#5		12	9-#5	
30	9		11-#5	12		11-#5
31	9	9-#5		12	9-#5	
32	9		11-#5	8.5		11-#5
33	9	9-#5		3	9-#5	
34	9		6-#6	2.5		11-#6
35	7.5	7-#5		2.5	7-#5	
36	7.5		11-#6	3		6-#6
37	13	7-#5		6	7-#5	
38	13		9-#5	12		9-#5
39	13	13-#7		12	13-#7	
40	13		11-#5	12		11-#5
41	13	13-#7		12	13-#7	
42	13		11-#5	12		11-#5
43	13	13-#7		12	13-#7	
44	13		11-#5	12		11-#5

45	13	13-#7		12	13-#7	
46	15		11-#5	12		11-#5
47	15	13-#7		12	13-#7	
48	15		11-#5	12		11-#5
49	15	13-#7		12	13-#7	
50	15		11-#5	12		11-#5
51	15	7-#5		6	13-#5	
52	13		6-#6	12		10-#6
53	13	9-#5		12	9-#5	
54	13		11-#5	12		11-#5
55	13	9-#5		12	9-#5	
56	13		11-#5	12		11-#5
57	13	9-#5		12	9-#5	
58	13		11-#5	12		11-#5
59	13	9-#5		12	9-#5	
60	13		11-#5	12		11-#5
61	13	9-#5		12	9-#5	
62	13		11-#5	12		11-#5
63	13	9-#5		12	9-#5	
64	13		11-#5	12		11-#5
65	13		11-#6	12		6-#6
66	13	6-#6		3	11-#6	
67	8.5		6-#6	6		6-#6
68	8.5	13-#5		12	7-#5	
69	8.5		11-#6	12		6-#6
70	8.5	13-#5		12	7-#5	
71	8.5		11-#6	12		6-#6
72	8.5	13-#5		12	7-#5	
73	8.5		11-#6	12		6-#6
74	8.5	13-#5		12	7-#5	
75	8.5		11-#6	12		6-#6
76	9.5	13-#7		12	13-#7	
77	8.5		11-#5	12		11-#5
78	9.5	7-#5		6	13-#5	
79	10		6-#6	6		11-#6
80	10	9-#5		12	9-#5	
81	10		11-#5	12		11-#5
82	10	9-#5		12	9-#5	
83	6	7-#5		6	7-#5	
84	11		11-#5	12		11-#5
85	11	13-#7		12	13-#7	
86	11		11-#5	12		11-#5
87	11	7-#5		6	13-#5	
88	12		6-#6	6		11-#6
89	12	9-#5		12	9-#5	
90	12		11-#5	12		11-#5
91	12	9-#5		14	9-#5	

92	12		6-#6	6		11-#6
93	10.5	7-#5		6	13-#5	
94	10.5		11-#5	12		11-#5
95	10.5	13-#7		12	13-#7	
96	10.5		11-#5	14		11-#5
97	10.5	7-#5		6	13-#5	
98	9		6-#6	6		10-#6
99	9	9-#5		12	9-#5	
100	9		11-#5	12		11-#5
101	9	9-#5		14	9-#5	
102	9		6-#6	6		11-#6
103	10.5	7-#5		6	13-#5	
104	10.5		11-#5	12		11-#5
105	10.5	13-#7		12	13-#7	
106	10.5		11-#5	14		11-#5
107	10.5	7-#5		6	13-#5	
108	12		6-#6	6		10-#6
109	12	9-#5		12	9-#5	
110	12		11-#5	12		11-#5
111	12	9-#5		14	9-#5	
112	12		6-#6	6		11-#6
113	11	7-#5		6	13-#5	
114	11		11-#5	8		11-#5
115	11	13-#7		8	13-#7	
116	11	13-#7		12	13-#7	
117	11		11-#5	12		11-#5
118	11	7-#5		6	13-#5	
119	10		6-#6	6		11-#6
120	10		11-#5	12		11-#5
121	10	13-#7		12	13-#7	
122	10	13-#7		8	13-#7	
123	6		11-#5	8		11-#5
124	6		6-#6	6		6-#6
125	5		6-#6	4		6-#6
126	5	13-#5		8	7-#5	
127	7	13-#5		12	13-#5	
128	7		11-#5	12		11-#5
129	7	7-#5		6	13-#5	
130	4		6-#6	6		11-#6
131	4		11-#6	12		6-#6
132	4		6-#6	6		11#6
133	2	7-#5		6	7-#5	
134	2	7-#5		6	7-#5	

Appendix K: Traditional Slab Estimate



Traditional Slab

Data Release : Year 20 Unit Cost Estimate

Quantity	Line Number	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
16.26	032110600400	Reinforcing Steel, in place, elevated slabs, #4 to #7, A615, grade 60,	4 Rodm	2.9	11.03	Ton	$ 1,034.25	$ 363.29	$ -	$ 1,397.54	$ 16,816.91	$ 5,907.10	$ -	$ 22,724.00
14708	031113351000	C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 1 use, includes shoring, erecting, bracing, stripping and cleaning	C2	470	0.1	S.F.	$ 3.10	$ 2.54	$ -	$ 5.64	$ 45,584.80	$ 37,358.32	$ -	$ 82,953.12
454	033105350400	Structural concrete, ready mix, regular weight, 5000 psi, includes local aggregate, sand, Portland cement and water, delivered		0	0	C.Y.	$ 141.48	$ -	$ -	$ 141.48	$ 64,231.92	$ -	$ -	$ 64,231.92
Total											$ 126,643.63	$ 43,265.42	$ -	$ 169,909.04

Executive Summary

After American University's 2011 Campus Plan was approved the by District of Columbia Zoning Commission on March 8, 2012 Grunley Construction Company was awarded the construction contract on April 23, 2012 for American University's newest dormitory, North Hall. North Hall is an eight story, tracked for LEED Gold upon completion, dormitory building that is located on American University's Main Campus in downtown Washington, D.C. The 122,200 square foot building will house 358 undergraduate students in 94 suite style dorm rooms consisting of six bed, four bed and, RA units (1 bed). Grunley bid North Hall with a Guaranteed Maximum Price (GMP) of just under $ 29 Million. North Hall is scheduled to house students for the start of the Fall 2013 semester.

Analysis 1: Modularization of Bathrooms

North Hall has both an extremely tight and congested site and well as a very tight schedule. Modularization will more some of the work to an offsite facility and will allow the bathroom units to be constructed before they would be needed onsite and with a less expensive labor force. Modularization allows for 13.2 weeks in schedule savings as well as a cost savings of $92,315.52.

Analysis 2: GPS Tracking of Precast Panels

The installation of the precast panels is confined to a small window in the schedule and the site entrance for deliveries is extremely congested. With a GPS tag tracking system the precast panel can be tracked from the time they leave the factory until they are installed. The tracking will not stop at installation, the same GPS tags will be used to track the testing required for the façade panels. The cost of the tacking system will be roughly $112,785. The schedule did not see any savings.

Analysis 3: Solar Panel Upgrade, Electrical Breadth

North Hall will have two arrays of solar panels when construction is complete. The current design only has the capability to heat domestic hot water. By upgrading the solar panels to a hybrid/cogeneration solar panel system the capability to generate electricity will be added. Upgrading the solar panel system, Analysis 3, is recommended to be implemented on North Hall. The solar panel system will be upgrade from the current solar hot water panel system to a hybrid (cogeneration) system that will have both solar hot water and electrical generation. With the upgrade of the panel system approximately $18,600 a year could be saved in utility costs.

Analysis 4: Traditional Reinforced Cast in Place Floor Slabs, Structural Breadth

Currently floors 3 through 7 are post-tensioned floor slabs. This post-tensioning adds extra cost that can be value engineered to a traditional reinforced cast-in-place concrete slab. Removing the post tensioned cable will cause the slabs to be thickened from 7 inches to 10 inches. The reinforcing will also need to be increased. These required increases in the material need cause the cost to increase by $33,729.40 per slab and $168,647 for all five slabs. The schedule was not shortened by eliminating the post-tensioning due to the increase amount of reinforcement that needs to be placed.

need cause the cost to increase by $33,729.40 per slab and $168,647 for all five slabs. The schedule was not shortened by eliminating the post-tensioning due to the increase amount of reinforcement that needs to be placed. Since there is only an increase in the cost from removing the post tensioned cables it is not recommended that the slabs be changed from the current design.