Westinghouse Electric Company
Nuclear Power Engineering Campus

Final Report

Senior Thesis

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Construction Management

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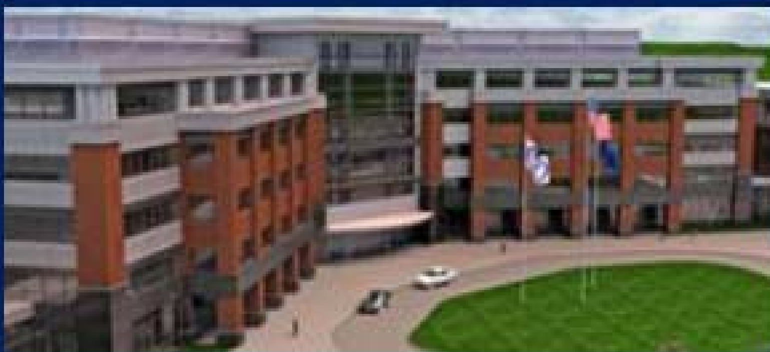
Westinghouse Electric Company Nuclear Power Engineering Headquarters Campus



The Westinghouse Headquarters campus consists of three buildings which primarily serve as office space for over 4,000 engineers. Building One, the main building, in addition to offices consists of meeting spaces, conference rooms, a fitness center, a cafeteria and a data center. Buildings two and three are primarily office space.

General Building Data

Location: Cranberry Township, PA
Occupant: Westinghouse Electric Co.
Building Occupancy Type: Office
Size: 844,595 sq. ft.
No. of Stories: 5 above grade/ 1 below
Construction Dates: Feb2008-May2010
Overall Project Cost: $240,000,000
Delivery Method: Design-Bid-Build

Project Team:

- Owner– Wells Reit II
- GC/CM– Turner Construction Co.
- Architect– IKM Incorporated
- Engineer– LLI Engineering

Structural

The structural system of the building is primarily a steel framing system. Typical sizes of members include:

- Columns- W14x120
- Girders- W24x55
- Beams- W18x55

The building is supported by a caisson foundation system. The caissons were placed anywhere from 12 to 20 feet deep and vary in size from 36 to 84 inches.

Mechanical

The mechanical system of the building consists of four air handling units (AHUs) and 3 air conditioning units (ACUs). Together these units deliver almost 300,000 CFM. The air is circulated through the spaces using fan powered boxes and distributed to variable air volume boxes.

Lighting/Electrical

The main electrical supply enters the building and runs to the main electrical room located in the basement at 480/277 volt, 3 phase, 4 wires.
The lighting for the primary office space consists of 1x4 florescent fixtures.

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EXECUTIVE SUMMARY

This purpose of this document is to study of the Westinghouse Electric Company Nuclear Power Headquarters Campus and the construction methods used to complete the project. Located in Cranberry Township, Pennsylvania, the Westinghouse Campus consists of three buildings. This senior thesis focuses on Building One of the campus. Building One is the largest of the three buildings and consists of office space, conference rooms, a data center, and a cafeteria among others. This report provides more background on the campus including preconstruction, architecture, and construction information. Following the background information, three in-depth analyses were performed. These analyses focused on energy and the environment, the concrete slab systems, and the implementation of Building Information Modeling. All of these analyses were done with specific goals in mind, but all of them were done in an attempt to add value to the project.

One of the leading issues confronting the construction industry today is the "green" movement. Owners are demanding more environmentally friendly and energy efficient buildings. Because of this the first analysis explores the finishes within Building One of the Westinghouse Headquarters Campus. These items were checked for their compliance with LEED standards as set forth by the U.S. Green Building Council. In additions, the performance of the windows was investigated. It was determined that a large amount of energy could be saved by implementing PPG Solarban 80 windows instead of typical double pane, tinted window. This energy savings also could affect the mechanical system by reducing the load on the building. The cost to run the mechanical system would also decrease.

The second analysis focused on the concrete slab-on-decks in Building One. The pouring of these slabs lied on the critical path of the construction schedule. The purpose of this analysis was to explore the possibility of implementing a precast concrete deck system in an attempt to reduce the current schedule and possibly save money. The analysis looks at using Nitterhouse Concrete Products to fabricate double tees, ship them to the site, and erect the double tee members using a crane. It was found that the schedule could be reduced by 58 days and a cost savings of approximately $1.6 million could have been seen. Implementing this system had an effect on the structural system. These ramifications were investigated and it was determined a larger beam size would need to be used.

The final analysis involved another leading issue facing the construction industry: implementation of Building Information Modeling (BIM). BIM was not utilized due to a fast track approach to construction. The assigned staff to the project was not familiar or comfortable with its use; therefore BIM was viewed as an obstacle to successful completion instead of an effective tool. This analysis explores the advantages to using BIM. Also, a mechanical room of Building One was modeled and clash detection software was used. Clashes were detected between the plumbing and mechanical systems and the plumbing and structural systems. The potential savings from detecting the clashes are difficult to quantify. Also difficult to determine is the overall cost and schedule affects of using BIM. A discussion of these points is also included.

INTRODUCTION

Wells Reit II, a development company and building owner, is constructing a campus for Westinghouse Electric Company who will occupy the building on a 15 year lease. Westinghouse Electric Company was growing and unable to hold their employees in their current offices. The campus will be Westinghouse's nuclear power engineering headquarters. The 83 acre campus located in Cranberry Township, Pennsylvania will become the new office location for over 4,000 engineers.

The campus consists of three buildings. Building One is the largest of the three at approximately 460,000 square feet. In addition to office space, Building One consists of a fitness center, data center, kitchen, and a cafeteria. Buildings Two and Three are smaller at approximately 230,000 square feet and primarily hold just office space. Detailed data was only available for Building One. Therefore, this final report and thesis will primarily be an analysis of Building One and the construction thereof.

Turner Construction was awarded the project and began work in February 2008. The project is being constructed in three phases; one phase for each of the three buildings. Building One was completed in May 2009 and is currently occupied while construction is continuing on Buildings Two and Three. The campus should be completed in its entirety by May 2010.

PROJECT OVERVIEW

CLIENT INFORMATION

"We pride ourselves on being the landlord of choice to some of the world's greatest companies."

--Wells REIT II

Although Westinghouse Electric Company is the occupant of the headquarters campus, they are not the owner. The 82 acre site was purchased by Wells REIT II. Wells REIT II is a real estate investment trust which specializes in office properties. They own over 61 buildings throughout the United Sates worth over $3 billion. Like the Cranberry Woods property, 98% of their properties are leased. Following the completion of the project, Westinghouse will occupy the property under a 15-year lease.

Because the property is a build-to-suit development, Wells REIT is not the only client to Turner Construction Company. The needs of Westinghouse must also be met. Westinghouse Electric Company is one of the world's top nuclear power companies. They supplied the world's first pressurized water reactor in 1957 in Shippingport, PA. It was very important to the state of Pennsylvania that Westinghouse stayed in the state. With the employment of over 4,000 of the world's top nuclear engineers, Westinghouse will be providing a boost to the economy of the Pittsburgh region.

The decision Wells REIT II bought the property was due to the need of Westinghouse to grow. With little room to expand, the Cranberry area not only provided room in the present, but sufficient space for continual growth. Due to the reputation of both Wells REIT and Westinghouse, it is important the campus be constructed with the upmost quality. Also, it was designed to be LEED-certified, again to enhance the reputations of the associated companies.

The building was to be completed in two phases. With the hiring of many new engineers and the need for a place to hold them, Building One was completed in May 2009. Buildings Two and Three are to be completed and ready for more engineers in May 2010.

PROJECT DELIVERY SYSTEM

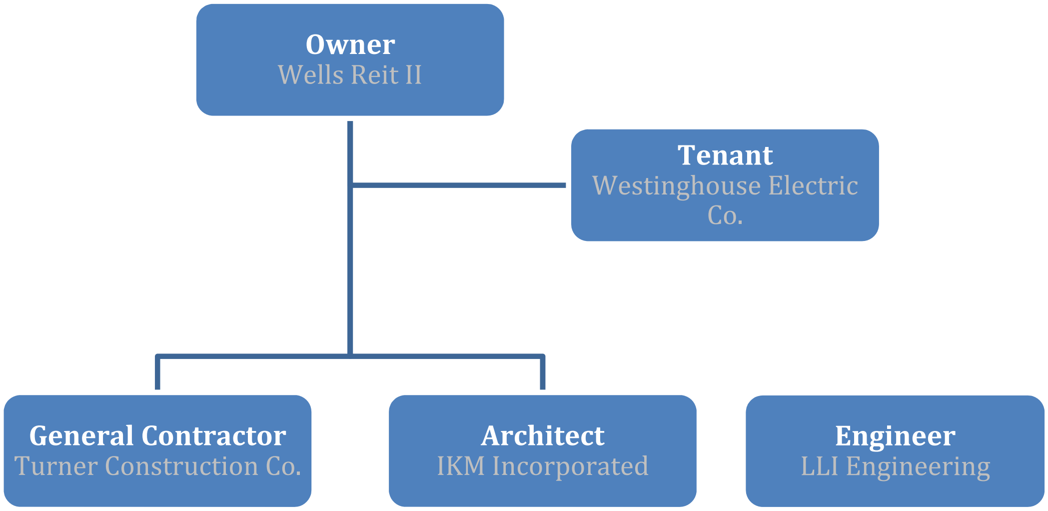


Figure 1: Organization chart of the project team and delivery method

Above is an organization chart outlining the project delivery system for the Westinghouse campus which will be a design-bid-build project. Westinghouse Electric Company is holding a 15 year lease with Wells Reit II, the owner. It is Wells Reit II which holds contracts with both the general contractor (Turner Construction Company) and the architect (IKM Incorporated).

Wells Reit II holds an AIA Owner/Architect agreement with LLI/IKM. IKM Incorporated (an architect) and LLI Engineering (general engineering services including structural, mechanical, electrical, and fire protection systems) hold a joint venture contract for the design of the Westinghouse campus.

There are three contracts held between Wells Reit II and Turner Construction, all of which are guaranteed maximum price (GMP) contracts. Because the three buildings on the campus are to be constructed in three phases, it was decided to hold separate contracts for each. A GMP was chosen due to the incomplete design. The design which was bid on was merely the core and shell of the buildings. A complete design was to be coordinated with the needs of Westinghouse Electric Co. and performed later. A GMP contract type allows for the potential of change orders which would most likely occur due to the tenant's improvements.

STAFFING PLAN

A true staffing plan was not able to be obtained from Turner Construction Company. Below you will find a typical staffing plan which was developed through familiarity with the project and past Turner Construction projects. The team is primarily on-site with the exception of the project executive. On-site the project engineers and secretary are primarily in the office, while the field superintendant, safety manager, and field engineer are in the field. The project manager will usually split his time between the field and office.

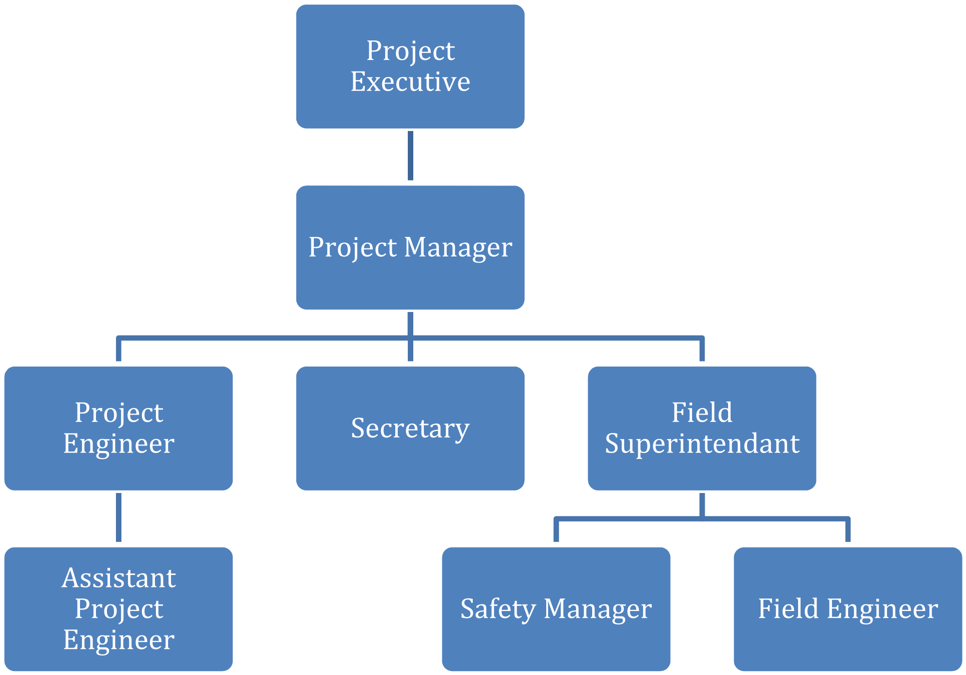


Figure 2: Typical Turner staffing plan

DESIGN AND CONSTRUCTION OVERVIEW

BUILDING SYSTEMS SUMMARY

Yes	No	Work Scope
	X	Demolition Required
X		Structural Steel Frame
X		Cast in Place Concrete
	X	Precast Concrete
X		Mechanical System
X		Electrical System
X		Masonry
X		Curtain Wall
X		Support of Excavation

Structural Steel Frame:

The structural system of the buildings on the Westinghouse Campus is a primarily a steel framing system. The columns are typically spliced in two places with typical sizes of W14x211, W14x120, and W14x11 as you move from the basement to the roof. The steel girders are typically W24x55 with W18x55 beams creating a bay size of 8' x 24'. On top of the beams is a 2", 22 gauge composite deck .

Cast in Place Concrete:

- 5" slab on grade in basements
- 2 ½" lightweight concrete slabs on upper floors
- The entire building is supported by a caisson foundation system. The caissons were placed anywhere from 12 to 20 feet deep and vary in size from 36 to 84 inches.

Mechanical System:

The mechanical system of the building consists of four air handling units (AHUs) located in the mechanical penthouse and 3 air conditioning units (ACUs) located in the basement. Together these units deliver almost 300,000 CFM. The ACUs are used to cool the mechanical and electrical spaces in the basement, whereas the AHUs are used to cool the spaces on the occupied floors (1 through 5). The air is circulated through the space using fan powered boxes and distributed to variable air volume boxes. These boxes control the amount of air to actually enter the space depending on user controlled thermostats in each zone.

Electrical System:

- 480Y/277V, 3 phase, 4 wire main supply
- Main electrical room located in the basement
- Two 3,000 amp main distribution switchgears
- Two 1,500 kVA transformers

Masonry/Curtain Wall:

The exterior of the building is a combination of an aluminum curtain wall system, aluminum windows, and polished concrete block.

Support of Excavation:

Excavation was necessary with each building having a basement, however no information was provided on how the excavation was supported.

LOCAL CONDITIONS

The Westinghouse Headquarters Campus is located 20 miles north of Pittsburgh in Cranberry Township, PA. The campus is conveniently located off of both Interstate-79 and the Pennsylvania Turnpike (Interstate-76). The campus is now served by Cranberry Woods Drive which extends off of Route 228.

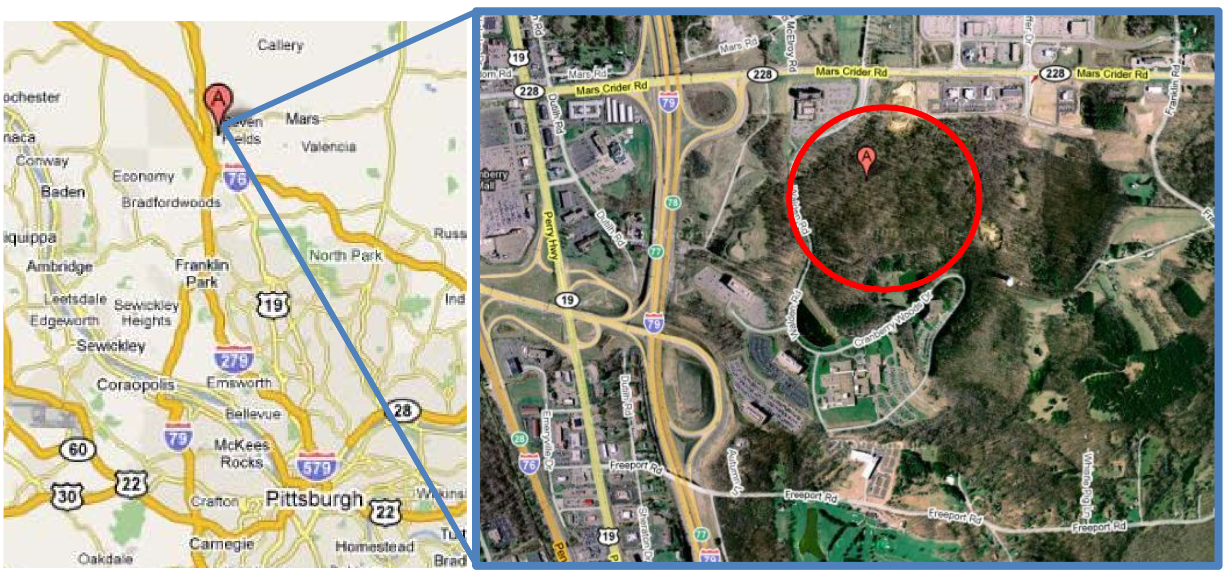


Figure 3: Location of project and image of the site

Historically the Pittsburgh area has been known for the production of steel. Although the amount of steel produced in the area has decreased steel is still the material of choice.

Due to the somewhat isolated site location, logistics were not much of an issue. There was space available for not only Turner Construction to have on-site office trailers, but also for many of the subcontractors to as well. These trailers were located in the rear of the building. On-site parking for the workers was also provided in the rear of the building.

A soil survey report was created using the United States Department of Agriculture's (USDA) Web Soil Survey Tool. The majority of the site is covered with Brinkerton silt loam at a three to eight percent slope. A typical profile would be:

- Silt loam: 0 to 8 inches
- Silty clay loam: 8 to 21 inches
- Silt Loam: 21to 42 inches
- Channery silt loam: 42 to 65 inches

SITE PLAN OF EXISTING CONDITIONS

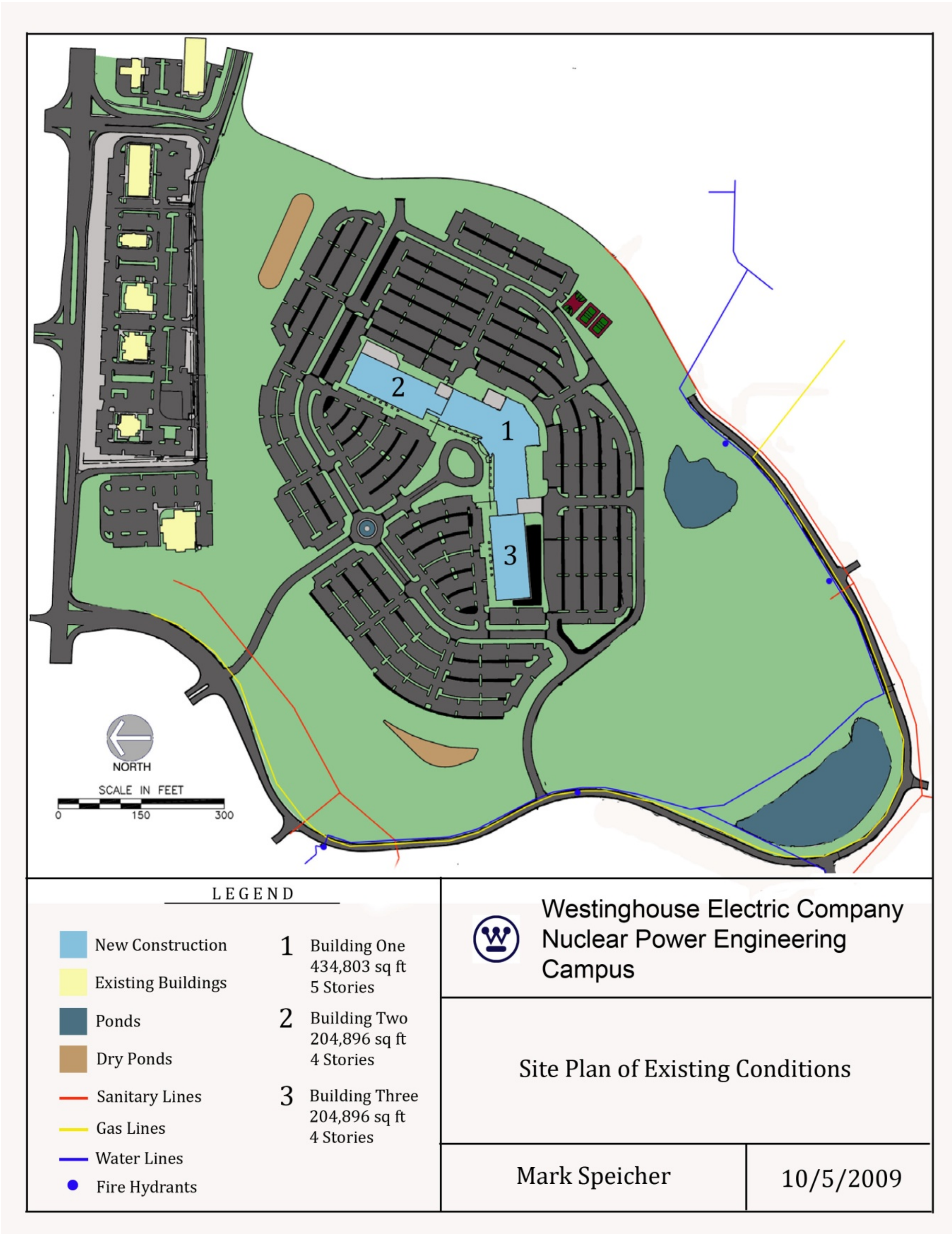


Figure 4: Site plan of the existing conditions

SITE LAYOUT PLANNING

A full version of the site plan can be found in Appendix B.

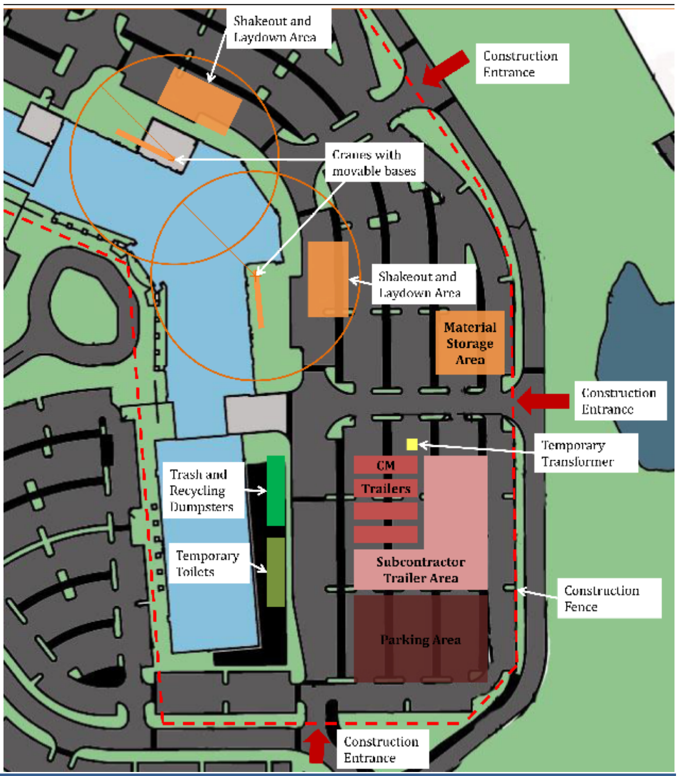


Figure 5: Site layout planning for the superstructure phase

Superstructure Phase:

The superstructure phase of the project primarily consisted of two crawler cranes for the erection of steel. As discussed above, Crane One will erect steel on the center and west portions of the building, while Crane Two will erect steel on the East side. Shakeout and lay-down areas were placed to provide easy access for both the delivery trucks and the cranes.

With the access roads being completed, there are easy access points throughout the site. This allows for ease of delivery of materials. In addition, the trash and recycling can be easily removed. Also the site of the parking lot provided a good location for construction trailers and a parking area intended for the workers.

The entire site is surrounded by a fence with gates located at each construction entrance. The fence includes the parking in the rear so these areas could be used. However the fence omits the parking area in the front. This is done so as Building One is occupied in later phases, parking will be available to Westinghouse employees.

PROJECT LOGISTICS

MILESTONE SCHEDULE

The design was completed when Turner Construction Company was awarded the project. Turner bid the project as separate Guaranteed Maximum Price contracts for each of the three buildings. Only the schedule for Building One was supplied by Turner. Therefore, the focus will be on Building One, the main building. Turner began construction on this building on February 11, 2008. At this time mobilization began on the caissons and the foundations as well as excavation for access roads and ramps.

The first four months was spent working on the substructure. During this time the caissons, foundation walls foundation waterproofing, underground utilities, and slab on grade were begun. Construction on the superstructure did not begin until June 4th with the start of structural steel, process which was not completed for five months on November 4th. Other tasks were also being performed during this time. The slab-on-deck, exterior framing, MEP rough-in, and the roof are all examples of activities which were being performed while the structural steel was not yet completed.

When Turner was awarded the project, they only provided a bid for the core and shell of the building. The interior work was to be designed as per the tenant's request, with the tenant being Westinghouse Electric Company. Work on the Tenant's Improvements began in October of 2008. Substantial completion of the core and shell occurred in March of 2009; however, the Tenant work was not completed until almost two months later on May 6, 2009. At this time, Building One was ready to be occupied.

A summary of the schedule can be found on the next page. A copy of the Microsoft Project file in which the summary was taken can be found in Appendix C.

No.	Activity	Duration	Start	Finish
1	Start Construction	0 days	2/11/2008	2/11/2008
2	Mobilization	0 days	2/11/2008	2/11/2008
3	Footer Excavation	30 days	2/18/2008	3/28/2008
4	Caissons	15 days	2/18/2008	3/7/2008
5	Foundation Walls	80 days	3/17/2008	7/4/2008
6	Underground Utilities	35 days	3/31/2008	5/16/2008
7	Slab on Grade	114 days	4/28/2008	10/2/2008
8	Foundation Waterproofing	114 days	5/8/2008	10/14/2008
9	Structural Steel Start	0 days	6/4/2008	6/4/2008
10	Slab on Deck	90 days	7/16/2008	11/18/2008
11	Exterior Framing	75 days	8/20/2008	12/2/2008
12	MEP Rough In	135 days	8/21/2008	2/25/2009
13	Start Roof	0 days	8/21/2008	8/21/2008
14	Metal Panels	75 days	9/17/2008	12/30/2008
15	Glass and Glazing	85 days	9/17/2008	1/13/2009
16	Start Tenant Improvement Work	0 days	10/1/2008	10/1/2008
17	Elevator Install	65 days	10/6/2008	1/2/2009
18	Structural Steel Erection Complete	0 days	11/4/2008	11/4/2008
19	MEP/FP Finishes	90 days	11/3/2008	3/6/2009
20	Roof Complete	0 days	12/2/2008	12/2/2008
21	Substantially Complete Core and Shell	0 days	3/20/2009	3/20/2009
22	Finish Tenant Improvement Work	0 days	5/6/2009	5/6/2009

Table 1: Summary/milestone schedule for the project

DETAILED SCHEDULE

The full detailed schedule can be found in Appendix A.

Construction Sequences

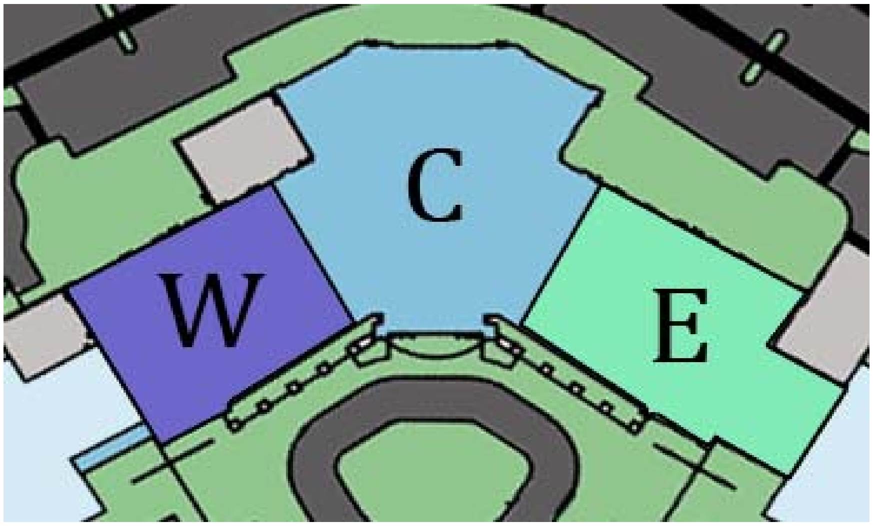


Figure 6: Typical workflow pattern for the project (C-->E-->W)

In the beginning of the construction process, the general workflow is linear with the work progressing from the east side of Building One to the west side. This flow is maintained throughout the excavation and construction of the substructure. This includes the construction of:

- Footings
- Caissons
- Foundation Walls
- Grade Beams
- Waterproofing

However, when work begins on the superstructure, specifically the structural steel, a new pattern is used. Structural steel is first erected in the center of the building using crane 1. Midway through the erection of the center's steel, a second crane is used to begin erecting steel on the east side of the building. Once the first crane finishes work on the center portion, it is then used to erect steel on the west side. It is with the erection of steel the workflow for the duration of the project is established. From this point forward work will begin first in the center and move to the east and finally the west. This is true for the following:

- Slab-on-deck
- MEP Hangers
- Spray on Fireproofing
- MEP Rough-in
- Roof
- Masonry
- Exterior Framing

- Metal Panels
- Glass and Glazing
- Interior Shaft Walls
- Interiors
- MEP Finishes

PROJECT COST SUMMARY

On February 25, 2009 the reported cost of the Westinghouse Headquarters Campus by Turner Construction Company was $134,000,000. The number has increased dramatically since that time. Currently, the reported cost of the campus is $240,000,000. With the increase, the **Total Project Cost/Square Foot = $284/sf.** The increase is mostly due to the Tenant Improvements which were not originally planned for. For example, Westinghouse called for twice the amount of restrooms as was required and planned for.

Building systems cost was not included in the information from the contractor. Values were obtained using information from R.S. Means and will be treated as actual costs until the information is received.

Building Systems Cost Calculations			
		% of Subtotal	Cost
Structural			
Substructure		2.1%	$3,825,753
Superstructure		19.0%	$34,613,957
Exterior Enclosure		15.3%	$27,873,345
Roofing		0.5%	$910,894
	Total	36.9%	$67,223,949
Mechanical			
	Total	12.3%	$22,407,983
Electrical			
	Total	15.1%	$27,508,987

Table 2: Estimated cost of the building systems

In order to evaluate this project cost a square foot estimate was developed using RS Means and D4 Cost software. These estimates are represented below.

<u>D4 Cost Software:</u>

D4 Cost software provides the user with an estimate based on previously built projects. Similarities are found between these projects and the user's project and a "smart averaging" tool is used. At the same time D4, adjusts for location and square footage to better represent the cost. Upon completion of the "smart averaging" tool, a report is produced which provides a CSI division breakdown of the cost, as well as a total building cost.

To estimate the cost of the Westinghouse project, three other projects which shared properties with the Westinghouse campus were averaged together. These projects included the Ha-Lo Headquarters, Infonet Corporate Headquarters, and the Rio San Diego Plaza.

Project	Use	Size	No. of Floors	Bldg. Cost
Ha-Lo Headquarters	Office	267,334 sq ft	7	$ 37,643,382
Infonet Corporate Hedquarters	Office	156,000 sq ft	3	$ 20,777,000
Rio San Diego Plaza	Office	198,000 sq ft	6	$ 11,209,795

Table 3: Properties of the projects selected for the D4 estimate

These projects share other features besides their use as office buildings. The features include:

- New construction projects
- Curtain walls
- Concrete floors
- Membrane roofs
- Caisson foundations

As was previously stated, D4 adjusts for location and square footage. Pittsburgh was inputted as the project location and 844,595 square feet was inputted as the total square footage. The smart averaging tool was then used.

The D4 software calculated a Total Building Cost estimate of $179,552,529 or a $212/sf value. This is approximately 75% of the value reported by Turner. Reasons for this difference could be a result of the amenities added by Westinghouse. As was the case with the original estimate Turner provided, the additions were not accounted for within the software. A complete Statement of Probable Cost provided by D4 can be found in Appendix B of this report.

R.S. Means Square Foot estimate:

To obtain an estimate for the Westinghouse buildings, the project was likened to a 5-10 story office building from R.S. means. Complete data for this building type can be found in Appendix C. The calculation of the estimate is as follows.

Building Values	
Square Footage	844,595
Perimeter	3,062
Story Height	14
Basement Square Footage	189,409
No. of Elevators*	4

**Building One only*

Table 4: Properties of Building One

Estimate Calculations					
Cost/Square Foot					
Base cost				=	$146
Perimeter Adjustment					
(3062/100)	x	$	1.90	=	$58
Story Height Adjustment					
2	x	$	1.05	=	$2
					$207
Cost					
844595	x		$207	=	$174,601,435
Basement Cost					
189409	x	$	36.40	=	$6,894,488
Common Additives (Elevators)					
4	x	$	170,700	=	$682,800
			Subtotal		$182,178,723
			Location Factor		0.96
			TOTAL		**$174,891,574**

Table 5: Calculation of the square foot estimate using RS Means

Values used for the calculations and the tables they came from can be found in Appendix C.

Assumptions:

- Building type- M.470, Office, 5-10 story
- Exterior wall type- Face Brick with Concrete Block Back-up/Steel Frame
- Square Foot Cost, Perimeter Adjustment, and Story Height Adjustment values for 300,000 sq ft. building were used (no extrapolation).

This estimate is close but less representative than the estimate created using the D4 Cost software. R.S. Means gives a cost/square foot value of $207/sf. There are several possible sources of deviation. First, the value obtained using R.S. Means does not include any contractor or architects fees. Therefore, this number represents just the construction costs rather than the total project cost. Also, R.S. Means did not have values associated with a curtain wall system which the Westinghouse buildings primarily are. As mentioned above in the D4 section, the Westinghouse tenant improvements also drove the costs past what would be the typical numbers produced in R.S. Means. This is the most likely source for a high percentage of the difference.

GENERAL CONDITIONS ESTIMATE SUMMARY

Description	Total Cost
General Expenses	$ 303,733
Project Staff	$ 1,153,595
Temporary Utilities	$ 1,841,472
Fees and Permits	$ 7,776,000
Total	**$ 11,074,800**

Table 6: General Conditions Estimate Summary

The General Conditions estimate for Building One was performed using R.S. Means 2009 cost data. The total for the estimate was **$11,074,800**. This took into account some general expenses, the project staff, temporary utilities, as well as some fees and permits. Overall, the general conditions of Building One made up **4.6%** of the overall project cost. This estimate is reflective of just the core and shell of Building One. However the fees and permits were calculated based on a percentage of the overall project cost. This was done because no cost data was given for just Building One.

For complete takeoffs and calculation see Appendix D.

STRUCTURAL SYSTEMS ESTIMATE SUMMARY

CSI Division	Description	Total Cost	Cost/SF
03 11 13	Concrete Forming	$ 2,395,221	$ 5.51
03 21 10	Reinforcing Steel	$ 59,307	$ 0.14
03 22 05	Welded Wire Fabric Reinforcing	$ 219,845	$ 0.51
03 31 05.35	Structural Concrete	$ 622,664	$ 1.43
03 31 07.70	Placing Concrete	$ 265,022	$ 0.61
05 12 23.17	Columns, Structural	$ 1,183,335	$ 2.72
05 12 23.75	Structural Steel Members (Beams)	$ 6,075,760	$ 13.97
Total		**$ 10,821,154**	**$ 24.89**

Table 7: Summary of the detailed estimate performed for the structural system

The structural systems estimate for Building One was performed using cost data from R.S. Means 2009. The concrete from the caissons, footings and slabs (slab-on-grade and slab-on-decks) were taken into account for the concrete estimate. For steel all beams and columns were taken into account. All steel beams were assumed to be W24x55. This was the most common size and assumed to be typical. For columns, R.S. Means did not provide cost data for all sizes. Three sizes closest to the column sizes within the project were selected and an average cost per ton was determined. This value was used for all sizes.

All slabs were reinforced with 6 x 6- W2.1 x 2.1 welded wire fabric and was estimated using the square footage of the slabs. Typical reinforcing layouts were used for the footings and caissons. For the footings (20) #9 bars were assumed (10 in each direction). For the caissons, (12) # 8 bars were assumed.

The overall superstructure cost for Building One was determined to be **$10,821,154**. The cost per square foot for Building One would then be **$24.89**. No actual cost data was provided by Turner and therefore cannot be compared to the actual value. However, this value is significantly lower than the value obtained from Technical Assignment One. The *overall* project superstructure cost was determined to be $34,613,957. Building One would consist of approximately 40% of this value.

Tables of the takeoff and calculations can be found in Appendix C.

ANALYSIS I: ENERGY AND THE ENVIRONMENT

BACKGROUND

The Westinghouse Headquarters Campus is pursuing and should achieve a LEED Certified status. As an energy company I believe Westinghouse has an opportunity to raise the standard by including even more energy saving ideas and greener materials into their building. Also, as the owner, Wells Reit II would benefit from ideas to aid in saving energy and reduced lifecycle costs.

GOAL

The goal of this analysis will be to identify finishes that when implemented will reduce energy costs. Even though there may be a higher upfront cost, it is a goal that ultimately the lifecycle cost of the building will be reduced. In addition, "greener" materials will be researched that may not reduce cost or energy. Instead these materials will be healthier for the environment and increase the indoor environmental quality of the building.

METHODOLOGY

- Determine current finishes an products placed within Building One
- Calculate cost of replacing finishes with "greener" products
- Calculate potential energy saving from implementing green products
- Research LEED requirements
- Determine impact on mechanical systems from implementing energy savings ideas

CURRENT FINISHES

To investigate the kind of materials which could possibly be replaced with "greener" materials the current finishes within Building One were researched. From the finish schedule the product information for the paints, the carpeting, and the tile used on the project were identified.

The paint used was a product of PPG Pittsburgh Paints. First, as one can gather from the name, PPG Pittsburgh Paints is a local company located just 17 miles from the Westinghouse campus. In addition to being a local company the paint chosen to be used within the building meets the requirements set forth by LEED for New Construction v 2.2, credit 4.2. This credit states requirements for the VOC content limits which the specified paint meets. As this finish already meets the standard which this analysis was attempting to create, it was not investigated further.

Next the carpeting specified for Building One was investigated. The carpet specified was Mohawk Commercial, Milan Square MC531. It was found that this particular carpet meets the requirements to obtain an IAQ Green Label Plus from The Carpet and Rug Institute. This green label test carpets and identifies those with low VOC emissions. This also meets the requirement set forth by LEED for New Construction v 2.2, credit 4.2. As with the paint, since this finish already meets the standard which this analysis was attempting to create, it was not investigated further.

Finally, the tile used on for flooring in Building One was researched. It was found to be a variety of colors and styles but all from the same manufacturer and product line: Crossville Empire Series. Crossville Empire series tile is meets the requirements for two LEED New Construction v 2.2

credits. First the tile qualifies for credit 5.1, 5.2 as it is a regionally manufactured material. Also, the tile has a recycled content of 20% (verified by Scientific Certification Systems) which meets the requirements of credits 4.1/4.2. Again, since this finish already meets the standard which this analysis was attempting to create, it was not investigated further.

As research into the finishes of Building One was performed it was found that many of them met the requirements set forth by lead. Therefore, other ideas were developed to establish a way in which to save energy within the building. Although, not technically considered a "finish", the windows used on the building were investigated. With a large amount of exterior glass, high efficiency windows provided an excellent opportunity to save energy.

CURRENT WINDOWS

To determine the potential savings from implementing high efficiency windows, a survey of the current window was performed. First the square footage of the orientation of each window was found at each orientation. The percent of window square footage to wall square footage was also found. The take off can be found in Appendix D. A summary of this takeoff can be found below:

Orientation	Window Square Footage	Wall Square Footage	% of Wall
North	14367	25902	55%
South	6717	18327	37%
East	6717	18327	37%
West	12547	25902	48%
Northwest	5299	8140	65%
Southeast	5896	7599	78%
Total	51542	104196	49%

Table 8: Summary of the window locations and sizes

The data given for the windows included in the drawings were given as 1" insulated tempered glass. To determine the glass performance data, it was assumed that the windows were double pane tinted glass. The performance data is as follows:

- U-Value: 0.57
- Shading Coefficient (SC): 0.72
- Solar Heat Gain Factor (SHGC): .62

From these numbers, it is apparent there is an opportunity to better the efficiency of the building envelope. Other windows were explored and it was eventually decided to use a product of PPG Industries because of the local ties in Pittsburgh.

PROPOSED WINDOWS

Figure 7: An example of a building with Solarban 80 windows

I propose to use PPG Solarban 80 windows. These windows provide both excellent thermal properties and are manufactured locally. PPG has identified United Plate Glass as a qualified manufacturer. United Plate Glass is located in Butler, PA, just 15 miles from the Westinghouse campus in Cranberry. This cuts down on the shipping costs and the impact on the environment associated with transporting materials.

Solarban 80 windows also have the ability to increase the efficiency of the building envelope. Below is a chart from the data sheet provided by PPG. I propose the use of Solarban 80 (2) OPTIBLUE + Clear. As you can see, this product has a very low U value, shading coefficient (SC), and solar heat gain factor (SHGF).

Solarban® 80 Glass Performance

Insulating Vision Unit Performance 1-inch (25mm) units with 1/2-inch (13mm) airspace and two 1/4-inch (6mm) lites; interior lite clear

Glass Type	Transmittance			Reflectance		U-Value (Imperial)		European U-Value	Shading Coefficient	Solar Heat Gain Coefficient	Light to Solar Gain (LSG)
	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time				
SOLARBAN® 80 Solar Control Low-E Glass											
SOLARBAN 80 (2) Clear + Clear	13	48	20	33	38	0.29	0.27	1.52	0.28	0.24	1.98
SOLARBAN 80 (2) Clear + *OPTIBLUE*	10	34	15	32	38	0.29	0.27	1.52	0.27	0.23	1.48
SOLARBAN 80 (2) *OPTIBLUE* + Clear	9	34	15	19	28	0.29	0.27	1.52	0.23	0.20	1.70
SOLARBAN 80 (2) *OPTIBLUE* + *OPTIBLUE*	7	25	11	19	28	0.29	0.27	1.52	0.23	0.20	1.23

All performance data calculated using LBNL Window 5.2 software, except European U-Value, which is calculated using WinDat version 3.0.1 software. For detailed information on the methodologies used to calculate the aesthetic and performance values in this table, please visit www.ppgglazing.com or request our Architectural Glass Catalog.

Figure 8: Image of the performance data for Solarban 80 windows

The comparison of this window versus the original is as follows:

	Solarban 80 (2)	Tinted Double Pane
U-value	0.29	0.57
Shading Coefficient (SC)	0.28	0.72
Solar Heat Gain Factor (SHGF)	0.24	0.62

Table 9: Comparison of performance data for Solarban and typical double pane window

ENERGY ANALYSIS (MECHANICAL BREADTH STUDY)

In order to calculate the potential energy savings which could be obtained from implementing the Solarban 80 windows, PPG has an energy modeling program available on their website. This modeling is conducted using the U.S. Department of Energy (DOE) 2.2 Building Energy Analysis Simulation Tool which was developed at the Lawrence Berkeley National Laboratory and Los Alamos National Laboratory. DOE-2 calculates hour-by-hour energy consumption by a "prototype" facility using hourly climate data.

Assumptions:

This modeling program, although recognized as being one of the most accurate energy modeling tool available in the U.S., was run using a base of assumptions which were not necessarily representative of the Westinghouse Electric Company. The assumptions which were made and entered into the analysis tool were:

- Glazing Type: Solarban 80 (2)
- City: Philadelphia, PA
- Glazing Design: Window Wall
- Building Type: Office

Other assumptions which were made by the DOE-2 simulation tool include glazing type performance data, a city's utility rate and weather data, glazing design (square footage), and the building description and characteristics.

1. The glazing type and performance data were taken to be as follows:

Glazing	Tvis	Rfvis	Tsol	Rfsol	U-Value	Shading Coefficient (SC)	Solar Heat Gain Coefficient (SHGC)
Double Pane Tinted	0.620	0.100	0.540	0.090	0.570	0.720	0.620
Solarban 60 (2)	0.704	0.112	0.328	0.293	0.291	0.438	0.380
Solarban 70XL (2)	0.617	0.108	0.227	0.347	0.286	0.311	0.270
Solarban 80 (2)	0.470	0.330	0.200	0.380	0.290	0.280	0.240
Solarban z50 (2)	0.510	0.080	0.250	0.230	0.290	0.360	0.310
Solexia Sungate 500 (3)	0.640	0.140	0.330	0.090	0.350	0.510	0.450
VE 1-52 (2)	0.500	0.160	0.320	0.200	0.320	0.460	0.400
VE 2-2M (2)	0.600	0.090	0.240	0.100	0.290	0.360	0.310

Figure 9: Performance data used for energy modeling

The highlighted values for the double pane tinted and Solarban windows will be the areas investigated.

2. The following weather data for Philadelphia was assumed. The averages for Pittsburgh were compared to these. Similarities were seen showing that reasonable assumptions were made.

	Philadelphia
Average Drybulb Temperature (F)	53.6
Average Wetbulb Temperature (F)	47.9
Average Daily Max Temperature (F)	62.0
Average Daily Min Temperature (F)	45.4
Heating Degree Days (Base 65)	5,181
Cooling Degree Days (Base 65)	1,053
Maximum Temp (F)	95
Minimum Temp (F)	11
No of Days Max Temp 90 and Above	12
No of Days Max Temp 32 and Below	19
No of Days Min Temp 32 and Below	99
No of Days Max Temp 0 and Below	0
Average Wind Speed (MPH)	9.6
Average Day Temp (F)	59.1
Average Night Temp (F)	48.1
Average RH at 4 AM	78.0
Average RH at 10 AM	63.1
Average RH at 4 PM	53.9
Average RH at 10 PM	71.2

Figure 10: Weather data used for energy modeling

3. The total square footage of windows that was assumed in the DOE-2 software was 50,976 square feet. This is very comparable to the square footage of the windows on Building One of the Westinghouse Campus. On Building One, there is 51,542 square feet of windows.

4. The DOE-2 software also made assumptions regarding the building description and characteristics. These assumptions are as follows:

	Office
Geometry and U-values	
Floor Area (sq ft)	270,000
Number of Stories	8
Punch Window to Wall Ratio[1]	59%
Wall Window to Wall Ratio[2]	90%
Wall U-Value (Btu/ ft2-hr-F)[3]	0.124
Roof U-Value (Btu/ ft2-hr-F)[4]	0.065
Glazing Type	Dual Pane Tint
	Solarban-60
	Solarban-70
	Solarban-80
	VE 2-2M
	Solexia x S500
	Solarban z50
	VE 1-52
Operating Conditions	
Cooling Temp Setpoint (F)	75
Heating Temp Setpoint (F)	70
Standard Day Schedule	7 AM - 6 PM Wkdays
	8 AM - 12 PM Wkends
	All Year
HVAC Equipment	
Air Handling System	VAV
Cooling Plant Type	Centrifugal Chiller
Economizer	Yes
Heating Plant Type	Hot Water Boilers
Service Hot Water	Hot Water Boilers
Internal Loads (Peak)	
Occupants (ft2/ person)	448
Lighting (W/ ft2)	1.3
Equipment (W/ ft2)	0.75

Figure 11: Summary of the building type assumed for energy modeling

Results:

Glazing	Electricity	Gas	Total Operating Electric Cost	Total Operating Gas Cost	Total Operating Cost	Total Capital Cooling HVAC Cost	Annual Operating Cost Savings of Low E Coatings vs DT	Initial Capital Cost Savings of Low E Coatings vs DT	Annual CO2 Savings of Low E vs DT	40 Year Building Life CO2 Savings of Low E Coatings vs DT
Double Pane Tinted	4,227,796	80,139	$270,227	$108,093	$378,320	$1,772,085	$	$		
Solarban 60 (2)	3,994,281	67,312	$259,954	$91,054	$351,008	$1,652,488	$27,312	$119,597	193	7,734
Solarban 70XL (2)	3,937,998	64,914	$257,477	$87,809	$345,286	$1,556,917	$33,034	$215,169	236	9,446
Solarban 80 (2)	**3,916,355**	**65,265**	**$256,524**	**$88,247**	**$344,771**	**$1,551,027**	**$33,549**	**$221,059**	**246**	**9,824**
Solexia Sungate 500 (3)	4,078,747	72,311	$263,670	$97,705	$361,375	$1,718,370	$16,945	$53,715	121	4,858
VE 2-2M (2)	3,980,163	65,311	$259,332	$88,358	$347,690	$1,580,829	$30,630	$191,257	212	8,471

Figure 12: Summary of the results of the DOE Energy Modeling Tool

The table above represents the cost to operate a building meeting the description assumptions for one year. As you can see there is the potential for considerable saving through the use of the Solarban 80 windows over the typical double pane. From this table the annual operating cost could be reduced by $53,874 by switching window types. Also, the Solarban windows are better for the environment. It can also be seen that the CO2 emissions associated with the Solarban 80 windows are lower both annually and after a 40 year time period. This makes the Solarban windows advantageous to the current user, Westinghouse, but also the long term building owner, Wells Reit II.

From these results, it is obvious there is a cost saving as well as an environmental advantage to using the Solarban 80 window. However, to get a better quantification of the actual savings a further analysis was performed by relating the cost and savings to a per square foot number and extrapolating from there. The table below is a summary of the per square foot data.

	Electricity (kwh/sf)	Gas (Therms/sf)	Total Operating Electric Cost ($/sf)	Total Operating Gas Cost ($/sf)	Total Operating Cost ($/sf)	Total Capital Cooling HVAC Cost ($/sf)
Double Pane Tinted	$15.66	$0.30	$1.00	$0.40	$1.40	$6.56
Solarban 80 (2)	$14.51	$0.24	$0.95	$0.33	$1.28	$5.74

Table 10: Reults of energy modeling broken down into a unit price

From these values, estimated values for Building one were calculated using its square footage of 460,000. Potential savings were then found. Another summary of this data can be found below.

Building One=460,000 square feet						
	Electricity	Gas	Total Operating Electric Cost	Total Operating Gas Cost	Total Operating Cost	Total Capital Cooling HVAC Cost
Double Pane Tinted	$7,202,912	$136,533	$460,387	$184,158	$644,545	$3,019,108
Solarban 80 (2)	$6,672,309	$111,192	$437,041	$150,347	$587,388	$2,642,490
Savings	**$530,603**	**$25,341**	**$23,346**	**$33,812**	**$57,158**	**$376,617**

Table 11: The results of the energy modeling extrapolated for Building One

Possible Effects on the Mechanical System:

Due to the changing of the windows, the results show a reduction in the heat flow through the building envelope. This reduction in heat flow includes less heat escaping during the winter months and less heat entering the building during the summer months. This change may have an impact on the mechanical system of Building One.

The mechanical system of the building consists of four air handling units (AHUs) located in the mechanical penthouse and 3 air conditioning units (ACUs) located in the basement. Together these units deliver almost 300,000 CFM. The ACUs are used to cool the mechanical and electrical spaces in the basement, whereas the AHUs are used to cool the spaces on the occupied floors (1 through 5). The results of the energy modeling analysis show a reduction in the cost of running the HVAC equipment. Either these AHUs will be running less frequently or they could be downsized. Also, the size of the ductwork could be reduced resulting in a materials cost savings.

The impact of this energy reduction has many possible impacts on the mechanical system. All of these impacts would be positive as the cost to run the equipment and the energy being put into the building would be reduced.

CONCLUSIONS AND RECOMMENDATIONS

From this analysis it has been determined that the current finishes located within Building One are acceptable. These materials meet the requirements for a LEED building as set forth by the U.S. Green Building Council. They have low levels of VOC and are regionally manufactured.

An opportunity to save energy was found in replacing the windows with PPG Solarban 80 windows. These windows are environmentally friendly. They meet the LEED requirements as a regionally manufactured product and also have the the ability to reduce the CO2 emissions from the building. This reduces the impact Building One has upon the environment.

In addition, Solarban 80 windows would reduce the costs associated with the building. Total operating costs would lower approximately 9% from implementing these windows. The cost to cool the building would also be reduced as the new windows have a better thermal resistance. This thermal resistance works better to keep the solar heat gain down in the summer time and keep the heat in during the winter months. The mechanical equipment may be able to be downsized with the reduced load. If not done, the equipment would run less regardless of its size. As stated above, this would lower the overall cost of running the HVAC system. According to the DOE-2 simulation tool this costs could be lowered by 12.5%

This analysis shows the owner would have benefited from implementing these windows. A substantial cost savings could have been found and the overall impact of the building on the environment could have been reduced.

ANALYSIS II: CONCRETE SLABS

BACKGROUND

The Westinghouse Headquarters Campus was constructed on a compressed schedule. The original schedule was developed at 22 months and was then reduced to 15 months. With the compressed schedule a large emphasis was placed on pouring of the slabs which lied on the critical path. The slab-on-decks needed to be poured and cured so the crews could begin interior work as soon as possible. The impact these items had on the schedule were vast. Because the work needed to be completed so fast a large amount of overtime was utilized in order to complete the project. If the schedule could be reduced the additional cost of overtime could be lessened.

GOAL

The goal of this analysis is to explore the possibility of using precast concrete slabs to replace the poured elevated slab-on-deck. If the prefabricated slabs could be put into place in an efficient manner the schedule may be reduced. This could allow the interior work to begin earlier and reduce the schedule or the amount of overtime needed. My goal will be to reduce both the schedule and the cost of the slab-on-deck. This analysis will also explore the structural ramifications of implementing precast slabs and will encompass a breadth topic.

METHODOLOGY

- Determine current schedule and cost of slabs
- Contact local prefabricated concrete slab manufacturer to determine cost and time needed
- Develop schedule for delivery and placing of precast slabs
- Calculate potential schedule and cost reduction
- Determine structural ramifications of changing floor systems
- Overall cost and schedule analysis including structural changes

CURRENT CONCRETE SLAB-ON-DECK SYSTEM

Building One of the Westinghouse campus makes use 2 ½" lightweight concrete slabs on metal deck for the first floor up to the floor of the mechanical penthouse on the sixth floor. The cast in place concrete decks were poured in the in the typical workflow pattern utilized on the project.

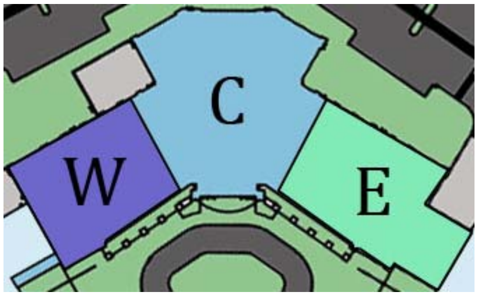


Figure 13: Visualization of typical workflow pattern (C-->E-->W)

The slab on first floor of the center portion was poured first. From there, the workflow continued upwards pouring the 2nd, 3rd, 4th, 5th and 6th floors in the center. The same upwards pattern was utilized next in the east section followed by the west section. A summary schedule of pouring the slabs is provided below.

Location	Duration (days)	Start Date	End Date
Slab on Deck- Center	35	16-Jul-08	2-Sep-08
Slab on Deck- East	35	13-Aug-08	30-Sep-08
Slab on Deck- West	35	1-Oct-08	18-Nov-08
Total	**90**	**16-Jul-08**	**18-Nov-08**

Table 12: Summary of the schedule for the poured slab-on-deck

The cost of the current system was taken from the detailed estimate performed. Since no actual cost data was provided, this information was taken from RS Means. The total cost of the current system was found to be approximately 3.4 million. A breakdown and summary can be found on the chart below.

Location	Forming	Placing	WWF	Material	Total
1st Floor	$476,079		$ 36,641	$126,564	$639,284
2nd Floor	$476,079		$ 36,641	$126,564	$639,284
3rd Floor	$476,079		$ 36,641	$126,564	$639,284
4th Floor	$476,079		$ 36,641	$126,564	$639,284
5th Floor	$476,079		$ 36,641	$126,564	$639,284
Total	$2,380,395	$ 181,192	$ 183,205	$632,820	$3,377,612

Table 13: Cost summary for the poured slab-on-decks

PREFABRICATED CONCRETE SLABS

In an attempt to reduce the schedule and cost of placing the concrete slabs, precast concrete products were explored. Nitterhouse Concrete Products were looked at. Although located in

Chambersburg, PA (175 miles from Cranberry Township) Nitterhouse is the closest Precast/Prestressed Concrete Institute (PCI) Certified Plant to offer a wide range of building products for commercial construction.

The typical application of precast concrete into office buildings includes using Hollow Core planks. Hollow Core planks were not advantageous to apply to the Westinghouse buildings due to the size of the building. Hollow Core Planks come in a width of 4'-0". This would require approximately 2400 members in order to complete Building One. Assuming a 20 minute erection time for each member and an 8 hour workday, Hollow Core planks would require approximately 100 days to construct. For this reason, Double Tee concrete panels were further explored.

Double Tee members are conventionally used for parking structures; however they can be effectively used elsewhere. With a longer width, double tees were a much more attractive option for the Westinghouse Campus. They could reduce the number of members to one third of that achievable with Hollow Core planks. In additions the double tees could reduce the number of steel members in the building further reducing the cost and schedule.

Upon selecting double tees as the product to pursue a layout was developed. In an effort to keep structural changes to a minimum, the bay sizes were maintained and the length of the double tees was proposed from the bay lengths. Since the bay sizes were a uniform 24 feet wide, a 12 foot wide double tee was selected.

In order to select an appropriate double tee whose span can handle the load, Nitterhouse provides an allowable live load equation which they have used to create their tables. This equation is as follows:

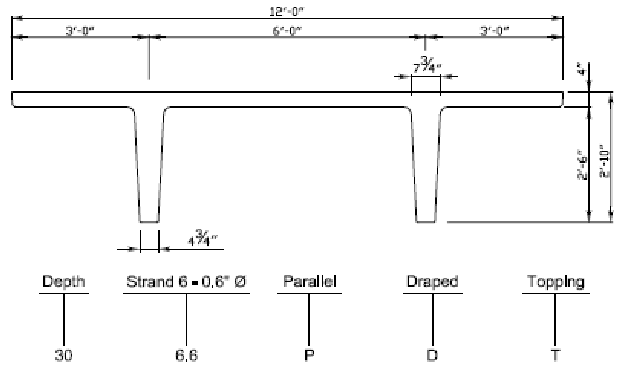
$$Allowable\ Live\ Load = ((1.6)(Load\ Table\ Value) - (1.2)(Superimposed\ Dead\ Load))/1.6$$

The live load for the building was assumed to be 100 psf and the superimposed dead load was assumed to be 25 psf. After plugging this into the equation, it was found that the allowable live load is **81.25 psf**. This number was compared to the allowable spans and a 34" x 12' double tee was selected. Below the physical properties and the load table provided for this product. From the load table the allowable spans for each section can be found. The highlighted areas are the spans which can be achieved for the allowable load found above.

Prestressed Concrete
34" x 12' DOUBLE TEE
(PRETOPPED)

PHYSICAL PROPERTIES

$A = 951\ In.^2$ $S_b = 3{,}301\ In.^3$
$I = 85{,}054\ In.^4$ $S_t = 10{,}334\ In.^3$
$Y_b = 25.77$ in. Wt.= 991 PLF
$Y_t = 8.23$ in. Wt.= 83 PSF



ALLOWABLE SUPERIMPOSED LIVE LOADS (psf)		IBC 2006 & ACI 318-05 (1.2 D + 1.6 L)																							
Section	Ø Mn (In. Kips)	Span (Feet)																							
		44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90
34 - 6.6 P	9,416	106	92	79	68	58	50	42	35																
34 - 8.6 P	12,099				106	93	82	72	62	54	47	40	34												
34 - 10.6 P	14,554							99	88	78	69	61	54	47	41	35									
34 - 12.6 P	16,782									99	89	80	71	64	56	50	44	38							
34 - 14.6 D	21,882												111	101	92	83	76	68	61	55	49	43	38		
34 - 16.6 D	24,688														107	98	89	81	74	66	59	53	48	42	37
34 - 18.6 D	27,414															110	101	92	84	76	69	63	57	51	46

Figure 14: Specifications for the selected double tee. Allowable spans for the allowable live load are highlighted.

The maximum span which is needed for Building One is 56'. Therefore section 31 – 10.6P was selected for use. The depth of these members is 34". A negative effect using these members will have on the space is the lowering of the ceiling height. Currently, the ceiling height is 12 feet. The use of these concrete members will reduce the ceiling height an additional 8". However, even with the reduced height, Building One still should meet requirements to be considered a class 'A' office space. There are no set criteria for this distinction, but such a minor change should not affect the buildings rating.

A typical layout can be found below. Notice that the bay sizes are being maintained as to reduce the effects on the structural system and layout. Because of the double tees, two steel beams can be removed from each of the 24' wide bay.

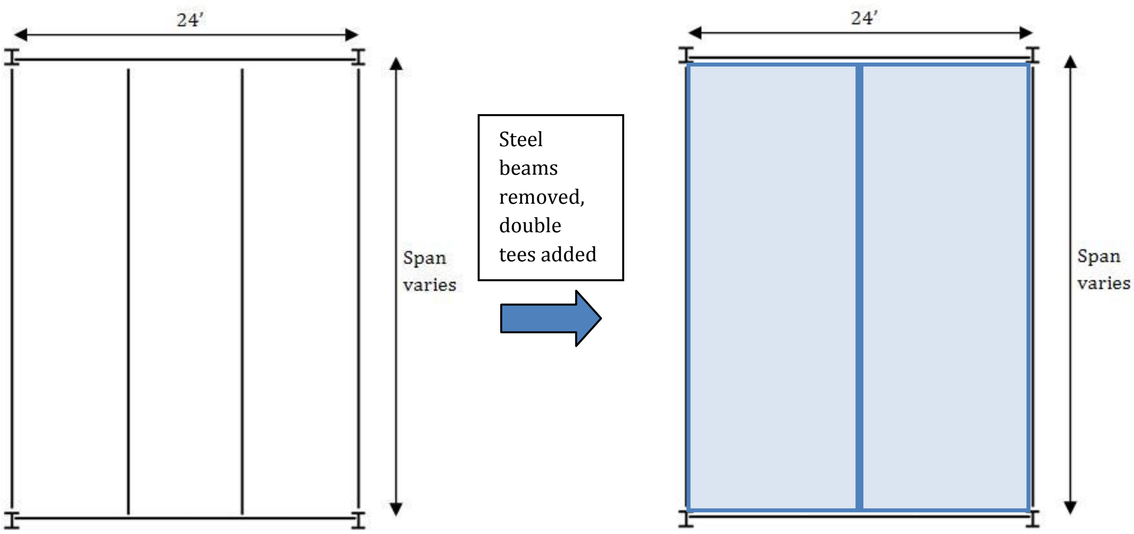


Figure 15: Typical bay. Shown with current steel and then with double tee members.

STRUCTURAL RAMIFICATIONS

The proposed precast concrete slabs would cause an effect on the structural system of the building. The bay sizes and layouts would remain the same with the exception of the removal of the steel members between bays. This load these members were designed to handle would then be taken by the double tee. These double tees will however add a considerable amount of weight to the building. Therefore the steel which is to remain will need to be redesigned in order to take these loads.

More detailed calculations for the design of these joists can be found in Appendix E. The results of the calculations are as follows:

- Tributary Area: A_t= 864 sq ft
- Live Load Reduction: L=61 psf
- Dead Load: D=108 psf
- Factored Load: W_u= 227 psf = 8.2 klf
- Maximum Shear: V_u= 98 kips ≈ 100 kips
- Maximum Moment: M_u=590 kip – ft ≈ 600 kip – ft

Because the unbraced length of the steel exceeds the limits to use the Z tables, table 3-10 of the AISC Steel Construction Manual was used. This table compares the available moment vs. the unbraced length. From this table it was determined that a W21 x 101 would be the most economical choice for the new steel members. This actually decreases the depth of the member, but it does increase the weight.

As these members are slightly bigger, the cost may rise for replacing the existing steel. However, with the removal of beams where the double tees are being placed, the total cost of steel would be reduced.

SCHEDULE ANALYSIS

An erection schedule was developed for the concrete members. When scheduling, Nitterhouse typically assumes 20-30 minutes for the erection of each double tee. It was assumed here that each member took 20 minutes. The lesser time was chosen because of the vast quantity of members. Although some members may take longer, especially in the early stages of erection, the repetitive nature will allow crews to gain efficiency during erection. Towards the end of the erection process, it is likely the time needed will have lessened considerably. The start date was assumed to be the same as the first day the concrete slabs were to be performed. Also, the workflow pattern of pouring the concrete was maintained. With the proposed schedule, the concrete slabs would have been in place after 32 days on August 28, 2008. This would finish 58 working days ahead of the original schedule which was scheduled to finish on November 18, 2008. A summary of the schedule can be found below.

Location	Members	Erection Time (Minutes)	Erection Time (Days)	Start Date	End Date
Slab on Deck- Center	**332**	**6640**	**13.83**	**16-Jul-08**	**4-Aug-08**
1st Floor	84	1680	3.5	16-Jul-08	21-Jul-08
2nd Floor	66	1320	2.75	21-Jul-08	24-Jul-08
3rd Floor	54	1080	2.25	24-Jul-08	28-Jul-08
4th Floor	54	1080	2.25	28-Jul-08	30-Jul-08
5th Floor	54	1080	2.25	30-Jul-08	1-Aug-08
6th Floor	20	400	0.83	4-Aug-08	4-Aug-08
Slab on Deck- East	**212**	**4240**	**8.83**	**5-Aug-08**	**15-Aug-08**
1st Floor	48	960	2	5-Aug-08	6-Aug-08
2nd Floor	36	720	1.5	7-Aug-08	8-Aug-08
3rd Floor	36	720	1.5	8-Aug-08	11-Aug-08
4th Floor	36	720	1.5	12-Aug-08	13-Aug-08
5th Floor	36	720	1.5	13-Aug-08	14-Aug-08
6th Floor	20	400	0.83	15-Aug-08	15-Aug-08
Slab on Deck- West	**212**	**4240**	**8.83**	**18-Aug-08**	**28-Aug-08**
1st Floor	48	960	2	18-Aug-08	19-Aug-08
2nd Floor	36	720	1.5	20-Aug-08	21-Aug-08
3rd Floor	36	720	1.5	21-Aug-08	22-Aug-08
4th Floor	36	720	1.5	25-Aug-08	26-Aug-08
5th Floor	36	720	1.5	26-Aug-08	27-Aug-08
6th Floor	20	400	0.83	28-Aug-08	28-Aug-08

Table 14: Schedule for the placement of the double tee members

COST ANALYSIS

A cost analysis was performed comparing the original cost of the cast-in-place concrete to the cost of the precast method. Data for the material and shipping costs was obtained from Nitterhouse. It was estimated that the cost of the member would be $7.50 per square foot. In addition, the cost to ship each double tee was $9.00 per mile which equated to $1,575 to ship each piece. Nitterhouse did not provide any data for the erection costs. This information was obtained from RS Means Heavy Construction Cost Data. A "Standard weight, 32" x 10' wide, 60' span" member was assumed and the labor and equipment cost was determined to be an additional $360 per member. A summary of these costs can be found below.

Location	Number of Slabs	Square Footage	Material Cost ($7.50/sf)	Shipping Cost ($9/mile)	Erection Costs* ($360 ea.)
1st Floor	180	74000	$ 555,000	$ 283,500	$ 64,800
2nd Floor	138	74000	$ 555,000	$ 217,350	$ 49,680
3rd Floor	126	74000	$ 555,000	$ 198,450	$ 45,360
4th Floor	126	74000	$ 555,000	$ 198,450	$ 45,360
5th Floor	126	74000	$ 555,000	$ 198,450	$ 45,360
6th Floor	60	37000	$ 277,500	$ 94,500	$ 21,600
Total	**756**	**407000**	**$ 3,052,500**	**$ 1,190,700**	**$ 272,160**

Table 15: Summary of the cost analysis for precast concrete

If these totals are summed the cost of using double tees in Building One is equal to **$4,515,360**. However due to the reduction in the amount of steel, this number does not truly reflect the potential savings. To estimate the savings from this, RS Means was again used. It was calculated that a total of **$2,792,343** could be saved from steel material and erection costs. A summary of this calculation can be found below.

Location	Beams Omitted	Length of Beams	Beam Cost Savings
1st Floor	180	6660	$ 639,160
2nd Floor	138	5712	$ 548,181
3rd Floor	126	4960	$ 476,011
4th Floor	126	4960	$ 476,011
5th Floor	126	4960	$ 476,011
6th Floor	60	1844	$ 176,969
Total	**756**	**29096**	**$2,792,343**

Table 16: Cost savings associated with removal of steel beams

When this is considered the overall cost analysis can be performed:

Precast Cost:		$ 4,515,360
Steel Savings:	-	$ 2,792,343
CIP Cost:	-	$ 3,377,612
Cost Savings		**$ (1,654,595)**

Table 17: Cost savings associated with using precast

By implementing this precast system it has been determined that a cost saving of **$1,654,595** could be obtained. This does not take into the account the potential savings from the reduction in the schedule. Obviously reducing the schedule by 58 working days would have a positive effect in the overall cost.

CONCLUSIONS AND RECOMMENDATIONS

From this analysis it has been determined that precast/prestressed concrete slab could have been beneficial to the delivery of the project. It has been found that the cost of using a precast system would have been lower than using the poured slab-on-deck system which was used on the project. The calculated savings of $1,655,000 does not include the cost savings associated with reducing the schedule.

The pouring of the slabs lied upon the critical path of the schedule. By implementing a precast system it was found that the schedule could have been reduced by 58 working days. This would significantly reduce the cost of the project. Overtime was a huge expenditure on the project. If the finish date remained unchanged even with the schedule saving, the amount of overtime paid could have been reduced. A greater savings than found above could have been achieved.

There were some disadvantages to implementing this system. First, the double tees had a depth which would have lowered the ceiling height. The Westinghouse Campus was classified as a class 'A' office space. One of the criteria for this distinction is the ceiling height. There is no set height which must be maintained to get this rating, but there may be adverse effects. Next, the size of the steel member would have to be increased. This would have a cost associated with it; however this price would be offset by the potential savings.

Another drawback to using precast is the planning which must be done beforehand. There is a long lead time for the members, and it must be exactly known what is needed. Also, increased coordination must be done to ensure the correct members arrive on site when they are supposed to and that the crane and crews are ready to set them. The increased planning is why precast was not used on the Westinghouse Campus. The drawings were incomplete when construction began, and the timeline did not suit using precast.

In conclusion, if the preconstruction process had a longer duration and more planning could have taken place, using precast double tees could have been beneficial. The schedule and cost of the project could have been reduced.

ANALYSIS III: BUILDING INFORMATION MODELING (BIM) IMPLEMENTATION

BACKGROUND

There has recently been a large push towards the implementation of building information modeling (BIM) throughout the construction industry. BIM can provide great value during the construction process by identifying potential clashes, enhancing coordination, reducing change orders, and communicating ideas. BIM was not implemented on the Westinghouse Headquarters Campus project.

GOAL

Although no major coordination issues were encountered, the shortened construction schedule may have benefited from the use of building information modeling (BIM). The use of BIM could not only prevent coordination issues from occurring, but could have made these processes more efficient. Through the use of BIM the subcontractors would have a definitive idea of exactly what they were supposed to get done and where, before the day began. The goal of this analysis will be to determine where BIM could have been effectively used on the Westinghouse project. I will also explore the effects on the Turner staff and their views towards BIM. Finally, I will analyze the effects BIM would have on the schedule and the cost of the project.

METHODOLOGY

- Assess the Westinghouse Turner staff's knowledge and views of BIM
- Determine areas where BIM could be applied
- Develop 3D and 4D models of the basement mechanical space
- Show models to project team and assess their response using attached survey
- Assess potential effects on the cost and schedule

WESTINGHOUSE'S TURNER STAFF VIEWS

An important aspect to the successful implementation of Building Information Modeling (BIM) on a project is the level of commitment shown by the project team. The level of commitment usually stems from how comfortable a team is in using the product. Many construction managers are set in their ways and do not like spending the upfront time to learn the technology. Instead many will continue to deliver projects as they have for years. Obviously such an attitude does not allow for growth within the construction industry.

Turner Construction is an example of a company who does not shy away from such advancement. Turner has been a leader in the construction industry and has implemented BIM on many projects, including the Butler Memorial Hospital project located within 30 miles of the Westinghouse project. However not all members of the Turner staff are comfortable using BIM. In order to gauge the knowledge of the staff on the Westinghouse, a brief survey was given to the project executive. In the survey, the project executive revealed that he has not used BIM on any previous projects and voiced some concerns about it use.

One of the concerns voiced was that having complete drawing is very rare at the beginning of the project limiting the potential effectiveness. Although this is true, many design firms will perform the initial design in 3D software. This has many benefits. It allows the architect to convey the design intent to the client more effectively. Models are able to organize material information which can include quantities and cost information. This can allow for more effective estimating at the start of the project. It was found that both the architect and engineering firms have the capability to provide this product. The architect, IKM Incorporated, actually designs every new healthcare facility using 3D software and is pushing to include this service in every job. LLI, the engineer, is not as advanced as IKM, but still provides the service.

Another concern was the availability of a capable coordinator in-house to navigate the system. With many professionals learning the software and with a large company such as Turner, this could have been easily accommodated. It would have also given the opportunity for other to learn.

Finally, the cost was one of the major concerns. The cost of implementing BIM will be discussed later in this analysis.

BUILDING INFORMATION MODELING (BIM) APPLICATIONS

There are several advantageous applications of BIM. These include but are not limited to:

- *Helps client and end-users in understanding and visualizing the end product*- As mentioned above, BIM gives the owner a better understanding of what the designer is doing. This allows the client to have a greater say in how the building is designed which can result in a lower number of change orders throughout the construction process.

- *Marketing presentation of construction approaches*- BIM can allow a construction manager or general contractor to convey their ideas on how to construct a building more effectively. This again just allows the flow of information to be communicated more effectively.

- *Helps owners make informed decisions about proposed project or changes.*- During the construction process, conflicts may occur which cause the owner to make a decision on how to proceed. BIM can allow an owner to see the effects of his decision before the change has been put in place.

- *Good estimation during bidding and procurement*- This point was also mentioned above. To reiterate, models are able to organize material information. This information can be used to calculate quantities and cost information of materials. This can be an effective tool for estimating at the start of the project.

- *Helps identify conflicts that may arise during building construction*- BIM can be used to identify design errors which may cause conflicts during the construction process. Since these errors can be identified earlier and corrected, the number of RFIs and change orders can be reduced. This has the potential to save costs and resources throughout the process.

- *Improved coordination in construction sequences*- Construction sequences can be better conveyed to subcontractors by using BIM. 4D schedules can be developed which give subcontractors a better visualization of the time in each area and who may be working around them.

For the purpose of the Westinghouse project, I chose to look at the advantages BIM could provide in identifying potential clashes. Clashes can be costly to a project using valuable time, resources and thus money in order to rectify them. Many potential conflicts occur between different MEP systems. For this reason I chose to create a model of a mechanical room located in the basement of Building One on the Westinghouse campus. The mechanical room is home to boilers, air handling units, and several pumps. Also contained in the room is several feet of ductwork and piping as well as exposed steel beams supporting the floor above.

3D AND 4D MODELING

The model was created using Autodesk Revit Architecture 2010 and Autodesk Revit MEP 2010. Although the equipment placed within the model represents the same equipment, the same models were not used. The dimensions of the equipment were transformed to match the size of the equipment shown in the drawings. Upon completion of the model within Revit, the model was exported as an Industry Foundation Class (.ifc) file and opened with Autodesk Navisworks Manage 2010. In Navisworks, materials were applied to the elements within the model to better distinguish between these elements. These materials may not be representative of the actual material properties, instead were used for visual purposes.

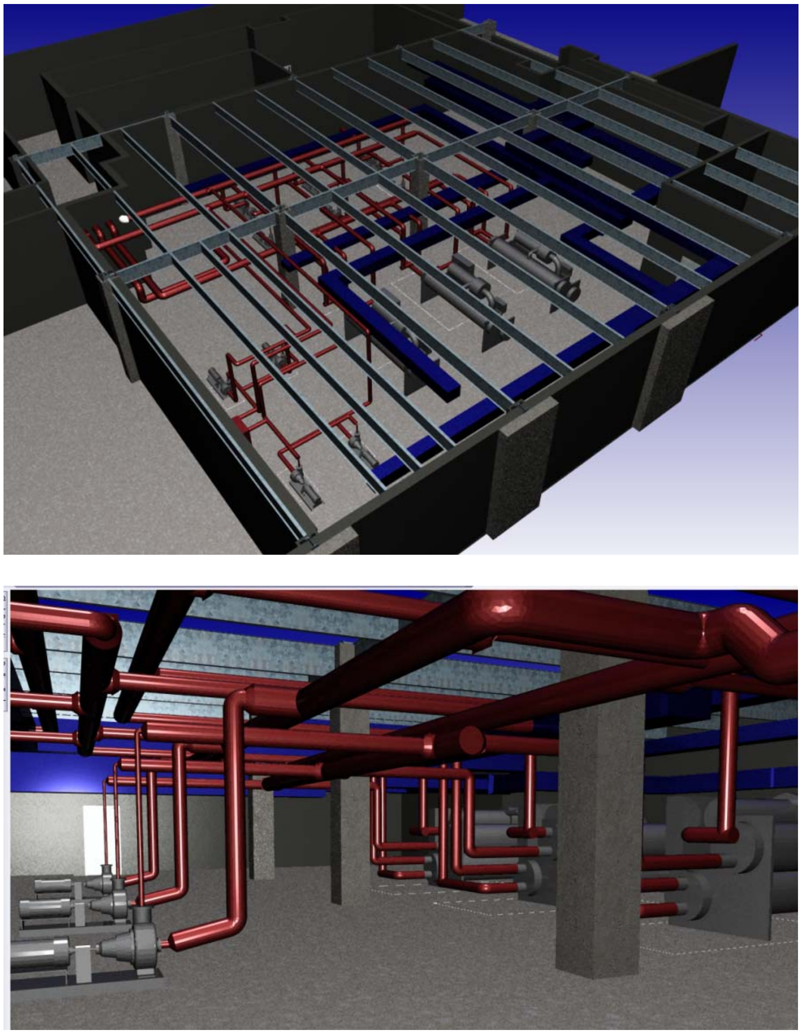


Figure 16: Images of the model created of the mechanical room in Building One

The clash detection software within Navisworks was then used. Three tests were run to identify potential clashes. These tests were run between the mechanical and plumbing systems, mechanical and structural systems, and the plumbing and structural systems. The test which produced the most number of conflicts was between the mechanical and plumbing system. Ten clashes were found between these systems. The test between the plumbing and structural systems only produced two clashes. Finally the test run between the mechanical and structural systems did not produce any clashes. This is usually a place in which a lot of clashes are found. However, due to the high ceilings, all ductwork was placed under the steel. No ductwork runs between joists.

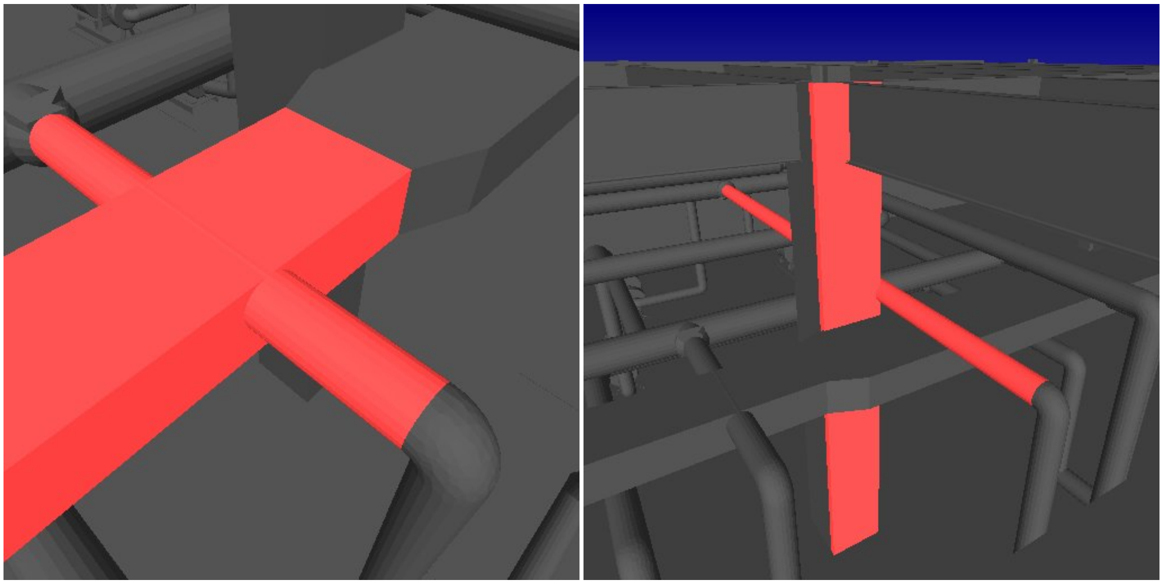


Figure 17: Images taken from Navisworks' clash detection software

These clashes were a result of developing a model for just the mechanical room of Building One. Surely other issues would have been encountered of this was done for the entire building. Coordination issues can result in Requests for Information (RFIs) and change orders (COs) which can cause delays in the schedule and an additional cost.

COST AND SCHEDULE EFFECTS

It is difficult to assess the cost and schedule affects that implementing BIM can have. With the recent push towards BIM, many architectural and engineering firms use BIM as a standard and no additional costs are associated with its use. It is also hard to estimate the affect on the schedule. It is a general belief in the industry that if BIM in implemented early in the design and preconstruction process that there are no delays in beginning construction. One of the benefits of BIM is its ability to reduce delays in the construction schedule. However, this value is hard to quantify since these problems are never actually faced. Even with the difficulty in quantifying this value, identifying clashes early in the process is viewed as much less costly to the overall schedule as opposed to problems in the field. This can also reduce the number of change orders which have the potential to add significant cost to the project.

Overall, the potential effects of implementing BIM on the schedule and cost of the project are not substantial. The upfront cost may be slightly greater, but BIM has the potential to cause cost savings. The schedule should not be negatively impacted, but again implementing BIM could have a positive effect.

CONCLUSIONS AND RECOMMENDATIONS

It has been concluded that BIM could have had a positive effect on the construction of the Westinghouse Headquarters campus. BIM has several potential benefits which have been discussed in the above sections. The most important of which may be the ability to identify potential clashes early in the process. This analysis looked at these would be benefits of using clash detection in a very small portion of the building. Even in the limited area of the mechanical room, conflicts between systems were found. It is difficult to quantify the cost and schedule implications of finding these problems early as opposed to later, but the effect would be positive.

The view of the construction staff was that BIM could not have been effectively implemented as the drawings were incomplete at the beginning of the project. However, if BIM was used in the design process this would not have been an issue. It is my view that BIM could have been successfully employed, however its value is unknown.

SUMMARY AND CONCLUSIONS

The Westinghouse Headquarters Campus was generally constructed in an efficient manner. Very few problems were incurred in the actual construction process. One of the few problems was the amount of overtime which was necessary to complete the project on the fast track schedule. Analysis 2: Concrete Slabs was performed in an attempt to reduce the schedule and limit the additional costs of overtime. Analysis 1: Energy and Environment was performed to add value to the project in terms of sustainability and the lower environmental impact. Finally, Analysis 3: BIM Implementation addressed a current industry issue and its value to the Westinghouse project.

It was determined that all three of these analyses could add value to the project:

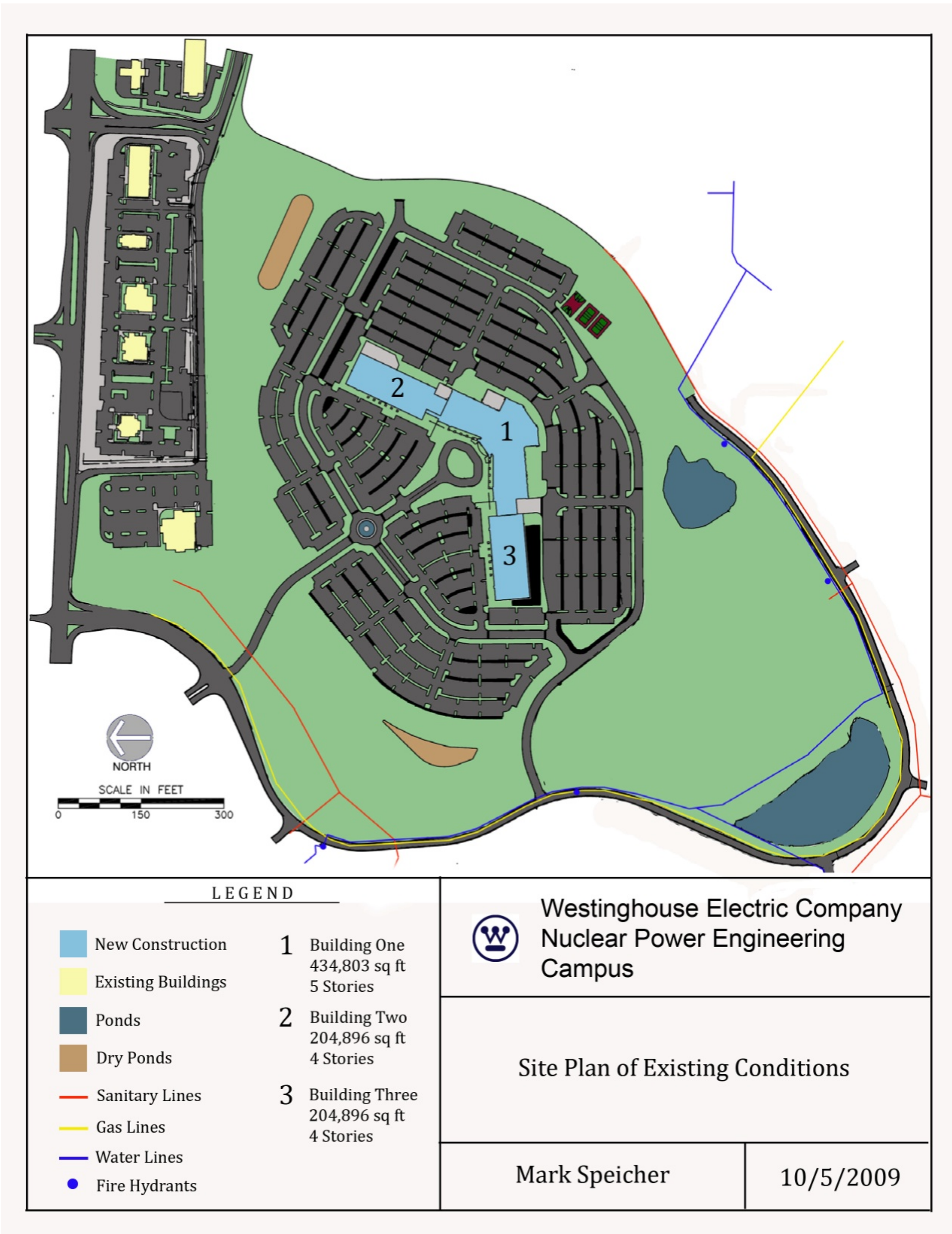
Analysis 1: Energy and the Environment- This analysis provided a means to save energy and limit the operating cost of the building by replacing the current windows with PPG Solarban 80 windows. In addition to lowering the energy consumption of the building, these windows produced less VOC and were a regionally manufactured material. The environmental impact of the finishes was also found to be minimal.

Analysis 2: Concrete Slabs- This analysis provided a cost and schedule analysis of using precast double tee members instead of a poured concrete slab-on-deck system. It was found that a schedule savings of 58 days and a cost savings of $1.6 million could have been realized. However there is a trade off with the ceiling height. Also, the steel beams would need to be made larger due to the increased weight of the precast system.

Analysis 3: BIM Implementation- This analysis explored the advantages of using building information modeling on construction projects. On this project, clash detection was specifically looked at. Several clashes were found in the mechanical space of Building One. These clashes had the potential to add time to the schedule and a cost to the project. The actual effects of implementing BIM on the cost and schedule are difficult to determine. However, the general view is that BIM adds value to a project. Without using BIM from the beginning of the project it may not have been ideal to use it on the Westinghouse project.

APPENDIX A: SITE LOGISTICS PLANS

SITE PLAN OF EXISTING CONDITIONS



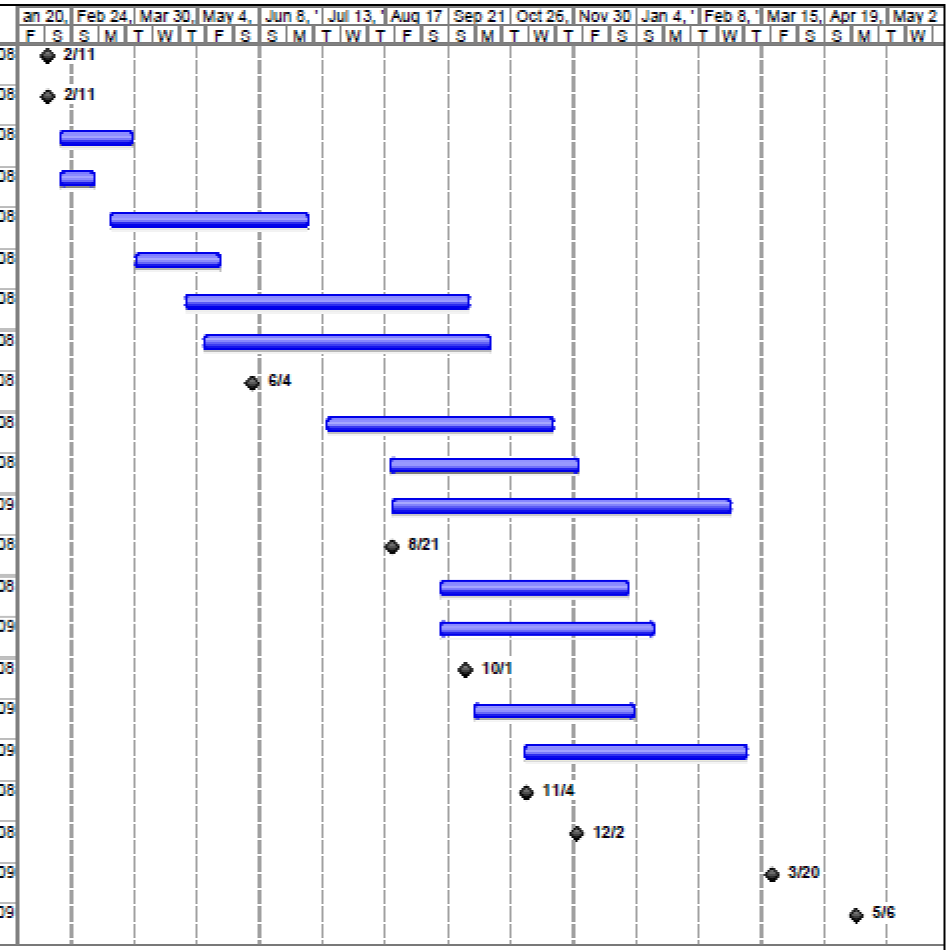
SITE LAYOUT PLANNING: SUPERSTRUCTURE PHASE

Westinghouse Electric Company Nuclear Power Engineering Campus	Superstructure (Steel Erection) Phase	Mark Speicher	October 28, 2009

APPENDIX B: PROJECT SCHEDULE SUMMARY

MILESTONE SCHEDULE

ID	Task Name	Duration	Start	Finish
1	Start Construction	0 days	Mon 2/11/08	Mon 2/11/08
2	Mobilization	0 days	Mon 2/11/08	Mon 2/11/08
3	Footer Excavation	30 days	Mon 2/18/08	Fri 3/28/08
4	Caissons	15 days	Mon 2/18/08	Fri 3/7/08
5	Foundation Walls	80 days	Mon 3/17/08	Fri 7/4/08
10	Underground Utilities	35 days	Mon 3/31/08	Fri 5/16/08
11	Slab on Grade	114 days	Mon 4/28/08	Thu 10/2/08
6	Foundation Waterproofing	114 days	Thu 5/8/08	Tue 10/14/08
7	Structural Steel Start	0 days	Wed 6/4/08	Wed 6/4/08
12	Slab on Deck	90 days	Wed 7/16/08	Tue 11/18/08
16	Exterior Framing	75 days	Wed 8/20/08	Tue 12/2/08
13	MEP Rough In	135 days	Thu 8/21/08	Wed 2/25/09
14	Start Roof	0 days	Thu 8/21/08	Thu 8/21/08
17	Metal Panels	75 days	Wed 9/17/08	Tue 12/30/08
18	Glass and Glazing	85 days	Wed 9/17/08	Tue 1/13/09
21	Start Tenant Improvement Work	0 days	Wed 10/1/08	Wed 10/1/08
19	Elevator Install	65 days	Mon 10/6/08	Fri 1/2/09
9	MEP/FP Finishes	90 days	Mon 11/3/08	Fri 3/6/09
8	Structural Steel Erection Complete	0 days	Tue 11/4/08	Tue 11/4/08
15	Roof Complete	0 days	Tue 12/2/08	Tue 12/2/08
20	Substantially Complete Core and Shell	0 days	Fri 3/20/09	Fri 3/20/09
22	Finish Tenant Improvement Work	0 days	Wed 5/6/09	Wed 5/6/09



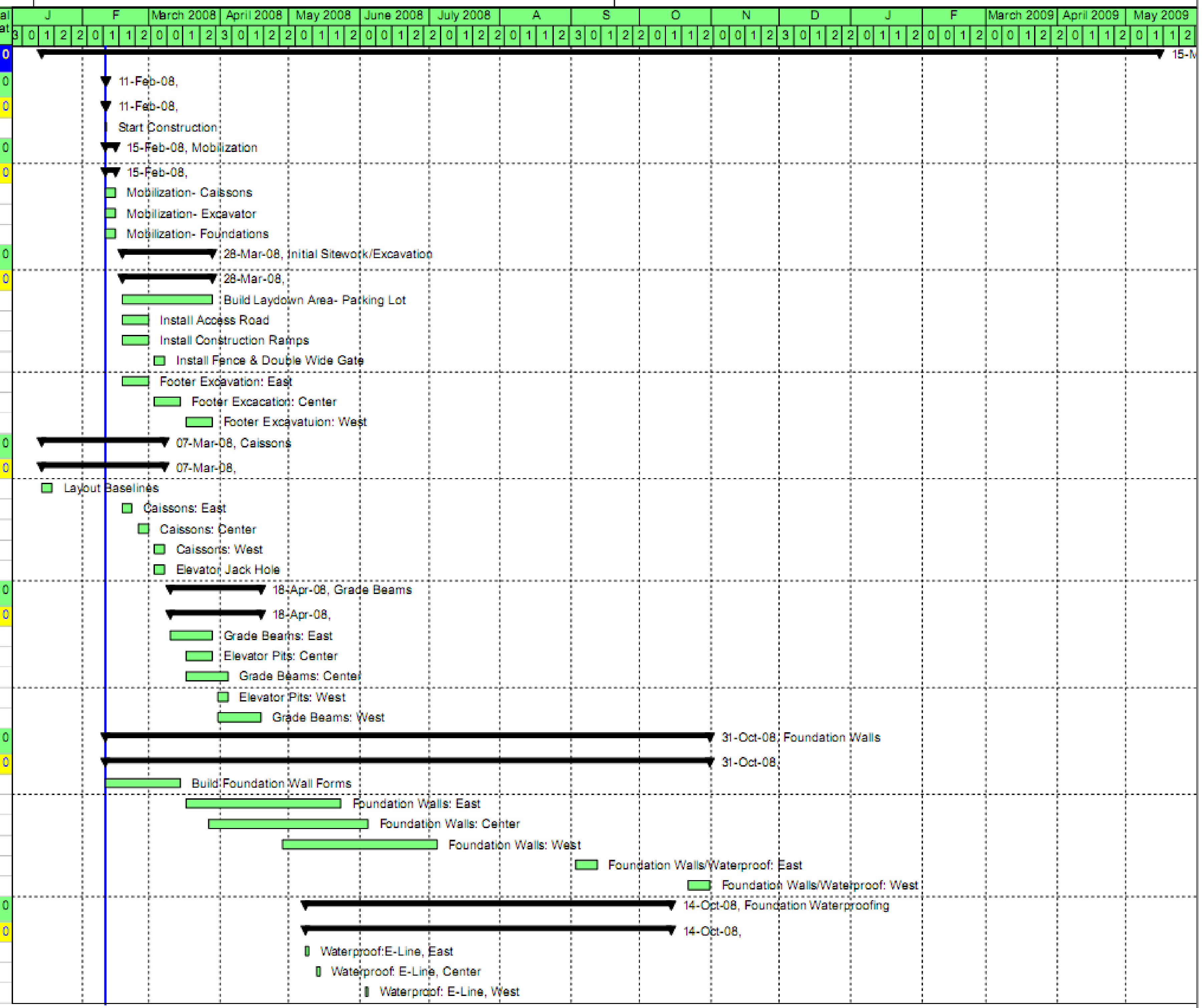
Project: Summary Schedule
Date: Sun 10/4/09

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

Page 1

DETAILED PROJECT SCHEDULE

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
	Westinghouse	350	14-Jan-08	15-May-09	0
		1	11-Feb-08	11-Feb-08	0
		1	11-Feb-08	11-Feb-08	0
A1C	Start Construction	1	11-Feb-08	11-Feb-08	
	Mobilization	5	11-Feb-08	15-Feb-08	0
		5	11-Feb-08	15-Feb-08	0
A1C	Mobilization- Caissons	5	11-Feb-08	15-Feb-08	
A1C	Mobilization- Excavator	5	11-Feb-08	15-Feb-08	
A1C	Mobilization- Foundations	5	11-Feb-08	15-Feb-08	
	Initial Sitework/Excavation	30	18-Feb-08	28-Mar-08	0
		30	18-Feb-08	28-Mar-08	0
A1C	Build Laydown Area- Parkin...	30	18-Feb-08*	28-Mar-08	
A1C	Install Access Road	10	18-Feb-08*	29-Feb-08	
A1C	Install Construction Ramps	10	18-Feb-08*	29-Feb-08	
A1C	Install Fence & Double Wid...	5	03-Mar-08*	07-Mar-08	
A1C	Footer Excavation: East	10	18-Feb-08*	29-Feb-08	
A1C	Footer Excacation: Center	10	03-Mar-08*	14-Mar-08	
A11	Footer Excavatuion: West	10	17-Mar-08*	28-Mar-08	
	Caissons	40	14-Jan-08	07-Mar-08	0
		40	14-Jan-08	07-Mar-08	0
A11	Layout Baselines	5	14-Jan-08*	18-Jan-08	
A11	Caissons: East	5	18-Feb-08*	22-Feb-08	
A11	Caissons: Center	5	25-Feb-08*	29-Feb-08	
A11	Caissons: West	5	03-Mar-08*	07-Mar-08	
A11	Elevator Jack Hole	5	03-Mar-08*	07-Mar-08	
	Grade Beams	30	10-Mar-08	18-Apr-08	0
		30	10-Mar-08	18-Apr-08	0
A11	Grade Beams: East	15	10-Mar-08*	28-Mar-08	
A11	Elevator Pits: Center	10	17-Mar-08*	28-Mar-08	
A11	Grade Beams: Center	15	17-Mar-08*	04-Apr-08	
A11	Elevator Pits: West	5	31-Mar-08*	04-Apr-08	
A12	Grade Beams: West	15	31-Mar-08*	18-Apr-08	
	Foundation Walls	190	11-Feb-08	31-Oct-08	0
		190	11-Feb-08	31-Oct-08	0
A12	Build Foundation Wall Forms	25	11-Feb-08	14-Mar-08	
A12	Foundation Walls: East	50	17-Mar-08*	23-May-08	
A12	Foundation Walls: Center	50	27-Mar-08*	04-Jun-08	
A12	Foundation Walls: West	50	28-Apr-08*	04-Jul-08	
A12	Foundation Walls/Waterpro...	8	03-Sep-08*	12-Sep-08	
A12	Foundation Walls/Waterpro...	8	22-Oct-08*	31-Oct-08	
	Foundation Waterproofing	114	08-May-08	14-Oct-08	0
		114	08-May-08	14-Oct-08	0
A12	Waterproof:E-Line, East	2	08-May-08*	09-May-08	
A12	Waterproof: E-Line, Center	2	13-May-08*	14-May-08	
A12	Waterproof: E-Line, West	2	03-Jun-08*	04-Jun-08	

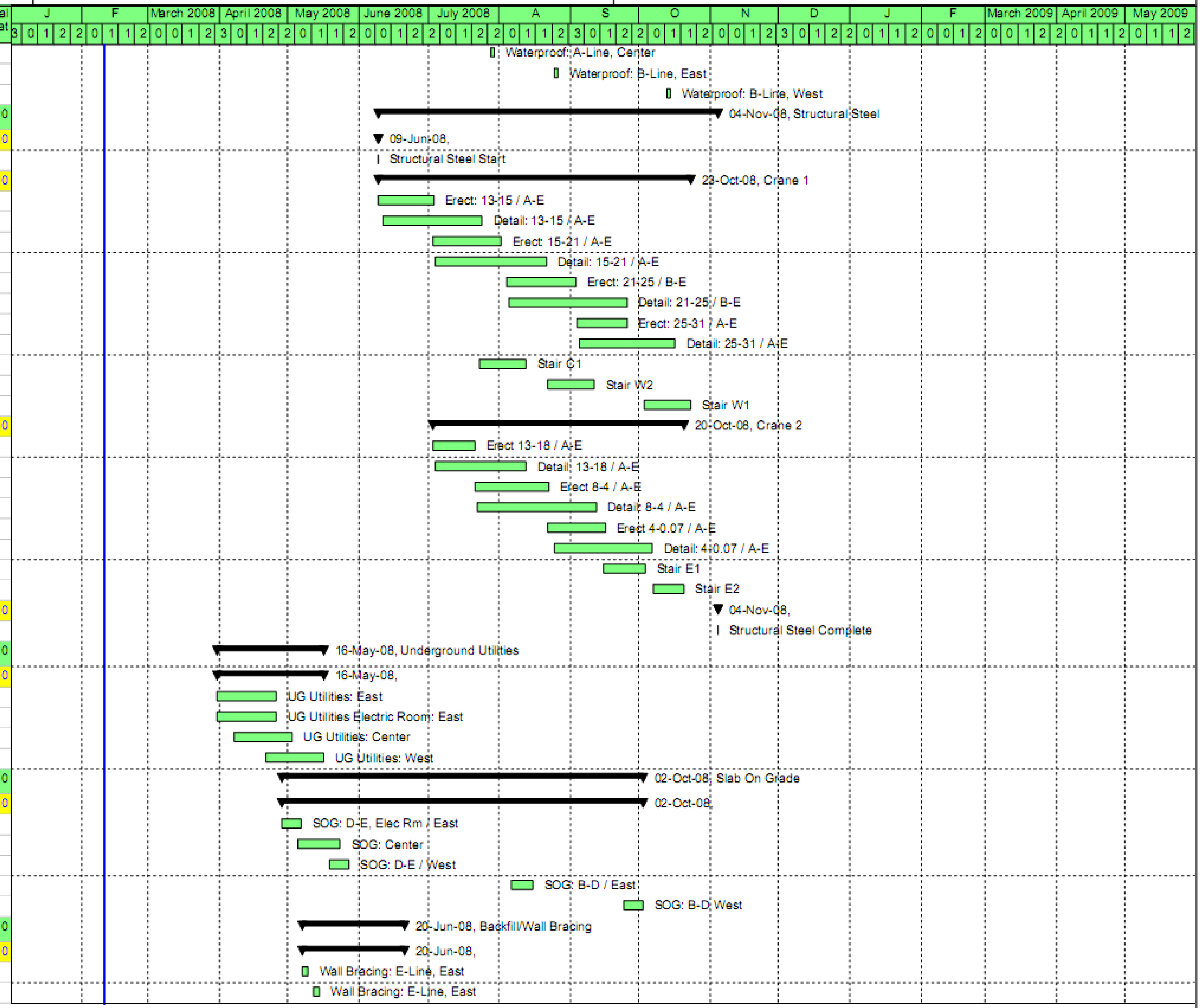


Westinghouse Electric Company Nuclear Power Engineering Headquarters Campus

Mark Speicher

Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A13	Waterproof: A-Line, Center	2	28-Jul-08*	29-Jul-08	
A13	Waterproof: B-Line, East	2	25-Aug-08*	26-Aug-08	
A13	Waterproof: B-Line, West	2	13-Oct-08*	14-Oct-08	
	Structural Steel	106	09-Jun-08	04-Nov-08	0
		0	09-Jun-08	09-Jun-08	0
A13	Structural Steel Start	0	09-Jun-08*	09-Jun-08	
	Crane 1	99	09-Jun-08	23-Oct-08	0
A13	Erect: 13-15 / A-E	19	09-Jun-08*	03-Jul-08	
A13	Detail: 13-15 / A-E	32	11-Jun-08*	24-Jul-08	
A13	Erect: 15-21 / A-E	22	03-Jul-08*	01-Aug-08	
A13	Detail: 15-21 / A-E	35	04-Jul-08*	21-Aug-08	
A13	Erect: 21-25 / B-E	23	04-Aug-08*	03-Sep-08	
A13	Detail: 21-25 / B-E	38	05-Aug-08*	25-Sep-08	
A14	Erect: 25-31 / A-E	16	04-Sep-08*	25-Sep-08	
A14	Detail: 25-31 / A-E	30	05-Sep-08*	16-Oct-08	
A14	Stair C1	15	23-Jul-08*	12-Aug-08	
A14	Stair W2	15	22-Aug-08*	11-Sep-08	
A14	Stair W1	15	03-Oct-08*	23-Oct-08	
	Crane 2	78	03-Jul-08	20-Oct-08	0
A14	Erect 13-18 / A-E	13	03-Jul-08*	21-Jul-08	
A14	Detail: 13-18 / A-E	28	04-Jul-08*	12-Aug-08	
A14	Erect 8-4 / A-E	25	21-Jul-08*	22-Aug-08	
A14	Detail: 8-4 / A-E	39	22-Jul-08*	12-Sep-08	
A14	Erect 4-0.07 / A-E	18	22-Aug-08*	16-Sep-08	
A15	Detail: 4-0.07 / A-E	31	25-Aug-08*	06-Oct-08	
A15	Stair E1	15	15-Sep-08*	03-Oct-08	
A15	Stair E2	10	07-Oct-08*	20-Oct-08	
		0	04-Nov-08	04-Nov-08	0
A15	Structural Steel Complete	0	04-Nov-08*	04-Nov-08	
	Underground Utilities	35	31-Mar-08	16-May-08	0
		35	31-Mar-08	16-May-08	0
A15	UG Utilities: East	20	31-Mar-08*	25-Apr-08	
A15	UG Utilities Electric Room: ...	20	31-Mar-08*	25-Apr-08	
A15	UG Utilities: Center	20	07-Apr-08*	02-May-08	
A15	UG Utilities: West	20	21-Apr-08*	16-May-08	
	Slab On Grade	114	28-Apr-08	02-Oct-08	0
		114	28-Apr-08	02-Oct-08	0
A15	SOG: D-E, Elec Rm / East	7	28-Apr-08*	06-May-08	
A15	SOG: Center	15	05-May-08*	23-May-08	
A16	SOG: D-E / West	7	19-May-08*	27-May-08	
A16	SOG: B-D / East	8	06-Aug-08*	15-Aug-08	
A16	SOG: B-D West	7	24-Sep-08*	02-Oct-08	
	Backfill/Wall Bracing	33	07-May-08	20-Jun-08	0
		33	07-May-08	20-Jun-08	0
A16	Wall Bracing: E-Line, East	3	07-May-08*	09-May-08	
A16	Wall Bracing: E-Line, East	3	12-May-08*	14-May-08	

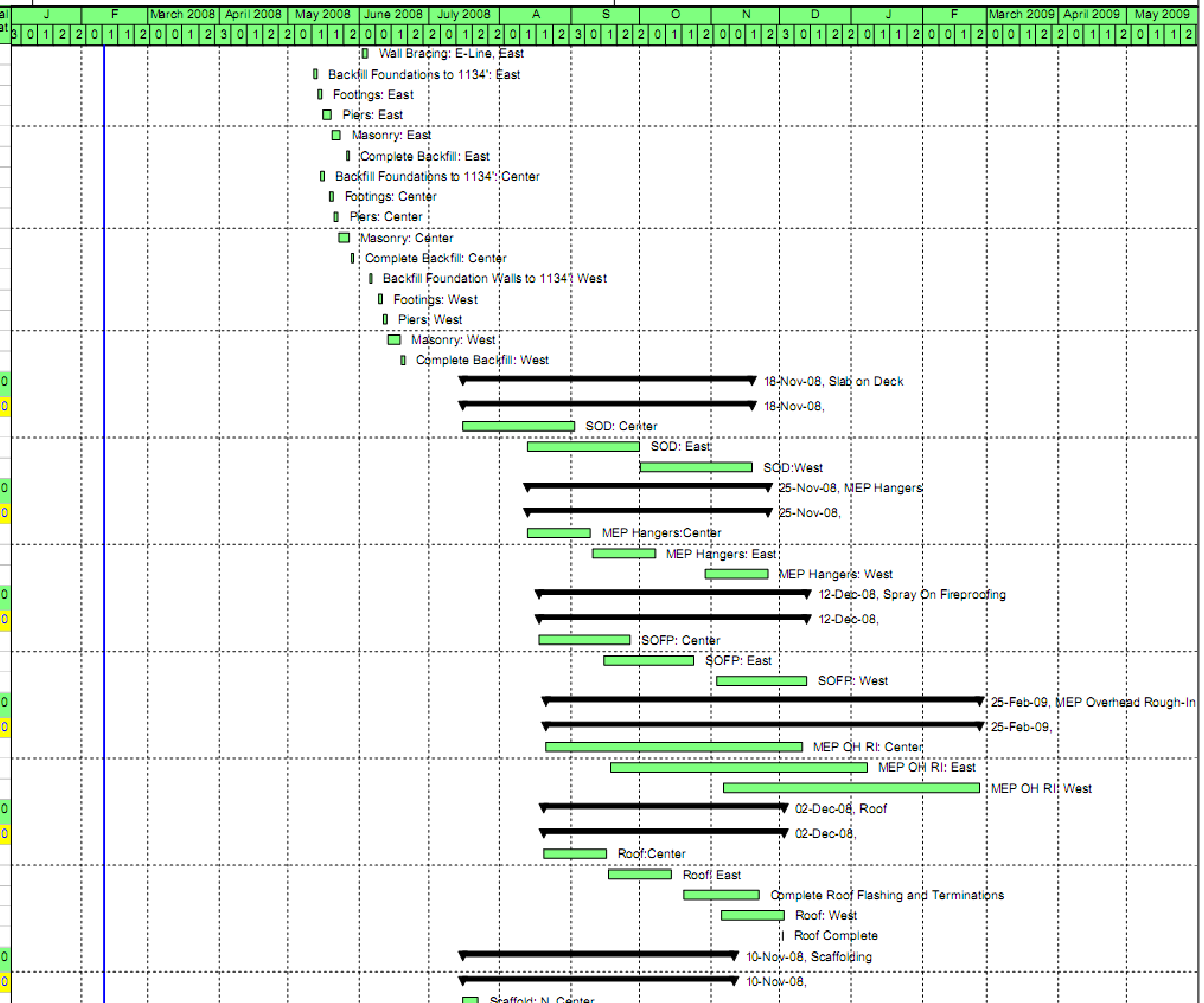


Westinghouse Electric Company Nuclear Power Engineering Headquarters Campus

Mark Speicher

Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A16	Wall Bracing: E-Line, East	3	02-Jun-08*	04-Jun-08	
A16	Backfill Foundations to 113...	2	12-May-08*	13-May-08	
A17	Footings: East	2	14-May-08*	15-May-08	
A17	Piers: East	2	16-May-08*	19-May-08	
A17	Masonry: East	4	20-May-08*	23-May-08	
A17	Complete Backfill: East	2	26-May-08*	27-May-08	
A17	Backfill Foundations to 113...	2	15-May-08*	16-May-08	
A17	Footings: Center	2	19-May-08*	20-May-08	
A17	Piers: Center	2	21-May-08*	22-May-08	
A17	Masonry: Center	3	23-May-08*	27-May-08	
A17	Complete Backfill: Center	2	28-May-08*	29-May-08	
A17	Backfill Foundation Walls to...	2	05-Jun-08*	06-Jun-08	
A18	Footings: West	2	09-Jun-08*	10-Jun-08	
A18	Piers: West	2	11-Jun-08*	12-Jun-08	
A18	Masonry: West	4	13-Jun-08*	18-Jun-08	
A18	Complete Backfill: West	2	19-Jun-08*	20-Jun-08	
Slab on Deck		90	16-Jul-08	18-Nov-08	0
		90	16-Jul-08	18-Nov-08	0
A18	SOD: Center	35	16-Jul-08*	02-Sep-08	
A18	SOD: East	35	13-Aug-08*	30-Sep-08	
A18	SOD:West	35	01-Oct-08*	18-Nov-08	
MEP Hangers		75	13-Aug-08	25-Nov-08	0
		75	13-Aug-08	25-Nov-08	0
A18	MEP Hangers:Center	20	13-Aug-08*	09-Sep-08	
A18	MEP Hangers: East	20	10-Sep-08*	07-Oct-08	
A18	MEP Hangers: West	20	29-Oct-08*	25-Nov-08	
Spray On Fireproofing		85	18-Aug-08	12-Dec-08	0
		85	18-Aug-08	12-Dec-08	0
A19	SOFP: Center	30	18-Aug-08*	26-Sep-08	
A19	SOFP: East	30	15-Sep-08*	24-Oct-08	
A19	SOFP: West	30	03-Nov-08*	12-Dec-08	
MEP Overhead Rough-In		135	21-Aug-08	25-Feb-09	0
		135	21-Aug-08	25-Feb-09	0
A19	MEP OH RI: Center	80	21-Aug-08*	10-Dec-08	
A19	MEP OH RI: East	80	18-Sep-08*	07-Jan-09	
A19	MEP OH RI: West	80	06-Nov-08*	25-Feb-09	
Roof		75	20-Aug-08	02-Dec-08	0
		75	20-Aug-08	02-Dec-08	0
A19	Roof:Center	20	20-Aug-08*	16-Sep-08	
A19	Roof: East	20	17-Sep-08*	14-Oct-08	
A19	Complete Roof Flashing an...	25	20-Oct-08*	21-Nov-08	
A19	Roof: West	20	05-Nov-08*	02-Dec-08	
A20	Roof Complete	0	02-Dec-08*	02-Dec-08	
Scaffolding		84	16-Jul-08	10-Nov-08	0
		84	16-Jul-08	10-Nov-08	0
A20	Scaffold: N. Center	5	16-Jul-08*	22-Jul-08	

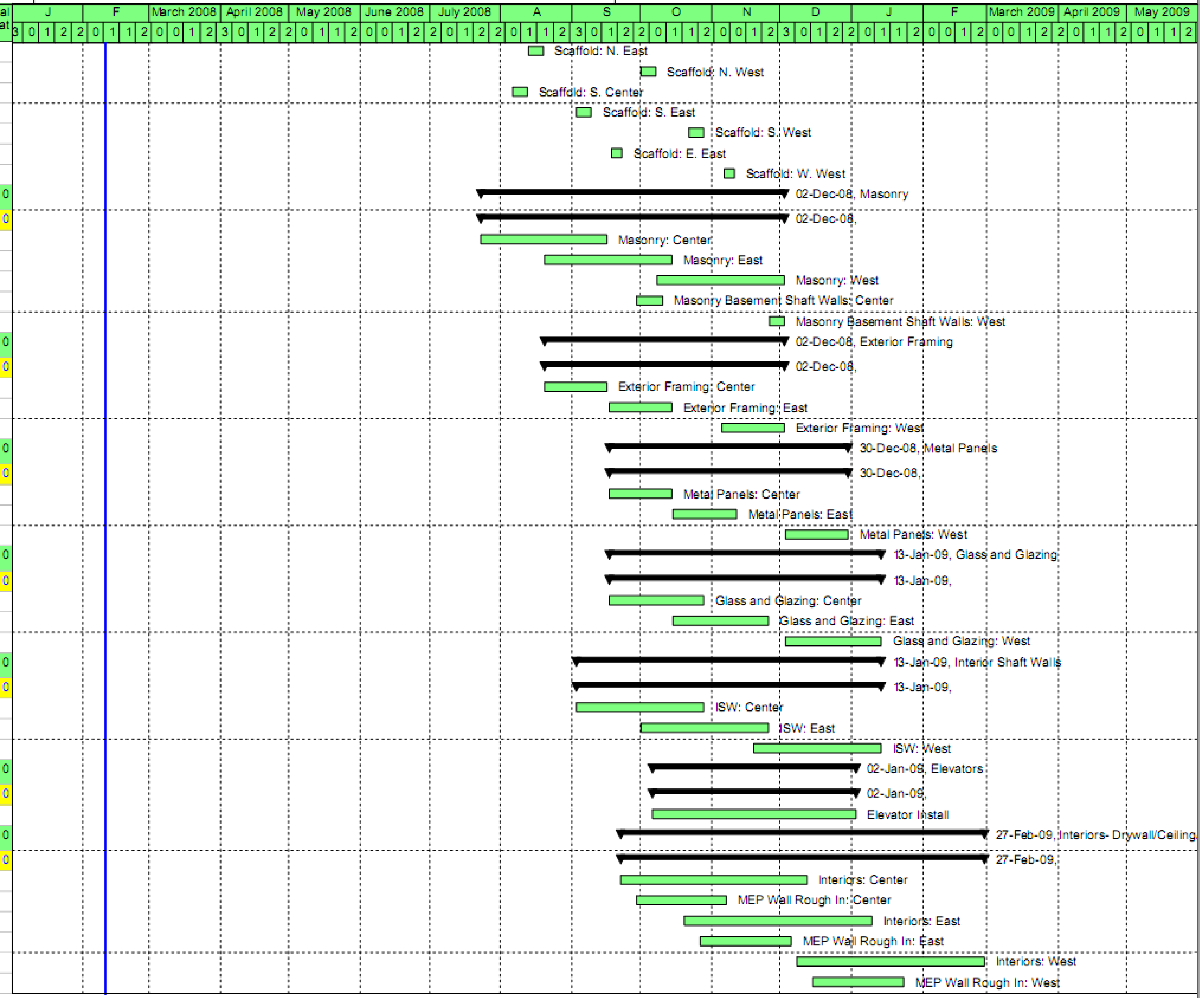


Westinghouse Electric Company Nuclear Power Engineering Headquarters Campus

Mark Speicher

Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

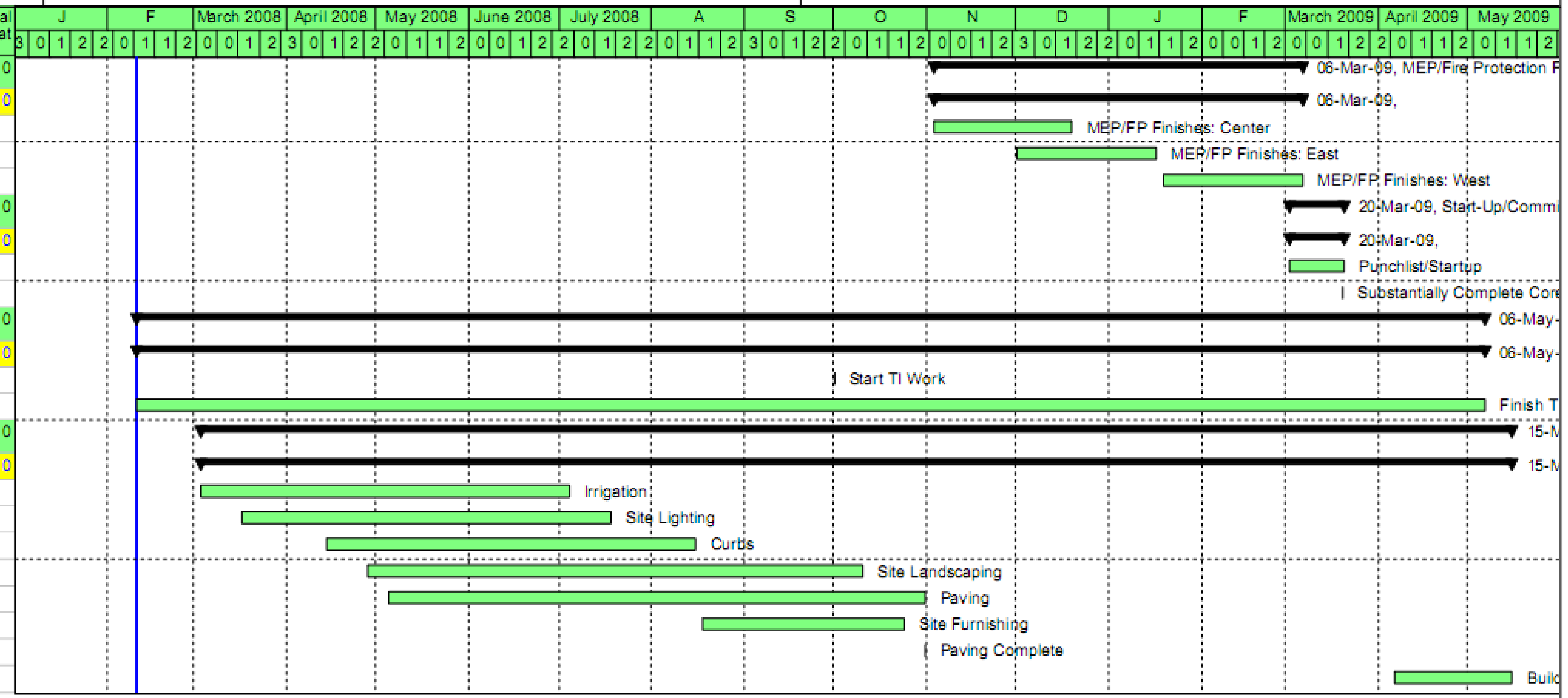
Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
A20	Scaffold: N. East	5	13-Aug-08*	19-Aug-08	
A20	Scaffold: N. West	5	01-Oct-08*	07-Oct-08	
A20	Scaffold: S. Center	5	06-Aug-08*	12-Aug-08	
A20	Scaffold: S. East	5	03-Sep-08*	09-Sep-08	
A20	Scaffold: S. West	5	22-Oct-08*	28-Oct-08	
A20	Scaffold: E. East	3	18-Sep-08*	22-Sep-08	
A20	Scaffold: W. West	3	06-Nov-08*	10-Nov-08	
Masonry		95	23-Jul-08	02-Dec-08	0
		95	23-Jul-08	02-Dec-08	0
A20	Masonry: Center	40	23-Jul-08*	16-Sep-08	
A21	Masonry: East	40	20-Aug-08*	14-Oct-08	
A21	Masonry: West	40	08-Oct-08*	02-Dec-08	
A21	Masonry Basement Shaft W...	10	29-Sep-08*	10-Oct-08	
A21	Masonry Basement Shaft W...	5	26-Nov-08*	02-Dec-08	
Exterior Framing		75	20-Aug-08	02-Dec-08	0
		75	20-Aug-08	02-Dec-08	0
A21	Exterior Framing: Center	20	20-Aug-08*	16-Sep-08	
A21	Exterior Framing: East	20	17-Sep-08*	14-Oct-08	
A21	Exterior Framing: West	20	05-Nov-08*	02-Dec-08	
Metal Panels		75	17-Sep-08	30-Dec-08	0
		75	17-Sep-08	30-Dec-08	0
A21	Metal Panels: Center	20	17-Sep-08*	14-Oct-08	
A21	Metal Panels: East	20	15-Oct-08*	11-Nov-08	
A21	Metal Panels: West	20	03-Dec-08*	30-Dec-08	
Glass and Glazing		85	17-Sep-08	13-Jan-09	0
		85	17-Sep-08	13-Jan-09	0
A22	Glass and Glazing: Center	30	17-Sep-08*	28-Oct-08	
A22	Glass and Glazing: East	30	15-Oct-08*	25-Nov-08	
A22	Glass and Glazing: West	30	03-Dec-08*	13-Jan-09	
Interior Shaft Walls		95	03-Sep-08	13-Jan-09	0
		95	03-Sep-08	13-Jan-09	0
A16	ISW: Center	40	03-Sep-08*	28-Oct-08	
A16	ISW: East	40	01-Oct-08*	25-Nov-08	
A16	ISW: West	40	19-Nov-08*	13-Jan-09	
Elevators		65	06-Oct-08	02-Jan-09	0
		65	06-Oct-08	02-Jan-09	0
A22	Elevator Install	65	06-Oct-08*	02-Jan-09	
Interiors- Drywall/Ceiling/P...		115	22-Sep-08	27-Feb-09	0
		115	22-Sep-08	27-Feb-09	0
A22	Interiors: Center	60	22-Sep-08*	12-Dec-08	
A22	MEP Wall Rough In: Center	30	29-Sep-08*	07-Nov-08	
A22	Interiors: East	60	20-Oct-08*	09-Jan-09	
A22	MEP Wall Rough In: East	30	27-Oct-08*	05-Dec-08	
A22	Interiors: West	60	08-Dec-08*	27-Feb-09	
A22	MEP Wall Rough In: West	30	15-Dec-08*	23-Jan-09	



Westinghouse Electric Company Nuclear Power Engineering Headquarters Campus

Mark Speicher

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
	MEP/Fire Protection Finish...	90	03-Nov-08	06-Mar-09	0
		90	03-Nov-08	06-Mar-09	0
A23	MEP/FP Finishes: Center	35	03-Nov-08*	19-Dec-08	
A23	MEP/FP Finishes: East	35	01-Dec-08*	16-Jan-09	
A23	MEP/FP Finishes: West	35	19-Jan-09*	06-Mar-09	
	Start-Up/Commissioning/P...	15	02-Mar-09	20-Mar-09	0
		15	02-Mar-09	20-Mar-09	0
A23	Punchlist/Startup	15	02-Mar-09*	20-Mar-09	
A23	Substantially Complete Cor...	0	20-Mar-09*	20-Mar-09	
	Tenant Improvements	323	11-Feb-08	06-May-09	0
		323	11-Feb-08	06-May-09	0
A23	Start TI Work	0	01-Oct-08*	01-Oct-08	
A23	Finish TI Work	323	11-Feb-08	06-May-09	
	Sitework/Landscaping	315	03-Mar-08	15-May-09	0
		315	03-Mar-08	15-May-09	0
A23	Irrigation	90	03-Mar-08*	04-Jul-08	
A23	Site Lighting	90	17-Mar-08*	18-Jul-08	
A23	Curbs	90	14-Apr-08*	15-Aug-08	
A24	Site Landscaping	120	28-Apr-08*	10-Oct-08	
A24	Paving	130	05-May-08*	31-Oct-08	
A24	Site Furnishing	50	18-Aug-08*	24-Oct-08	
A24	Paving Complete	1	31-Oct-08*	31-Oct-08	
A24	Building Landscaping	30	06-Apr-09*	15-May-09	



Westinghouse Electric Company Nuclear Power Engineering Headquarters Campus

Mark Speicher

Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

APPENDIX C: PROJECT COST INFORMATION

STRUCTURAL SYSTEM TAKEOFFS AND CALCULATIONS

Concrete Takeoffs

Caissons					
Diameter	Depth	Volume	Diameter	Depth	Volume
78	12.17	44.86	36	22.167	17.41
78	18.67	68.84	36	22.167	17.41
66	20.17	53.24	42	25.67	27.44
36	20.67	16.23	36	29.67	23.30
36	21.67	17.02	42	31.167	33.32
84	22.67	96.94	66	12	31.68
84	16.67	71.28	66	15	39.60
84	18.17	77.68	66	18	47.52
48	23.67	33.05	66	21	55.44
42	27.67	29.58	66	22	58.08
42	28.17	30.11	36	19.67	15.45
36	29.67	23.30	36	13.67	10.74
72	14.67	46.09	36	13.67	10.74
84	18.67	79.83	42	14.67	15.68
84	19.17	81.96	36	12.167	9.56
48	22.67	31.65	36	12.167	9.56
36	28.67	22.52	66	12.167	32.12
54	30.67	54.20	48	13.67	19.09
66	14.67	38.73	36	7.67	6.02
66	16.67	44.01	48	13.5	18.85
36	12.5	9.82	48	25.5	35.60
36	18.5	14.53	30	31.167	17.00
36	16.5	12.96	78	30.167	111.23
36	19.5	15.32	78	29.167	107.54
36	24.67	19.38	30	28.167	15.36
36	30.67	24.09	54	18.67	32.99
36	30.17	23.69	54	24.67	43.60
36	11.67	9.17	66	8	21.12
36	16.67	13.09	66	8	21.12
36	17.67	13.88	66	8	21.12
72	18.17	57.07	66	8	21.12
72	21.67	68.08	66	8	21.12
66	22.17	58.52			
Total Volume			**2268.59**		

Footings			
Volume (CF)	Volume (CY)	Quantity	Total Volume
432	48	14	672
37.5	4.17	2	8.33333
507	56.33	11	619.667
562.77	62.53	2	125.06
294.37	32.71	2	65.4156
432	48	2	96
50.52	5.61	2	11.2267
170.88	18.99	22	417.707
210.2825	23.36	1	23.3647
267	29.67	10	296.667
342.83	38.09	2	76.1844
Total			**2411.6**

Slabs						
Location	Area	Thickness	Cubic Yards	SFCA	Reinforcing	Deck
SOG	74022	5	3427	588	6x6 W2.1xW2.1 WWF	
1	74022	2.5	1713	294	6x6 W2.1xW2.1 WWF	2" 22 Ga. Comp.
2	74022	2.5	1713	294	6x6 W2.1xW2.1 WWF	2" 22 Ga. Comp.
3	74022	2.5	1713	294	6x6 W2.1xW2.1 WWF	2" 22 Ga. Comp.
4	74022	2.5	1713	294	6x6 W2.1xW2.1 WWF	2" 22 Ga. Comp.
5	74022	2.5	1713	294	6x6 W2.1xW2.1 WWF	2" 22 Ga. Comp.

Concrete Calculations

Concrete Forming					
Elevated Slabs, 1 use					
Location	Square Footage	Material Cost/SF	Labor Cost/SF	Total Cost/SF	Cost
1	74022	$ 2.92	$ 3.39	$ 6.31	$ 467,079
2	74022	$ 2.92	$ 3.39	$ 6.31	$ 467,079
3	74022	$ 2.92	$ 3.39	$ 6.31	$ 467,079
4	74022	$ 2.92	$ 3.39	$ 6.31	$ 467,079
5	74022	$ 2.92	$ 3.39	$ 6.31	$ 467,079
Total	**370110**				**$ 2,335,394**
Slab on Grade, 1 use					
Location	SFCA	Material Cost/SF	Labor Cost/SF	Total Cost/SF	Cost
Base	**7055**	**$ 2.83**	**$ 5.65**	**$ 8.48**	**$ 59,826**
Footings, 4 use					
Location	SFCA	Material Cost/SF	Labor Cost/SF	Total Cost/SF	Cost
Base		$ 2.42	$ 2.50	$ 4.92	$ -
Total				**$2,395,221**	

Reinforcing Steel					
Welded Wire Fabric, 6 x 6-W2.1 x W2.1					
Location	C.S.F.	Material Cost/SF	Labor Cost/SF	Total Cost/SF	Cost
SOG	740.22	$ 26.50	$ 23.00	$ 49.50	$ 36,641
1	740.22	$ 26.50	$ 23.00	$ 49.50	$ 36,641
2	740.22	$ 26.50	$ 23.00	$ 49.50	$ 36,641
3	740.22	$ 26.50	$ 23.00	$ 49.50	$ 36,641
4	740.22	$ 26.50	$ 23.00	$ 49.50	$ 36,641
5	740.22	$ 26.50	$ 23.00	$ 49.50	$ 36,641
Total					**$ 219,845**
Reinforcing Steel					
	Tons	Material Cost/SF	Labor Cost/SF	Total Cost/SF	Cost
Footings	23.819	$ 1,400.00	$ 395.00	$ 1,795.00	$ 42,755.11
Caissons	7.34	$ 1,575.00	$ 680.00	$ 2,255.00	$ 16,551.70
Total					**$ 59,307**

Structural Concrete			
Type	Cubic Yards	Cost/CY	Total Cost
Caissons	2268.59	$ 106.00	$ 240,471
Footings	2411.6	$ 106.00	$ 255,630
Slabs	1194	$ 106.00	$ 126,564
Total			$ 622,664

Placing Concrete					
	Cubic Yards	Labor Cost/CY	Equipment Cost/CY	Total Cost/CY	Total Cost
Elevated Slabs, less than 6", pumped	8567	$ 15.50	$ 5.65	$ 21.15	$ 181,192
Footings, spread, direct chute	2411.6	$ 13.20	$ 0.43	$ 13.63	$ 32,870
Slab on Grade, up to 6" direct chute	3427	$ 14.40	$ 0.47	$ 14.87	$ 50,959
Total					**$265,022**

Steel Takeoffs/Calculations

Beams							
Length of Member	Quantity	Total Linear Feet	Unit Cost ($/LF)			Total	Total Cost
			Material	Labor	Equipment		
12	6	72	91	3.18	1.69	95.87	$ 6,903
12.33	18	221.94	91	3.18	1.69	95.87	$ 21,277
12.5	4	50	91	3.18	1.69	95.87	$ 4,794
14	12	168	91	3.18	1.69	95.87	$ 16,106
15	3	45	91	3.18	1.69	95.87	$ 4,314
18	14	252	91	3.18	1.69	95.87	$ 24,159
20	14	280	91	3.18	1.69	95.87	$ 26,844
20.5	4	82	91	3.18	1.69	95.87	$ 7,861
22.5	24	540	91	3.18	1.69	95.87	$ 51,770
24	111	2664	91	3.18	1.69	95.87	$ 255,398
25	5	125	91	3.18	1.69	95.87	$ 11,984
25.67	18	462.06	91	3.18	1.69	95.87	$ 44,298
26	4	104	91	3.18	1.69	95.87	$ 9,970
29	2	58	91	3.18	1.69	95.87	$ 5,560
32	21	672	91	3.18	1.69	95.87	$ 64,425
35	6	210	91	3.18	1.69	95.87	$ 20,133
36	82	2952	91	3.18	1.69	95.87	$ 283,008
39	2	78	91	3.18	1.69	95.87	$ 7,478
42	2	84	91	3.18	1.69	95.87	$ 8,053
45	79	3555	91	3.18	1.69	95.87	$ 340,818
TOTAL							**$ 6,075,761**

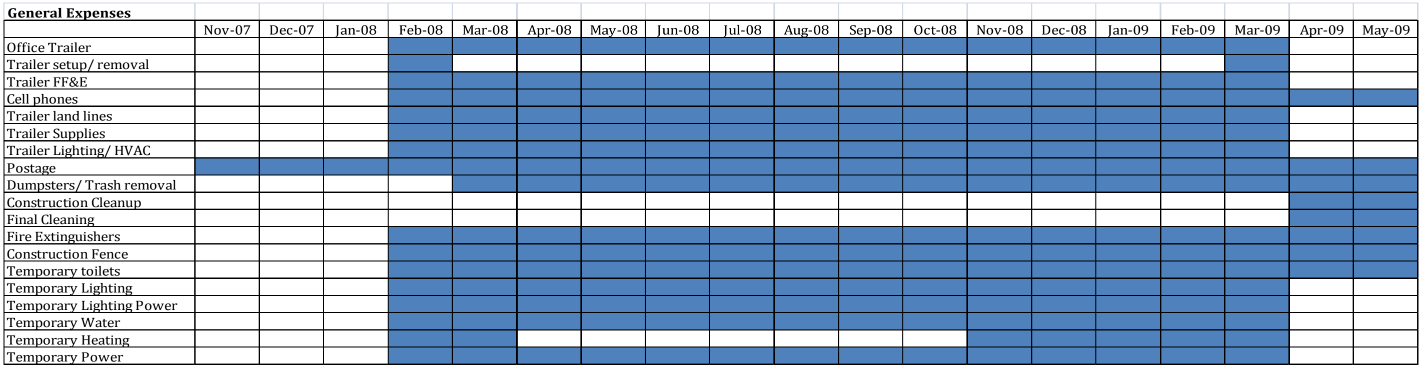
Steel Columns

Size	Linear Feet	Tons	Unit Cost ($/ton)			Unit Cost ($/ton)	Cost
			Material	Labor	Equipment		
W14x49	252	12348	1.65	0.023	0.017	1.69	$ 20,868
W14x68	144	9792	1.65	0.023	0.017	1.69	$ 16,548
W14x90	2726	245340	1.65	0.023	0.017	1.69	$ 414,625
W14x100	728	72800	1.65	0.023	0.017	1.69	$ 123,032
W14x120	784	94080	1.65	0.023	0.017	1.69	$ 158,995
W14x193	306	59058	1.65	0.023	0.017	1.69	$ 99,808
W14x211	980	206780	1.65	0.023	0.017	1.69	$ 349,458
TOTAL							**$ 1,183,335**

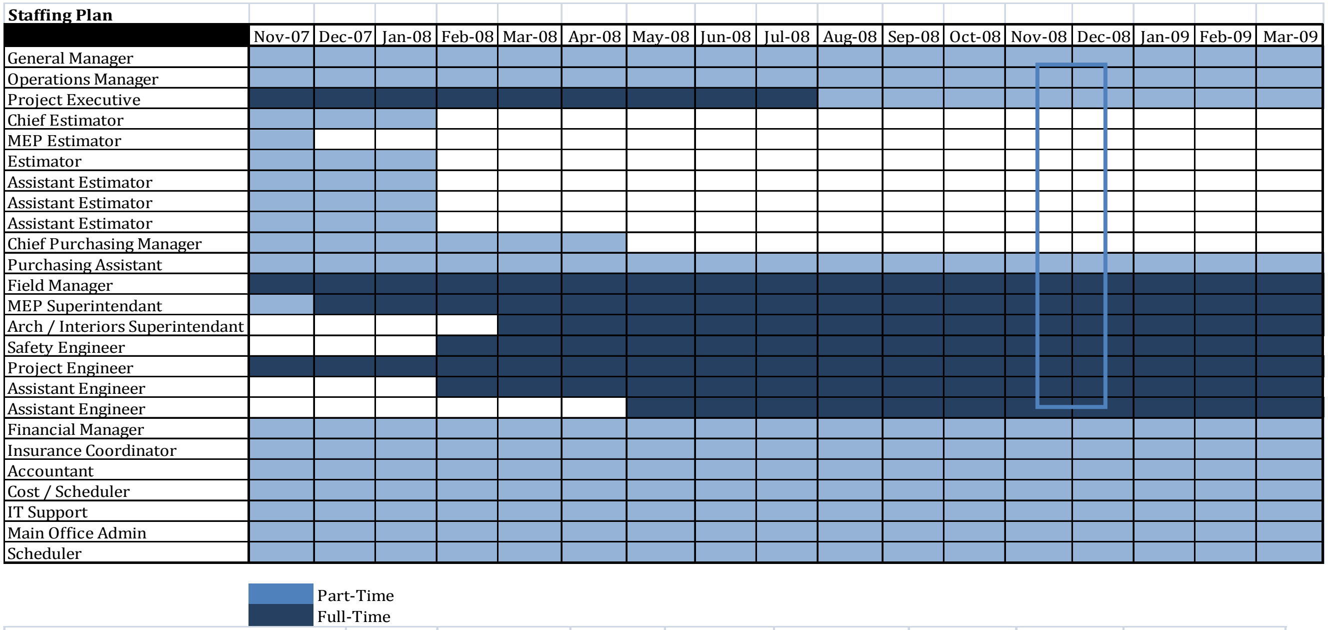
Unit Cost per Ton from RS Means

	Material	Labor	Equipment	Total
W14x74	1.65	0.034	0.024	1.71
W14x120	1.65	0.021	0.015	1.69
W14x176	1.65	0.015	0.011	1.67
Average	**1.649**	**0.023**	**0.017**	**1.689**

GENERAL CONDITIONS TAKEOFFS AND CALCULATIONS



General Expenses					
	Quantity	Months	Units	Unit Price	Total
Office Trailer	4	14	$/Month	$ 281	$ 15,736
Trailer setup/ removal	4	14	Each	$ 3,200	$ 12,800
Trailer FF&E	4	14	$/Month	$ 155	$ 8,680
Cell phones	8	16	$/Month	$ 200	$ 25,600
Trailer land lines	4	14	$/Month	$ 80	$ 4,480
Trailer Supplies	4	14	$/Month	$ 85	$ 4,760
Trailer Lighting/ HVAC	4	14	$/Month	$ 150	$ 8,400
	Quantity	Weeks	Units	Unit Price	Total
Dumpsters/ Trash removal	4	48	Weeks	$ 775	$ 148,800
Construction Cleanup	435	8	MSF	$ 27	$ 11,845
Fire Extinguishers	20	64	EA	$ 159	$ 3,180
Construction Fence	4264	64	LF	$ 9	$ 40,252
Temporary Toilets	8	64	EA	$ 150	$ 19,200
Temporary Utilities					
	Quantity	Months	Units	Unit Price	Total
Temporary Lighting	2000	16	CSF Flr	$ 14	$ 27,360
Temporary Lighting Power	2000	16	CSF Flr/Mo	$ 1	$ 24,000
Temporary Water	-	16	Month	$ 62	$ 992
Temporary Heating	2000	7	CSF Flr/Wk	$ 30	$ 1,695,120
Temporary Power	2000	11	CSF Fl	$ 47	$ 94,000
Fees and Permits					
	Quantity	Months	Units	Unit Price	Total
Insurance, Builders risk	$ 240,000,000	16	Job	0.24%	576000
Performance bond	$ 240,000,000	16	Job	2.50%	6000000
Permits, Rule of thumb	$ 240,000,000	16	Job	0.50%	1200000
Total					**$ 9,921,205**



Staffing

	Qty	Weeks (full-time)	Hours/ Week	Cost/ Week	Weeks (part-time)	Hours/ Week	Cost/ Week	Total
General Manager	1	0	40	$ 2,500	68	15	$ 938	$ 63,750
Operations Manager	1	0	40	$ 2,500	68	15	$ 938	$ 63,750
Project Executive	1	36	40	$ 2,175	32	15	$ 816	$ 104,400
Chief Estimator	1	0	40	$ 1,350	12	20	$ 675	$ 8,100
MEP Estimator	1	0	40	$ 1,165	4	20	$ 583	$ 2,330
Estimator	1	0	40	$ 1,165	12	20	$ 583	$ 6,990
Assistant Estimator	3	0	40	$ 1,000	12	20	$ 500	$ 6,000
Chief Purchasing Manager	1	0	40	$ 1,350	24	15	$ 506	$ 12,150
Purchasing Assistant	1	0	40	$ 1,165	68	15	$ 437	$ 29,708
Field Manager	1	68	40	$ 1,925	0	0	$ -	$ 130,900
MEP Superintendant	1	64	40	$ 1,775	4	20	$ 888	$ 117,150
Arch / Interiors Superintendant	1	52	40	$ 1,775	0	0	$ -	$ 92,300
Safety Engineer	1	56	40	$ 1,165	0	0	$ -	$ 65,240
Project Engineer	1	68	40	$ 1,350	0	0	$ -	$ 91,800
Assistant Engineer	1	56	40	$ 1,165	0	0	$ -	$ 65,240
Assistant Engineer	1	44	40	$ 1,165	0	0	$ -	$ 51,260
Financial Manager	1	0	40	$ 1,650	68	15	$ 619	$ 42,075
Insurance Coordinator	1	0	40	$ 1,165	68	15	$ 437	$ 29,708
Accountant	1	0	40	$ 1,165	68	15	$ 437	$ 29,708
Cost / Scheduler	1	0	40	$ 1,165	68	15	$ 437	$ 29,708
IT Support	1	0	40	$ 1,040	68	15	$ 390	$ 26,520
Main Office Admin	1	0	40	$ 2,175	68	15	$ 816	$ 55,463
Scheduler	1	0	40	$ 1,165	68	15	$ 437	$ 29,708
Total								**$ 1,153,955**

APPENDIX D: ANALYSIS 1 INFORMATION

SOLARBAN 80 WINDOW DATA

SOLARBAN®80
SOLAR CONTROL LOW-E GLASS

PPG IdeaScapes™
Glass • Coatings • Paint

Solarban® 80 glass, a high-performance, low-e glass, features versatile aesthetics, good visible light transmittance and unequaled solar control, all in a single product.

Aesthetic Description

On its own or teamed with ***Optiblue***® glass by PPG in an insulating glass unit, ***Solarban*** 80 glass creates a dynamic exterior aesthetic. In a clear/clear insulating unit, ***Solarban*** 80 glass on the second surface exhibits a steel-jade appearance if shaded from the sun and a bright reflective finish when bathed in direct sunlight.

In addition to this classic, familiar look, ***Solarban*** 80 glass can now be combined with ***Optiblue*** glass to produce three dynamic blue-green tints in the following configurations:

- ***Solarban*** *80 (2) on clear glass with an interior lite of* ***Optiblue*** glass produces a subtle green-gray aesthetic
- ***Solarban*** *80 (2) on* ***Optiblue*** *glass with a clear interior lite* displays a light, steely blue-green appearance
- ***Solarban*** *80 (2) on* ***Optiblue*** *glass with an* ***Optiblue*** *glass interior lite* reveals a deep steel-blue tint

Performance

Solarban 80 glass also is an environmental leader. When employed on the second surface in a one-inch insulating glass unit with clear glass, ***Solarban*** 80 glass combines an excellent solar heat gain coefficient (SHGC) of 0.24 with high visible light transmittance (VLT) of 48% to generate a light to solar gain (LSG) ratio of 1.98, one of the highest in the industry.

When teamed with ***Optiblue*** glass as an interior lite, the performance of ***Solarban*** 80 glass is equally impressive. In its green-gray configuration – on clear glass with an interior lite of ***Optiblue*** glass – ***Solarban*** 80 glass achieves visible light transmittance of 34% and a solar heat gain coefficient (SHGC) of 0.23.

In applications where a deeper color is desired, or daylight control is an issue, ***Solarban*** 80 coating on ***Optiblue*** glass with an ***Optiblue*** interior lite delivers exceptional solar heat gain coefficient in a stunning aesthetic. The dark steel-blue appearance produces visible light transmittance (VLT) of 25% and a solar heat gain coefficient (SHGC) of 0.20.

Even better solar control performance is realized when the ***Solarban*** 80 coating is applied to an ***Optiblue*** glass substrate and married to a clear glass interior lite. This pairing yields a light to solar gain (LSG) ratio of 1.70, with visible light transmittance (VLT) of 34% and an exceptional solar heat gain coefficient (SHGC) of 0.20.

Eight-Story Office Building, Window Wall Modeled Energy Savings

City	Annual Operating Expenses		Annual Savings	Total HVAC Equipment Cost		Immediate Equipment Savings	1st Year Savings
	SB60	SB80		SB60	SB80		
Atlanta	$633,108	$589,527	$43,581	$1,894,098	$1,651,357	$242,741	$286,32
Boston	$790,066	$748,550	$44,516	$2,123,627	$1,882,220	$241,407	$285,923
Chicago	$379,484	$357,409	$22,075	$1,898,094	$1,669,254	$228,840	$250,91
Denver	$405,496	$379,063	$26,433	$1,967,146	$1,729,022	$238,124	$264,55
Houston	$790,708	$743,861	$48,847	$1,939,134	$1,719,355	$219,829	$268,676
Los Angeles	$644,749	$598,741	$46,008	$2,027,546	$1,767,719	$259,827	$307,83
Mexico City	$729,290	$679,512	$49,778	$1,837,383	$1,608,947	$228,396	$278,174
Ottawa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Philadelphia	$394,141	$378,637	$15,504	$1,903,811	$1,667,658	$236,153	$251,65
Phoenix	$409,066	$387,519	$21,547	$1,972,002	$1,753,147	$218,856	$240,40
St. Louis	$328,689	$301,109	$19,580	$1,994,961	$1,747,709	$247,252	$266,83
Seattle	$307,774	$290,549	$17,225	$1,759,554	$1,550,431	$209,123	$226,34

Total Glass Area: 30,640 ft²

The chart above is taken from a study conducted by an independent energy and environmental research firm. It shows that ***Solarban*** *80 glass can dramatically reduce costs for cooling equipment while generating significant savings on annual cooling costs when compared with other industry-leading high-performance glasses such as* ***Solarban*** *60 Solar Control Low-E Glass.*

SOLARBAN® 80

SOLAR CONTROL LOW-E GLASS

Fabrication and Availability

PPG Certified Fabricator® Network

MSVD sputter-coated *Solarban* 80 glass and *Solarban* 80 *Optiblue* glasses can be annealed, heat-strengthened or tempered. All are available as standard products through more than 60 locations of the PPG Certified Fabricator Network. PPG Certified Fabricators can meet tight construction deadlines and accelerate the delivery of replacement glass before, during and after construction.

To locate a PPG Certified Fabricator in your area, visit www.ppgcfp.com or call 1-888-PPG-IDEA (774-4332).

Additional Resources

ecological Building Solutions™

Solarban 80 and *Solarban* 80 *Optiblue* glasses are part of the *EcoLogical Building Solutions* from PPG. For more information, or to obtain samples of these products, call 1-888-PPG-IDEA, or visit www.ppgideascapes.com. All PPG architectural glass is Cradle to Cradle Certified℠

PPG *IdeaScapes*™ Surface solutions to inspire your sustainable design and color vision.

Solarban 80 glass can be combined with clear and Optiblue glasses in an insulating glass unit to achieve four distinct aesthetics, including (from left to right), metallic green-gray (Solarban 80 clear with Optiblue interior lite), satin-reflective (Solarban 80 clear with clear), deep steel-blue (Solarban 80 Optiblue with Optiblue) and light steel-blue (Solarban 80 Optiblue with clear).

Photo Credit From Front:

Maria Parham Medical Center
Location: Henderson, NC
Products: Solarban® 80 glass
Architect: Wilmot Sanz
Glazing Contractor: SPS Corporation
Glass Fabricator: Vitro America

Solarban® 80 Glass Performance

Insulating Vision Unit Performance 1-inch (25mm) units with 1/2-inch (13mm) airspace and two 1/4-inch (6mm) lites; interior lite clear

Glass Type	Transmittance			Reflectance		U-Value (Imperial)		European U-Value	Shading Coefficient	Solar Heat Gain Coefficient	Light to Solar Gain (LSG)
	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time				
SOLARBAN® 80 Solar Control Low-E Glass											
SOLARBAN 80 (2) Clear + Clear	13	48	20	33	38	0.29	0.27	1.52	0.28	0.24	1.98
SOLARBAN 80 (2) Clear + OPTIBLUE	10	34	15	32	38	0.29	0.27	1.52	0.27	0.23	1.48
SOLARBAN 80 (2) OPTIBLUE + Clear	9	34	15	19	28	0.29	0.27	1.52	0.23	0.20	1.70
SOLARBAN 80 (2) OPTIBLUE + OPTIBLUE	7	25	11	19	28	0.29	0.27	1.52	0.23	0.20	1.23

All performance data calculated using LBNL Window 5.2 software, except European U-Value, which is calculated using WinDat version 3.0.1 software. For detailed information on the methodologies used to calculate the aesthetic and performance values in this table, please visit www.ppgglazing.com or request our Architectural Glass Catalog.

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Glass • Coatings • Paint

PPG Industries, Inc. Glass Technology Center 400 Guys Run Road Cheswick, PA 15024 1-888-PPG-IDEA www.ppgideascapes.com

DOE-2 SIMULATION TOOL REPORT

PPG IdeaScapes™
Glass • Coatings • Paint

Report on Energy Modeling of Select Architectural Glazings

The data generated by this energy modeling program is for comparative purposes only. It is general in nature and will vary for specific buildings according to numerous variables, including building design and type, site location, occupation and utilization levels, local utility costs and more.

Energy consumption simulations are based on modeling conducted with the U.S. Department of Energy (DOE) 2.2 Building Energy Analysis Simulation Tool developed at the Lawrence Berkeley National Laboratory and Los Alamos National Laboratory. It is the most accurate and well-documented energy modeling tool available in the U.S.

DOE-2 calculates hour-by-hour energy consumption by the prototype facility over an entire year (8,760 hours) using hourly climate data for the location under consideration. Input into the DOE-2 Model consists of detailed descriptions of the buildings being analyzed, including the hourly scheduling of occupants, lighting, equipment and thermostat settings.

The DOE-2 Model provides accurate simulation of building features such as shading, fenestration, interior building mass, envelope building mass, and the dynamic response of differing heating and air conditioning system types and controls.

All energy simulation scenarios are calculated with the following data:

- Total Electric Consumption (kWh)
- Total Natural Gas Consumption (therms)
- Total Electric Cost ($)
- Total Natural Gas Cost ($)
- Total Building Energy Consumption Cost ($)
- Total Cooling HVAC Capital Cost ($)
- Annual Energy Savings Using Low E Coatings ($)
- Initial Capital Savings Using Low E Coatings ($)
- Annual CO2 Reduction Using Low E Coatings (tons)
- 40 Year CO2 Reduction Using Low E Coatings (tons)

Results

Glazing	Electricity	Gas	Total Operating Electric Cost	Total Operating Gas Cost	Total Operating Cost	Total Capital Cooling HVAC Cost	Annual Operating Cost Savings of Low E Coatings vs DT	Initial Capital Cost Savings of Low E Coatings vs DT	Annual CO2 Savings of Low E vs DT	40 Year Building Life CO2 Savings of Low E Coatings vs DT
Double Pane Tinted	1,227,706	80,130	$270,227	$108,003	$378,320	$1,772,086	$	$		
Solarban 60 (2)	3,004,281	67,312	$260,061	$01,064	$351,008	$1,662,488	$27,312	$110,607	103	7,734
Solarban 70XL (2)	3,937,998	64,914	$257,477	$87,809	$345,286	$1,556,917	$33,034	$215,169	236	9,446
Solarban 80 (2)	**3,916,355**	**65,265**	**$256,524**	**$88,247**	**$344,771**	**$1,551,027**	**$33,549**	**$221,059**	**246**	**9,824**
Solexia Surgate 500 (3)	4,078,747	72,311	$263,670	$97,705	$361,375	$1,718,370	$16,945	$53,715	121	4,858
VE 2-2M (2)	3,980,163	65,311	$259,332	$88,358	$347,690	$1,580,829	$30,630	$191,257	212	8,471

Criteria: Solarban 80 (2), 8-Story Office with Punched Openings in Philadelphia

Details on Selection Criteria

1. *Glazing Type* – This energy modeling program contains comparative data for eight (8) commonly specified glazing types. The table below lists the specific glazing types along with their manufacturer-published performance characteristics (when they are used as part of a standard one-inch insulating glass unit).

To ensure valid comparisons, this program automatically reports data on glazings that are similar in appearance to the one selected by the user. For example, when Solarban 60 glass (PPG) is chosen by the user, comparative data for Solarban 70XL glass (PPG) and VE2-2M (Viracon) are included in the report. That's because these glazings feature a clear, color-neutral aesthetic. Tinted glazings such as Solexia glass (PPG), Solarban z50 glass (PPG) and VE1-52 (Viracon) are grouped similarly.

Glazing	Tvis	Rfvis	Tsol	Rfsol	U-Value	Shading Coefficient (SC)	Solar Heat Gain Coefficient (SHGC)
Double Pane Tinted	0.620	0.100	0.540	0.090	0.570	0.720	0.620
Solarban 60 (2)	0.704	0.112	0.328	0.293	0.291	0.438	0.380
Solarban 70XL (2)	0.617	0.108	0.227	0.347	0.286	0.311	0.270
Solarban 80 (2)	0.470	0.330	0.200	0.380	0.290	0.280	0.240
Solarban z50 (2)	0.510	0.080	0.250	0.230	0.290	0.360	0.310
Solexia Sungate 500 (3)	0.640	0.140	0.330	0.090	0.350	0.510	0.450
VE 1-52 (2)	0.500	0.160	0.320	0.200	0.320	0.460	0.400
VE 2-2M (2)	0.600	0.090	0.240	0.100	0.290	0.360	0.310

Figures may vary due to manufacturing tolerances. All tabulated data is based on NFRC methodology using the LBL 5.2 software. Variations from previously published data are due to minor changes in the LBL Window 5.2 software versus Version 4.1.

2. *City* - Energy simulations with DCE 2.2 software are based on the utility rates and weather data of the city selected.

Philadelphia

Electric Rates:		PECO Energy Company
Monthly Charge:		$25.00
Energy Charge:		
First 100 kWh		0.2246 $/kWh
Next 50,000 kWh		0.1145 $/kWh
Next 100,000 kWh		0.0785 $/kWh
Over 150,100 kWh		0.044 $/kWh
Demand Charge:		No Demand Charge
Gas Rates:		PECO Energy Company
Monthly Charge:		$14.40
Energy Charge:		
First 2,000 Therms		1.41095 $/Therm
Over 2,000 Therms		1.32434 $/Therm

	Philadelphia
Average Drybulb Temperature (F)	53.6
Average Wetbulb Temperature (F)	47.9
Average Daily Max Temperature (F)	62.0
Average Daily Min Temperature (F)	45.4
Heating Degree Days (Base 65)	5,181
Cooling Degree Days (Base 65)	1,053
Maximum Temp (F)	95
Minimum Temp (F)	11
No of Days Max Temp 90 and Above	12
No of Days Max Temp 32 and Below	19
No of Days Min Temp 32 and Below	99
No of Days Max Temp 0 and Below	0
Average Wind Speed (MPH)	9.6
Average Day Temp (F)	59.1
Average Night Temp (F)	48.1
Average RH at 4 AM	78.0
Average RH at 10 AM	63.1
Average RH at 4 PM	53.9
Average RH at 10 PM	71.2

3. *Glazing Design* – This DOE-2 simulation is based on a Punched Openings scenario.

The following chart shows the estimated total glass area for the façade of the glazing design/building selection.

Glazing Design / Building	Total Wall Area (sqft)	Window to Wall Ratio	Total Glass Area (sqft)
Punched Openings / 8 - Story Office	56,640	59%	33,418

4. *Building Prototype Description and Characteristics* – The characteristics for the selected building type is displayed below. These characteristics were developed in a study conducted by the Lawrence Berkley Laboratory's Applied Science Division, based on regional and national criteria. Each building type was adjusted to be compliant with ASHRAE 90.1-1999.

	Office
Geometry and U-values	
Floor Area (sq ft)	270,000
Number of Stories	8
Punch Window to Wall Ratio[1]	59%
Wall Window to Wall Ratio[2]	90%
Wall U-Value (Btu/ ft2-hr-F)[3]	0.124
Roof U-Value (Btu/ ft2-hr-F)[4]	0.065
Glazing Type	Dual Pane Tint Solarban-60 Solarban-70 Solarban-80 VE 2-2M Solexia x S500 Solarban z50 VE 1-52
Operating Conditions	
Cooling Temp Setpoint (F)	75
Heating Temp Setpoint (F)	70
Standard Day Schedule	7 AM - 6 PM Wkdays 8 AM - 12 PM Wkends All Year
HVAC Equipment	
Air Handling System	VAV
Cooling Plant Type	Centrifugal Chiller
Economizer	Yes
Heating Plant Type	Hot Water Boilers
Service Hot Water	Hot Water Boilers
Internal Loads (Peak)	
Occupants (ft2/ person)	448
Lighting (W/ ft2)	1.3
Equipment (W/ ft2)	0.75

1 Punch Window to Wall Ratio is based on most of the walls being window
2 Wall Window to Wall Ratio is based on the national building prototype
3 Wall U-Values are based on ASHRAE 90.1-1999 for each selected city
4 Roof U-Values are based on ASHRAE 90.1-1999 for each selected city

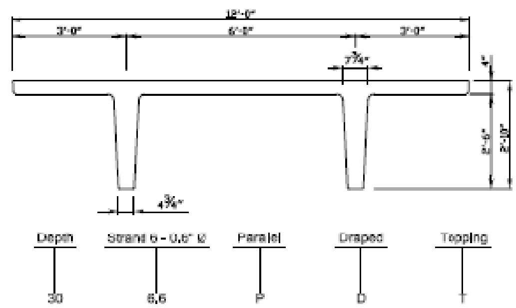
APPENDIX E: ANALYSIS 2 INFORMATION

NITTERHOUSE DOUBLE TEE INFORMATION

Prestressed Concrete
34" x 12' DOUBLE TEE
(PRETOPPED)

PHYSICAL PROPERTIES

A = 951 In.^{2}	S_b = 3,301 In.^{3}
I = 85,054 In.^{4}	S_t = 10,334 In.^{3}
Y_b = 25.77 In.	Wt.= 991 PLF
Y_t = 8.23 In.	Wt.= 83 PSF



DESIGN DATA

1. Precast Strength @ release = 3,500 PSI.
2. Precast Strength @ release for draped tees = 4,500 PSI.
3. Precast Strength @ 28 days = 6,000 PSI.
4. Precast Density = 150 PCF.
5. Strand = 0.6" Ø 270K Lo-Relaxation.
6. Maximum moment capacity is critical at midspan for parallel strands and is critical near 0.4 span for draped strands.
7. Maximum bottom tensile stress is $12\sqrt{f'c}$ = 930 PSI.
8. Flexural capacity is based on stress/strain strand relationships.
9. All superimposed load is treated as live load in the flexural strength analysis. To determine the allowable live load if the amount of superimposed dead load is known use the following conversion method...

$$\text{Allowable Live Load} = \frac{(1.6)(\text{Load Table Value}) - (1.2)(\text{Superimposed Dead Load})}{1.6}$$

10. If the above conversion is used then allowable stress limits must be checked so they are not exceeded.
11. Deflection limits were not considered when determining allowable loads in this table.

ALLOWABLE SUPERIMPOSED LIVE LOADS (psf) — IBC 2006 & ACI 318-05 (1.2 D + 1.6 L)

Section	Ø Mn	Span (Feet)																							
	(in. Kips)	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90
34 - 6.6 P	9,416	106	92	79	68	58	50	42	35																
34 - 8.6 P	12,099				106	93	82	72	62	54	47	40	34												
34 - 10.6 P	14,554							99	88	78	69	61	54	47	41	35									
34 - 12.6 P	16,782									99	89	80	71	64	56	50	44	38							
34 - 14.6 D	21,882												111	101	92	83	76	68	61	55	49	43	38		
34 - 16.6 D	24,688														107	98	89	81	74	66	59	53	48	42	37
34 - 18.6 D	27,414															110	101	92	84	76	69	63	57	51	46

NITTERHOUSE
CONCRETE PRODUCTS

2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17202-9203
717-267-4505 Fax 717-267-4518

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, etc..

04/24/09

12DT34P

COST AND SCHEDULE TAKEOFF INFORMATION

PRECAST							
Location	Number of Slabs			Total	Square Footage	Material Cost ($7.50/sf)	Shipping Cost ($9/mile)
	Center	East	West				
1st Floor	84	48	48	180	74000	$ 555,000	$ 283,500
2nd Floor	66	36	36	138	74000	$ 555,000	$ 217,350
3rd Floor	54	36	36	126	74000	$ 555,000	$ 198,450
4th Floor	54	36	36	126	74000	$ 555,000	$ 198,450
5th Floor	54	36	36	126	74000	$ 555,000	$ 198,450
6th Floor	20	20	20	60	37000	$ 277,500	$ 94,500
Total	332	212	212	756	407000	$ 3,052,500	$ 1,190,700

	STEEL			CAST-IN-PLACE			
Erection Costs*	Beams Omitted	Length of Beams	Beam Cost Savings	Forming	Placing	WWF	Material
$ 64,800	180	6660	$ 639,160	$476,079		$ 36,641	$ 126,564
$ 49,680	138	5712	$ 548,181	$476,079		$ 36,641	$ 126,564
$ 45,360	126	4960	$ 476,011	$476,079		$ 36,641	$ 126,564
$ 45,360	126	4960	$ 476,011	$476,079		$ 36,641	$ 126,564
$ 45,360	126	4960	$ 476,011	$476,079		$ 36,641	$ 126,564
$ 21,600	60	1844	$ 176,969				
$ 272,160	756	29096	$ 2,792,343	$2,380,395	$ 181,192	$ 183,205	$ 632,820

*Taken from R.S. Means (includes labor and equipment)

Precast Cost	-	Reduced Steel Savings	-	CIP Cost	=	Additional Cost
$ 4,515,360		$2,792,343		$3,377,612		-$1,654,595

CURRENT SCHEDULE

Location	Duration	Start Date	End Date
Slab on Deck- Center	35	16-Jul-08	2-Sep-08
Slab on Deck- East	35	13-Aug-08	30-Sep-08
Slab on Deck- West	35	1-Oct-08	18-Nov-08
Total	**90**	**16-Jul-08**	**18-Nov-08**

PRECAST SCHEDULE

Location	Members	Erection Time (Minutes)	Erection Time (Days)	Start Date	End Date
Slab on Deck- Center	**332**	**6640**	**13.83**	**16-Jul-08**	**4-Aug-08**
1st Floor	84	1680	3.5	16-Jul-08	21-Jul-08
2nd Floor	66	1320	2.75	21-Jul-08	24-Jul-08
3rd Floor	54	1080	2.25	24-Jul-08	28-Jul-08
4th Floor	54	1080	2.25	28-Jul-08	30-Jul-08
5th Floor	54	1080	2.25	30-Jul-08	1-Aug-08
6th Floor	20	400	0.83	4-Aug-08	4-Aug-08
Slab on Deck- East	**212**	**4240**	**8.83**	**5-Aug-08**	**15-Aug-08**
1st Floor	48	960	2	5-Aug-08	6-Aug-08
2nd Floor	36	720	1.5	7-Aug-08	8-Aug-08
3rd Floor	36	720	1.5	8-Aug-08	11-Aug-08
4th Floor	36	720	1.5	12-Aug-08	13-Aug-08
5th Floor	36	720	1.5	13-Aug-08	14-Aug-08
6th Floor	20	400	0.83	15-Aug-08	15-Aug-08
Slab on Deck- West	**212**	**4240**	**8.83**	**18-Aug-08**	**28-Aug-08**
1st Floor	48	960	2	18-Aug-08	19-Aug-08
2nd Floor	36	720	1.5	20-Aug-08	21-Aug-08
3rd Floor	36	720	1.5	21-Aug-08	22-Aug-08
4th Floor	36	720	1.5	25-Aug-08	26-Aug-08
5th Floor	36	720	1.5	26-Aug-08	27-Aug-08
6th Floor	20	400	0.83	28-Aug-08	28-Aug-08
Total	**756**	**15120**	**32**	**16-Jul-08**	**28-Aug-08**

STRUCTURAL CALCULATIONS

LIVE LOAD

$$L = L_o\left(.25 + \frac{15}{\sqrt{2A_T}}\right)$$

$L_o = 100$ psf
$A_T = 864$ ft^2

$$L = 100\left(.25 + \frac{15}{\sqrt{2(864)}}\right)$$

$L = 61$ psf

DEAD LOAD

$D = SID + WT$

$SID = 25$ psf
$WT = 83$ psf

$D = 108$ psf

FACTORED LOAD

$$W_u = 1.2D + 1.6L$$
$$= 1.2(108) + 1.6(61)$$
$$= 227 \text{ psf} = 8.2 \text{ klf}$$

MAX SHEAR

$$V = w\left(\frac{l}{2} - x\right)$$

$w = 8.2$ klf
$l = 24'$
$x = 0$

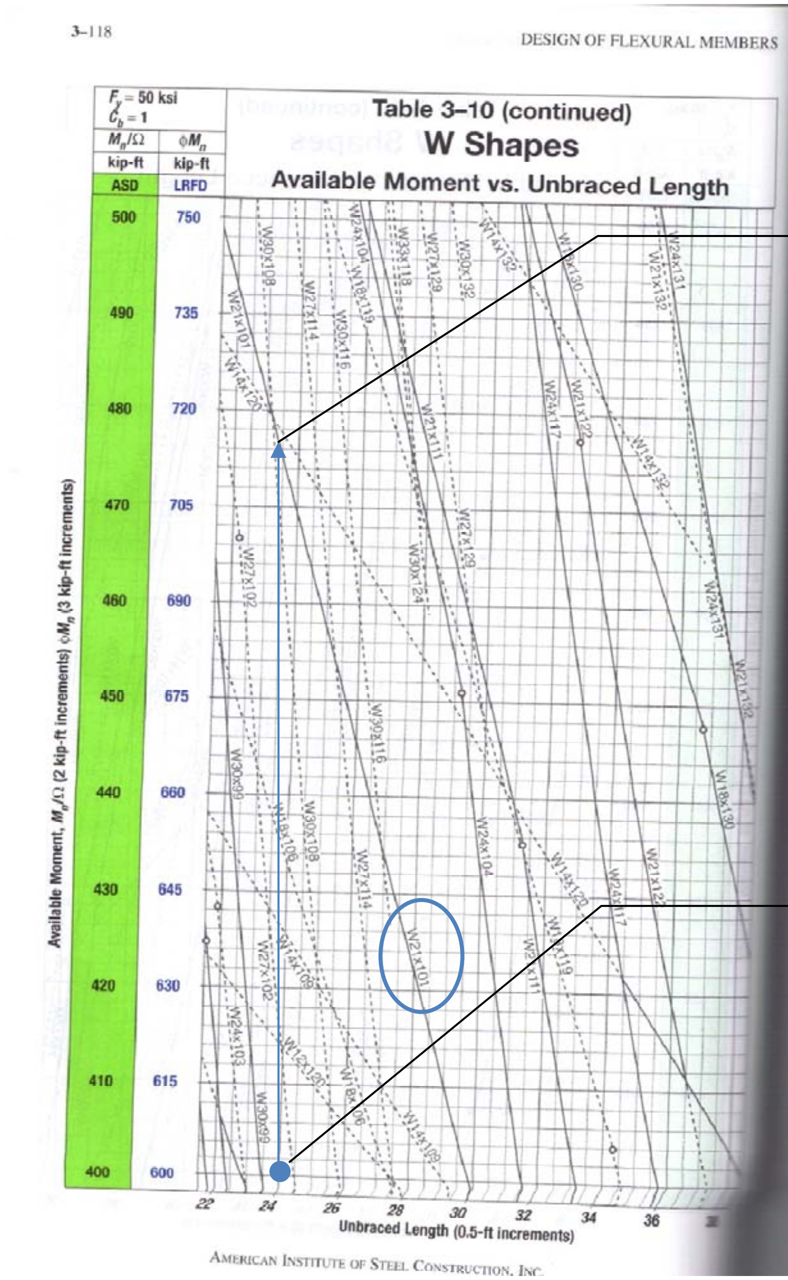
$V = 98.4 \approx 100$ k

MAX MOMENT

$$M = \frac{wl^2}{8}$$

$w = 8.2$ klf
$l = 24'$

$M = 590^k \approx 600^k$



Most economical choice for given unbraced length and available moment→W21x101

Point for 24' unbraced length and available moment of 600 k-ft